Minutes of October 13, 2005meeting with Ventura County MS4 Permittees and the Regional Board held at the Ventura County Watershed Protection District office.

MS4 Permittees

Jack Phillips from Division of Building & Safety acted as moderator. Jeff Pratt spoke on behalf of the District summarizing Ventura County's MS4 Program. Darla Wise (Ventura Watershed Protection District), Vicky Musgrove and Richard Bradley (City of San Buenaventura), Mark Pumford (City of Oxnard), Bert Rapp (City of Fillmore), Joe Drakin (City of Simi Valley), Arne Anselm (City of Thousand Oaks), Anita Kuhlman (City of Camarillo), complemented with comments on behalf of the Permittees.

- Would like to maintain good working relationships with the Regional Board;
- Would like to develop a permit that attains and addresses water quality;
- Public and the community is behind implementing compliance with water quality;
- Beach replenishment is a concern for coastal cities;
- The Watershed Protection District has done continuous modeling simulation for flow impacts. The most detailed are for Calleguas Creek, but has sufficient information to do the same for the other watersheds;
- County would like an interim period prior to a Hydromodification Control Plan taking effect;
- Concern with implementing Low Impact Development in built-out areas. Support additional detail in the permit in order to improve the Permittees ability to work with developers;
- Concern with submitting 2 reports- the monitoring report in June and the Annual Report in October, due to cost and workload;
- Principal Permittee will most likely remain the Watershed Protection District;
- Request a change from the existing schedule for permit adoption in order to discuss significant issues; and
- The Governor has signed legislation authorizing the District to go to voters to impose a storm water charge.

Regional Board

Debbie Smith provided a general overview of the Water Board's policy in advancing storm water permits and compliance with TMDLs. Xavier Swamikannu then described the significant areas of advancement in the proposed permit, and highlighted the key areas within each permit program area, including Public Involvement/Participation; Development Planning, Development Construction, Public Agency Activities; Illicit Connection/Illicit Discharge Elimination; TMDL Compliance, and Monitoring.

- Storm water program is progressive and contains emergent issues;
- Permit format will be in-line with both LAs' and Long Beachs', with new additions such as TMDL compliance;
- Permit will make sure that its requirements are clear and its expectations are also clearly known;
- Water Quality Exceedences will be dealt through the permit in the form of violations, and corrective actions;
- No separate Storm Water Management Plan will be required. Each Permittee has the discretion to develop Standard Operating Procedures for implementation;
- Hydromodification Plan will be required, size dependent;

- Education issues will be addressed in the Public Information and Participation Program;
- Storm drain systems will need to be mapped as a GIS layer for the ICID program;
- Permit will contain a TMDL section;
- Waters with exceedences in water quality standards but for which a TMDL(s) has not been developed will be required to implement BMPs focused on the pollutant(s) causing impairment,
- A trash study will be required to document the extent of the problem;
- Post construction BMPs will be include a municipal inspection program for implementation and effectiveness;
- Low Impact Development measures will be required for new and re-development projects
- Nurseries not covered by the Agricultural wavier will have to be inspected under the Industrial/Commercial Business Program;
- Recommend including ecologically sensitive areas (such as: wetlands) within the ESAs;
- Electronic data submittal within 90 days of sampling may be required instead of a separate June monitoring report;
- Annual Report will be submitted in an electronic format; and
- Will schedule 2 separate meetings to discuss significant issues, prior to issuing a draft permit. Will not be able to provide an advance copy of the draft before public release, for reason of equity.

Issues to be Discussed at a Future Meeting

- Hydromodification;
- Low Impact Development;
- Monitoring;
- Program Effectiveness; and
- ESA maps.

Watershed Protection District will obtain for the Regional Board

- Definition of Hillside (% slope/grade) from all permittees with a definition; and
- Estimated dollar amount spent on K-12 education

Watershed Protection District will look for:

- GIS layers of habitat areas such as: wetlands.

VC SW Permit Mtg w/ RWQCB
Sign In Sheet

10/13/05

Darla Wise	VCWPD
MARK PUMFORD	City of Oxnard
RICHARD BRADLEY	City of VENTURA
BERT RAPP	FILLMORE
Vicki Musgrove	City of Ventura
JACK PHILLIPS	COUNTY OF VENTURA
JOE DRAKIN DEAKIN	CITY OF SIMI VALLEY
~~ARNE ANSELM~~	City of Thousand Oaks
Anita Kuhlman	City of Camarillo
Xavier Swamikannu	RWQCB - LA
Tracy Woods	RWQCB - LA
Debbie Smith	RWQCB - LA
Jeff Pratt	VCWPD

From: Tracy Woods
To: Mark
Date: 10/24/2005 12:49:51 PM
Subject: Re: October 13, 2005, Minutes and Attendance Sheet

Hello Mark,

If you would submit your comments on the minutes from the 10/13/05 meeting, I will put them in the administrative record and attribute them to you.

Thanks-

Tracy Woods
RWQCB-LA/Storm Water Section
320 W. 4th Street, #200
Los Angeles, CA 90013
Phone: (213) 620-2095
Fax: (213) 576-5777
E-mail: twoods@waterboards.ca.gov

>>> "Mark" <mark.pumford@nextel.blackberry.net> 10/20/2005 7:55 PM >>>
I hope we have a chance to comment on the minutes in a formal fashion, since my recollection of some of the discussion, especially enforcement and a trash study requirement, differ from these minutes.

Thanks!

mp
-----Original Message-----
From: "Tracy Woods" <twoods@waterboards.ca.gov>
Date: Thu, 20 Oct 2005 19:32:39
To:<akuhlman@ci.camarillo.ca.us>, <brapp@ci.fillmore.ca.us>, <mmathews@ci.moorpark.ca.us>, <fcamarillo@ci.port-humeneme.ca.us>, <cfinley@ci.santa-paula.ca.us>, <rbradley@ci.ventura.ca.us>, <vmusgrove@ci.ventura.ca.us>, <mark.pumford@nextel.blackberry.net>, <hawksassoc@prodigy.net>, <aschuber@simivalley.org>, <jkelly@toaks.org>, <Darla.Wise@ventura.org>, <Elyse.Ditzel@ventura.org>, <jack.phillips@ventura.org>, <Jeff.Pratt@ventura.org>, <Paul.Tantet@ventura.org>, "Carlos Urrunaga" <currunaga@waterboards.ca.gov>, "Dan Radulescu" <dradulescu@waterboards.ca.gov>, "Deborah Smith" <Dsmith@waterboards.ca.gov>, "Ejigu Solomon" <ESOLOMON@waterboards.ca.gov>, "Ivar Ridgeway" <iridgeway@waterboards.ca.gov>, "Xavier Swamikannu" <Xswamikannu@waterboards.ca.gov>
Subject: October 13, 2005, Minutes and Attendance Sheet

Hello,

Attached are the minutes and attendance sheet from the 10/13/05 meeting with Ventura County MS4 Permittees and the Regional Board, held at the Ventura County Watershed Protection District Office. If I have left anyone out of the e-mail list let me know and I will send a copy to them.

Thanks-

Tracy Woods

Monitoring

NPDES Meeting Sign-in Sheet 11-4-05

	NAME	AGENCY
1.	Kevin Gieschen	City of Simi Valley ECD
2.	Tracy Woods	LA-RWQCB
3.	Xavier Swamikannu	" "
4.	Debbie Smith	RWQCB-LA
5.	Gerhardt Hubner	Ventura County / Districts
6.	Darla Wise	VCWPD
7.	Ashli Desai	LWA
8.	Richard Bradley	City of Ventura
9.	Paul Tantet	Ventura County
10.	Mark Pumford	City of Oxnard
11.	Anita Kuhlman	City of Camarillo
12.		
13.		
14.		
15.		

Storm Water MS4 Meeting with Ventura County Permittees & LA-RWQCB
November 9, 2005

Signature	Agency
1. [illegible signature]	City of Oxnard
2. Jim K Ridgway	Los Angeles Regional Water Board
3. DAN RADULESCU	— " —
4. ARNE ANSELM	city of Thousand Oaks
5. Vicki Musgrove	Ventura
6. RICHARD BRADLEY	CITY OF VENTURA
7. Xavier Swamikannu	RWQCB - LA.
8. TRACY WOODS	LA - RWQCB
9. BERT RAPP	CITY OF FILLMORE
10. Gerhardt Hubner	County of Ventura - District
11. PAUL TANTET	VENTURA COUNTY
12. Anita Kuhlman	City of Camarillo
13. Elyse Ditzel	VCWPD
14. Darla Wise	VCWPD
15. Deb Smith	RWQCB - LA
16. JOE DEAKIN	CITY OF SIMI VALLEY
17.	
18.	

Ventura Countywide Stormwater Quality Management Program

Stormwater Permit Negotiation Workgroup Meeting

December 14, 2005
10:00 AM-12:00 PM
RWQCB, Los Angeles

Meeting called by:	VCWPD
Facilitator:	Darla Wise

-----Meeting Agenda----

1. Introductions
2. Event Reporting
3. Source Identification
4. Land Use
5. Mass Emission Sites - Part of TMDL
6. Adaptive Management
7. Blackout Dates
8. Other Items

Monitoring Program

- Mass Emissions
- Aquatic Toxicity Monitoring
- Tributary Monitoring
- Landuse Monitoring
- Compliance Monitoring
- Bioassessment Monitoring
- Trash and Debris Study
- Pyrethroid Insecticides Study
- Hydromodification Control Study
- Low Impact Development
- Volunteer Monitoring Programs
- Standard Monitoring Provisions

Storm Water MS4 Meeting with Ventura County Permittees, LA-RWQCB& SCCWRP
December 14, 2005

Signature	Agency	Phone
1. Richard Bradley	City of Ventura	(805) 652-4582
2. Joe Deakin	City of Simi Valley	(805) 583-6401
3. David F Thomas	Ventura Co Watershed Protection Dist.	805 650-4086
4. Eric Stein	SCCWRP	714-372-9233
5. Gerhardt Hubner	Ventura Co Watershed Prot Dist	805 654-5051
6. Mark Pumford	City of Oxnard	805.271.2220
7. Michael Lyons	LARWQCB	213-576-6718
8. Deb Smith	RWQCB	213-576-6609
9. Xavier Swamikannu	"	213-620-2094
10. Ken Schiff	SCCWRP	714 372 9202
11. Dale Wise	VCWPD	805 654-3942
12. Tommy Liddell	VCWPD	(805) 662-6758
13. Tracy Woods	LA-RWQCB	213/620-2095
14. Arne Anselm	City of Thousand Oaks	805 449-2386
15.		
16.		
17.		

From: "Darla Wise" <Darla.Wise@ventura.org>
To: <twoods@waterboards.ca.gov>
Date: 1/12/2006 2:36:51 PM
Subject: Response to monitoring issues discussed at Dec. 14th Permit Renewal Discussion meeting

We met with Regional Water Quality Control Board staff on December 14th to discuss monitoring requirements that may be included in the renewed Ventura Countywide NPDES Stormwater Permit. The following outlines issues that were discussed during that meeting and our responses to the issues:

1. Relocate the SCR ME station lower in the watershed to capture contribution from the cities of Ventura and Oxnard. Relocate current station from the Freeman Diversion to the Hwy 101 Bridge * If relocation is not possible, add additional monitoring stations to capture major inputs from the cities of Oxnard and Ventura.

Comments: Relocating the SCR ME station to the Hwy 101 Bridge is not advisable due to logistical problems such as maintaining connectivity with the river, safe access, flow measurement, maintaining a rating curve with no hydraulic controls, and power. Adding two additional stations to monitor input from the cities of Ventura and Oxnard would cost approximately $60,000 to $75,000 per station for equipment and installation and approximately $10,000 per event for labor and analytical costs. Estimated cost for first year setup and operation - $200,000.

2. At ME sites, monitoring all storm events equal to or greater than 0.25" for TSS as an indication of pollutant load variability from storm to storm.

Comments * Ventura Count is very different from Los Angeles County in that it is largely comprised of undeveloped open space with a high degree of sediment contribution from natural sources. The RWQCB's approach to determine urban pollutant load variability based on TSS contribution does not make sense in Ventura County where TSS contribution from natural sources is high. Estimated cost for monitoring ME sites for all storm events greater than 0.25" is approximately $50,000.

3. Addition of tributary monitoring sites in four watersheds in an attempt to identify pollutant sources on a sub-basin level. Each watershed will have between 2 and 5 stations. Two watersheds will be monitored on a two year basis and rotated every 2 years. The stations will collect time paced composite samples with a full suite analysis for the first event followed by parameters based on POC's, 303d listings and water quality exceedances. The Coastal watersheds will include the harbors of Port Hueneme, Channel Islands, and Ventura. Sample collection at the harbor sites includes all inputs to the harbors.

Comments * This element of the expanded monitoring program has a very high price tag of approximately $250,000 per year including equipment, labor and chemical analyses. Due to logistical issues, the cost to establish a semi-permanent monitoring station for a two year time frame is substantial. The same issues faced when installing a permanent station (vandalism, safety, flow measurement viability, maintaining a rating curve, river connectivity, access, power, etc.) must be addressed when adding a station for a two year time frame. This element of the monitoring program will add a substantial annual cost to the Ventura County Program without resulting in meaningful benefit to the Stormwater Program.

4. Special Studies * Including Regional Hydrologic, Pyrethroid Water Quality, Trash Studies, and The BIGHT Study.

Comments: While special studies are important they must be undertaken in a prudent manner due to the substantial costs for such scientific efforts. Participation in all of these special studies will require a financial commitment of approximately $270,000. This represents a significant cost to the co-permittees of the VC stormwater program. If the RWQCB expects the cost of such research to be covered by our Stormwater program, state funding opportunities should to be identified to support this research effort. Currently Ventura County Stormwater and the Los Angeles Stormwater Monitoring programs spend approximately $500,000 per Million population. The added requirements discussed at the December 14th meeting will increase Ventura County's program cost to approximately $1,000,000 per Million population, over $1.2 dollars for each and every Ventura County resident. This is a heavy financial burden to place on the Ventura County Co-permittees. There seems to have been little thought towards the financial consequences of the proposed monitoring elements of the new permit.

5. A consolidated SCREMP Nutrient TMDL Work Plan was expected one year from the adoption of the SCR Nutrient TMDL.

Comments: The Nutrient TMDL was established for this reach because the area from Santa Paula to the Freeman diversion was impacted by nutrients due to the discharge from the Santa Paula WWTP. It should be noted that the cities of Santa Paula and Fillmore will be going to zero discharge with new Sewage Treatment Plants in 2008.

The nutrient modeling for Nutrient TMDL showed that when the Santa Paula Sewage Treatment plant is upgraded with nutrient removal technologies the river will no longer be impacted for nutrients. Therefore, any monitoring as part of the stormwater program would be a waste of time and money.

The staff report for the development of the SCR Nutrient TMDL stated that the "mass emission monitoring data conducted for MS4 NPDES Permit compliance indicate that the MS4 discharges are below the WLA in both wet and dry weather samples." As the MS4 discharges are "a minor load of ammonia, nitrite, and nitrate to the Santa Clara River, the compliance alternative is an iterative approach*" This indicates that our existing Stormwater Management Plan is adequate for the protection of receiving water quality. Since total nitrogen and ammonia are both pollutants of concern for the Ventura County program, the sources are being addressed and tracked under a number of program elements, including residential, new development, and public infrastructure. Our recent trend analysis showed a "statistically significant increase in ammonia" at our industrial site that will be looked at under the next permit cycle; however, "no trends were observed for nitrates on any of the sites", indicating that we have probably reached MEP for that nutrient under our existing program.

The monitoring requirements for the SCR Nutrient TMDL are spelled out in section 10.5.3 of the staff report, and differ from the expectations voiced by regional board staff at our meeting. According to the staff report, "MS4 Monitoring will be in accordance with Work Plans to be submitted by MS4 permittees in Los Angeles and Ventura Counties, respectively. The Work Plans can include a phased approach in which initial monitoring will be provided by existing mass emission monitoring stations*" Our current monitoring program includes the SCR mass emission monitoring station at the lower end of SCR Reach 3. The TMDL Work Plan requirements are met.

Let me know if you have questions or comments regarding the above items. I'd be happy to talk to you further about the monitoring requirements or any other permit item.

Darla D. Wise
Water Quality Manager
Watershed Protection District
Ventura County
805 654-3942

CC: <akuhlman@CI.CAMARILLO.CA.US>, <brapp@ci.fillmore.ca.us>, <MMathews@ci.moorpark.ca.us>, <mark.pumford@ci.oxnard.ca.us>, <cmattingly@ci.port-hueneme.ca.us>, <fcamarillo@ci.port-hueneme.ca.us>, <cfinley@ci.santa-paula.ca.us>, <JDeakin@ci.simi-valley.ca.us>, <rbradley@ci.ventura.ca.us>, <VMusgrove@ci.ventura.ca.us>, <hawksassoc@prodigy.net>, <aschuber@simivalley.org>, <jkelly@toaks.org>, "Gerhardt Hubner" <Gerhardt.Hubner@ventura.org>, "Jack Phillips" <Jack.Phillips@ventura.org>, "Marty Robinson"

<Marty.Robinson@ventura.org>, "Raymond Gutierrez" <Raymond.Gutierrez@ventura.org>,
<Xswamikannu@waterboards.ca.gov>

Calleguas Creek TMDL Implementation Plan Meeting

March 13, 2006 minutes of 1000 teleconference meeting held at the Regional Board and the County of Ventura with the Ventura County MS4 Permittees, the Regional Board, and Larry Walker Associates.

Agenda:

- Larry Walker Associates spoke to the Ventura MS4 Permitees and the Regional Board about the Calleguas Creek TMDL implementation plan and its monitoring requirements.
- Calleguas Creek TMDL implementation plan consistent with Storm Water Permit.

MS4 Permittees

David Thomas WPD
Darla Wise WPD
Paul Tantet WPD
Anita Kuhlman, City of Camarillo
Richard Bradley, City of Ventura
Darrell Siegrist, Ventura County

- Permittees had no comments.

Larry Walker Associates

Chris Minton, LWA
Ashli Desai, LWA

- Preliminary drafts of the Calleguas Creek Watershed Coordinated Monitoring Program (WMP) for Toxicity and OCs TMDL have been submitted to RB4 (April & June 2005).
- Currently efforts are being made to coordinate Agriculture Waiver requirements with the WMP. The Agriculture Waiver monitoring plan is due August 2006.
- Stakeholder group is working on how to implement the WMP.
- TMDL Monitoring Program (WMP) must be submitted 6 months after effective date of amendment.
- Initiate TMDL Monitoring Program (WMP) 6 months after Executive Officer approval of WMP.
- TMDL monitoring will be done primarily in receiving waters.
- To track exceedences (identify sources) in the sub-watersheds land-use sites will be monitored. The exact number and locations of the land-use sites has not been determined, at this time.

March 13, 2006 minutes of 1000 teleconference meeting held at the Regional Board and the County of Ventura with the Ventura County MS4 Permittees, the Regional Board, and Larry Walker Associates.

- Composite sampling in sub-watersheds may be done if selected sampling sites have mass emissions stations.
- Single grab samples have been proposed for sampling sites in sub-watershed locations that do not have mass emissions stations.
- TMDL monitoring will follow an adaptive approach, with revisions based on monitoring results.
- Funding for the WMP has not been determined, as of yet.
- Point Mugu (US Navy-military) has committed to sharing monitoring responsibilities, but military funding has not been decided.
- The TMDL has 20 years from adoption to achieve Final WLAs and there is no date for Interim WLAs.
- Siltation load and WLAs requirements will be addressed in Special Study #1, 8 years after effective date of amendment.

Regional Board
Xavier Swamikannu, RWQCB
Ivar Ridgeway, RWQCB
Tracy Woods, RWQCB
Carlos Urrunaga, RWQCB
Sam Unger, RWQCB

- Storm water monitoring emphasizes wet weather load allocation.
- Dry weather load allocation will be expressed as a prohibition.
- The proposed Ventura MS4 monitoring scheme will use 30 day monitoring to verify the effectiveness of the dry weather prohibition.
- Compliance will be measured in sub-watershed locations.
- Calleguas Creek TMDLs do not preclude end of pipe sampling.
- The IC/ID program component will be the vehicle for compliance with the dry weather prohibition, which necessitates end –of-pipe sampling.
- Exceedences of the WLAs are not addressed in either the TMDLs or WMP.

Calleguas Creek TMDL Implementation Plan Meeting

March 13, 2006 minutes of 1000 teleconference meeting held at the Regional Board and the County of Ventura with the Ventura County MS4 Permittees, the Regional Board, and Larry Walker Associates.

- Manner of enforcement of WLA exceedences has not been determined.
- There will be no end of pipe limits for storm water discharges in this MS4 Permit cycle.
- There will be a ramp up of the IC/ID program in the MS4 Permit.
- Staff report will note there are 2 options for Permit compliance of TMDLs:
  1) Program in-place as stated in MS4 Permit will take effect when Permit is adopted;
  2) Program in-place as stated in MS4 Permit will take effect in a specified amount of time (example: 1year) so that Permittees have an added incentive to develop their own TMDL implementation and monitoring plan for adoption by the Board.

Meeting Sign-in Sheet

Date: 13 March 2006 **Location: CRWQCB – Los Angeles Region**
320 West 4th Street, Suite 200, Los Angeles, CA 90013

Subject: Monitoring Meeting (Ventura County)

	Name	Agency/ Company/ Resident	Mailing and Email Address	Telephone	FAX #
1	Carlos Urrunaga	RWQCB -LA	ABOVE	213 620 2083	213 576 6640
2	TRACY Woods	RWQCB - LA	"	213/620-2095	213/576-5777
3	Sam Unger	RWQCB-LA	"	213/576 6784	213/576-6686
4	Ivar K. Ridgeway	RWQCB-LA	"	(213) 620-2150	(213) 576-5777
5	Ashli Desai	LWA	429 Santa Monica Blvd. Ste 270 SM, CA ashli@lwa.com	310-394-1036	310-394-8959
6	Xavier Swamikannu	RWQCB-LA		213-620-2094	
7	Chris Minton	LWA	429 Santa Monica Blvd Ste 270 SM, CA 90401 chrism@lwa.com	310-394-1036	310-394-8959
8					
9					
10					
11					
12					
13					
14					

A000824

CC Monitoring Program - TMDL

03/13/06

Conf Call attendees:

DAVID F THOMAS	VCWPD
Anita Kuhlman	City of Camarillo
PAUL TANTET	VCWPD
DARRELL SIEGRIST	VCRMA
Darla Weil	VCWPD
RICHARD BRADLEY	CITY OF VENTURA

To Tracy Woods

Fax 213-576-5997

FAXED 3/16/06

Phone 213-576-1323

(X S
JB
DS

Public Works Department • Wastewater Division
6001 South Perkins Rd. • Oxnard, CA 93033-9047 • (805) 488-3517 • Fax (805) 488-2036

January 26, 2006

Mr. Jonathan Bishop, Executive Officer
Regional Water Quality Control Board - Los Angeles
320 W. 4th Street, Suite 200
Los Angeles, CA 90012

Subject: **PERMIT RENEWAL - WASTE DISCHARGE REQUIREMENTS FOR MUNICIPAL STORM WATER AND URBAN RUNOFF DISCHARGES** (NPDES PERMIT NO. CAS004002)

Dear Mr. Bishop:

On December 14, 2005, representatives of the Ventura Countywide Municipal Stormwater Management Program met with staff from the Regional Water Quality Control Board to discuss monitoring requirements that may be included in the next round of permit renewal, expected in 2006. These meetings have been extremely valuable in understanding Regional Board staff's monitoring expectations, and providing the permittee's expertise in evaluating conditions specific to the watersheds of Ventura County. You have received comments from the principal permittee by e-mail dated January 12, 2006. While the City of Oxnard concurs with the evaluation of the proposed new monitoring requirements by Ventura County Watershed Protection District staff, we would like to add the following comments:

1. The Porter/Cologne Water Quality Control Act section 13385.5 addresses storm water discharge monitoring requirements, and requires that:

> (8) For the purposes of determining constituents to be sampled for, sampling intervals, and sampling frequencies, to be included in a municipal storm water permit monitoring program, the regional board shall consider the following information, as the regional board determines to be applicable:
>
> (A) Discharge characterization monitoring data.
>
> (B) Water quality data collected through the permit monitoring program.
>
> (C) Applicable water quality data collected, analyzed, and reported by federal, state, and local agencies, and other public and private entities.

(D) Any applicable listing under Section 303(d) of the Clean Water Act (33 U.S.C. Sec. 1313).

(E) Applicable water quality objectives and criteria established in accordance with the regional board basin plans, statewide plans, and federal regulations.

(F) Reports and studies regarding source contribution of pollutants in runoff not based on direct water quality measurements.

A new suite of monitoring is being proposed for the next permit cycle. We request that the above information and their roles in developing the new monitoring requirement be explained in the staff report for the draft permit.

2. The requirements of the California Water Code for standardized sampling and analysis protocols in municipal stormwater monitoring programs led to the development of the model monitoring program. This document was developed by the Southern California Stormwater Monitoring Coalition (SMC), represented by three regional boards, municipal permittees representing six counties, Heal the Bay, and SCCWRP. The basic philosophy is:

   "Monitoring should be focused on decision making; data not helpful in making a decision about clearly defined regulatory, management, or technical issues should not be collected."

   The Core Management Questions presented in the Model Monitoring document are:

   Are conditions in receiving waters protective, or likely to be protective, of beneficial uses?
   What is the extent and magnitude of the current or potential receiving water problems?
   What is the relative urban runoff contribution to the receiving water problem(s)?
   What are the sources to urban runoff that contribute to receiving water problems?
   Are conditions in receiving waters getting better or worse?

The current stormwater monitoring program, in conjunction with other monitoring programs within the county (e.g., NPDES, SWAMP, conditional waiver for agricultural discharges, TMDL, etc.), will continue to provide information to answer the first two questions; however, lacking a state-wide stormwater policy, the relative impacts of urban runoff cannot be assessed. The short-term impacts from stormwater and urban runoff are recognized and made part of the findings in permits for municipal separate storm sewer systems (MS4s), but are not addressed in

Basin Plan for the Los Angeles region. The most pressing questions for an MS4 permit are what are the sources to urban runoff that contribute to receiving water problems, and are conditions getting better or worse? The most effective way to do this is to draw the focus of the monitoring to the urban areas, instead of monitoring on a watershed basis. None of the proposed monitoring program changes apparently accomplish this, and the rationale for a departure from the model monitoring should accompany the staff report for the draft permit.

At this point in the implementation of our monitoring and management plans (twelve + years), we should be able to determine some of the sources of pollutants of concern in the urban runoff of Ventura County, and address them in the program elements currently in place, or develop new focus areas to mitigate the sources.

3. We have been told by staff that there will be a new trash monitoring requirement in the monitoring program of the renewed permit. As you know, trash has been the focus of a multi-year study in the major, and now minor, open channels in the Oxnard area. While the major focus of the studies is identify sources of trash in the channel and address them with the programmatic elements of our Stormwater Management Plan, another is to identify possible funding sources through an Adopt-a-Channel program. Since we don't know the specific language that is proposed for the new monitoring program, and the associated quality control/quality assurance requirements, our Adopt-a-Channel program is effectively on hold. We urge the Regional Board staff to provide draft language to the copermittees at the earliest possible point in the renewal process, and to justify in the staff report the need to place a requirement for trash monitoring in the permit, when it has been in place for the last three years.

We look forward to continued participation with Regional Board staff on the development of the next urban runoff permit, and the monitoring program designed to evaluate its effectiveness.

If you have any questions on the above early comments on the permit renewal, or would like any additional information on the current stormwater program, please feel free to call me at (805) 271 – 2205.

Sincerely,

Mark S. Norris
Wastewater Superintendent

C:\Documents and Settings\pwmarp\My Documents\LettersMemos\jbishopSWpermit_ltr.doc

State of California

M e m o r a n d u m

To : Archie Matthews
Division of Water Quality

Date: FEB 11 1993

Elizabeth M. Jennings

Elizabeth Miller Jennings
Senior Staff Counsel
OFFICE OF THE CHIEF COUNSEL

From : **STATE WATER RESOURCES CONTROL BOARD**
901 P Street, Sacramento, CA 95814
Mail Code: G-8

Subject: DEFINITION OF "MAXIMUM EXTENT PRACTICABLE"

ISSUE

What is the meaning of the standard "maximum extent practicable" (MEP) as used in the Clean Water Act's storm water provisions, and how can this standard be communicated to the regulated community? How can this concept be included in the draft BMP manual?

CONCLUSION

The standard "maximum extent practicable" is not specifically defined for use in the storm water program. It has been defined in other rules, however, to require taking all actions which are technically feasible. I have included draft language for the manual.

DISCUSSION

Section **402(p) of the Clean** Water Act **(33** U.S.C. § 1342(p)) provides that permits issued for discharges from municipal separate storm sewers must require controls to reduce the discharge of pollutants "to the maximum extent practicable". The statutory language provides that municipal permits:

> "Shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other

> provisions as the [EPA] Administrator or the State determines appropriate for the control of such pollutants." Clean Water Act Section 402(p)(3)(B)(iii); 33 U.S.C. § 1342(p)(3)(B)(iii).

Neither Congress nor the U.S. Environmental Protection- Agency (EPA) has defined the term "maximum extent practicable", and yet this is the critical standard which municipal dischargers must attain in order to comply with their permits. (The State could have spelled out the specific controls which the municipalities were required to undertake. However, such an approach would have relinquished the municipal dischargers of any flexibility in implementing their storm water programs.)

On its face, it is possible to discern some outline of the intent of Congress in establishing the MEP standard. First, the requirement is to <u>reduce</u> the discharge of pollutants, rather than totally prohibit such discharge. Presumably, the reason for this standard (and the difference from the more stringent standard applied to industrial dischargers in Section 402(p)(3)(A)), is the knowledge that it is not possible for municipal dischargers to prevent the discharge of all pollutants in storm water. The second point which is clearly encompassed in the standard is that it is the permitting agency, and not the discharger, which is the ultimate arbiter on whether there has been sufficient reduction of pollutants.

The most difficult issue is determining how much pollutants must be reduced, or, in other words, which best management practices (BMPs) must be employed in order to comply with the MEP standard. While the term is not defined in the Clean Water Act or the EPA regulations, the same term does appear in other federal laws and regulations, and there are some definitions or interpretations which may be useful to the storm water program.

In the Uranium Mill Tailings Radiation Control Act of 1978 (42 U.S.C. § 7901, et seq.), the Department of Energy was required to designate within one year of the Act's adoption "to the maximum extent practicable" contaminated areas within the vicinity of uranium processing sites. In addressing a lawsuit brought after the Department designated very few of the "vicinity properties", the federal court declared that MEP means "a substantial majority of the locations" should have been designated within the year. <u>Sierra Club v. Edwards</u> (D.C.D.C. 1983) 19 ERC 1357. Where a NEPA regulation required that "to the maximum extent practicable" environmental clearance was required for uncompleted projects which had never undergone NEPA review, a court held that the regulation "mandates a meaningful environmental review" rather than a "perfunctory evaluation". Save the Courthouse Committee v. Lynn (S.D.N.Y. 1975) 408 F.Supp. 1323.

In an interim final regulation recently promulgated by the Department of Transportation, MEP is defined, where operators of onshore oil pipelines must have resources "to the maximum extent practicable" to remove and to mitigate or prevent worst case discharges. 49 CFR Part 194. MEP is defined to mean:

> "The limits of available technology and the practical and technical limits on an individual pipeline operator in planning the response resources required to provide the on-water recovery capability and the shoreline protection and cleanup capability to conduct response activities . . .."

Finally, the term MEP is used in the Superfund legislation, wherein permanent solutions and alternative treatment technologies must be selected "to the maximum extent practicable". CERCLA, Section 121(b). The legislative history of the language indicates that the relevant factors in determining whether MEP is met include technical feasibility, cost, and state and public acceptance. 132 Cong. Rec. H 9561 (Oct. 8, 1986).

While each of the above interpretations and definitions varies, they do follow a pattern. The pattern that emerges is that there must be a serious attempt to comply, and that practical solutions may not be lightly rejected. If a municipality reviews a lengthy menu of BMPs, and chooses to select only a few of the least expensive, it is likely that MEP has not been met. On the other hand, if a municipal discharger employs all applicable BMPs except those where it can show that they are not technically feasible in the locality, or whose cost would exceed any benefit to be derived, it would have met the standard. In any case, the burden would be on the municipal discharger to show compliance.

The definitions contained in the pipeline regulation and the Superfund leg-islative history are most analogous to storm water regulation. The major emphasis in both of these rules are technical feasibility. Similarly, the municipal dischargers should be required to employ whatever BMPs are feasible, i.e., ~~are likely to be effective and are not cost prohibitive.~~ Thus, where a choice may be made between two BMPs which should provide generally comparative effectiveness, the discharger may choose the least expensive alternative and exclude the more expensive BMP. However, it would not be acceptable either to reject all BMPs which would address a pollutant source or to pick a BMP based solely on cost, which would be clearly less effective.

As you know, the BMP Guidance manual is being published by the Task Force, which is made up of dischargers, rather than by the State Water Board. As far as I know, there is no intention for the State Water Board to adopt the manual as its own guidance document. Therefore, it is important to stress in the manual, both in the section on MEP and in the front of the manual, that this manual is not a publication of the State or the Regional Water Boards, and that these Boards have not specifically endorsed the contents. Rather, the manual was assembled by a group of dischargers in the interest of assisting themselves and others to comply with the storm water permits. In the section on MEP, it should be stated that the final determination regarding whether a discharger was reduced pollutants to the maximum extent practicable can only be made by the Regional or State Water Boards, but that selection and implementation of BMPs through consideration of the listed factors should assist dischargers in achieving compliance.

The following language is suggested in order to clarify that the manual is not the product of the State Water Board:

> "This Manual was produced and published by the Storm Water Task Force, an advisory body of municipal agencies regulated by the storm water program. This Manual is not a publication of the State Water Resources Control Board or any Regional Water Quality Control Board, and none of these Boards has specifically endorsed the contents thereof. The purpose of this manual is to assist the members of the Task Force and other dischargers subject to storm water permits, ,in attaining compliance with such permits."

The following language is recommended in place of Insert A in the manual for municipal dischargers:

> "Although MEP is not defined by the federal regulations, use of this manual in selecting BMPs should assist municipalities in achieving MEP. In selecting BMPs which will achieve MEP, it is important to remember that municipalities will be responsible to reduce the discharge of pollutants in storm water to <u>the maximum extent practicable</u>. This means choosing <u>effective BMPs, and rejecting</u> applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs would not be technically feasible, or the cost would be prohibitive. The following factors may be useful to consider:
>
> "1. Effectiveness: Will the BMP address a pollutant of concern?

"2. Regulatory Compliance: Is the BMP in compliance with storm water regulations as well as other environmental regulations?

"3. Public acceptance: Does the BMP have public support?

"4. cost: Will the cost of implementing the BMP have a reasonable relationship to the pollution control benefits to be achieved?

"5. Technical Feasibility: Is the BMP technically feasible considering soils, geography, water resources, etc.?

"After selecting a menu of BMPs, it is of course the responsibility of the discharger to insure that all BMPs are implemented."

Alan C. Lloyd, Ph.D.
Agency Secretary

State Water Resources Control Board

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Arnold Schwarzer
Governor

TO: Board Members
Central Coast RWQCB

/s/

FROM: Lori T. Okun
Staff Counsel
OFFICE OF CHIEF COUNSEL

DATE: January 11, 2005

SUBJECT: MUNICIPAL SEPARATE STORM SEWER SYSTEM PERMITS

The purpose of this memorandum is to provide some legal background information regarding municipal separate storm sewer system permits ("MS4s" or "municipal permits"). The staff reports for the Salinas MS4 permit, the Monterey Regional Storm Water Management Plan and the update on storm water activities provides additional information.

NPDES permits must generally contain numeric effluent limits to ensure the protection of beneficial uses. Industrial permits (including construction permits) are subject to Clean Water Act effluent limit requirements.[1] However, industrial and construction permits usually require best management practices (BMPs) rather than establishing numeric effluent limits, because developing numeric limits is generally infeasible.[2]

Unlike industrial permits, MS4 permits do not have to include effluent limits. Rather, MS4 permits must include "controls to reduce the discharge of pollutants to the *maximum extent practicable*, including management practices, control techniques and systems, design and engineering methods, and such other provisions as . . . the State determines appropriate for the control of such pollutants."[3] MS4 permits must also "effectively prohibit non-storm water discharges" into the system.[4]

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[1] Clean Water Act § 402(p)(3)(A).

[2] 40 CFR § 122.44(k).

[3] Clean Water Act § 402(p)(3)(B) (emphasis added); *Building Industry Ass'n of San Diego County v. State Board* (2004) 124 Cal.App.4th 866.

[4] Clean Water Act § 402(p)(3)(B).

Maximum Extent Practicable

The Court of Appeal recently ruled that since the Clean Water Act does not define MEP, it was proper for the Regional Board to define MEP in the permit:

> . . . As broadly defined in the Permit, the maximum extent practicable standard is a highly flexible concept that depends on balancing numerous factors, including the particular control's technical feasibility, cost, public acceptance, regulatory compliance, and effectiveness. This definition conveys that the Permit's maximum extent practicable standard is a term of art, and is not a phrase that can be interpreted solely by reference to its everyday or dictionary meaning. Further, the Permit's definitional section states that the maximum extent practicable standard "considers economics and is generally, but not necessarily, *less* stringent than BAT." (Italics added.) BAT is an acronym for "best available technology economically achievable," which is a technology-based standard for industrial storm water dischargers that focuses on reducing pollutants by treatment or by a combination of treatment and best management practices. [Citation omitted.] If the maximum extent practicable standard is generally "less stringent" than another Clean Water Act standard that relies on available technologies, it would be unreasonable to conclude that anything more stringent than the maximum extent practicable standard is necessarily impossible. In other contexts, courts have similarly recognized that the word "practicable" does not necessarily mean the most that can possibly be done. [Citations omitted.][5]

The State Board has explained MEP as follows:

> MEP is the technology-based standard established by Congress in CWA section 402(p)(3)(B)(iii) that municipal dischargers of storm water must meet. Technology-based standards establish the level of pollutant reductions that dischargers must achieve. MEP is generally a result of emphasizing pollution prevention and source control BMPs as the first lines of defense in combination with structural and treatment methods where appropriate serving as additional lines of defense. The MEP approach is an ever evolving, flexible, and advancing concept, which considers technical and economic feasibility. As knowledge about controlling urban runoff continues to evolve, so does that which constitutes MEP. The individual and collective activities elucidated in the MS4's SWMP become its proposal for reducing or eliminating pollutants in storm water to the MEP. The way in which MEP is met may vary between communities.

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[5] *Building Industry Ass'n of San Diego County v. State Board, supra.*

> The MEP standard applies to all regulated MS4s, including those in Phase I and small MS4s regulated by [the Phase II] General Permit. Consistent with U.S. EPA guidance, the MEP standard in California is applied so that a first-round storm water permit requires BMPs that will be expanded or better-tailored in subsequent permits. In choosing BMPs, the major focus is on technical feasibility, but cost, effectiveness, and public acceptance are also relevant. If a Permittee chooses only the most inexpensive BMPs, it is likely that MEP has not been met. If a Permittee employs all applicable BMPs except those that are not technically feasible in the locality, or whose cost exceeds any benefit to be derived, it would meet the MEP standard. MEP requires Permittees to choose effective BMPs, and to reject applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs are not technically feasible, or the cost is prohibitive. (See SWRCB Order WQ 2000-11 [citation].)
>
> Generally, in order to meet MEP, communities that have greater water quality impacts must put forth a greater level of effort. Alternatively, for similar water quality conditions, communities should put forth an equivalent level of effort. However, because larger communities have greater resources (both financial resources as well as existing related programs that can help in implementing storm water quality programs), it may appear that they have more robust storm water programs. Additionally, because storm water programs are locally driven and local conditions vary, some BMPs may be more effective in one community than in another. A community that has a high growth rate would derive more benefit on focusing on construction and post-construction programs than on an illicit connection program because illicit connections are more prevalent in older communities.[6]

Although the Regional Board must consider costs in determining what constitutes MEP, the Board need not perform a cost-benefit analysis and need not demonstrate that the benefits of a particular control or BMP outweigh the costs.[7] In considering whether a BMP's cost is reasonable, the Board should also consider the cost of any impairments from storm water runoff, such as the impacts of beach closures on the local economy.[8]

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[6] State Board Order No. DWQ 2003-0005 (Phase II General Permit), Fact Sheet, pp. 8-9; *see also,* State Board Order No. WQ 2000-0011 (City of Bellflower et al.).

[7] State Board Order No. WQ 2000-0011 (City of Bellflower et al.).

[8] *Id.*

Iterative Process for Achieving Water Quality Standards

Phase I (large and medium) MS4 permits in California typically prohibit any discharges that would violate water quality standards in the receiving water. The proposed Salinas permit includes such a prohibition. (Prohibition A.2 and Receiving Water Limitation C.1.) The Regional Board enforces these prohibitions differently than prohibitions in other permits. These are not absolute prohibitions, as in a typical NPDES permit. Rather, the permittee must comply with the prohibition through an iterative process. Thus, upon discovering a discharge that is causing or contributing to a water quality exceedance (or a condition of pollution, contamination or nuisance; see Prohibition A.1 and Receiving Water Limitation C.2), the permittee must propose more stringent controls in order to reduce the exceedance to the MEP. The proposal is subject to the approval of the Executive Officer or Regional Board, who may require the permittee to implement more stringent BMPs. The permittee complies with the prohibition by undertaking this process and implementing the approved BMPs.

Thus, the State Board generally does not require "strict compliance" with water quality standards through numeric effluent limitations. The iterative approach instead achieves compliance over time. "The iterative approach is protective of water quality, but at the same time considers the difficulties of achieving full compliance through BMPs that must be enforced throughout large and medium municipal storm sewer systems."[9]

The Phase II (small MS4) only requires compliance with water quality standards in areas of high growth or areas with populations over 50,000. These locales must comply with Attachment 4 of the Phase II permit, which, among other things, prohibits causing or contributing to a receiving water exceedance, subject to the MEP iterative process.

Requirements More Stringent than MEP

Even though the iterative approach does not require strict compliance with water quality standards, it is still more stringent than the MEP standard. However, MEP is not an upper limit for MS4 permits where a regional board determines that other pollutant controls are "appropriate."[10] That is, the provision in Clean Water Act Section 402(p) that allows the State to impose "such other provisions as the . . . State determines appropriate for the control of such pollutants" does not limit those other provisions to the MEP standard.

Thus, the Phase II permit incorporates the Ocean Plan and Basin Plan prohibition against discharges into Areas of Special Biological Significance. The Lahontan Region's Basin plan

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[9] State Board Order No. WQ 2001-15 (Building Industry Ass'n of San Diego County).

[10] *Building Industry Association of San Diego County v. State Board, supra; Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159, 1166.

imposes numeric effluent limits for MS4 discharges into the Lake Tahoe basin, which protects an outstanding national resource water.[11] More stringent requirements may be necessary for discharges into impaired waters.[12] Absent special-status waters or other justification for more immediate compliance, the State Board requires that receiving water limitations be subject to the iterative approach.[13]

Non-Storm Water Discharges

MS4 permits must also "effectively prohibit non-storm water discharges" into the system. "Storm water" means "storm water runoff, snow melt runoff, and surface runoff and drainage."[14] Thus, permits for MS4s must "effectively prohibit" all discharges into storm drains which are not comprised of "storm water runoff, snow melt runoff, and surface runoff and drainage." Discharge of sediment in storm water runoff is not a non-storm water discharge.[15]

While MS4s must develop programs that are effective in prohibiting non-storm water discharges to the sewer system, they are not responsible for completely prohibiting all non-storm water discharges. In general, the requirement to "effectively prohibit" non-storm water discharges requires either prohibiting the flows from the MS4 system or ensuring that operators of non-storm water discharges obtain NPDES permits. MS4s meet this requirement by implementing a program to detect and remove, or to require the discharger into the system to obtain a separate NPDES permit for, illicit discharges and improper disposal into the storm sewer.[16]

Most low-threat discharges, such as landscape irrigation water, dechlorinated swimming pool water or air conditioner condensate, are exempt from these requirements unless that type of discharge is a significant contributor of pollutants to the MS4.[17]

If you have any questions or would like further clarification, please contact me at (916) 341-5165 or email me at Lokun@waterboards.ca.gov.

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[11] State Board Order No. WQO 2001-11.

[12] See, e.g., 40 CFR § 122.34(3)(1) (small MS4s must comply with requirements more stringent than MEP in a TMDL or equivalent analysis).

[13] State Board Order No. WQO 2001-11; State Board Order No. WQO 99-05 (Environmental Health Coalition).

[14] 40 CFR § 122.26(b)(13).

[15] State Board Order No. WQO 2003-0004 (Weyrich).

[16] 40 CFR §§ 122.26(d)(2)(iv)(B), 122.34(b)(3).

[17] 40 CFR §§ 122.26(d)(2)(iv)(B)(1), 122.34(b)(3)(iii).

cc: Mr. Roger Briggs, **[via email]**
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Ms. Donnette Dunaway, **[via email]**
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April 16, 2004

MEMORANDUM

Subject: Implementing the Partial Remand of the Stormwater Phase II Regulations Regarding Notices of Intent & NPDES General Permitting for Phase II MS4s

From: James A. Hanlon /s/
Director, Office of Wastewater Management

To: Water Management Division Directors, Regions I - X

The purpose of this memorandum is to provide guidance on implementing a partial remand of the Stormwater Phase II regulations. The U.S. Court of Appeals for the Ninth Circuit recently denied EPA's petition for rehearing in the Phase II litigation. Environmental Defense Center, et al. v. EPA, No. 70014 & consolidated cases (9th Cir., Sept. 15, 2003). The Department of Justice has informed us that further review by the U.S. Supreme Court is not available. This memorandum provides interim guidance to EPA and State NPDES permitting authorities pending a rulemaking to conform the Phase II rule to the court's order.

The Relevant Provisions of the Rules

This case challenged the NPDES stormwater regulations issued pursuant to Clean Water Act ("CWA") section 402(p)(6). That section directs EPA to "establish a comprehensive program to regulate" stormwater discharges designated by EPA. We commonly describe these regulations as stormwater "Phase II." The regulations require NPDES permits for discharges from certain municipal separate storm sewer systems ("MS4s") for which NPDES permits were not required under CWA section 402(p)(2) and the Phase 1 regulations.

The Phase II regulations require that MS4s reduce the discharge of pollutants "to the maximum extent practicable" (or "the MEP standard"). The regulations also require the MS4s to develop, implement and enforce a stormwater management program containing, among other things, best management practices ("BMPs") identified by the discharger. The regulations authorize the use of "general permits" and require that these BMPs (as well as measurable goals associated with these BMPs) be identified in the Notice of Intent ("NOI") filed by the MS4 in seeking authorization under a general permit. Relying on the "traditional" general permit model, the Agency did not require NOIs to be subject to public hearings.

The Ninth Circuit's Decision

The Ninth Circuit held that these NOI requirements violated various provisions of CWA section 402. They concluded that "the EPA's failure to require review of NOIs, which are the functional equivalents of permits under the Phase II General Permit option, and its failure to make NOIs available to the public or subject to public hearings contravene the express requirements of the Clean Water Act." The remand raises important questions regarding the procedures that would be appropriate for authorization of Phase II MS4 discharges *other than* through an individual permit.

In denying EPA's motion for rehearing the court "vacated" the portions of the Phase II rule that address the procedural issues relating to the general permitting option for Phase II MS4s. Therefore, the Agency needs to take affirmative action to clarify the general permitting option for Phase II MS4s. In any such action, we believe it is imperative that implementation of the MEP standard remain an "iterative" process that optimizes the reduction of stormwater pollutants, rather than a static pollution reduction requirement.

In looking at options for implementing the court's decision, we want to continue to provide States with maximum flexibility. Some State Phase II MS4 permitting procedures already appear to meet the court's intent and will not need changes. However, the general permits and procedures of other States, along with the provisions developed by EPA in States where EPA has program implementation responsibilities, will need to change. To assist MS4 permitting authorities in moving forward with implementing program revisions where needed, EPA provides the following recommendations to address the court's decision.

Guidance for Issuance of New General Permits

1. Public availability of NOIs The Phase II rules already require that Phase II MS4 permittees make the records of their stormwater management plans publicly available at reasonable times during regular business hours. 40 C.F.R. 122.34(g)(2). NOIs (which essentially summarize stormwater management plans) should also be made publicly available. Permitting authorities can ensure the public availability of Phase II MS4 NOIs by providing notice on the web of the facilities applying for coverage under a general permit with either an electronic posting of the NOIs or information on how NOIs can be accessed. NOIs could also be public noticed in a newspaper, or by another effective manner.

Unless a permitting authority has already otherwise incorporated public notice procedures into its processes for issuance of Phase II MS4 general permits, NPDES agencies that have not yet issued final permits should include permit language explaining that (and how) NOIs will be made available to the public with sufficient time to allow for meaningful public comment. EPA recommends that permitting authorities make the NOIs available to the public at least thirty days before authorization to discharge.

2. Opportunity for public hearing The court's decision requires that the public be given an opportunity to request a public hearing. If the Phase II MS4 general permittee provides public notice for the NOI, the permitting authority will still need to provide the public an opportunity to request a hearing. EPA recommends that permitting authorities include permit language explaining the process for requesting a public hearing on an NOI, the standard by which such requests will be judged, the procedures for conducting public hearing requests that are granted, and the procedures for permitting authority consideration of the information submitted at the hearing in determining whether to grant authorization to discharge to the submitter of the NOI. If a public hearing is requested, the permitting authority should consider both whether to grant a hearing and the range of options for the conduct of the hearing, including, for example, a single public hearing for consideration of multiple Phase II MS4 permittee NOIs.

3. Permitting Authority reviews of NOIs The permitting authority will need to conduct an appropriate review of Phase II MS4s' NOIs to ensure consistency with the permit. General permits should, to the extent practicable, specify in objective terms what is expected of a Phase II MS4 in order to meet the MEP standard. Due to the iterative nature of the MEP standard, we do not believe official "approval" of NOIs is necessary, but the general permits will need to specify when authorization occurs, such as after notice from the permitting authority that review is complete, or after a specified waiting period. EPA notes that this process does not preclude the permitting authority from denying an MS4 authorization to discharge. Either of these timing options should provide the permitting authority with sufficient time to review NOIs, to ensure that NOIs have been publicly available, and that there has been an opportunity to request a public hearing to provide input.

Guidance for General Permits Already Issued for MS4s

Permitting authorities that already have issued general permits should determine the most effective way to provide public notice and review of MS4 NOIs. Unless a permitting authority has already otherwise incorporated such procedures into its processes for issuance of Phase II MS4 general permits, NPDES agencies that have issued final permits should:

- List on the State or EPA Region's web site those MS4 permittees who have submitted NOIs and how NOIs can be reviewed by the public. Include information on how comments can be submitted and a hearing can be requested. If a public hearing is requested, the permitting authority should consider both whether to grant a hearing and the range of options for the conduct of the hearing, including, for example, a single public hearing for consideration of multiple Phase II MS4 permittee NOIs.

- Conduct an appropriate review of submitted NOIs (to determine compliance with the permit) and contact the MS4 when changes appear to be needed.

MS4s continue to have an obligation to apply for permit coverage, whether under an individual NPDES permit or an NPDES general permit. We do not believe that the court ruling creates legal vulnerability for violations of the CWA for Phase II MS4 permittees that have filed timely applications, whether or not authorization has been granted. The Phase II regulations establish application deadlines, not authorization deadlines. Even when Phase II MS4 permittees are authorized, the regulations do not require immediate compliance with the MEP standard, i.e., development and full implementation of the Phase II MS4 stormwater management program. Instead, the permitting authority specifies the applicable time period, which maybe be as long as five years after permit issuance.

We request that you communicate this guidance to States within your Region which are authorized to administer the NPDES program. If you have questions or concerns, please contact Linda Boornazian at (202) 564-0221 or Wendy Bell at (202) 564-0746.

cc: Ben Grumbles, OW
NPDES Branch Chiefs, EPA Regions I - X
Susan Lepow, OGC
Mark Pollins, ORE
Robbi Savage, ASIWPCA

State of California

Memorandum

To : Bruce Fujimoto
Division of Water Quality

Date: OCT 3 1995

Elizabeth M. Jennings

Elizabeth Miller Jennings
Senior Staff Counsel

From : OFFICE OF THE CHIEF COUNSEL
STATE WATER RESOURCES CONTROL BOARD
901 P Street, Sacramento, CA 95814
Mail Code G-8

Subject: MUNICIPAL STORM WATER PERMITS: COMPLIANCE WITH WATER QUALITY OBJECTIVES

ISSUE

Must storm water permits for municipal separate storm sewer systems (MS4s) include requirements necessary to achieve water quality objectives?

CONCLUSION

Storm water permits issued to MS4s must include requirements necessary to achieve water quality objectives.

DISCUSSION

Section 301 of the Clean Water Act prohibits the discharge of any pollutant unless pursuant to a National Pollutant Discharge Elimination System (NPDES) permit. Section 301 also requires compliance with effluent limitations necessary to achieve compliance with technology-based standards (e.g., best practicable control technology currently available or secondary treatment). Finally, Section 301 requires compliance with any more stringent effluent limitation which are necessary to protect water quality standards.

Section 402(p) of the Clean Water Act includes a technology-based standard for storm water permits issued to MS4s. Such permits must require:

> "controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods ...."

Section 402(p) does not discuss water quality-based standards. A question is therefore raised whether permits issued to MS4s must include only effluent limitations to meet the technology-based standard of "maximum extent practicable" (MEP), or whether they must also include water quality-based effluent limitations.

This question has already been answered by the SWRCB in Order No.WQ 91-03. The answer is that permits issued to MS4s must include effluent limitations which will achieve the MEP standard, and will also achieve compliance with water quality objectives. The SWRCB stated:

> We therefore conclude that permits for municipal separate storm sewer systems issued pursuant to Clean Water Act Section 402(p) must contain effluent limitations based on water quality standards. Order No. WQ 91-03, at slip op. 36.

The specific language in effluent limitations or other permit conditions is left to the discretion of the agency issuing the permit. Thus, for storm water permits for MS4s, it is appropriate to include "best management practices" (BMPs) instead of numeric effluent limitations. See, Order No. WQ 91-03, at slip op. 37-38. These BMPs may be adequate as both technology-based limitations and water quality-based limitations. *Id.* Section 301(b)(1)(C) of the Clean Water Act broadly requires compliance with "any more stringent limitation, including those necessary to meet water quality standards". The legal requirements for determining effluent limitations in permits are listed in 40 Code of Federal Regulations (CFR) Section 122.44. The SWRCB interpreted these provisions in Order No. WQ 91-03, and concluded permits for MS4s may include BMPs as effluent limitations.

In Order No. WQ 91-04, the SWRCB considered a storm water permit issued to a MS4 that included BMPs as effluent limitations, and did not specifically require compliance with water quality objectives. The SWRCB stated that even where a permit does not specifically reference violation of water quality standards, it should be read "so as to require the implementation of practices which will achieve compliance with applicable standards". Slip op. at 15.

In conclusion, the SWRCB has determined storm water permits for MS4s must include requirements necessary to achieve compliance with both MEP and water quality standards. The SWRCB has allowed RWQCBs to determine the specific requirements to place in permits. The SWRCB has approved permits for MS4s which include BMPs rather than numeric effluent limitations. The SWRCB has also approved a permit that did not specifically prohibit violation of water quality objectives. The permit was approved because it contained BMPs adequate to meet water quality objectives.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

NOV 15 2006

OFFICE OF WATER

MEMORANDUM

SUBJECT: Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in *Friends of the Earth, Inc. v. EPA, et al.*, No.05-5015, (April 25, 2006) and Implications for NPDES Permits

FROM: Benjamin H. Grumbles
Assistant Administrator

TO: Director, Office of Ecosystem Protection, Region 1
Director, Division of Environmental Planning and Protection, Region 2
Water Division Directors, Regions 3-7 and Region 9
Director, Office of Ecosystems Protection and Remediation, Region 8
Director, Office of Environmental Cleanup, Region 10

The purpose of this memorandum is to clarify EPA's expectations concerning the appropriate time increment used to express "total maximum daily loads" (TMDLs) in light of the recent decision by the U. S. Court of Appeals for the D.C. Circuit in *Friends of the Earth, Inc. v. EPA, et al.*, No. 05-5015 (D.C. Cir. 2006). In *Friends of the Earth*, the D.C. Circuit held that two TMDLs for the Anacostia River (one established by EPA and one approved by EPA) did not comply with the Clean Water Act because they were not expressed as "daily" loads.

The *Friends of the Earth* decision has raised some questions regarding the establishment of both TMDLs and effluent limits in National Pollutant Discharge Elimination System (NPDES) permits that implement wasteload allocations established in TMDLs. As explained in more detail below, EPA recommends that all future TMDLs and associated load allocations and wasteload allocations be expressed in terms of daily time increments. However, EPA does not believe that the *Friends of the Earth* decision requires any changes to EPA's existing policy and guidance describing how a TMDL's wasteload allocations are implemented in NPDES permits.

EPA's Expectations Regarding "Daily" Loads in TMDLs

EPA continues to believe that the use of the word "daily" in the term "total maximum daily load" is not an unambiguous direction from Congress that TMDLs must be stated in the form of a uniformly applicable 24-hour load. However at this time, there is significant legal uncertainty about whether courts across the country will follow the reasoning of the D.C. Circuit decision in *Friends of the Earth* or that of the U.S. Court of Appeals for the Second Circuit in their decision in *NRDC v. Muszynski*[1]. In light of that uncertainty, EPA recommends that all TMDLs and associated load allocations and wasteload allocations be expressed in terms of daily time increments. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards. TMDLs must continue to be established at a level necessary to attain and maintain the applicable water quality standards, account for seasonal variations and include a margin of safety. Because water quality standards are expressed in a variety of ways and because pollutants and water bodies have different characteristics, EPA believes that there is some flexibility in how the daily time increments may be expressed. The following are a few examples of this potential flexibility:

- If consistent with the applicable water quality standard and technically suitable for the pollutant and water body type in question, a TMDL and associated load allocations and wasteload allocations may be expressed as both minimum and maximum daily loads, or as average daily loads. For example, a TMDL for the pollutant parameter pH may include both minimum and maximum values consistent with how the applicable WQS for the parameter pH is expressed (commonly as a range.)

- If technically appropriate and consistent with the applicable water quality standard, it may also be appropriate for the TMDL and associated load allocations and wasteload allocations to be expressed in terms of differing maximum daily values depending on the season of the year, stream flow (e.g., wet v. dry weather conditions) or other factors. In situations where pollutant loads, water body flows, or other environmental factors are highly dynamic, it may be appropriate for TMDLs and associated allocations to be expressed as functions of controlling factors such as water body flow. For example, a load-duration curve approach to expressing a TMDL and associated allocations might be appropriate, provided it clearly identifies the allowable daily pollutant load for any given day as a function

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[1] In *NRDC v. Muszynski*, 268 F.3d 91 (2nd Cir. 2001), NRDC challenged EPA's approval of nutrient TMDLs with annual loads established by New York for reservoirs. The Second Circuit held that "the term 'total maximum daily load' is susceptible to a broader range of meanings" than loads calculated on a daily basis. 268 F.3d at 98-99. The D. C. Circuit decision in *Friends of the Earth* is controlling legal precedent for cases brought in the District of Columbia Circuit while the Second Circuit decision in *Muszynski* is controlling legal precedent in cases brought in the Second Circuit, which includes the States of New York, Connecticut, and Vermont. EPA encourages the three States within the Second Circuit, to submit TMDLs with "daily" loads in a manner consistent with this memorandum. EPA also recognizes that, while the Second Circuit did not vacate the TMDLs in question merely because they did not contain "daily" loads, it required a reasoned explanation for the choice of any particular "non-daily" load.

of the flow occurring that day. Using the load-duration curve approach also has the advantage of addressing seasonal variations as required by the statute and the regulations.

- For TMDLs that are expressed as a concentration of a pollutant, a possible approach would be to use a table and/or graph to express the TMDL as daily loads for a range of possible daily stream flows. The in-stream water quality criterion multiplied by daily stream flow and the appropriate conversion factor would translate the applicable criterion into a daily target (TMDL).

EPA will issue additional technical guidance providing specific information regarding the establishment of daily loads for specific pollutants that will take into consideration the averaging period of the pollutant, the type of water body, and the type of sources the TMDL needs to address.

Facilitating Implementation of Wasteload Allocations through the NPDES Permit Process

In certain circumstances (e.g., impairments caused by storm water), or where the applicable water quality criteria are expressed as a long-term average, it may be appropriate for TMDL documents or their supporting analysis to clearly set forth the implementation-related assumptions underlying any wasteload allocation expressed as a "daily" load. To facilitate implementation of such a load in water bodies where the applicable water quality standard is expressed in non-daily terms, it may be appropriate for the TMDL documentation to include, in addition to wasteload allocations expressed in daily time increments, wasteload allocations expressed as weekly, monthly, seasonal, annual, or other appropriate time increments. When this approach is taken, the TMDL and its supporting documentation should clearly explain that the non-daily loads and allocations are implementation-related assumptions of the daily wasteload allocations and are included to facilitate implementation of the daily allocations as appropriate in NPDES permits and nonpoint source directed management measures. The supporting documentation should discuss the reasons for, and assumptions behind, the non-daily loads to facilitate their understanding and use in the implementation phase.

Recommendations Concerning Existing TMDLs and TMDLs in Process

Through significant effort of the States and EPA regions, more than 20,000 TMDLs have been established, most of them in the last five or six years. EPA's database also shows that approximately 65,000 causes of impairment still need to be addressed by TMDLs. EPA believes that continued development of TMDLs pursuant to State TMDL development schedules is the highest priority at this time. If already existing TMDLs need to be revised in the future, revision of the TMDLs and allocations should be consistent with the recommendations in this memorandum.

For TMDLs under development that have not yet been adopted by States or established by EPA, EPA recommends that such TMDLs and allocations be revised, if feasible, to be consistent with this memorandum prior to their adoption or establishment. If States adopt and submit TMDLs expressed solely in non-daily terms, EPA expects to ask the submitting State to provide written documentation regarding how the submitted TMDLs and allocations would be expressed in daily terms. Such documentation provided by States could then be included in the administrative records supporting EPA's decisions on the TMDLs. If it is unable to obtain such documentation from a State, EPA may develop calculations for its administrative approval record demonstrating how the State's TMDLs and allocations would be expressed in daily terms. In this case, EPA would make it clear that its approval of the State's TMDL is contingent on the assumption that such TMDL contains the daily load calculations developed by EPA.

We recommend that States consult with EPA regarding specific TMDL projects early in the development process to determine appropriate approaches to expressing the TMDLs and allocations. We are working to provide technical support as soon as practicable. First, we will be providing a draft of a technical document outlining an approach for deriving daily limits for bacteria, TSS, sediments and nutrients using the load duration curve approach. In addition, we are preparing a series of technical fact sheets and case studies based on typical averaging periods of criteria, types of water body and types of sources, to provide technical support in developing daily loads for all pollutants. These should be available for review and comment within the next few months.

Implications of the *Friends of the Earth* Decision for NPDES Permits

The *Friends of the Earth* decision does not affect an NPDES permitting authority's ability to use the discretion available to it under the CWA and the NPDES regulations in establishing permit effluent limits and conditions.

There is no express or implied statutory requirement that effluent limitations in NPDES permits necessarily be expressed in daily terms. The CWA definition of "effluent limitation" is quite broad ("effluent limitation" is "any restriction . . . on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources . . ."). See CWA 502(11). Unlike the CWA's definition of TMDL, the CWA definition of "effluent limitation" does not contain a "daily" temporal restriction. Indeed, the central statutory requirement for water-quality based effluent limits in NPDES permits is that they implement applicable water quality standards. See CWA 301(b) (1) (C). Such water quality standards will include water quality criteria for various pollutant parameters that are expressed in terms of differing temporal periods of duration, including hourly, daily, weekly, monthly, seasonal, and annual, as appropriate for each pollutant parameter.[2] Accordingly, effluent limits in NPDES permits may be written in a

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[2] Section 2.1of EPA's *Technical Support Document for Water Quality-based Toxics Control* (TSD) dated March 1991, describes the basis for establishing water quality criteria. EPA's recommended water quality criteria consist of three components: (1) magnitude, (2) duration, and (3) frequency. Magnitude refers to the concentration of the pollutant. Duration is the period of time (averaging period) over which the in-water concentration is averaged for comparison with criteria concentrations. This specification limits the length of time that in-water concentrations may exceed the criteria concentrations. Frequency is how often the criteria can be exceeded.

form that derives from, and complies with, applicable water quality standards that use any of these various time measures. See 122.44(d) (1) (vii) (A).

EPA's regulations at 40 CFR § 122.44(d)(1)(vii) require the permitting authority to ensure that: (a) the level of water quality to be achieved by limits on point sources is derived from, and complies with, all applicable water quality standards; and (b) effluent limitations developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, *are consistent with the assumptions and requirements of any available wasteload allocation* for the discharge prepared by the State and approved by EPA pursuant to 40 C.F.R. 130.7. This provision does not require that effluent limits in NPDES permits be expressed in a form that is identical to the form in which an available wasteload allocation for the discharge is expressed in a TMDL. Rather, permit limits need only be "consistent with the assumptions and requirements" of a TMDL's wasteload allocation.[3] To facilitate implementation of the TMDL, one of the stated "assumptions" of a TMDL's daily load or daily wasteload allocation might be that, for purposes of NPDES implementation in an appropriate context (e.g., storm water), the permit writer has the flexibility to express the permit's effluent limitation using a time frame in keeping with, and appropriate to, the water body and pollutant in question and the applicable water quality standard. Indeed, the TMDL submission might even include such alternate temporal expressions of the total load or the wasteload allocation as implementation assumptions.

The *Friends of the Earth* decision does not affect the NPDES permitting authority's ability to use all available tools to translate TMDLs and their wasteload allocations into enforceable effluent limitations in discharge permits. For example, while the NPDES permitting regulations require "daily maximum" limits for continuous discharges from some point sources, the same regulations specifically authorize "average weekly" and "average monthly" limitations – rather than daily limitations – for discharges from publicly owned water treatment plants. See 40 C.F.R. 122.45(d). Moreover, the regulations further authorize the permit writer to use other unspecified units of time if it is impracticable to calculate daily, weekly or monthly limitations. Id. For non-continuous discharges, the regulations provide flexibility as to the manner in which such discharges are to be limited based on a consideration of factors, including frequency, total mass, maximum rate of discharge of pollutants and prohibition or limitation of specified pollutants by mass, concentration or other appropriate measure. See 40 C.F.R. 122.45(e).

NPDES permit regulations do not require that effluent limits in permits be expressed as maximum daily limits or even as numeric limitations in all circumstances, and such discretion exists regardless of the time increment chosen to express the TMDL. Therefore, expressing a TMDL as a daily load does not interfere with a permit writer's authority under the regulations to translate that daily load into the appropriate permit

[3] EPA's position on this issue was affirmed by the Environmental Appeals Board in *In re: City of Moscow, Idaho,* 10 E.A.D. 135, 148 (July 27, 2001) ("While the governing regulations require *consistency*, they do not require that the permit limitations that will finally be adopted in a final NPDES permit be *identical* to any of the WLAs that may be provided in a TMDL.")

limitation, which in turn could be expressed as an hourly, weekly, monthly or other measure.

EPA will continue to use existing guidance and policy memoranda to guide the development of WQBELs that are consistent with both 40 CFR § 122.44(d) (1) (vii) and 40 CFR §122.45(d). These include: the *Technical Support Document for Water Quality-based Toxics Control* (TSD) dated March 1991, an EPA Memorandum titled *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs* dated November 22, 2002, and a memorandum titled *Annual Permit Limits for Nitrogen and Phosphorus for Permits Designed to Protect Chesapeake Bay and its tidal tributaries from Excess Nutrient Loading under the National Pollutant Discharge Elimination System* dated March 3, 2004.

Recommendation Concerning NPDES Permits

EPA recommends that NPDES permitting authorities continue to establish effluent limits that implement wasteload allocations established in approved TMDLs in accordance with existing regulation, policy and guidance as described above.

cc: Ephraim King
Steve Neugeboren
Suzanne Schwartz
James Hanlon

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

NOV 22 2002

OFFICE OF
WATER

MEMORANDUM

SUBJECT: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs

FROM: Robert H. Wayland, III, Director
Office of Wetlands, Oceans and Watersheds

James A. Hanlon, Director
Office of Wastewater Management

TO: Water Division Directors
Regions 1 - 10

This memorandum clarifies existing EPA regulatory requirements for, and provides guidance on, establishing wasteload allocations (WLAs) for storm water discharges in total maximum daily loads (TMDLs) approved or established by EPA. It also addresses the establishment of water quality-based effluent limits (WQBELs) and conditions in National Pollutant Discharge Elimination System (NPDES) permits based on the WLAs for storm water discharges in TMDLs. The key points presented in this memorandum are as follows:

NPDES-regulated storm water discharges must be addressed by the wasteload allocation component of a TMDL. See 40 C.F.R. § 130.2(h).

NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. See 40 C.F.R. § 130.2 (g) & (h).

Storm water discharges from sources that are not currently subject to NPDES regulation may be addressed by the load allocation component of a TMDL. See 40 C.F.R. § 130.2(g).

It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs. See 40 C.F.R. § 130.2(i). In cases where wasteload allocations are developed for categories of discharges, these categories should be defined as narrowly as available information allows.

The WLAs and LAs are to be expressed in numeric form in the TMDL. See 40 C.F.R. § 130.2(h) & (i). EPA expects TMDL authorities to make separate allocations to NPDES- regulated storm water discharges (in the form of WLAs) and unregulated storm water (in the form of LAs). EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability in the system.

NPDES permit conditions must be consistent with the assumptions and requirements of available WLAs. See 40 C.F.R. § 122.44(d)(1)(vii)(B).

WQBELs for NPDES-regulated storm water discharges that implement WLAs in TMDLs may be expressed in the form of best management practices (BMPs) under specified circumstances. See 33 U.S.C. §1342(p)(3)(B)(iii); 40 C.F.R. §122.44(k)(2)&(3). If BMPs alone adequately implement the WLAs, then additional controls are not necessary.

EPA expects that most WQBELs for NPDES-regulated municipal and small construction storm water discharges will be in the form of BMPs, and that numeric limits will be used only in rare instances.

When a non-numeric water quality-based effluent limit is imposed, the permit's administrative record, including the fact sheet when one is required, needs to support that the BMPs are expected to be sufficient to implement the WLA in the TMDL. See 40 C.F.R. §§ 124.8, 124.9 & 124.18.

The NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. See 40 C.F.R. § 122.44(i). Where effluent limits are specified as BMPs, the permit should also specify the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data).

The permit should also provide a mechanism to make adjustments to the required BMPs as necessary to ensure their adequate performance.

This memorandum is organized as follows:

(I). Regulatory basis for including NPDES-regulated storm water discharges in WLAs in TMDLs;

(II). Options for addressing storm water in TMDLs; and

(III). Determining effluent limits in NPDES permits for storm water discharges consistent with the WLA

(I). Regulatory Basis for Including NPDES-regulated Storm Water Discharges in WLAs in TMDLs

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the Act requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4), i.e., systems serving a population over 250,000 or systems serving a population between 100,000 and 250,000, respectively. These discharges are referred to as Phase I MS4 discharges.

In addition, the Administrator was directed to study and issue regulations that designate additional storm water discharges, other than those regulated under Phase I, to be regulated in order to protect water quality. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s (including all systems within "urbanized areas" and other systems serving populations less than 100,000) and storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This program expansion is referred to as Phase II.

Section 402(p) also specifies the levels of control to be incorporated into NPDES storm water permits depending on the source (industrial versus municipal storm water). Permits for storm water discharges associated with industrial activity are to require compliance with all applicable provisions of Sections 301 and 402 of the CWA, i.e., all technology-based and water quality-based requirements. See 33 U.S.C. §1342(p)(3)(A). Permits for discharges from MS4s, however, "shall require controls to reduce the discharge of pollutants to the maximum extent practicable ... and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." See 33 U.S.C. §1342(p)(3)(B)(iii).

Storm water discharges that are regulated under Phase I or Phase II of the NPDES storm water program are point sources that must be included in the WLA portion of a TMDL. See 40 C.F.R. § 130.2(h). Storm water discharges that are not currently subject to Phase I or Phase II of the NPDES storm water program are not required to obtain NPDES permits. 33 U.S.C. §1342(p)(1) & (p)(6). Therefore, for regulatory purposes, they are analogous to nonpoint sources and may be included in the LA portion of a TMDL. See 40 C.F.R. § 130.2(g).

(II). Options for Addressing Storm Water in TMDLs

Decisions about allocations of pollutant loads within a TMDL are driven by the quantity and quality of existing and readily available water quality data. The amount of storm water data available for a TMDL varies from location to location. Nevertheless, EPA expects TMDL authorities will make separate aggregate allocations to NPDES-regulated storm water discharges (in the form of WLAs) and unregulated storm water (in the form of LAs). It may be reasonable to quantify the allocations through estimates or extrapolations, based either on knowledge of land use patterns and associated literature values for pollutant loadings or on actual, albeit limited, loading information. EPA recognizes that these allocations might be fairly rudimentary because of data limitations.

EPA also recognizes that the available data and information usually are not detailed enough to determine waste load allocations for NPDES-regulated storm water discharges on an outfall-specific basis. In this situation, EPA recommends expressing the wasteload allocation in the TMDL as either a single number for all NPDES-regulated storm water discharges, or when information allows, as different WLAs for different identifiable categories, e.g., municipal storm water as distinguished from storm water discharges from construction sites or municipal storm water discharges from City A as distinguished from City B. These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial storm water sources or dischargers).

(III). Determining Effluent Limits in NPDES Permits for Storm Water Discharges Consistent with the WLA

Where a TMDL has been approved, NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the TMDL. See 40 CFR § 122.44(d)(1)(vii)(B). Effluent limitations to control the discharge of pollutants generally are expressed in numerical form. However, in light of 33 U.S.C. §1342(p)(3)(B)(iii), EPA recommends that for NPDES-regulated municipal and small construction storm water discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. See *Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits*, 61 FR 43761 (Aug. 26, 1996). The Interim Permitting Approach Policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

EPA's policy recognizes that because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. The variability in the system and minimal data generally available make it difficult to determine with precision or certainty actual and projected loadings for individual dischargers or groups of dischargers. Therefore, EPA believes that in these situations, permit limits typically can be expressed as BMPs, and that numeric limits will be used only in rare instances.

Under certain circumstances, BMPs are an appropriate form of effluent limits to control pollutants in storm water. See 40 CFR § 122.44(k)(2) & (3). If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the storm water component of the TMDL, EPA recommends that the TMDL reflect this.

EPA expects that the NPDES permitting authority will review the information provided by the TMDL, see 40 C.F.R. § 122.44(d)(1)(vii)(B), and determine whether the effluent limit is appropriately expressed using a BMP approach (including an iterative BMP approach) or a numeric limit. Where BMPs are used, EPA recommends that the permit provide a mechanism to require use of expanded or better-tailored BMPs when monitoring demonstrates they are necessary to implement the WLA and protect water quality.

Where the NPDES permitting authority allows for a choice of BMPs, a discussion of the BMP selection and assumptions needs to be included in the permit's administrative record, including the fact sheet when one is required. 40 C.F.R.§§ 124.8, 124.9 & 124.18. For general permits, this may be included in the storm water pollution prevention plan required by the permit. See 40 C.F.R. § 122.28. Permitting authorities may require the permittee to provide supporting information, such as how the permittee designed its management plan to address the WLA(s). See 40 C.F.R. § 122.28. The NPDES permit must require the monitoring necessary to assure compliance with permit limitations, although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. See 40 CFR § 122.44(i). EPA recommends that such permits require collecting data on the actual performance of the BMPs. These additional data may provide a basis for revised management measures. The monitoring data are likely to have other uses as well. For example, the monitoring data might indicate if it is necessary to adjust the BMPs. Any monitoring for storm water required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. This approach is further supported by the recent report from the National Research Council (NRC), *Assessing the TMDL Approach to Water Quality Management* (National Academy Press, 2001). The NRC report recommends an approach that includes "adaptive implementation," i.e., "a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards" . . . and adjustments made as necessary. *NRC Report* at ES-5.

This memorandum discusses existing requirements of the Clean Water Act (CWA) and codified in the TMDL and NPDES implementing regulations. Those CWA provisions and regulations contain legally binding requirements. This document describes these requirements; it does not substitute for those provisions or regulations. The recommendations in this memorandum are not binding; indeed, there may be other approaches that would be appropriate in particular situations. When EPA makes a TMDL or permitting decision, it will make each decision on a case-by-case basis and will be guided by the applicable requirements of the CWA and implementing regulations, taking into account comments and information presented at that time by interested persons regarding the appropriateness of applying these recommendations to the particular situation. EPA may change this guidance in the future.

If you have any questions please feel free to contact us or Linda Boornazian, Director of the Water Permits Division or Charles Sutfin, Director of the Assessment and Watershed Protection Division.

cc:
Water Quality Branch Chiefs
Regions 1 - 10

Permit Branch Chiefs
Regions 1 - 10

ATTACHMENT AVAILABLE UPON REQUEST

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

OFFICE OF WATER

AUG - 8 1990

MEMORANDUM

SUBJECT: Designation of Storm Water Discharges for Immediate Permitting

FROM: James R. Elder, Director
Office of Water Enforcement and Permits

TO: Water Management Division Directors
Regions I - X
NPDES State Directors

The Water Quality Act of 1987 (WQA) provides EPA and NPDES States with new deadlines for the development of NPDES permit requirements for storm water discharges. This memorandum is intended to inform Regional and State offices of the authority under the Act to continue or initiate efforts to permit storm water discharges that are causing environmental problems.

Background

Section 405 of the WQA amends the Clean Water Act (CWA) by adding section 402(p) to address storm water discharges. The Act provides a moratorium for certain storm water discharges from the requirement to obtain permits until after October 1, 1992. However, there are specific exceptions to this moratorium:

(A) A discharge with respect to which a permit has been issued under Section 402 before the date of enactment of section 402(p).

(B) A discharge associated with industrial activity.

(C) A discharge from a municipal separate storm sewer system serving a population of 250,000 or more.

(D) A discharge from a municipal separate storm sewer system serving a population of 100,000 or more, but less than 250,000.

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(E) A discharge for which the Regional Administrator or the State Director, as the case may be, determines that the storm water discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to the waters of the United States.

The existing delegation of authority to Regional Administrators to issue and condition permits or to deny applications for permits for discharges pursuant to section 402 of the Clean Water Act includes the authority to implement section 402(p)(2)(E) (Delegations Manual 7/25/84, 2-20 NPDES). This authority may be redelegated to the Directors of the Regional Water Divisions, subject to the provisions of 40 CFR 124 and 125.

Section 402(p)(2)(A) preserves the ability to enforce existing permits. On December 7, 1988 (53 FR 49416), EPA issued a notice of proposed rulemaking (NPRM) addressing permit application requirements for discharges covered by sections 402(p)(2)(B) through (E). This memorandum will discuss implementation of section 402(p)(2)(E).

Discussion

Although EPA is currently amending regulatory requirements for permit applications for industrial and municipal storm water discharges, some storm water discharges have already been identified as representing significant sources of pollutants with discernible adverse effects on water quality and should be regulated through the permits program now. Regional Offices and NPDES approved States should designate those storm water discharges for permit issuance under the authority of section 402(p)(2)(E) as soon as possible after their impact is documented.

Storm water dischargers required to obtain an NPDES permit under section 402(p)(2)(E) can include dischargers from any conveyance or system of conveyances used for collecting and conveying storm water runoff including municipal separate storm sewer systems, storm water dischargers associated with industrial activity, and other dischargers from a point source. To be designated for a permit under section 402(p)(2)(E), the Administrator, or in States with approved NPDES programs, the Director, must determine that the storm water discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

Section 502(14) of the CWA defines the term "point source" broadly to include "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." Many courts have supported broad interpretations of this term, for example, the court in Sierra Club v. Abston Construction Co., Inc., 620 F.2d 41 (5th Cir. 1980) found that conveyances formed either as a result of natural erosion or by material means, and which constitute a component of a drainage system, were point sources.

However, it should be noted that agricultural storm water discharges and return flows from irrigated agriculture are specifically excluded from the CWA definition of point source, and cannot be designated for a permit under section 402(p)(2)(E). In addition, Section 402(l)(2) prohibits EPA from requiring an NPDES permit for discharges of storm water runoff from mining operations or oil and gas operations composed entirely of storm water which is not contaminated by contact with, or does not come into contact with any overburden, raw material, intermediate products, finished product, by-product or waste products located on the site of such operations. Storm water discharges from mining operations or oil and gas operations which meet the criteria of section 402(p)(2)(E) as being either a significant contributor of pollutants to waters of the United States or contributing to a water quality standard violation either will be contaminated by contact with, or will have come into contact with overburden, raw material, intermediate products, finished product, by-product or waste products located on the site of such operations.

At a minimum, Regions and States should consider immediately designating any storm water discharges as requiring an NPDES permit if the discharges are known/suspected to:

1. Contribute to a violation of a water quality standard for a waterbody segment listed under section 304(l)(1)(B), or contribute significant amounts of pollutants to any waterbody segment listed under sections 304(l)(1)(A), 319(a)(1), or 314(a)(1)(F)[1].

2. Contribute significant amounts of pollutants to waters of the United States, including sensitive wetlands, drinking water sources, estuaries, lakes, scenic rivers/streams, or near coastal areas that are highly valued natural resources.

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[1] Many discharges of pollutants associated with urban runoff, construction, mining, agricultural (feedlots), and waste disposal have traditionally been considered nonpoint sources. However, legally, storm water from these sources discharged through conveyances are point sources under the CWA.

3. Originate from municipal separate storm sewer systems that have, or are suspected of having, process waste or sanitary wastes discharged to them.

4. Originate from municipal separate storm sewer systems that are suspected of containing a significant contribution of pollutants.

The four categories presented include (but are not limited to) discharges which require storm water permits. Each category is described and further clarified using example case histories categorized in the following pages.

1. **CONTRIBUTE TO A VIOLATION OF A WATER QUALITY STANDARD FOR A WATERBODY SEGMENT LISTED UNDER SECTION 304(1)(1)(B), OR CONTRIBUTE SIGNIFICANT POLLUTANTS TO ANY WATERBODY SEGMENT LISTED UNDER SECTIONS 304(1)(1)(A), 319(a)(1), OR 314(a)(1)(F).**

   A. Contribute to a violation of a water quality standard for a waterbody segment listed under section 304(1)(1)(B), or contribute significant amounts of pollutants to any waterbody segment listed under section 304(1)(1)(A).

Section 304(l) of the CWA requires States to develop three lists of related waters impaired by toxic and nontoxic pollutants. The first list (section 304(l)(1)(A)(i)) includes waters that will not achieve numeric water quality standards for the 126 priority pollutants identified as toxic pursuant to section 307(a) of the CWA after application of CWA technology-based requirements. The second list (section 304(l)(1)(A)(ii)) is a comprehensive list of waters impaired by any pollutant from any source such that the water is not meeting the goals of the CWA after application of technology-based requirements. The section 304(l)(1)(B) list consists of those waters which, after application of technology-based requirements, are not expected to achieve numeric or narrative water quality standards due entirely or substantially to point source discharges of any of the 126 priority toxic pollutants. The fourth list (section 304(l)(1)(C)) is a list of point sources affecting the waterbodies on the section 304(l)(1)(B) list. On this fourth list, States must identify the specific point sources discharging the toxic pollutant responsible for the listing, and provide an individual control strategy (ICS) for each source. The statutory language for section 304(l)(1) is as follows:

"State list of Navigable Waters and Development of Strategies. . .

(A) a list of those waters within the State which after the application of effluent limitations required under section 301(b)(2) of this Act cannot reasonably be anticipated to attain or maintain (i) water quality standards for such waters reviewed, revised, or adopted in accordance with section 303(c)(2)(B) of this Act, due to toxic pollutants, or (ii) that water quality which shall assure protection of public health, public water supplies, agricultural and industrial uses, and the protection and propagation of a balanced population of shellfish, fish and wildlife, and allow recreational activities in and on the water;

(B) list of all navigable waters in such state for which the State does not expect the applicable standard under section 303 of this Act will be achieved after the requirements of sections 301(b), 306, and 307(b) are met, due entirely or substantially to discharges from point sources of any toxic pollutants listed pursuant to section 307(a);

(C) for each segment of the navigable waters included on such lists, a determination of the specific point sources discharging any such toxic pollutant which is believed to be preventing or impairing such water quality and the amount of each such toxic pollutant discharged by each such source."

Waterbodies may be listed under section 304(l) because of storm water discharges associated with urban runoff, construction site runoff, mining runoff, or other runoff categories which contribute to a water quality standard violation. For waterbodies listed on the section 304(l)(1)(B) list, States or EPA must have identified the specific point source discharging the toxic pollutant by June 4, 1989. States must have developed an individual control strategy (ICS/NPDES permit) by June 4, 1989 or EPA in cooperation with States must have done so by June 4, 1990. If the storm water discharge does not have an NPDES permit that will control the point source and bring the waterbody into compliance with State water quality standards, then the discharge should be designated under section 402(p)(2)(E). After designation, the ICS should have been developed by June 4, 1990 in accordance with 304(l) regulatory requirements established on June 2, 1989 (54 FR 23868).

Paragraph (A)(ii) of section 304(l)(1) includes a listing of waterbodies which, after application of technology-based limits, fail to meet applicable water quality standards that assure the attainment of designated uses and the fishable/swimmable goals of the CWA. This list is comprehensive (i.e. it is not limited to waterbodies impaired by toxic pollutants); and where storm water discharges impair these listed waters, the storm water discharge should be considered for designation and permit issuance under section 402(p)(2)(E).

Example

The lower Duwamish River, which empties into the Puget Sound in Washington, has been categorized as having extremely poor water quality, partly attributable to metals contamination. The major causes of the river's condition are industrial discharges, polluted storm water discharges, overland runoff, and combined sewer overflows. As a result, the lower Duwamish River was originally included on Washington's section 304(l)(1)(B) list. As part of the Puget Sound Estuary Program's activities, storm water discharges were characterized for pollutant loadings of metals and organics. Several storm drains were listed due to metals contributions under section 304(l)(1)(C). Since the original listings were submitted, however, the State has suggested that storm drains be delisted. If any storm drains remain on the section 304(l)(1)(C) list, an ICS/NPDES permit will be developed. For storm drains not listed, additional information should be collected; and if this information shows a contribution to a water quality impairment, such storm water discharges should be designated for permitting under section 402(p)(2)(E).

B. Contribute significant pollutants to any waterbody segment listed under section 319(a)(1).

Many storm water discharges have traditionally been considered to be nonpoint sources of pollution because of their diffuse and intermittent nature. Legally, however, they are considered point sources if discharged from a conveyance. Section 319(a)(1)(A) of the CWA requires States to identify in Nonpoint Source Assessment Reports those navigable waters within the State which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards or goals and requirements of the CWA. Section 319(a)(1)(B) requires States to identify those categories and subcategories of nonpoint sources which add significant pollution to navigable waters identified under section 319(a)(1)(A). These lists were required to be developed by States by August 4, 1988. Similarly, section 305(b) requires that water quality impacts from diffuse sources be identified. Discharges from storm water point sources may be classified in categories such as urban runoff or construction site runoff in these reports. The statutory language of section 319(a)(1) is as follows:

"The Governor of each State shall, after notice and opportunity for public comment, prepare and submit to the Administrator for approval, a report which:

(A) identifies those navigable waters within the State which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards or the goals and requirements of the Act;

(B) identifies those categories and subcategories of nonpoint sources or, where appropriate, particular nonpoint sources which add significant pollution to each portion of the navigable waters identified under subparagraph (A) in amounts which contribute to such portion not meeting such water quality standards or such goals and requirements;"

As previously stated, identifiable categories under section 319(a)(1)(B) may include discharges that are associated with urban runoff, construction site runoff, mining runoff, etc. (i.e., those categories that are identified in the State Nonpoint Source Assessment Reports). After a State's Nonpoint Source Assessment Report is approved by the Regional Administrator, storm water discharges covered by section 402(p), which may be listed in the section 319 assessment that impact listed waterbodies, should be considered for designation under section 402(p)(2)(E).

<u>Example</u>

The Minnesota Pollution Control Agency lists Ryan Creek in its State Nonpoint Source Assessment Report as being impacted solely by storm sewers and surface runoff. The Report also lists Shingle Creek as being impacted by land development, storm sewers and surface runoff. Those storm water discharges that contribute to the impairment could be considered for designation and permitting under section 402(p)(2)(E).

C. Contribute significant pollutants to any waterbody segment listed under section 314(a)(1)(F).

As required by section 314, each State will conduct a two-part study to determine a lake's condition and develop methods and strategies for restoration and protection. Such information will specify the location and loading characteristics of significant sources polluting the lake. The statutory language appears in the following lines:

"Each State on a biennial basis shall prepare and submit to the Administrator for his approval --

(F) an assessment of the status and trends of water quality in lakes in such State, including but not limited to, the nature and extent to which the use of lakes is impaired as a result of such pollution, particularly with respect to toxic pollution."

In accordance with section 314(a)(1)(F), States have already submitted Lake Water Quality Assessment Reports. These reports, in many cases, document the impact of storm water discharges on lakes, and were included as part of the State 305(b) Report. Where this information is provided in an Assessment Report that has been approved by the Regional Administrator, any storm water discharges included in the section 314(a)(1)(F) assessment (such as urban runoff, construction site runoff, mining runoff, etc.) which impact a given waterbody should be considered for designation under section 402(p)(2)(E).

Example

In the 1988 Lake Water Quality Assessment Report, the Illinois Environmental Protection Agency lists Levings Park Lagoon, Winnebago County as being water quality limited and partially supporting of one or more designated uses with moderate impairment. The principal source of impairment has been identified as urban runoff. Therefore, discharges resulting from the urban runoff that impact the Levings Park Lagoon could be considered for designation under section 402(p)(2)(E).

2. **SIGNIFICANTLY IMPACT SENSITIVE WETLANDS, DRINKING WATER SOURCES, ESTUARIES, LAKES, OR NEAR COASTAL AREAS THAT ARE HIGHLY VALUED NATURAL RESOURCES.**

Under section 402(p)(2)(E), the Regional Administrator or State Director must determine whether a storm water discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. Based on such a determination, 402(p)(2)(E) designations should be considered for storm water discharges that significantly impact certain waters that warrant special consideration such as wetlands, lakes, scenic rivers/streams, high quality headwaters, estuaries, or coastal regions. Such waterbodies are often spawning, feeding, and nursery grounds for various species, and include sensitive habitats such as mangrove marshes, seagrass beds, and coral reefs. Storm water may enhance eutrophication of these water bodies, and contribute to an overall deterioration in water quality. BOD loads will generally lower the dissolved oxygen (DO) in receiving waters. Petroleum hydrocarbon loads in receiving waters may result from storm water discharges. Sediment loading from storm water runoff can settle to cover spawning habitat or can shade submerged vegetation and limit photosynthesis. Lakes and estuaries have long detention times and tend to concentrate nutrients, such as phosphorous and nitrogen, and other pollutants in the muds and water columns. Where such waterbodies are significantly impacted by storm water discharges, these discharges should be considered for designation. The Regional Administrator or NPDES State Directors may use the Lake Water Quality Assessment Reports and other available information necessary to prioritize impacted waterbodies for discharge designation.

Example

The quality and productivity of the Chesapeake Bay and its tributaries have declined due to the impact of human activity that has caused increased levels of pollutants, nutrients, and toxics in the Bay system and declines in protective land uses, such as forested and undeveloped lands. Shoreline areas of the Bay system are particularly sensitive and susceptible to adverse impacts due to storm water discharges. Where storm water discharges, such as urban runoff, construction site runoff, mining runoff, etc., have been determined to represent a significant source of pollutants to a segment of the Bay or a particular stream segment of a Bay tributary, the discharge could be considered for designation under section 402(p)(2)(E).

3. **MUNICIPAL SEPARATE STORM SEWERS THAT ARE KNOWN TO HAVE OR SUSPECTED OF HAVING PROCESS WASTE OR SANITARY WASTES DISCHARGED TO THEM.**

Studies have shown that many storm sewers contain illicit discharges of non-storm water. In some municipalities, illicit connections of sanitary, commercial and industrial discharges to storm sewer systems have had a significant impact on the water quality of receiving waters. Removal of these discharges presents opportunities for improvement in the quality of storm water discharges.

Under the proposed storm water permit application regulations, municipalities with separate storm sewers serving a population over 100,000 must submit a management plan that requires screening for illicit discharges and improper disposal. Municipal separate storm sewer systems with identified improper discharges that significantly impact receiving waters should be considered for designation under section 402(p)(2)(E). Once designated, the affected municipality will be responsible for submitting a permit application. The permitting authority may request the municipality to submit a description of a storm water management plan, or any aspect of a management plan that may call for monitoring and screening for illicit connections and improper discharges. Such plans are to include subsequent measures for the removal and elimination of such known discharges. The following examples document cases where such problems existed and where improvement in water quality was achieved following the elimination of illicit connections. It is important to note that the section 402(p)(2)(E) designation authority can be used to require NPDES permits for any size municipal separate storm sewer system or specific discharges points within the system. This authority may be useful to address municipal separate storm sewer systems that serve populations of less than 100,000, since those cities are not required to file applications for storm water permits before October 1, 1992.

Example

One recent study performed in Ann Arbor, Michigan concluded that illegal and improper industrial and commercial point source connections to storm drains represents a significant source of pollutants in storm water discharges. Half of the businesses investigated in Ann Arbor had at least one storm drain connection through which potentially hazardous pollutants could enter the storm sewer. Significant improvements in water quality were realized as these connections were removed and the flows shifted to sanitary sewers. Over two-thirds of auto-related businesses such as repair shops, tire stores, service stations and body shops, and half of the car washes investigated had illegal or improper connections to the storm drainage system. Similar municipal separate storm water systems should be considered for designation under section 402(p)(2)(E).

Example

The City of Fort Worth has begun a surveillance program to curb illegal dumping of industrial and domestic waste into the city's estimated 200 storm drains that feed streams flowing to the Trinity River. Over a period of one year, 57 cases of illegal waste dumping by businesses and industries were investigated. Eighteen cases of improper connection of domestic sewage lines to storm drains were discovered. The city has implemented corrective measures and several citations have been issued to violators. The surveillance effort was initiated, after a series of devastating fish kills plagued the Trinity River. Monitoring has shown that diesel fuel, chemical solvents, pesticides, raw sewage and chlorine are present in storm water discharges. Similar storm water corrective measures could be required after the municipal system is designated under section 402(p)(2)(E).

4. **MUNICIPAL SEPARATE STORM SEWER DISCHARGES THAT ARE SUSPECTED OF CONTAINING A SIGNIFICANT CONTRIBUTION OF POLLUTANTS.**

The characterization of storm water discharges in terms of concentrations and pollutant loads viewed together with water quality standards and National Urban Runoff Program (NURP) data derived from typical urban runoff characteristics, provides an indication of whether the discharge is a significant contributor of pollutants. For instance, the mean concentration is defined as the total constituent mass discharge, divided by the total runoff volume for a rainfall event. These simplified approximations can be used as the basis for designation as a significant contributor of pollutants. Where such specific information is lacking for a particular municipality, NURP data can be used to make initial screening estimates of pollutant loads associated with municipal separate storm sewers. Using the NURP recommendations for load estimates provided in Attachment A, pollutant loadings can be calculated for a range of pollutant concentrations. As municipal dischargers provide a more accurate estimate of pollutants based on site specific data and the use of more sophisticated models, such as the Storm Water Management Model (SWMM), pollutant concentrations and loads can be compared to NURP and other estimates. Based on the resulting characterizations, discharges from municipal separate storm sewer systems that contain a significant contribution of pollutants can be determined and, where appropriate, considered for 402(p)(2)(E) designation.

Procedures for Designation

On January 12, 1989, (54 FR 246), EPA published a final rule which codified portions of section 402(p), including section 402(p)(2)(E), into EPA regulation at 40 CFR 122.26(a). In addition, on December 7, 1988 (53 FR 49416), EPA proposed revisions to procedures at 40 CFR 124.52 for designating storm water discharges on a case-by-case basis. Until EPA promulgates these regulations, procedures for case-by-case designations should be modeled after existing regulatory procedures at 40 CFR 124.52. The Regional Administrator, or in States with approved NPDES programs, the Director, will notify the discharger in writing that the discharge is being considered for designation and the reasons for the consideration. In addition, an application form is to be sent with the notice.

Until EPA promulgates specific permit application requirements for storm water discharges, operators of storm water discharges considered for designation under section 402(p)(2)(E) should generally submit Form 1 and Form 2C permit applications. For designation of discharges from a municipal separate storm sewer system, Form 1 and Form 2C applications for each outfall may not be appropriate. In this case, the permitting authority may request the applicant to submit information modelled after the permit application requirements for large and medium municipal separate storm sewer systems proposed in the December 7, 1988, notice.

Deadlines for submitting permit applications will be established on a case-by-case basis. Although a 60-day period from the date of notice for submitting a permit application may be appropriate for many designated storm water discharges, site specific factors may dictate that the Regional Administrator or NPDES State provide additional time for submitting a permit application. For example, due to the complexities associated with designation of a municipal separate storm sewer system for a system- or jurisdiction-wide permit, the Regional Administrator or NPDES State may provide the applicant with additional time to submit relevant information or may require that information be submitted in phases.

Attachment B contains example reports from the "Waterbody System," which is an information system which retains the results of the section 305(b) reports. The 305(b) reporting process is a critical source of information for making determinations under the authority of section 402(p)(2)(E). The data system is now only partially implemented, but beginning with the 1990 305(b) reporting cycle should contain the assessment data for all States.

Regional Offices and States can use data from the 305(b) Waterbody System, the 1988 Lake Water Quality Assessment Report, and other available information characterizing storm water discharges to make determinations under the authority of section 402(p)(2)(E). The permitting procedures should commence as soon as the impact from storm water discharges is recognized. In addition, when industrial permits that regulate only non-storm water discharges expire, they should be evaluated to determine whether storm water discharges need to be addressed.

If you have any questions regarding this matter, please contact Cynthia Dougherty at FTS/202 475-9545 or have your staff contact Mike Mitchell at FTS/202 475-7057.

Attachments

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EPA/240/B-01/003
March 2001

EPA Requirements for Quality Assurance Project Plans

EPA QA/R-5

Quality

FOREWORD

The U.S. Environmental Protection Agency (EPA) has developed the Quality Assurance Project Plan (QA Project Plan) as a tool for project managers and planners to document the type and quality of data needed for environmental decisions and to describe the methods for collecting and assessing those data. The development, review, approval, and implementation of the QA Project Plan is part of EPA's mandatory Quality System. The EPA Quality System requires all organizations to develop and operate management structures and processes to ensure that data used in Agency decisions are of the type and quality needed for their intended use. The QA Project Plan is an integral part of the fundamental principles and practices that form the foundation of the EPA Quality System.

This document provides the QA Project Plan requirements for organizations that conduct environmental data operations on behalf of EPA through contracts, financial assistance agreements, and interagency agreements; however, it may be used by EPA as well. It contains the same requirements as Chapter 5 of EPA Order 5360 A1 (EPA 2000), *The EPA Quality Manual for Environmental Programs*, which has been developed for internal use by EPA organizations. A companion document, *EPA Guidance for Quality Assurance Project Plans (QA/G-5)* (EPA 1998) provides suggestions for both EPA and non-EPA organizations on preparing, reviewing, and implementing QA Project Plans that satisfy the requirements defined in this document.

This document is one of the *EPA Quality System Series* documents which describe EPA policies and procedures for planning, implementing, and assessing the effectiveness of a quality system. Questions regarding this document or other *EPA Quality System Series* documents should be directed to:

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ACKNOWLEDGMENTS

This document reflects the collaborative efforts of many quality management professionals who participate in the challenge for continual improvement in quality systems supporting environmental programs. These individuals, representing the EPA, other Federal agencies, State and local governments, and private industry, reflect a diverse and broad range of needs and experiences in environmental data collection programs. Their contributions and the comprehensive reviews during the development of this document are greatly appreciated.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Environmental programs conducted by or funded by the U.S. Environmental Protection Agency (EPA) involve many diverse activities that address complex environmental issues. The EPA annually spends several hundred million dollars in the collection of environmental data for scientific research and regulatory decision making. In addition, non-EPA organizations may spend as much as an order of magnitude more each year to respond to Agency requirements. If decision makers (EPA and otherwise) are to have confidence in the quality of environmental data used to support their decisions, there must be a structured process for quality in place.

A structured system that describes the policies and procedures for ensuring that work processes, products, or services satisfy stated expectations or specifications is called a quality system. All organizations conducting environmental programs funded by EPA are required to establish and implement a quality system. EPA also requires that all environmental data used in decision making be supported by an approved Quality Assurance Project Plan (QA Project Plan). This requirement is defined in EPA Order 5360.1 A2 (EPA 2000), *Policy and Program Requirements for the Mandatory Agency-wide Quality System*, for EPA organizations. Non-EPA organizations funded by EPA are required to develop a QA Project Plan through:

- 48 CFR 46, for contractors;
- 40 CFR 30, 31, and 35 for assistance agreement recipients; and
- other mechanisms, such as consent agreements in enforcement actions.

The QA Project Plan integrates all technical and quality aspects of a project, including planning, implementation, and assessment. The purpose of the QA Project Plan is to document planning results for environmental data operations and to provide a project-specific "blueprint" for obtaining the type and quality of environmental data needed for a specific decision or use. The QA Project Plan documents how quality assurance (QA) and quality control (QC) are applied to an environmental data operation to assure that the results obtained are of the type and quality needed and expected.

The ultimate success of an environmental program or project depends on the quality of the environmental data collected and used in decision-making, and this may depend significantly on the adequacy of the QA Project Plan and its effective implementation. Stakeholders (i.e., the data users, data producers, decision makers, etc.) shall be involved in the planning process for a program or project to ensure that their needs are defined adequately and addressed. While time spent on such planning may seem unproductive and costly, the penalty for ineffective planning includes greater cost and lost time. Therefore, EPA requires that a systematic planning process be used to plan all environmental data operations. To support this requirement, EPA has developed a process called the Data Quality Objectives (DQO) Process. The DQO Process is the Agency's preferred planning process and is described in the *Guidance for the Data Quality Objectives Process (QA/G-4)* (EPA 2000b). The QA Project Plan documents the outputs from systematic planning.

This requirements document presents specifications and instructions for the information that must be contained in a QA Project Plan for environmental data operations funded by EPA. The document also discusses the procedures for review, approval, implementation, and revision of QA Project Plans. Users of this document should assume that all of the elements described herein are required in a QA Project Plan unless otherwise directed by EPA.

1.2 QA PROJECT PLANS, THE EPA QUALITY SYSTEM, AND ANSI/ASQC E4-1994

EPA Order 5360.1 A2 and the applicable Federal regulations (defined above) establish a mandatory Quality System that applies to all EPA organizations and organizations funded by EPA. Components of the EPA Quality System are illustrated in Figure 1. Organizations must ensure that data collected for the characterization of environmental processes and conditions are of the appropriate type and quality for their intended use and that environmental technologies are designed, constructed, and operated according to defined expectations. The QA Project Plan is a key project-level component of the EPA Quality System.

EPA policy is based on the national consensus standard, ANSI/ASQC E4-1994, *Specifications and Guidelines for Environmental Data Collection and Environmental Technology Programs*. The ANSI/ASQC E4-1994 standard describes the necessary management and technical elements for developing and implementing a quality system. This standard recommends using a tiered approach to a quality system. This standard recommends first documenting each organization-wide quality system in a Quality Management Plan or Quality Manual (to address requirements of *Part A: Management Systems* of the standard) and then documenting the applicability of the quality system to technical activity-specific efforts in a QA Project Plan or similar document (to address the requirements of *Part B: Collection and Evaluation of Environmental Data* of the standard). EPA has adopted this tiered approach for its mandatory Agency-wide Quality System. This document addresses Part B requirements of the standard.

A Quality Management Plan, or equivalent Quality Manual, documents how an organization structures its quality system, defines and assigns QA and QC responsibilities, and describes the processes and procedures used to plan, implement, and assess the effectiveness of the quality system. The Quality Management Plan may be viewed as the "umbrella" document under which individual projects are conducted. EPA requirements for Quality Management Plans are defined in *EPA Requirements for Quality Management Plans (QA/R-2)* (EPA 2001). The

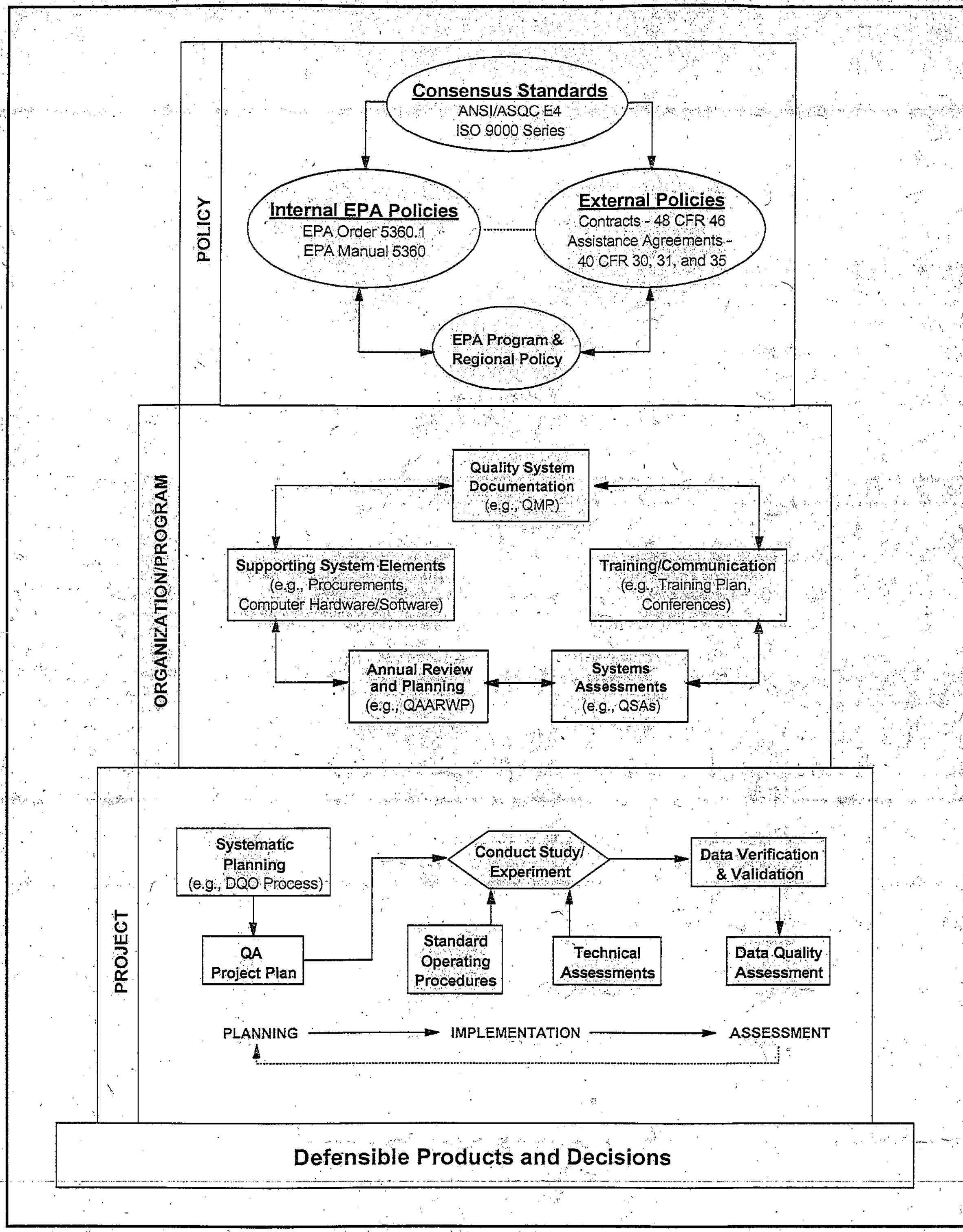

Figure 1. EPA Quality System Components and Tools

Quality Management Plan is then supported by project-specific QA Project Plans. In some cases, a QA Project Plan and a Quality Management Plan may be combined into a single document that contains both organizational and project-specific elements. The QA Manager for the EPA organization sponsoring the work has the authority to determine when a single document is applicable and will define the content requirements of such a document.

1.3 THE GRADED APPROACH AND THE EPA QUALITY SYSTEM

Recognizing that a "one size fits all" approach to quality requirements will not work in organizations as diverse as EPA, implementation of the EPA Quality System is based on the principle of graded approach. Applying a graded approach means that quality systems for different organizations and programs will vary according to the specific objectives and needs of the organization. For example, the quality expectations of a fundamental research program are different from that of a regulatory compliance program because the purpose or intended use of the data is different. The specific application of the graded approach principle to QA Project Plans is described in Section 2.4.2.

1.4 INTENDED AUDIENCE

This document specifies the requirements for developing QA Project Plans for organizations that conduct environmental data operations funded by EPA through contracts, financial assistance agreements, and interagency agreements. EPA organizations may also use this document to develop QA Project Plans since this document is clearer and more user-friendly than the equivalent requirements defined in Section 5.3 of EPA Order 5360 A1 (EPA 2000), *The EPA Quality Manual for Environmental Programs* (an internal policy document). However, the preparation, submission, review, and approval requirements for EPA organizations are still contained in Section 5.2 of EPA Order 5360 A1 as these represent internal EPA policy.

1.5 PERIOD OF APPLICABILITY

This document shall be valid for a period of up to five years from the official date of publication. After five years, it shall either be reissued without change, revised, or withdrawn from the EPA Quality System.

1.6 ADDITIONAL RESOURCES

Guidance on preparing QA Project Plans may be found in a companion document, *EPA Guidance for Quality Assurance Project Plans (QA/G-5)* (EPA 1998). This guidance discusses the application of the QA Project Plan requirements and provides examples. Other documents that provide guidance on activities critical to successful environmental data operations and complement the QA Project Plan preparation effort include:

- *Guidance for the Data Quality Objectives Process (QA/G-4)*, (EPA 2000b)
- *Guidance for the Preparation of Standard Operating Procedures for Quality-Related Documents (QA/G-6)*, (EPA 1995)
- *Guidance for Data Quality Assessment: Practical Methods for Data Analysis (QA/G-9)*, (EPA 2000a)

1.7 SUPERSESSION

This document replaces QAMS-005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980) in its entirety.

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CHAPTER 2

QA PROJECT PLAN REQUIREMENTS

2.1 POLICY

All work funded by EPA that involves the acquisition of environmental data generated from direct measurement activities, collected from other sources, or compiled from computerized data bases and information systems shall be implemented in accordance with an approved QA Project Plan. The QA Project Plan will be developed using a systematic planning process based on the graded approach. No work covered by this requirement shall be implemented without an approved QA Project Plan available prior to the start of the work except under circumstances requiring immediate action to protect human health and the environment or operations conducted under police powers.

2.2 PURPOSE

The QA Project Plan documents the planning, implementation, and assessment procedures of, and how specific QA and QC activities will be applied during a particular project. The QA Project Plan demonstrates conformance to Part B requirements of ANSI/ASQC E4-1994.

2.3 APPLICABILITY

These requirements apply to all environmental programs funded by EPA that acquire, generate, or compile environmental data including work performed through contracts, work assignments, delivery orders, task orders, cooperative agreements, interagency agreements, State-EPA agreements, State, local and Tribal Financial Assistance/Grants, Research Grants, and in response to statutory or regulatory requirements and consent agreements. These requirements are negotiated into interagency agreements, including sub-agreements, and, in some cases, are included in enforcement settlement and consent agreements and orders. Where specific Federal regulations require the application of QA and QC activities (see Section 1.1), QA Project Plans shall be prepared, reviewed, and approved in accordance with the specifications contained in this document unless explicitly superseded by the regulation.

2.4 GENERAL CONTENT AND DETAIL REQUIREMENTS

2.4.1 General Content

The QA Project Plan must be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment. Chapter 3 of this document describes specific elements to address for QA Project Plans submitted to EPA. In some cases, it may be necessary to add special requirements to the QA Project Plan. The EPA organization sponsoring the work has the authority to define any special requirements beyond those listed in this document. If no additional requirements are specified, the QA Project Plan shall address all required elements. Each EPA organization defines their organizational-specific requirements for QA Project Plan documentation in their Quality Management Plan. All applicable elements defined by the EPA organization sponsoring the work must be addressed.

While most QA Project Plans will describe project- or task-specific activities, there may be occasions when a *generic* QA Project Plan may be more appropriate. A generic QA Project Plan addresses the general, common activities of a program that are to be conducted at multiple locations or over a long period of time; for example, it may be useful for a large monitoring program that uses the same methodology at different locations. A generic QA Project Plan describes, in a single document, the information that is not site or time-specific but applies throughout the program. Application-specific information is then added to the approved QA Project Plan as that information becomes known or completely defined. A generic QA Project Plan shall be reviewed periodically to ensure that its content continues to be valid and applicable to the program over time.

2.4.2 Level of Detail

The level of detail of the QA Project Plan should be based on a graded approach so that the level of detail in each QA Project Plan will vary according to the nature of the work being performed and the intended use of the data. As a result, an acceptable QA Project Plan for some environmental data operations may require a qualitative discussion of the experimental process and its objectives while others may require extensive documentation to adequately describe a complex environmental program.

2.5 QA PROJECT PLAN PREPARATION AND APPROVAL

The QA Project Plan may be prepared by an EPA organization, a contractor, an assistance agreement holder, or another Federal agency under an interagency agreement. Except where specifically delegated in the Quality Management Plan of the EPA organization sponsoring the work, all QA Project Plans prepared by non-EPA organizations must be approved by EPA before implementation.

The QA Project Plan shall be reviewed and approved by an authorized EPA reviewer to ensure that the QA Project Plan contains the appropriate content and level of detail. The authorized reviewer, for example the EPA project manager[1], with the assistance and approval of the EPA QA Manager or by the EPA QA Manager alone, are defined by the EPA organization's Quality Management Plan. In some cases, the authority to review and approve QA Project Plans is delegated to another part of the EPA organization covered by the same Quality Management

[1] This term refers to the EPA official responsible for the project. This individual may also be called Project Officer, Delivery Order Project Officer, Work Assignment Manager, or Principal Investigator.

Plan. In cases where the authority to review and approve QA Project Plans is delegated in writing by EPA to another organization (i.e., a Federal agency or a State under an EPA-approved Quality Management Plan when the environmental data operation itself has been delegated to that organization for implementation), it is possible that the EPA project manager and EPA QA Manager may not be involved in the review and approval steps.

2.6 QA PROJECT PLAN IMPLEMENTATION

None of the environmental work addressed by the QA Project Plan shall be started until the QA Project Plan has been approved and distributed to project personnel except in situations requiring immediate action to protect human health and the environment or operations conducted under police powers. Subject to these exceptions, it is the responsibility of the organization performing the work to assure that no environmental data are generated or acquired before the QA Project Plan is approved and received by the appropriate project personnel. However, EPA may grant conditional approval to a QA Project Plan to permit some work to begin while non-critical deficiencies in the QA Project Plan are being resolved.

The organization performing the work shall ensure that the QA Project Plan is implemented as approved and that all personnel involved in the work have direct access to a current version of the QA Project Plan and all other necessary planning, implementation, and assessment documents. These personnel should understand the requirements prior to the start of data generation activities.

2.7 QA PROJECT PLAN REVISION

Although the approved QA Project Plan must be implemented as prescribed, it is not inflexible. Because of the complex and diverse nature of environmental data operations, changes to original plans are often needed. When such changes occur, the approving official shall determine if the change significantly impacts the technical and quality objectives of the project. When a substantive change is warranted, the originator of the QA Project Plan shall modify the QA Project Plan to document the change and submit the revision for approval by the same authorities that performed the original review. Only after the revision has been received and approved (at least verbally with written follow-up) by project personnel, shall the change be implemented.

For programs or projects of long duration, such as multi-year monitoring programs or projects using a generic QA Project Plan, the QA Project Plans shall be reviewed at least annually by the EPA Project Manager (or authorized representative). When revisions are necessary, the QA Project Plan must be revised and resubmitted for review and approval.

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CHAPTER 3

QA PROJECT PLAN ELEMENTS

3.1 CONTENT REQUIREMENTS

The QA Project Plan is a formal document describing in comprehensive detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. The QA Project Plan must provide sufficient detail to demonstrate that:

- the project technical and quality objectives are identified and agreed upon;
- the intended measurements, data generation, or data acquisition methods are appropriate for achieving project objectives;
- assessment procedures are sufficient for confirming that data of the type and quality needed and expected are obtained; and
- any limitations on the use of the data can be identified and documented.

Most environmental data operations require the coordinated efforts of many individuals, including managers, engineers, scientists, statisticians, and others. The QA Project Plan must integrate the contributions and requirements of everyone involved into a clear, concise statement of what is to be accomplished, how it will be done, and by whom. It must provide understandable instructions to those who must implement the QA Project Plan, such as the field sampling team, the analytical laboratory, modelers, and the data reviewers. In all aspects of the QA Project Plan, the use of national consensus standards and practices are encouraged.

In order to be effective, the QA Project Plan must specify the level or degree of QA and QC activities needed for the particular environmental data operations. Because this will vary according to the purpose and type of work being done, EPA believes that the graded approach should be used in planning the work. This means that the QA and QC activities applied to a project will be commensurate with:

- the purpose of the environmental data operation (e.g., enforcement, research and development, rulemaking),
- the type of work to be done (e.g., pollutant monitoring, site characterization, risk characterization, bench level proof of concept experiments), and
- the intended use of the results (e.g., compliance determination, selection of remedial technology, development of environmental regulation).

The QA Project Plan shall be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment. These elements are presented in that order and have been arranged for convenience into four general groups. The four groups of elements and their intent are summarized as follows:

A Project Management - The elements in this group address the basic area of project management, including the project history and objectives, roles and responsibilities of the participants, etc. These elements ensure that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planning outputs have been documented.

B Data Generation and Acquisition - The elements in this group address all aspects of project design and implementation. Implementation of these elements ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and are properly documented.

C Assessment and Oversight - The elements in this group address the activities for assessing the effectiveness of the implementation of the project and associated QA and QC activities. The purpose of assessment is to ensure that the QA Project Plan is implemented as prescribed.

D Data Validation and Usability - The elements in this group address the QA activities that occur after the data collection or generation phase of the project is completed. Implementation of these elements ensures that the data conform to the specified criteria, thus achieving the project objectives.

All applicable elements, including the content and level of detail under each element, defined by the EPA organization sponsoring the work must be addressed in the QA Project Plan. If an element is not applicable, state this in the QA Project Plan. Documentation, such as an approved Work Plan, Standard Operating Procedures, etc., may be referenced in response to a particular required QA Project Plan element to reduce the size of the QA Project Plan. Current versions of all referenced documents must be attached to the QA Project Plan itself or be placed on file with the appropriate EPA office and available for routine referencing when needed. The QA Project Plan shall also address related QA planning documentation (e.g., Quality Management Plans) from suppliers of services critical to the technical and quality objectives of the project or task.

3.2 GROUP A: PROJECT MANAGEMENT

The elements in this group (Table 1) address project management, including project history and objectives, roles and responsibilities of the participants, etc. These elements document that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planning outputs have been documented.

Table 1. Group A: Project Management Elements	
A1	Title and Approval Sheet
A2	Table of Contents
A3	Distribution List
A4	Project/Task Organization
A5	Problem Definition/Background
A6	Project/Task Description
A7	Quality Objectives and Criteria
A8	Special Training/Certification
A9	Documents and Records

3.2.1 A1 - Title and Approval Sheet

On the Title and Approval Sheet, include the title of the plan, the name of the organization(s) implementing the project, the effective date of the plan, and the names, titles, signatures, and approval dates of appropriate approving officials. Approving officials may include:

- Organization's Project Manager
- Organization's QA Manager
- EPA Project Manager
- EPA QA Manager
- Others, as needed (e.g., field operations manager, laboratory managers, State and other Federal agency officials)

3.2.2 A2 - Table of Contents

Provide a table of contents for the document, including sections, figures, tables, references, and appendices. Apply a document control format (Figure 2) on each page following the Title and Approval Sheet when required by the EPA Project Manager and QA Manager.

Section No. ______
Revision No. _____
Date______________
Page ___ of ___

Figure 2. Example Document Control Format

3.2.3 A3 - Distribution List

List the individuals and their organizations who need copies of the approved QA Project Plan and any subsequent revisions, including all persons responsible for implementation (e.g., project managers), the QA managers, and representatives of all groups involved. Paper copies need not be provided to individuals if equivalent electronic information systems can be used.

3.2.4 A4 - Project/Task Organization

Identify the individuals or organizations participating in the project and discuss their specific roles and responsibilities. Include the principal data users, the decision makers, the project QA manager, and all persons responsible for implementation. The project quality assurance manager must be independent of the unit generating the data. (This does not include being independent of senior officials, such as corporate managers or agency administrators, who are nominally, but not functionally, involved in data generation, data use, or decision making.) Identify the individual responsible for maintaining the official, approved QA Project Plan.

Provide a concise organization chart showing the relationships and the lines of communication among all project participants. Include other data users who are outside of the organization generating the data, but for whom the data are nevertheless intended. The organization chart must also identify any subcontractor relationships relevant to environmental data operations, including laboratories providing analytical services.

3.2.5 A5 - Problem Definition/Background

State the specific problem to be solved, decision to be made, or outcome to be achieved. Include sufficient background information to provide a historical, scientific, and regulatory perspective for this particular project.

3.2.6 A6 - Project/Task Description

Provide a summary of all work to be performed, products to be produced, and the schedule for implementation. Provide maps or tables that show or state the geographic locations of field tasks. This discussion need not be lengthy or overly detailed, but should give an overall picture of how the project will resolve the problem or question described in A5.

3.2.7 A7 - Quality Objectives and Criteria

Discuss the quality objectives for the project and the performance criteria to achieve those objectives. EPA requires the use of a systematic planning process to define these quality objectives and performance criteria.

3.2.8 A8 - Special Training/Certification

Identify and describe any specialized training or certifications needed by personnel in order to successfully complete the project or task. Discuss how such training will be provided and how the necessary skills will be assured and documented.

3.2.9 A9 - Documents and Records

Describe the process and responsibilities for ensuring the appropriate project personnel have the most current approved version of the QA Project Plan, including version control, updates, distribution, and disposition.

Itemize the information and records which must be included in the data report package and specify the reporting format for hard copy and any electronic forms. Records can include raw data, data from other sources such as data bases or literature, field logs, sample preparation and analysis logs, instrument printouts, model input and output files, and results of calibration and QC checks.

Identify any other records and documents applicable to the project that will be produced, such as audit reports, interim progress reports, and final reports. Specify the level of detail of the field sampling, laboratory analysis, literature or data base data collection, or modeling documents or records needed to provide a complete description of any difficulties encountered.

Specify or reference all applicable requirements for the final disposition of records and documents, including location and length of retention period.

3.3 GROUP B: DATA GENERATION AND ACQUISITION

The elements in this group (Table 2) address all aspects of data generation and acquisition to ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and documented. The following QA Project Plan elements describe the requirements related to the actual methods or methodology to be used for the:

- collection, handling, and analysis of samples;

- data obtained from other sources (e.g., contained in a computer data base from previous sampling activities, compiled from surveys, taken from the literature); and

- the management (i.e., compiling, handling) of the data.

The methods described in these elements should have been summarized earlier in element A6. The purpose here is to provide detailed information on the methods. If the designated methods are well documented and are readily available to all project participants, citations are adequate; otherwise, detailed copies of the methods and/or SOPs must accompany the QA Project Plan either in the text or as attachments.

Table 2. Group B: Data Generation and Acquisition Elements	
B1	Sampling Process Design (Experimental Design)
B2	Sampling Methods
B3	Sample Handling and Custody
B4	Analytical Methods
B5	Quality Control
B6	Instrument/Equipment Testing, Inspection, and Maintenance
B7	Instrument/Equipment Calibration and Frequency
B8	Inspection/Acceptance of Supplies and Consumables
B9	Non-direct Measurements
B10	Data Management

3.3.1 B1- Sampling Process Design (Experimental Design)

Describe the experimental data generation or data collection design for the project, including as appropriate:

- the types and numbers of samples required,
- the design of the sampling network,
- the sampling locations and frequencies,
- sample matrices,
- measurement parameters of interest, and
- the rationale for the design.

3.3.2 B2 - Sampling Methods

Describe the procedures for collecting samples and identify the sampling methods and equipment, including any implementation requirements, sample preservation requirements, decontamination procedures, and materials needed for projects involving physical sampling. Where appropriate, identify sampling methods by number, date, and regulatory citation. If a method allows the user to select from various options, then the method citations should state exactly which options are being selected. Describe specific performance requirements for the method. For each sampling method, identify any support facilities needed. The discussion should also address what to do when a failure in the sampling or measurement system occurs, who is responsible for corrective action, and how the effectiveness of the corrective action shall be determined and documented.

Describe the process for the preparation and decontamination of sampling equipment, including the disposal of decontamination by-products; the selection and preparation of sample containers, sample volumes, and preservation methods; and maximum holding times to sample extraction and/or analysis.

3.3.3 B3 - Sample Handling and Custody

Describe the requirements for sample handling and custody in the field, laboratory, and transport, taking into account the nature of the samples, the maximum allowable sample holding times before extraction or analysis, and available shipping options and schedules for projects involving physical sampling. Sample handling includes packaging, shipment from the site, and storage at the laboratory. Examples of sample labels, custody forms, and sample custody logs should be included.

3.3.4 B4 - Analytical Methods

Identify the analytical methods and equipment required, including sub-sampling or extraction methods, laboratory decontamination procedures and materials (such as in the case of hazardous or radioactive samples), waste disposal requirements (if any), and any specific performance requirements for the method. Where appropriate, analytical methods may be identified by number, date, and regulatory citation. Address what to do when a failure in the analytical system occurs, who is responsible for corrective action, and how the effectiveness of the corrective action shall be determined and documented. Specify the laboratory turnaround time needed, if important to the project schedule.

List any method performance standards. If a method allows the user to select from various options, then the method citations should state exactly which options are being selected. For non-standard method applications, such as for unusual sample matrices and situations, appropriate method performance study information is needed to confirm the performance of the method for the particular matrix. If previous performance studies are not available, they must be developed during the project and included as part of the project results.

3.3.5 B5 - Quality Control

Identify QC activities needed for each sampling, analysis, or measurement technique. For each required QC activity, list the associated method or procedure, acceptance criteria, and corrective action. Because standard methods are often vague or incomplete in specifying QC requirements, simply relying on the cited method to provide this information is usually insufficient. QC activities for the field and the laboratory include, but are not limited to, the use of blanks, duplicates, matrix spikes, laboratory control samples, surrogates, or second column confirmation. State the frequency of analysis for each type of QC activity, and the spike compounds sources and levels. State or reference the required control limits for each QC activity and corrective action required when control limits are exceeded and how the effectiveness of the corrective action shall be determined and documented.

Describe or reference the procedures to be used to calculate applicable statistics (e.g., precision and bias). Copies of the formulas are acceptable as long as the accompanying narrative or explanation specifies clearly how the calculations will address potentially difficult situations such as missing data values, "less than" or "greater than" values, and other common data qualifiers.

3.3.6 B6 - Instrument/Equipment Testing, Inspection, and Maintenance

Describe how inspections and acceptance testing of instruments, equipment, and their components affecting quality will be performed and documented to assure their intended use as specified. Identify and discuss the procedure by which final acceptance will be performed by independent personnel (e.g., personnel other than those performing the work) and/or by the EPA project manager. Describe how deficiencies are to be resolved, when re-inspection will be performed, and how the effectiveness of the corrective action shall be determined and documented.

Describe or reference how periodic preventive and corrective maintenance of measurement or test equipment or other systems and their components affecting quality shall be performed to ensure availability and satisfactory performance of the systems. Identify the equipment and/or systems requiring periodic maintenance. Discuss how the availability of critical spare parts, identified in the operating guidance and/or design specifications of the systems, will be assured and maintained.

3.3.7 B7 - Instrument/Equipment Calibration and Frequency

Identify all tools, gauges, instruments, and other sampling, measuring, and test equipment used for data generation or collection activities affecting quality that must be controlled and, at specified periods, calibrated to maintain performance within specified limits. Describe or reference how calibration will be conducted using certified equipment and/or standards with known valid relationships to nationally recognized performance standards. If no such nationally recognized standards exist, document the basis for the calibration. Identify the certified equipment and/or standards used for calibration. Indicate how records of calibration shall be maintained and be traceable to the instrument.

3.3.8 B8 - Inspection/Acceptance of Supplies and Consumables

Describe how and by whom supplies and consumables (e.g., standard materials and solutions, sample bottles, calibration gases, reagents, hoses, deionized water, potable water, electronic data storage media) shall be inspected and accepted for use in the project. State acceptance criteria for such supplies and consumables.

3.3.9 B9 - Non-direct Measurements

Identify any types of data needed for project implementation or decision making that are obtained from non-measurement sources such as computer data bases, programs, literature files, and historical data bases. Describe the intended use of the data. Define the acceptance criteria for the use of such data in the project and specify any limitations on the use of the data.

3.3.10 B10 - Data Management

Describe the project data management process, tracing the path of the data from their generation to their final use or storage (e.g., the field, the office, the laboratory). Describe or reference the standard record-keeping procedures, document control system, and the approach used for data storage and retrieval on electronic media. Discuss the control mechanism for detecting and correcting errors and for preventing loss of data during data reduction, data reporting, and data entry to forms, reports, and databases. Provide examples of any forms or checklists to be used.

Identify and describe all data handling equipment and procedures to process, compile, and analyze the data. This includes procedures for addressing data generated as part of the project as well as data from other sources. Include any required computer hardware and software and address any specific performance requirements for the hardware/software configuration used. Describe the procedures that will be followed to demonstrate acceptability of the hardware/software configuration required. Describe the process for assuring that applicable information resource management requirements are satisfied.

Describe the process for assuring that applicable Agency information resource management requirements (EPA Directive 2100) are satisfied (EPA QA Project Plans only). If other Agency data management requirements are applicable, such as the Chemical Abstract Service Registry Number Data Standard (EPA Order 2180.1), Data Standards for the Electronic

Transmission of Laboratory Measurement Results (EPA Order 2180.2), the Minimum Set of Data Elements for Ground-Water Quality (EPA Order 7500.1A), or new data standards as they are issued by EPA, discuss how these requirements are addressed.

3.4 GROUP C: ASSESSMENT AND OVERSIGHT

The elements in this group (Table 3) address the activities for assessing the effectiveness of project implementation and associated QA and QC activities. The purpose of assessment is to ensure that the QA Project Plan is implemented as prescribed.

Table 3. Group C: Assessment and Oversight Elements	
C1	Assessments and Response Actions
C2	Reports to Management

3.4.1 C1 - Assessments and Response Actions

- Describe each assessment to be used in the project including the frequency and type. Assessments include, but are not limited to, surveillance, management systems reviews, readiness reviews, technical systems audits, performance evaluations, audits of data quality, and data quality assessments. Discuss the information expected and the success criteria (i.e., goals, performance objectives, acceptance criteria specifications, etc.) for each assessment proposed. List the approximate schedule of assessment activities. For any planned self-assessments (utilizing personnel from within the project groups), identify potential participants and their exact relationship within the project organization. For independent assessments, identify the organization and person(s) that shall perform the assessments if this information is available. Describe how and to whom the results of each assessment shall be reported.

Define the scope of authority of the assessors, including stop work orders, and when assessors are authorized to act.

Discuss how response actions to assessment findings, including corrective actions for deficiencies and other non-conforming conditions, are to be addressed and by whom. Include details on how the corrective actions will be verified and documented.

3.4.2 C2 - Reports to Management

Identify the frequency and distribution of reports issued to inform management (EPA or otherwise) of the project status; for examples, reports on the results of performance evaluations and system audits; results of periodic data quality assessments; and significant quality assurance problems and recommended solutions. Identify the preparer and the recipients of the reports, and any specific actions recipients are expected to take as a result of the reports.

3.5 GROUP D: DATA VALIDATION AND USABILITY

The elements in this group (Table 4) address the QA activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether or not the data conform to the specified criteria, thus satisfying the project objectives.

Table 4. Group D: Data Validation and Usability Elements

D1	Data Review, Verification, and Validation
D2	Verification and Validation Methods
D3	Reconciliation with User Requirements

3.5.1 D1 - Data Review, Verification, and Validation

State the criteria used to review and validate -- that is, accept, reject, or qualify -- data, in an objective and consistent manner.

3.5.2 D2 - Verification and Validation Methods

Describe the process to be used for verifying and validating data, including the chain-of-custody for data throughout the life of the project or task. Discuss how issues shall be resolved and the authorities for resolving such issues. Describe how the results are conveyed to data users. Precisely define and interpret how validation issues differ from verification issues for this project. Provide examples of any forms or checklists to be used. Identify any project-specific calculations required.

3.5.3 D3 - Reconciliation with User Requirements

Describe how the results obtained from the project or task will be reconciled with the requirements defined by the data user or decision maker. Outline the proposed methods to analyze the data and determine possible anomalies or departures from assumptions established in the planning phase of data collection. Describe how reconciliation with user requirements will be documented, issues will be resolved, and how limitations on the use of the data will be reported to decision makers.

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REFERENCES

40 CFR 30, Code of Federal Regulations, "Grants and Agreements With Institutions of Higher Education, Hospitals, and Other Non-Profit Organizations."

40 CFR 31, Code of Federal Regulations, "Uniform Administrative Requirements for Grants and Cooperative Agreement to State and Local Governments."

40 CFR 35, Code of Federal Regulations, "State and Local Assistance."

48 CFR 46, Code of Federal Regulations, "Federal Acquisition Regulations."

ANSI/ASQC E4-1994, *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs*, American National Standard, January 1995.

EPA Directive 2100 (1998), *Information Resources Management Policy Manual*, U.S. Environmental Protection Agency, Washington, DC.

EPA Order 2180.1 (June 1987), *Chemical Abstract Service Registry Number Data Standard*, U.S. Environmental Protection Agency, Washington, DC.

EPA Order 2180.2 (December 1988), *Data Standards for the Electronic Transmission of Laboratory Measurement Results*, U.S. Environmental Protection Agency, Washington, DC.

EPA Order 5360 A1 (May 2000). *EPA Quality Manual for Environmental Programs*, U.S. Environmental Protection Agency, Washington, DC.

EPA Order 5360.1 A2 (May 2000), *Policy and Program Requirements for the Mandatory Agency-wide Quality System*, U.S. Environmental Protection Agency, Washington, DC.

EPA Order 7500.1A (October 1992), *Minimum Set of Data Elements for Ground-Water Quality*, U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency, 2001. *EPA Requirements for Quality Management Plans (QA/R-2)*, EPA/240/B-01/002, Office of Environmental Information.

U.S. Environmental Protection Agency, 2000a. *Guidance for Data Quality Assessment: Practical Methods for Data Analysis (QA/G-9)*, EPA/600/R-96/084, Office of Environmental Information.

U.S. Environmental Protection Agency, 2000b. *Guidance for the Data Quality Objectives Process (QA/G-4)*, EPA/600/R-96/055, Office of Environmental Information.

U.S. Environmental Protection Agency, 1998. *Guidance for Quality Assurance Project Plans (QA/G-5)*, EPA/600/R-98/018, Office of Research and Development.

U.S. Environmental Protection Agency, 1995. *Guidance for the Preparation of Standard Operating Procedures (SOPs) for Quality-Related Documents (QA/G-6)*, EPA/600/R-96/027, Office of Research and Development.

U.S. Environmental Protection Agency, 1980. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans*, QAMS-005/80, Office of Research and Development.

APPENDIX A

CROSSWALKS AMONG QUALITY ASSURANCE DOCUMENTS

A.1 BACKGROUND

This appendix contains crosswalks between this document and other QA planning documents. The first crosswalk compares this requirements document with its predecessor document, QAMS 005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980). The second crosswalk compares the elements of the QA Project Plan defined in this document with the steps defined in *Guidance for the Data Quality Objectives Process (QA/G-4)* (EPA 2000b), the Agency's preferred systematic planning process for environmental decision making. This crosswalk is provided to assist the reader in determining how the outputs from the DQO Process can be integrated into a QA Project Plan.

A.2 CROSSWALK BETWEEN EPA QA/R-5 AND QAMS-005/80

QAMS-005/80 ELEMENTS		QA/R-5 ELEMENTS	
1.0	Title Page with Provision for Approval Signatures	A1	Title and Approval Sheet
2.0	Table of Contents	A2	Table of Contents
3.0	Project Description	A5	Problem Definition/Background
		A6	Project/Task Description
4.0	Project Organization and Responsibility	A3	Distribution List
		A4	Project/Task Organization
		A8	Special Training/Certification
		A9	Documents and Records
5.0	QA Objectives for Measurement Data (PARCC)	A7	Quality Objectives and Criteria
6.0	Sampling Procedures	B1	Sampling Process Design
		B2	Sampling Methods
7.0	Sample Custody	B3	Sample Handling and Custody
8.0	Calibration Procedures and Frequency	B7	Instrument/Equipment Calibration and Frequency

QAMS-005/80 ELEMENTS		QA/R-5 ELEMENTS	
9.0	Analytical Procedures	B4	Analytical Methods
10.0	Data Reduction, Validation, and Reporting	D1	Data Review, Verification, and Validation
		D2	Verification and Validation Methods
		B9	Non-direct Measurements
		B10	Data Management
11.0	Internal Quality Control Checks and Frequency	B5	Quality Control
12.0	Performance and Systems	C1	Assessments and Response Actions
13.0	Preventive Maintenance	B6	Instrument/Equipment Testing, Inspection, and Maintenance
14.0	Specific Routine Procedures Measurement Parameters Involved	D3	Reconciliation with User Requirements
15.0	Corrective Action	C1	Assessments and Response Actions
16.0	QA Reports to Management	C2	Reports to Management

A.3 CROSSWALK BETWEEN THE DQO PROCESS AND THE QA PROJECT PLAN

Elements	Requirements	DQO Overlap
	PROJECT MANAGEMENT	
A1 Title and Approval Sheet	Title and approval sheet.	N/A
A2 Table of Contents	Document control format.	N/A
A3 Distribution List	Distribution list for the QA Project Plan revisions and final guidance.	Step 1: State the Problem
A4 Project/Task Organization	Identify individuals or organizations participating in the project and discuss their roles, responsibilities and organization.	Step 1: State the Problem
A5 Problem Definition/ Background	1) State the specific problem to be solved or the decision to be made. 2) Identify the decision maker and the principal customer for the results.	Step 1: State the Problem Step 2: Identify the Decision
A6 Project/Task Description	1) Hypothesis test, 2) expected measurements, 3) ARARs or other appropriate standards, 4) assessment tools (technical audits), 5) work schedule and required reports.	Step 1: State the Problem Step 2: Identify the Decision Step 3: Identify the Inputs to the Decision Step 6: Specify Limits on Decision Errors
A7 Quality Objectives and Criteria	Decision(s), population parameter of interest, action level, summary statistics and acceptable limits on decision errors. Also, scope of the project (domain or geographical locale).	Step 4: Define the Boundaries Step 5: Develop a Decision Rule Step 6: Specify Limits on Decision Errors
A8 Special Training/ Certification	Identify special training that personnel will need.	N/A
A9 Documents and Records	Itemize the information and records that must be included in a data report package, including report format and requirements for storage, etc.	Step 3: Identify the Inputs to the Decision Step 7: Optimize the Design for Obtaining Data

Elements	Requirements	DQO Overlap
	DATA GENERATION AND ACQUISITION	
B1 Sampling Process Design (Experimental Design)	Outline the experimental design, including sampling design and rationale, sampling frequencies, matrices, and measurement parameter of interest.	Step 5: Develop a Decision Rule Step 7: Optimize the Design for Obtaining Data
B2 Sampling Methods	Sample collection method and approach.	Step 7: Optimize the Design for Obtaining Data
B3 Sample Handling and Custody	Describe the provisions for sample labeling, shipment, chain-of-custody forms, procedures for transferring and maintaining custody of samples.	N/A
B4 Analytical Methods	Identify analytical method(s) and equipment for the study, including method performance requirements.	Step 3: Identify the Inputs to the Decision Step 7: Optimize the Design for Obtaining Data
B5 Quality Control	Describe quality control procedures that should be associated with each sampling and measurement technique. List required checks and corrective action procedures.	Step 3: Identify the Inputs to the Decision
B6 Instrument/Equipment Testing, Inspection, and Maintenance	Discuss how inspection and acceptance testing, including the use of QC samples, must be performed to ensure their intended use as specified by the design.	Step 3: Identify the Inputs to the Decision
B7 Instrument/Equipment Calibration and Frequency	Identify tools, gauges and instruments, and other sampling or measurement devices that need calibration. Describe how the calibration should be done.	Step 3: Identify the Inputs to the Decision
B8 Inspection/Acceptance of Supplies and Consumables	Define how and by whom the sampling supplies and other consumables will be accepted for use in the project.	N/A

Elements	Requirements	DQO Overlap
B9 Non-direct Measurements	Define the criteria for the use of non-measurement data, such as data that come from databases or literature.	Step 1: State the Problem Step 7: Optimize the Design for Obtaining Data
B10 Data Management	Outline the data management scheme including the path and storage of the data and the data record-keeping system. Identify all data handling equipment and procedures that will be used to process, compile, and analyze the data.	Step 3: Identify the Inputs to the Decision Step 7: Optimize the Design for Obtaining Data
ASSESSMENT AND OVERSIGHT		
C1 Assessments and Response Actions	Describe the assessment activities needed for this project.	Step 7: Optimize the Design for Obtaining Data
C2 Reports to Management	Identify the frequency, content, and distribution of reports issued to keep management informed.	N/A
DATA VALIDATION AND USABILITY		
D1 Data Review, Verification, and Validation	State the criteria used to accept or reject the data based on quality.	Step 7: Optimize the Design for Obtaining Data
D2 Verification and Validation Methods	Describe the process to be used for verifying and validating data, including the chain-of-custody for data throughout the lifetime of the project.	Step 3: Identify the Inputs to the Decision
D3 Reconciliation With User Requirements	Describe how results will be evaluated to determine if performance criteria have been satisfied.	Step 7: Optimize the Design for Obtaining Data

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APPENDIX B

TERMS AND DEFINITIONS

assessment - the evaluation process used to measure the performance or effectiveness of a system and its elements. As used here, assessment is an all-inclusive term used to denote any of the following: audit, performance evaluation, management systems review, peer review, inspection, or surveillance.

audit (quality) - a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

calibration - comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments.

chain-of-custody - an unbroken trail of accountability that ensures the physical security of samples, data, and records.

contractor - any organization or individual that contracts to furnish services or items or perform work; a supplier in a contractual situation.

data quality assessment - a statistical and scientific evaluation of the data set to determine the validity and performance of the data collection design and statistical test, and to determine the adequacy of the data set for its intended use.

data usability - the process of ensuring or determining whether the quality of the data produced meets the intended use of the data.

design - specifications, drawings, design criteria, and performance requirements. Also the result of deliberate planning, analysis, mathematical manipulations, and design processes.

environmental conditions - the description of a physical medium (e.g., air, water, soil, sediment) or biological system expressed in terms of its physical, chemical, radiological, or biological characteristics.

environmental data - any measurements or information that describe environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology. For EPA, environmental data include information collected directly from measurements, produced from models, and compiled from other sources such as data bases or the literature.

environmental data operations - work performed to obtain, use, or report information pertaining to environmental processes and conditions.

environmental processes - manufactured or natural processes that produce discharges to or that impact the ambient environment.

environmental programs - work or activities involving the environment, including but not limited to: characterization of environmental processes and conditions; environmental monitoring; environmental research and development; the design, construction, and operation of environmental technologies; and laboratory operations on environmental samples.

environmental technology - an all-inclusive term used to describe pollution control devices and systems, waste treatment processes and storage facilities, and site remediation technologies and their components that may be utilized to remove pollutants or contaminants from or prevent them from entering the environment. Examples include wet scrubbers (air), soil washing (soil), granulated activated carbon unit (water), and filtration (air, water). Usually, this term will apply to hardware-based systems; however, it will also apply to methods or techniques used for pollution prevention, pollutant reduction, or containment of contamination to prevent further movement of the contaminants, such as capping, solidification or vitrification, and biological treatment.

financial assistance - the process by which funds are provided by one organization (usually government) to another organization for the purpose of performing work or furnishing services or items. Financial assistance mechanisms include grants, cooperative agreements, performance partnership agreements, and government interagency agreements.

graded approach - the process of basing the level of application of managerial controls applied to an item or work according to the intended use of the results and the degree of confidence needed in the quality of the results.

independent assessment - an assessment performed by a qualified individual, group, or organization that is not a part of the organization directly performing and accountable for the work being assessed.

information resources management - the planning, budgeting, organizing, directing, training and controls associated with information. The term encompasses both information itself and related resources such as personnel, equipment, funds and technology.

inspection - an activity such as measuring, examining, testing, or gauging one or more characteristics of an entity and comparing the results with specified requirements in order to establish whether conformance is achieved for each characteristic.

management system - a structured, non-technical system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for conducting work and producing items and services.

method - a body of procedures and techniques for performing an activity (e.g., sampling, modeling, chemical analysis, quantification) systematically presented in the order in which they are to be executed.

participant - when used in the context of environmental programs, an organization, group, or individual that takes part in the planning and design process and provides special knowledge or skills to enable the planning and design process to meet its objective.

performance evaluation - a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst or laboratory.

quality - the totality of features and characteristics of a product or service that bear on its ability to meet the stated or implied needs and expectations of the user.

quality assurance (QA) - an integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.

quality assurance manager - the individual designated as the principal manager within the organization having management oversight and responsibilities for planning, documenting, coordinating, and assessing the effectiveness of the quality system for the organization.

quality assurance project plan - a document describing in comprehensive detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

quality control (QC) - the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality.

quality management - that aspect of the overall management system of the organization that determines and implements the quality policy. Quality management includes strategic planning, allocation of resources, and other systematic activities (e.g., planning, implementation, documentation, and assessment) pertaining to the quality system.

quality management plan - a document that describes a quality system in terms of the organizational structure, policy and procedures, functional responsibilities of management and staff, lines of authority, and required interfaces for those planning, implementing, documenting, and assessing all activities conducted.

quality system - a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, documenting, and assessing work performed by the organization and for carrying out required QA and QC activities.

readiness review - a systematic, documented review of the readiness for the start-up or continued use of a facility, process, or activity. Readiness reviews are typically conducted before proceeding beyond project milestones and prior to initiation of a major phase of work.

record - a completed document that provides objective evidence of an item or process. Records may include photographs, drawings, magnetic tape, and other data recording media.

specification - a document stating requirements and which refers to or includes drawings or other relevant documents. Specifications should indicate the means and the criteria for determining conformance.

supplier - any individual or organization furnishing items or services or performing work according to a procurement document or financial assistance agreement. This is an all-inclusive term used in place of any of the following: vendor, seller, contractor, subcontractor, fabricator, or consultant.

surveillance (quality) - continual or frequent monitoring and verification of the status of an entity and the analysis of records to ensure that specified requirements are being fulfilled.

technical systems audit (TSA) - a thorough, systematic, on-site, qualitative audit of facilities, equipment, personnel, training, procedures, record keeping, data validation, data management, and reporting aspects of a system.

validation - confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. In design and development, validation concerns the process of examining a product or result to determine conformance to user needs.

verification - confirmation by examination and provision of objective evidence that specified requirements have been fulfilled. In design and development, verification concerns the process of examining a result of a given activity to determine conformance to the stated requirements for that activity.

STANDARDIZED DATA TRANSFER FORMATS FOR THE STORMWATER MONITORING COALITION

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August 2004

Technical Report #421

A008911

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1.0 INTRODUCTION

One goal of the southern California Stormwater Monitoring Coalition (SMC) is to compile monitoring data from separate monitoring programs to make regionwide assessments. Thus far, data compilation has been difficult because the various monitoring programs have differing project goals and objectives, assorted sampling designs, various laboratory analytical methods, and incompatible information management systems. The goal of the current document is to increase communication among stormwater monitoring agencies by developing standardized data exchange formats. The comparability issues concerning study designs and laboratory methods are being addressed through related, but separate documents.

The SMC member agencies, which includes six lead agencies for National Pollutant Discharge Elimination System (NPDES) permittees for municipal separate storm sewer system (MS4), and the three Regional Water Quality Control Boards (Los Angeles, Santa Ana, San Diego RWQCBs) that regulate the MS4 permittees, store and analyze their data in separate data systems. Some agencies use complex, custom-designed relational database structures and advanced statistical software. Others use simple spreadsheets. In some instances, agencies maintain data in only in hardcopy or electronic equivalents (i.e. scanned documents). The result is an inability for permittees, regulatory agencies, or other interested organizations to quickly or easily exchange information to compare their local data or for compiling data to make larger regional-scale assessments.

Many of these obstacles have been surmounted through the use of standardized data transfer formats (SDTFs). For example, numerous data types are shared easily among the more than five dozen participants of the Regional Marine Monitoring of the southern California Bight (Cooper et al. 1998). The State Water Resources Control Board is using a similar approach for compiling statewide beach monitoring data. SDTFs are a structure for **sharing** data. The value and versatility of SDTFs is that they do not specify what format or software should be used by any single agency. SDTFs only stipulate what data should be shared and a common structure for transferring the data. If a common data structure is used, then the data can be shipped in any software including ASCII code. Once transferred, each agency can import, store, and analyze the data in any format or software they wish. This precludes the need for purchasing new information technologies (i.e. hardware or software) or for hiring specialty staff; SDTFs can be accomplished with the existing information technology infrastructure.

1.1 Objectives and Goals of the Document

The objective of this guidance manual is to capture the data types and structure for SDTFs for stormwater monitoring data. The goal of this document is to create a series of defined data tables, which can be related to one another through commonly defined fields. Whenever, two agencies share data, the minimum data requirements defined herein shall be the default data structure.

This guidance manual is a living document. Permittees may wish to use this guidance document for receiving data from their contractors and/or regulatory agencies may wish to use this guidance document for receiving data from their permitees. It should be revisited periodically as the data needs for the SMC evolve. The SDTFs can be easily expanded to include new and different data types as new monitoring techniques, or data assessment needs, develop.

General Approach:

The general approach for creating SDTFs included a process for selecting data types to include, guided by a series of philosophical design elements, and finally a definition of data table structures.

A technical committee was formed comprising representatives of the SMC member agencies, the State Water Resources Control Board, and a non-governmental organization to help select what data types were to be used for SDTFs (Table 1). These are the agencies that will be sharing data with one another, are most knowledgeable about the information management within their own agency, and understand the needs of the data analysis community that will be relying on the SDTFs. A concensus-based process was used to create the philosophical approaches, select data types (e.g. tables), and define table structures (e.g. specific fields) for the SDTFs.

Table 1. Collaborators for developing stormwater monitoring standardized data exchange formats for the Stormwater Monitoring Coalition.

Contact Name	Company
Brock Bernstein	Workgroup facilitator
Larry Cooper	Southern California Coastal Water Research Project
Pamela Creedon	State Water Resources Control Board
Linda Garcia	Riverside County Flood Control District
Fred Gonzales	Los Angeles County Department of Public Works
Phil Hammer	San Diego Regional Water Quality Control Board
Bruce Moore	Orange County Public Facilities and Resources Department
Kenneth Schiff	Southern California Coastal Water Research Project
Bob Smith	Independent Consultant
Xavier Swammikannu	Los Angeles Regional Water Quality Control Board
Mitzi Taggart	Heal the Bay
JoAnne Weber	San Diego County Department of Environmental Health
Bob Whitaker	Santa Ana Regional Water Quality Control Board
Darla Wise	Ventura County Watershed Protection Division
Matt Yeager	San Bernardino Flood Control District

The conceptual design used by the technical committee followed four philosophical principals:

- SDTFs are for transferring data in a relational structure. They are not intended to be stand alone databases;
- SDTFs are software independent. No new hardware or software is required to implement their use;
- Capture data at the replicate level. This means capturing raw data whenever possible, as opposed to calculated or summarized data;
- Inclusion of quality assurance data. This will allow for an independent assessments of data quality;
- SDTFs are a first step to an integrated information management system. This document will not resolve all information management issues related to sharing stormwater data. The SMC has a future project in its research workplan that calls for the contruction of an integrated information management system for stormwater agencies in southern California.

The technical committee then focused on what general types of data they wished to share. They selected nine types that include data about stations, station occupation, microbiology results, chemistry batches (quality assurance), chemistry results, flow, rain, storm events, field collected results. Each data type is represented by a relational table (Figure 1). Each table is uniquely linked in order to efficiently transfer data by minimizing redundant information and enhancing data extraction. When agencies share data, they should use these tables for transmitting the data. Finally, not all of the tables in Figure 1 are required when sharing data because these data are not owned by the stormwater agencies. The optional tables are Rain Gauge data, Toxicity Batch, Toxicity Results, and Toxicity Water Quality.

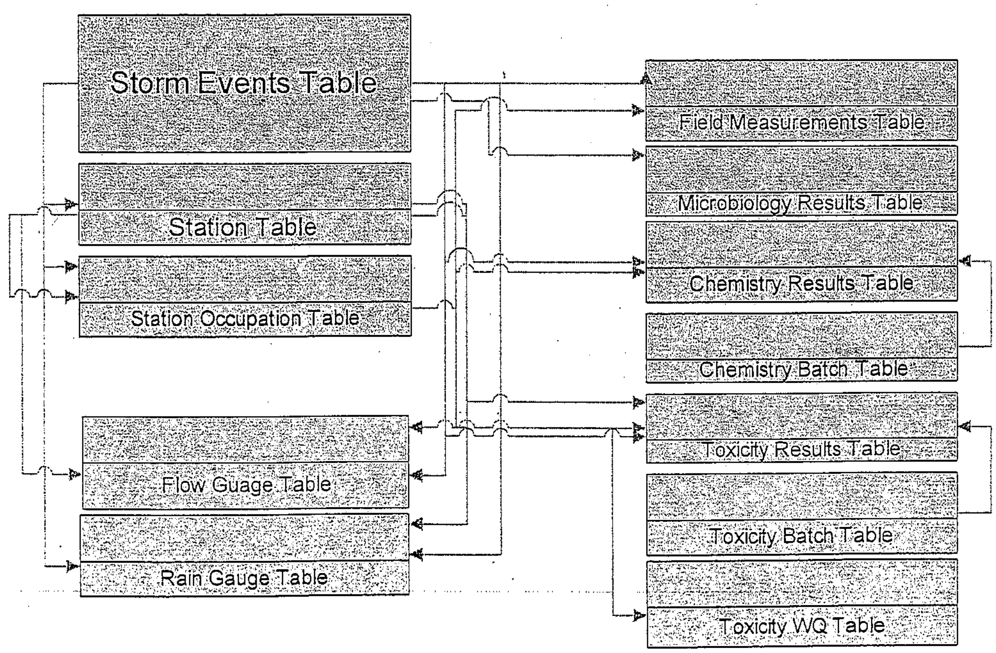


Figure 1. Table relationship diagram.

The last step in the process was to define the table structures. Table structures are the fields within each table. The technical committee went table-by-table, field-by-field, ensuring that each table had the correct and complete information. All of the table structures are defined in Section 2.0. When sharing data, SDTFs should follow the defined table structures. In order to make this process more efficient, the technical committee developed an access file with empty tables that can serve as a template SDTF. This access file is available on the SCCWRP web page (www.sccwrp.org).

2.0 RELATIONAL TABLE STRUCTURES

This section defines all of the relational table structures for SDTFs on a table-by-table basis. For each table, there is a table purpose, guidelines for use, and a table summary that lists and defines fields (field name, variable type, etc.).

The table summaries give useful information to the person(s) responsible on field definitions for constructing the tables. The summaries are in the form of a list. The first column in the list contains the exact name for the field as it should be used for data submissions. Do not add spaces or other characters to the field names since this syntax is important when importing and appending data. Field names in **bold** indicate a combination of fields that provide a unique value within the table.

The second column in the list describes the type of variable used for data in that field. The variable types are:

- Text any alphanumeric character
- Number numbers with decimal places or whole numbers only, no decimal places
- Y/N Boolean indicating Yes or No
- Memo unlimited number of alphanumeric characters

The third column in the list indicates whether the field is mandatory or not.

- Y indicates that the field is mandatory,
- * indicates that the field is conditionally mandatory
- N indicates the field is not mandatory.
- R indicates that the field is recommended, but not mandatory.

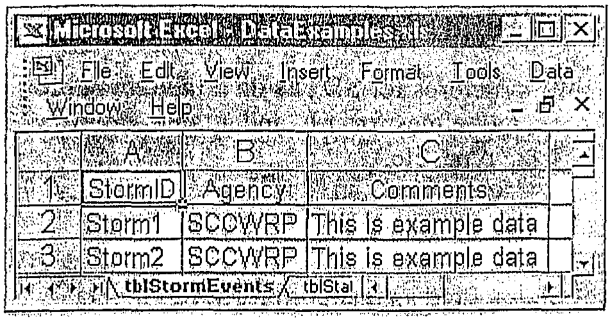
The fourth column in the list is a description and indicates the intended use for that field. For those fields that are senstive to syntax, a look up list is referenced that contains a constrained list of values allowable in that field.

2.1 Storm Events

PURPOSE: The purpose of this table is to provide a unique identifier that will be used to link all tables for data extraction and analysis for a particular storm event. The StormID may be expressed in any format at the discretion of the agency. This variable is not intended to provide a formal definition for what constitutes as storm, it is only used as an aid to analysis.

TABLE GUIDELINES: Each record will be unique based on a combination of StormID and Agency. The data exchange file will be named StormMaster.XXX.

Example Data:



Field Name	Type	Required	Description
StormID	Text	Y	A unique identifier for each storm assigned by each agency.
Agency	Text	Y	From luList01_AgencyCodes
Comments	Text	N	Additional remarks.

2.2 Station Data

PURPOSE: The station table is central to data relations in the database. Each record represents a description of a geographical location including stationID, latitude and longitude data. This table may be appended as stations are added by the monitoring agencies.

TABLE GUIDELINES: Each record will be unique based on a combination of StationID and Station Owner. The data exchange file will be named StationMaster.XXX.

Example Data:

Microsoft Excel - DataExamples.xls

	A	B	C	D	E	F	G	H
1	StationID	StationOwner	Description	Latitude	Longitude	StationType	HUC	LandUse
2	1	SCCWRP	Test 1	-99	-99	ME	1234567890	COMM

tblStations / tblStatonOccupation / tblFieldMeasurements / tblMic

Microsoft Excel - DataExamples.xls

	I	J	K	L
1	DrainageArea	ainageAreaUn	ChannelType	FlowType
2	12	Hectares	CMP	BA
3	45	Hectares	ERBOT	BM

tblStations / tblStatonOccupation

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes
Description	Text	Y	A general description of the stations
Latitude	Double	Y	Decimal degrees to 5 decimal places (NAD 83)
Longitude	Double	Y	Decimal degrees to 5 decimal places (NAD 83). Expressed as negative number
StationType	Text	Y	The type of station based on its analytical usage
HUC	Text	Y	Hydrologic Unit Code (must be consistent with state geo web database) From luList09_Hydrologic Unit Codes
LandUse	Text	N	The land use associated with the station From luList06_LandUses

DrainageArea	Number	*	The area of the drainage in which the station is located. Required for stations with the StationType = MassEmmission
DrainageAreaUnits	Text	*	The units associated with the drainage area from luList28_Units
ChannelType	Text	Y	The type of channel associated with the station from luList07_ChannelTypes
FlowType	Text	Y	The type of flow normally associated with the station form luList03_FlowTypes

2.3 Station Occupation

PURPOSE: The Station Occupation Event table contains environmental condition data collected when the sample is taken. Each record represents the conditions at the station where the sample was collected.

TABLE GUIDELINES: The combination of the fields StationID, StationOwner, SampleStartDate, SampleStartTime, FieldSampleType, and SamplingOrganization will ensure that each record in the table is unique. The data exchange file will be named StationOccupation.XXX

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

StationID	StationOwner	StormID	FieldSampleType	SampleStartDate	SampleStartTime	SampleStartTimeUnits	SampleEndTime
1	SOCWRP	Storm1	GRAB	18/Jan/2004	4:40	PST	00-Jan-00

tblStatonOccupation / tblFieldMeasurements / tblMicrobiologyResults / tblChemistr

Microsoft Excel - DataExamples.xls

SampleEndTimeUnits	SamplingOrganization	SampleDepth	SampleDepthUnits	Latitude	Longitude	WeatherCode	WaterOutletflowing	StationFailReason	Co
PST	SCCWRP	0	M	33.12	-118.12	Rain	Yes	None	Tes

tblStatonOccupation / tblFieldMeasurements / tblMicrobiologyResults / tblChemistryBatch / tblChemi

TABLE STRUCTURE:

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes
StormID	Text	Y	A unique identifier for each storm event from the Matching the Storm Events table.
FieldSampleType	Text	Y	The type of sample collected from

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			luList04_SampleTypes.
SampleStartDate	Date/Time	Y	The date the sample collection started expressed as dd-mmm-yyyy.
SampleStartTime	Date/Time	Y	The time the sample collection started expressed as 24 hour time hhmm.
SampleStartTimeUnits	Text	Y	From luList28_Units.
SampleEndDate	Date/Time	Y	The date the sample collection ended expressed as dd-mmm-yyyy.
SampleEndTime	Date/Time	Y	The time the sample collection ended expressed as 24 hour time hhmm.
SampleEndTimeUnits	Text	Y	From luList28_Units.
SamplingOrganization	Text	Y	The agency code from luList01_AgencyCodes.
SampleDepth	Number	Y	The depth at which the sample was taken expressed in meters.
SampleDepthUnits	Text	Y	From luList28_Units.
Latitude	Number	*	The latitude of the sample expressed in decimal degrees to five decimal places (NAD83).
Longitude	Number	*	Decimal Degrees to five places (NAD 83) expressed as a negative number.
WeatherCode	Text	Y	The weather code from luList08_WeatherCodes.
WaterOutletflowing	Text	Y	If the station is a water outlet is water flowing?
StationFailReason	Text	*	From luList40_EventFailCodes. Was the station abandoned for any reason? The default values will be None. *Required if the sample was not collected.
Comments	Text	N	Additional comments.

2.4 Field Measurements

PURPOSE: This table contains the raw qualified data as collected by field crews (i.e. dissolved oxygen, pH, conductivity, etc.)

TABLE GUIDELINES: The combination of the fields StationID, StationOwner, StormID, SampleDate, SampleTime, and SamplingOrganization will ensure that each record in the table is unique. The data exchange file will be named FieldMeasurements.XXX

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

File Edit View Insert Format Tools Data Window Help — Type a question for help

	A	B	C	D	E	F	G	H	I	J	K
1	StationID	StationOwner	StormID	SampleDate	SampleTime	SamplingOrganization	ParmaterCode	Qualifier	Result	Units	Comments
2	1	SCCWRP	Storm1	18-Jan-2004	4:40	SCCWRP	DO	None	12	mg/kg	Test Record

tblFieldMeasurements / tblMicrobiologyResults / tblChemistryBatch / tblChemistryResult

NAME	TYPE	REQUIRED	DESCRIPTION
StationID	Text	Y	A geographic location label from the station table.
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes.
StormID	Text	Y	A unique identifier for each storm event.
SampleDate	Date/Time	Y	The date the sample was collected expressed as dd-mmm-yyyy.
SampleTime	Date/Time	Y	The time the sample was collected.
SamlingOrganization	Text	Y	From luList01_AgencyCodes.
ParameterCode	Text	Y	The parameter being measured.
Qualifier	Text	Y	A qualifier for the result.
Result	Number	Y	The numerical value of the result.
Units	Text	Y	The units of the result.
Comments	Text	N	Additional Remarks.

2.5 Microbiology Results

PURPOSE: The Microbiology results table contains bacteriological results data. Each record represents the results of an individual sample including collected samples and QA check samples. SamplingOrganization is carried in both the results table and the event table because one agency may collect samples that are analyzed by another laboratory.

TABLE GUIDELINES: The combination of the fields StationID, StationOwner, StormID, SampleStartTime, SampleStartDate, AnalysisDate,ParameterCode, LabCode, LabRep, and SampleType will ensure that each record is unique in the table. The data exchange file will be named MicrobiologyResults.XXX

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

File Edit View Insert Format Tools Data Window Help — Type a question for help

	A	B	C	D	E	F	G	H	I	
1	StationID	StationOwner	StormID	SampleID	SampleStartTime	SampleStartTimeUnits	SamplingOrganization	SampleStartDate	ProcessingStartTime	Pr
2	1	SCCWRP	Storm1	ASFD4321	4:40	PST	SCCWRP	18/Jan/2004	6:00	PS

tblMicrobiologyResults / tblChemistryBatch / tblChemistryResults / tblToxicityBatch / tblToxicityRe

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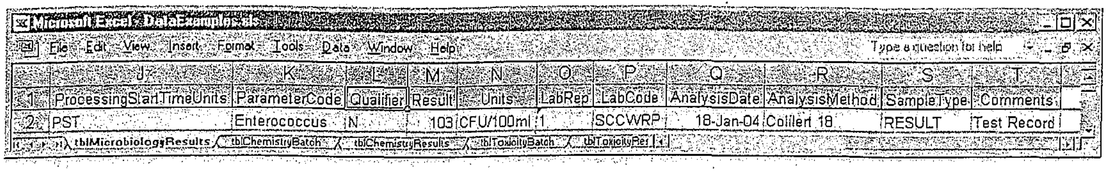

TABLE STRUCTURE:

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label from tblStations.
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes.
StormID	Text	Y	A unique identifier for each storm event.
SampleID	Text	N	The laboratory internal sample identifier.
SampleStartTime	Date/Time	Y	The time the sample was collected in 24 hour time expressed as hhmm.
SampleStartTimeUnits	Text	Y	From luList28_Units.
SamplingOrganization	Text	Y	From luList01_AgencyCodes.
SampleStartDate	Date/Time	Y	The date the sample was analyzed expressed as dd-mmm-yyyy.
ProcessingStartTime	Date/Time	N	The time the testing was started expressed as hhmm.
ProcessingStartTimeUnits	Text	N	From luList28_Units.
AnalysisDate	Date/Time	N	The date the sample was analyzed expressed as dd-mmm-yyyy.
ParameterCode	Text	Y	What type of bacteria are being analyzed from luList15_ParameterCodes
Qualifier	Text	N	Qualifier for the result, from luList11_QualifierCodes.
Result	Number	Y	The numerical results of the test.
Units	Text	Y	The units for the results from luList28_Units.
LabRep	Number	Y	The count of the lab replicate.
LabCode	Text	Y	From luList01_AgencyCodes.
AnalysisMethod	Text	Y	The Method used to do the analysis from luList24_Analysis Methods.

SampleType	Text	Y	From luList04_SampleTypes.
Comments	Text	N	Additional comments.

2.6 Chemistry Batch Data

PURPOSE: This table contains information about preparation methods and dates within each lab. A batch is defined as a group of samples with which the QA results are associated. For some labs, QA data is associated with the preparation batch while other labs associate the QA data with analytical batches. Samples prepared in the same batch may move through the lab in different analytical batches. To minimize redundant data entry, the preparation batch information has been broken off into a separate table and is related to the tblChemistryResults through the PreparationBatchID code. Each record in this table represents all information common to each preparation batch.

TABLE GUIDELINES: The QABatch and AnalyticalLabCode fields will ensure that each record in the table is unique. The data exchange file will be named ChemistryBatchData.XXX

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

QABatch	PreparationCode	PreparationDate	AnalyticalLabCode	Comments
1/18/04	EPA245.5	18/Jan/2004	SCCWRP	Test Record

tblChemistryBatch / tblChemistryResults / tblToxi

TABLE STRUCTURE:

Field Name	Type	Required	Description
QABatch	Text	Y	The code for all of the samples processed in the same preparation batch.
PreparationCode	Text	Y	The PreparationCode from luList25_PreparationCodes.
PreparationDate	Date/Time	Y	The date the sample was extracted expressed as dd-mmm-yyyy.
AnalyticalLabCode	Text	Y	Agency code from luList01_AgencyCodes.
Comments	Text	N	Additional comments.

2.7 Chemistry Results

PURPOSE: The purpose of the chemistry results table is to document the analysis results for water chemistry. Each record represents a result from a specific analysis for a particular parameter at a single station or a single QA sample. This table will also contain all supporting QA sample results.

This table contains some information that will be derived from field data in order to differentiate samples collected at a single station, but at multiple times.

SPECIAL CASES:

Results vs. TrueValue:
The reported result is the number gathered from the analytical instrument. The "True Value" is the concentration of the parameter in the reference sample. The purpose of the "True Value" is to facilitate the calculation of percent recovery. The True Value is only reported for matrix spikes. A True Value of –99 will be reported for all other samples.

Since the mean True Value of Certified reference materials is considered of little use, the range values for the minimum and maximum for parameters in the certified reference material will be carried in an ancillary table within the analytical database and will not be described here.

Matrix spikes:
The reported result is the number gathered from the instrument and is the net amount recovered from the sample after being corrected for the concentration from the non-spiked sample. For spiked samples the "True Value" is the concentration of the parameter added to the sample before analysis. Percent recovery will be calculated by dividing the result by the True Value times 100.

Recovery corrected data:
This is not reported because it can be calculated using the True Value of the reference material processed within the same batch.

Lab Duplicates:
Lab duplicates are defined as duplicate samples taken from the same jar. The result for each duplicate will be numbered starting at one, e.g. the result for the first duplicate will have a LabDuplicate of 1 and the result for the second duplicate will have a LabDuplicate of 2, etc. Replicate samples taken in the field will have separate sample ID numbers and a LabDuplicate of 1.

Non-Detects:
If the result is not reportable, a qualifier of "ND" should be used and the result reported as –99. In the case where the result is below method detection level or below the reporting level, but is being reported anyway, a qualifier of BMDL (below method detection limit) or BRL (below reporting level) should be used and the result reported.

QA Samples:
The field SampleType is used to distinguish QA and blank data from actual sample results. Since the QA samples are usually blanks, spikes, or certified reference materials, they do not have a station number associated with them. In this case the value "0000" will be used as the StationID. These samples will be associated to other samples with the same PreparationBatch code. These samples require a true value to allow for the calculation of percent recovery.

Units:
Values expressed in parts per billion will carry the units tag of MG/L. Values expressed in parts per million will carry the units tag of UG/L.

TABLE GUIDELINES: The combination of the fields StationID, StationOwner, StormID, QABatch, FieldSampleType, Matrix, SampleType, ParameterCode, LabDuplicate, and AnalyticalLabCode will ensure that all records in the table are unique. The data exchange file will be named ChemistryResults.XXX

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

	A	B	C	D	E	F	G	H
1	StationID	StationOwner	StormID	eldSampleTy	ampleStartDa	ampleStartTin	pleStartTime	QABatch
2	1	SCCWRP	Storm1	Grab	18/Jan/2004	00-Jan-00	PST	1/18/04

tblChemistryResults / tblToxicityBatch / tblToxicityResults / tblToxici

Microsoft Excel - DataExamples.xls

	I	J	K	L	M	N	O
1	Matrix	SampleType	ParameterCode	Qualifier	Result	Units	asurementBa
2	ER	RESULT	1,6,7-Trimethylnaphthalene	N	3	MG/KG	WW

tblChemistryResults / tblToxicityBatch / tblToxicityResults / tblToxici

Microsoft Excel - DataExamples.xls

	P	Q	R	S	T	U	V	W	X	Y
1	FieldDuplicate	LabDuplicate	LabSampleID	TrueValue	MDL	RL	alyticalLabCo	AnalysisDate	nalysisMetho	Comments
2	1	1	asdf3214	-99	2	3	SCCWRP	18-Jan-04	GCMS	Test Record

tblChemistryResults / tblToxicityBatch / tblToxicityResults / tblToxicityWQ / tblFlow / tblF

TABLE STRUCTURE:

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label from tblStations.
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes.
StormID	Text	Y	A unique identifier for each storm event.
FieldSampleType	Text	Y	The type of sample collected in the field from luList04_SampleTypes.
SampleStartDate	Date/Time	Y	The date the sample was collected expressed as dd-mmm-yyyy.
SampleStartTime	Date/Time	Y	The time the sample was collected expressed as 24 hour time hhmm.
SampleTimeUnits	Text	Y	From luList28_Units.
SamplingOrganization	Text	Y	From luList01_AgencyCodes.
QABatch	Text	Y	The code for all samples processed in the same batch.
Matrix	Text	Y	The test material from luList14_TestMatrices.
SampleType	Text	Y	The type of result from luList04_SampleTypes.
ParameterCode	Text	Y	The measured parameter from luList15_ParameterCodes.
Qualifier	Text	N	Any necessary qualifier from luList11_QualifierCodes.
Result	Number	Y	Dry wt for sediment / wet weight for tissue.
Units	Text	Y	Units for the result from LuList28_Units.
MeasurementBasis	Text	Y	Wet weight, Dry weight, or Liquid Sample WW / DW / LS from luList17_MeasurementBasisCodes.
FieldDuplicate	Number	Y	Count from the field.
LabDuplicate	Number	Y	Count from the laboratory.
LabSampleID	Text	N	Unique sample identifier for the reporting agency.
TrueValue	Number	N	Required for all Spiked Samples only.
MDL	Number	Y	Method Detection Limit based on 40CFR136.

RL	Number	Y	Reporting Level as defined in metadata.
AnalyticalLabCode	Text	Y	Agency code from luList01_AgencyCodes.
AnalysisDate	Date/Time	Y	The date the samples were analyzed expressed as dd-mmm-yyyy.
AnalysisMethod	Text	Y	The method used to analyze the samples.
Comments	Text	N	Additional remarks.

2.8 Toxicity Batch Information

This table is optional for reporting purposes.

PURPOSE: This table is used to record information specific to each test batch processed in the laboratory and is used as supporting documentation for the Toxicity Test data. Each record represents specific information common to a group of samples processed at the same time and is pertinent to all replicates processed. This table includes the QA/QC data needed to document the test results.

TABLE GUIDELINES: Each record will be unique based on a combination of the fields QABatch and AnalyticalLabCode. The data exchange file will be submitted with the name ToxicityBatch.XXX.

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

	A	B	C	D	E	F	G
1	QABatch	AnalyticalLabCode	Species	Protocol	TestDate	Matrix	TestDuration
2	1/18/04	SCCWRP	SP	ASTM 1853	18/Jan/2004	OL	10

tblToxicityBatch / tblToxicityResults / tblToxicityWQ

Microsoft Excel - DataExamples.xls

	H	I	J	K	L
1	TestDurationUnits	Temperature	TemperatureUnits	TestAcceptability	Comments
2	Days	15	C	A	Test Record

tblToxicityBatch / tblToxicityResults / tblToxicityWQ

TABLE STRUCTURE:

Field Name	Type	Required	Description

QABatch	Text	Y	The batch code for the sample processing batch.
AnalyticalLabCode	Text	Y	The agency code from luList01_AgencyCodes of the processing laboratory.
Species	Text	Y	The species code from luList34_ToxicitySpecies.
Protocol	Text	Y	The test protocol from luList35_ToxicityProtocols.
TestDate	Date/Time	Y	The starting date of the test expressed as dd-mmm-yyyy.
Matrix	Text	Y	The test matrix from luList36_ToxicityMatrices.
TestDuration	Number	Y	The duration of the test expressed in days.
TestDurationUnits	Text	Y	From luList28_Units (Days or Hours).
Temperature	Number	Y	The temperature at which the test was conducted (degrees C).
TemperatureUnits	Text	Y	From luList28_Units.
TestAcceptability	Text	Y	Evaluation of the test results from luList39_ToxicityTestAcceptabilityCodes.
Comments	Text	N	Additional remarks.

2.9 ToxicityResults

This table is optional for reporting purposes.

PURPOSE: The Toxicity table carries data relevant to sediment or water toxicity tests and their replicates. Each record represents the results of an individual replicate for an individual species processed in a batch of replicates.

TABLE GUIDELINES: Each record will be unique based on a combination of the fields StationID, StationOwner, StormID, SampleType, QABatch, AnalyticalLabCode, Species/TestType, Dilution, Concentration and LabRep. The data exchange file will be submitted with the file name ToxicityResults.XXX.

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

File Edit View Insert Format Tools Data Window Help

	A	B	C	D	E	F	G
1	StationID	StationOwner	StormID	SampleDepth	SampleType	QABatch	AnalyticalLabCo
2	1	SCCWRP	Storm1	0	Grab	1/18/04	SCCWRP
3	1	SCCWRP	Storm1	0	Grab	1/18/04	SCCWRP
4	1	SCCWRP	Storm1	0	Grab	1/18/04	SCCWRP
5	1	SCCWRP	Storm1	0	Grab	1/18/04	SCCWRP
6	1	SCCWRP	Storm1	0	Grab	1/18/04	SCCWRP

tblToxicityResults / tblToxicityWQ / tblFlow / tblRainGa

Microsoft Excel - DataExamples.xls

File Edit View Insert Format Tools Data Window Help — Type a question for help

	H	I	J	K	L	M	N	O	P	Q	R
1	Species/TestType	Dilution	Concentration	ConcentrationUnits	EndPoint	Units	LabRep	Value	QACode	Comments	
2	SP	0	-99	NR	PF	Percent	1	9	A	Test Record	
3	SP	0	-99	NR	PF	Percent	2	10	A	Test Record	
4	SP	0	-99	NR	PF	Percent	3	10	A	Test Record	
5	SP	0	-99	NR	PF	Percent	4	10	A	Test Record	
6	SP	0	-99	NR	PF	Percent	5	8	A	Test Record	

tblToxicityResults / tblToxicityWQ / tblFlow / tblRainGauge

TABLE STRUCTURE:

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table.
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes.
StormID	Text	Y	A unique identifier for the storm from the storm event table.
SampleType	Text	Y	Sample type from luList04_SampleTypes.
QABatch	Text	Y	Batch number for batch processed samples.
AnalyticalLabCode	Text	Y	The agency code from luList01_AgencyCodes.
Species/TestType	Text	Y	Test species from luList34_ToxicitySpecies.
Dilution	Number	Y	The dilution factor expressed as a proportion.
Concentration	Number	Y	Concentration in mg/L.
ConcentrationUnits	Text	Y	From luList28_Units.
EndPoint	Text	Y	The type of end point from luList37_ToxicityEndPoints.
LabRep	Number	N	Count.
Value	Number	Y	The numerical result of the test.

QACode	Text	Y	The quality assurance code from luList39_ToxicityTestAcceptabilityCodes.
Comments	Text	N	Additional remarks.

2.10 ToxicityWQ

This table is optional for reporting purposes.

PURPOSE: This table is used to document water quality during the course of a toxicity test. Each record represents a measurement of an individual water quality parameter at a specific time interval during the course of the test batch.

TABLE GUIDELINES: Each record will be unique based on a combination of the fields StationID, StationOwner, QABatch, Parameter, Matrix, TimePoint, LabRep, and AnalyticalLabCode. The data exchange file will be submitted with the file name ToxicityWQ.XXX.

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

	A	B	C	D	E	F	G	H
1	QABatch	StationID	LabRep	Parameter	Matrix	Dilution	Concentration	ConcentrationUni
2	1/18/04	1	1	NH3T	OL	0	0	NR

tblToxicityResults / tblToxicityWQ / tblFlow / tblRainGa

Microsoft Excel - DataExamples.xls

	I	J	K	L	M	N	O
1	TimePoint	Qualifier	Value	ValueUnits	AnalyticalLabCode	Comments	
2	0	N	1	mg/kg	SCCWRP	Test Record	

tblToxicityResults / tblToxicityWQ / tblFlow / tblRainGa

TABLE STRUCTURE:

Field Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table.
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes.

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QABatch	Text	Y	The batch code for the sample processing batch.
Matrix	Text	Y	The test matrix from luList36_ToxicityMatrices.
Dilution	Number	Y	The dilution factor expressed as a proportion.
Concentration	Number	Y	Concentration expressed in mg/L.
ConcentrationUnits	Text	Y	From luList28_Units.
TimePoint	Number	Y	The number of days from the start of the test.
Parameter	Text	Y	The water quality parameter being measured from luList15_ParameterCodes.
Qualifier	Text	N	Any necessary qualifier from luList11_QualifierCodes.
Value	Number	Y	The numerical result for the parameter.
ValueUnits	Text	Y	Any necessary qualifier from luList11_QualifierCodes.
LabRep	Text	Y	The number of the replicate in which the measurement was taken.
AnalyticalLabCode	Text	Y	From luList01_AgencyCodes.
Comments	Text	N	Additional remarks.

2.11 Flow Gauge Data

PURPOSE: The purpose of this table is to capture the raw flow data. It is generally intended to accept data from instruments, but can also be used to store manual flow measurements.

TABLE GUIDELINES: Each record will be unique based on a combination of StationID, StationOwner, StormID, SampleDate, SampleTime, and SamplingOrganization. The data exchange file will be reported with the file name Flow.XXX.

EXAMPLE DATA:

Microsoft Excel - DataExamples.xls

	A	B	C	D	E	F	G	H	I	J	K
1	StationID	StationOwner	StormID	SampleDate	SampleTime	SamplingOrganization	Level	Velocity	Flow	FlowType	FlowMeasurementQualifier
2	1	SCCWRP	Storm1	1/18/2004	4:40:00 AM	SCCWRP	2	1	3	SF	None

tblFlow / tblRainGauge

TABLE STRUCTURE

FieldName	Type	Required	Description
StationID	Text	Y	A geographic location label
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes
StormID	Text	Y	A unique identifier for each storm event
SampleDate	Date/Time	Y	Date of the measurement expressed as dd-mmm-yyyy
SampleTime	Date/Time	Y	Time of the measurement on the 24 hour clock expressed as hh:mm:ss
SamplingOrganization	Text	Y	From luList01_AgencyCodes
Level	Number	N	Water level expressed in inches
Velocity	Number	N	Velocity expressed in feet per second
Flow	Number	Y	Flow expressed as cubic feet per second
FlowType	Text	Y	From luList03 FlowTypes
FlowMeasurementQuaifier	Text	Y	From luList11_QualifierCodes

2.12 Rain Gauge Data

This table is optional for reporting purposes.

PURPOSE: The purpose of this table is to contain summary rain gauge data from rain gauges in the watershed.

TABLE GUIDELINES: Each record will be unique based on a combination of the fields StationID, StationOwner, and StormID.. The data exchange file will be reported with the file name RainMeasures.XXX

EXAMPLE DATA:

Microsoft Excel - DataExample.xls

	A	B	C	D	E
1	StationID	StationOwner	StormID	CumulativeInches	
2	1	SCCWRP	Storm1	1	
3					

tblFlow / tblRainGauge

TABLE STRUCTURE

FieldName	Type	Required	Description
StationID	Text	Y	A geographic location label
StationOwner	Text	Y	The agency that owns the station from luList01_AgencyCodes
StormID	Text	Y	A unique identifier for each storm event
CumulativeInches	Number	Y	The amount of rain accumulated for the storm

APPENDIX 1. Look up Lists

Look up list 01 Agency Codes

Code	Description
ABC	Aquatic Bioassay and Consulting Inc.
AETLI	American Environmental Testing Laboratory Inc.
Agoura Hills HDPW	Agoura Hills Department of Public Works
AlhambraDPW	Alhambra Department of Public Works
Aliso Viejo	City of Aliso Viejo
ArcadiaDPW	Arcadia Department of Public Works
ArtesiaDPW	Artesia Department of Public Works
ASSOC	Associated Laboratories
AzusaDPW	Azusa Department of Public Works
Baldwin ParkDPW	Baldwin Park Department of Public Works
Bell GardensDPW	Bell Gardens Department of Public Works
BellflowerDPW	Bellflower Department of Public Works
BellPW	Bell Department of Public Works
Beverly HillsDPW	Beverly Hills Department of Public Works
BradburyDPW	Bradbury Department of Public Works
BurbankDPW	Burbank Department of Public Works
CalabasasDPW	Calabasas Department of Public Works
CamarilloDPW	Camarillo Department of Public Works
Carlsbad	City of Carlsbad
CarsonDPW	Carson Department of Public Works
CerritosDPW	Cerritos Department of Public Works
Chula Vista	City of Chula Vista
ClaremontDPW	Claremont Department of Public Works
CommerceDPW	Commerce Department of Public Works
ComptonDPW	Compton Department of Public Works
Coronado	City of Coronado
CovinaDPW	Covina Department of Public Works
CRG	CRG Labs
CSD	City of San Diego
CSDDPW	County of San Diego Department of Public Works
CudahyDPW	Cudahy Department of Public Works
Culver CityDPW	Culver City Department of Public Works
Dana Point	City of Dana Point
Del Mar	City of Del Mar
Diamond BarDPW	Diamond Bar Department of Public Works
DowneyDPW	Downey Department of Public Works
DuarteDPW	Duarte Department of Public Works
El Cajon	City of El Cajon
El MonteDPW	El Monte Department of Public Works
El SegundoDPW	El Segundo Department of Public Works
Encinitas	City of Encinitas
Escondido	City of Escondido
FillmoreDPW	Fillmore Department of Public Works
GardenaDPW	Gardena Department of Public Works
GlendaleDPW	Glendale Department of Public Works
GlendoraDPW	Glendora Department of Public Works
Hawaiian GardensDPW	Hawaiian Gardens Department of Public Works

HawthorneDPW	Hawthorne Department of Public Works
Hermosa BeachDPW	Hermosa Beach Department of Public Works
Hidden HillsDPW	Hidden Hills Department of Public Works
HTB	Heal The Bay
Huntington ParkDPW	Huntington Park Department of Public Works
Imperial Beach	City of Imperial Beach
IndustryDPW	Industry Department of Public Works
InglewoodDPW	Inglewood Department of Public Works
IrwindaleDPW	Irwindale Department of Public Works
KLI	Kinnetic Laboratories Inc.
La Canada FlintridgeDPW	La Canada Flintridge Department of Public Works
La Habra HeightsDPW	La Habra Heights Department of Public Works
La Mesa	City of La Mesa
La MiradaDPW	La Mirada Department of Public Works
La PuenteDPW	La Puente Department of Public Works
La VerneDPW	La Verne Department of Public Works
LABS	Los Angeles Bureau of Sanitation
LACDPW	Los Angeles County Department of Public Works
LACSD	Los Angeles County Sanitation Districts
LADWP	Los Angeles Department of Water and Power
Laguna Beach	City of Laguna Beach
Laguna Hills	City of Laguna Hills
Laguna Niguel	City of Laguna Niguel
Laguna Woods	City of Laguna Woods
Lake Forest	City of Lake Forest
LakewoodDPW	Lakewood Department of Public Works
LARWQCB	Los Angeles Regional Water Quality Control Board
LawndaleDPW	Lawndale Department of Public Works
Lemon Grove	City of Lemon Grove
LomitaDPW	Lomita Department of Public Works
Long BeachDPW	Long Beach Department of Public Works
LynwoodDPW	Lynwood Department of Public Works
MalibuDPW	Malibu Department of Public Works
Manhattan BeachDPW	Manhattan Beach Department of Public Works
MaywoodDPW	Maywood Department of Public Works
MEC	MEC Analytical Systems Inc.
Mission Viejo	City of Mission Viejo
MonroviaDPW	Monrovia Department of Public Works
MontebelloDPW	Montebello Department of Public Works
Monterey ParkDPW	Monterey Park Department of Public Works
MoorparkDPW	Moorpark Department of Public Works
Murrieta	City of Murrieta
MWH	Montgomery Watson Laboratories
National City	City of National City
NorwalkDPW	Norwalk Department of Public Works
Oceanside	City of Oceanside
OCPFRD	Orange County Public Facilities and Resources Department
OCSD	Orange County Sanitation Districts
OjaiDPW	Ojai Department of Public Works

ORWD	Orange County Water District
OxnardDPW	Oxnard Department of Public Works
Palos Verdes EstatesDPW	Palos Verdes Estates Department of Public Works
ParamountDPW	Paramount Department of Public Works
PasadenaDPW	Pasadena Department of Public Works
Pico RiveraDPW	Pico Rivera Department of Public Works
PomonaDPW	Pomona Department of Public Works
Port HuenemeDPW	Port Hueneme Department of Public Works
Poway	City of Poway
PSD	Port of San Diego
Rancho Palos VerdesDPW	Rancho Palos Verdes Department of Public Works
Rancho Santa Margarita	City of Rancho Santa Margarita
RCFCD	Riverside County Flood Control District
Redondo BeachDPW	Redondo Beach Department of Public Works
Rolling Hills EstatesDPW	Rolling Hills Estates Department of Public Works
Rolling HillsDPW	Rolling Hills Department of Public Works
RosemeadDPW	Rosemead Department of Public Works
San BuenaventuraDPW	San Buenaventura Department of Public Works
San Clemente	City of San Clemente
San DimasDPW	San Dimas Department of Public Works
San FernandoDPW	San Fernando Department of Public Works
San GabrielDPW	San Gabriel Department of Public Works
San Juan Capistrano	City of San Juan Capistrano
San Marcos	City of San Marcos
San MarinoDPW	San Marino Department of Public Works
Santa ClaritaDPW	Santa Clarita Department of Public Works
Santa Fe SpringsDPW	Santa Fe Springs Department of Public Works
Santa MonicaDPW	Santa Monica Department of Public Works
Santa PaulaDPW	Santa Paula Department of Public Works
Santee	City of Santee
SARWQCB	Santa Ana Regional Water Quality Control Board
SBFCD	San Bernardino Flood Control District
SCCWRP	Southern California Coastal Water Research Project
SDCC	San Diego County Copermittees
SDCDEH	San Diego County Department of Environmental Health
SDCRAA	San Diego County Regional Airport Authority
SDRWQCB	San Diego Regional Water Quality Control Board
Sierra MadreDPW	Sierra Madre Department of Public Works
Signal HillDPW	Signal Hill Department of Public Works
Simi ValleyDPW	Simi Valley Department of Public Works
SMBRP	Santa Monica Bay Restoration Project
SMURF	Santa Monica Urban Runoff Facility
SOCWA	Southern Orange County Wastewater Authority
Solana Beach	City of Solana Beach
South El MonteDPW	South El Monte Department of Public Works
South GateDPW	South Gate Department of Public Works
South	South Pasadena Department of Public Works

PasadenaDPW	
Temecula	City of Temecula
Temple CityDPW	Temple City Department of Public Works
Thousand OaksDPW	Thousand Oaks Department of Public Works
TorranceDPW	Torrance Department of Public Works
VCWPD	Ventura County Watershed Protection Division
VernonDPW	Vernon Department of Public Works
Vista	City of Vista
WalnutDPW	Walnut Department of Public Works
WECK	Weck Laboratories
West CovinaDPW	West Covina Department of Public Works
West HollywoodDPW	West Hollywood Department of Public Works
Westlake VillageDPW	Westlake Village Department of Public Works
WhittierDPW	Whittier Department of Public Works

Look up list 02 Station Types

Code	Description
CRW	Coastal Receiving Water
CSDO	Coastal Storm water Drain Outfall
HE	Harbor/Estuary
IB	Indicator Bacteria
ICID	Reconnaissance
LU	Land Use
ME	Mass Emissions
RG	Rain Gauge
TMDL	TMDL Monitoring
SB	Stream Bioasssessment

Look up list 03 Flow Types

Code	Description
TV	Time to fill volume of known container
SF	Speed of floating object/Cross-sectional wetted surface area
PM	Pressure transducer/Manning equation
PW	Pressure transducer/Weir equation
PR	Pressure transducer/rating curve
PA	Pressure transducer/Area-Velocity sensor
BM	Bubbler/Manning equation
BW	Bubbler/Weir equation
BR	Bubbler/rating curve
BA	Bubbler/Area-Velocity sensor
SM	Staff gauge/Manning equation

SW	Staff gauge/Weir equation
SR	Staff gauge/rating curve

Look up list 04 Sample Types

Code	Description
CHK	Laboratory Check Sample
CRM	Certified Reference Material
DB	Dilution Blank
DUP	Duplicate
EB	Extraction Blank
FBLANK	Final Blank at end of batch
FWBLANK	Fresh water blank
IBLANK	Initial Blank at start of batch
ICAL	Intercalibration Result
LCM	Laboratory Control Matierial
MS	Matrix spike and matrix spike duplicate
QA	Quality Assurance value
RESULT	Numerical Result of analysis
SB	Sampling blank
SRM	Standard Reference Material
SWBLANK	Seawater blank
TWC	Time weighted composite
SG	Surface Grab
DIG	Depth integrated grab
BG	Bottom mounted grab
FWC	Flow weighted composite

Look up list 05 Ordinal Directions

Code	Description
E	East
N	North
NE	Northeast
NR	Not Recorded
NW	Northwest
S	South
SE	Southeast
SW	Southwest
W	West
XX	Calm

Look up list 06 LandUses

Code	Description
AGRI	Agricultural (incl. farmlands, orchards, nurseries)
OPEN	Open Space (undeveloped within developed area)
PARK	Developed (Recreation Fields, Maintained Landscape) Park Land
WILD	National Forests
INDUS	Industrial (excluding Petroleum related activities)
PETROL	Oil Refinery, Distribution Center
RESID	Residential
DEVEL	On-going Major Development
GOVT	Military Installation
EDUC	School, College, University
COMM	Commercial

Look up list 07 Channel Types

Code	Description
ETRAP	Earthen Trapezoidal
RCTRAP	Reinforced Concrete Trapezoidal
RCRECT	Reinforced Concrete Rectangular
RCB	Reinforced Concrete Box
RCP	Reinforced Concrete Pipe
CMP	Corrugated Metal Pipe
NAT	Natural (sides and bottom)
ERBOT	Earthen Bottom
GABI	Reinforced Gabion Sides
RIPRAP	Reinforced Riprap Sides
PUMPSTN	Pump Station Outlet
DAMOUT	Dam Outlet

Look up list 08 Weather Codes

Code
Clear
Drizzle
Fog
Fog and Drizzle
Haze
NR
Overcast
Partly Cloudy
Rain
Thunderstorm

Look up list 09 Hydrologic Unit Codes

Code	Description

http://www.epa.gov/nerlesd1/land-sci/southern_california/geodata/hucs_10digit.html

Look up list 11 Qualifier Codes

Code	Description
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
A	Count base on calculation of Aliquot
AE	Analyst Error
BMDL	Below Method Detection Limit (requires a -99 result)
BRL	Below Reporting Level
CT	Contaminated
DNQ	Detected but not quantified
E	Estimated
I	Inerference
None	None
NA	Not Analyzed
ND	Not Detected
NS	Not Sampled

Look up list 13 Tidal Stages

Code
Ebb
Flood
NR
Slack

Look up list 14 Test Matrices

Code	Description
SOLVENT	Extraction Solvent
FRESHWATER	Fresh water
EX	Extract
DW	Dilution Water
SEAWATER	Sea Water
SEDIMENT	Sediment

Look up list 15 Parameter Codes

Code	Description
1,6,7-Trimethylnaphthalene	PAH
1-Methylnapthalene	PAH
1-Methylphenanthrene	PAH
2,4'-DDD	PCB
2,4'-DDE	PCB
2,4'-DDT	PCB
2,6-Dimethylnaphthalene	PAH
2-Methylnapthalene	PAH
2-phenyldecane	LAB
2-phenyldodecane	LAB
2-phenyltetradecane	LAB
2-phenyltridecane	LAB
2-phenylundecane	LAB
3-phenyldecane	LAB
3-phenyldodecane	LAB
3-phenyltetradecane	LAB
3-phenyltridecane	LAB
3-phenylundecane	LAB
4,4'-DDD	PCB
4,4'-DDE	PCB
4,4'-DDT	PCB
4-phenyldecane	LAB
4-phenyldodecane	LAB
4-phenyltetradecane	LAB
4-phenyltridecane	LAB
4-phenylundecane	LAB
5-phenyldecane	LAB
5-phenyldodecane	LAB
5-phenyltetradecane	LAB
5-phenyltridecane	LAB
5-phenylundecane	LAB
6-phenyldodecane	LAB
6-phenyltetradecane	LAB
6-phenylundecane	LAB
7&6-phenyltridecane	LAB
7-phenyltetradecane	LAB
Acenaphthene	PAH
Acenaphthylene	PAH
aChlordane	PCB
Acid Volitile Sulfide	AVS
Aluminum	METAL

Code	Description
Ammonium	Inorganic
Anthracene	PAH
Antimony	METAL
Arsenic	METAL
Barium	METAL
Benz[a]anthracene	PAH
Benzo[a]pyrene	PAH
Benzo[b]fluoranthene	PAH
Benzo[e]pyrene	PAH
Benzo[g,h,i]perylene	PAH
Benzo[k]fluoranthene	PAH
Beryllium	METAL
Biphenyl	PAH
Cadmium	METAL
Chlorophyll a	Nutrient
Chromium	METAL
Chrysene	PAH
Copper	METAL
Dibenz[a,h]anthracene	PAH
Dissolved Oxygen	Oxygen
Enterococcus	Bacteria
Fecal Coliforms	Bacteria
Fluoranthene	PAH
Fluorene	PAH
gChlordane	PCB
Hydrogen Sulfide	Inorganic
Indeno(1,2,3-c,d)pyrene	PAH
Iron	METAL
Lead	METAL
Lipid	LIPID
Mercury	METAL
Naphthalene	PAH
Nickel	METAL
NO2	Nutrient
NO2/NO3	Nutrient
NO3	Nutrient
NPH	
OI	
o-phosphate	Nutrient
PCB 101	PCB
PCB 105	PCB
PCB 110	PCB
PCB 114	PCB

Code	Description
PCB 118	PCB
PCB 119	PCB
PCB 123	PCB
PCB 126	PCB
PCB 128	PCB
PCB 138	PCB
PCB 149	PCB
PCB 151	PCB
PCB 153	PCB
PCB 156	PCB
PCB 157	PCB
PCB 158	PCB
PCB 167	PCB
PCB 168	PCB
PCB 169	PCB
PCB 170	PCB
PCB 177	PCB
PCB 18	PCB
PCB 180	PCB
PCB 183	PCB
PCB 187	PCB
PCB 189	PCB
PCB 194	PCB
PCB 201	PCB
PCB 206	PCB
PCB 28	PCB
PCB 37	PCB
PCB 44	PCB
PCB 49	PCB
PCB 52	PCB
PCB 66	PCB
PCB 70	PCB
PCB 74	PCB
PCB 77	PCB
PCB 81	PCB
PCB 87	PCB
PCB 99	PCB
PCB153168	PCB
Percent Fines	Inorganic
Perylene	PAH
pH	Inorganic
Phaeo	Nutrient
Phenanthrene	PAH

Code	Description
Pyrene	PAH
Salinity	Inorganic
Selenium	METAL
Si(OH)4	Nutrient
Silver	METAL
SubPAR	Light
Tail Movement	
TerPAR	Light
TOC	TOC
Total Ammonia	Inorganic
Total Coliforms	Bacteria
Total Nitrogen	TN
Total Sulfide	Inorganic
Total Suspenede Solids	TSS
Unionized Ammonia	Inorganic
Zinc	METAL

Look up list 17 Measurement Basis Codes

Code	Description
DW	Dry Weight
WW	Wet Weight
LS	Liquid Sample

Look up list 19 Current Directions

Code	Description
DC	down coast
IN	indeterminant
NC	no current
UC	up coast

Look up list 24 Analysis Method Codes

Code	Description
AlpKem RFA 300 Series Nutrient Analyzer	AlpKem RFA 300 Series Nutrient Analyzer
CHN	EA1108 CHN Elemental Analyzer
Colilert 18	Idexx
CVAA	Cold Vapor Atomic Absorption Analysis
Entrolert	Idexx
EPA 160.2	Total Suspended Solids analysis method
EPA200.7	

Code	Description
EPA200.8	
EPA206.2	
EPA245.5	
EPA270.2	
FAA	Flame Atomic Absorption Spectrometer
FIAS	Flow Injection Analysis System
FIMS	Flow Injection Mercury System
FLUORO	Fluiorometric analysis method for chlorophyll a and phaeopigment
GCECD	CG/ECD
GCMS	GS/MS
GFAA	Graphite Furnace Atomic Absorption Analysis
Gravimetric	Sediment Grain Size Sieve Analysis
HAA	Hydride Atomic Absorption Analysis
ICPAES	Inductively Coupled Plasma Atomic Emmision Spectrometer
ICPMS	Inductively Coupled Plasma Mass Spectrometer
IONGCMS	Ion Trap GC/MS
MARPCN I	High temperature combustion method
Mettler H54AR Balance	
MF	Membrane Filtration
MTF	Multiple Tube Fermentation
NA	Not analyzed
NR	Missing data
PCB Congeners Consistent with NPDES method 608	
PSEP86	Sediment Grain Size
Real Time	
SM2540D	
SM4500NH3	
SM4500NO3	
SM4500P	
SW6010	
SW7060	
SW7740	
SW8081	
SW80818082	
SW8270	
Turner Designs 10-005R Fluorometer	
Wet Sieve Analysis	
XX	
Sedigraph 5100	Sediment Grain Size (Silt/Clay fraction)
Turner Designs 10-AU Fluormeter	
Visual Accumulation Tube	Sediment Grain Size (fine sand fraction)

Code	Description
FILTERED	0.45 Micron USGS Groundwater Capsule

Look up list 25 Preparation Method Codes

Code	Description
90% Acetone	90% Acetone Extract for chlorophyll a and phaeopigment
ASE	Accelerated Solvent Extraction
Conventional Oven	Conventional Oven
EPA245.5	Mercury in Sediment (Cold Vapor with Permanganate Digestion)
EPA3050A	Strong Acid Hot Plate Method (EPA3050A)
EPA3050B	Strong Acid Hot Plate or Microwave Method (EPA3050B)
EPA3051	Strong Acid Microwave Method (EPA 3051)
EPA3052	
EPA3052/3050B	
EPA3053	
EPA3055	Strong Acid Hot Plate Method (EPA 3055)
MASE	Microwave Assisted Solvent Extraction
MgNO3	Magnesium Nitrate
NA	No Applicable Prepcode
NR	Missing data
PSEP86	Sediment Grain Size
ROLLER	Roller Table Extraction
SFE	Supercritical Fluid Extraction
Solvent extraction	Solvent extraction
SONIC	Ultrasonic Extraction
SOXHLET	Soxhlet Solvent Extraction
Varian-EPA245.5	

Look up list 27 Surf Conditions

Code	Description
High(7+)	Surf height greater than seven feet.
Low(1-3)	Surf height between one and three feet.
Mid(4-6)	Surf height between four and six feet.

Look up list 28 Units

Code	Description
C	Degrees Centigrade
CFU/100ml	Colony Forming Units
CM	Centimeters
DAYS	Days

Code	Description
FT	Feet
G	grams
HOURS	Hours
KG	Kilograms
KTS	Knots
M	Meters
MG/KG	Milligrams per Kilogram
MG/L	Milligrams per liter
MPN/100ml	Most Probable Number
PERCENT	Percent
PSDT	Pacific Daylight savings time
PST	Pacific Standard Time
PSU	Practical Salinity Units also called parts per thousand
UG/L	micrograms per liter

Look up list 30 Missing Value Codes

Code	Description
Date	01/Jan/SampleYear
Time	2300 incremented in minutes for multiple records at the same station
Numerical	-99
Text	NR

Look up list 34 ToxictySpecies/TestType

Code	Description
EE	Eohaustorius estuarius
SP	Strongylocentrotus purpuratus
MB	Mysidopsis bahia
CD	Ceriodaphnia dubia
PP	Pimephales promelas
SC	Selenastrum capricornutum
HA	Hyallela azteca

Look up list 35 ToxicityProtocols

Code	Description
ASTM 1853	ASTM 1997. E 1853-96
EPA 1994	EPA amphipod test method (EPA/600/R-94/025)
EPA 4425	From standard methods.
USGS F10.6	From standard methods.
USGS F10.7	From standard methods.
USGS SOP F10.6	Sea Urchin Fertilization Toxicity Test

Code	Description
USGS SOP F10.7	Sea Urchin Embryological Development Test
EPA/600/4-91/002	EPA Ceriodaphnia and Selenastrum test methods (EPA/600/4-91/002)
EPA/600/4-90/027F	EPA Pimephales test method (EPA/600/4-90/027F)
EPA/600/R-99/064	EPA Hyallela test method-modified (EPA/600/R-99/064)
EPA/600/R-95/136	EPA Mysidopsis and Sea Urchin test methods (EPA/600/R-95/136)

Look up list 36 ToxicityMatrices

Code	Description
BS	bulk sediment
DW	Dilution Water
EL	elutriate
EX	extract
IW	interstitial water
OL	overlaying water
RT	reference toxicant

Look up list 37 ToxicityEndPoints

Code	Description
B[a]Peq	Benzo [a] Pyrene equivalents
DV	Percent Normal Pluteus Stage
EC50	median effective concentration
FP	Fertilized Percent
IC50	median inhibitory concentration
RL	relative luminescence
SP	survival percent

Look up list 38 ToxicityWaterQualityParameters

Code	Description	Units
COND	Conductivity	uSiemens
DO	Dissolved Oxygen	mg/L
H2S	Hydrogen Sulfide	mg/L
NH3T	Total Ammonia	mg/L
NH3U	Unionized Ammonia	mg/L
PH	pH	pH
SAL	Salinity	g/L
ST	Total Sulfide	ug/L
TEMP	Temperature	C

Look up list 39 ToxicityTestAcceptabilityCodes

Code	Description
A	Acceptable data for analysis
AEHJ	Combination Code
AH	Combination Code
AHJ	Combination Code
AJ	Combination Code
AK	Combination Code
C	Reduced number of replicates
CDEH	Combination Code
D	Control performance criteria not met
DE	Combination Code
DEH	Combination Code
DJ	Combination of codes D and J
E	Sample stored > 14 days
EK	combination of codes E and K
G	Reference test missing or outside limits
H	Water quality data incomplete
HD	Combination Code
J	Minor deviation in test conditions
K	Incoming sample temperature exceeds limits
Q	Control did not meet replicate acceptability criterion (>or=80% in any one rep)

Surface Water Ambient Monitoring Program (SWAMP)

Water Boards

SWAMP Surface Water Ambient Monitoring Program

Program Goal & Vision

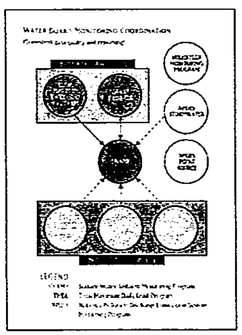
Adequate and accurate monitoring and assessment are the cornerstones to preserving, enhancing and restoring water quality. The information gathered from monitoring activities is critical to protect the beneficial uses of water, to develop water quality standards, conduct federal Clean Water Act assessments and to determine the effects of pollution and of pollution prevention programs.

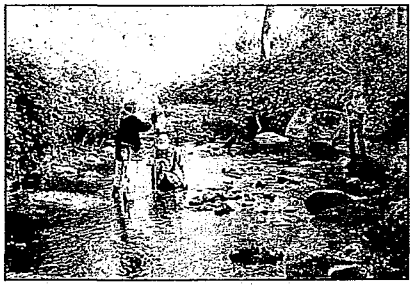
The SWAMP VISIONS are:

- That water quality is comprehensively measured to protect beneficial uses, and to evaluate our protection and restoration efforts.
- To define a complete set of monitoring objectives, based on beneficial use attainment and reflecting the full range of regulatory responsibilities and water quality programs for all waterbody types.
- To develop and implement a monitoring design that maximizes our ability to meet our monitoring objectives with existing resources.
- To develop and implement a set of monitoring indicators (and assessment thresholds), which can be used to track the status and trends of water quality and to evaluate the effectiveness of management actions to improve water quality in California.
- To develop and implement a progressive quality assurance program using a systems-based approach to the generation and storage of application-appropriate data/metadata.
- To make credible ambient monitoring data available to all stakeholders in a timely manner.
- To provide a consistent science-based framework for the evaluation of monitoring data relative to state and regional standards and the protection of beneficial uses and for tracking the effectiveness of management actions.
- To report all collected data as information and in a timely and publicly accessible manner.
- To conduct periodic reviews of each aspect of the program to determine its scientific validity and how well it serves the water quality decision needs of the state.
- To provide the support needed to implement a coordinated and comprehensive monitoring and assessment program.

SWRCB & RWQCB Boards Coordination

- Capture Monitoring Data
- Ensure Data Comparability
- Coordinate for QA and Data Formats
- Programs Involved:
  - Regional Watershed Assessments
  - TMDLs
  - Grant Projects
  - Aquatic Pesticide Monitoring
  - Waivers
  - Clean Water Team (volunteer groups)
  - Fish/Shellfish Bioaccumulation





Monitoring Framework
(National Water Quality Monitoring Council)

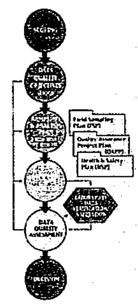
Ten Basic Elements of a State Water Monitoring and Assessment Program

1) Monitoring Program Strategy
2) Monitoring Objectives
3) Monitoring Design
4) Core Indicators of Water Quality
5) Quality Assurance
6) Data Management
7) Data Analysis/Assessment
8) Reporting
9) Programmatic Evaluation
10) General Support & Infrastructure

SWAMP Participants

- State Water Resource Control Board
- Regional Water Quality Control Boards
- Department of Fish & Game
  - Marine Pollution Studies Laboratory, Granite Canyon
  - Marine Pollution Studies Laboratory, Moss Landing
  - Fish and Wildlife Water Pollution Control Laboratory, Nimbus
  - Aquatic Bioassessment Laboratory, Nimbus

Monitoring Design

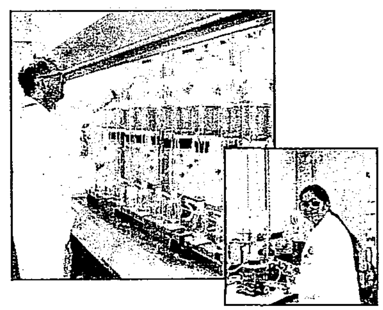


To find out how to be comparable with SWAMP, see:

http://mpsl.mlml.calstate.edu/swcompare.htm

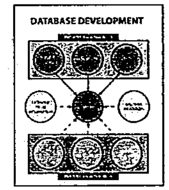
Quality Assurance

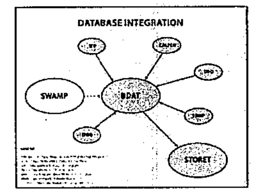
- QA Team
- QA Toolbox
- QA Website www.waterboards.ca.gov/swamp/qapp.html
- QA "Expert System" software



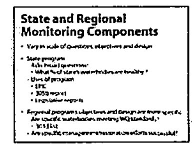
Data Management

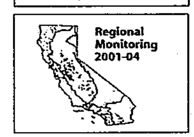
- Make data available in a timely manner
- An accessible electronic data system
- Metadata and geo-locational standards
- Database support and training
- Data will be available through CEDEN
- Data will be uploaded to EPA's STORET

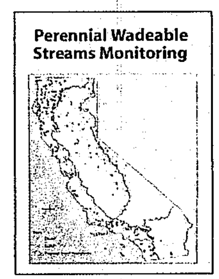




STATEWIDE SWAMP MONITORING







SWAMP Training Track

-All SWAMP "partners"?
-Use of SWAMP "toolbox"

- Introductory Monitoring Design
- Design
- SWAMP Field Methods (CD rom)
- Introductory Quality Assurance
- SWAMP Advisor
- SWAMP Data Management
- SWAMP Collaboration Workshop
- Annual mtg - CA Bioassessment Workgroup
- SWAMP for Ag. Coalitions
- Monitoring Grant Project Effectiveness

SWAMP Website: http://www.waterboards.ca.gov/swamp

The National Stormwater Quality Database (NSQD, version 1.1)

February 16, 2004

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This paper, or earlier versions, have been presented (or are scheduled) for the following conferences, and has been published in the associated conference proceedings:

Watershed 2004. Dearborn, MI. July 2004
World Water and Environmental Resources Congress, Salt Lake City, UT. ASCE. June 2004
Water Environment Federation Technical Exposition and Conference, Los Angeles. Oct 2003
South Pacific Stormwater Conference, Auckland Regional Council, New Zealand. June 2003
National Stormwater Coordinators Meeting, US EPA, Austin, TX. April 2003
National Conference on Urban Stormwater, Chicago Botanical Gardens and US EPA, Chicago, February 2003
Conference on Stormwater and Urban Water Systems Modeling, CHI and EPA, Toronto, Ontario. February 2003

Abstract

The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permit holders. The initial version of this database, the National Stormwater Quality Database (NSQD, version 1.1) is currently being completed. These stormwater quality data and site descriptions are being collected and reviewed to describe the characteristics of national stormwater quality, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas having limited data.

The monitoring data collected over nearly a ten-year period from more than 200 municipalities throughout the country have a great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. This project is creating a national database of stormwater monitoring data collected as part of the existing stormwater permit program, providing a scientific analysis of the data, and providing recommendations for improving the quality and management value of future NPDES monitoring efforts.

Each data set is receiving a quality assurance/quality control review based on reasonableness of data, extreme values, relationships among parameters, sampling methods, and a review of the analytical methods. The statistical analyses are being conducted at several levels. Probability plots are used to identify range, randomness and normality. Clustering and principal component analyses are utilized to characterize significant factors affecting the data patterns. The master data set is also being evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. Regional and climatic differences are being tested, including the influences of land use, and the effects of storm size and season, among other factors. The data will be used to develop a method to predict expected stormwater quality for a variety of significant factors and will be used to examine a number of preconceptions concerning the characteristics of stormwater, sampling design decisions, and some basic data analysis issues. Some of the issues that are being examined with this data include: the occurrence and magnitude of first-flushes, the effects of different sampling methods (the use of grab sampling vs. automatic samplers, for example) on stormwater quality data, trends in stormwater quality with time, the effects of infrequent wrong data in large data bases, appropriate methods to handle values that are below detection limits, the necessary sampling effort needed to characterize stormwater quality, for example. This paper describes the data collected to date and presents some preliminary data findings.

When this National Stormwater Quality Database (NSQD) is completed (populated with most of the NPDES stormwater monitoring data), the continued routine collection of outfall stormwater quality data in the U.S. for basic characterization purposes may have limited use. Some communities may have obviously unusual conditions, or adequate data may not be available in their region. In these conditions, outfall monitoring may be needed. However, stormwater monitoring will continue to be needed for other purposes in many areas having, or anticipating, active stormwater management programs (especially when supplemented with other biological, physical, and hydrologic monitoring components). These new monitoring programs should be designed specifically for additional objectives, beyond basic characterization. These objectives may include receiving water assessments to understand local problems, source area monitoring to identify critical sources of stormwater pollutants, treatability tests to verify the performance of stormwater controls for local conditions, and assessment monitoring to verify the success of the local stormwater management approach (including model calibration and verification). In many cases, the resources being spent for outfall monitoring could be more effectively spent to better understand many of these other aspects of an effective stormwater management program.

Project Description and Background

The importance of this project is based on the scarcity of nationally summarized and accessible data from the existing U.S. EPA's NPDES stormwater permit program. There have been some local and regional data summaries, but little has been done with nationwide data. A notable exception is the Camp, Dresser, and McGee (CDM) national stormwater database (Smullen and Cave 2002) that combined historical Nationwide Urban Runoff Program (NURP) (EPA 1983), available urban U.S. Geological survey (USGS), and selected NPDES data. Their main effort has been to describe the probability distributions of these data (and corresponding EMCs, the event mean concentrations). They concluded that concentrations for different land uses were not significantly different, so all their data were pooled.

Between 1978 and 1983, the EPA conducted the NURP that examined stormwater quality from separate storm sewers in different land uses (EPA 1983). This project studied 81 outfalls in 28 communities throughout the U.S. and included the monitoring of approximately 2300 storm events. The data was presented for several land use categories, although most of the information was obtained from residential lands. Since NURP, other important studies have been conducted that characterize stormwater. The USGS created a database with more than 1100 storms from 98 monitoring sites in 20 metropolitan areas. The Federal Highway Administration (FHWA) analyzed stormwater runoff from 31 highways in 11 states during the 1970s and 1980s (Cave 1995). Strecker (personal communication) is also collecting information from highway monitoring as part of a current NCHRP-funded project. The city of Austin also developed a database having more than 1200 events (Smullen 2003).

Other regional databases also exist, mostly using local NPDES data. These include the Los Angeles area database, the Santa Clara and Alameda County (California) databases, the Oregon Association of Clean Water Agencies Database, and the Dallas, Texas, area stormwater database. These regional data are (or will be) included in the NSQD national database. However, the USGS or historical NURP data will not be included in the NSQD database due to lack of consistent descriptive information for the older drainage areas and because of the age of the data from those prior studies. Much of the NURP data is available in electronic form at the University of Alabama student American Water Resources Association web page at: http://www.eng.ua.edu/~awra/download.htm. The results (especially the stormwater characteristic prediction procedures) from these other databases will be compared to similar findings from the final analyses using this expanded database to indicate any important differences.

Outside the U.S., there have been important efforts to characterize stormwater. In Toronto, Canada, the Toronto Area Watershed Management Strategy Study (TAWMS) was conducted during 1983 and 1984 and extensively monitored industrial stormwater, along with snowmelt in the urban area (Pitt and McLean 1986), for example. Numerous other investigations in South Africa, the South Pacific, Europe and Latin America have also been conducted over the past 30 years, but no large-scale summaries of that data have been prepared. About 3,500 international references on stormwater have been reviewed and compiled since 1996 by the Urban Wet Weather Flows literature review team for publication in *Water Environment Research* (Field, *et al.* 1997, 1998; O'Connor, *et al.* 1999; Fan, *et al.* 2000; Clark, *et al.* 2001, 2001, 2003). An overall compilation of these literature reviews is available at:

http://www.eng.ua.edu/~rpitt/Publications/Publications.shtml

The reviews include short summaries of the papers and are organized by major topics. Besides journal articles, many published conference proceedings are also represented (including the extensive conference proceedings from the 8th International Conference on Urban Storm Drainage held in Sydney, Australia, in 1999, the 9th International Conference on Urban Storm Drainage held in Portland, OR, in 2002, and the Toronto Stormwater and Urban Water Systems Modeling conference series, amongst many other specialty conferences).

The NSQD is unique in that detailed descriptions of the test areas and sampling conditions are also being collected, including aerial photographs and topographic maps that are being obtained from public domain Internet sources. Land use information used is as supplied by the communities submitting the data, although aerial photographs and maps are also used to help clarify questions concerning specific development characteristics. Most of the sites have homogeneous land uses, although many are mixed. These characteristics are all fully noted in the database.

Stormwater runoff data from existing NPDES permit applications and annual monitoring reports are being collected during this project. This project also includes extensive QA/QC (quality assurance/quality control) evaluations of these data; and performing statistical analyses and summaries of these data. The final information will be published on the Internet (such as on an EPA OW-OWM, Office of Water and Office of Wastewater Management, site and on the Center for Watershed Protection's SMRC, Stormwater Manager's Resources Center, site at: http://www.stormwatercenter.net/). Some of the information is currently located at Pitt's teaching and research web site at:

http://www.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

The Phase I NPDES communities included areas with:

- A stormwater discharge from a MS4 serving a population of 250,000 or more (large system), or
- A stormwater discharge from a MS4 serving a population of 100,000 or more, but less than 250,000 (medium system).

More than 200 municipalities, plus numerous additional special districts and governmental agencies were included in this program. Part 2 of the NPDES discharge permit application specified that sampling was needed and that the following items were to be included in the application:

- Proposed monitoring program for representative data collection during the term of the permit;
- Quantitative data from 5 to 10 representative locations;
- Estimates of the annual pollutant load and event mean concentration (EMC) of system discharges; and
- Proposed schedule to provide estimates of seasonal pollutant loads and the EMC for certain detected constituents during the term of the permit.

The permit applications were due in 1992 and 1993. For Part 2 of the application, municipalities were to submit grab (for certain pollutants having severe holding time restrictions, such as bacteria) and flow-weighted sampling data from selected sites (5 to 10 outfalls) for three representative storm events at least one month apart. In addition, the municipalities must have also developed programs for future sampling activities that specified sampling locations, frequency, pollutants to be analyzed, and sampling equipment.

Numerous constituents were to be analyzed, including typical conventional pollutants (TSS, TDS, COD, BOD_5, oil and grease, fecal coliforms, fecal strep., pH, Cl, TKN, NO_3, TP, and PO_4), plus many heavy metals (including total forms of arsenic, chromium, copper, lead, mercury, and zinc, plus others), and numerous listed organic toxicants (including PAHs, pesticides, and PCBs). Many communities also analyzed samples for filtered forms of the heavy metals. This database currently includes information for about 125 different stormwater quality constituents, although the current database is mostly populated with data from 35 of the commonly analyzed pollutants (as summarized later in Table 1). Therefore, there has been a substantial amount of stormwater quality data collected during the past 10 years throughout the U.S., although most of these data are not readily available, nor have detailed statistical analyses been conducted and presented.

Data Collection and Analysis Efforts to Date

As of mid-summer 2003, 3,770 separate events from 66 agencies and municipalities from 17 states have been collected and the data entered into NSQD. Figure 1 shows the locations of these municipalities on a national map, along with EPA Rain Zones. Excellent national coverage is anticipated, although there will be few municipalities from the northern, west-central states of Montana, Wyoming, and North and South Dakota (where cities are generally small, and few were included in the Phase 1 NPDES program). This current database (NSQD, Version 1.1) covers areas mostly in the southern, Atlantic, central, and western parts of the US. Anticipated future project phases will help extend the national coverage.

Some of the municipalities that have been contacted (and some in which data was received) have information that could not be used for various reasons. One of the most common reasons was that the samples had been collected from receiving waters (such as Washington state, Nashville, and Chattanooga). Only data from well-described stormwater outfall locations are being used for the database. These can be open channel outfalls in completely developed areas, but are more commonly conventional outfall pipes. The other major problem is that the sampling locations and/or the drainage areas were not described. Data with some missing information is being used for now, with the intention of obtaining the needed information later. However, there will likely still be some minor data gaps that will not be able to be filled. In addition, the list of constituents being monitored has varied for different locations. Most areas evaluated the common stormwater constituents, but few have included organic toxicants. The most serious gap is the frequent lack of runoff volume data, although all sites have included rain data. Finally, if all the data were collected that was requested, the current project resources will not permit their full utilization, as it requires a great deal of time to enter and review this information. About 10% of the collected data needed verification during the QA/QC process. If that potentially faulty data remained in the database, spurious statistical analyses would have resulted. The collection and review of the data is a necessary first step to facilitate later analyses.

The assembled data was entered into NSQD, including site descriptions (state, municipality, land use components, and EPA rain zone), sampling information (date, season, rain depth, runoff depth, sampling method, sample type, etc.), and constituent measurements (concentrations, grouped in categories). In addition, more detailed site, sampling, and analysis information has been collected for most sampling sites and is also included as supplemental information. The reported land use information supplied by the communities is being used, with verification of some areas with aerial photographs and maps. In many cases, the sampled watersheds have multiple land uses and those designations are included in the database (the database lists the percentages of the drainage as residential, commercial, industrial, freeway, institutional, and open space). The final data analyses will consider these mixed sites also, especially for verification for the model development activities, although the following preliminary results are only for the homogeneous land use sites.

Preliminary Summary of U.S. NPDES Phase 1 Stormwater Data

Additional site information is being acquired to complete most of the missing records before the final data analyses. The following data and analysis descriptions should therefore be considered preliminary and will change with this additional data and analyses. However, this presentation only uses the most basic and robust analyses for preliminary consideration. The final report and data presentations will obviously be much more comprehensive.

Table 1 is a summary of the Phase 1 data collected and entered into the database as of mid-summer 2003. The data are separated into 11 land use categories: residential, commercial, industrial, institutional, freeways, and open space, plus mixtures of these land uses. Summaries are also shown for mixed land use areas (indicating the most prominent land use), and for the total data set combined. Only data having at least 50 total detected observations and at least 10 detected observations per land use category are shown on this table. The full database includes all of the data. In most cases, many more than these minimum numbers are available. The total number of observations and the percentage of observations above the detection limits are also shown on this summary table. However, some constituents were not monitored by very many stormwater permit holders, and some constituents were mostly all in the "not detected" category, and those data are not shown. As an example, filtered heavy metal observations, and especially organic analyses, have many fewer detected values than other constituents.

The total number of individual events included in the database is 3,770, with most in the residential category (1,069 events). For most common constituents, detectable values are available for almost all monitored events. The median and coefficient of variation (COV) values are only for those data having detectable concentrations. If the non-detected results were used in these calculations, extreme biases would invalidate many of the calculations. The final analyses will further examine issues associated with different detection limits, multiple laboratories, and varying analytical methods on the reported results and statistical analyses. Burton and Pitt (2002), and the many included references in that book, contains further discussions on these important issues.

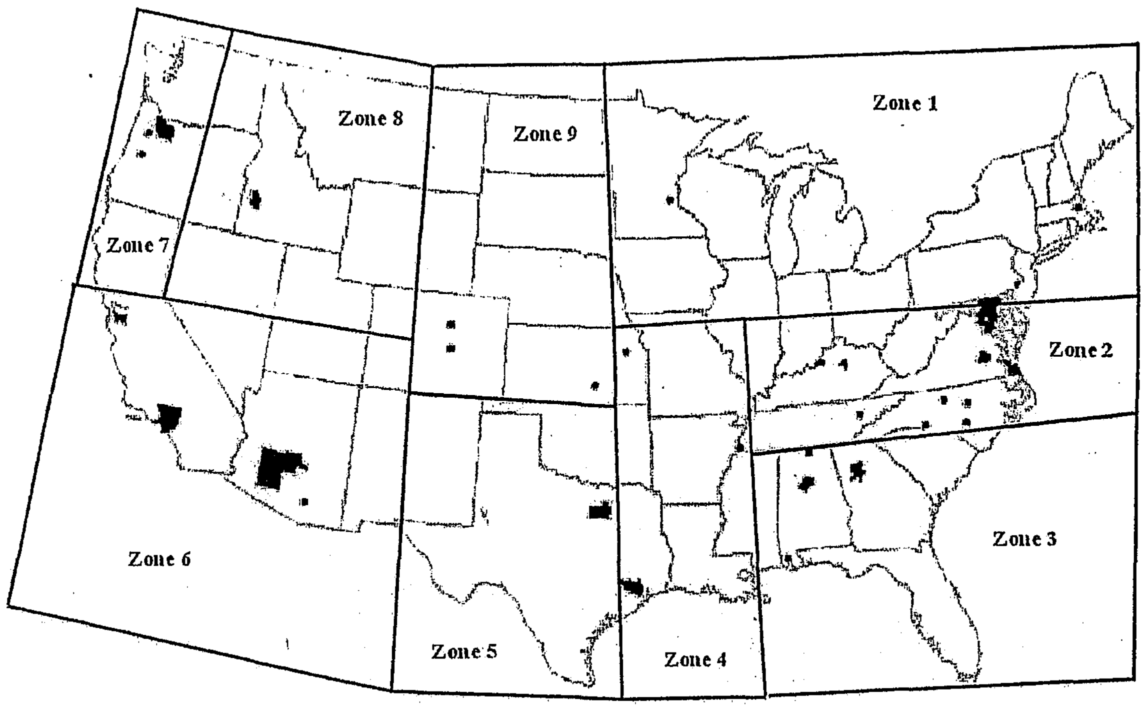

Figure 1. Communities from which data has been obtained and entered in the NSQD, along with EPA Rain Zones.

Table 2 is a summary of methylene chloride and bis(2-ethylhexyl) phthalate, the most commonly reported and detected organic constituents. There were up to several hundred events that included PAH and pesticide data. The percentage of samples that had observable concentrations of these constituents ranged from 15 to 35%, about the same detection rate as in previous stormwater investigations, such as Pitt, *et al.* 1995.

Statistical analyses are being conducted in stages. Probability plots were used to identify range, randomness, and normality. Figure 2 is an example of log-normal probability plots for some of the constituents and for all data pooled. Probability plots shown as straight lines indicate that the concentrations can be represented by log-normal distributions. This is important as it indicates that data transformations, or the use of nonparametric statistical analyses, will be needed. Plots with obvious discontinuities imply that multiple data populations may be included. The future analyses will identify the significance of these different data categories (such as land use, region, and season).

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1

	Area (acres)	% Imperv.	Precip. Depth (in)	Runoff Depth (in)	Cond. (uS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Temp. (C)	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)
Overall Summary (3765)													
Number of observations	3759	2202	3186	1454	685	1082	1834	1665	861	2957	3390	3105	2751
% of samples above detection	100	100	100	100	100	98.7	66.1	100	100	99.3	98.8	96.2	98.4
Median	57.0	53.0	0.47	0.18	121	38.0	4.3	7.50	16.5	80	58	8.6	53
Coefficient of variation	3.7	0.4	1.0	2.0	1.6	1.4	9.7	0.1	0.4	3.4	1.8	7.4	1.1
Residential (1081)													
Number of observations	1077	658	915	422	106	250	533	325	205	861	991	941	796
% of samples above detection	100	100	100	100	100	100	57.8	100	100	99.2	98.6	97.6	98.9
Median	57.3	37.0	0.46	0.11	96.5	32.0	3.9	7.3	16.4	72.0	49	9	55
Coefficient of variation	4.7	0.4	1.0	1.9	1.5	1.0	7.7	0.1	0.4	1.1	1.8	1.5	0.93
Mixed Residential (615)													
Number of observations	617	281	441	216	105	157	258	322	141	471	585	558	445
% of samples above detection	100	100	100	100	100	98.1	68.2	100	100	99.2	98.8	94.3	99.3
Median	150.8	44.9	0.54	0.18	112	39.7	4.4	7.50	16.0	86	68	7.6	42
Coefficient of variation	2.1	0.3	0.8	1.4	1.2	1.2	2.4	0.1	0.3	5.2	1.6	1.3	1.2
Commercial (503)													
Number of observations	503	264	421	135	66	139	308	171	79	399	458	432	373
% of samples above detection	100	100	100	100	100	100	70.8	100	100	99.5	98.3	97.5	98.4
Median	38.8	83.0	0.39	0.23	119	38.9	4.7	7.30	16.0	74	42	11.0	60
Coefficient of variation	1.2	0.1	1.0	1.2	1.0	1.1	3.2	0.1	0.4	1.9	2.0	1.1	1.0
Mixed Commercial (311)													
Number of observations	311	238	284	109	44	88	122	143	84	256	288	268	258
% of samples above detection	100	100	100	100	100	98.9	82.0	100	100	99.6	99.7	98.9	99.6
Median	49.0	60.0	0.47	0.34	101	35.0	5.0	7.60	14.7	70	54	9.25	60
Coefficient of variation	2.1	0.3	1.0	1.1	0.6	1.8	2.9	0.1	0.4	1.9	1.4	1.7	1.0
Industrial (525)													
Number of observations	525	320	438	2012	108	138	327	234	140	413	428	406	362
% of samples above detection	100	100	100	100	100	96.4	65.1	100	100	99.5	99.1	95.3	98.9
Median	39.0	75.0	0.49	0.14	136	39.0	5.0	7.50	17.9	92	78	9	60
Coefficient of variation	1.6	0.3	1.0	2.7	1.3	1.5	12.0	0.1	0.3	3.6	1.5	9.6	1.2

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Area (acres)	% Imperv.	Precip. Depth (in)	Runoff Depth (in)	Cond. (uS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Temp. (C)	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)
Mixed Industrial (251)													
Number of observations	251	133	226	117	57	83	80	179	70	222	243	219	217
% of samples above detection	100	100	100	100	100	94.0	77.5	100	100	99.6	100	95.4	98.6
Median	127.7	44.0	0.45	0.29	111	33.0	4.75	7.70	18.1	80	82	7.2	40.4
Coefficient of variation	2.0	0.3	0.8	1.2	0.8	0.5	1.9	0.1	0.4	0.8	1.4	1.7	1.1
Institutional (18)													
Number of observations	18	18	17	14						18	18	18	18
% of samples above detection	100	100	100	100						100	94.4	88.9	88.9
Median	36.0	45.0	0.18	0.00						52.5	17	8.5	50
Coefficient of variation	0	0	0.9	2.1						0.7	0.83	0.7	0.9
Freeways (185)													
Number of observations	185	154	182	144	86	127	60	111	31	97	134	26	67
% of samples above detection	100	100	100	100	100	100	71.7	100	100	99.0	99.3	84.6	98.5
Median	1.6	80.0	0.54	0.41	99	34.0	8.0	7.10	14.0	77.5	99	8	100
Coefficient of variation	1.4	0.13	1.1	1.7	1.0	1.9	0.6	0.1	0.4	0.8	2.6	1.3	1.1
Mixed Freeways (20)													
Number of observations	20		20		13	12	15	19	19	17	17	17	17
% of samples above detection	100		100		100	100	100	100	100	100	100	100.0	100.0
Median	63.1		0.68		418	83	4.0	7.80	16.0	174	81	7.4	48
Coefficient of variation	0.3		0.6		0.6	0.3	1.6	0.06	0.3	0.4	1.2	0.7	0.5
Open Space (49)													
Number of observations	49	37	41	11	2	8	19	19	2	45	44	44	43
% of samples above detection	100	100	100	100	100	100	36.8	100	100	97.8	95.5	86.4	76.74
Median	85	2.0	0.52	0.05	113	150	1.3	7.70	14.6	125	48.5	5.4	42.1
Coefficient of variation	1.5	1.0	1.2	1.4	0.5	0.6	0.7	0.08	0.7	0.7	1.5	0.7	1.5
Mixed Open Space (189)													
Number of observations	189	97	188	81	83	70	96	128	76	148	174	166	145
% of samples above detection	100	100	100	100	100	100	62.5	100	100	99.3	97.7	95.2	96.6
Median	115.4	34.0	0.43	0.16	204	64.2	6.0	7.9	16.0	109	83.5	6.0	34
Coefficient of variation	0.9	0.2	0.9	1.2	1.7	1.3	1.6	0.07	0.3	2.2	1.51	2.5	1.6

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Fecal Coliform (mpn/100 mL)	Fecal Strep. (mpn/100 mL)	Total Coliform (mpn/10 0 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phos., filtered (mg/L)	Phos., total (mg/L)	Sb, total (ug/L)	As, total (ug/L)	As, filtered (ug/L)	Be, total (ug/L)
Overall Summary (3765)													
Number of observations	1704	1141	83	67	1909	3076	3192	2477	3285	874	1507	210	947
% of samples above detection	91.2	94.0	90.4	95.5	71.7	97.3	95.6	85.1	96.6	7.2	49.9	27.1	7.7
Median	5091	17000	12000	1750	0.44	0.6	1.4	0.13	0.27	3.0	3.0	1.5	0.4
Coefficient of variation	4.61	3.8	2.4	2.3	1.4	1.1	1.3	1.6	1.5	1.7	2.6	1.0	2.5
Residential (1069)													
Number of observations	446	305		14	595	927	7	738	963		426		301
% of samples above detection	88.3	89.5		100	81.5	97.4	96.8	84.2	96.9		42.0		7.31
Median	8345	24600		700	0.32	0.6	1.4	0.17	0.30		3.0		0.5
Coefficient of variation	5.0	1.8		1.6	1.1	1.1	1.1	0.9	1.1		2.2		2.5
Mixed Residential (615)													
Number of observations	313	156	26	11	259	535	525	410	556		179		91
% of samples above detection	94.9	98.1	84.6	90.9	57.9	98.1	95.1	82.4	96.2		65.9		12.1
Median	11000	26000	5667	1050	0.39	0.6	1.35	0.12	0.27		3.0		0.3
Coefficient of variation	3.3	2.2	1.31	2.1	1.6	0.8	1.8	1.1	1.7		4.2		2.7
Commercial (497)													
Number of observations	233	181			299	425	449	323	446		213		
% of samples above detection	88.0	91.7			83.3	98.1	97.3	81.1	95.7		32.9		
Median	4300	10285			0.50	0.6	1.6	0.11	0.22		2.4		
Coefficient of variation	2.8	2.7			1.2	1.1	0.9	1.2	1.2		3.0		
Mixed Commercial (303)													
Number of observations	109	88			170	275	267	223	281	80	131		
% of samples above detection	94.5	98.9			68.2	96.7	96.3	93.3	98.6	12.5	48.1		
Median	4980	11000			0.60	0.58	1.39	0.12	0.26	15.0	2.0		
Coefficient of variation	3.3	2.8			1.0	0.7	0.9	2.1	1.5	1.0	1.0		
Industrial (524)													
Number of observations	297	195			254	418	440	325	434	164	267		209
% of samples above detection	87.9	93.9			85.8	96.2	95.9	87.1	96.3	14.6	54.3		10.5
Median	2500	13000			0.50	0.73	1.4	0.11	0.26	3.7	4.0		0.39
Coefficient of variation	5.6	6.9			1.2	0.9	1.2	1.2	1.4	1.4	1.4		2.5

Table 1. Summary of Available Stormwater Data Included in NSQD Database, version 1.1 (continued)

	Fecal Coliform (mpn/100 mL)	Fecal Strep. (mpn/100 mL)	Total Coliform (mpn/100 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phos., filtered (mg/L)	Phos., total (mg/L)	Sb, total (ug/L)	As, total (ug/L)	As, filtered (ug/L)	Be, total (ug/L)
Mixed Industrial (252)													
Number of observations	115	70	39		125	213	196	215	217		101		
% of samples above detection	95.7	97.1	89.7		31.2	98.6	93.9	87.0	96.3		86.1		
Median	3033	10000	16000		0.43	0.57	1.0	0.08	0.20		3.0		
Coefficient of variation	2.5	2.6	2.4		0.7	0.7	1.5	2.2	1.5		0.9		
Institutional (18)													
Number of observations					18	18	18	17	17				
% of samples above detection					88.9	100	100	82.4	94.1				
Median					0.31	0.6	1.35	0.13	0.18				
Coefficient of variation					0.5	0.6	0.5	0.5	1.0				
Freeways (185)													
Number of observations	49	25	16	13	79	25	125	22	128		61	72	
% of samples above detection	100	100	100	100	87.3	96.0	96.8	95.5	99.2		55.7	50.0	
Median	1700	17000	50000	1900	1.07	0.28	2.0	0.20	0.25		2.4	1.4	
Coefficient of variation	2.0	1.2	1.5	2.2	1.3	1.2	1.4	2.1	1.8		0.7	2.0	
Mixed Freeways (20)													
Number of observations	16	12				14	16	13	14		15		
% of samples above detection	81.3	93.8				100	100	100	100		80		
Median	730	19000				0.6	1.6	0.04	0.26		3.0		
Coefficient of variation	2.0	1.1				0.7	0.9	0.8	0.8		0.7		
Open Space (68)													
Number of observations	23	22			32	44	45	44	46		19		
% of samples above detection	91.3	90.9			18.8	84.1	71.1	79.6	84.8		31.6		
Median	7200	24900			0.18	0.59	0.74	0.13	0.31		4.0		
Coefficient of variation	1.1	1.0			1.24	0.9	0.9	0.9	3.5		0.4		
Mixed Open Space (159)													
Number of observations	95	75			71	172	144	148	173		88		
% of samples above detection	97.9	100			22.5	97.7	91.0	85.8	96.5		44.3		
Median	2600	21000			0.51	0.7	1.12	0.09	0.27		3.0		
Coefficient of variation	2.3	2.4			1.2	0.8	1.3	1.1	1.0		0.9		

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Cd, total (ug/L)	Cd, filtered (ug/L)	Cr, total (ug/L)	Cr, filtered (ug/L)	Cu, total (ug/L)	Cu, filtered (ug/L)	Pb, total (ug/L)	Pb, filtered (ug/L)	Hg, total (ug/L)	Ni, total (ug/l)	Ni, filtered (ug/L)	Zn, total (ug/L)	Zn, filtererd (ug/L)
Overall Summary (3765)													
Number of observations	2575	389	1599	261	2724	411	2950	446	1014	1431	246	3008	382
% of samples above detection	40.8	30.3	70.2	60.5	87.4	83	77.7	49.8	10.2	59.8	64.2	96.6	96.1
Median	1.0	0.50	7.0	2.1	16	8.0	17.0	3.0	0.20	8.0	4.0	117	52
Coefficient of variation	3.7	1.1	1.5	0.7	2.2	1.6	1.8	2.0	2.5	1.2	1.5	3.3	3.9
Residential (1069)													
Number of observations	723		435		799	90	788	108	297	419	25	810	88
% of samples above detection	30.3		55.4		83.6	63.3	71.3	33.3	7.41	45.4	44.0	96.4	89.6
Median	0.5		4.6		12	7.0	12.0	3.0	0.20	5.4	2.0	73	31.5
Coefficient of variation	3.4		1.4		1.8	2.0	1.9	1.9	0.9	1.2	0.5	1.3	0.8
Mixed Residential (615)													
Number of observations	432	30	187	21	448	29	516	30	106	136	25	531	28
% of samples above detection	39.6	40.0	81.3	52.4	84.4	72.4	79.7	46.7	14.2	62.5	72.0	92.7	100
Median	0.8	0.30	7.0	2.0	17	5.5	18.0	3.0	0.20	7.9	5.5	99.5	48
Coefficient of variation	3.9	0.6	1.5	0.8	1.1	0.9	1.4	0.7	0.9	0.8	0.9	1.0	0.9
Commercial (497)													
Number of observations	358	47	235	27	387	48	377	59	160	232	23	392	49
% of samples above detection	43.0	23.4	58.7	40.7	92.8	79.2	85.4	52.5	6.9	59.5	47.8	99.0	100
Median	0.89	0.30	6.0	2.0	17	7.57	18.0	5.0	0.20	7.0	3.0	150	59
Coefficient of variation	2.7	1.34	0.9	0.6	1.5	0.8	1.6	1.6	0.8	1.2	0.8	1.2	1.4
Mixed Commercial (303)													
Number of observations	178	30	124	22	182	30	235	30		98	21	234	28
% of samples above detection	48.3	40.0	87.9	72.7	93.4	83.3	87.7	70.0		80.6	76.2	98.7	100
Median	0.9	0.40	5.0	2.5	17	10	17.0	5.25		5.0	3.0	135	92
Coefficient of variation	1.1	0.8	1.1	0.7	2.9	0.6	1.5	0.7		1.3	0.6	1.7	0.7
Industrial (524)													
Number of observations	395	42	256	36	416	42	412	51	211	250	36	433	42
% of samples above detection	49.4	54.8	72.7	55.6	89.9	90.5	76.5	52.9	12.8	62.4	58.3	98.6	95.2
Median	2.0	0.60	14.0	3.0	22	8.0	25.0	5.0	0.20	16.0	5.0	210	112
Coefficient of variation	2.3	1.1	1.2	0.7	2.0	0.7	1.8	1.6	2.7	1.0	1.4	2.3	3.6

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Cd, total (ug/L)	Cd, filtered (ug/L)	Cr, total (ug/L)	Cr, filtered (ug/L)	Cu, total (ug/L)	Cu, filtered (ug/L)	Pb, total (ug/L)	Pb, filtered (ug/L)	Hg, total (ug/L)	Ni, total (ug/l)	Ni, filtered (ug/L)	Zn, total (ug/L)	Zn, filtererd (ug/L)
Mixed Industrial (252)													
Number of observations	182	25	124	15	183	24	246	25	65	82	15	245	24
% of samples above detection	49.5	92.0	91.1	66.7	85.8	100.0	78.1	92.0	21.5	85.4	100.0	98.8	95.8
Median	1.6	0.60	8.0	2.0	18	6.0	20.0	5.0	0.25	9.0	5.0	160	2100
Coefficient of variation	1.91	0.6	1.7	0.7	0.9	0.6	1.4	1.0	0.6	0.9	0.6	3.3	1.2
Institutional (18)													
Number of observations							18					18	
% of samples above detection							77.8					100	
Median							5.75					305	
Coefficient of variation							0.8					0.8	
Freeways (185)													
Number of observations	95	114	76	101	97	130	107	126		99	95	93	105
% of samples above detection	71.6	26.3	98.7	78.2	99.0	99.2	100	50.0		89.9	67.4	96.8	99.1
Median	1.0	0.68	8.3	2.3	34.7	10.9	25	1.8		9.0	4.0	200	51
Coefficient of variation	0.9	1.0	0.7	0.7	1.0	1.5	1.5	1.7		0.9	1.4	1.0	1.9
Mixed Freeways (20)													
Number of observations	15		15		17		17					17	
% of samples above detection	80		100		94		82					100	
Median	0.5		6.0		8.5		10.0					90	
Coefficient of variation	0.7		1.1		1.1		0.9					0.9	
Open Space (68)													
Number of observations	38		36		39		45					45	
% of samples above detection	55.3		36.1		74.4		42.2					71.1	
Median	0.38		5.4		10		10.0					40	
Coefficient of variation	1.9		1.7		2.0		1.7					1.3	
Mixed Open Space (159)													
Number of observations	128		88		126		176			51		177	
% of samples above detection	16.4		81.8		91.3		66.5			72.6		98.3	
Median	2.0		6.0		10		10			8.0		88.0	
Coefficient of variation	1.4		1.3		1.5		2.3			1.1		1.1	

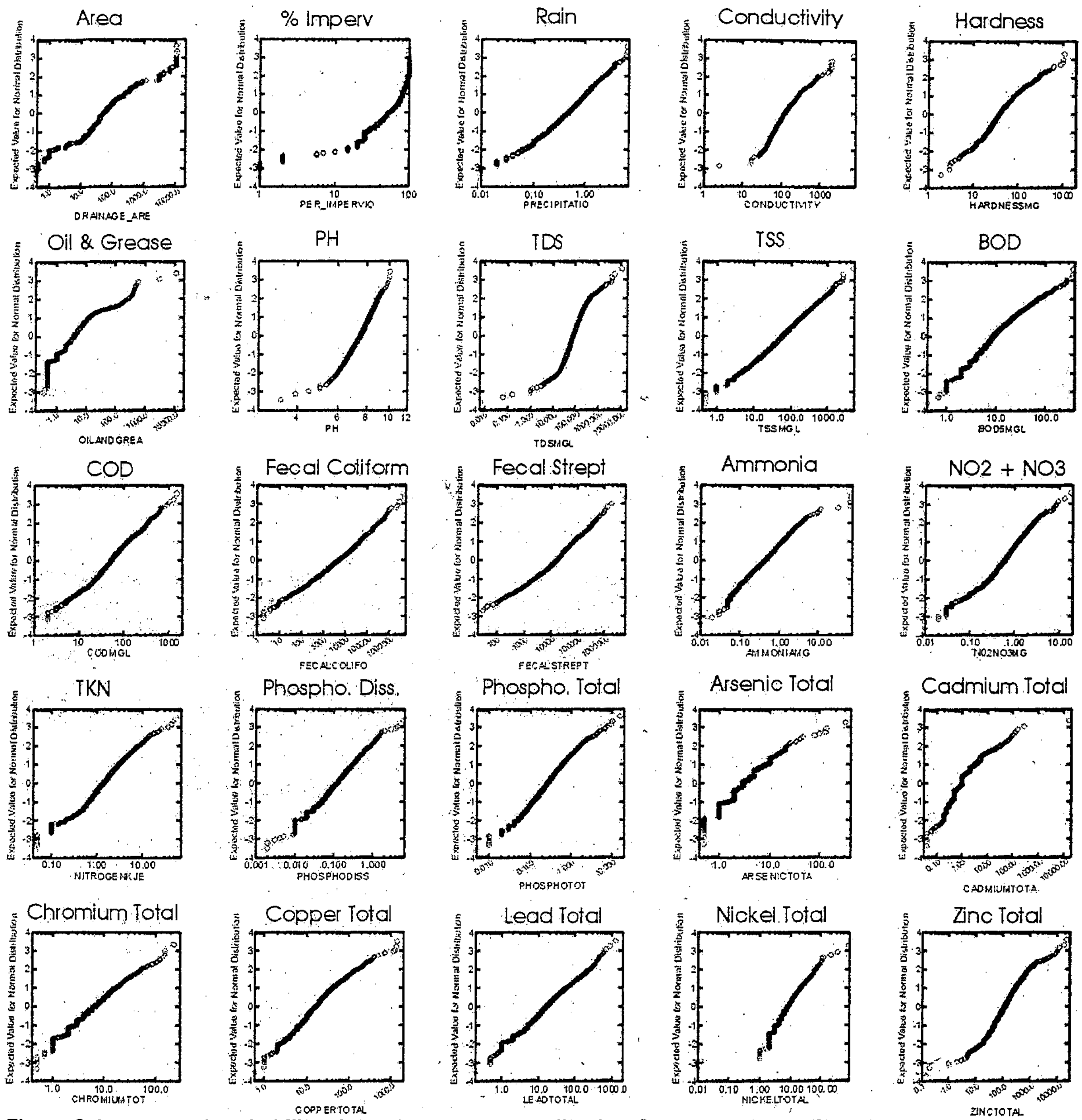

Figure 2. Log-normal probability plots of stormwater quality data for selected constituents.

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Table 2. Summary of Selected Organic Information in NSQD, version 1.0

	Methylene-chloride (µg/L)	Bis(2-ethylhexyl) phthalate (µg/L)
All Data Combined		
Number of observations	251	250
% of samples above detection	36	30
Median of detected values	11.2	9.5
Coefficient of variation	0.77	1.13

Simple Data Relationships

The master data set will also be evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. The runoff data will then be evaluated to determine which factors have a strong influence on event mean concentrations, including sampling methods. Tests for regional and climatic differences will be conducted, including the influences of land use and the effects of storm size, among other factors. Figure 3 includes example scatter plots of COD vs. BOD_5, ammonia vs. TKN, filtered copper vs. total copper, and filtered zinc vs. total zinc, illustrating close relationships between these pairings, as expected.

Figure 4 shows scatter plots of suspended solids, phosphorus, fecal coliforms, and total zinc concentrations for different rain depths. Little variation of these concentrations with rain depth are seen when all of the data are combined, implying little likelihood of important "first-flush" effects at stormwater outfall locations. If a first-flush was evident, one would expect higher concentrations associated with smaller rain depths (see Maestre, *et al.* 2003 for more detailed analyses of first-flush effects using the NSQD database information). A simple plot of COD concentrations vs. percentage imperviousness of the drainage area (Figure 5) doesn't indicate any obvious trends. Each vertical set of observations represent a single monitoring location (all of the events at a single location have the same percent imperviousness). The variation of COD at any one monitoring location is seen to vary greatly, typically by about an order of magnitude. These large variations will make trends difficult to identify. All of the lowest percentage imperviousness sites are open space land uses, while all of the highest percentage imperiousness sites are freeway and commercial land uses. As indicated below in Figure 6, many of the constituents have significant concentration differences by land uses. Therefore, it is expected that these other constituents will show an obvious trend because of the strong correlation between percentage imperviousness and land use. In addition, currently there is little data in the NSQD showing how the impervious areas are connected to the drainage systems. Some historical data shows much smaller concentrations (and especially yields) for areas that are drained by grass swales compared to concrete curbs and gutters. With this additional information, the imperviousness data can be adjusted ("effective" imperviousness is commonly used to designate directly connected paved areas) to potentially identify more obvious data trends.

Figure 6 contains examples of grouped box and whisker plots for several constituents for different major land use categories. The TKN, plus copper, lead, and zinc observations are lowest for open space areas, while the freeway locations generally had the highest median values, except for phosphorus, nitrates, fecal coliforms, and zinc. The industrial sites had the highest reported zinc concentrations. Preliminary statistical ANOVA analyses for all land use categories (using SYSTAT) found significant differences for land use categories for all pollutants. The final analyses will further investigate this important finding and will also examine possible confounding factors.

The seasonal variations for the example residential data shown in Figure 7 are not as obvious, except that the bacteria values appear to be lowest during the winter season and highest during the summer and fall (a similar conclusion was obtained during the NURP, EPA 1983, data evaluations). The database does not contain any snowmelt data, so all of the data corresponds to rain-related runoff.

Figure 8 presents example plots for selected residential area data for different EPA rain zones for the country. Zones 3 and 7 (the wettest areas of the country) had the lowest concentrations for most of the constituents.

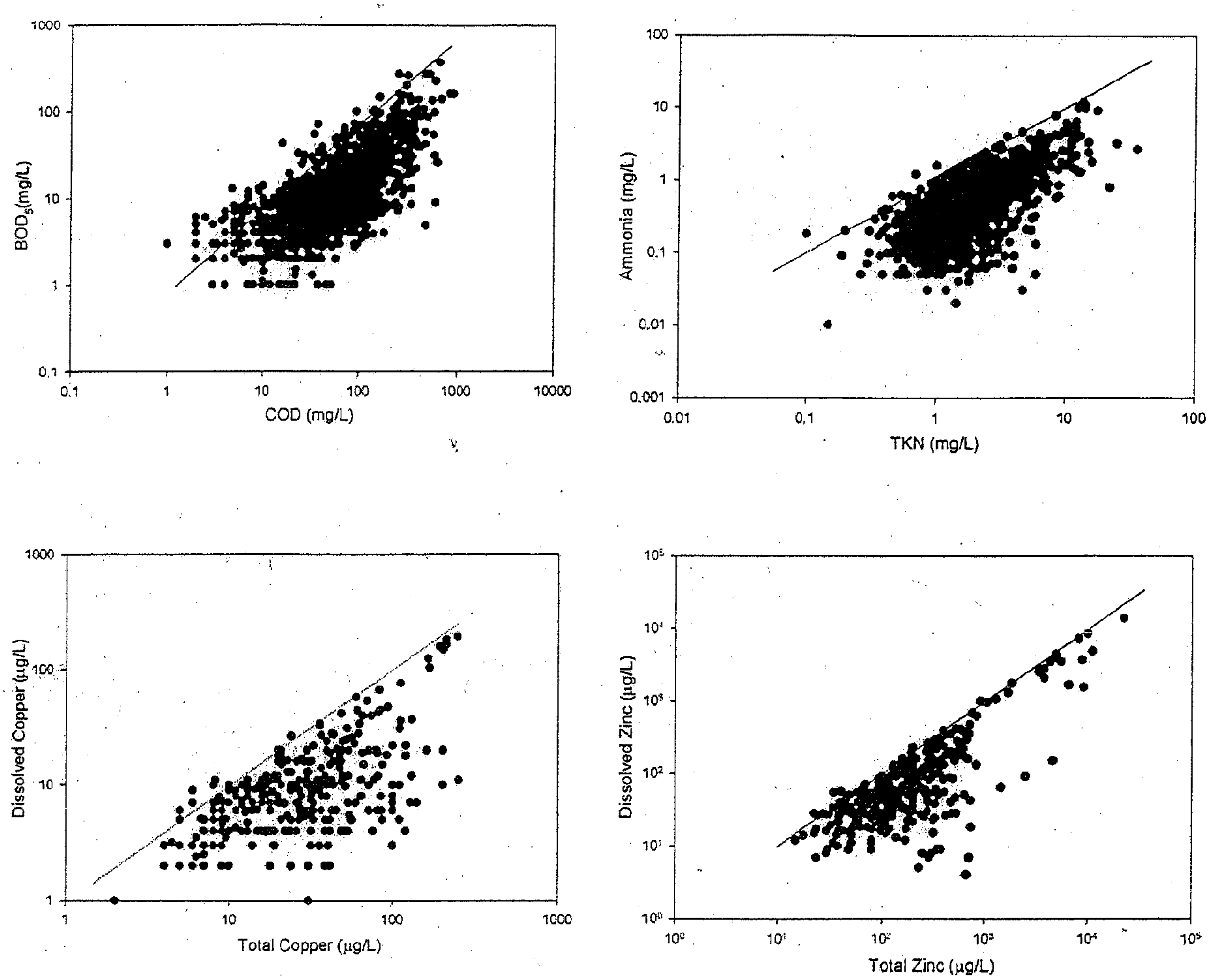

Figure 3. Example scatter plots of stormwater data (line of equivalent concentration shown).

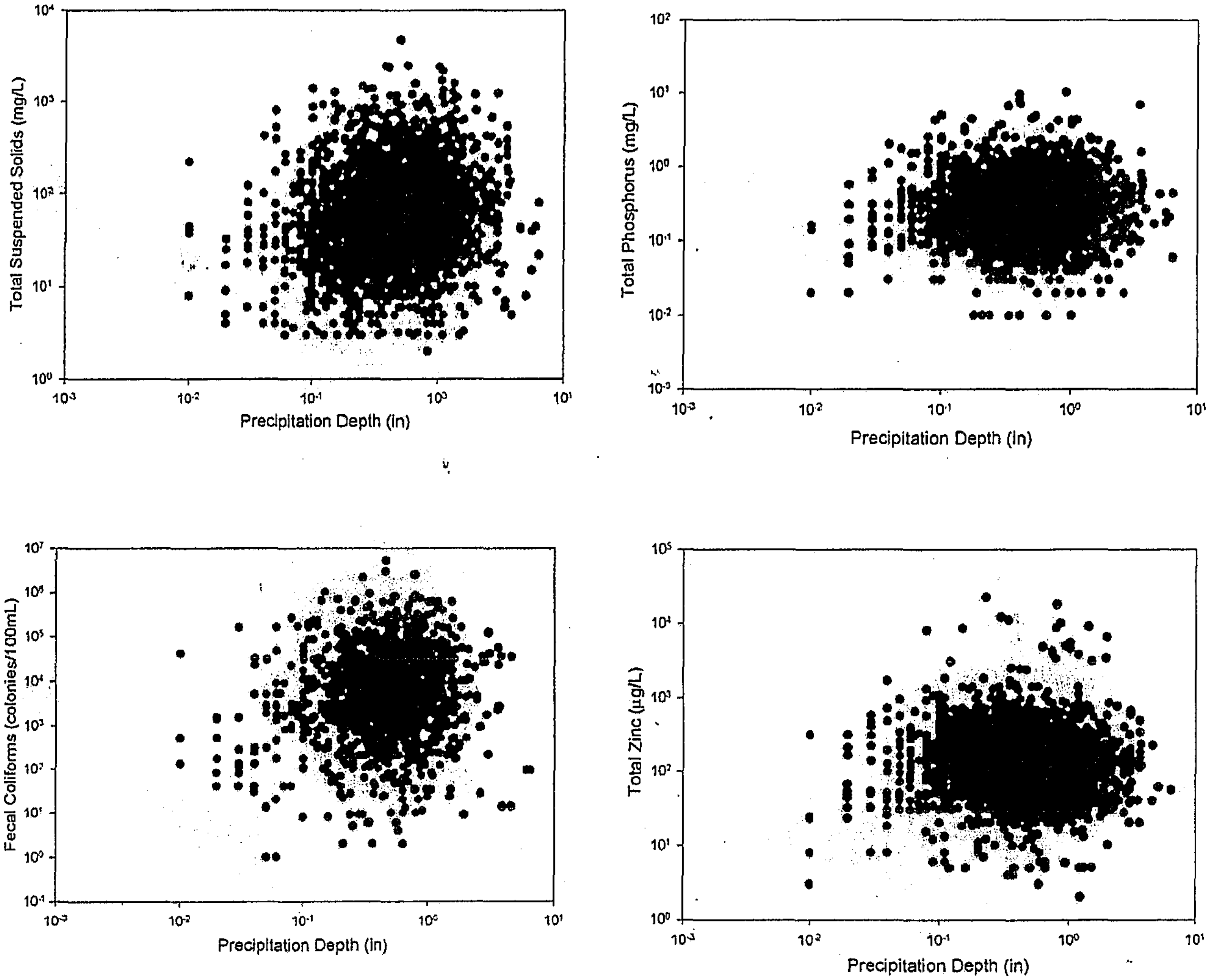

Figure 4. Example scatter plots of concentrations vs. rain depth.

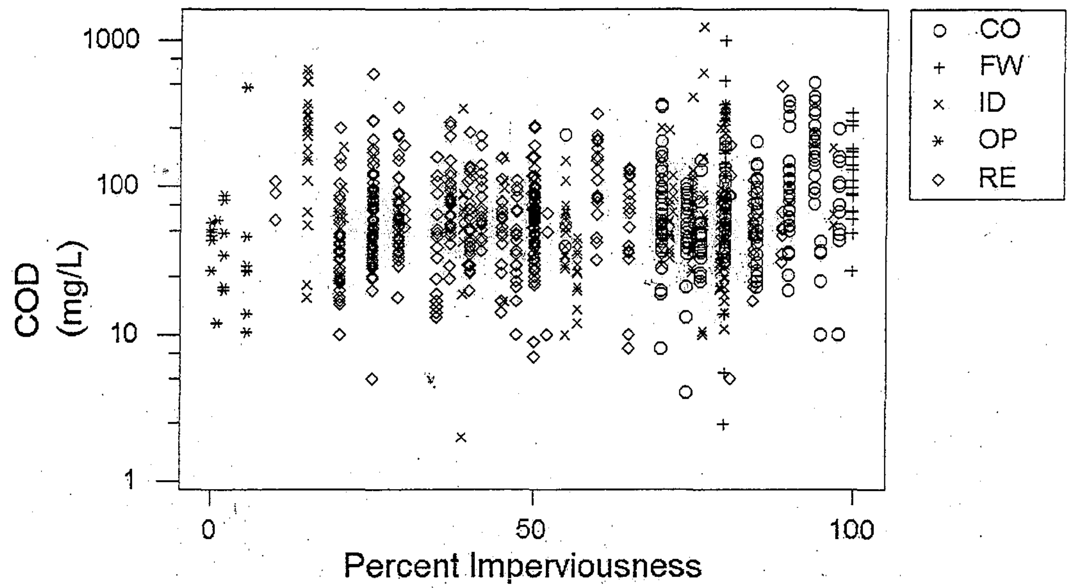

Figure 5. Plot COD concentrations against watershed area percent imperviousness values for different land uses (CO: commercial; FW: freeway; ID: industrial; OP: open space; and RE: residential)

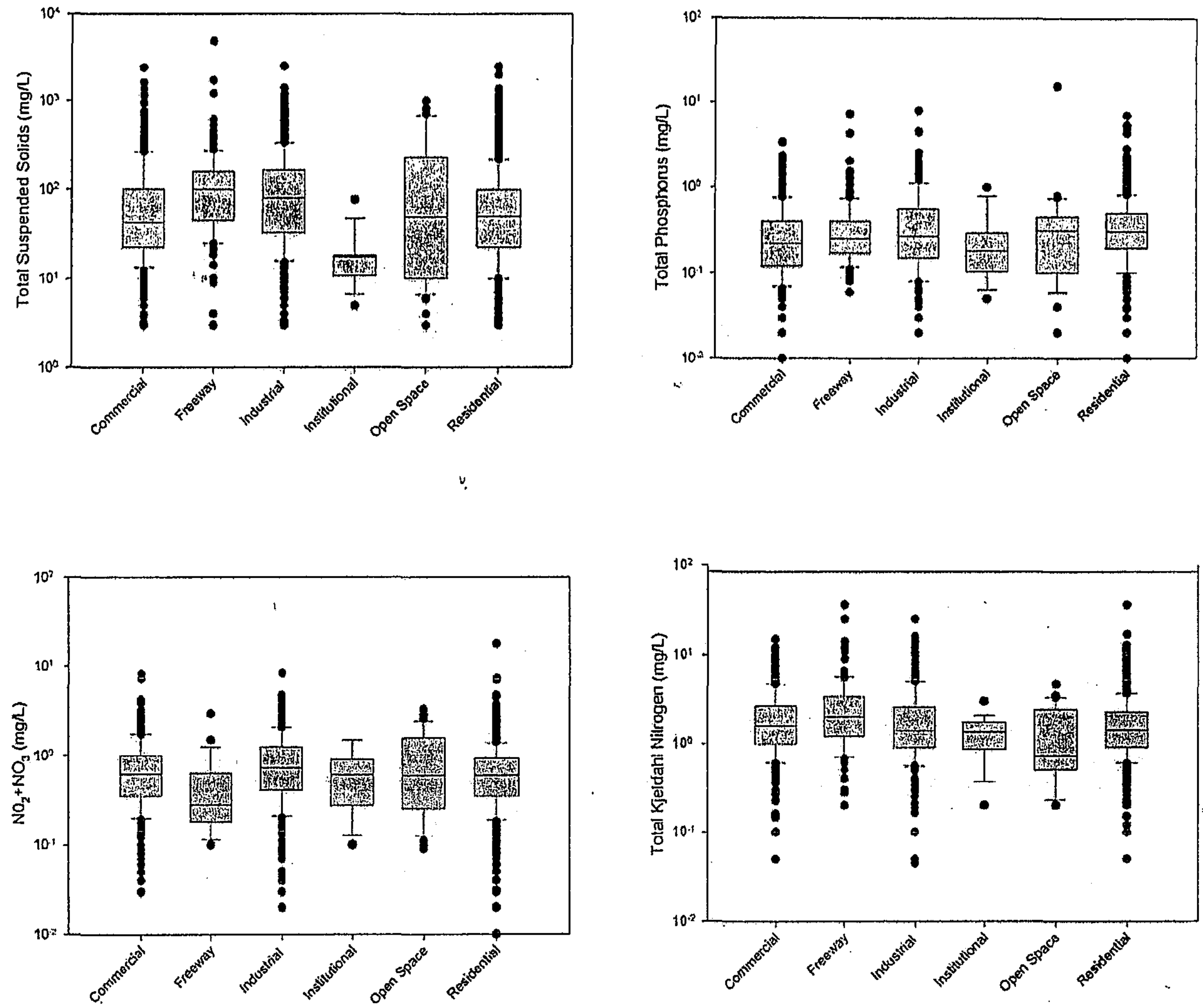

Figure 6. Example stormwater data sorted by land use (no mixed land use data included in plots).

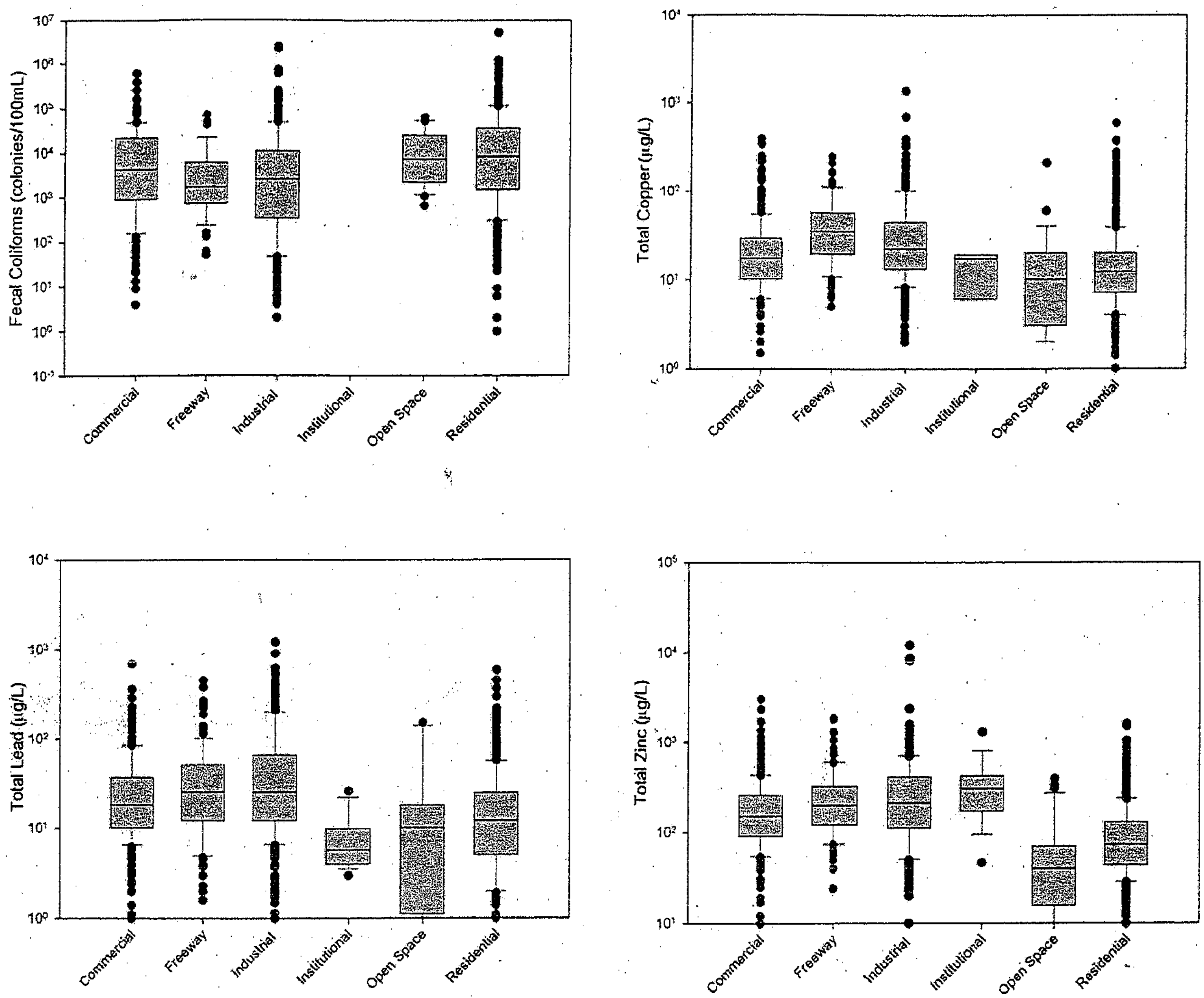

Figure 6. Example stormwater data sorted by land use (no mixed land use data included in plots) (continued).

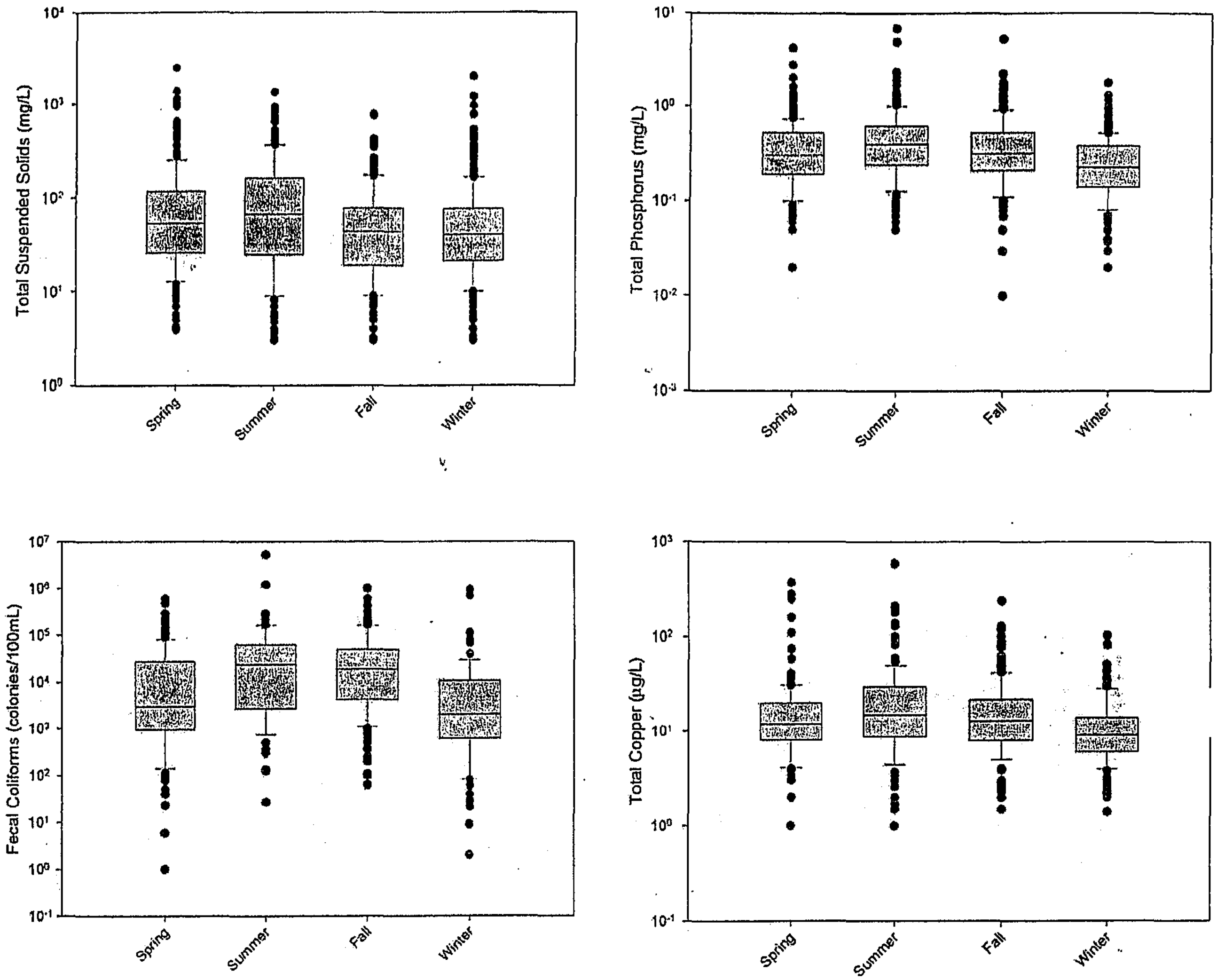

Figure 7. Example residential area stormwater pollutant concentrations sorted by season.

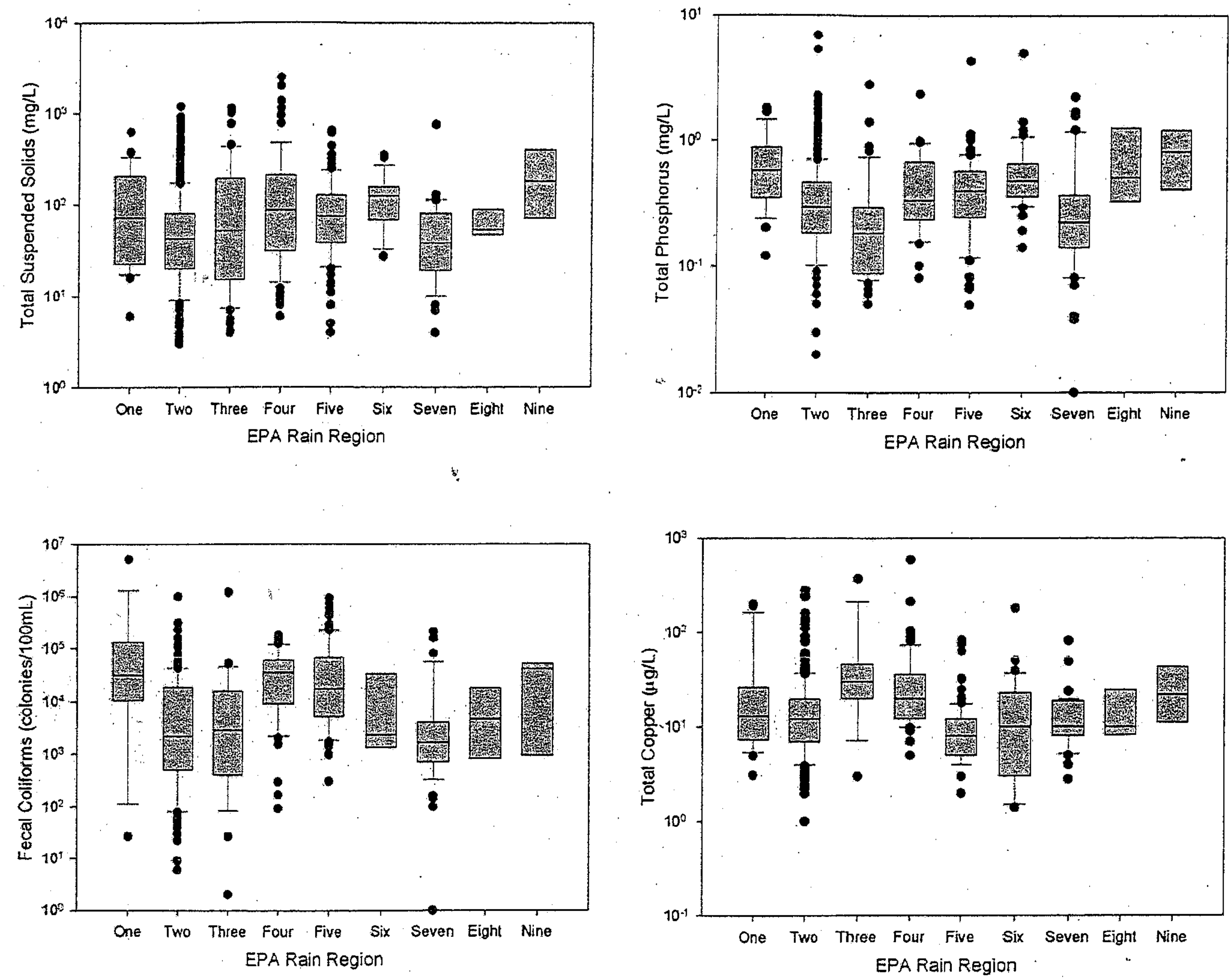

Figure 8. Example residential area stormwater pollutant concentrations sorted by geographical area.

We are also examining trends of concentrations with time. A classical example would be for lead, which is expected to decrease over time with the increased use of unleaded gasoline. Older stormwater samples from the 1970s typically have had lead concentrations of about 100 µg/L, or higher, while most current data indicate concentrations in the range of 1 to 10 µg/L. Figure 9 shows a plot of lead concentrations for residential areas only (in rain zone 2), for the time period from 1991 to 2002. This preliminary plot shows likely decreasing lead concentrations with time. Statistically however, the trend line is not significant due to the large variation in observed concentrations ($p=0.41$; there is insufficient data to show that the slope term is significantly different from zero). The similar COD concentrations in Figure 9 also have an apparent downward trend with time, but again, the slope term is not significant ($p=0.12$).

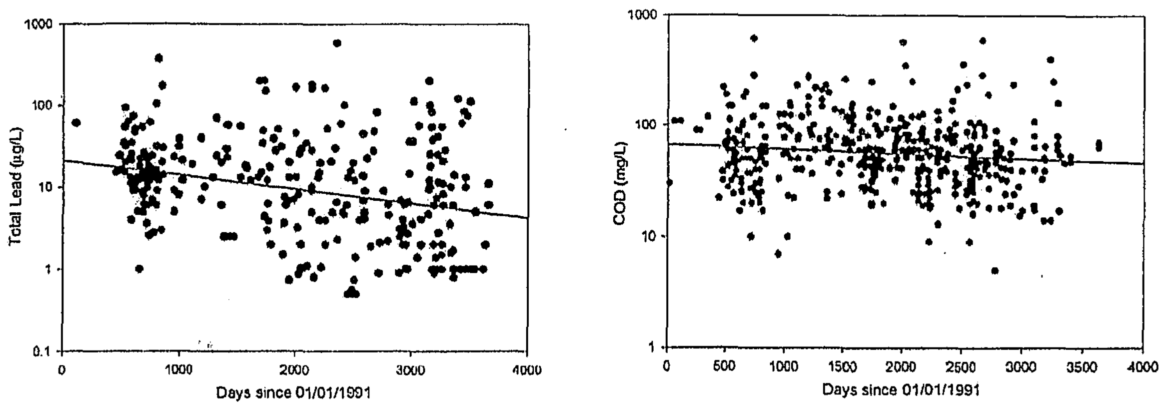

Figure 9. Residential lead and COD concentrations with time (EPA Rain Zone 2 data only).

As part of their MS4 phase 1 applications, Denver and Milwaukee both returned to some of their earlier sampled monitoring stations used during the local NURP projects. In the time between the early 1980s (NURP) and the early 1990s (MS4), they did not detect any significant differences, except for large decreases in lead concentrations. Figure 10 compares suspended solids, copper, lead, and zinc concentrations at the Wood Center NURP monitoring site in Milwaukee. The average site concentrations remained the same, except for lead, which decreased from about 450 down to about 110 µg/L.

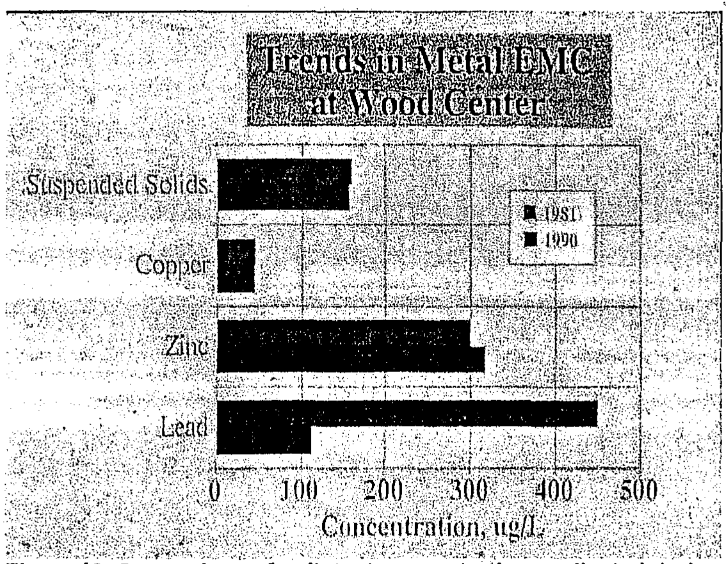

Figure 10. Comparison of pollutant concentrations collected during NURP (1981) to MS4 application data (1990) at the same location (personal communication, Roger Bannerman, WI DNR).

Similar comparisons were made in the Denver Metropolitan area by the Urban Drainage and Flood Control District. Table 3 compares stormwater quality for commercial and residential areas for 1980/91 (NURP) and 1992/93 (MS4 application). Although there was an apparent difference in the averages of the event concentrations between the sampling dates, they concluded that the differences were all within the normal range of stormwater quality variations, except for lead, which decreased by about a factor of four.

Table 3. Comparison of Commercial and Residential Stormwater Runoff Quality from 1980/81 to 1992/93 (Urban Drainage District, *Flood Hazard News*, Dec 1993.)

Constituent	Commercial 1980/81	Commercial 1992/93	Residential 1980/82	Residential 1992/93
Total suspended solids (mg/L)	251	165	226	325
Total nitrogen (mg/L)	3.0	3.9	3.2	4.7
Nitrate plus nitrite (mg/L)	0.80	1.4	0.61	0.92
Total phosphorus (mg/L)	0.46	0.34	0.61	0.87
Dissolved phosphorus (mg/L)	0.15	0.15	0.22	0.24
Copper, total recoverable (µg/L)	27	81	28	31
Lead, total recoverable (µg/L)	200	59	190	53
Zinc, total recoverable (µg/L)	220	290	180	180

Example Statistical Analyses of Data Comparing First Flush and Composite Sample Concentrations

As part of their NPDES stormwater permit, some communities collected grab samples during the first 30 minutes of the event to evaluate a "first flush" in contrast to the flow-weighted composite data. More than 400 paired samples representing the first flush and composite samples from eight communities (mostly located in the southeast U.S.) from NSQD were reviewed. Box and probability plots were prepared for 22 major constituents. Nonparametric statistical analyses were then used to measure the differences between the sample sets. This discussion summarizes the results of this preliminary analysis, including the effects of storm size and land use on the presence and importance of first flushes. Only concentration data were available for these analyses, so traditional accumulative mass curves could not be developed.

First flush refers to an assumed elevated load of pollutants discharged in the first part of a runoff event. First flush has been observed more in small catchments than in large catchments (Thompson, *et al.* 1995; WEF and ASCE 1998). In large catchments (>162 ha, or >400 acres) the highest concentrations have been observed at the times of flow peak (Soeur, *et al.* 1994; Brown, *et al.* 1995). The presence of a first flush has been reported to be associated with runoff duration by the City of Austin, TX (Swietlik, *et al.* 1995). An observed first flush may be present for some pollutants, but not others (Ellis 1986; Adams 2000). Adams (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

It is expected that peak concentrations generally occur during periods of peak flow (and highest rain energy). On relatively small paved areas, however, it is likely that there will always be a short period of relatively high concentrations associated with washing off of the most available material near the beginning of the runoff event (Pitt 1987). This peak period of high concentrations may be overwhelmed by periods of high rain intensity that may occur later in the event. In addition, in more complex drainage areas, the routing of these short periods of peak concentrations may blend with larger flows and may not be noticeable. A first flush in a separate storm drainage system is therefore most likely to be seen if a rain occurs at relatively constant intensity over a paved area having a simple and small drainage system.

A total of 417 storm events with paired first flush and composite storm samples were available from the NSQD. The majority of the events were located in North Carolina (76.2%), but some events were also from Alabama (3.1%), Kentucky (13.9%) and Kansas (6.7%). All of the data were from end-of pipe samples in separate storm drainage systems.

The initial analyses were used to select the constituents and land uses that meet the requirements of the statistical comparison tests. Probability plots, box plots, concentration vs. precipitation, and standard descriptive statistics, were performed for 22 constituents for each land use, and for all land uses combined. Nonparametric statistical analyses were performed after the initial analyses. Mann Whitney and Fligner Policello tests were most commonly used. Minitab and Systat statistical programs, along with Word and Excel macros, were used for the analyses.

The Mann-Whitney and Fligner-Policello non-parametric tests were selected to determine if there were statistically significant differences between the first flush and composite data sets for each land use and constituent. These tests are very useful because they require only data symmetry, not normality, to evaluate the hypothesis. The null hypothesis during the analysis was that the median concentrations of the first flush and composite data sets were the same. The alternative hypothesis was that the medians were different, with a confidence of at least 95%.

A complete description of these analyses is presented in Maestre, *et al.* (2004). Table 4 summarizes the results of the analysis. The ">" sign indicates that the median of the first flush data set is higher than for the composite storm data set. The "=" sign indicates that the there is not enough information to reject the null hypothesis. Events without enough data for the analyses are represented with an "X". Also shown on this table are the ratios of the medians of the first flush and the composite data sets for each constituent and land use. The first flush samples were larger than for the composite samples if the ratio is great than one. Generally, a statistically significant first flush is associated with a median concentration ratio of about 1.4, or greater (the exceptions occurred when the number of samples in a specific category is small). The largest significant ratios are about 2.5, indicating that the first flush concentrations may be about 2.5 times greater than the composite concentrations. More of the larger ratios are found in the commercial and institutional land use categories, areas where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open space land uses, locations where there may be larger areas of unpaved surfaces.

Results indicate that for 55% of the evaluated cases, the medians of the first flush data sets were significantly larger than for the composite sample sets. In the remaining 45% of the cases, both medians were expected to be the same, or the concentrations were possibly greater later in the events. About 70% of the constituents in the commercial land use category had first-flushes, while about 60% of the constituents in the residential, institutional and the mixed (mostly commercial and residential) land use categories had first flushes, and about 45% of the constituents in the industrial land use category had first-flushes. In contrast, no constituents were found to have first-flushes in the open space category.

COD, BOD_5, TDS, TKN, and Zn all had first flushes in all areas (except for the open space category). In contrast, turbidity, pH, fecal coliforms, fecal strep., total N, dissolved and ortho-P never showed a statistically significant first flush in any category. The conflict with TKN and total N implies that there may be some other factors involved in the identification of first flushes besides land use. If additional paired data become available during later project periods, it may be possible to extend these analyses to consider rain effects, drainage area, and geographical location.

Table 4. Presence of Significant First Flushes (ratio of first flush to composite median concentrations)

Parameter	Commercial	Industrial	Institutional	Open Space	Residential	All Combined
Turbidity	= (1.32)	X	X	X	= (1.24)	= (1.26)
pH	= (1.03)	= (1.00)	X	X	= (1.01)	= (1.01)
COD	> (2.29)	> (1.43)	> (2.73)	= (0.67)	> (1.63)	> (1.71)
TSS	> (1.85)	= (0.97)	> (2.12)	= (0.95)	> (1.84)	> (1.60)
BOD_5	> (1.77)	> (1.58)	> (1.67)	= (1.07)	> (1.67)	> (1.67)
TDS	> (1.82)	> (1.32)	> (2.66)	= (1.07)	> (1.52)	> (1.55)
O&G	> (1.54)	X	X	X	= (2.05)	> (1.60)
Fecal Coliform	= (0.87)	X	X	X	= (0.98)	= (1.21)
Fecal Strep.	= (1.05)	X	X	X	= (1.30)	= (1.11)
Ammonia	> (2.11)	= (1.08)	> (1.66)	X	> (1.36)	> (1.54)
NO_2 NO_3	> (1.73)	> (1.31)	> (1.70)	= (0.96)	> (1.66)	> (1.50)
Total N	= (1.35)	= (1.79)	X	= (1.53)	= (0.88)	= (1.22)
TKN	> (1.71)	> (1.35)	X	= (1.28)	> (1.65)	> (1.60)
Total P	> (1.44)	= (1.42)	= (1.24)	= (1.05)	> (1.46)	> (1.45)
P Dissolved	= (1.23)	= (1.04)	= (1.05)	= (0.69)	> (1.24)	= (1.07)
Phosphate Ortho	X	= (1.55)	X	X	= (0.95)	= (1.30)
Cd	> (2.15)	= (1.00)	X	= (1.30)	> (2.00)	> (1.62)
Cr	> (1.67)	= (1.36)	X	= (1.70)	= (1.24)	> (1.47)
Cu	> (1.62)	> (1.24)	= (0.94)	= (0.78)	> (1.33)	> (1.33)
Pb	> (1.65)	> (1.41)	> (2.28)	= (0.90)	> (1.48)	> (1.50)
Ni	> (2.40)	= (1.00)	X	X	= (1.20)	> (1.50)
Zn	> (1.92)	> (1.540	> (2.48)	= (1.25)	> (1.58)	> (1.59)

Modeling Building using the NSQD

As indicated earlier, an important objective of the NSQD is to develop a predictive tool to enable stormwater managers to determine the likely stormwater quality for their area. In many cases, adequate data may be available in the NSQD to fit their situation. However, it is also expected that some will need to establish a local monitoring program to obtain reliable estimates of their stormwater quality. The next subsection provides some monitoring guidance for this situation, while this subsection presents an example of the model building process that we are currently using.

Factors Potentially Affecting Stormwater Pollutant Concentrations

The database contains information for the monitored watersheds, along with the outfall runoff quality. Each sample is labeled with the land use, season, geographical area, percent imperviousness, rain amount, and many other attributes in the database. The first phase of the NSQD project focused on the mid Atlantic and Gulf coast areas, although additional data has been collected for other locations. About 54% of the existing data in the database is from communities located in Maryland, Virginia, Pennsylvania, North Carolina, Kentucky and Tennessee. The following factors may affect the reported stormwater pollutant concentrations:

- Landuse: All of the watershed areas were separated into residential, commercial, industrial, open space and freeway land uses. Data are also available from mixed landuse areas which will be used later to verify the prediction methods.
- EPA Rain Zone: As shown in Figure 1, the country is divided in 9 rain/climatic regions representing all combinations of areas having warm summers, cold winters, large rainfalls, and little rain.
- Season: Four seasons were identified by the month when the samples were collected: Winter (December to February); Spring (March to May); Summer (June to August); and Fall (September to November).
- Percentage Imperviousness: About 2/3 of the monitoring sites currently have percentage imperviousness data.
- Rainfall: Almost all of the events have the rainfall amount associated with the monitored event.
- Type of sample collection: Some of the events represent special "first-flush" and composite sample pairs for the same event. These data were evaluated previously to identify these effects on runoff water quality. The type of sampler and sampling method has been identified for about ¼ of the sampling locations.
- Runoff amount: About 1/3 of the events have the runoff amounts associated with the monitored events.
- Watershed area: All of the monitored locations have the watershed areas identified.
- Date of sample collection: All of the data are associated with the date of sample collection. In addition to the seasonal effects, this information can be used to examine any trends in concentration that may have occurred during the 10 years of sample collection represented in the NSQD.
- Type of conveyance system: About 1/3 of the sites have the conveyance system identified.
- Aerial photographs and topographic maps have been obtained for almost all of the monitoring areas.

Figure 11 is a probability plot for the observed COD concentrations separated by land use. This plot is similar to the previously presented box and whisker plots for the different constituents separated by land use. These plots do show additional information that is useful for developing predictive models. As typically assumed, the COD values closely follow log-normal probability plots for much of the data range (Figure 2 illustrates log-normal probability plots for many of the constituents available in the NSQD, but grouped for all factors combined). Figure 11 shows significant differences by land uses. The open space COD concentrations are the lowest, and the freeway COD concentrations are the largest for most all of the data range. The residential, commercial, and industrial areas are very similar for the lower half of the distribution, while the residential areas are lower than the commercial and industrial areas in the upper portion of the distribution. The effects of some of the above listed factors on concentrations have been previously illustrated. The following shows how we plan to develop the predictive tool for the main watershed factors listed above. In this example, we will examine COD concentrations as a function of EPA rain zones and season, for the residential areas.

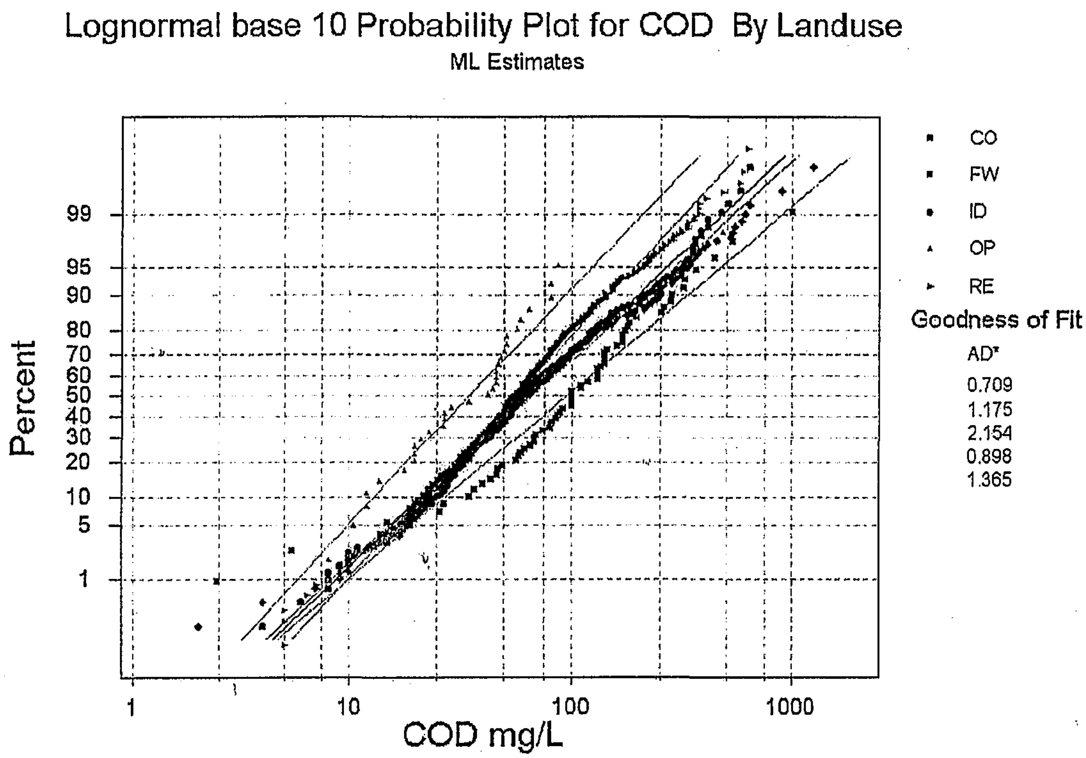

Figure 11. Probability plots of COD concentrations for different land uses.

It is possible to identify statistically significant differences in the COD concentrations for residential land uses in different EPA zones and seasons. Table 5 shows the total number of storm events collected which has residential COD values for the different rain zones and seasons.

Table 5. Number of Events with Detected COD Values in Residential Land Use Areas in the NSQD

EPA Rain Zone	Total	Spring	Summer	Fall	Winter
1	6	1	5	-	-
2	490	116	102	135	137
3	53	12	10	14	17
4	43	9	15	8	11
5	95	39	5	22	29
6	44	7	19	6	12
7	49	15	1	18	15
8	7	3	1	3	-
9	-	-	-	-	-

Table 5 shows that EPA rain zone 2 has about 62% of the total number of COD observations in the database. This unbalance of sample numbers can potentially lead to confusing results if the other areas do not adequately represent the actual conditions in their areas and is a violation of the data assumptions needed for a successful ANOVA test. It is possible to see if there is a difference in the COD concentrations for the different seasons in each zone during the four seasons using a one-way analysis of variance test, as the numbers of samples in each season for each main zone are relatively even.

The analysis of variance requires that the residuals are normally distributed and there is the same variance for each of the seasons. After log transforming the data, it was found that the residuals can be considered normal with a p-value of 0.8 using the Kolmogorov-Smirnov Goodness of fit test. To test if the variances are the same for the four seasons, Barlett's test was used. This test is powerful when the normality assumption of the residuals is achieved, as in this example. The results indicated that the variance can be considered the same for each season in EPA rain zone 2, with a p-value of 0.44. The results of the ANOVA found that there is a significant difference in the COD concentrations during the four seasons. The COD concentration in EPA rain zone two during winter seems to be smaller than summer and spring. The pooled standard deviation of the observations was calculated as 0.677

Power Calculations as a Function of Numbers of Data Observations

Figure 12 is a set of power curves showing the difference in the mean COD concentrations for the different subgroups that can be identified for different numbers of samples. If the ANOVA test indicated a significant difference with a confidence of five percent (α=0.05), these mean differences can be detected for the noted sample sizes. Table 6 lists the sample sizes needed, for a power level of 0.8 and a confidence of 0.05, to detect the noted differences in mean concentrations. If a goal of at least a 25% difference was desired, then about 120 samples in each season would be needed. This is approximately the conditions for EPA rain zone 2 residential land uses. However, if only 10 samples are available for each season, then the "detectable" difference would be relatively large (larger than 50%).

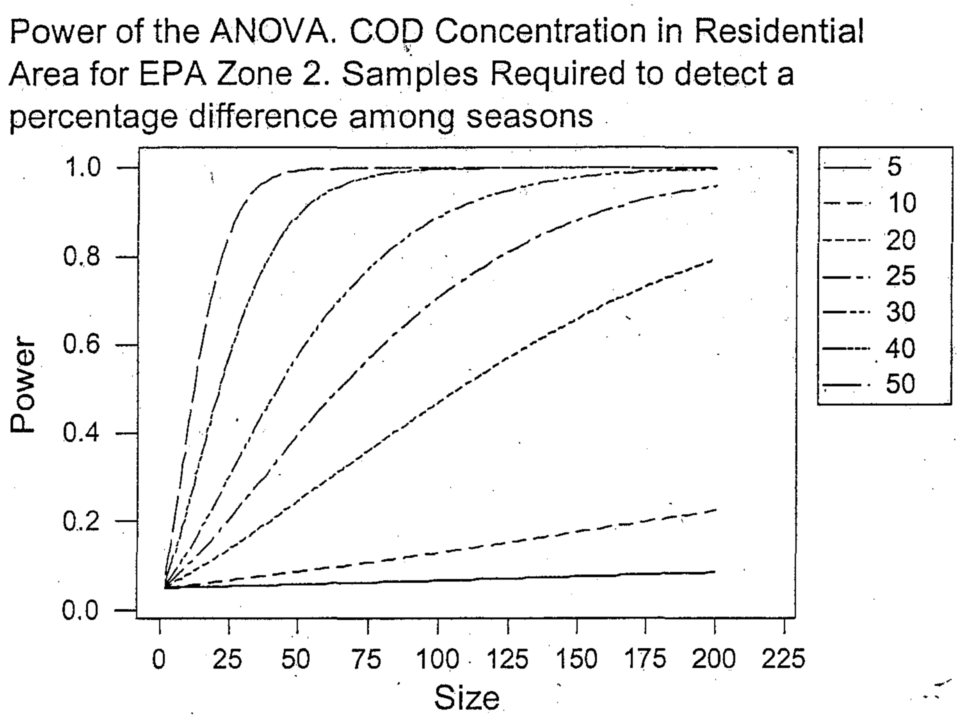

Figure 12. Power of the one way ANOVA test for COD in EPA rain zone 2.

Table 6. Samples required to detect specific differences in the COD for different seasons

Percentage difference between the mean values (%)	Samples Required
5	3844
10	908
20	202
25	122
30	80
40	40
50	22

Multivariate Analyses of Factors

A two-way analysis can also be conducted to examine the effects of both seasons and rain zones together, and their interaction. In the following example, rain zones 3, 4, 5, 6, and 7 were evaluated for all four seasons. Rain zone 2 was excluded from this preliminary analysis because it had many more samples than the other regions and could have overly emphasized those conditions. The first step in this analysis is to check the distributions and variances of the data sets. The residuals (the differences of the observations from the mean) can be considered normal as they had a p-value higher than 15% (no significant difference from a normal distribution). Barlett's test also indicated that the variance for the different groups can be considered the same with a p-value of 0.35. A two-way ANOVA can therefore be used to identify any differences between the seasons and EPA rain zones, plus their interaction, because the data were normally distributed and they have the same variance within each group.

The 2-way ANOVA results indicated that there are no significant differences between the different seasons (p-value = 0.091), but that there is a difference between the EPA rain zones (p-value < 0.001). Figure 13 contains probability plots of the residential COD values for each season, showing no clear distinction of these concentrations for the different seasons. The ANOVA test also found no significant interaction between rain zone and season (p-value = 0.25).

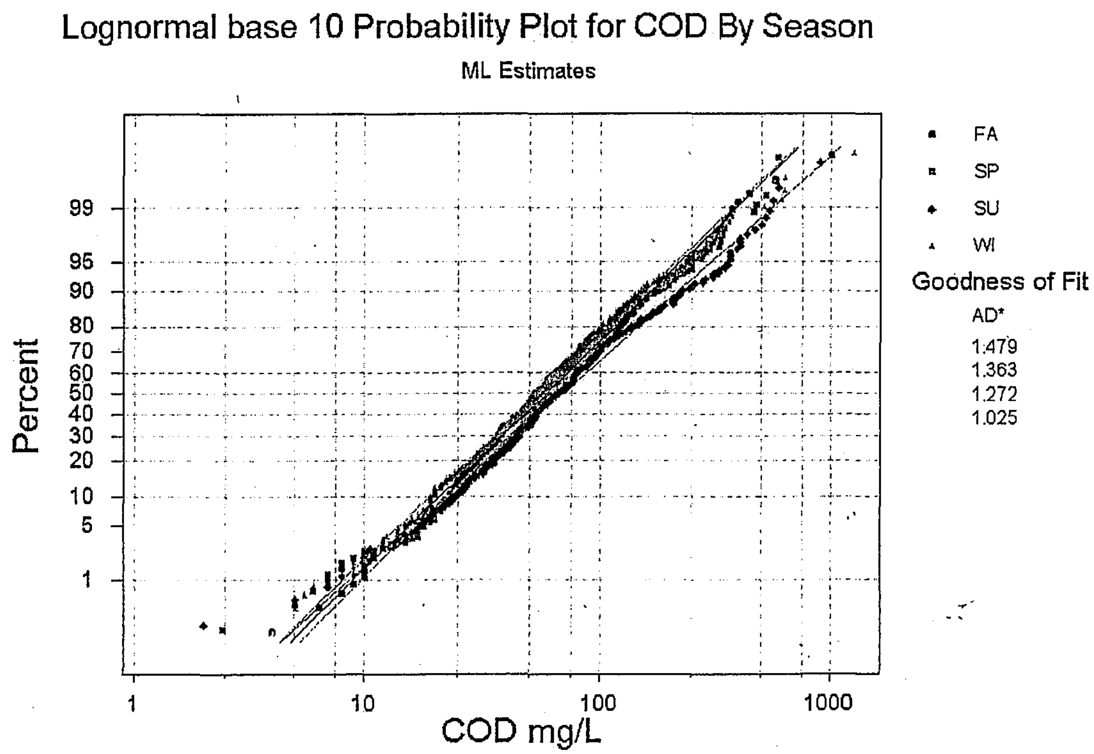

Figure 13. Probability plots of residential COD concentrations for different seasons.

Figure 14 shows probability plots of residential area COD concentrations for each EPA rain zone. There are likely three distinct groupings for residential COD values, based on their geographical location. Samples collected in zone 6 had the highest mean concentrations and were collected in Arizona. Samples collected in zones 2, 4 and 5 were intermediate in COD concentration and were collected in the mid Atlantic states and Texas. Samples collected in zones 3 and 7 had the lowest COD concentrations and were collected in Alabama, Georgia, and in Oregon.

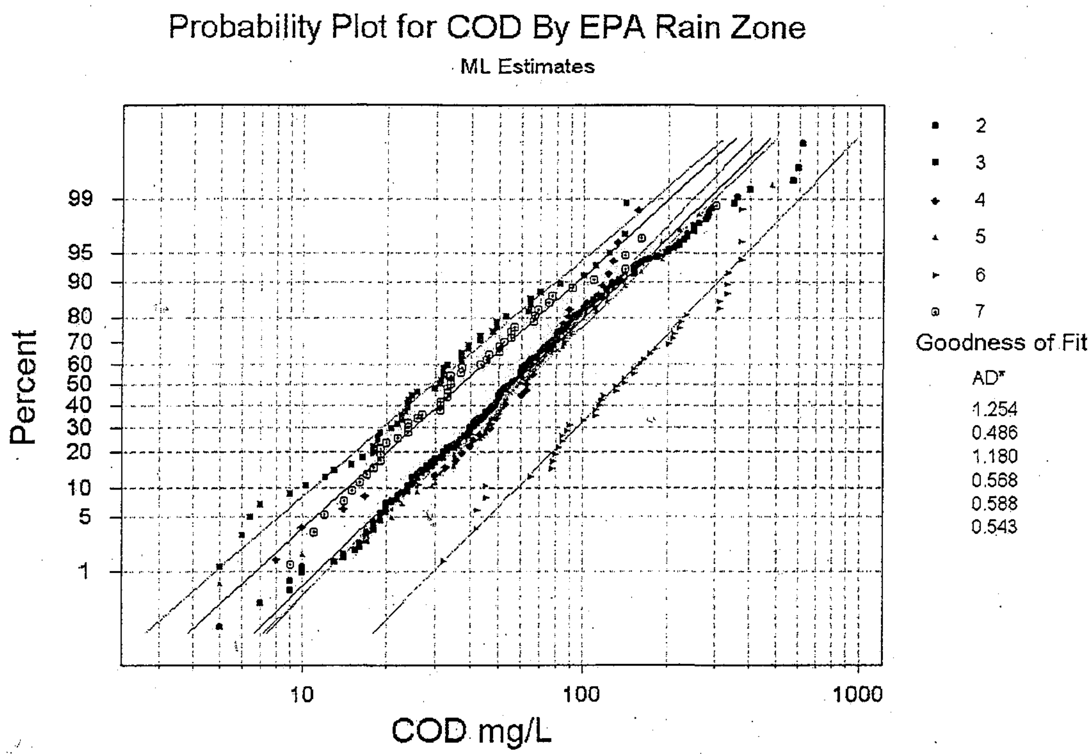

Figure 14. Probability plots of residential COD concentrations in different EPA Ran Zones.

Therefore, COD residential area concentrations can be divided into the following three groups, based on EPA rain zone:

Zones 3 and 7: average: 44.4 mg/L, standard deviation: 41.9 (102 observations)
Zones 2, 4 and 5: average: 72.8 mg/L, standard deviation: 61.6 (628 observations)
Zone 6: average: 162.1 mg/L, standard deviation: 100.0 (44 observations)

Overall residential COD: average: 74.1, standard deviation: 69.2 mg/L

The statistical analyses of the available NSQD COD residential area data did not identify any significant differences in any rain zones that can be explained by season. There was insufficient data in zones 1, 8, and 9 to be evaluated by season and the overall residential COD values should therefore be used for those areas until additional data is collected and evaluated.

Clustering and principal component analyses (PCA) are also being used to identify expected factors influencing sample variability. Figure 15 is an example dendogram from a cluster analysis of all of the preliminary data combined. However this analysis did not include most of the site characteristics when it was conducted; only rain depth, watershed size, and percentage imperviousness were included for this analysis, in addition to the runoff concentrations. This plot indicates very close relationships between rain depth and the nutrients (total phosphorus, dissolved phosphorus, nitrite plus nitrate, ammonia, and Total Kjeldahl Nitrogen). Some of the heavy metals (cadmium, nickel, and chromium) are closely related to each other, but copper, lead and zinc are much more independent. BOD_5, COD, dissolved solids, and suspended solids are poorly related to other pollutants for the pooled data. Pearson correlation analyses did show relatively strong relationships between suspended solids and the total forms of most of the heavy metals, substantiating the observation that most of the stormwater metals are not in filtered forms.

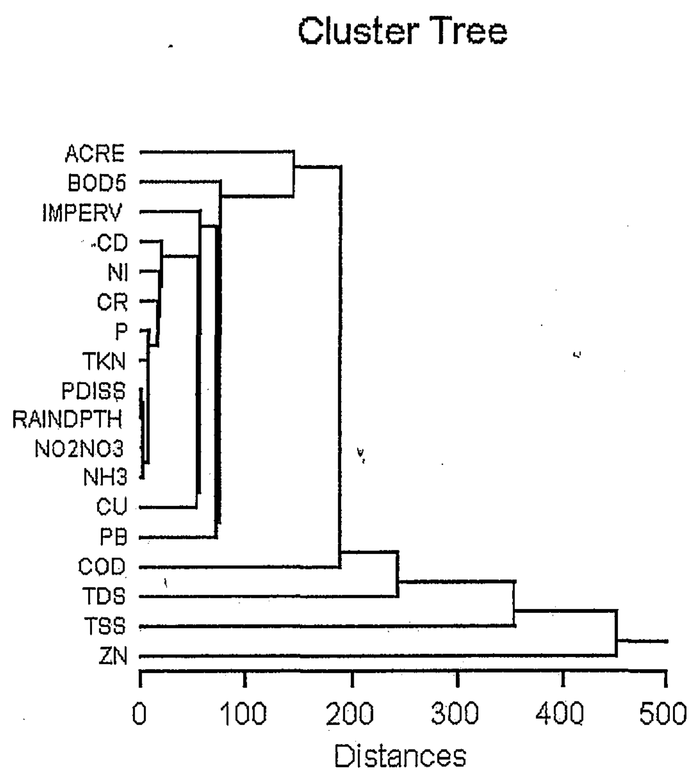

Figure 15. Cluster analysis (dendogram) showing relationships between stormwater pollutants.

Sampling Guidance for Stormwater Monitoring

A number of sampling issues can be statistically investigated using the information contained in the NSQD. The following discussion is a summary of the types of monitoring guidance that can be developed and refined using the database information.

Numbers of Samples Needed

An important aspect of any research is the assurance that the samples collected represent the conditions to be tested and that the number of samples to be collected are sufficient to provide statistically relevant conclusions. An experimental design process can be used that estimates the number of needed samples based on the allowable error, the variance of the observations, and the degree of confidence and power needed for each parameter. The number of samples needed is therefore dependent on the objectives of the data (characterization, comparison, trends, etc.), the variation of the concentrations in the category being investigated (typically described by the coefficient of variation, or the ratio of the mean to the standard deviation), and the allowable errors (the confidence and the power).

A basic equation that can be used to estimate the number of samples to characterize a set of conditions (given in Burton and Pitt 2001) is as follows:

$$n = [COV(Z_{1-\alpha} + Z_{1-\beta})/(error)]^2$$

where:

n = number of samples needed

α= false positive rate (1-α is the degree of confidence. A value of α of 0.05 is usually considered statistically significant, corresponding to a 1-α degree of confidence of 0.95, or 95%.)

β= false negative rate (1-β is the power. If used, a value of β of 0.2 is common, but it is frequently and improperly ignored, corresponding to a β of 0.5.)

$Z_{1-\alpha}$ = Z score (associated with area under normal curve) corresponding to 1-α. If α is 0.05 (95% degree of confidence), then the corresponding $Z_{1-\alpha}$ score is 1.645 (from standard statistical tables).

$Z_{1-\beta}$= Z score corresponding to 1-β value. If β is 0.2 (power of 80%), then the corresponding $Z_{1-\beta}$ score is 0.85 (from standard statistical tables). However, if power is ignored and β is 0.5, then the corresponding $Z_{1-\beta}$ score is 0.

error = allowable error, as a fraction of the true value of the mean

COV = coefficient of variation (sometimes noted as CV), the standard deviation divided by the mean (Data set assumed to be normally distributed.)

This equation assumes a normal distribution of the data, which would require a log transformation of most stormwater quality data. If an allowable error of about 25% is desired and the COV is estimated to be 0.4, then about 20 samples would have to be analyzed. The use of stratified random sampling can usually be used to advantage by significantly reducing the COV of the sub-population in the strata, requiring fewer samples for characterization.

Typical Numbers of Samples Needed for a Basic Stormwater Monitoring Program
The COV values for many constituents shown in Table 1 for the NPDES database range from unusually low values of about 0.1 (for pH) to highs between 1 and 2. There are a few COV values that are larger. One objective of a data analysis procedure is to categorize the data into separate stratifications, each having small variations in the observed concentrations. The only stratification in Table 1 is land use. However, Figure 6 shows many differences by geographical area (refer to Figure 1 for the EPA Rain Zone map). It is expected that the final data analyses for this project will identify separate stratifications of data (possibly considering the combination of land use, geographical area, and season factors) to significantly reduce the variations in each category. It is expected that COV values in the range of 0.5 to 1.0 will be common for many of these data stratifications. With a reasonable confidence of 95% (α= 0.05) and power of 80% (β= 0.20), and a commonly accepted allowable error of 25%, the number of samples needed to characterize conditions would likely range from about 25 to 50. If only 12 samples are obtained for each category (strata), the allowable errors would range from about 50% to 100%. Burton and Pitt (2001) present many additional experimental design equations and plots for other data quality objectives, including the effects of log transforming the data for more appropriate sampling effort approximations. In many cases, the actual errors in presenting data are larger than expected, due to relatively small numbers of samples. A continuing monitoring program (such as the Phase I stormwater NPDES permit monitoring effort) will result in better data as more samples are obtained with time.

Detection Limits of Analytical Methods

The NSQD can also be useful when selecting analytical methods. There are many important factors that must be considered when selecting an analytical method (availability, cost, detection limit, repeatability, safety and disposal problems, comparisons with historical data, etc.), but the detection limit is likely most important when ensuring the suitability of the data. In many cases, analytical methods are used that have detection limits that are actually larger than a criterion value, making accurate exceedence frequencies impossible (Burton and Pitt 2001).

Environmental researchers need to be concerned with many attributes of numerous analytical methods when selecting the most appropriate methods to use for analyses of their samples. The main factors that affect the selection of an analytical method include: cost, reliability (the "data quality objectives," or DQO which includes sensitivity, selectivity, repeatability), and safety. Most of these issues are not well documented in the literature for environmental sample analyses. Aspects of analytical reliability have received the most attention in the literature, but most of the other aspects noted above have not been adequately discussed for the many analytical alternatives available. It is therefore difficult for a water quality analyst to decide which methods to select, or even if a choice exists.

The selection of the appropriate analysis procedure is dependent on the use of the data and how false negatives or false positives would affect water use decisions or regulatory questions. The QA objectives for the method detection limit (MDL) and precision (RPD) for the compounds of interest have been shown to be a function of the anticipated median concentrations in the samples (Pitt, *et al.* 1993). The MDL objectives should generally be about 0.25, or less, of the median value for sample sets having typical concentration variations (COV values ranging from 0.5 to 1.25), based on many Monte Carlo evaluations to examine the rates of false negatives and false positives. Table 7 lists the typical median stormwater runoff constituent concentrations and the associated calculated MDL goals, for a typical stormwater monitoring project.

Using analytical methods having these detection limits, at least, will result in relatively few "non-detected" values. In most cases, analytical methods are available that can easily meet these goals. However, common problems are associated with some of the heavy metals, as most modern laboratories use ICP (inductively-coupled plasma) instruments that are capable of analyzing a broad range of metals simultaneously, but may not be able to meet these detection limit goals. When dissolved forms of the heavy metals need to be analyzed, the detection limits must be much smaller.

The NPDES stormwater database can be used to indicate the likely concentrations of interest for conditions similar to those that will be monitored. These expected values are a good start in determining the needed detection limits.

Sampling Methods

Details for all monitoring locations are desired for the database. Basic information (land use, season, geographic location, and if the sample is a first-flush or a composite sample) is available for all events in NSQD, and relatively complete site and monitoring descriptions are available for about 1/3 of the events. This data includes sampling methods (automatic samplers vs. manual samplers; manufacture and model of sampler; etc.). Investigations of how these factors may influence the monitoring results will be made, as illustrated in the initial evaluation of first-flush vs. composited samples. The effects of automatic vs. manual sampling will also be examined when sufficient information has been collected. One example of a previous investigation on stormwater sampling methods was conducted by Roa-Espinosa and Bannerman (1995). They collected samples from five industrial sites using different monitoring methods. They concluded that many time-composited subsamples combined for a single analysis can provide improved accuracy compared to fewer samples associated with flow-weighted samplers, and especially compared to samples only taken during a portion of an event.

Conclusions

A major goal of this project is to provide guidance to stormwater managers and regulators. Especially important will be the use of this data as an updated benchmark for comparison with locally collected data. These comparisons will enable local monitoring data to be compared to typical values that should be expected for similar situations. If the local stormwater quality is significantly worse than expected, then it may be possible to quantify a treatment goal that should be attainable. In addition, this data may be useful for preliminary calculations when using the "simple method" for predicting mass discharges for unmonitored areas. This data can also be used as guidance when designing local stormwater monitoring programs (Burton and Pitt 2002), especially when determining the needed sampling effort based on expected variations. The final data analyses will expand on these preliminary examples and will also investigate other stormwater data and sampling issues.

Table 7. Example QA Objectives for a Stormwater Characterization Project

Constituent	Units	Typical COV category[1]	Typical Median Conc.	Estimated MDL Goal
Turbidity	NTU	low	5	4
COD	mg/L	medium	50	12
suspended solids	mg/L	medium	50	12
nitrates	mg/L	low	0.6	0.4
chromium	µg/L	medium	7	1.5
copper	µg/L	medium	15	3.5
lead	µg/L	medium	15	3.5
nickel	µg/L	medium	10	2.3
zinc	µg/L	medium	100	23
1,3-dichlorobenzene	µg/L	medium	10	2
benzo(a) anthracene	µg/L	medium	30	8
bis(2-ethylhexyl) phthalate	µg/L	medium	10	2.3
butyl benzyl phthalate	µg/L	medium	15	3
fluoranthene	µg/L	medium	6	1.4
pentachlorophenol	µg/L	medium	10	2
pyrene	µg/L	medium	5	1
lindane and chlordane	µg/L	medium	1	0.2

1

COV value:	Multiplier for MDL
<0.5 (low)	0.8
0.5 to 1.25 (medium)	0.23
>1.25 (high)	0.12

from: Burton and Pitt 2001

The example investigation of first-flush conditions indicated that a first flush effect was not present in all the land uses and certainly not for all the constituents. Commercial and residential areas were more likely to show the phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that the effect will be more likely in watersheds with larger amounts of imperviousness. However, the industrial category had large amounts of imperviousness, but indicated first-flushes less than 50% of the time. All the metals evaluated show a higher concentration at the beginning of the event in the commercial land use category.

Suggested Role for Continued Stormwater Monitoring

The current data and information contained in NSQD indicates the potential value that a completed database (containing most of the NPDES stormwater data) can provide. The excellent U.S. national coverage, along with the broad representation of land uses, seasons, and other factors, makes this information highly valuable for numerous basic stormwater management needs. Monitoring with no specific objective, except for general characterization in an area, is not likely to provide any additional value beyond the data and information contained in NSQD. After a sufficient amount of data has been collected by a Phase 1 community for representative land uses and other conditions, outfall characterization monitoring resources should be re-directed to other specific data collection and evaluation needs. Burton and Pitt (2001) provide much additional information on determining an adequate outfall monitoring program. Similarly, communities that have not initiated a stormwater monitoring program (such as the Phase II NPDES small communities) may not require general characterization monitoring (monitoring is not specifically required as part of the Phase II regulations), if they can identify a regional Phase I community that has compiled extensive monitoring data as part of their required NPDES stormwater permit. Obviously, there will be some situations that are not well represented in NSQD and additional characterization monitoring may be warranted. These situations will be identified in the final data analyses.

This is not to say that stormwater quality monitoring has no role as part of a stormwater management program. Burton and Pitt (2001) present extensive examples and procedures showing the importance of a balanced monitoring program. This publication is available from CRC Press, and a version is available at:

http://civil.eng.ua.edu/~rpitt/Publications/BooksandReports/Stormwater%20Effects%20Handbook%20by%20%20Burton%20and%20Pitt%20book/MainEDFS_Book.html

Stormwater quality monitoring is a crucial component of local programs. Specific objectives for these include:

• Receiving water assessments to understand local problems. Receiving water monitoring is needed to identify local problems, especially when identifying beneficial use impairments. Assimilative capacity calculations (TMDLs) require knowledge of local source discharges. The NSQD data and information can be used for preliminary designs and cost estimates, but it is also important to invest a small amount of resources to accurately determine local discharge conditions before expensive controls are designed.

• Source area monitoring to identify critical sources. In many cases, source area controls may be more cost-effective than regional controls. The identification of critical source areas is therefore needed as part of a comprehensive stormwater management program. Monitoring within a critical drainage area should be conducted to identify the sources of pollutants, while simultaneous outfall monitoring is needed to verify these source area measurements.

• Detailed monitoring at selected outfalls, with complete monitoring of rainfall and runoff, with high-resolution data to examine time-variability characteristics of certain problem pollutants. This would be especially important at small, highly paved areas where "first-flush" conditions are most likely. This information is needed to evaluate the benefits and to quantify design approaches of critical source area controls.

• Treatability tests to verify performance of stormwater controls for local conditions. In areas where stormwater controls are being installed, local measurements of performance are a good investment. Before and after monitoring, or parallel monitoring, is usually needed to measure the performance of many types of stormwater controls. The ASCE National Stormwater BMP database (http://www.bmpdatabase.org/) is a good place to start in predicting the performance of controls, but site-specific validations in an area where the controls have not been previously used should be conducted.

• Assessment monitoring to verify success of stormwater management approach. Stormwater quality monitoring is a critical component of an assessment monitoring effort. Receiving water monitoring needs to focus on beneficial use impairments, and associated chemical, physical, and biological monitoring. In many cases, source area or outfall controls are being used as part of comprehensive management programs. Therefore, outfall monitoring may also be needed.

Acknowledgements

Many people and institutions need to be thanked for their help on this research project. Project support and assistance from Bryan Rittenhouse, the US EPA project officer for the Office of Water, is gratefully acknowledged. The many municipalities who worked with us to submit data and information were obviously crucial and the project could not be conducted without their help. Finally, the authors would like to thank a number of graduate students at the University of Alabama (especially Veera Rao Karri, Sanju Jacob, Sumandeep Shergill, Yukio Nara, and Soumya Chaturvedula) and employees of the Center for Watershed Protection (Ted Brown, Chris Swann, Karen Cappiella, and Tom Schueler) for their careful work on this project.

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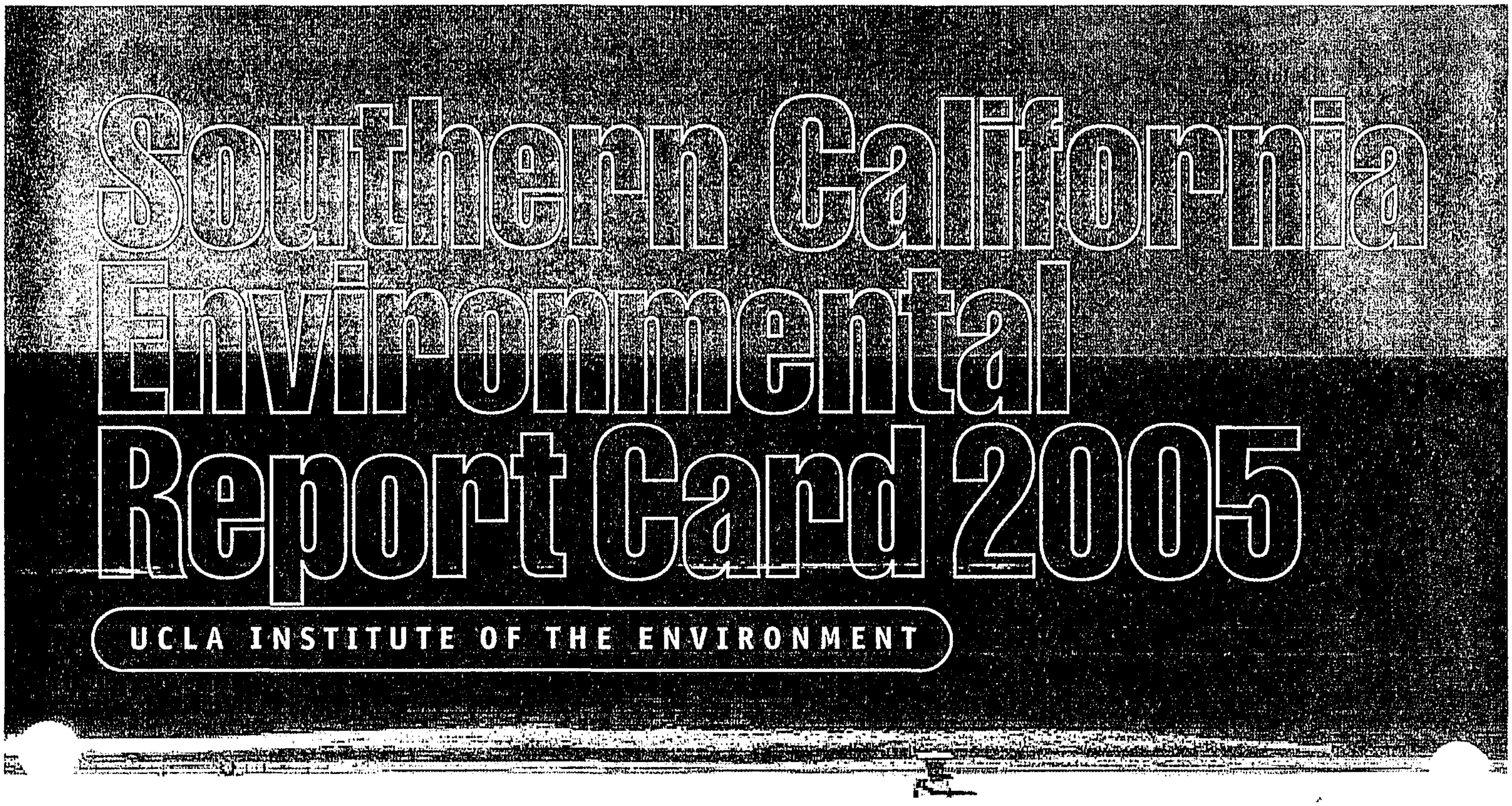

Southern California Environmental Report Card 2005

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Contents

RC 2005

From the Director

Mary D. Nichols, J.D.
Director
UCLA Institute of the Environment

If this is your first glance at a Southern California Environmental Report Card, be prepared for a much more searching evaluation than is usual under most grading systems. The authors of the four essays that make up the 2005 Report Card have taken great care to summarize the key factors contributing to four of our region's most pressing environmental concerns—drought, impaired water quality, releases of toxic and hazardous wastes, and the loss of marine resources from our coast. They provide scientific data and objective analysis. The final grades may provide useful feedback to the government agencies responsible for enforcing the laws that have been put in place to address these concerns, but their primary purpose is to give the people of Southern California a sense of what a select group of UCLA environmental researchers think is working well—and what is not.

The UCLA Institute of the Environment publishes a Report Card annually, in what is now an eight year conversation with policy makers and interested members of the community. I use the term "conversation" advisedly, because some of the data that are reported here can actually be traced back to recommendations in previous Report Cards. Proposition O, a $500 million bond approved by the City of Los Angeles voters in November 2004 with a convincing margin of 74.9%, is a terrific example of the Report Card's influence. The resounding victory demonstrates a strong consensus that we need to get serious about fixing the polluted storm water runoff that has degraded our local groundwater, frequently closing our beaches and backing up onto streets when it rains.

Government officials, environmental advocates, business leaders and the news media all played critical roles in developing the ideas and building the political will to pass this much-needed measure. But it was the science and policy analysis that made the case. Years (actually, decades) of work by UCLA researchers and others have built the case for action and demonstrated the technologies that can reverse the damage caused by past failures of policy and planning. So when the City Council decided to put Prop. O before the electorate, the facts were widely known and the public was well aware that our water quality problems are real. Voters felt confident they were supporting a well-crafted set of policies and projects with a high likelihood of success.

I served as co-chair of Yes on Proposition O. It was a remarkable campaign: at a time when the nation was being divided into red states and blue states, we had no active opposition. So instead of the typical negative television ads, we could focus on the benefits of

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The IOE's Report Card is now part of an eight year conversation with policy makers and interested members of the community.

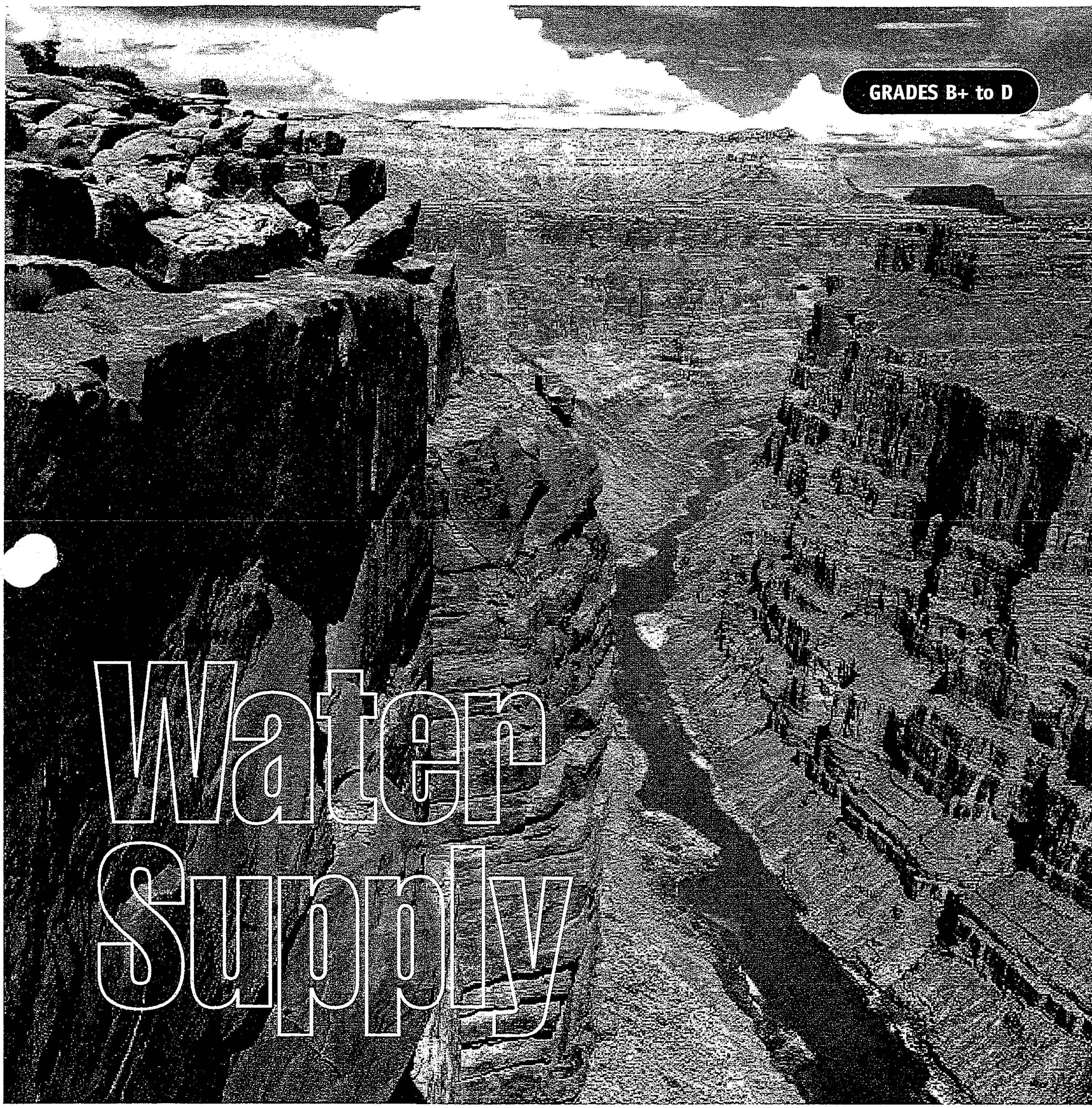
re-engineering the city to capture rain water and allow it to permeate the soil, greening neighborhoods and keeping trash and toxics out of the ocean. At every step we had the backing of studies documenting the sources of pollution, the effects on human and ecosystem health, and the cost-effective solutions. For once, science and social science really did inform the debate.

I'm proud to report that research and analysis by two of this year's Report Card authors, biologist Richard Ambrose and engineer Michael Stenstrom, played a critical role in developing the scientific consensus that paved the way for a public policy victory that seems all too rare these days. Their articles address the progress we've made in improving water quality and marine resources and the problems that remain. But I also want to push the point a bit farther because without sustained funding for research on important environmental issues, future victories will be less likely. Public skepticism, fueled by press reports of "scientists say this" or "a new study reveals that," has contributed to severe cutbacks in the funds given to federal and state agencies for the kind of policy-relevant research needed to make further environmental progress. One of my not-so-secret hopes for the Report Card is that by communicating the results of academic research in a non-academic format, we can demonstrate the value of long-term public support for environmental studies at nonpartisan research institutions like UCLA.

Toxic and hazardous waste—addressed in the RC by two public policy experts, J.R. DeShazo and Bowman Cutter—continues to stay buried in urban areas and buried in the public consciousness until a truck overturns on the freeway or a leaking underground tank threatens local drinking water supplies. Professors DeShazo and Cutter have examined the data and come to a couple of important conclusions. One is that cities are doing a pretty good job of carrying out the inspections required by law but that counties need to do more. The other, more disturbing, finding is that the data are simply not being collected that would enable the legislature or the public to assess how well or poorly individual companies are managing their wastes. Clearly a program that inspects but then doesn't act on the information revealed by inspections is only a partial solution to the release of toxic chemicals into the environment.

While most Southern Californians are aware that they are dependent on water imported from Northern California to meet their basic needs, and the decline of the San Francisco-Sacramento Bay-Delta is the focus of a massive federal and state recovery effort, a much larger threat to Southern California's water supply and environment is the looming loss of Colorado River water. Glen McDonald's lead article succinctly lays out the impacts of the changing weather patterns and long-term drought, as well as the institutional and legal constraints that are coming together to force massive changes in the way we import and use water. This article should help re-focus our attention on the fastest-growing area of Southern California, the Inland Empire, and the effects this growth will have on the region as a whole.

continued on page 40


GRADES B+ to D
Water
Supply

by Glen MacDonald, Ph.D.

Professor of Geography

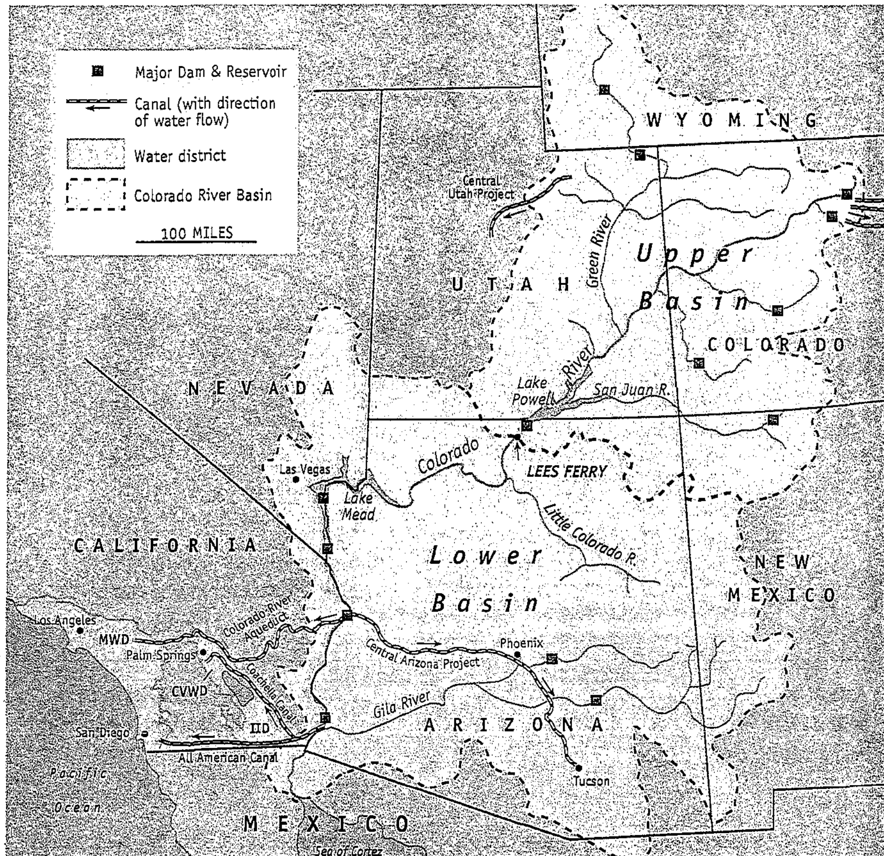
Drought is not the first word that comes to mind at the end of a record-breaking rainfall season in Southern California. Nonetheless, the state remains on the verge of a potential water crisis and faces severe uncertainties in long-term planning to meet Southern California water demands. The Colorado River system—a principal source of supply—is experiencing both severe drought and increasing water demands from other states and Mexico. In this article we examine water demands in Southern California and consider the capacity of the Colorado system to meet those demands. We also consider evidence the Colorado system could experience severe and sustained droughts that make the current situation, or any drought experienced over the past 200 years, pale in comparison. Finally, we outline current actions California is taking to plan for the sustainable use of Colorado River water.

SOUTHERN CALIFORNIA WATER USAGE AND SUPPLIES

The big player in southland water distribution for urban and suburban areas is the Metropolitan Water District of Southern California (MWD). This consortium of 26 cities and smaller water districts serves almost 18 million people over a 5200 square mile area that extends from San Diego County to Ventura County. For the City of Los Angeles, the Department of Water and Power relies heavily on the eastern Sierra Nevada, but draws more upon the other MWD sources in times of shortage. To meet water demands, the MWD delivers 1.7 billion gallons of water each day, almost 100 gallons per day for every person in its service area. This is the water for drinking, bathing, industrial uses, parks and recreation and other demands required to support the Southern California population and lifestyle. Water allocations of this scale are measured by the acre-foot, the amount of water required to cover one acre to a depth of one foot, 326,000 gallons. Today the MWD requires about 1.8 million acre-feet of water per-year to keep the major urban and suburban areas of Southern California functioning.

Although the billions of gallons of water distributed by the MWD is an appreciable amount, Southern California agriculture uses an even larger proportion of water. For example, the Imperial Irrigation District (IID) distributes over 3 million acre-feet of water per-year, yet the entire population of Imperial County is only about 150,000 people. In some cases, the agricultural users have priority over urban and suburban users.

Southern California is an arid to semi-arid environment with low annual precipitation. Even in years of record precipitation such as 2004-05, Southern California retains less precipitation than it needs to meet its water requirements. The average annual precipitation in the Los Angeles Basin is about 15 inches per year. Over the area of the MWD this would provide a total of around 4 million acre-feet of water. However, about 60% of this moisture evaporates, is used by vegetation, or enters the soil. Much of the rest runs directly into the ocean as surface flow where it often serves vital ecological functions in systems such as coastal estuaries. Only a small proportion is captured in reservoirs. For more than 100 years Southern California has had to import water to support its large population. At present less than half the water we use



The Upper and Lower Basins of the Colorado River with the locations of major reservoirs and aqueducts, as well as the areas serviced by the large southern California water districts that draw from the river.

The Colorado River system—a principal source of supply—is experiencing both severe drought and increasing water demands from other states and Mexico.

comes from local surface or groundwater sources. The rest is imported from outside of Southern California.

Some of our imported water comes from the Sierra Nevada Mountains and northern portions of the state. However, a large proportion is derived from the Colorado River. The Colorado River water is perhaps the most critical and uncertain element of water resource planning in Southern California and for the MWD.

COLORADO RIVER WATER AND SOUTHERN CALIFORNIA

So important is the Colorado River that MWD spokesman Bob Muir has called it "the backbone of water supply in Southern California." Today Colorado River water contributes about 65% of the water distributed in Southern California. Water in the Colorado arises mainly from the upper portions of its drainage basin, which includes portions of Wyoming, Utah, Colorado, New Mexico and Arizona.

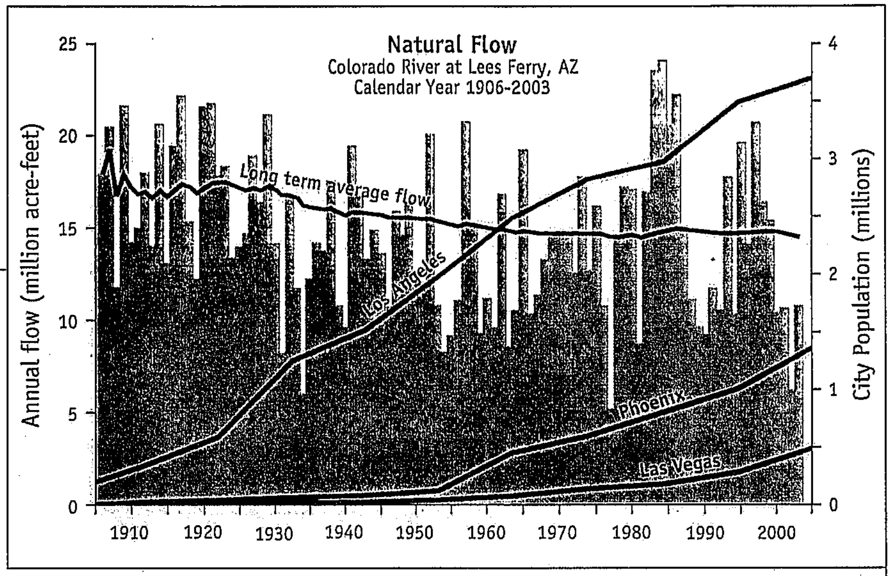
Water from the Colorado is used for drinking, irrigation and other purposes by California, the other states of the basin and Mexico. In 1922 the seven states of the upper and Lower Colorado Basins implemented the first stages of the Colorado River Compact, which apportioned 7.5 million acre-feet per-year to Colorado, New Mexico, Utah, Wyoming, Arizona, Nevada and California. In 1944, Mexico was apportioned 1.5 million acre-feet. This total allocation—16.5 million acre-feet—was based on the premise that the average annual river flow at Lees Ferry, just below present Lake Powell, is 17 million acre-feet.

Under the Boulder Canyon Project Act of 1928, California was apportioned 4.4 million acre-feet of water per year under normal conditions. In total this amount is less than the current or anticipated future total water needs for the MWD and the IID, not to mention other users such as the Cochella Valley Water District (CVWD). California has enjoyed a cushion in that the Compact allowed us to draw upon the 'surplus' water not used

Today Colorado River water contributes about 65% of the water distributed in Southern California.

by other states. So long as populations in Nevada and Arizona remained small, California had access to additional water from the Colorado. California's recent consumptive use of Colorado River water has been approximately 5.2 million acre-feet per year, well above the base level of 4.4 million apportioned under the Compact. Much of this 'surplus' water has in the past been used by the MWD.

A massive system of dams stores water to mitigate seasonal and annual variability in Colorado River flow and generate electricity. Hoover Dam, which produced Lake Mead, was completed in 1935 and there are now a number of major reservoirs throughout the Upper and Lower Basins. The reservoir system, which can hold 60 million acre-feet of water, is supposed to provide a four to five year buffer supply of water in case of severe drought.

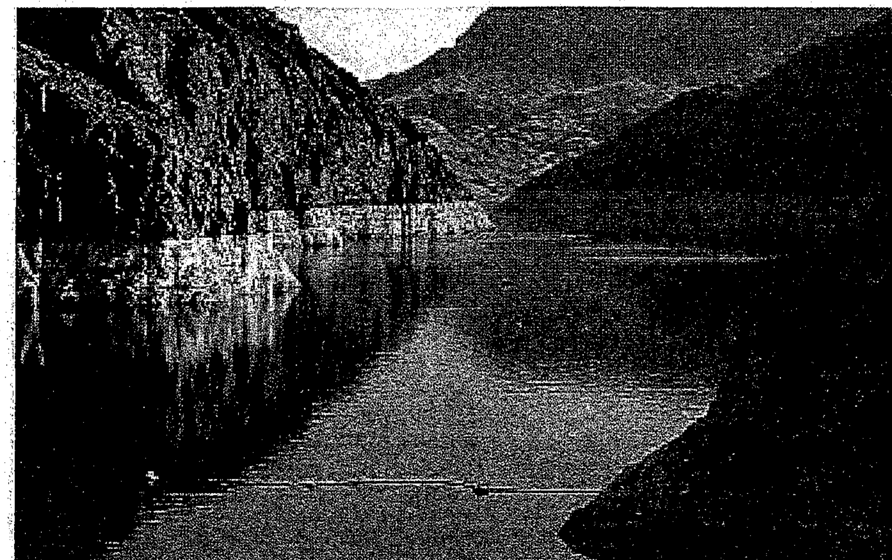


Annual and long-term Colorado River water variability flow compared to population growth of the cities of Los Angeles, Las Vegas and Phoenix. City populations include only residents living within city jurisdictions.[1]

THE LOOMING CRISES

Two crises confront Southern California in terms of water management and the Colorado River. The first concerns the Colorado Compact and the annual allocations of water, where we face two challenges—decreased supply and increased demand.

Water allocations under the Colorado River Compact assume the average flow of water from the Upper to Lower Basin at Lees Ferry is 17 million acre-feet per year. This assumption was based upon the short record of observed river flow available in 1922. In subsequent years, annual measurements of Colorado River flow have highlighted two problems. First, the average flow during the period 1905 to 1922 was anomalously high compared to most of the 20th century. Long-term average flow on the Colorado is more likely to lie between 13 million to 15 million acre-feet per-year. The result is that more water may have been allocated than the river can be expected to provide in a sustained fashion. In addition, flow over the 20th century has been much more variable that could have been anticipated when the Compact apportions were granted. For example, during the Dust Bowl years of 1930 to1937 the annual flow at Lees Ferry averaged only about 10 million acre-feet. The most recent drought, which commenced in 1999, has led to some even lower flows. The average flow between 2001 and 2003 at Lees Ferry reached a low of only 5.4 million acre-feet. This is 11 million acre-feet below the total current water allocations



A white rim along the rocky shores of Lake Mead provides evidence of the former water height in the reservoir and the drawdown in storage reserves caused by recent prolonged drought.

A continued drought could soon overwhelm the buffering capacity of the reservoirs.

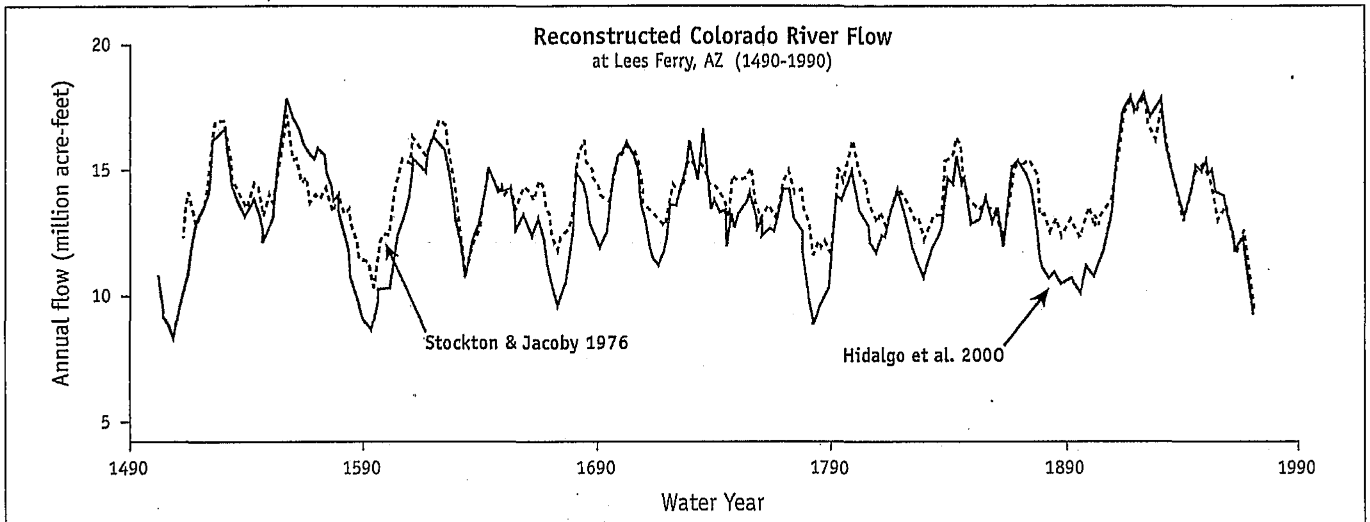
and is only slightly higher than California's recent consumptive use of Colorado River water of 5.2 million acre-feet.

The reservoir system in the Colorado Basin is supposed to allow the system to provide adequate water to users during times of drought. However, this current drought is straining the capacity of reservoirs to mitigate the low flows. Lake Mead has seen a drop in water levels of over 30 feet and reached its lowest level since 1965. Water levels have fallen by over 100 feet in Lake Powell and are at their lowest levels since initial filling of the reservoir. A continued drought could soon overwhelm the buffering capacity of the reservoirs.

It is clear the current flow rates of the Colorado River are insufficient to meet the water allocations from the system if all states and Mexico were to withdraw their full portions. It is also clear the high variability in flow and the occurrence of prolonged droughts such as occurred in the 1930s and today exacerbate this problem despite the extensive reservoir system.

The other challenge confronting us is increasing demand caused by growing populations in the Southwest. This problem is particularly acute in the Lower Basin states of California, Nevada and Arizona. The booming cities and metropolitan areas of Los Angeles, Phoenix, Tucson and Las Vegas are all supplied with water from the Colorado. Since the Colorado Compact was first devised in the early 1920s and 2000 the city of Los Angeles has grown six times, from about 577,000 people to over 3.7 million. Even more striking, since 1920 the population of Las Vegas has grown by 200 times and Phoenix by 47 times its 1920 population. Much of this growth has occurred in the past 50 years. This has generated a massive increase in water needs, including a 410% increase in domestic water use in the Southwest since 1950. All projections indicate robust population growth will continue throughout the Southwest. No longer can California count on the 'surplus' unallocated water from Arizona or Nevada to meets its needs.

The second looming crisis for Colorado River water allocations is the specter of severe and sustained drought beyond the magnitude of any drought experienced in the past 100 years. A severe drought that persisted for a decade or more could overwhelm the buffering capacity of the Colorado reservoir system and lead to a crisis in water supply for irrigation and domestic use in Southern California. How real are the



Long-term variations in Colorado River flow and large scale drought induced episodes of decreased flow reconstructed by two independent studies using tree-rings.[2]

chances of such a 'mega-drought' occurring on the Colorado system? Historical records of river flow only date back to the early 20th century, but the record of flow can be extended back hundreds of years using tree-rings. Many long-lived species of pines and other coniferous trees grow in the Colorado River region. In many instances the annual growth rings of the trees are sensitive to precipitation and large growth rings are formed in years with high precipitation. These wet years with good tree-ring growth coincide with years of high flow in the Colorado River.

Since the 1970s scientists at UCLA and elsewhere have produced reconstructions of river flow on the Colorado using tree-ring records. These records show that in periods such as the late 19th century and the late 16th century there were severe sustained droughts on the Colorado that lasted up to a decade or more. Even more troubling is evidence from other studies for a centuries-long period of enhanced droughts throughout much of western North America in the 10th to 14th centuries. In view of the prehistoric record, the recent Colorado Basin drought is not exceptional and dry conditions could conceivably persist into future years.

PLANNING COLORADO RIVER WATER USAGE

The problems confronting the management of the Colorado River water under the original 1922 Compact are widely recognized by Upper and Lower Basin states and Mexico. Increasingly, the possibility of severe sustained drought as revealed by tree-ring records is playing a role in such considerations. Legal and political debate have long been features of management of the Colorado River and have become increasingly heated at state, national and international levels. One example is the lengthy battle between the IID, San Diego and the MWD over the allocation of Colorado River water for irrigation versus allocations to municipalities. Additionally, ecological concerns now play a greater role in water planning: reduced flows to the Colorado Delta in the Sea of Cortez are damaging delta ecosystems. And decreased flood flows caused through the

More water-efficient irrigation practices and crop selections can make significant contributions to lessening Southern California's need for Colorado river water.

control of the river by dams and reservoirs is harming riparian ecosystems in the Grand Canyon. Finally, the Salton Sea of California was created by an accidental release of Colorado River water from irrigation systems during 1905 to 1907. The Sea supports fish and migrant bird populations today but may become too saline to support current populations if more water from the Colorado is not allocated to it.

Against this backdrop of uncertainty and potential crisis, Southern California has taken some very positive steps. First, following the impact of drought in the 1980s and early 1990s, MWD users adopted conservation practices and other measures that have resulted in a significant decline in annual water usage. In 1990 the amount of water distributed by the MWD peaked at around 2.6 million acre-feet, 1.7 times more than the amount of water distributed today. The MWD continues to pursue conservation strategies and alternatives such as desalinization and waste water recycling.

Second, California, under the leadership of a state agency called the Colorado River Board, has instituted the 4.4 Plan to limit use of Colorado River water in California to 4.4 million acre-feet per year. The plan requires compromise agreements on water use and allocation between the MWD, IID, CVWD and other users, and institution of a number of conservation measures such as the lining of the All American Canal with impermeable material to stop the leakage of irrigation water. Within the 4.4 Plan, agriculture users will have the first three priorities to 3.85 million acre-feet of Colorado River water per year and the MWD will have fourth priority for 555,000 acre-feet.

The implementation of the 4.4 Plan will require adjustments in water supply and use by the MWD. The 4.4 Plan is to be implemented in stages and will result in a decline in Colorado River use from 5.2 million acre-feet to 4.6 million acre-feet to take place between now and 2010 to 2015. Further reductions will follow. The 4.4 Plan is now seen by some as a model for states' responses to develop a sustainable allocation system for Colorado River water.

The relatively long time lines in the 4.4 plan are reasonable in terms of developing conservation strategies and alternative water sources needed to shift dependence away from Colorado River water, but they also contain perils. First, the rapid growth of populations and water use in other Lower Basin states may lead to increasing strife between Nevada, Arizona, California and Mexico while the state attempts to implement the 4.4 Plan. Second, if the current severe drought is sustained along the Colorado system, there simply will not be enough water in the river to satisfy the needs of California alone,

The specter of severe and sustained drought beyond the magnitude of any drought experienced in the last 100 years could create a massive water and power crisis.

much less to be shared with the other states and Mexico. Should such a severe and sustained drought occur we could see one of the biggest water and power crises ever to confront the Southwest.

POLICY RECOMMENDATIONS

In light of the possibility of resource battles because of the low average flow of the Colorado, the potential for long term drought, and increasing regional populations, we make the following recommendations:

1. Aggressive implementation of the 4.4 Plan;
2. Continued efforts to increase water conservation and recycling in agricultural and urban districts;
3. Comprehensive planning for emergency water conservation, alternative supplies and reallocation of water between users within water management districts and between water management districts;
4. An integrated drought response strategy that examines the potential for, and response to, severe and sustained droughts.

GRADES

For water conservation and other measures taken following recent California droughts and the 4.4 Plan in response to current demands for Colorado River water. **Grade B+**

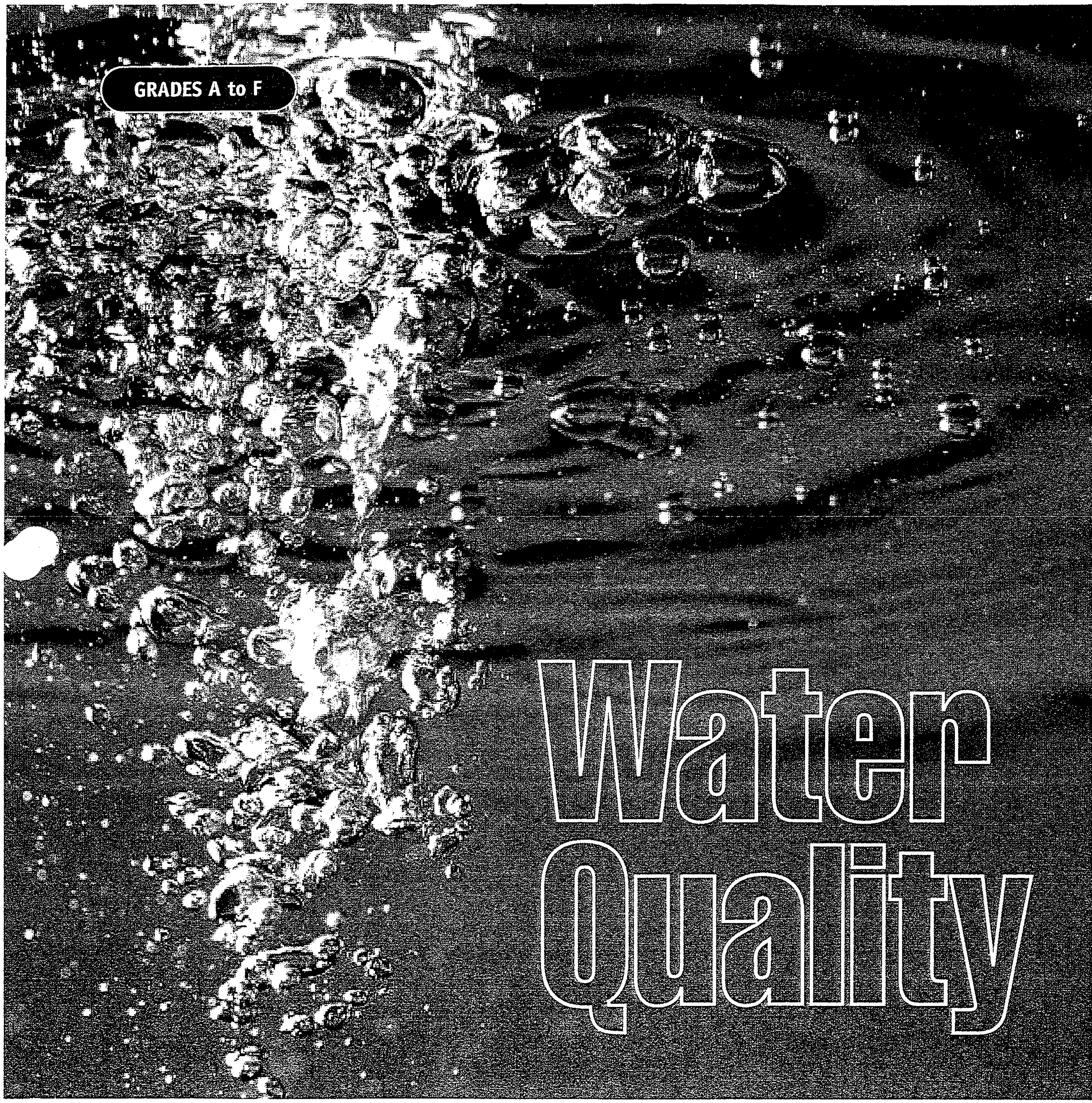
For long-term planning for the double threats of rapidly increasing population and water demand and the potential for severe and sustained drought of greater magnitude than any experienced in the past 100 years. **Grade D**

NOTES

1. River flow versus population data from US Bureau of Reclamation and US Census Bureau.

2. Data from Stockton, C.W. and G.C. Jacoby. 1976. Long-term surface water supply and streamflow levels in the upper Colorado River basin. Lake Powell Research Project Bulletin No. 18, Inst. of Geophysics and Planetary Physics, University of California, Los Angeles, 70 pp and Hidalgo-Leon, H.G., Piechota, T.C. and Dracup, J.A. 2000. Alternative principal components regression procedures for dendrohydrologic reconstructions, Water Resources Research, 36: 3241-3249.

Glen MacDonald is a Professor of Geography and of Ecology and Evolutionary Biology at UCLA. He is also the current Chair of the UCLA Geography Department. Following an undergraduate degree in Geography at UC Berkeley he pursued a M.Sc. in Geography at the University of Calgary and a Ph.D. in Botany at the University of Toronto. Before returning to California he taught for a number of years in Canada. His research focuses upon climatic variability over the past 10,000 years, the impacts of such variability on ecosystems and people, and the potential impacts of climatic variability and global warming in the future. He conducts research around the world and has been awarded the Cowles Award for Excellence in Publication by the American Association of Geographers twice, the University of Helsinki Medal and a Life Membership at Clare Hall, Cambridge. Glen MacDonald was raised in California and has benefited greatly from the state's natural and cultural diversity. He has two children and hopes that we will pass the same opportunities on to them.


GRADES A to F
Water
Quality

by Michael K. Stenstrom, Ph.D., P.E.

Professor, Department of Civil and Environmental Engineering

As the previous article demonstrates, water *supply* is of extraordinary concern to the long term health, welfare and economy of Southern California. But supply is not our only concern. The *quality* of the water we use—to drink, to swim, to irrigate—is also key to the region's future. Our previous Report Cards have dealt in various ways with the quality of our water: wastewater treatment plants and water conservation (1998), stormwater (1999), drinking water (2000), bottled water (2001), reclaimed water (2002) and stormwater regulations (2004). These reports have generally praised our region for its efforts to manage our water quality, although each report details at least some problems that require innovative solutions. But each of these Report Card articles examined only an individual piece of the water quality picture. In this report we integrate issues described in the previous Report Cards and discuss how water research, regulation and treatment systems are crucial not only for the Southern California environment but also for our long term economic health.

WASTEWATER TREATMENT

Southern Californians live primarily on the coastal plain. In order to provide adequate sewage treatment for our regional population, various jurisdictions have created large treatment plants, called coastal plants, that service this community. These plants discharge effluent into salt water through submerged pipelines that are several miles long. Traditionally, these plants have operated at lower efficiency than inland plants, based upon the belief that ocean discharge and the large dilution provided by the long pipe lines would mitigate environmental impacts. Inland communities are served by smaller plants, generally operating at higher efficiency and in many cases, providing source water for reclamation facilities.

In RC 1998, we gave treatment plants inland to the coast of California A grades because of their high treatment efficiency needed to provide reclaimed water. Since 1998, new regulations have required these plants to improve even more and to remove nitrogen, an important stimulus to eutrophication and a potential toxic material to human infants, fish and wildlife. The Sanitation Districts of Los Angeles County (LACSD) have largely completed the conversion of their inland plants for nutrient removal. The Inland Empire Utilities District has also met the challenge. The City of Los Angeles has begun conversion of its two inland plants. The "A" grade for inland plants in RC 1998 was well deserved and our treatment agencies have continued to build and maintain advanced technology wastewater treatment plants for environmental protection and water reclamation.

By contrast, the grade for coastal wastewater treatment plants in 1998 was low, only a C. The Report Card article described a long protracted process of legal battles, delays and expensive or failed projects. Major treatment agencies such as the City of Los Angeles and LACSD had not met Clean Water Act (CWA) goals other cities had generally achieved in 1977. The Orange County Sanitation Districts and the City of San Diego were operating with permits requiring only partial secondary treatment.

This situation has dramatically changed in the intervening seven years. The City of Los Angeles and LACSD

The Hyperion Wastewater treatment plant was the first large plant in the United States to achieve new EPA standards for land application of biosolids. The new "egg-shaped" digesters at the plant, while not required for thermophilic digestion, facilitate high temperature digestion by providing better mixing and reduced cleaning frequency.

Thermophilic digestion reduces Hyperion's power consumption from outside sources by 75 percent.

have each implemented full secondary treatment at their two major coastal plants and are now tackling the associated problems of secondary treatment—energy conservation and biosolids disposal. The City of Los Angeles has done well in being one of the first major US cities to achieve Biosolids A treatment. Biosolids A is a US EPA classification for biosolids that meet especially high standards for reduced pathogen and heavy metal content, and is generally required before biosolids can be applied beneficially for uses such as soil amendments. The City received an award for its use of high temperature solids treatment, called thermophilic digestion, at its Hyperion Treatment Plant. The plant recovers energy from biogas by treating it to remove sulfur compounds and burning it at the City's Scattergood power plant. This reduces Hyperion's power consumption from outside sources by 75 percent.

The situation has improved in other southern California locations as well. Voters in Orange County approved the conversion of county treatment facilities from partial secondary to full secondary. This contrasts with experience in Los Angeles that involved a 22-year legal battle. The Orange County Sanitation District is moving quickly to implement full secondary treatment at its two major treatment plants. The City of San Diego, while still believing that secondary treatment is not necessary, has been proactive in testing new technologies for secondary treatment in the event the City is required to upgrade its major plant at Point Loma. These plants are also participating in water reclamation projects, which are discussed below.

The treatment agencies are also making progress in reducing chlorine usage at treatment plants. Chlorination has traditionally been the most effective and least expensive way of disinfecting effluents. Over the past 20 years, however, research has shown that byproducts of chlorination can be harmful to the environment. Transportation of the chlorine from production facilities to consuming facilities is also a problem, and one or more fatal chlorine spills are reported each year in the United States. We are pleased to report our treatment agencies are making good progress to reduce chlorine usage by adopting more advanced technologies such as ultraviolet (UV) light disinfection. This technology is more expensive but has the advantage of reduced byproducts and the elimination of the transport of a hazardous chemical.

A000063

The Ballona Wetlands and the fresh water marsh, a facility designed to treat stormwater runoff from surrounding areas and protect the salt water marsh from excessive fresh water intrusion.

We concluded in the RC 1998 article on wastewater treatement that the region's environmental regulatory agencies had to "drag our treatment agencies, screaming and kicking" into new construction programs. The situation is quite different now, with goals accomplished in Los Angeles and Los Angeles County, and pro-active voters in Orange County voluntarily seeking improved wastewater treatment.

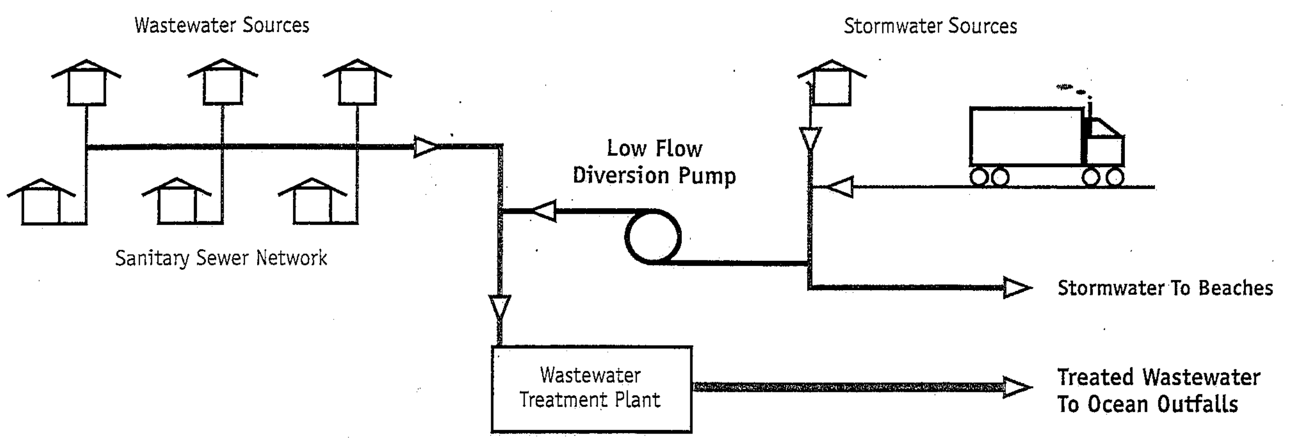
STORMWATER MANAGEMENT

We described Stormwater management in RC 1999 and RC 2004, noting major challenges, many of which were institutional as opposed to technical. We are pleased to report progress on all areas of stormwater management.

A major advance in stormwater management occurred when the Los Angeles Regional Water Quality Control Board enacted runoff controls for new and modified developments. In the past, new developments had no special requirement to mitigate stormwater runoff, other than to ensure no flood damage occurred. Every new development—by increasing impervious surfaces that do not absorb water—increases runoff to the Santa Monica Bay and taxes the existing surface drainage systems. This situation changed when the Regional Board required all new developments to treat or mitigate the impacts of the first 0.75 inches of rainfall. This means 60 to 70 percent of all storms will be completely treated, and the larger storms will be partially treated.

The new regulations have been criticized by developers as being too costly and having undefined benefits. Developers also criticized the regulations for being unscientific in failing to differentiate between high and low rates of rainfall, which may require different types of mitigation techniques. We disagree with these criticisms and believe the regulations are a large step forward for environmental protection. Though the new regulations cannot reverse the amount of impervious surface created by development, they will cap total runoff rate. And many of the stormwater management options required to implement the regulations, called best management practices (BMPs), will provide additional benefits. Grassy swales and infiltration areas create open space and, in the case of very large projects, habitat for birds.

A good example of environmental mitigation on new developments is the Playa Vista Project in Playa del Rey.



The separate sewer systems in Southern California are being converted to "hybrid systems" in order to divert summer low flow runoff into the wastewater treatment system via low flow diversion pumps.

Although the project was highly controversial and the topic of extensive litigation, it created several important environmental benefits that have been overlooked. The first is the stormwater management controls installed by the developer, which far exceed those required of other developments and set a good example for future developers to meet. The second is the construction of a freshwater marsh. The marsh was controversial because it occupied space formerly occupied by salt water marsh. The marsh provides treatment for runoff from the Playa Vista Project as well as surrounding areas such as Loyola Marymount University. In the case of the Playa Vista Development, runoff is treated by state-of-the-art source controls even before it enters the fresh water marsh. The fresh water marsh provides habitat, buffers the runoff flow rate, and improves its quality before being released to Ballona Creek. Bird watchers are already "seeing" the benefits of the new habitat. Finally, the fresh water marsh also protects parts of the salt water wetlands from fresh water runoff, which can be toxic to a salt water marsh.

There are other accomplishments. The City of Los Angeles has committed to providing the low flow diversions of runoff to the Hyperion treatment plant for its storm drains entering Santa Monica Bay. This technology and several others were described in RC 1999. This is an example of a simple technology that utilizes existing infrastructure in a new and innovative way, at low cost to taxpayers. This method of treating low flow runoff in a separate sewer system, called a hybrid sewer system, is being copied around the State, and other agencies, such as the Orange County Sanitation District, have adopted the concept. The days of stormwater puddles on public beaches, like the beach south of the Santa Monica pier, from stormdrains like the Pico-Kenter drain, are over.

Beach water quality continues to be a problem, but we are making progress. New regulations enacted by AB411 require more frequent and improved monitoring. The regulations created more postings and it initially appeared our beach water quality was getting worse. Closer examination of beach postings and closures, such as those in Huntington Beach, revealed that many problems were either long term issues exposed by the new regulations, or problems the reg-

It is remarkable that litter management remains an environmental problem. It is entirely preventable.

Accumulation of litter at a storm drain in downtown Los Angeles.

ulations created. For this reason the results have been mixed and technological barriers remain.

Beach water quality is quantified by a suite of bacterial measurements. The two most common are coliforms and enterococcus, which are not true pathogens but associated with pathogens, and for this reason are called indicator organisms. Coliforms (strictly fecal and thermo tolerant coliforms) were used over the past century with great success in predicting the pathogenic content of drinking water and treated wastewater. They are problematic in surface waters such as stormwater, and often appear even when pathogens are not present. More importantly, they require too much time to measure. An analysis by the Southern California Coastal Water Research Project (SCCWRP) showed that as many as 70% of the beach postings due to high bacterial counts could be in error. The reason is described as follows: a sample is taken on day 1 and analyzed by a laboratory; on day 2 the laboratory reports a high bacteria count, the beach is posted and additional samples are collected; on day 3 the laboratory reports that the bacterial counts are low, the beach is safe and the posting is removed. The problem is that the beach should have been posted on day 1 when counts were high, but was posted on day 2 when counts were low. Our technology is not adequate to implement the spirit of the new regulation.

In spite of this problem, the new regulations have had major benefits. They have exposed chronic infrastructure problems at Avalon, on Catalina Island, which have now been repaired. In some locations they have quantified the positive impacts of BMPs such as low flow diversions. They have stimulated research on new methods for quantifying beach water quality, and we look forward to rapid, molecular biology techniques to cure the monitoring problems. The topic of beach water quality will be explored more fully in a future Report Card article.

We continue to struggle with other stormwater problems. In RC 2004, we described the total maximum daily load (TMDL) regulatory concept, and the benefits it is providing. Litter management was one example. We continue to struggle with litter and the TMDL is still opposed by some cities and groups. It is remarkable that litter management remains an environmental problem. It is entirely preventable. The photo above shows an all too familiar situation. Caltrans also reports the most common items recovered in highway litter are cigarette butts. The enactment of a one cent per pack tax on cigarettes or other high litter potential items, with revenues given to the agencies responsible for clean up, such as Caltrans, would help mitigate our litter problems.

TMDLs are being used by regulatory agencies to create consensus solutions to reduce pollution emissions at reduced cost. In RC 1999, we noted the major source of many pollutants was stormwater, and suggested focusing efforts and funds on solving stormwater problems

rather than on improving wastewater treatment for those plants that have achieved full secondary treatment and implemented nutrient removal. The new TMDL for mercury pollution enacted in the San Francisco Bay area is a good example of how the process can work. There are many sources of mercury, as well as legacy pollution from past practices such as gold mining that are still having significant impacts. The TMDL reviewed known sources of mercury and found the most cost effective and most sustainable methods to reduce mercury discharge. An old mining area was identified as a high emitter, stormwater runoff was targeted—taking advantage of the BMPs that will be implemented to reduce emissions for a large number of pollutants—and pollution prevention practices were stressed. Reducing emissions from dental amalgams, reducing the mercury content of fluorescent bulbs and ensuring they are properly recycled, are all promising alternatives. The discharges from treatment plants were not reduced, recognizing that emissions were already low and additional reductions would not be cost effective. A challenge still exists from mercury emissions from coal-burning power plants. This is another example of how more scientific regulations can help us attain our goals.

The most gratifying report we make is on the passage of Proposition O. Last year Los Angeles voters approved by a 74% majority the expenditure of $500 million for environmental improvements. This is undeniable proof the public wants, and will pay for, environmental improvements. This measure, and the others discussed, go a long way toward making it safe to swim in Santa Monica Bay after a storm.

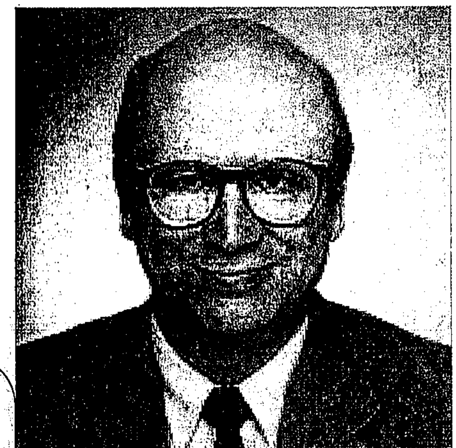
WATER RECLAMATION

RC 2002 described water reclamation efforts in Southern California, giving agencies an A for their efforts and the public a failing grade for not understanding the technology, and its risks and benefits. Water reclamation is an important resource because of the water supply problems described in the previous article.

There is some positive water reclamation news to report. The pioneering work at Water Factory 21 by the Orange County Water District, which reclaimed wastewater to prevent salt water intrusion and augment ground water supplies (a technology called indirect potable reclamation, see RC 2002) is being replaced by a project that is more than 10 times larger. The new project will receive treated wastewaters from the Orange County Sanitation District, reducing their discharge to the ocean. The new plant will treat the wastewater with new technologies, including micro-filtration, reverse osmosis and UV disinfection. The net result will be increased water supplies, reduced environmental impact on ocean waters, and reduced construction costs associated with deferring the need for an additional ocean diffuser.

Another example is the West Basin project, near El Segundo, which is using Hyperion Treatment Plant effluent to produce Title 22 reclaimed water, barrier water and industrial use water. Three major refineries have displaced large fractions of their fresh water use with reclaimed water. Ironically, this was done not to save money, but to create a secure water supply during the next drought.

The failure of the East Valley Water Reclamation Project has taught us that we need to better inform the public and politicians about the safety, risks and benefits of water reclamation.



Michael K. Stenstrom is a Professor in the Civil and Environmental Engineering Department at the University of California, Los Angeles. He has a Ph.D. in Environmental Systems Engineering from Clemson University (1976) and is a registered professional engineer in California. He has been with UCLA since 1977 and has served as Chair of the Civil and Environmental Engineering Department, Director of the Institute of the Environment, and Associate Dean of the Henry Samueli School of Engineering and Applied Science.

He teaches courses in water and wastewater treatment, mathematical modeling of environmental systems, and laboratory analysis. He has published over 200 papers in journals and conference proceedings. Stenstrom's most recent research focuses on stormwater management in highly urbanized environments such as Los Angeles.

Prior to joining UCLA, he worked for the Amoco Oil Company where he designed wastewater treatment facilities. He has won several awards including the Harrison Prescott Eddy Prize for innovative research (Water Environment Federation), the Walter L. Huber Award (ASCE), the Best Dissertation Award (Association of Environmental Engineering and Science Professors), the Dow Environmental Care Award, the Los Angeles Basin Section (California WEF) Research Award, and the EWRI Service Award.

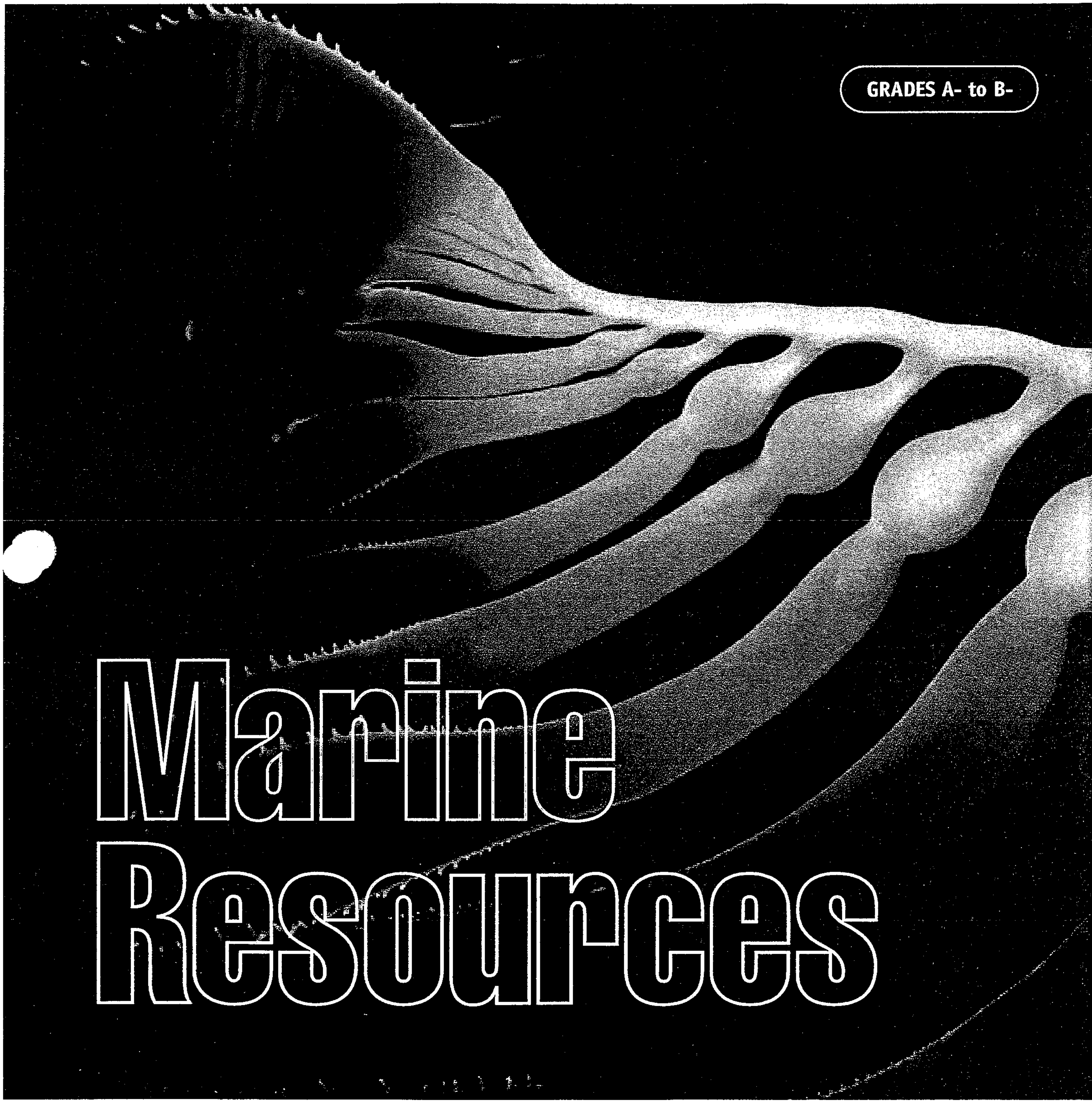
Agencies like the West Basin Facility will be providing water even during the next serious drought. This is one example of environmental improvements creating a better climate for business—a sustainable water supply.

Another positive development is the experience we have gained with failed projects. The failure of the East Valley Water Reclamation Project has taught us we need to better inform the public and politicians about the safety, risks and benefits of water reclamation. The plan died when it became a political football, with candidates for City offices wooing voters with statements like "toilet to tap" (see RC 2002 to learn why water reclamation is not toilet to tap). Voters and candidates need to understand that our water supplies already contain reclaimed wastewater, that we need to reclaim more in the future, and that it's low risk.

THE GRADES

We give mixed grades for the various responsible parties.

- The wastewater treatment agencies receive an **A** for complying with the Clean Water Act, being proactive in building new treatment plants and committing to improvements without lengthy legal fights.
- Our regulatory agencies, such as the Los Angeles Regional Water Quality Board, receive an **A** for adopting far reaching strategies that are sustainable, and using newer, more scientific approaches to regulation.
- The public receives a mixed grade—an **A** for supporting environmental improvements, such as Proposition O and secondary treatment at the Orange County Sanitation District, but an **F** for not working harder to solve problems like litter.
- Researchers receive a **C** for not being able to provide the needed technology to implement beach water quality regulations.


GRADES A- to B-
Marine
Resources

by Richard F. Ambrose, Ph.D.

Professor of Environmental Health Sciences, School of Public Health

As human use of ocean resources has grown over the past few decades, so has concern about impacts to these resources. At the national level, two blue-ribbon commissions have recently concluded that marine resources have declined to crisis levels, and that traditional management approaches must be changed radically to meet the challenge of protecting the nation's marine resources into the future. No similar comprehensive assessment has been conducted for marine resources in southern California, although there have been a number of narrower studies. This article focuses on Santa Monica Bay as an indicator of the state of southern California's marine resources.

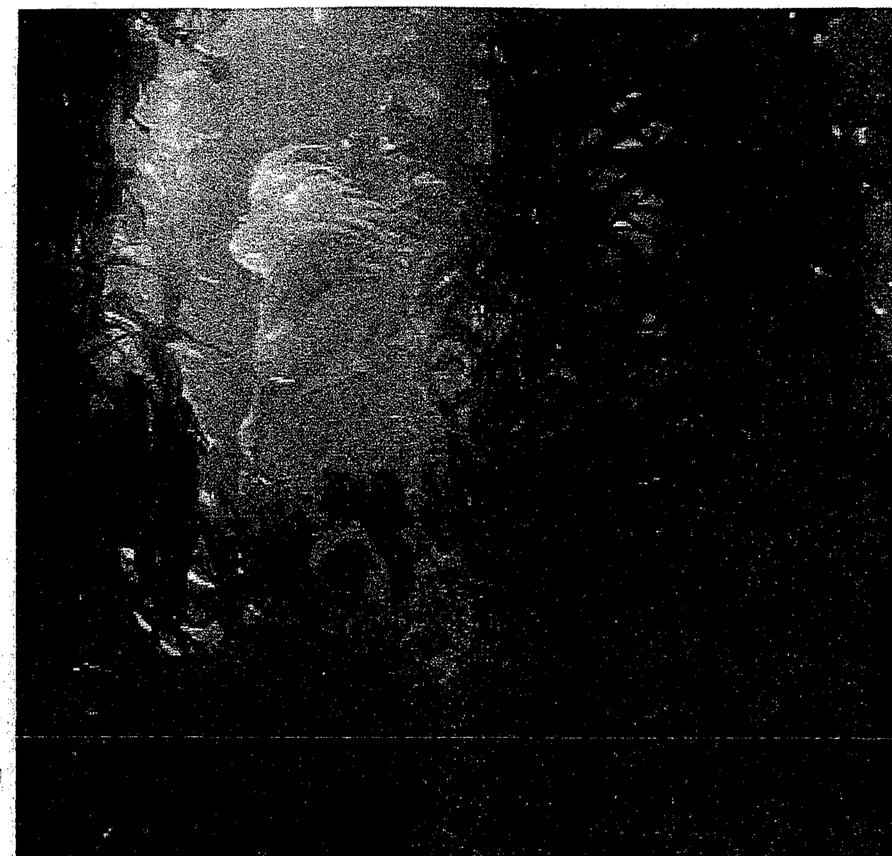
Located adjacent to one of the largest urban areas in the United States, Santa Monica Bay is a popular area for recreation by residents and visitors alike. Each year, the Bay's beaches attract 50-60 million people who contribute more than $200 million to the local economy. Stretching from the Palos Verdes Peninsula to Malibu, the Bay's most conspicuous amenity is its broad sandy beaches for bathing and swimming, but it also supports abundant biological resources.

The value of Santa Monica Bay was recognized for thousands of years by the native Chumash and Gabrieleno/Tongva tribes, who had dense settlements along its coast. After losing to San Pedro in a bid for a deepwater port in the 1890s, the Santa Monica area was developed to attract tourists. With good access from Los Angeles through a network of electric trolley cars, the areas of Santa Monica, Playa del Rey and Venice increased in popularity. Initially attracted by the climate and beaches, early Los Angelinos soon discovered the rich marine resources, including fishing and harvesting invertebrates such as abalone.

As elsewhere in the United States, the rising population of Los Angeles along with increased industrialization created environmental damage to the Bay, and pollution became severe. The Bay was used as the repository for millions of gallons of untreated sewage and industrial discharges, including dangerous chemicals such as DDT, and the living resources of the Bay were degraded. At the same time, commercial and recreational fishing pressure increased and, as elsewhere, fish populations declined. After several decades of environmental regulations and other efforts to reverse damage to the Bay, what is the status of its important marine resources?

RESOURCE STATUS AND TRENDS

Kelp Beds Kelp beds are restricted to rocky bottom habitats, which are concentrated around the Palos Verdes Peninsula and Malibu coastline. Kelp beds are naturally dynamic, being particularly affected by El Niño events when storms rip out large areas of kelp. In Santa Monica Bay, however, these natural fluctuations have been overridden by two long term trends. Around Palos Verdes, kelp beds were practically eliminated in the 1950-60s, due largely to pollution from wastewater discharges and the associated population explosion of kelp-eating sea urchins. However, following large-scale restoration efforts and the clean-up of the wastewater discharges, the Palos Verdes kelp beds have partly recovered, and they now represent a valuable resource in the region (see Figure 1).



Kelp is an important resource in the Santa Monica Bay.

Rocky intertidal sites in Santa Monica Bay are heavily used; popular sites may receive up to 50,000 visitors per year along one 100 meter stretch of coast.

Along the Malibu coastline, kelp beds experienced a precipitous decline during the 1980s—which itself was a continuation of a long-term decline from the early 1900s—from which they have not yet recovered. The cause of the decline is not known, but is believed to be related to increased development, and perhaps sedimentation, in the region. Recent surveys of hard bottom habitat along the Malibu coast shows much less rocky habitat than existed 100 years ago. Although the kelp beds off the Palos Verdes Peninsula appear somewhat more stable, these beds, like the Malibu beds, are substantially less extensive than they were in the early 1900s. Thus, kelp bed resources are much less abundant than they were a century ago.

Although today's giant kelp forests support a rich and varied community of fish, invertebrates and algae, the kelp forest community is dramatically different from the one present 100 years ago. Before being driven locally extinct due to hunting for the fur trade, sea otters were keystone predators who fed voraciously on sea urchins, crabs, abalone, and other bottom-dwelling species. Other top predators, especially black sea bass, have been reduced to such low abundances by fishing that they are ecologically extinct; that is, they no longer play the roles they once did in the natural ecosystem. These ecosystem effects from harvesting top predators persist today.

Rocky Intertidal Like kelp beds, rocky intertidal habitats occur in Palos Verdes and Malibu. These rocky areas are under water during high tide, but during low tide a rich variety of marine animals and plants are exposed to the air, making these two areas popular places to view marine life up close. Rocky intertidal sites in Santa Monica Bay are heavily used; popular sites may receive up to 50,000 visitors per year along one 100 meter stretch of coast (see Figure 2). Long-time visitors to rocky intertidal habitats often comment on how much the rocky intertidal community has changed, and recent studies have confirmed some species are less common at heavily used sites compared to lightly used sites.

In spite of a decades-old ban, DDT concentrations remain high around the Palos Verdes Peninsula.

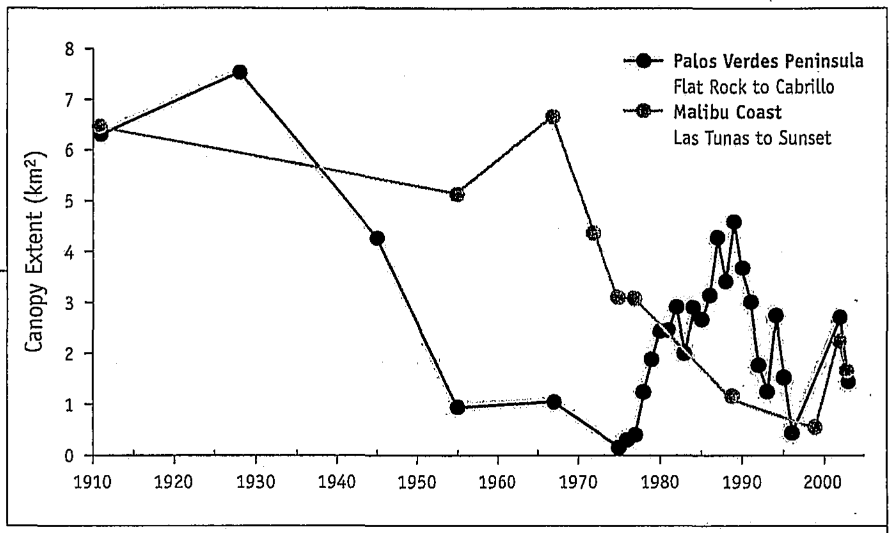


Figure 1. Change in kelp bed areas in Palos Verdes and Malibu over time. Data from California Department of Fish and Game and MBC Applied Environmental Sciences.

Other species, such as black abalone, have disappeared completely due to overharvesting. Few large individuals are found of a conspicuous limpet, the owl limpet, also due to overharvesting. The loss of large individuals may have greater population consequences for this species than one might expect because of its interesting life history: owl limpets start life as males and then change sex to females when they grow larger. Thus, harvesting the largest limpets removes most of the females from a population, reducing the population's chance to sustain itself. Other species are sensitive to trampling by visitors to the tidal area.

Although it is clear that collecting and trampling have affected many species, we don't know how much water quality problems are affecting intertidal organisms. Studies done in the 1950s indicated wastewater discharges reduced algal species diversity, and many studies have shown that intertidal organisms can be affected by water pollution. However, there are no recent studies to show whether intertidal organisms in Santa Monica Bay are currently being affected by poor water quality.

Soft Bottom Most of Santa Monica Bay consists of soft-bottom habitat. Until recently, the animals living in this habitat were severely affected by wastewater discharges, with areas around discharge points having degraded communities. Following improvements in sewage treatment beginning in the 1970s, these communities recovered well, and today the animals close to sewage discharge points are similar to those in other areas of the Bay.

DDT has had a particularly severe impact on the organisms of Santa Monica Bay, an impact felt throughout southern California. Montrose Chemical Corporation, a major manufacturer of DDT, discharged millions of pounds of DDT through the municipal sewer system and onto the Palos Verdes Shelf. Recent surveys estimate that more than 100 tons of DDT remain in the sediments off of Palos Verdes. DDT, which is bioconcentrated up the food chain, resulted in near-extinctions of some species (peregrine falcons, brown pelicans, bald eagles) and serious human health risks to people eating some fish species caught in the Bay. In spite of a decades-old ban, DDT concentrations remain high around the Palos Verdes Peninsula, and fish advisories still warn fishers not to consume a number of species caught in Santa Monica Bay.

Nonpoint source pollution is currently the major source of impact to the soft bottom community. This pollution source includes stormwater runoff as well

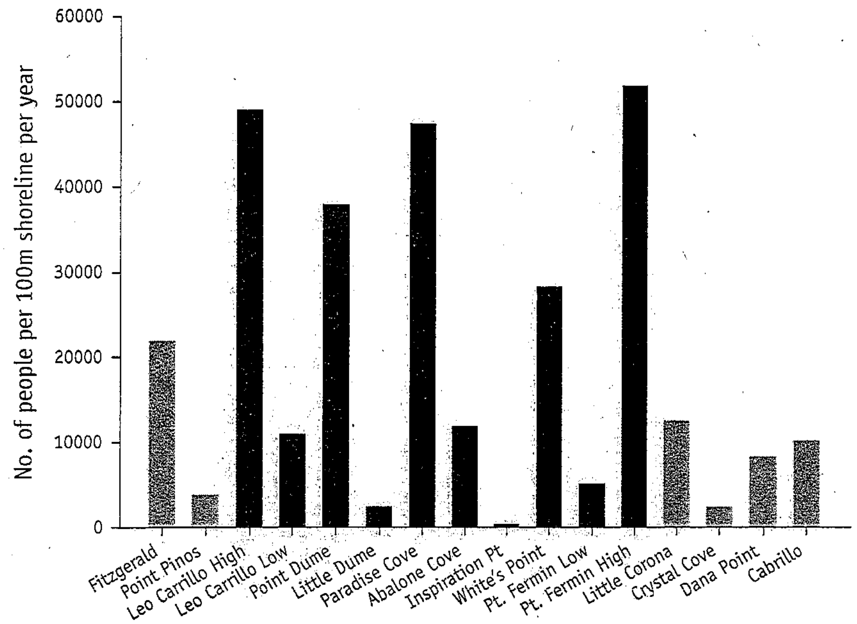


Figure 2. Visitor use at California intertidal sites. Data for Santa Monica Bay (dark bars) from Ambrose and Smith (2004); for other sites from various sources as summarized in Tenera (2003).

as dry weather flows resulting from irrigation and other types of runoff. As the regional human population grows, the amount of nonpoint source pollution grows, and efforts to control nonpoint sources have not been as effective as past efforts to control point source pollution. The previous article on water quality provides some reason for optimism in controlling nonpoint source pollution.

Fish In the 1960s and 1970s, concern about the health of Santa Monica Bay was heightened by the regular occurrence of clearly unhealthy fish with tumors, lesions and fin erosion. Following passage of the Clean Water Act and subsequent reduction of contaminants in wastewater discharges, water quality in the Bay improved (see below) and the number of fish with conspicuous anomalies decreased. Currently, individual fish appear to be healthy, although some species continue to have high concentrations of contaminants in their tissues (see DDT discussion above).

Although the health of individual fish is better than 30 years ago, the status of fish populations is largely unknown. The Bay once supported a commercial fishery, but commercial fishing has been banned from the Bay. Recreational fishing, however, is still popular from the shoreline, piers and boats. Surprisingly, there has been no systematic scientific assessment of fish populations in the Bay. As in many places, our information about fish populations in the Bay comes from fisheries data, principally the catch per unit effort of fishing. Since fishing effort and catch vary in response to changes in climate, availability of alternative fish species, and economic and other factors unrelated to the size of fish populations, fisheries data may not reflect the true status of fish populations. Since no fisheries-independent data are available, we do not know the status of fish stocks in Santa Monica Bay. What we do know about the fisheries suggests that some fish stocks are healthy, while others are likely depleted.

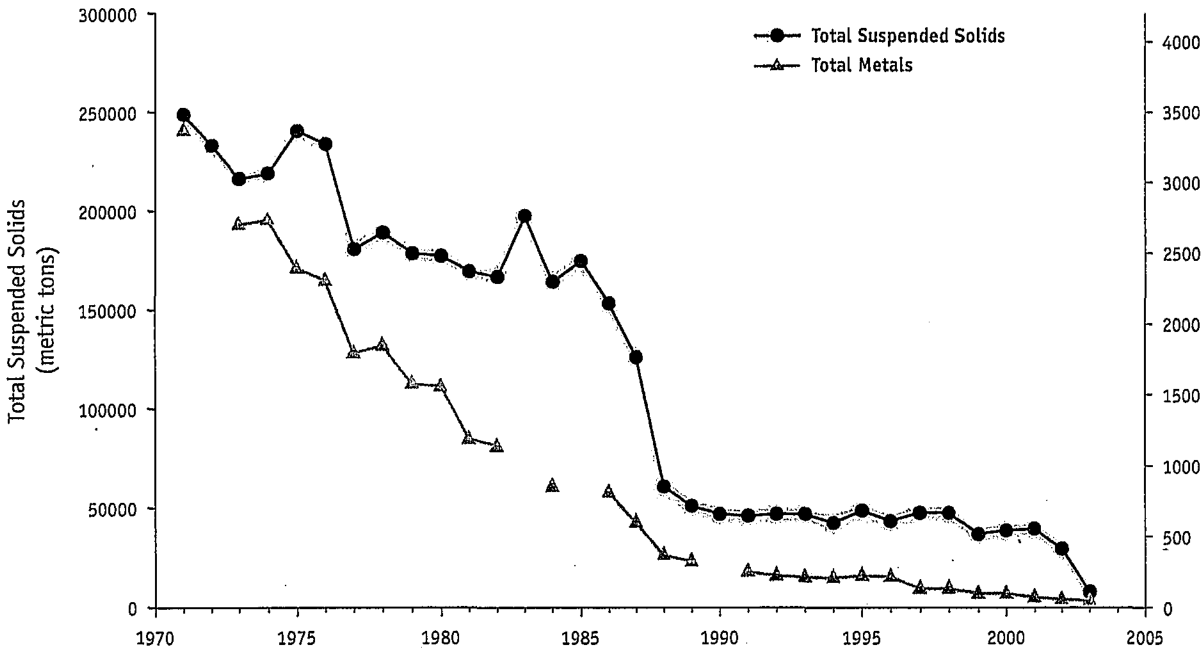


Figure 3. Decline of key pollutants after enactment of the Clean Water Act of 1972. Annual pollutant loads from Hyperion and JWPCP Wastewater Treatment Plants. Figure by permission of SMBRC; data sources SCCWRP, CLAEMD, LACSD.

MANAGEMENT

Concern about the health of Santa Monica Bay and its marine resources captured the public's attention in the 1960's, mirroring concerns throughout the United States about environmental degradation. Although not as dramatic as the 1969 conflagration of Cleveland's Cuyahoga River, tumors and lesions similar to those observed for Santa Monica Bay fish were found in fish throughout the country, and were partly responsible for the public concern that culminated in the passage of the Clean Water Act of 1972 (CWA). The CWA resulted in a rapid reduction in the contaminants in wastewater discharged to Santa Monica Bay (see Figure 3). However, the CWA was less successful at controlling the more diffuse non-point sources of contamination (such as storm drains). Although currently a number of efforts are underway to control pollution from non-point sources, this discrepancy reveals a limitation with the approach of using national legislation to protect local marine resources. As a consequence, the effectiveness of the Los Angeles Regional Water Quality Control Board, which implements most sections of the CWA in Santa Monica Bay, has been mixed.

In part because of these limitations, there have a number of key legal actions that have influenced the health of Santa Monica Bay. Lawsuits by environmental groups such as Heal the Bay, Natural Resources Defense Council and the Santa Monica Baykeeper have resulted in improved sewage treatment and the implementation of important water qual-

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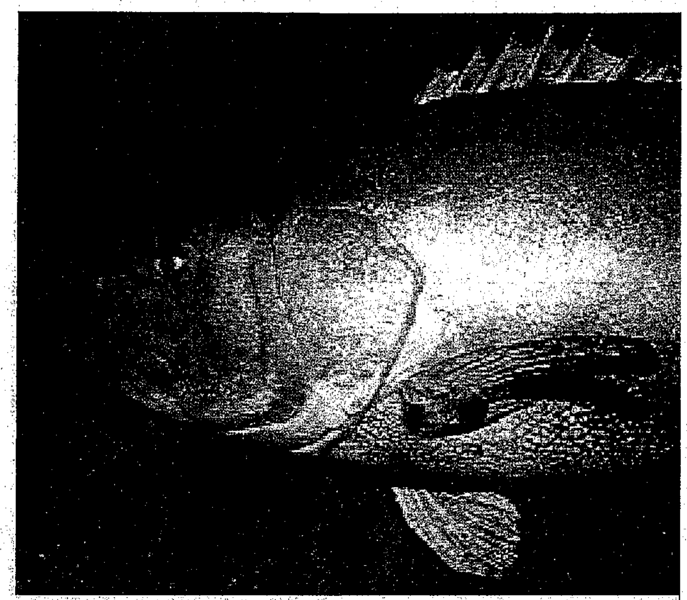
Black abalone was so heavily overharvested that it can no longer be found in the Santa Monica Bay.



Black sea bass are now ecologically extinct in the Santa Monica Bay.

ity regulations. As noted earlier, one of the most critical sources of pollution in Santa Monica Bay is the large deposit of DDT off the Palos Verdes Peninsula. In 1990, the U.S. Government and State of California filed suit under the federal Superfund law against Montrose Chemical Corporation (the manufacturer) and many other entities. The lawsuit was settled in 2000 for $140 million, to be used to restore affected bird and fish populations and to restore opportunities to fish for uncontaminated fish, as well as to address the contaminated sediments offshore and public health risks.

Since 1988, government efforts to clean up Santa Monica Bay have been guided by an unusual coordination of local, state and federal agencies and other local stakeholders through the Santa Monica Bay Restoration Commission (SMBRC). The SMBRC has created a vision for improving the Bay ecosystem, produced a management plan, coordinated efforts by various groups, and funded research to fill data gaps and projects to improve water quality or restore habitats.

Although substantial progress has been made towards reducing water pollution in the Bay, past efforts have focused less on protecting and restoring marine habitats. The scientific community has focused recently on the value of using Marine Protected Areas (MPAs) for both ecosystem protection and fisheries management, and the recent Marine Life Protection Act has initiated a process for developing a network of marine reserves in California. Despite good scientific evidence for the ecological benefits of marine reserves, their implementation has been controversial, particularly among sportfishing groups. Several MPAs already exist in Santa Monica Bay, but they provide little real protection to marine resources. There currently are no no-take marine reserves in the Bay that prohibit harvesting of all species. Moreover, even though collecting is prohibited at many of the popular rocky intertidal sites, there is little enforcement and collecting is rampant. Existing regulations also do nothing to

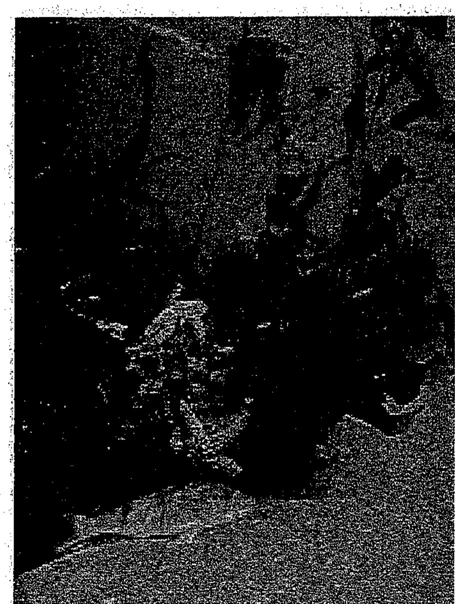
Perhaps the most encouraging sign about the future of marine resources in Santa Monica Bay is the tremendous public support for improving conditions in the Bay. The Bay enjoys substantial stakeholder involvement from organized environmental groups such as Heal the Bay and the Santa Monica Baykeeper as well as from many individuals.

reduce the impacts of trampling in the intertidal areas.

There have been relatively few attempts to restore the Bay's marine resources. Kelp restoration helped the Palos Verdes kelp beds to recover in the 1970s, and there are again efforts to restore kelp beds along the Malibu and Palos Verdes coastlines. The money from the settlement of the DDT lawsuit will be used for a variety of purposes, including restoring fishing opportunities and fish habitat in Santa Monica Bay, possibly by constructing artificial reefs in the Bay. Restoration of the Bay's rocky intertidal resources will depend on the elimination of both collection of intertidal organisms and trampling from visitors. Although this has been accomplished elsewhere in California, it would require a dramatic shift in attitude about open access to coastal habitats and there are currently no specific plans for implementing such a management technique in the Santa Monica Bay. It might be politically simpler to restore key intertidal species. For example, black abalone disappeared from Santa Monica Bay intertidal habitats after extensive harvesting, and they might be re-established at sites with adequate enforcement against collecting. However, their restoration is complicated by the fact that a disease has since virtually eliminated black abalone from southern California, so restoration would depend on the availability of resistant individuals.

Perhaps the most encouraging sign about the future of marine resources in Santa Monica Bay is the tremendous public support for improving conditions in the Bay. The Bay enjoys substantial stakeholder involvement from organized environmental groups such as Heal the Bay and the Santa Monica Baykeeper as well as from many individuals. Recently, there has been an influx of funds from bond acts and legislation for safer beaches, improved water quality, and preserving and restoring habitats. In 2000, State Propositions 12 and 13 passed, providing $2 billion for the acquisition and improvement of parks, including $700 million to the County and City of Los Angeles. In 2002, State Propositions 40 and 50 passed, providing $5 billion for clean drinking water, safe beaches and coastal waters, and wildlife and open space protection. Most recently, in November 2004 the voters of Los Angeles passed a $500 million bond act to help the City clean up stormwater.

There are currently many projects focused on implementing actions to improve the quality of water in the Bay as well as projects to restore kelp forests in the Bay. The challenges remaining are many, since the simplest and least expensive approaches have already been implemented. It is likely some species will not return to their former prominence for decades, if ever. Even in these cases, though, there is reason to be optimistic about their long-term prospects. For example, black sea bass have begun to recover after decades of low abundances through a combination of closure of the fishery and a ban on nearshore gillnet fishing that had been catching black sea bass incidentally. Most importantly, the commitment to protecting the marine resources of the Bay is strong and widespread, and with the recent availability of funds for water quality improvement and restoration, the prospects for improving the status of marine resources in the Bay are excellent.



Kelp forest in Malibu following restoration efforts.

The commitment to protecting the marine resources of the Bay is strong and widespread, and with the recent availability of funds for water quality improvement and restoration, the prospects for improving the status of marine resources in the Bay are excellent.

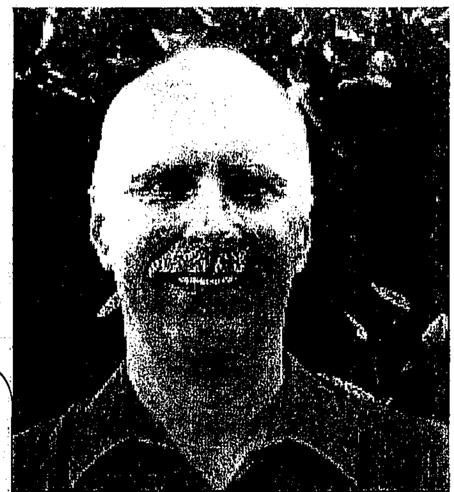
GRADES

Status Of The Resources The marine resources of Santa Monica Bay (and elsewhere in southern California) suffer from being so close to a large metropolis. The Bay's oceanography coupled with recent management actions result in a rich marine fauna and flora, certainly in better condition than it was 30 years ago but still suffering the effects of historic (e.g., removal of top predators) and recent (e.g., harvesting and trampling of rocky intertidal organisms) impacts. There are also critical gaps in our understanding about the status of some resources. The grade might drop to a C if, for example, studies demonstrate ongoing impacts of water quality on rocky reef organisms or depressed fish populations. **Grade B-**

Agencies Marine resources in Santa Monica Bay are managed and influenced by the actions of a broad array of local, state and federal agencies. Many of these have been effective at protecting and restoring the resources of the Bay. For example, the Santa Monica Bay Restoration Commission is focused entirely on the Bay, and the Los Angeles Regional Water Quality Control Board has been working hard to implement stormwater regulations that would protect the health of the Bay (given a grade of A in the 2004 Environmental Report Card). Some municipalities, such as Santa Monica, have acted decisively to minimize their impact on the Bay's resources. These agencies have had mixed success in protecting the Bay, however, in part because of the complexity of the environmental and political conditions. Moreover, a number of local governments (often those away from the coast, whose watersheds nonetheless drain into the Bay) have chosen to resist regulatory attempts to improve water quality. In addition, critical information gaps remain and the protection of rocky intertidal communities has been ineffective. **Grade B**

Community Support Santa Monica Bay enjoys tremendous support from the community. Non-profit groups such as Heal the Bay and the Santa Monica Baykeeper have played a critical role in focusing the public's attention on the problems of the Bay and in encouraging (sometimes through litigation) agencies to act to protect the Bay. These organizations provide a model for how science-based advocacy can influence environmental policy, with significant effects on the resources of the Bay. Local citizens have literally voted with their wallet, passing state and local propositions that are providing much-needed funds to improve the resources of the Bay. On the other hand, many members of the public remain ignorant or apathetic about their impacts on the resources of Santa Monica Bay, and the resulting non-point source pollution is a serious problem for the Bay. It is a difficult task, but agencies and non-profits

Yet many members of the public remain ignorant or apathetic about their impacts on the resources of Santa Monica Bay, and the resulting non-point source pollution is a serious problem for the Bay.



Richard F. Ambrose is Professor of Environmental Health Sciences and Director of the Environmental Science and Engineering Program in UCLA's School of Public Health. His research focuses on the ecological aspects of environmental problems, particularly in coastal environments. His current research includes the restoration of degraded wetlands and other coastal habitats; monitoring change in rocky intertidal habitats (with a particular focus on being able to detect effects of oil spills) using a network of monitoring sites throughout California, assessing human activities in rocky intertidal habitats and determining ways to restore degraded intertidal communities, evaluating alternatives for managing watershed-level ecological problems, and assessing the effectiveness of wetland mitigation required under the Clean Water Act. Professor Ambrose received his B.S. in Biological Sciences from UC Irvine and his Ph.D. in Marine Ecology from UCLA. He is Chair of the Scientific Advisory Panel of the California Coastal Commission overseeing a large marine mitigation project, and he serves on technical advisory panels for the Santa Monica Bay Restoration Commission and the Southern California Wetlands Recovery Project.

must do a better job educating the general public about how their activities impact Santa Monica Bay, and why they should care. **Grade A-**

ACKNOWLEDGEMENTS

Much of the information in this chapter was compiled by the Santa Monica Bay Restoration Commission (SMBRC) for its 2004 State of the Bay report.

I thank the SMBRC staff and my fellow Technical Advisory Committee members for their help in compiling these data. The SMBRC also supported the research on the impacts of visitors on rocky intertidal communities. The opinions expressed are those of the author.

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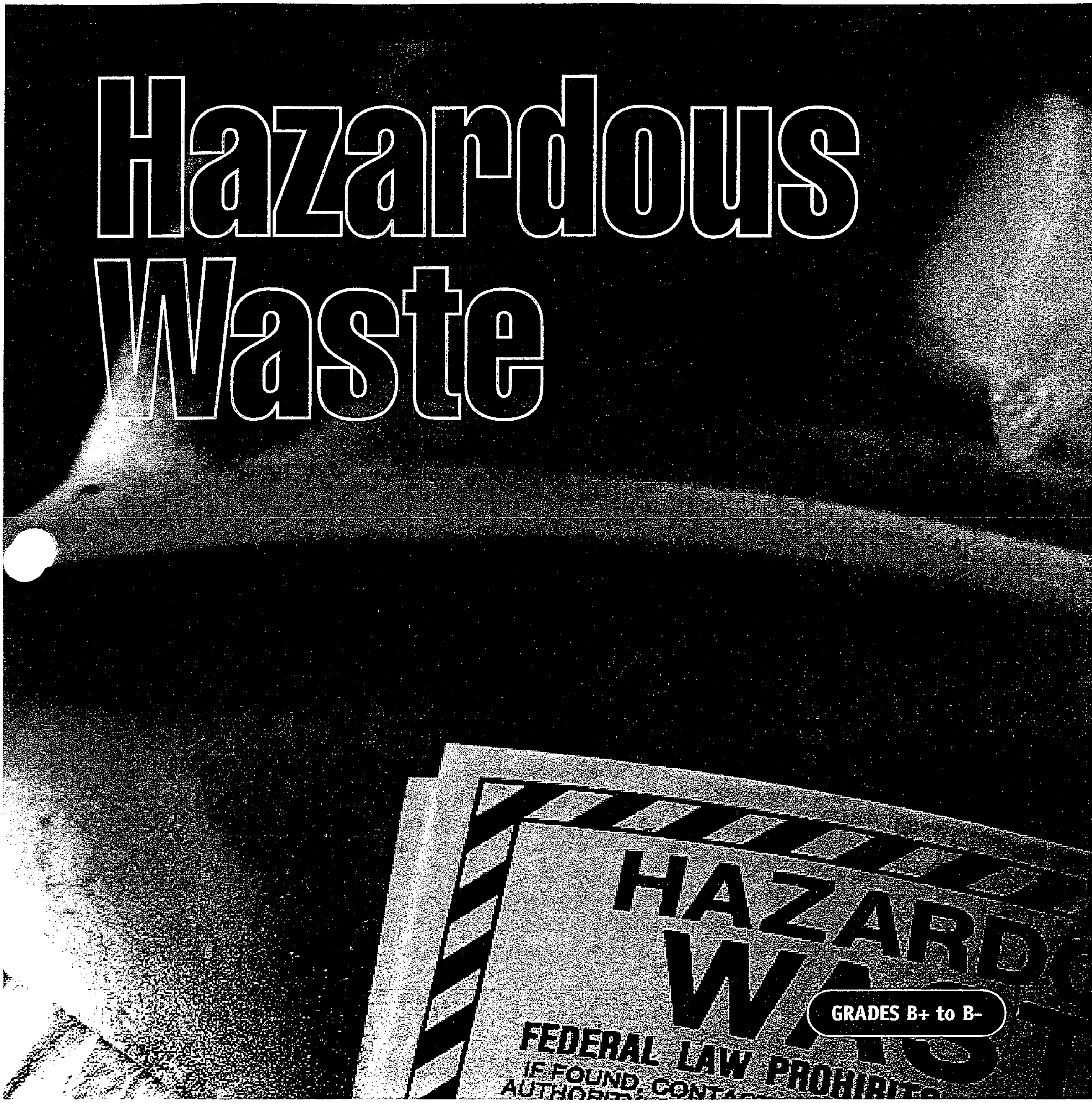
Hazardous Waste



GRADES B+ to B-

by W. Bowman Cutter, Ph.D., Assistant Professor, UC Riverside Department of Environmental Science
J.R. DeShazo, Ph.D., Associate Professor, UCLA Department of Public Policy

Southern California has experienced a variety of crises resulting from the release of hazardous waste and toxic substances. The mishandling of hazardous waste by industry has created the region's 23 superfund sites. Leaks from underground storage tanks, owned primarily by gas stations, have contaminated important sources of drinking water from groundwater. Soil contamination has led to difficult problems with urban redevelopment and school placement. These problems are particularly important because they degrade water and land resources, both of which are in short supply in Southern California.

Recently California restructured its regulatory approach to try to deal more effectively with these hazardous waste releases. We describe this effort, focusing upon the regulation of underground storage tanks and hazardous waste generators, and compare the regulatory performance of county and city governments in Southern California. Although we show that hazardous waste releases and underground storage tank leakages are declining, we document areas of inadequate rates of inspection, enforcement actions and compliance strategies. We conclude by recommending specific changes in 1) the targeting of oversight efforts towards counties rather than cities, 2) setting fees to more adequately support local staffing needs, 3) creating monitoring systems to track progress towards compliance once a violation is detected and 4) strengthening local legal capacity for enforcement.

REGULATORY RESTRUCTURING

Until 1993, the public response to problems of hazardous waste management was incomplete and fragmented. The prior approach was a poorly designed system of delegation to local governments. Under the overlapping jurisdiction of the State Water Quality Control Board, the Department of Toxic Substances Control, and CalEPA, over 1300 local government agencies had fragmented jurisdiction. Each agency regulated some aspect of hazardous waste generation or treatment, or storage by firms. This "let a thousand flowers bloom" approach to local regulation produced some excellent regulatory programs, but led to a lack of consistency and uniformity. Many businesses complained of confusing and contradictory requirements from multiple regulators with often overlapping responsibilities.

In 1993, then-Governor Pete Wilson supported legislation for the Certified Unified Program Agency (or CUPA) program, which mandated the consolidation of six major hazardous waste programs by 1997 into one agency in each responsible local government.[1] This push was driven in part by a desire to ease the regulatory burden on business by decreasing the number of overlapping inspections, fees, and permits. However, the legislation also contained provisions intended to improve the monitoring and enforcement of hazardous waste laws, requiring that every area be under the jurisdiction of a county or city CUPA and instituting minimum inspection procedures and frequencies.

The CUPA program generally operates under the auspices of the Federal Resource Conservation and Recovery Act (RCRA). RCRA mandates the tracking and monitoring of hazardous waste from its generation to its disposal. The

Leaking underground storage tanks and hazardous waste generators represent the two largest toxic threats in Southern California.

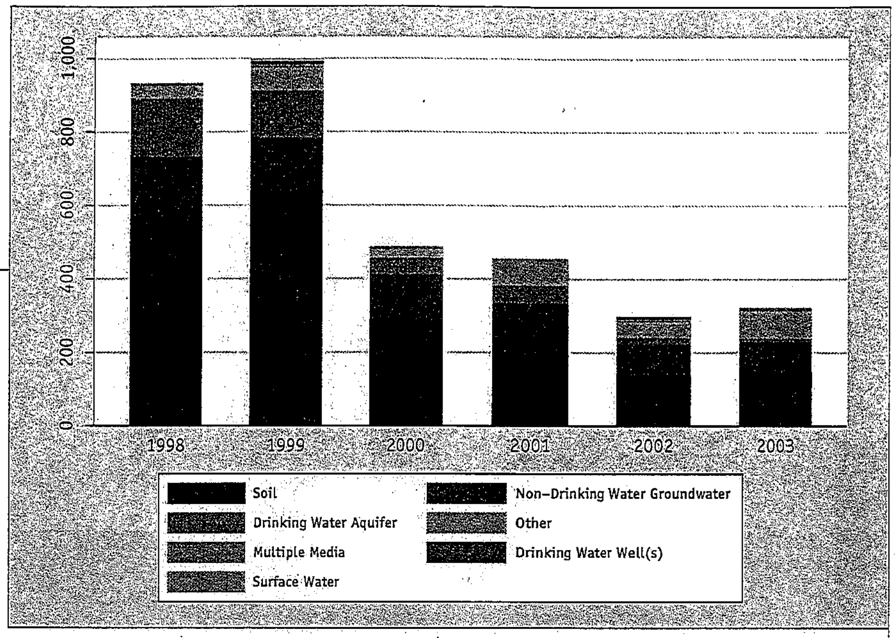


Figure 1. Reported leaks from underground storage tanks by media affected.

Department of Toxics Substances Control (DTSC) is charged with ensuring that RCRA requirements are followed in California. It delegates authority to local governments who implement the CUPA program through inspections and enforcement actions in four areas: storage tanks, hazardous waste generating facilities, safety plans for hazardous waste releases, and treatment and recycling facilities. The DTSC then oversees CUPA efforts and is directly responsible for some larger facilities.

An interesting feature of the CUPA program is that cities can assume responsibility for implementing hazardous waste programs if they petition their surrounding county and it approves. This selection process has produced a set of cities with distinctive characteristics. One might expect that volunteer cities are likely to prefer a higher level of regulation than their surrounding county. The state and the surrounding county are likely to veto cities that might want lower levels in light of the state minimum inspection regime and other performance requirements. As we will see shortly, this conjecture turns out to be true in the case of the underground storage tank (UST) and hazardous waste generator (HWG) programs, where various indicators of regulatory effort show the involved cities are doing a better job of regulation than counties.

LEAKING UNDERGROUND STORAGE TANK REGULATION

Each of the seven Southern California counties has designated one of its agencies (commonly their environmental, public health, or fire departments) as its CUPA agency. In addition, 11 cities have volunteered to run CUPA agencies. Among CUPA programs, the leaking underground storage tanks and hazardous waste generators represent the two largest toxic threats in Southern California. The principal public concern about underground storage tanks in recent years has been the contamination of groundwater supplies with MTBE, a gasoline additive. In response to the MTBE crisis, California increased the required inspection frequency for tanks from triennially to annually, effective in FY 2000-01. Another concern about CUPAs is whether they have the ability to carry out their enforcement responsibilities, in part because localities must involve the local District Attorney for many types of violations. In response,

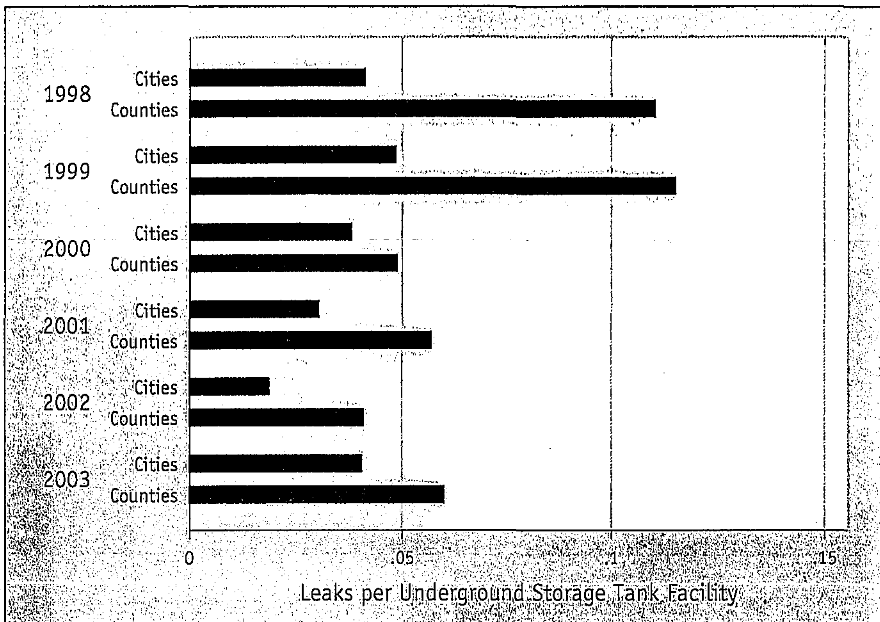


Figure 2. Reported leaks from underground storage tanks.

Cities on average do far more inspections per underground storage tank facility than counties.

there are ongoing efforts to provide all CUPAs with an administrative enforcement ability to avoid using the DA and to save costs.

Issues of groundwater contamination, especially by MTBE, have grown in importance. The CUPAs are the front-line regulators of USTs, which are responsible for the lion's share of MTBE contamination, as well as contributing to other soil and water contamination. A key event in UST regulation was the requirement that all tanks be upgraded to new, more leak-proof standards by the end of 1998. By the end of 1999, most tanks were in compliance. The data from Southern California show that the tank standards upgrade seems to have reduced the number of leaks substantially.

Because most of the leaks from USTs occur in the county CUPA's jurisdiction (as opposed to in the 11 cities), it is not surprising these declines in leaks mostly occurred in the County CUPA. Figure 2 shows a similar trend for the average number of leaks per facility with a UST.

The average rate of leaks has declined in both the city and county CUPAs since tanks were upgraded to the 1998 requirements. The graphs also raise several interesting questions. For example, the decrease in the leak rate is much more substantial for counties. The graph also shows that cities on average have fewer leaks per UST facility, even in the post 1999 period, at a time when there should not be significant differences in tank construction. It is also difficult to attribute these differences to differences in the size or type of facilities between cities and counties, since well over 90% of the UST facilities are gas stations which almost all have the same number of USTs (3 to 4 on average).

What accounts for the differences between cities and counties? The intensity of regulation may account for some of this observed difference in leak rates. Cities on average do far more inspections per UST facility than counties. Over the entire period of CUPA operation, cities conducted close to double the number of inspections that counties did (about 1.1 inspections/year for cities versus about 0.6 inspections/year by counties). For the recent period of FY 2001-2003, cities conducted approximately 1.2 inspections per year while counties have improved to 0.63 inspections per year. Our data show counties are not meeting the State requirement of annual inspections whereas cities are slightly above the requirement. In FY 2003 only 1 of 6

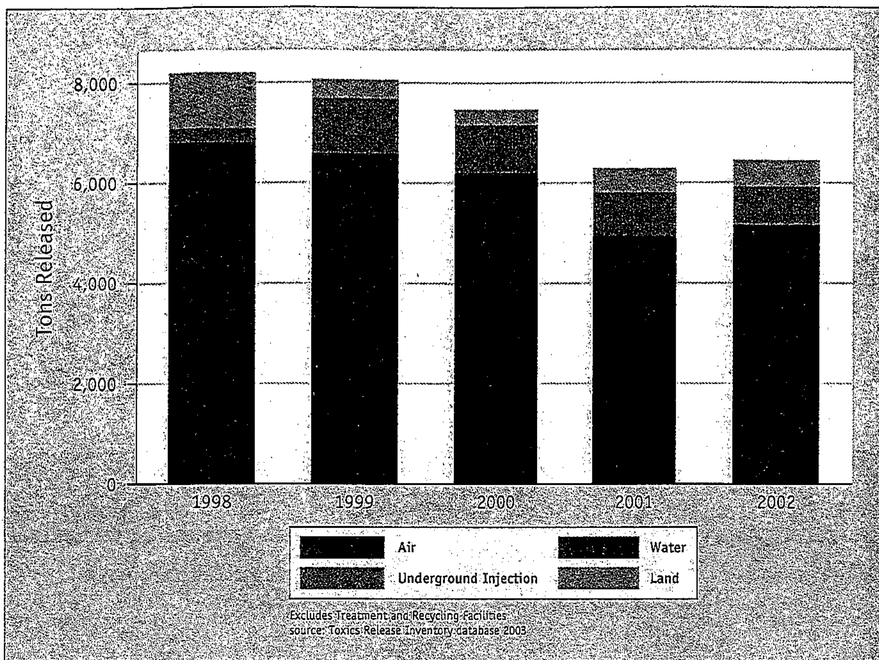


Figure 3. Hazardous waste environmental releases.

counties averaged at least 1 inspection/year while 8 of 11 cities averaged at least annual inspections in the UST program. These proportions persist to the present time.

Of course inspections are just one part of the enforcement story. For effective enforcement, local governments must follow up on inspections by correcting any violations they find through formal or informal enforcement actions. Again, it appears cities are outperforming counties when we look at the ratio of enforcement actions to violations. In recent years (FY 2001-2003), the weighted average[2] of enforcement actions/violations shows cities respond with almost twice as many enforcement actions for each violation. Counties do pursue more formal enforcement actions—civil, criminal, or administrative cases—which are more likely to produce larger fines. This may be because lower levels of monitoring mean that violations become more egregious before they are discovered.

The City CUPA programs appear to be generally in compliance with state requirements and to be pursuing vigorous UST regulatory enforcement programs. However, the county CUPAs have much more work to do to raise their inspection frequency up to state-mandated minimums. In addition, it appears the County CUPAs can do more to pursue the violations they do uncover in their inspections. Recently introduced State legislation that would give all CUPAs the ability to assess administrative penalties might assist the counties in increasing their enforcement. The combination of greater inspection and enforcement frequency could help counties lower the tank leak incidence rate to city levels and slow further degradation of Southern California's soil and water.

HAZARDOUS WASTE MANAGEMENT REGULATION

The Hazardous Waste Generators and Large Quantity Generators programs regulate a wide variety of businesses from small paint shops to dry cleaners to large manufacturing concerns. Unlike the UST program, the state does not track all releases of pollutants from facilities in these programs. However, the federal Toxics Release Inventory (TRI) database tracks hazardous waste releases from a wide variety of (mostly manufacturing) facilities. The TRI database overlaps con-

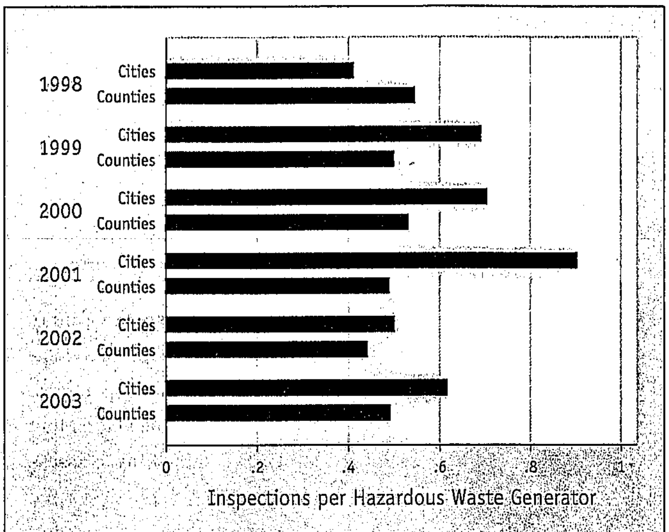


Figure 4. Mean inspections per facility for hazardous waste generators.

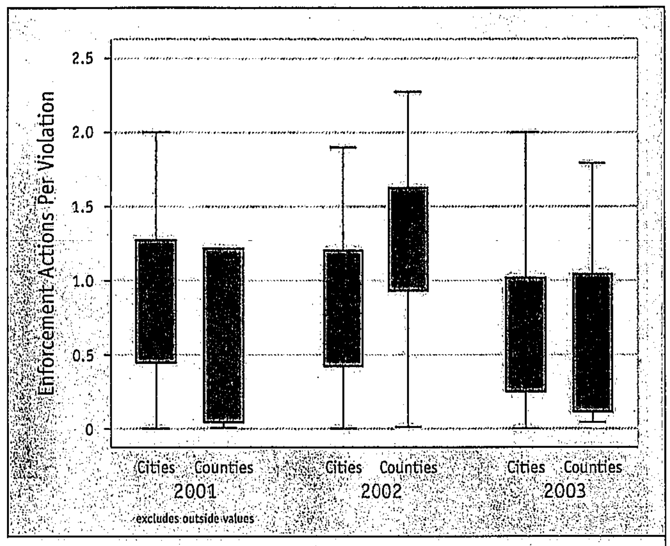


Figure 5. Enforcement rates per violation for hazardous waste generators.

siderably with the firms in these programs and gives us our best picture of toxic pollutant trends in Southern California.

Figure 3 shows total tons of hazardous waste environmental releases in Southern California.[3] For all years, about 80% of environmental releases are airborne, with the rest split between underground injection and soil. Since the inception of the CUPA program, total releases are down 27%. The CUPA program may be responsible for some portion of that decline, but it is likely that larger economic factors such as the decline in industrial output in Southern California explains some of the decline.

An examination of inspection rates again shows cities doing more than counties. Over FY 2001-2003, cities averaged 0.81 inspections/facility per year while counties averaged 0.43. Although this gap is narrowing it is due to a drop in cities' inspection rates, declining to 0.65 inspections/facility per year while counties remained at a rate of 0.43.

For the large quantity generators, there are not large city-county differences. Counties undertake slightly more inspections per year but this is probably because cities have few or no Large Quantity Generators.

Figure 4 shows the inspection rate trends for Hazardous Waste Generators. We computed a 3-year average of inspections/facility to determine whether jurisdictions were on average completing enough inspections to meet state requirements. Under this measure, by 2003 9 of the 11 cities and 4 of 7 counties were making enough inspections to fulfill state requirements. Cities are doing better than counties on this measure, but a slight majority of counties are completing enough inspections to fulfill their requirements.

Our final measure of regulatory effort is the enforcement rate. Figure 5 shows the distribution of enforcement rates. The median enforcement rates for both cities and counties hover around 1.0, meaning on average Hazardous Waste Generator violations are followed up by at least one informal or formal enforcement action. There are no significant differences between cities and counties on this measure.

Bowman Cutter is an Assistant Professor of water resources management at U.C. Riverside in the Department of Environmental Science. His research examines environmental regulation, the effects of the federal and state division of responsibility over environmental programs, and state and local environmental enforcement efforts. Current projects examine the effect of water pricing on water pollution and analyzing the cost-effectiveness of using stormwater to recharge Los Angeles area aquifers. He worked on environmental and agricultural topics in the Peace Corps in Bolivia and received his Ph.D. in economics from UCLA.

Local governments must follow up on inspections by correcting any violations they find through formal or informal enforcement actions. Again, it appears cities are outperforming counties.

RECOMMENDATIONS AND CONCLUSIONS

In Southern California, there has been a substantial reduction in environmental releases of hazardous waste since the inception of the CUPA program but significant improvements are needed to achieve uniform compliance with the goals of the Resource Conservation and Recovery Act and state statutes.

Cities are by and large putting enough effort into their inspection programs to fulfill state requirements, although the declining inspection rates for cities in the past several years bear watching. However, a much smaller proportion of counties are conducting enough inspections to satisfy state requirements. Clearly, the remaining counties need to improve their efforts, especially since the triennial inspection standard that we used to judge their performance is a low bar to meet.

Two policy changes would improve inspection behavior by CUPA. First, many CUPAs implement inspection fee structures that partially or fully support the staffing levels needed to achieve compliance. One way to increase CUPAs' enforcement capacity is for the State (via the Department of Toxic Substance Control) to set minimum fees based on the cost of fully-compliant inspection rates. This minimum fee structure should be based on the CUPA with the lowest statewide costs and indexed to the state rate of wage inflation. Second, the Department of Toxic Substance Control needs to increase its technical assistance and its oversight to counties. Both actions are needed since counties appear less able and willing to undertake adequate inspections.

The adequacy of CUPA enforcement behavior is much harder to evaluate.[4] This is because no firm-specific violation or enforcement data are currently

The combination of greater inspection and enforcement frequency could help counties lower the tank leak incidence rate to city levels and slow further degradation of Southern California's soil and water degradation.

reported. More critically, the CUPAs do not have a system to monitor whether compliance occurs after a violation is identified. The Department of Toxic Substance Control should support the creation of a common uniform database that tracks firms' progression from the initial discovery of violation through enforcement, if any is needed, and back into a state of compliance. In addition, the State has long recognized the need to strengthen CUPA's legal capacity to develop the evidentiary basis for prosecuting violators. Better tracking and documenting the extent of firms' non-compliance behavior would also strengthen CUPA legal capacity.

GRADES

Cities **B+**
Counties **B-**

NOTES

1. Under and above-ground storage tanks, Hazardous Waste Generators, California Accidental Release Prevention Program (CalARP), Hazardous Release Response Plans and Inventories (HMMRP), Permit by Rule, and Large Quantity Generators.

2. Weighting by number of UST facilities, so that small jurisdictions do not overly sway the mean.

3. These facilities also generate waste that is transferred off-site for recycling or disposal, but we do not include this waste because it may not end up in Southern California and because there may be some double-counting of these transfers in the current TRI database.

4. Both the Legislative Analyst's Office ("Analysis of the 2000-01 Budget Bill: State Agencies Can Do More") and the California State Auditor ("DTSC: The Generator Fee Structure is Unfair, Recycling Efforts Require Improvements, and State and Local Agencies Need to Fully Implement the Unified Program") have noted weaknesses in CUPA enforcement capabilities and performance.

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About the UCLA Institute of the Environment

WHAT IS THE IOE?

We are a community of scholars focused on finding sustainable solutions to major environmental problems. Our members and constituents represent a broad array of academic disciplines, research interests, policy concerns and outreach avenues. Los Angeles is our home, and it provides a rich mixture of urban environmental health challenges and opportunities for enhanced resource management. But our interests span the globe, from tropical ecosystems to innovative energy technologies.

WHAT DO WE DO?

- We create partnerships for new research that cross the traditional boundaries of science, social science, humanities, law, business, public health and public policy, to name a few.
- We develop new policy solutions that affect the global, regional and local environments, and work with non-governmental organizations, including businesses and environmental organizations, as well as government agencies to maintain a lively debate.
- We develop educational programs to meet the needs of today's students, whether they are environmental professionals or citizens of the world.

UCLA

THE NEW "GREEN" HEADQUARTERS FOR THE UCLA IOE

In June, 2005, the UCLA Institute of the Environment moved its headquarters into the third floor of the newly constructed La Kretz Hall, a three-story, 20,000-square-foot facility named for UCLA alumnus Morton La Kretz, the principal donor to the $8.5 million project. It is the first certified "green" building on the UCLA campus.

La Kretz Hall will provide classrooms for undergraduate education and distance learning, office space, and facilities for academic conferences. A conference center on the first floor includes a 350-seat auditorium, two 20-seat breakout seminar rooms, and a 45-seat classroom that can be equipped for distance-learning classes.

La Kretz Hall was designed by The Smith Group architectural firm and constructed by West Coast Nielsen.

WHAT DOES IT MEAN TO BE "GREEN"?

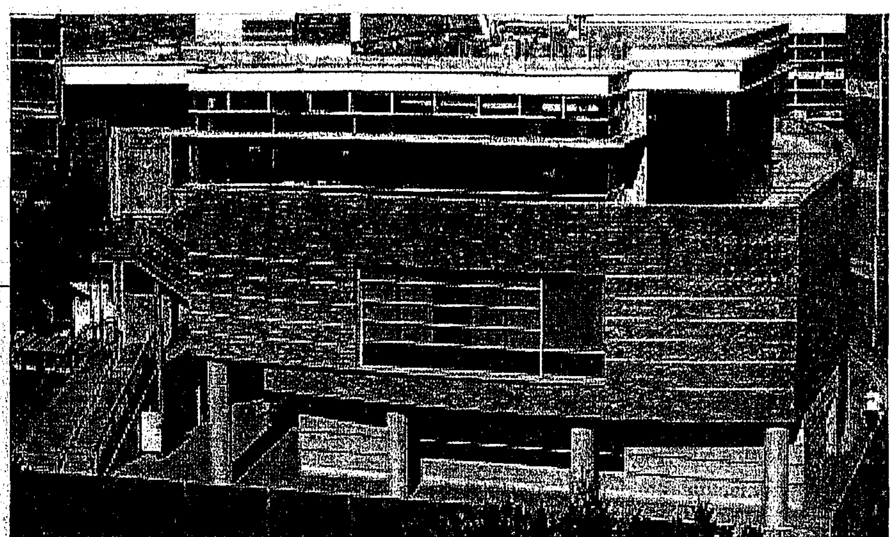
Rapidly renewable and low-emitting materials, operable windows, and low energy consumption will make La Kretz Hall the first UCLA facility certified by the prestigious U.S. Green Building Council LEED (Leadership in Energy and Environmental Design) Green Building Rating System.

The efficient mechanical systems in La Kretz Hall have sensors to measure and verify carbon dioxide content and overall air quality, providing a better working environment and lowering the building's energy consumption. The design includes infrastructure for future installation of building-integrated photovoltaic (BIPV) panels to provide a renewable source of energy. A displacement air system, which supplies ventilation from the floor rather than the ceiling, will reduce electricity usage even further. To encourage bicycle commuting, members of the Institute of the Environment will have access to protected bicycle storage, changing rooms and showers.

The building sits on top of an existing 5-million gallon tank, which supplies chilled water to UCLA's air conditioning systems. Stacking the new construction above an existing structure allowed the university to save valuable land space and avoid the environmental impact of developing a new site.

Other "green" design aspects of La Kretz Hall that satisfy certification standards of the US Green Building Council include:

- Use of recycled materials in construction. The building steel contains 80% recycled content. Other materials, such as rebar, concrete, gypsum wall board, miscellaneous metals, and concrete treads also use recycled content



La Kretz Hall

- Reuse of existing land, reducing the environmental impact of the new construction
- Light colored paving based on the UCLA standard, and an Energy Star roof to eliminate the "heat island effect"
- Interior and exterior lighting is designed to permit views of the night sky and reduce the impact on the nocturnal environment
- Carbon dioxide monitors guarantee indoor air quality
- Drought-tolerant plants instead of paving, and vines to cover the water tank and minimize storm water runoff, increase on-site filtration and reduce contaminants
- Premium water efficiency inside the building, which uses 20% less water than required by the Energy Policy Act of 1992, including water-conserving plumbing fixtures that exceed EPA requirements
- Heating, ventilation, air conditioning, service hot water, lighting, and other regulated systems are all designed to reduce energy use and cost
- Natural ventilation and displacement supply in the auditorium
- Accessible areas are dedicated to separation, collection and storage for recycling paper, glass, plastics and metals generated by building users
- Low-emitting materials including adhesives, paints, coatings, carpet, and composite wood
- Use of recycled furniture and flooring throughout the IoE offices.

From the Director, continued

Behind the Report Card are two very talented editors, Ann Carlson and Arthur Winer. These two professors took on the responsibility of selecting the authors and working with them to put the articles into a format that includes high-level graphics and illustrations, then shepherding the whole document through publication and release, for the second consecutive year. Their dedication to the environment is remarkable. Happily, they are not alone at UCLA in their enthusiasm for tackling multi-disciplinary, multi-faceted environmental problems.

This has been a landmark year for UCLA's Institute of the Environment. Our new office, atop La Kretz Hall, gives us a light-filled, highly functional, energy efficient space from which to carry out our mission of bringing people together to think about ways to address important environmental issues through interdisciplinary research, teaching and public service. Nearly 400 guests (including our benefactor Morton La Kretz and his family) attended the opening ceremony in the new science lecture hall that fills most of the lower two floors. The guests were treated to a provocative lecture by Professor Jared Diamond, whose latest book, Collapse, reminds us of the ways in which many formerly vital societies in the past have vanished because they failed to recognize the need to change in the face of a loss of important natural resources. The Report Card essays remind us that while there is much to encourage us in Southern California's efforts to grapple with the threats of pollution, waste and changing climate, we have a long way to go to achieve a healthy and sustainable environment. The authors have provided some of their own ideas and proposals; to continue the conversation, please visit the IoE website and feel free to communicate with us at our new address, shown inside the front cover.

RC 2005

Southern California Environmental Report Card 2005
UCLA Institute of the Environment

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A009630

SAMPLING ISSUES: COMPOSITES VERSUS GRABS

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ABSTRACT

Stormwater monitoring generally uses flow-weighted composite samplers to collect a representative sample of an entire storm event. Composite samplers are convenient but unfortunately they can be expensive, especially for temporary sampling needs or for research projects. An alternative method is to use a series of grab samples. This paper examines the relationship between a finite number of grab samples and an automated composite sampler. Both sampling techniques were simulated using runoff data collected from a three-year investigation of three highway sites. It is shown that a large number of grab samples is needed to approximate the flow weighted composite sample. Thirty grab samples per storm event provided a good estimate of a composite sample. To detect a first flush, it is necessary to take even more samples or to weight the samples towards the beginning of the storm. The superiority of the automatic sampling equipment is demonstrated.

INTRODUCTION

Event mean concentrations (EMCs) have been extensively used in the past to characterize stormwater pollutant loads. The EMC, by its name, represents the average concentration of the pollutant throughout the storm event. They differ from grab samples in that they estimate an entire event, as opposed to a single point in an event. EMCs are generally required for most monitoring programs.

Practically, an EMC is estimated from either an automated composite sampler or a series of grab samples taken during a storm event. When estimating EMCs from grab samples, each grab sample represents an instant concentration of pollutants within a storm event, and the EMC is calculated from these instant concentration values. A reasonable calculation method, used by many authors (Charbeneau and Barrett, 1998; Wu et al., 1998, among others) is to use a discharge-weighted average of these instant concentrations.

Automatic samplers are often preferred because they can be operated remotely and can be programmed to respond to a variety of conditions, including the start of a rainfall event. They operate by collecting a large number of individual samples (100 or more), forming a series of instant concentration samples. The EMC is equal to the result of analyzing the single, large sample. However, in this case, EMCs can still mathematically be viewed as a result from instant concentration measurements.

The goal of this paper is to compare the reliability of EMC data from the aspect of their estimation. A mathematical definition and its related calculation forms will be introduced first. Next a stochastic approach with computer simulations will be used to evaluate the error associated with limited numbers of samples. In the theory part, the objective is toward general cases, not parameter or site specific. In the computer simulation part, a pre-described concentration model will be used for a particular case, in which the field data were collected from three highway-monitoring sites for two seasons (1999-2001). Therefore, the simulation results are representative and useful in designing storm water monitoring programs. This paper presents only the methods and results of a more in-depth study (Ma, 2002), which should be consulted for additional information.

METHODOLOGY

Mathematically, EMCs can be defined as total pollutant mass (*M*) discharged during an event divided by total volume (*V*) discharge of the storm event.

$$EMC = \frac{M}{V} = \frac{\int C(t)Q(t)dt}{\int Q(t)dt} \tag{1}$$

In equation 1, *C(t)* is a smooth real-valued function of time that represents the pollutant concentration curve, and *Q(t)* is also a smooth real-valued function of time that represents the stormwater discharge flow rate curve. However, in practice, we estimate the integrals not by the functions of *Q(t)* and *C(t)* but by the measurements of *Q(t)* and *C(t)*. We estimate the EMC from discrete values. If we assume we measure the concentration and the discharge rate based on equal time-interval in a storm event, the EMC can be estimated as

$$EMC = \frac{\sum_i c_i q_i}{\sum_i q_i} \tag{2}$$

where q_i and c_i are the measurements for the discharge rate and pollutant concentration in the i^{th} interval. From the point of view of approximating the continuous functions in equation 1, the more measurements we take, the more accurate approximation we can obtain by equation 2.

When we view the measurements of the discharge rate as the weights, equation 2 becomes the discharge-weighted average throughout the storm event.

$$EMC = \sum_i w_i c_i \tag{3}$$

$$w_i = \frac{q_i}{\sum_i q_i} \tag{4}$$

where w_i is the flow weight, and $\sum_{i=1}^{n} w_i = 1$. In practice, one common situation is the number of concentration measurements does not match the number of discharge measurements. Generally there are many fewer concentration measurements, because concentration measurements are much more expensive and time consuming; discharge measurements can be easily and automatically obtained by the instrument. For most situations we have to adjust the weights for each concentration measurement in equation 3. One of the reasonable ways to adjust the weights is to use the discharge volume. One approach (Charbeneau and Barrett, 1998) splits the discharge volume from the mid-point between two consecutive concentration measurements. Figure 1 shows this approach, and the adjusted weight can be written as:

$$w_i = \frac{V_i}{\sum_i V_i} \tag{5}$$

where V_i is the corresponding discharge volume for the i^{th} concentration measurement. This mid-discharge splitting method can also be applied for measurements at unequal time-interval bases. Alternatively, if the concentration measurements are based on constant discharge volume, the weighted average of $w_i c_i$ from is reduced to the arithmetic average. Ideally, automated samplers can collect samples in proportion to discharge volume. Additionally there are always slight errors (noise) in sample volume and pace that change the equal weights. Thus, EMC is still an inherent weighted average of concentration measurements.

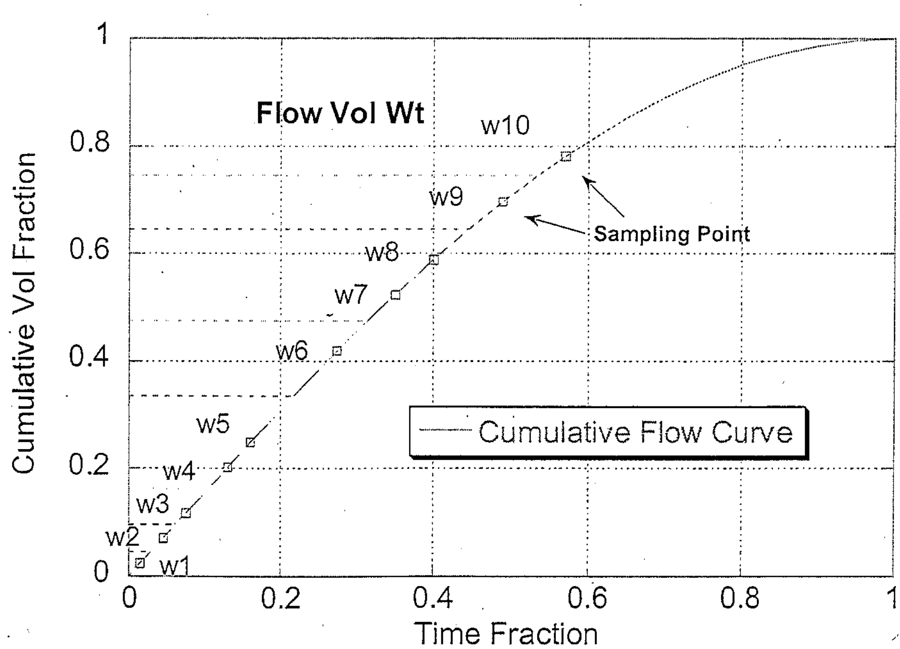


Figure 1 Determination of Flow Weights (w1 to w10) for Grab Samples

COMPUTER SIMULATIONS OF EMCS

A previously developed COD regression model will be used in this simulation, described as follows:

$$E(\log COD \mid \mathbf{x}) = 6.08 - 0.60 \log CumRs + 0.40 \log AtDry - 0.16 \log AtRs \qquad (6)$$

where,

COD = chemical oxygen demand concentration (mg/L),
CumRs = cumulative rainfall, corresponding to grab sample collection time, (0.01 inch increments),
AtDry = antecedent dry period before monitored events, days and
AtRs = previous event's precipitation before the monitored event, (0.01 inch increments)

Figure 2 shows the model's fitted values vs. the observations. The COD model can be used to predict any number of concentrations for a given hydrograph. In this way, collecting any number of grab samples can be simulated. A random component is added (white noise) which has mean zero and a variance equal to the variance in the original data. A special simulation will use equation 6 to generate COD concentrations at one-minute intervals. This special simulation will be used as the benchmark in simulation tasks and is the shortest possible sampling frequency, since the rainfall and flow data are collected at one-minute intervals. The EMC is then calculated using equation 3, where the weights are the discharge rates.

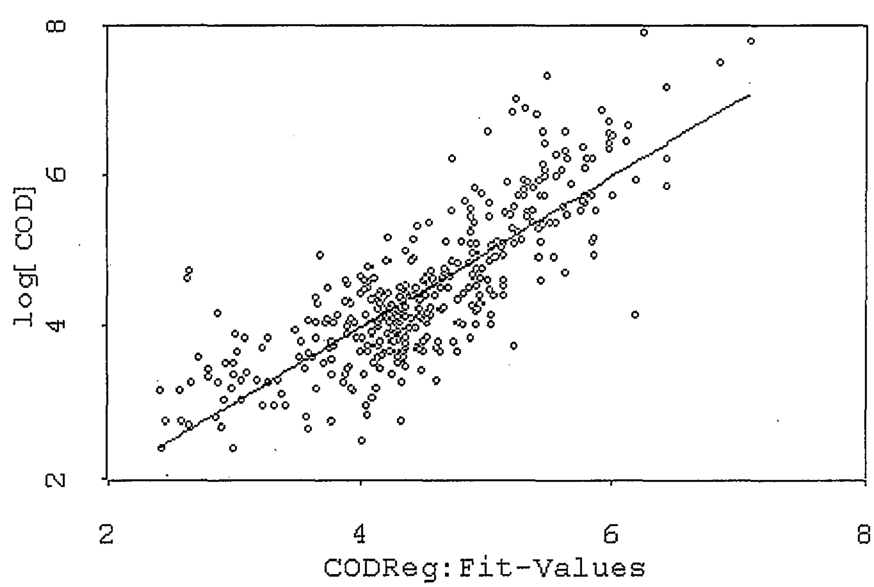


Figure 2 Regression's Fitted Values vs. Observation

In order to illustrate this one-minute simulation, one real event is used for demonstration. Figure 3 shows the original and the smoothed event hydrographs. The smoothed hydrograph will be used in simulation to correct fluctuations in original data. Figure 4 shows the histogram of 1000 simulated EMCs. The original sample mean is 116.36 (mg/L), and the mean of the simulations is 116.25 (mg/L).

To compare other sampling strategies, simulations were performed using different numbers and different strategies for collecting samples during typical storm events (e.g., random, equally spaced in time, equal volume, etc.). A total of 35 different rainfall patterns, corresponding to actual observed patterns in our monitoring program, were used. Table 1 summaries the events. Each type of simulation will generate a distribution of EMCs after multiple runs. Simulations that use more samples will produce EMCs that are closer to the original sample EMC. The value of differing numbers of samples as well as the strategy can be compared.

Five types of sampling strategies were evaluated. Type 1 used random timing of the samples. The simulation assumes a sample set with specified size (n) that is randomly collected from all possible time elements during each tested event. It is a random permutation of size n for a sequence. Theoretically, this is the most general case for a sample set with fixed size. The influence of sample size on EMC results is evaluated simulating 10, 20, 40, 60, and 100 samples per event. Type 2 used equal-time sampling. To avoid the extreme result of a sample sequence, each selected sample sequence was randomly shifted forward or backward in a range (10 minutes). Type 3 used equal-rainfall interval sampling by simulating the sample collection at equal intervals of rainfall depths. Type 4 used equal discharge-volume sampling. No weighting noise was assumed in this task (i.e., the weightings are perfectly known, without measurement error). Type 5 was similar to Type 4, except that random noise was applied to the weighting factors (i.e., the discharged volumes cannot be perfectly measured).

Table 1 Hydrologic Characteristics for 35 Monitored Events

Hydrologic Property	Average	StdDev	Minimum	Median	Maximum
Total Rainfall (in)	1.17	1.54	0.08	0.67	6.14
Max Rain Intensity (in/hr)	0.31	0.33	0.02	0.19	1.28
Discharge Volume (gal)	75022	99293	1799.5	36808	374217
Max Discharge Rate (gpm)	340	304	17	258	1465
Rain Duration (min)	660.5	512.7	93	610	2376

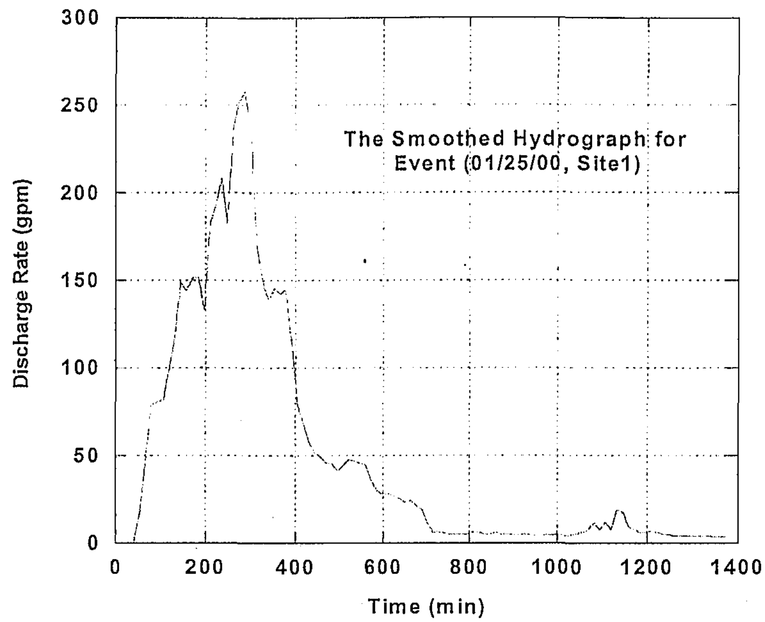


Figure 3 Smoothed Hydrographs (event recorded on 01/25/00, Site 1)

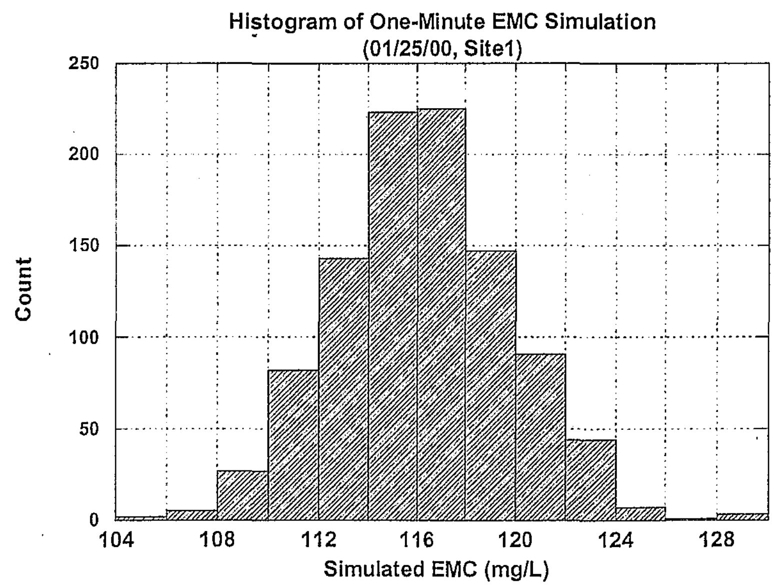


Figure 4 Sampling Distribution for One-Minute EMC Simulation (event recorded on 01/25/00, Site 1)

RESULTS AND DISCUSSION

The results of the various simulations for different types of sampling strategies are presented in a series of figures. The figures show the distribution of simulated EMCs for each number of samples. Figure 5 (top) is a box plot and shows the results for Type 1. The worst error percentage can be up to 80% for $n = 10$. The average error percentages for $n = 10, 20, 40, 60$, and 100, are 47.0%, 30.2%, 19.5%, 15.3%, and 11.6% respectively. The medians of errors are slightly lower than the averages. The corresponding standard deviations are 13.9%, 7.2%, 4.1%, 2.9% and 2.2%. Type 1 is a benchmark on the influence of sample size for estimating EMCs, and is the most general sampling strategy.

Figure 5 (middle) shows the sample distributions Type 2. Only one outlier was found for each n. The worst case is for $n = 10$ with error of approximately 66%, which is much improved over Type 1. The average error percentages for $n = 10, 20, 40, 60$, and 100, are 37.2%, 21.7%, 15.2%, 12.4%, and 9.2% respectively. The medians of errors are generally the same as the averages. The corresponding standard deviations are 11.1%, 4.4%, 2.7%, 2.8% and 1.7%. These statistics show an improvement over random sampling.

Figure 5 (bottom) shows the sample distributions from Type 3. Although several outliers were found for $n = 10$, the worst case is approximately 30%, which is much improved over Type 2. The average error percentages for $n = 10, 20, 40, 60$, and 100, are 23.9%, 17.5%, 13.5%, 11.9%, and 10.5% respectively. The medians of errors are generally the same as the averages. The corresponding standard deviations are 2.2%, 2.2%, 2.6%, 3.2% and 3.7%, a large improvement over time sampling.

Figure 6 (top) shows the sample distributions from Type 4. It is obvious on plot that this is the best result from the aspect of outliers, averages, or variances. The average error percentages for $n = 10, 20, 40, 60$, and 100, are 23%, 16.6%, 12.0%, 9.7%, and 7.5% respectively. The medians are generally the same as the averages. The corresponding standard deviations are 2.5%, 1.6%, 1.2%, 1.0% and 0.7%. Figure 6 (bottom) shows the sample distributions for Type 5. This is the same strategy as Type 4, except that the weights are not perfectly measured. The average error percentages for $n = 10, 20, 40, 60$, and 100, are 23.5%, 17.1%, 12.3%, 10.1%, and 7.8% respectively. The corresponding standard deviations are 2.1%, 1.6%, 1.3%, 0.9% and 0.8%. The effect of imperfect weights is not very large.

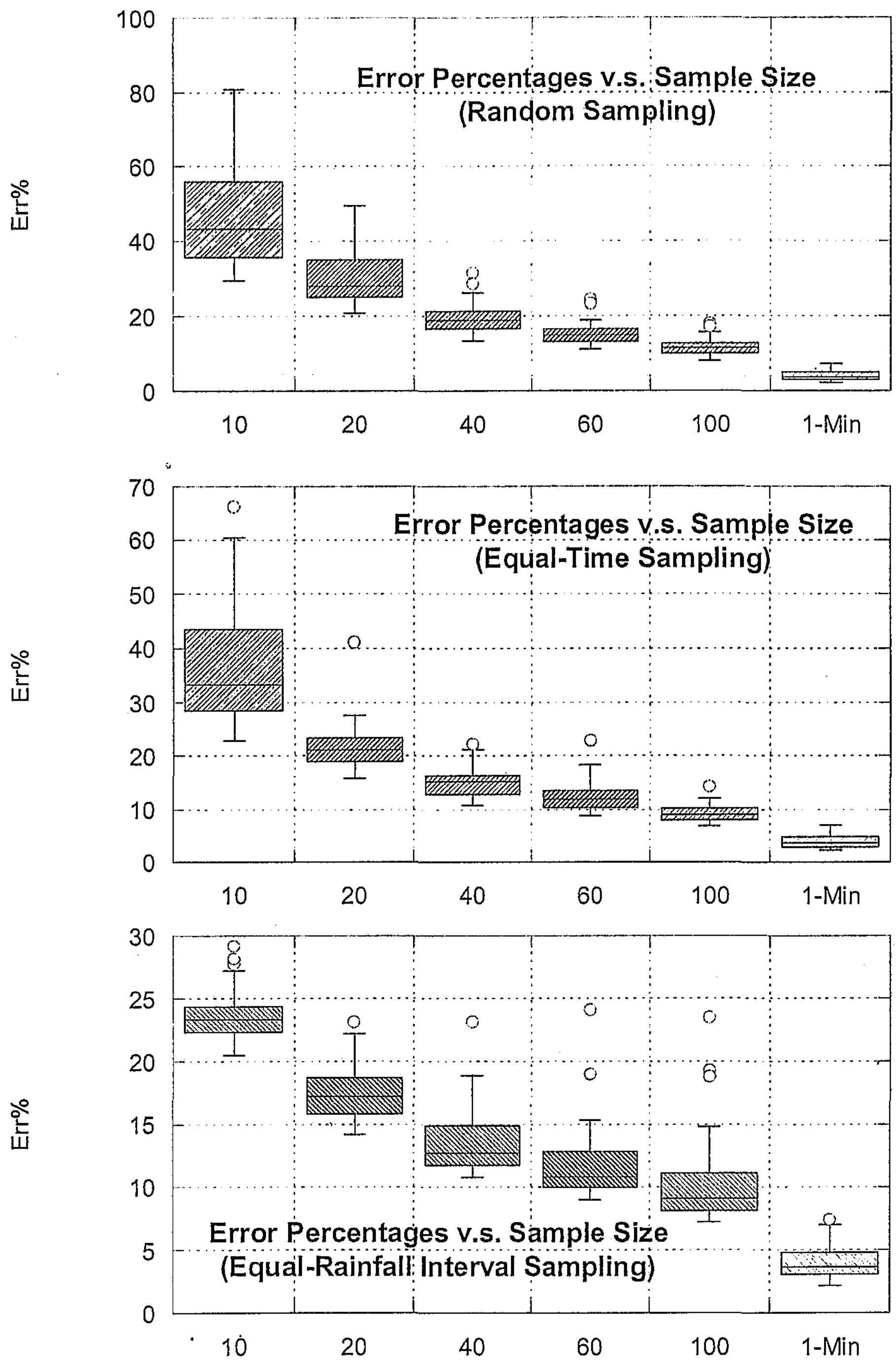
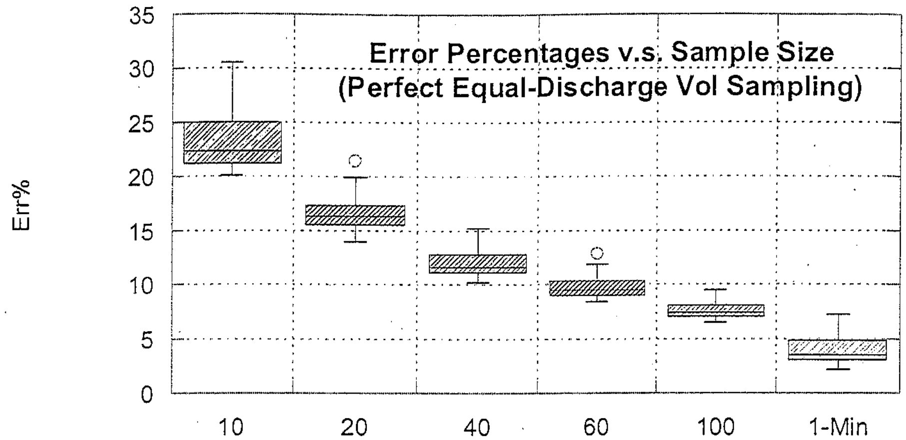


Figure 5 Sampling Distributions for Random Time (top), Equal Time (middle) and Equal Rainfall Interval (bottom) (with n = 10, 20, 40, 60, and 100) plus One-Minute Simulation



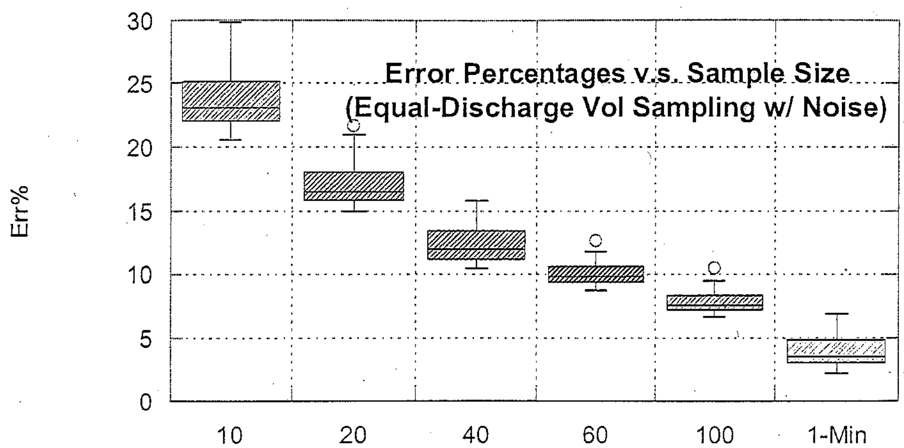


Figure 6 Sampling Distributions for Perfect Equal-Discharge Volume Sampling (top) and Equal-Discharge Volume Sampling with Noise (bottom) (as n = 10, 20, 40, 60, and 100) plus One-Minute Simulation.

CONCLUSIONS

This paper has shown that a flow weighted composite sample can be viewed as a series of grab samples summed with weights that reflect the flow. To evaluate the error of using a limited number of grab samples and the strategy for collecting the samples, a series of simulations was performed using a COD correlation, random noise and hydrographs from 35 different storm events.

The results show that a series of 10 grab samples provides a relatively poor estimate of the EMC, with median errors of 40% for randomly timed samples to 23% for samples collected at equal flow volumes. If the number of grab samples increases to 20, the error is reduced to 30% for randomly timed samples to 16% for samples collected at equal flow volumes. Even if 100 samples are collected, the error is still nearly twice as large as the minimum possible error, when samples are collected each minute.

The best strategy is to collect the grab samples at equal flow volume intervals. Equal rainfall interval is the second choice, with equal timing and random timing being less desirable strategies.

The results show that automatic flow weighted composite samples, which can be programmed to collect several hundred samples per storm, are far superior than a collection of grab samples, even if 100 grab samples are used. If automatic composite samplers can be used without chemical or physical biases (e.g., such as the concerns of sample carry-over when sampling for oil and grease, or the introduction of artifactual toxicity), they are always preferred.

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ACKNOWLEDGEMENTS

This project was supported by the Division of Environmental Analysis, California Department of Transportation through a contract with the University of California and task order 43A0073.

California Department of Health Services

Recommended Methods for the Analysis of Recreational Marine Water to Comply with AB 411

Last Update: March 28, 2000

The following methods are recommended by the Environmental Laboratory Accreditation Program (ELAP) and the Microbiological Disease Laboratory (MDL) for the analysis of recreational marine wa for compliance with Health and Safety Code §115880 [Assembly Bill 411 (AB 411), Statutes of 199 Chapter 765].

Recommended Methods for the Analysis of Recreational Marine Water for AB 411	
TOTAL COLIFORM BACTERIA	
Total Coliform by Multiple Tube Fermentation (MTF)	SM 9221 B (1,2)
Total Coliform by Membrane Filtration (MF) Using m-Endo	SM 9222 B (1,2)
See comments below on **Colilert™ 18 Medium (IDEXX) (Quanti-Tray™) for total coliforms**	
FECAL COLIFORM BACTERIA	
Fecal Coliform* by Multiple Tube Fermentation (MTF) Using EC Medium	SM 9221 C, E (1,2)
Fecal Coliform* by Membrane Filtration Using m-FC (7,8)	SM 9222 D (1,2)
* With the written approval of the local health officer and with data showing comparative numbers for fecal coliforms and *E. coli*, a laboratory may instead test for *E. coli*, a subset of fecal coliforms (US EPA's definition), using Colilert™ 18 Medium (IDEXX). Guidance on comparative testing is available in **DHS Salt Water Beaches Guidance**. Comparative testing must be performed only by laboratories certified by ELAP for the methods being compared. Laboratories must retain the results of the parallel testing in their files, consistent with their record retention procedures, and must make these data available for review upon request by the State.	
ENTEROCOCCUS BACTERIA	
Enterococci by Membrane Filtration (MF) Using mE (9) or mEI (11)	SM 9230 C (1,2) EPA Method 1600 (10)
Enterococci by Enterolert™ (3,4,5)	IDEXX Co.

JUSTIFICATION:

- The US EPA in its publication *Ambient Water Quality Criteria for Bacteria –1986* (13) has recommended the use of *E. coli* or enterococci for testing fresh waters and enterococci only for marine waters.

- AB 411 and its implementing regulations require that marine water be tested for total coliforms, fecal colifo and enterococci.

- Testing for three groups of indicator organisms with traditional methods for water testing requires much sta time, media and equipment space. Streamlined test methods with fast turnaround times and acceptable da are desired.

- Because of these concerns, ELAP and MDL reviewed the published literature to see if we could justify the of two rapid methods using chromogenic/ fluorogenic substrates, one that identifies both total coliforms an *coli* (5,10) and the other, enterococci.(3,4,5)

- A number of laboratories have indicated a desire to test for *E. coli* in place of fecal coliforms. In US EPA's *Action Plan for Beaches and Recreational Waters* (14), *E. coli* is defined as "a subset of the fecal coliform group that is part of the normal intestinal flora in humans and animals and is, therefore, a direct indicator o fecal contamination of the water." *E. coli* is considered to be a more specific indicator of fecal contaminatio (6,13)

- Colilert™ 18 Medium (IDEXX) (Quanti-Tray™) is being used by these laboratories to report *E. coli* in place fecal coliforms.

Each method has its advantages and its shortcomings. Since California is examining marine water for thr groups of indicator organisms, it is felt that, based on EPA's definition of *E. coli*, public health will not be compromised if ELAP is flexible on the substitution of *E.coli* for fecal coliforms.

- Colilert 18 is not recommended for the enumeration of total coliforms from marine water. Published studies suggest there are substantial false positives, yielding higher total coliform counts from marine water. (5,12) However, it is recognized that this method is easy to use, gives rapid and sensitive results, and has greate precision, when used for quantitative information, than the multiple tube fermentation test.

- If Colilert 18 is to be used for AB 411 monitoring for total coliforms it must be acknowledged that this meth may result in an overestimation of true total coliform numbers, which errors in favor of protecting public hea Total coliform results that repeatedly exceed the AB 411 standards should be verified with a more conservative method. Such tests must be performed only by laboratories certified by ELAP for the method.

- Enterolert™ medium in Quanti-Trays™ (IDEXX) is a 24-hour method for enterococci. Published literature supporting the use of this medium is available (3,4,5). The medium is approved for use in some states for th testing of marine recreational water.

Review of Available Methods:

Methods	Pros	Cons
Total Coliforms		
Multiple Tube Fermentation (MTF)	Much historical data. Substantial scientific support. Allows testing of all kinds of waters, including colored and turbid.	Requires up to 4 days for completion. Requires increase in tubes, media incubator space, labor and time. Imprecision of MPN enumeration. 95% confidence limits are broad.
Membrane Filtration (MF)	Substantial scientific support. Much historical data. A direct count of organisms.	Can require up to 3 days for completion. Verification of colonies required.

	Greater precision and accuracy.	May not pick up viable but stresse organisms. Not all waters can be filtered. Technically more complex than other methods. Labor intensive.
Colilert™ 18 Quanti-Tray	Easy to use. More sensitive. Results in 24 hrs. Greater precision in quantitation compared with MTF (5 tube mpn) Less staff time, media and incubator space required.	Substantial false positives with marine water yielding higher counts than MTF method.[12]
Fecal Coliforms or *E. coli*		
Multiple Tube Fermentation (MTF) for fecal coliforms	Much historical data. Substantial scientific support. Allows testing of all kinds of waters, including colored and turbid.	Requires up to 4 days for completion. Requires increase in tubes, media, incubator space, labor and time. Not all thermal tolerant fecal coliforms are *E. coli* .[1,2] Imprecision of MPN enumeration. 95 % confidence limits are broad.
Membrane Filtration (MF) for fecal coliforms	Much historical data. Substantial scientific support. Provides direct count of organisms.	Can require up to 3 days for completion. Verification of colonies required. Not all waters can be filtered. Technically more complex than other methods. Not all thermal tolerant fecal coliforms are *E.coli*
Colilert™ 18 Quanti-Tray™ for *E. coli*	Easy to use. Results in 24 hrs. Greater precision in quantitation compared with MTF. Sensitive *E. coli* is a (usually major) subset of fecal coliforms.	Not listed as one of the organism: required by AB 411. Not all *E. coli* are mug positive – false negatives; not all fluorescen organisms are *E. coli* – false positives.[12]

June Kani, ELAP, and Dan Mills, Ph.D., MDL

3/24/00

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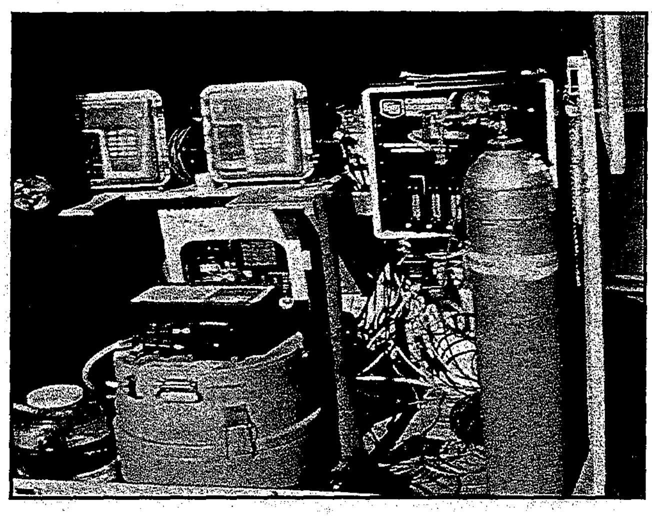
MS4 Project

Evaluation of NPDES Phase I Municipal Stormwater Monitoring Data



USGS Stormwater Monitoring Station in Madison , WI

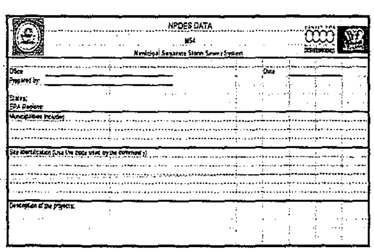
There have been serious concerns about the reliability and utility of Phase 1 stormwater NPDES monitoring data, mainly due to a wide variety of experimental designs, sampling procedures, and analytical techniques used. On the other hand, the cumulative value of the monitoring data collected over almost a ten year period from hundreds of municipal outfalls and streams has great potential value to characterize the quality of stormwater runoff, and compare it against historical benchmarks (such as the NURP and USGS national datasets). This project will create a national database of Phase 1 stormwater monitoring data, provide a scientific analysis of the data, and provide recommendations for improving the quality and management value of future NPDES monitoring efforts.

Recent Papers and Presentations

Click in the following link to visit the recent papers and presentations of the:

National Stormwater Quality Database.

National Stormwater Quality Database (NSQD). Version 1.1 -- Spreadsheets



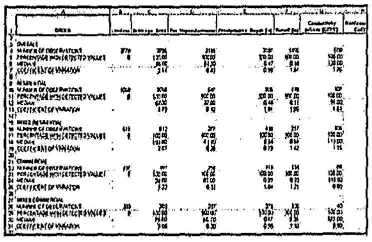
Click on the image to open or save the spreadsheet

NSQD Version 1.1 Spreadsheet.

This is the latest version of the NPDES MS4 database. It contains the data for more than 100 constituents in 64 communities for a total of 3700 events in 360 sites. The table is organized for different land uses and seasons.

Total size: 4.78 Mb

Updated: 03/04/05. Version 1.1



Click on the image to open or save the spreadsheet

Summary Table

This is the summary of observations by land use

Total size: 572 Kb

Updated: 04/30/05. Version 1.1

Site Descriptions

ALABAMA

Huntsville, Jefferson County, Mobile, Montgomery.

ARIZONA

Maricopa County, Tucson

CALIFORNIA

Alameda, Caltrans

COLORADO

Colorado Springs, Denver Metro

GEORGIA

Atlanta, Clayton County, Cobb County, Fulton County.

IDAHO

Ada County Highway District

KANSAS

Topeka, Wichita

KENTUCKY

Jefferson County-Louisville, Lexington

MASSACHUSETTS

Boston

MARYLAND

Anne Arundel County, Baltimore County, Baltimore City, Carroll County, Charles County, Harford County, Howard County, Montgomery County, Princes Georges County, State Highway

MINNESOTA

Minneapolis

NORTH CAROLINA

Charlotte, Fayetteville, Greensboro, Raleigh

OREGON

Clackamas County, Eugene, Gresham, Portland, Salem, ODOT

PENNSYLVANIA

Philadelphia

TENNESSEE

Knoxville, Memphis

TEXAS

Arlington, Dallas, Dallas County, Forth Worth, Gargland, Harris County, Houston, Irving, Mesquite Plano, Tarrant County

VIRGINIA

Arlington County,

Chesapeake, Chesterfield County, Fairfax County, Hampton, Henrico County, Newport News, Norfolk, Portsmouth, Virginia Beach.

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04/30/2005

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The National Stormwater Quality Database (NSQD, version 1.1)

February 16, 2004

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This paper, or earlier versions, have been presented (or are scheduled) for the following conferences, and has been published in the associated conference proceedings:

Watershed 2004. Dearborn, MI. July 2004
World Water and Environmental Resources Congress, Salt Lake City, UT. ASCE. June 2004
Water Environment Federation Technical Exposition and Conference, Los Angeles. Oct 2003
South Pacific Stormwater Conference, Auckland Regional Council, New Zealand. June 2003
National Stormwater Coordinators Meeting, US EPA, Austin, TX. April 2003
National Conference on Urban Stormwater, Chicago Botanical Gardens and US EPA, Chicago, February 2003
Conference on Stormwater and Urban Water Systems Modeling, CHI and EPA, Toronto, Ontario. February 2003

Abstract

The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permit holders. The initial version of this database, the National Stormwater Quality Database (NSQD, version 1.1) is currently being completed. These stormwater quality data and site descriptions are being collected and reviewed to describe the characteristics of national stormwater quality, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas having limited data.

The monitoring data collected over nearly a ten-year period from more than 200 municipalities throughout the country have a great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. This project is creating a national database of stormwater monitoring data collected as part of the existing stormwater permit program, providing a scientific analysis of the data, and providing recommendations for improving the quality and management value of future NPDES monitoring efforts.

Each data set is receiving a quality assurance/quality control review based on reasonableness of data, extreme values, relationships among parameters, sampling methods, and a review of the analytical methods. The statistical analyses are being conducted at several levels. Probability plots are used to identify range, randomness and normality. Clustering and principal component analyses are utilized to characterize significant factors affecting the data patterns. The master data set is also being evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. Regional and climatic differences are being tested, including the influences of land use, and the effects of storm size and season, among other factors. The data will be used to develop a method to predict expected stormwater quality for a variety of significant factors and will be used to examine a number of preconceptions concerning the characteristics of stormwater, sampling design decisions, and some basic data analysis issues. Some of the issues that are being examined with this data include: the occurrence and magnitude of first-flushes, the effects of different sampling methods (the use of grab sampling vs. automatic samplers, for example) on stormwater quality data, trends in stormwater quality with time, the effects of infrequent wrong data in large data bases, appropriate methods to handle values that are below detection limits, the necessary sampling effort needed to characterize stormwater quality, for example. This paper describes the data collected to date and presents some preliminary data findings.

When this National Stormwater Quality Database (NSQD) is completed (populated with most of the NPDES stormwater monitoring data), the continued routine collection of outfall stormwater quality data in the U.S. for basic characterization purposes may have limited use. Some communities may have obviously unusual conditions, or adequate data may not be available in their region. In these conditions, outfall monitoring may be needed. However, stormwater monitoring will continue to be needed for other purposes in many areas having, or anticipating, active stormwater management programs (especially when supplemented with other biological, physical, and hydrologic monitoring components). These new monitoring programs should be designed specifically for additional objectives, beyond basic characterization. These objectives may include receiving water assessments to understand local problems, source area monitoring to identify critical sources of stormwater pollutants, treatability tests to verify the performance of stormwater controls for local conditions, and assessment monitoring to verify the success of the local stormwater management approach (including model calibration and verification). In many cases, the resources being spent for outfall monitoring could be more effectively spent to better understand many of these other aspects of an effective stormwater management program.

Project Description and Background

The importance of this project is based on the scarcity of nationally summarized and accessible data from the existing U.S. EPA's NPDES stormwater permit program. There have been some local and regional data summaries, but little has been done with nationwide data. A notable exception is the Camp, Dresser, and McGee (CDM) national stormwater database (Smullen and Cave 2002) that combined historical Nationwide Urban Runoff Program (NURP) (EPA 1983), available urban U.S. Geological survey (USGS), and selected NPDES data. Their main effort has been to describe the probability distributions of these data (and corresponding EMCs, the event mean concentrations). They concluded that concentrations for different land uses were not significantly different, so all their data were pooled.

Between 1978 and 1983, the EPA conducted the NURP that examined stormwater quality from separate storm sewers in different land uses (EPA 1983). This project studied 81 outfalls in 28 communities throughout the U.S. and included the monitoring of approximately 2300 storm events. The data was presented for several land use categories, although most of the information was obtained from residential lands. Since NURP, other important studies have been conducted that characterize stormwater. The USGS created a database with more than 1100 storms from 98 monitoring sites in 20 metropolitan areas. The Federal Highway Administration (FHWA) analyzed stormwater runoff from 31 highways in 11 states during the 1970s and 1980s (Cave 1995). Strecker (personal communication) is also collecting information from highway monitoring as part of a current NCHRP-funded project. The city of Austin also developed a database having more than 1200 events (Smullen 2003).

Other regional databases also exist, mostly using local NPDES data. These include the Los Angeles area database, the Santa Clara and Alameda County (California) databases, the Oregon Association of Clean Water Agencies Database, and the Dallas, Texas, area stormwater database. These regional data are (or will be) included in the NSQD national database. However, the USGS or historical NURP data will not be included in the NSQD database due to lack of consistent descriptive information for the older drainage areas and because of the age of the data from those prior studies. Much of the NURP data is available in electronic form at the University of Alabama student American Water Resources Association web page at: http://www.eng.ua.edu/~awra/download.htm. The results (especially the stormwater characteristic prediction procedures) from these other databases will be compared to similar findings from the final analyses using this expanded database to indicate any important differences.

Outside the U.S., there have been important efforts to characterize stormwater. In Toronto, Canada, the Toronto Area Watershed Management Strategy Study (TAWMS) was conducted during 1983 and 1984 and extensively monitored industrial stormwater, along with snowmelt in the urban area (Pitt and McLean 1986), for example. Numerous other investigations in South Africa, the South Pacific, Europe and Latin America have also been conducted over the past 30 years, but no large-scale summaries of that data have been prepared. About 3,500 international references on stormwater have been reviewed and compiled since 1996 by the Urban Wet Weather Flows literature review team for publication in *Water Environment Research* (Field, *et al.* 1997, 1998; O'Connor, *et al.* 1999; Fan, *et al.* 2000; Clark, *et al.* 2001, 2001, 2003). An overall compilation of these literature reviews is available at:

http://www.eng.ua.edu/~rpitt/Publications/Publications.shtml

The reviews include short summaries of the papers and are organized by major topics. Besides journal articles, many published conference proceedings are also represented (including the extensive conference proceedings from the 8th International Conference on Urban Storm Drainage held in Sydney, Australia, in 1999, the 9th International Conference on Urban Storm Drainage held in Portland, OR, in 2002, and the Toronto Stormwater and Urban Water Systems Modeling conference series, amongst many other specialty conferences).

The NSQD is unique in that detailed descriptions of the test areas and sampling conditions are also being collected, including aerial photographs and topographic maps that are being obtained from public domain Internet sources. Land use information used is as supplied by the communities submitting the data, although aerial photographs and maps are also used to help clarify questions concerning specific development characteristics. Most of the sites have homogeneous land uses, although many are mixed. These characteristics are all fully noted in the database.

Stormwater runoff data from existing NPDES permit applications and annual monitoring reports are being collected during this project. This project also includes extensive QA/QC (quality assurance/quality control) evaluations of these data; and performing statistical analyses and summaries of these data. The final information will be published on the Internet (such as on an EPA OW-OWM, Office of Water and Office of Wastewater Management, site and on the Center for Watershed Protection's SMRC, Stormwater Manager's Resources Center, site at: http://www.stormwatercenter.net/). Some of the information is currently located at Pitt's teaching and research web site at:

http://www.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

The Phase I NPDES communities included areas with:

- A stormwater discharge from a MS4 serving a population of 250,000 or more (large system), or
- A stormwater discharge from a MS4 serving a population of 100,000 or more, but less than 250,000 (medium system).

More than 200 municipalities, plus numerous additional special districts and governmental agencies were included in this program. Part 2 of the NPDES discharge permit application specified that sampling was needed and that the following items were to be included in the application:

- Proposed monitoring program for representative data collection during the term of the permit;
- Quantitative data from 5 to 10 representative locations;
- Estimates of the annual pollutant load and event mean concentration (EMC) of system discharges; and
- Proposed schedule to provide estimates of seasonal pollutant loads and the EMC for certain detected constituents during the term of the permit.

The permit applications were due in 1992 and 1993. For Part 2 of the application, municipalities were to submit grab (for certain pollutants having severe holding time restrictions, such as bacteria) and flow-weighted sampling data from selected sites (5 to 10 outfalls) for three representative storm events at least one month apart. In addition, the municipalities must have also developed programs for future sampling activities that specified sampling locations, frequency, pollutants to be analyzed, and sampling equipment.

Numerous constituents were to be analyzed, including typical conventional pollutants (TSS, TDS, COD, BOD_5, oil and grease, fecal coliforms, fecal strep., pH, Cl, TKN, NO_3, TP, and PO_4), plus many heavy metals (including total forms of arsenic, chromium, copper, lead, mercury, and zinc, plus others), and numerous listed organic toxicants (including PAHs, pesticides, and PCBs). Many communities also analyzed samples for filtered forms of the heavy metals. This database currently includes information for about 125 different stormwater quality constituents, although the current database is mostly populated with data from 35 of the commonly analyzed pollutants (as summarized later in Table 1). Therefore, there has been a substantial amount of stormwater quality data collected during the past 10 years throughout the U.S., although most of these data are not readily available, nor have detailed statistical analyses been conducted and presented.

Data Collection and Analysis Efforts to Date

As of mid-summer 2003, 3,770 separate events from 66 agencies and municipalities from 17 states have been collected and the data entered into NSQD. Figure 1 shows the locations of these municipalities on a national map, along with EPA Rain Zones. Excellent national coverage is anticipated, although there will be few municipalities from the northern, west-central states of Montana, Wyoming, and North and South Dakota (where cities are generally small, and few were included in the Phase 1 NPDES program). This current database (NSQD, Version 1.1) covers areas mostly in the southern, Atlantic, central, and western parts of the US. Anticipated future project phases will help extend the national coverage.

Some of the municipalities that have been contacted (and some in which data was received) have information that could not be used for various reasons. One of the most common reasons was that the samples had been collected from receiving waters (such as Washington state, Nashville, and Chattanooga). Only data from well-described stormwater outfall locations are being used for the database. These can be open channel outfalls in completely developed areas, but are more commonly conventional outfall pipes. The other major problem is that the sampling locations and/or the drainage areas were not described. Data with some missing information is being used for now, with the intention of obtaining the needed information later. However, there will likely still be some minor data gaps that will not be able to be filled. In addition, the list of constituents being monitored has varied for different locations. Most areas evaluated the common stormwater constituents, but few have included organic toxicants. The most serious gap is the frequent lack of runoff volume data, although all sites have included rain data. Finally, if all the data were collected that was requested, the current project resources will not permit their full utilization, as it requires a great deal of time to enter and review this information. About 10% of the collected data needed verification during the QA/QC process. If that potentially faulty data remained in the database, spurious statistical analyses would have resulted. The collection and review of the data is a necessary first step to facilitate later analyses.

The assembled data was entered into NSQD, including site descriptions (state, municipality, land use components, and EPA rain zone), sampling information (date, season, rain depth, runoff depth, sampling method, sample type, etc.), and constituent measurements (concentrations, grouped in categories). In addition, more detailed site, sampling, and analysis information has been collected for most sampling sites and is also included as supplemental information. The reported land use information supplied by the communities is being used, with verification of some areas with aerial photographs and maps. In many cases, the sampled watersheds have multiple land uses and those designations are included in the database (the database lists the percentages of the drainage as residential, commercial, industrial, freeway, institutional, and open space). The final data analyses will consider these mixed sites also, especially for verification for the model development activities, although the following preliminary results are only for the homogeneous land use sites.

Preliminary Summary of U.S. NPDES Phase 1 Stormwater Data

Additional site information is being acquired to complete most of the missing records before the final data analyses. The following data and analysis descriptions should therefore be considered preliminary and will change with this additional data and analyses. However, this presentation only uses the most basic and robust analyses for preliminary consideration. The final report and data presentations will obviously be much more comprehensive.

Table 1 is a summary of the Phase 1 data collected and entered into the database as of mid-summer 2003. The data are separated into 11 land use categories: residential, commercial, industrial, institutional, freeways, and open space, plus mixtures of these land uses. Summaries are also shown for mixed land use areas (indicating the most prominent land use), and for the total data set combined. Only data having at least 50 total detected observations and at least 10 detected observations per land use category are shown on this table. The full database includes all of the data. In most cases, many more than these minimum numbers are available. The total number of observations and the percentage of observations above the detection limits are also shown on this summary table. However, some constituents were not monitored by very many stormwater permit holders, and some constituents were mostly all in the "not detected" category, and those data are not shown. As an example, filtered heavy metal observations, and especially organic analyses, have manv fewer detected values than other constituents.

The total number of individual events included in the database is 3,770, with most in the residential category (1,069 events). For most common constituents, detectable values are available for almost all monitored events. The median and coefficient of variation (COV) values are only for those data having detectable concentrations. If the non-detected results were used in these calculations, extreme biases would invalidate many of the calculations. The final analyses will further examine issues associated with different detection limits, multiple laboratories, and varying analytical methods on the reported results and statistical analyses. Burton and Pitt (2002), and the many included references in that book, contains further discussions on these important issues.

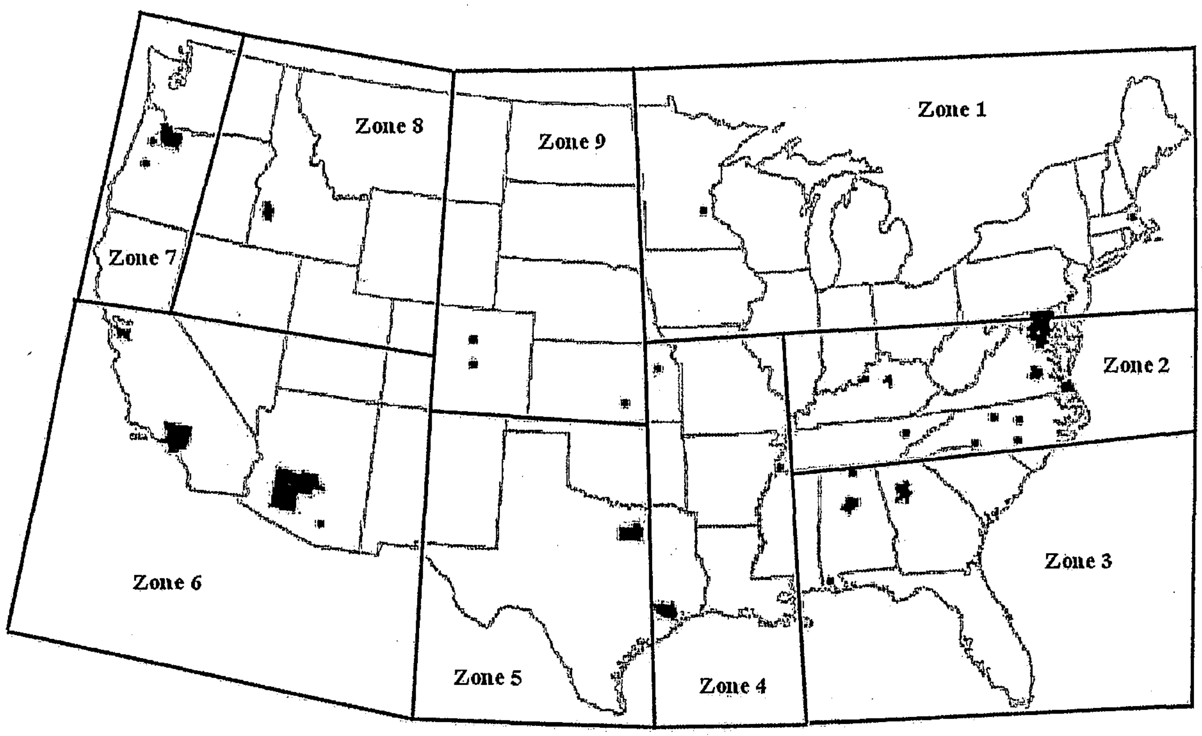


Figure 1. Communities from which data has been obtained and entered in the NSQD, along with EPA Rain Zones.

Table 2 is a summary of methylene chloride and bis(2-ethylhexyl) phthalate, the most commonly reported and detected organic constituents. There were up to several hundred events that included PAH and pesticide data. The percentage of samples that had observable concentrations of these constituents ranged from 15 to 35%, about the same detection rate as in previous stormwater investigations, such as Pitt, *et al.* 1995.

Statistical analyses are being conducted in stages. Probability plots were used to identify range, randomness, and normality. Figure 2 is an example of log-normal probability plots for some of the constituents and for all data pooled. Probability plots shown as straight lines indicate that the concentrations can be represented by log-normal distributions. This is important as it indicates that data transformations, or the use of nonparametric statistical analyses, will be needed. Plots with obvious discontinuities imply that multiple data populations may be included. The future analyses will identify the significance of these different data categories (such as land use, region, and season).

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1

	Area (acres)	% Imperv.	Precip. Depth (in)	Runoff Depth (in)	Cond. (uS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Temp. (C)	TDS (mg/L)	T (r
Overall Summary (3765)											
Number of observations	3759	2202	3186	1454	685	1082	1834	1665	861	2957	
% of samples above detection	100	100	100	100	100	98.7	66.1	100	100	99.3	
Median	57.0	53.0	0.47	0.18	121	38.0	4.3	7.50	16.5	80	
Coefficient of variation	3.7	0.4	1.0	2.0	1.6	1.4	9.7	0.1	0.4	3.4	
Residential (1081)											
Number of observations	1077	658	915	422	106	250	533	325	205	861	
% of samples above detection	100	100	100	100	100	100	57.8	100	100	99.2	
Median	57.3	37.0	0.46	0.11	96.5	32.0	3.9	7.3	16.4	72.0	
Coefficient of variation	4.7	0.4	1.0	1.9	1.5	1.0	7.7	0.1	0.4	1.1	
Mixed Residential (615)											
Number of observations	617	281	441	216	105	157	258	322	141	471	
% of samples above detection	100	100	100	100	100	98.1	68.2	100	100	99.2	
Median	150.8	44.9	0.54	0.18	112	39.7	4.4	7.50	16.0	86	
Coefficient of variation	2.1	0.3	0.8	1.4	1.2	1.2	2.4	0.1	0.3	5.2	
Commercial (503)											
Number of observations	503	264	421	135	66	139	308	171	79	399	
% of samples above detection	100	100	100	100	100	100	70.8	100	100	99.5	
Median	38.8	83.0	0.39	0.23	119	38.9	4.7	7.30	16.0	74	
Coefficient of variation	1.2	0.1	1.0	1.2	1.0	1.1	3.2	0.1	0.4	1.9	
Mixed Commercial (311)											
Number of observations	311	238	284	109	44	88	122	143	84	256	
% of samples above detection	100	100	100	100	100	98.9	82.0	100	100	99.6	
Median	49.0	60.0	0.47	0.34	101	35.0	5.0	7.60	14.7	70	
Coefficient of variation	2.1	0.3	1.0	1.1	0.6	1.8	2.9	0.1	0.4	1.9	
Industrial (525)											
Number of observations	525	320	438	2012	108	138	327	234	140	413	
% of samples above detection	100	100	100	100	100	96.4	65.1	100	100	99.5	
Median	39.0	75.0	0.49	0.14	136	39.0	5.0	7.50	17.9	92	
Coefficient of variation	1.6	0.3	1.0	2.7	1.3	1.5	12.0	0.1	0.3	3.6	

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Area (acres)	% Imperv.	Precip. Depth (in)	Runoff Depth (in)	Cond. (uS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Temp. (C)	TDS (mg/L)	(r
Mixed Industrial (251)											
Number of observations	251	133	226	117	57	83	80	179	70	222	
% of samples above detection	100	100	100	100	100	94.0	77.5	100	100	99.6	
Median	127.7	44.0	0.45	0.29	111	33.0	4.75	7.70	18.1	80	
Coefficient of variation	2.0	0.3	0.8	1.2	0.8	0.5	1.9	0.1	0.4	0.8	
Institutional (18)											
Number of observations	18	18	17	14						18	
% of samples above detection	100	100	100	100						100	
Median	36.0	45.0	0.18	0.00						52.5	
Coefficient of variation	0	0	0.9	2.1						0.7	
Freeways (185)											
Number of observations	185	154	182	144	86	127	60	111	31	97	
% of samples above detection	100	100	100	100	100	100	71.7	100	100	99.0	
Median	1.6	80.0	0.54	0.41	99	34.0	8.0	7.10	14.0	77.5	
Coefficient of variation	1.4	0.13	1.1	1.7	1.0	1.9	0.6	0.1	0.4	0.8	
Mixed Freeways (20)											
Number of observations	20		20		13	12	15	19	19	17	
% of samples above detection	100		100		100	100	100	100	100	100	
Median	63.1		0.68		418	83	4.0	7.80	16.0	174	
Coefficient of variation	0.3		0.6		0.6	0.3	1.6	0.06	0.3	0.4	
Open Space (49)											
Number of observations	49	37	41	11	2	8	19	19	2	45	
% of samples above detection	100	100	100	100	100	100	36.8	100	100		
Median	85	2.0	0.52	0.05	113	150	1.3	7.70	14.6	[illegible]	
Coefficient of variation	1.5	1.0	1.2	1.4	0.5	0.6	0.7	0.08	0.7	0.7	
Mixed Open Space (189)											
Number of observations	189	97	188	81	83	70	96	128	76	148	
% of samples above detection	100	100	100	100	100	100	62.5	100	100	99.3	
Median	115.4	34.0	0.43	0.16	204	64.2	6.0	7.9	16.0	109	
Coefficient of variation	0.9	0.2	0.9	1.2	1.7	1.3	1.6	0.07	0.3	2.2	

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Fecal Coliform (mpn/100 mL)	Fecal Strep. (mpn/100 mL)	Total Coliform (mpn/100 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phos., filtered (mg/L)	Phos., total (mg/L)	Sb, total (ug/L)	A (u
Overall Summary (3765)											
Number of observations	1704	1141	83	67	1909	3076	3192	2477	3285	874	
% of samples above detection	91.2	94.0	90.4	95.5	71.7	97.3	95.6	85.1	96.6	7.2	
Median	5091	17000	12000	1750	0.44	0.6	1.4	0.13	0.27	3.0	
Coefficient of variation	4.61	3.8	2.4	2.3	1.4	1.1	1.3	1.6	1.5	1.7	
Residential (1069)											
Number of observations	446	305		14	595	927	7	738	963		
% of samples above detection	88.3	89.5		100	81.5	97.4	96.8	84.2	96.9		
Median	8345	24600		700	0.32	0.6	1.4	0.17	0.30		
Coefficient of variation	5.0	1.8		1.6	1.1	1.1	1.1	0.9	1.1		
Mixed Residential (615)											
Number of observations	313	156	26	11	259	535	525	410	556		

% of samples above detection	94.9	98.1	84.6	90.9	57.9	98.1	95.1	82.4	96.2	
Median	11000	26000	5667	1050	0.39	0.6	1.35	0.12	0.27	
Coefficient of variation	3.3	2.2	1.31	2.1	1.6	0.8	1.8	1.1	1.7	
Commercial (497)										
Number of observations	233	181			299	425	449	323	446	
% of samples above detection	88.0	91.7			83.3	98.1	97.3	81.1	95.7	
Median	4300	10285			0.50	0.6	1.6	0.11	0.22	
Coefficient of variation	2.8	2.7			1.2	1.1	0.9	1.2	1.2	
Mixed Commercial (303)										
Number of observations	109	88			170	275	267	223	281	80
% of samples above detection	94.5	98.9			68.2	96.7	96.3	93.3	98.6	12.5
Median	4980	11000			0.60	0.58	1.39	0.12	0.26	15.0
Coefficient of variation	3.3	2.8			1.0	0.7	0.9	2.1	1.5	1.0
Industrial (524)										
Number of observations	297	195			254	418	440	325	434	164
% of samples above detection	87.9	93.9			85.8	96.2	95.9	87.1	96.3	14.6
Median	2500	13000			0.50	0.73	1.4	0.11	0.26	3.7
Coefficient of variation	5.6	6.9			1.2	0.9	1.2	1.2	1.4	1.4

Table 1. Summary of Available Stormwater Data Included in NSQD Database, version 1.1 (continued)

	Fecal Coliform (mpn/100 mL)	Fecal Strep. (mpn/100 mL)	Total Coliform (mpn/100 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phos., filtered (mg/L)	Phos., total (mg/L)	Sb, total (ug/L)	A
Mixed Industrial (252)											
Number of observations	115	70	39		125	213	196	215	217		
% of samples above detection	95.7	97.1	89.7		31.2	98.6	93.9	87.0	96.3		
Median	3033	10000	16000		0.43	0.57	1.0	0.08	0.20		
Coefficient of variation	2.5	2.6	2.4		0.7	0.7	1.5	2.2	1.5		
Institutional (18)											
Number of observations					18	18	18	17	17		
% of samples above detection					88.9	100	100	82.4	94.1		
Median					0.31	0.6	1.35	0.13	0.18		
Coefficient of variation					0.5	0.6	0.5	0.5	1.0		
Freeways (185)											
Number of observations	49	25	16	13	79	25	125	22	128		
% of samples above detection	100	100	100	100	87.3	96.0	96.8	95.5	99.2		
Median	1700	17000	50000	1900	1.07	0.28	2.0	0.20	0.25		
Coefficient of variation	2.0	1.2	1.5	2.2	1.3	1.2	1.4	2.1	1.8		
Mixed Freeways (20)											
Number of observations	16	12				14	16	13	14		
% of samples above detection	81.3	93.8				100	100	100	100		
Median	730	19000				0.6	1.6	0.04	0.26		
Coefficient of variation	2.0	1.1				0.7	0.9	0.8	0.8		
Open Space (68)											
Number of observations	23	22			32	44	45	44	46		
% of samples above detection	91.3	90.9			18.8	84.1	71.1	79.6	84.8		
Median	7200	24900			0.18	0.59	0.74	0.13	0.31		
Coefficient of variation	1.1	1.0			1.24	0.9	0.9	0.9	3.5		
Mixed Open Space (159)											
Number of observations	95	75			71	172	144	148	173		

% of samples above detection	97.9	100			22.5	97.7	91.0	85.8	96.5	
Median	2600	21000			0.51	0.7	1.12	0.09	0.27	
Coefficient of variation	2.3	2.4			1.2	0.8	1.3	1.1	1.0	

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Cd, total (ug/L)	Cd, filtered (ug/L)	Cr, total (ug/L)	Cr, filtered (ug/L)	Cu, total (ug/L)	Cu, filtered (ug/L)	Pb, total (ug/L)	Pb, filtered (ug/L)	Hg, total (ug/L)	Ni, total (ug/l)	N fil (u
Overall Summary (3765)											
Number of observations	2575	389	1599	261	2724	411	2950	446	1014	1431	
% of samples above detection	40.8	30.3	70.2	60.5	87.4	83	77.7	49.8	10.2	59.8	
Median	1.0	0.50	7.0	2.1	16	8.0	17.0	3.0	0.20	8.0	
Coefficient of variation	3.7	1.1	1.5	0.7	2.2	1.6	1.8	2.0	2.5	1.2	
Residential (1069)											
Number of observations	723		435		799	90	788	108	297	419	
% of samples above detection	30.3		55.4		83.6	63.3	71.3	33.3	7.41	45.4	
Median	0.5		4.6		12	7.0	12.0	3.0	0.20	5.4	
Coefficient of variation	3.4		1.4		1.8	2.0	1.9	1.9	0.9	1.2	
Mixed Residential (615)											
Number of observations	432	30	187	21	448	29	516	30	106	136	
% of samples above detection	39.6	40.0	81.3	52.4	84.4	72.4	79.7	46.7	14.2	62.5	
Median	0.8	0.30	7.0	2.0	17	5.5	18.0	3.0	0.20	7.9	
Coefficient of variation	3.9	0.6	1.5	0.8	1.1	0.9	1.4	0.7	0.9	0.8	
Commercial (497)											
Number of observations	358	47	235	27	387	48	377	59	160	232	
% of samples above detection	43.0	23.4	58.7	40.7	92.8	79.2	85.4	52.5	6.9	59.5	
Median	0.89	0.30	6.0	2.0	17	7.57	18.0	5.0	0.20	7.0	
Coefficient of variation	2.7	1.34	0.9	0.6	1.5	0.8	1.6	1.6	0.8		
Mixed Commercial (303)											
Number of observations	178	30	124	22	182	30	235	30		98	
% of samples above detection	48.3	40.0	87.9	72.7	93.4	83.3	87.7	70.0		80.6	
Median	0.9	0.40	5.0	2.5	17	10	17.0	5.25		5.0	
Coefficient of variation	1.1	0.8	1.1	0.7	2.9	0.6	1.5	0.7		1.3	
Industrial (524)											
Number of observations	395	42	256	36	416	42	412	51	211	250	
% of samples above detection	49.4	54.8	72.7	55.6	89.9	90.5	76.5	52.9	12.8	62.4	
Median	2.0	0.60	14.0	3.0	22	8.0	25.0	5.0	0.20	16.0	
Coefficient of variation	2.3	1.1	1.2	0.7	2.0	0.7	1.8	1.6	2.7	1.0	

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 (continued)

	Cd, total (ug/L)	Cd, filtered (ug/L)	Cr, total (ug/L)	Cr, filtered (ug/L)	Cu, total (ug/L)	Cu, filtered (ug/L)	Pb, total (ug/L)	Pb, filtered (ug/L)	Hg, total (ug/L)	Ni, total (ug/l)	N fi (u
Mixed Industrial (252)											
Number of observations	182	25	124	15	183	24	246	25	65	82	
% of samples above detection	49.5	92.0	91.1	66.7	85.8	100.0	78.1	92.0	21.5	85.4	
Median	1.6	0.60	8.0	2.0	18	6.0	20.0	5.0	0.25	9.0	
Coefficient of variation	1.91	0.6	1.7	0.7	0.9	0.6	1.4	1.0	0.6	0.9	
Institutional (18)											
Number of observations							18				
% of samples above detection							77.8				
Median							5.75				
Coefficient of variation							0.8				

Freeways (185)									
Number of observations	95	114	76	101	97	130	107	126	99
% of samples above detection	71.6	26.3	98.7	78.2	99.0	99.2	100	50.0	89.9
Median	1.0	0.68	8.3	2.3	34.7	10.9	25	1.8	9.0
Coefficient of variation	0.9	1.0	0.7	0.7	1.0	1.5	1.5	1.7	0.9
Mixed Freeways (20)									
Number of observations	15		15		17		17		
% of samples above detection	80		100		94		82		
Median	0.5		6.0		8.5		10.0		
Coefficient of variation	0.7		1.1		1.1		0.9		
Open Space (68)									
Number of observations	38		36		39		45		
% of samples above detection	55.3		36.1		74.4		42.2		
Median	0.38		5.4		10		10.0		
Coefficient of variation	1.9		1.7		2.0		1.7		
Mixed Open Space (159)									
Number of observations	128		88		126		176		51
% of samples above detection	16.4		81.8		91.3		66.5		72.6
Median	2.0		6.0		10		10		8.0
Coefficient of variation	1.4		1.3		1.5		2.3		1.1

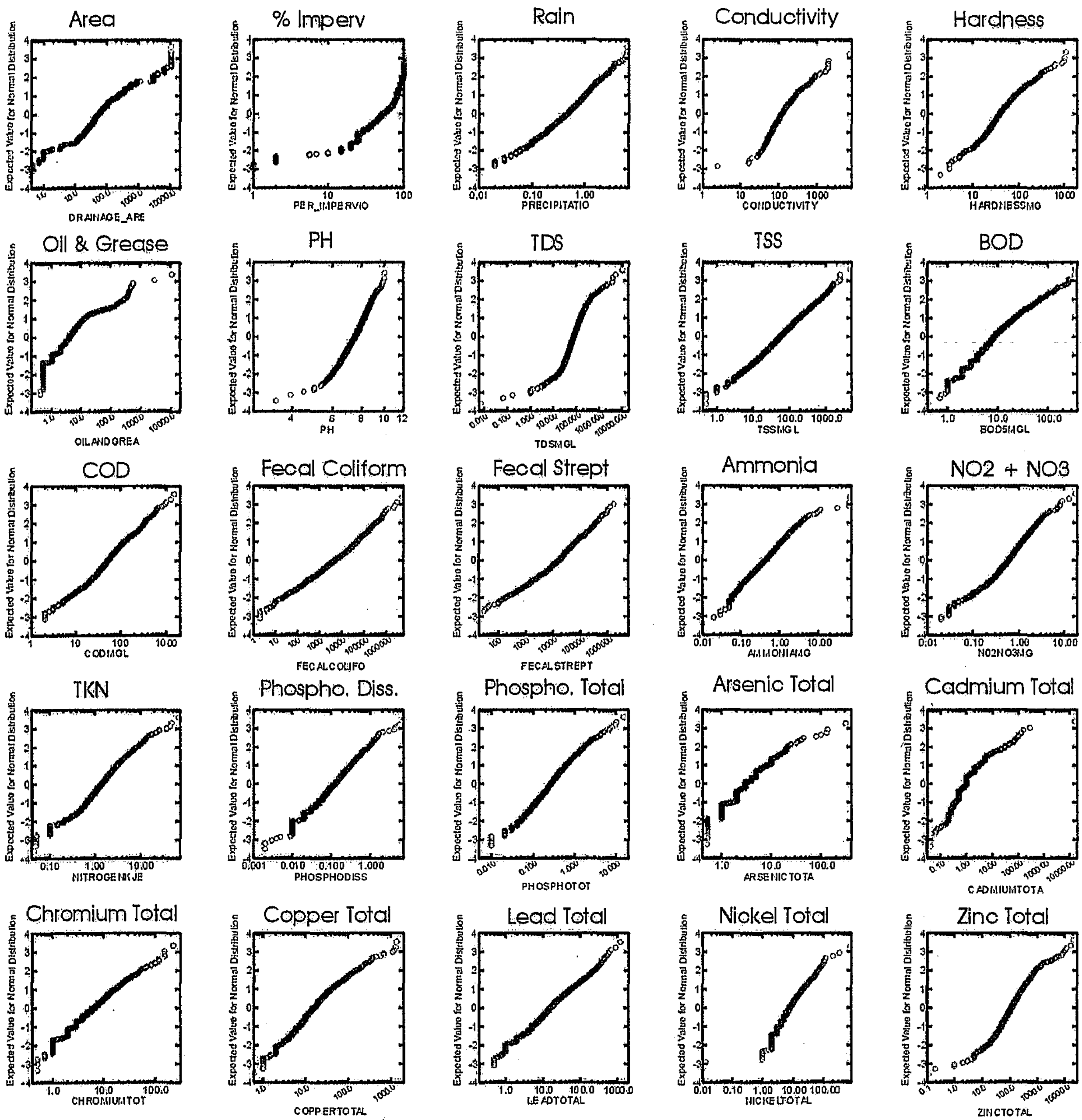


Figure 2. Log-normal probability plots of stormwater quality data for selected constituents.

Table 2. Summary of Selected Organic Information in NSQD, version 1.0

	Methylene-chloride (µg/L)	Bis(2-ethylhexyl) phthalate (µg/L)
All Data Combined		
Number of observations	251	250
% of samples above detection	36	30
Median of detected values	11.2	9.5

Coefficient of variation	0.77	1.13

Simple Data Relationships

The master data set will also be evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. The runoff data will then be evaluated to determine which factors have a strong influence on event mean concentrations, including sampling methods. Tests for regional and climatic differences will be conducted, including the influences of land use and the effects of storm size, among other factors. Figure 3 includes example scatter plots of COD vs. BOD_5, ammonia vs. TKN, filtered copper vs. total copper, and filtered zinc vs. total zinc, illustrating close relationships between these pairings, as expected.

Figure 4 shows scatter plots of suspended solids, phosphorus, fecal coliforms, and total zinc concentrations for different rain depths. Little variation of these concentrations with rain depth are seen when all of the data are combined, implying little likelihood of important "first-flush" effects at stormwater outfall locations. If a first-flush was evident, one would expect higher concentrations associated with smaller rain depths (see Maestre, *et al.* 2003 for more detailed analyses of first-flush effects using the NSQD database information). A simple plot of COD concentrations vs. percentage imperviousness of the drainage area (Figure 5) doesn't indicate any obvious trends. Each vertical set of observations represent a single monitoring location (all of the events at a single location have the same percent imperviousness). The variation of COD at any one monitoring location is seen to vary greatly, typically by about an order of magnitude. These large variations will make trends difficult to identify. All of the lowest percentage imperviousness sites are open space land uses, while all of the highest percentage imperiousness sites are freeway and commercial land uses. As indicated below in Figure 6, many of the constituents have significant concentration differences by land uses. Therefore, it is expected that these other constituents will show an obvious trend because of the strong correlation between percentage imperviousness and land use. In addition, currently there is little data in the NSQD showing how the impervious areas are connected to the drainage systems. Some historical data shows much smaller concentrations (and especially yields) for areas that are drained by grass swales compared to concrete curbs and gutters. With this additional information, the imperviousness data can be adjusted ("effective" imperviousness is commonly used to designate directly connected paved areas) to potentially identify more obvious data trends.

Figure 6 contains examples of grouped box and whisker plots for several constituents for different major land use categories. The TKN, plus copper, lead, and zinc observations are lowest for open space areas, while the freeway locations generally had the highest median values, except for phosphorus, nitrates, fecal coliforms, and zinc. The industrial sites had the highest reported zinc concentrations. Preliminary statistical ANOVA analyses for all land use categories (using SYSTAT) found significant differences for land use categories for all pollutants. The final analyses will further investigate this important finding and will also examine possible confounding factors.

The seasonal variations for the example residential data shown in Figure 7 are not as obvious, except that the bacteria values appear to be lowest during the winter season and highest during the summer and fall (a similar conclusion was obtained during the NURP, EPA 1983, data evaluations). The database does not contain any snowmelt data, so all of the data corresponds to rain-related runoff.

Figure 8 presents example plots for selected residential area data for different EPA rain zones for the country. Zones 3 and 7 (the wettest areas of the country) had the lowest concentrations for most of the constituents.

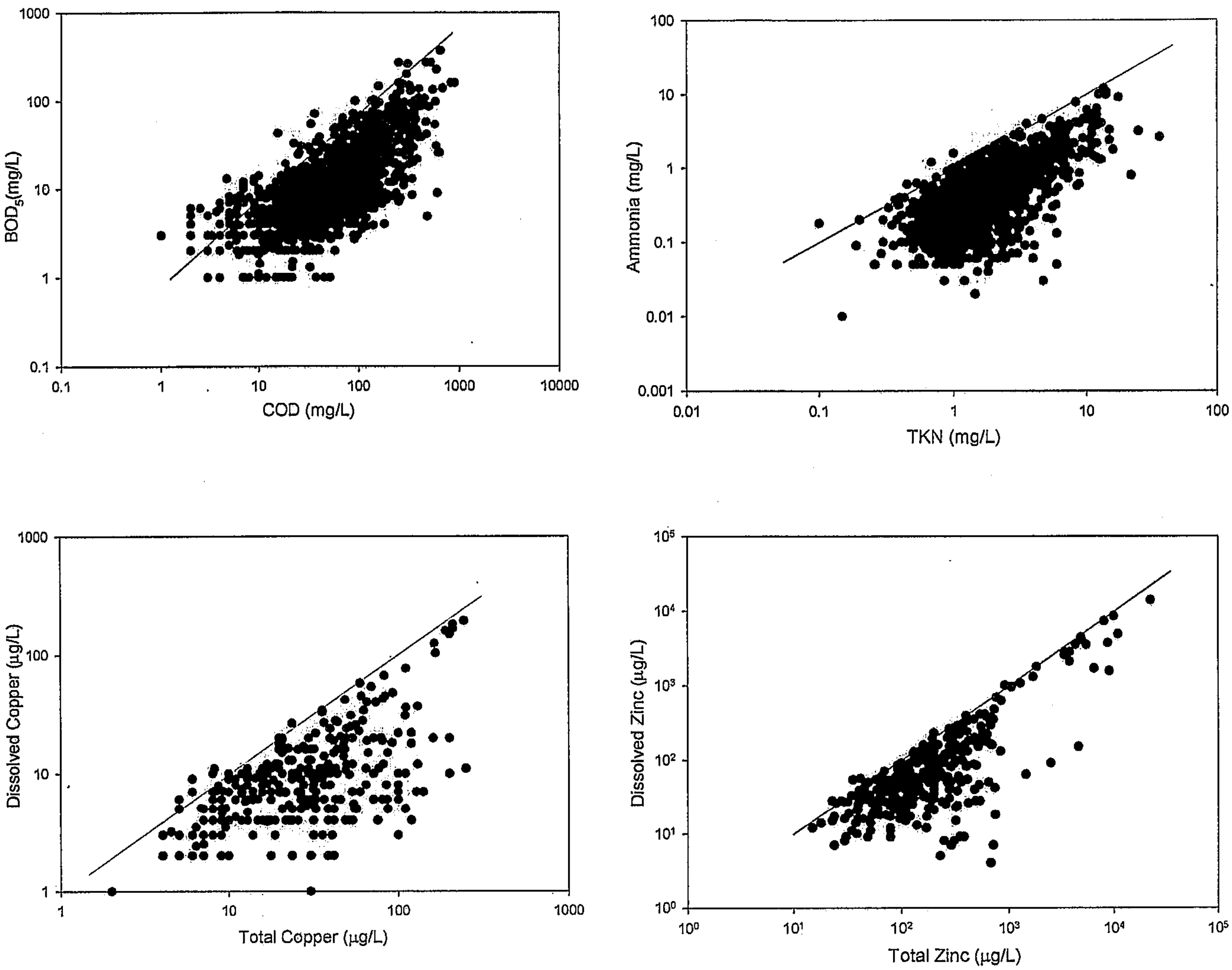


Figure 3. Example scatter plots of stormwater data (line of equivalent concentration shown).

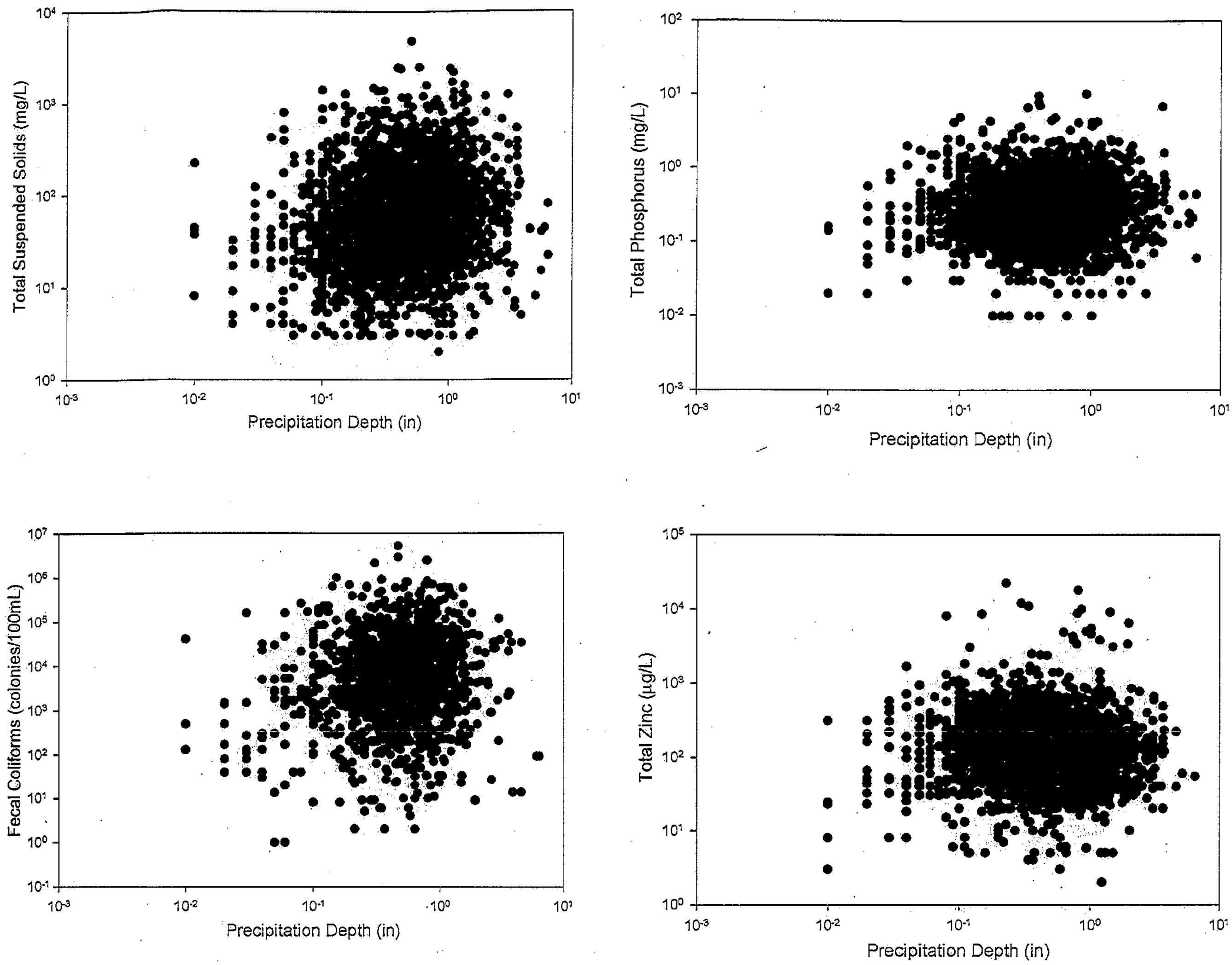


Figure 4. Example scatter plots of concentrations vs. rain depth.

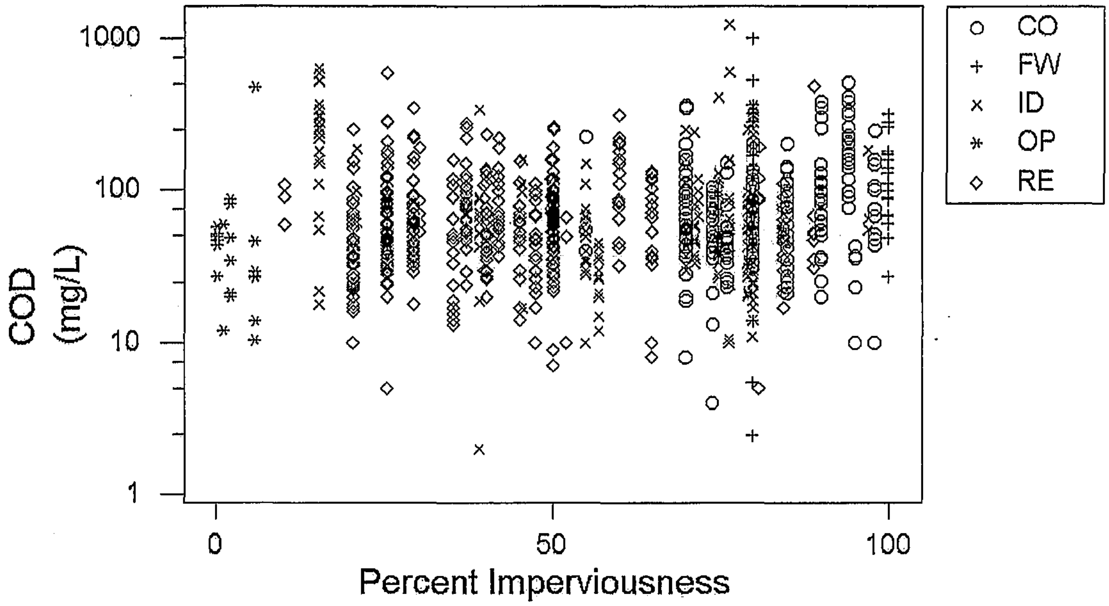
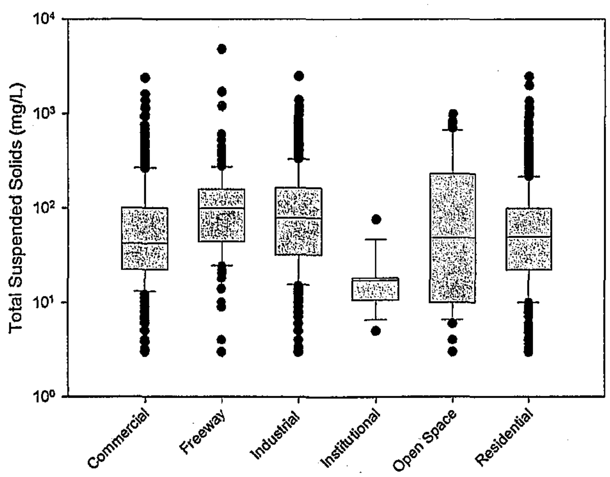
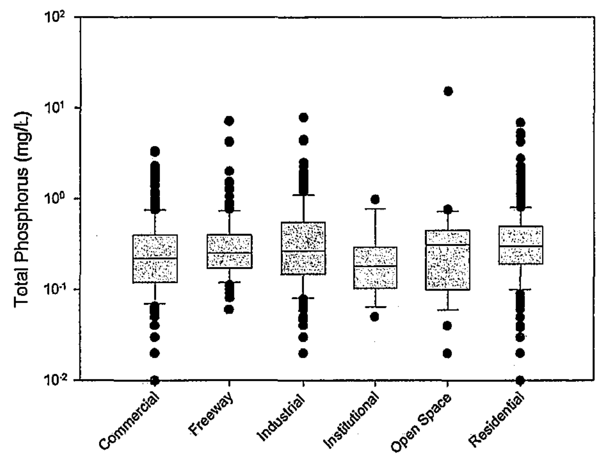


Figure 5. Plot COD concentrations against watershed area percent imperviousness values for different land uses (CO: commercial; FW: freeway; ID: industrial; OP: open space; and RE: residential)





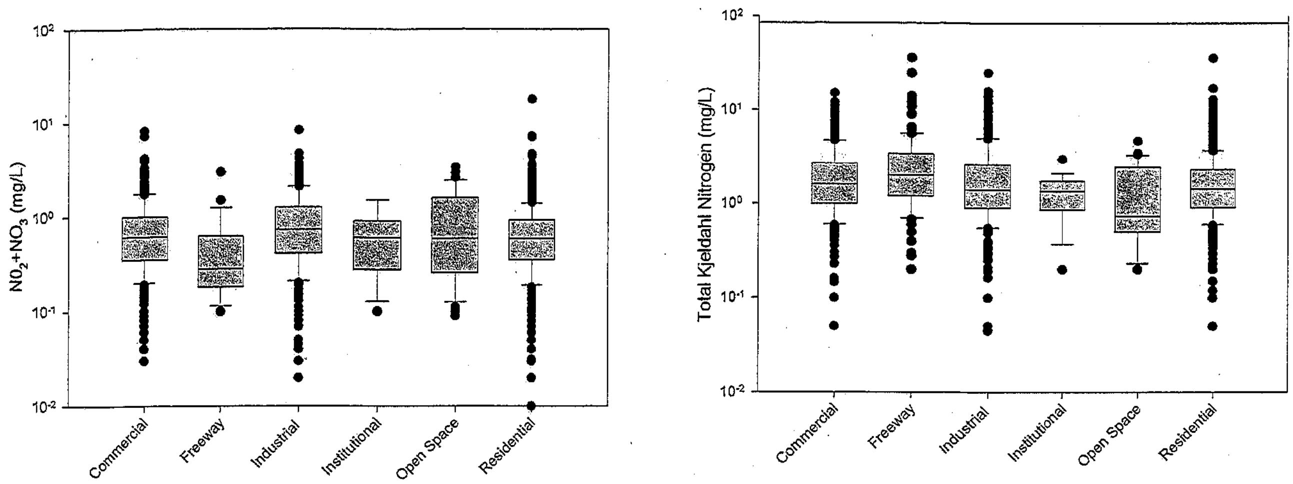
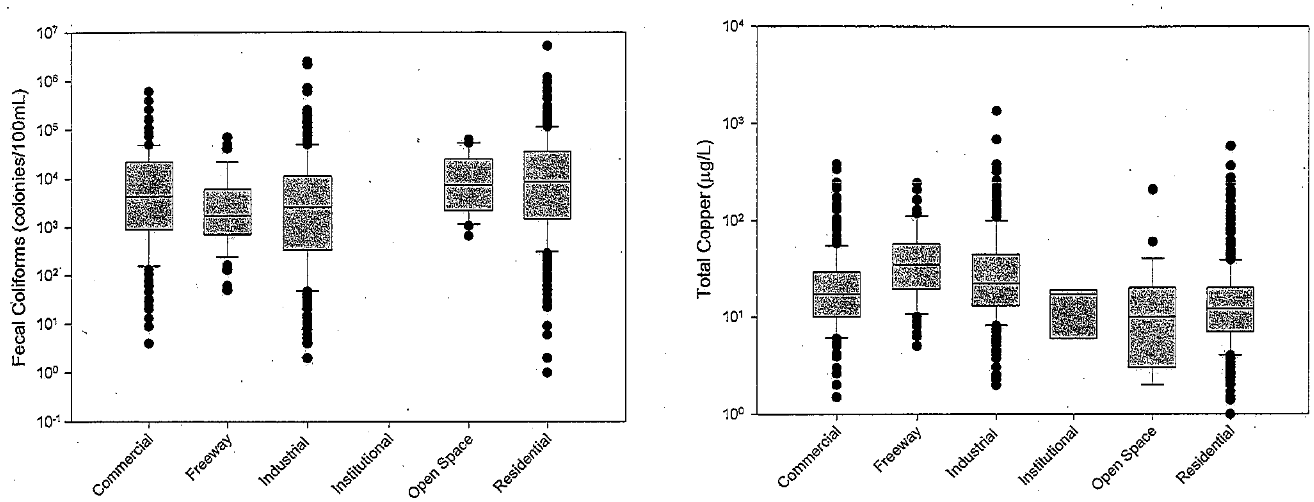


Figure 6. Example stormwater data sorted by land use (no mixed land use data included in plots).



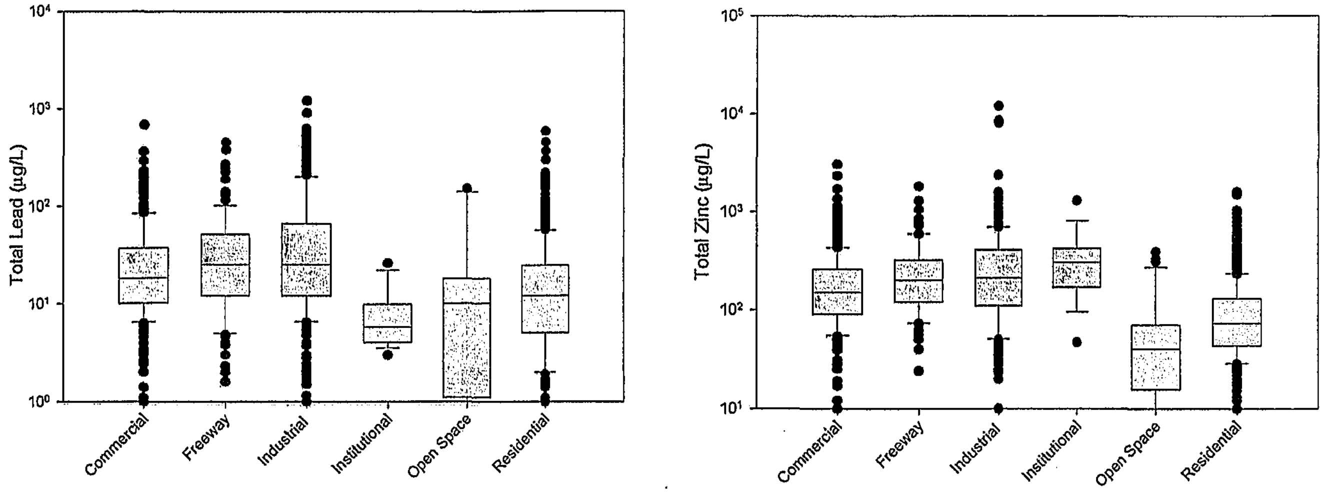
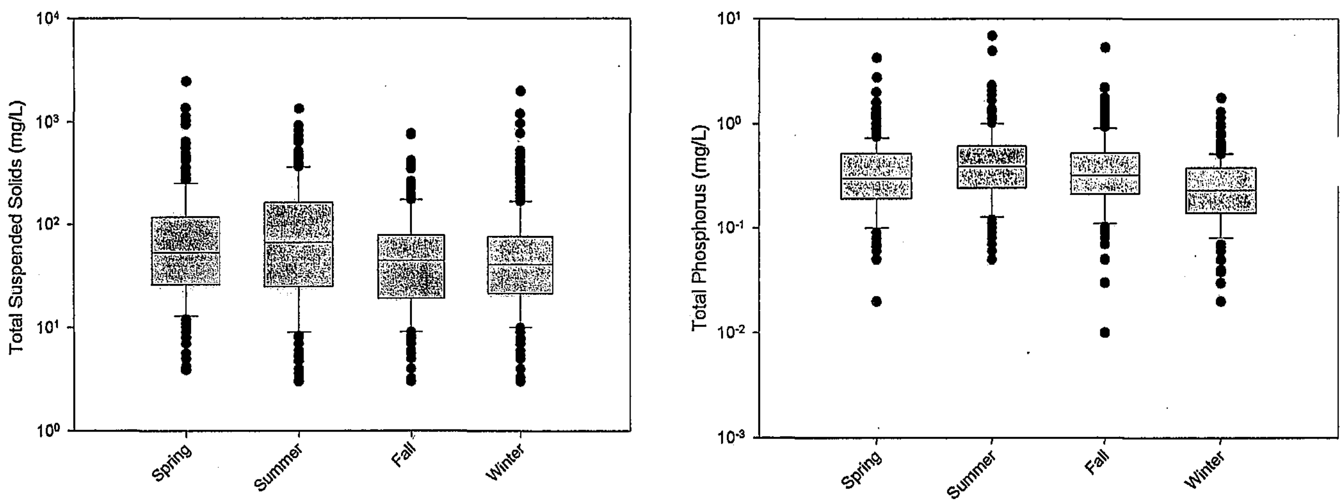


Figure 6. Example stormwater data sorted by land use (no mixed land use data included in plots) (continued).



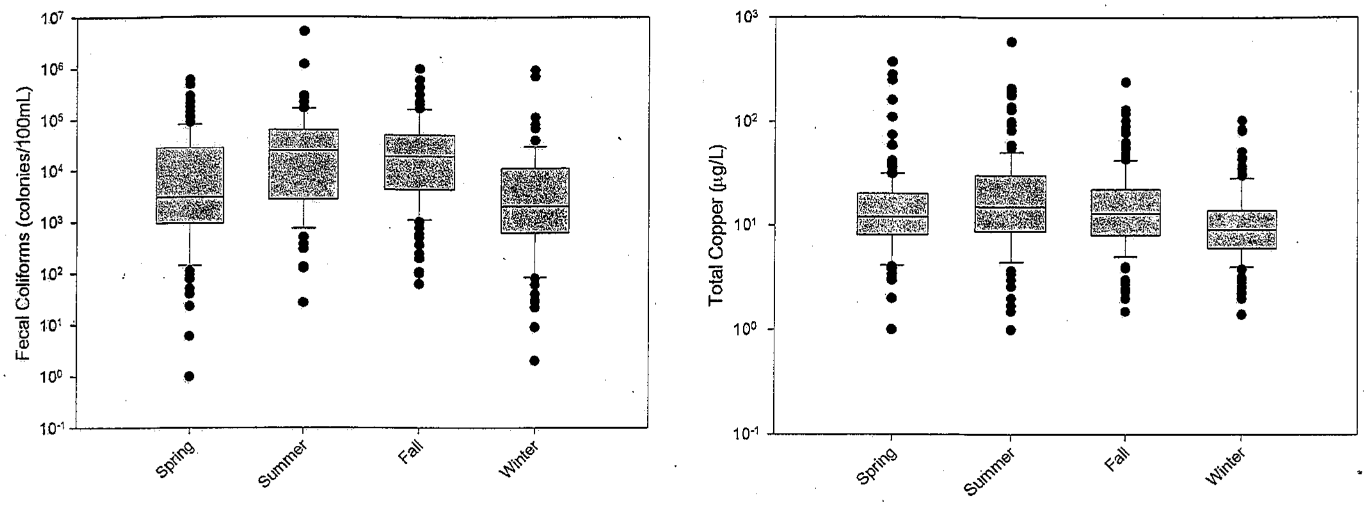
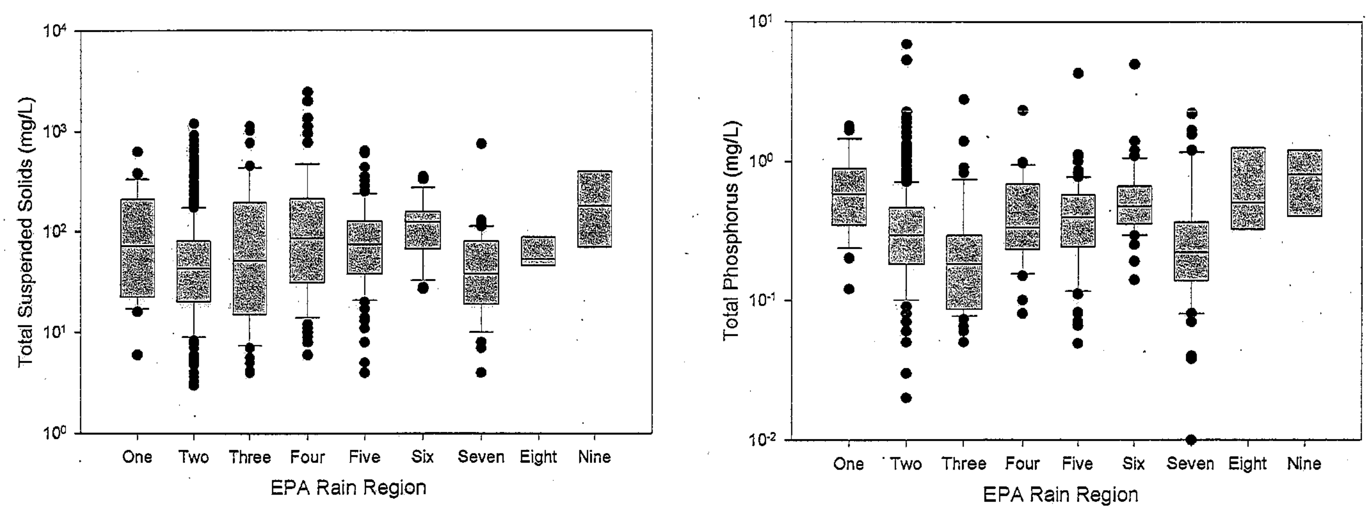


Figure 7. Example residential area stormwater pollutant concentrations sorted by season.



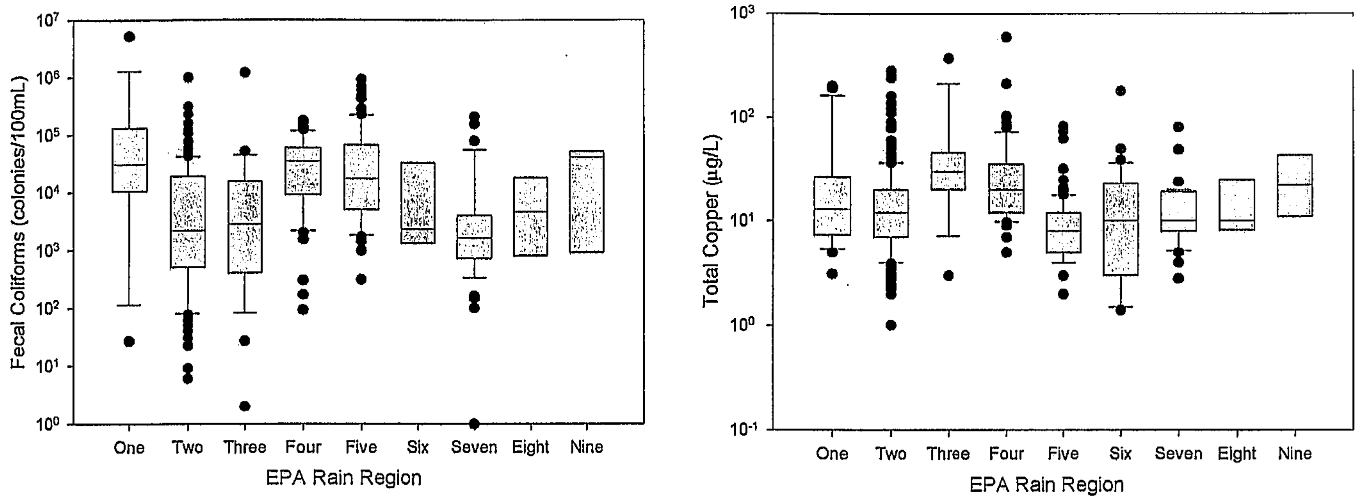


Figure 8. Example residential area stormwater pollutant concentrations sorted by geographical area.

We are also examining trends of concentrations with time. A classical example would be for lead, which is expected to decrease over time with the increased use of unleaded gasoline. Older stormwater samples from the 1970s typically have had lead concentrations of about 100 µg/L, or higher, while most current data indicate concentrations in the range of 1 to 10 µg/L. Figure 9 shows a plot of lead concentrations for residential areas only (in rain zone 2), for the time period from 1991 to 2002. This preliminary plot shows likely decreasing lead concentrations with time. Statistically however, the trend line is not significant due to the large variation in observed concentrations (p=0.41; there is insufficient data to show that the slope term is significantly different from zero). The similar COD concentrations in Figure 9 also have an apparent downward trend with time, but again, the slope term is not significant (p=0.12).

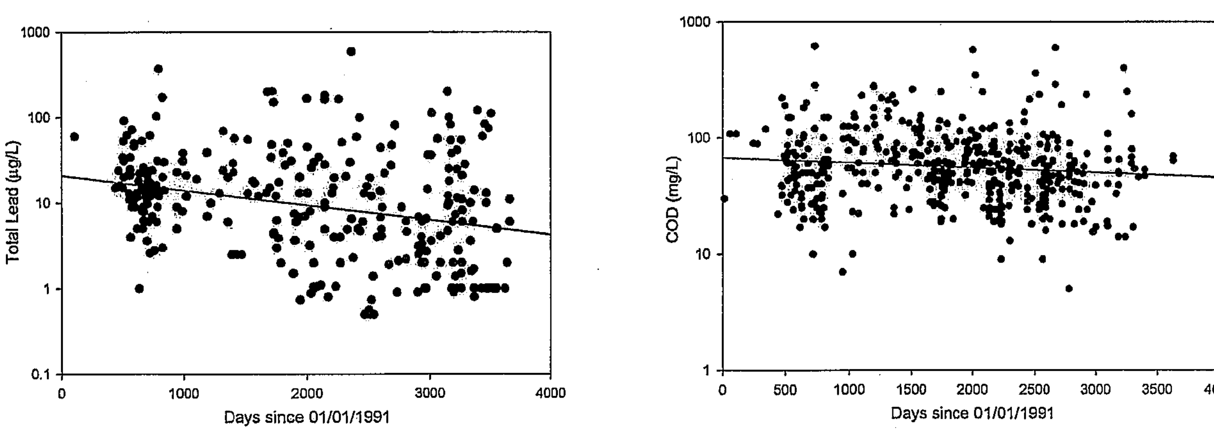


Figure 9. Residential lead and COD concentrations with time (EPA Rain Zone 2 data only).

As part of their MS4 phase 1 applications, Denver and Milwaukee both returned to some of their earlier sampled monitoring stations used during the local NURP projects. In the time between the early 1980s (NURP) and the early 1990s (MS4), they did not detect any significant differences, except for large decreases in lead concentrations. Figure 10 compares suspended solids, copper, lead, and zinc concentrations at the Wood Center NURP monitoring site in Milwaukee. The average site concentrations remained the same, except for lead, which decreased from about 450 down to about 110 µg/L.

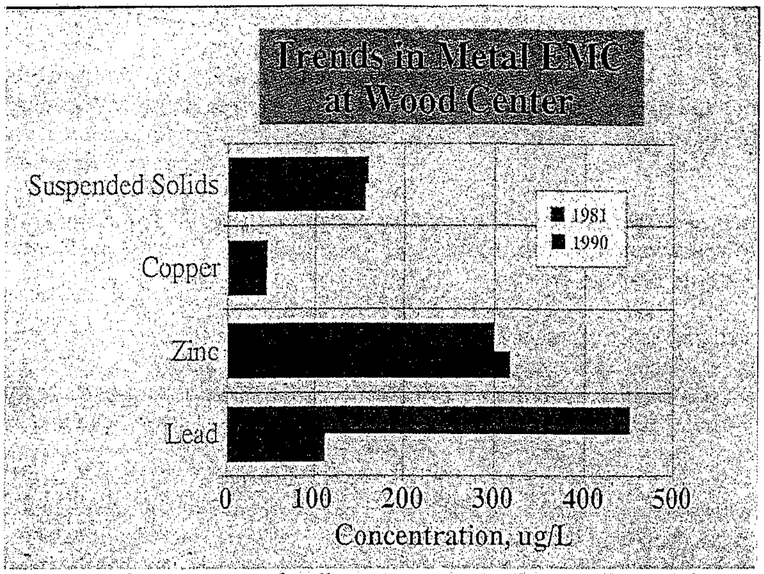


Figure 10. Comparison of pollutant concentrations collected during NURP (1981) to MS4 application data (1990) at the same location (personal communication, Roger Bannerman, WI DNR).

Similar comparisons were made in the Denver Metropolitan area by the Urban Drainage and Flood Control District. Table 3 compares stormwater quality for commercial and residential areas for 1980/91 (NURP) and 1992/93 (MS4 application). Although there was an apparent difference in the averages of the event concentrations between the sampling dates, they concluded that the differences were all within the normal range of stormwater quality variations, except for lead, which decreased by about a factor of four.

Table 3. Comparison of Commercial and Residential Stormwater Runoff Quality from 1980/81 to 1992/93 (Urban Drainage District, *Flood Hazard News*, Dec 1993.)

	Commercial		Residential	
Constituent	**1980/81**	**1992/93**	**1980/82**	**1992/93**
Total suspended solids (mg/L)	251	165	226	325
Total nitrogen (mg/L)	3.0	3.9	3.2	4.7
Nitrate plus nitrite (mg/L)	0.80	1.4	0.61	0.92
Total phosphorus (mg/L)	0.46	0.34	0.61	0.87
Dissolved phosphorus (mg/L)	0.15	0.15	0.22	0.24
Copper, total recoverable (µg/L)	27	81	28	31
Lead, total recoverable (µg/L)	200	59	190	53
Zinc, total recoverable (µg/L)	220	290	180	180

Example Statistical Analyses of Data Comparing First Flush and Composite Sample Concentrations

As part of their NPDES stormwater permit, some communities collected grab samples during the first 30 minutes of the event to evaluate a "first flush" in contrast to the flow-weighted composite data. More than 400 paired samples representing the first flush and composite samples from eight communities (mostly located in the southeast U.S.) from NSQD were reviewed. Box and probability plots were prepared for 22 major constituents. Nonparametric statistical analyses were then used to measure the differences between the sample sets. This discussion summarizes the results of this preliminary analysis, including the effects of storm size and land use on the presence and importance of first flushes. Only concentration data were available for these analyses, so traditional accumulative mass curves could not be developed.

First flush refers to an assumed elevated load of pollutants discharged in the first part of a runoff event. First flush has been observed more in small catchments than in large catchments (Thompson, *et al.* 1995; WEF and ASCE 1998). In large catchments (>162 ha, or >400 acres) the highest concentrations have been observed at the times of flow peak (Soeur, *et al.* 1994; Brown, *et al.* 1995). The presence of a first flush has been reported to be associated with runoff duration by the City of Austin, TX (Swietlik, *et al.* 1995). An observed first flush may be present for some pollutants, but not others (Ellis 1986; Adams 2000). Adams (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

It is expected that peak concentrations generally occur during periods of peak flow (and highest rain energy). On relatively small paved areas, however, it is likely that there will always be a short period of relatively high concentrations associated with washing off of the most available material near the beginning of the runoff event (Pitt 1987). This peak period of high concentrations may be overwhe by periods of high rain intensity that may occur later in the event. In addition, in more complex drainage areas, the routing of these periods of peak concentrations may blend with larger flows and may not be noticeable. A first flush in a separate storm drainage system is therefore most likely to be seen if a rain occurs at relatively constant intensity over a paved area having a simple and small drainage system.

A total of 417 storm events with paired first flush and composite storm samples were available from the NSQD. The majority of the events were located in North Carolina (76.2%), but some events were also from Alabama (3.1%), Kentucky (13.9%) and Kansas (6.7%). All of the data were from end-of pipe samples in separate storm drainage systems.

The initial analyses were used to select the constituents and land uses that meet the requirements of the statistical comparison tests. Probability plots, box plots, concentration vs. precipitation, and standard descriptive statistics, were performed for 22 constituents for each land use, and for all land uses combined. Nonparametric statistical analyses were performed after the initial analyses. Mann Whitney and Fligner Policello tests were most commonly used. Minitab and Systat statistical programs, along with Word and Excel macros, were used for the analyses.

The Mann-Whitney and Fligner-Policello non-parametric tests were selected to determine if there were statistically significant differences between the first flush and composite data sets for each land use and constituent. These tests are very useful because they require only data symmetry, not normality, to evaluate the hypothesis. The null hypothesis during the analysis was that the median concentrations of the first flush and composite data sets were the same. The alternative hypothesis was that the medians were different, with a confidence of at least 95%.

A complete description of these analyses is presented in Maestre, *et al.* (2004). Table 4 summarizes the results of the analysis. The ">" sign indicates that the median of the first flush data set is higher than for the composite storm data set. The "=" sign indicates that the there is not enough information to reject the null hypothesis. Events without enough data for the analyses are represented with an "X". Also shown on this table are the ratios of the medians of the first flush and the composite data sets for each constituent and land use. The first flush samples were larger than for the composite samples if the ratio is great than one. Generally, a statistically significant first flush is associated with a median concentration ratio of about 1.4, or greater (the exceptions occurred when the number of samples in a specific category is small). The largest significant ratios are about 2.5, indicating that the first flush concentrations may be about 2.5 times greater than the composite concentrations. More of the larger ratios are found in the commercial and institutional land use categories, areas where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open space land uses, locations where there may be larger areas of unpaved surfaces.

Results indicate that for 55% of the evaluated cases, the medians of the first flush data sets were significantly larger than for the composite sample sets. In the remaining 45% of the cases, both medians were expected to be the same, or the concentrations were possibly greater later in the events. About 70% of the constituents in the commercial land use category had first-flushes, while about 60% of the constituents in the residential, institutional and the mixed (mostly commercial and residential) land use categories had first flushes, and about 45% of the constituents in the industrial land use category had first-flushes. In contrast, no constituents were found to have first-flushes in the open space category.

COD, BOD_5, TDS, TKN, and Zn all had first flushes in all areas (except for the open space category). In contrast, turbidity, pH, fecal coliforms, fecal strep., total N, dissolved and ortho-P never showed a statistically significant first flush in any category. The conflict with TKN and total N implies that there may be some other factors involved in the identification of first flushes besides land use. If additional paired data become available during later project periods, it may be possible to extend these analyses to consider rain effects, drainage area, and geographical location.

Table 4. Presence of Significant First Flushes (ratio of first flush to composite median concentrations)

Parameter	Commercial	Industrial	Institutional	Open Space	Residential	All Combined
Turbidity	= (1.32)	X	X	X	= (1.24)	= (1.26)
pH	= (1.03)	= (1.00)	X	X	= (1.01)	= (1.01)
COD	> (2.29)	> (1.43)	> (2.73)	= (0.67)	> (1.63)	> (1.71)
TSS	> (1.85)	= (0.97)	> (2.12)	= (0.95)	> (1.84)	> (1.60)
BOD_5	> (1.77)	> (1.58)	> (1.67)	= (1.07)	> (1.67)	> (1.67)
TDS	> (1.82)	> (1.32)	> (2.66)	= (1.07)	> (1.52)	> (1.55)
O&G	> (1.54)	X	X	X	= (2.05)	> (1.60)
Fecal Coliform	= (0.87)	X	X	X	= (0.98)	= (1.21)

Fecal Strep.	= (1.05)	X	X	X	= (1.30)	= (1.11)
Ammonia	> (2.11)	= (1.08)	> (1.66)	X	> (1.36)	> (1.54)
NO_2 NO_3	> (1.73)	> (1.31)	> (1.70)	= (0.96)	> (1.66)	> (1.50)
Total N	= (1.35)	= (1.79)	X	= (1.53)	= (0.88)	= (1.22)
TKN	> (1.71)	> (1.35)	X	= (1.28)	> (1.65)	> (1.60)
Total P	> (1.44)	= (1.42)	= (1.24)	= (1.05)	> (1.46)	> (1.45)
P Dissolved	= (1.23)	= (1.04)	= (1.05)	= (0.69)	> (1.24)	= (1.07)
Phosphate Ortho	X	= (1.55)	X	X	= (0.95)	= (1.30)
Cd	> (2.15)	= (1.00)	X	= (1.30)	> (2.00)	> (1.62)
Cr	> (1.67)	= (1.36)	X	= (1.70)	= (1.24)	> (1.47)
Cu	> (1.62)	> (1.24)	= (0.94)	= (0.78)	> (1.33)	> (1.33)
Pb	> (1.65)	> (1.41)	> (2.28)	= (0.90)	> (1.48)	> (1.50)
Ni	> (2.40)	= (1.00)	X	X	= (1.20)	> (1.50)
Zn	> (1.92)	> (1.540	> (2.48)	= (1.25)	> (1.58)	> (1.59)

Modeling Building using the NSQD

As indicated earlier, an important objective of the NSQD is to develop a predictive tool to enable stormwater managers to determine the likely stormwater quality for their area. In many cases, adequate data may be available in the NSQD to fit their situation. However, it is also expected that some will need to establish a local monitoring program to obtain reliable estimates of their stormwater quality. The next subsection provides some monitoring guidance for this situation, while this subsection presents an example of the model building process that we are currently using.

Factors Potentially Affecting Stormwater Pollutant Concentrations

The database contains information for the monitored watersheds, along with the outfall runoff quality. Each sample is labeled with the land use, season, geographical area, percent imperviousness, rain amount, and many other attributes in the database. The first phase of the NSQD project focused on the mid Atlantic and Gulf coast areas, although additional data has been collected for other locations. About 54% of the existing data in the database is from communities located in Maryland, Virginia, Pennsylvania, North Carolina, Kentucky and Tennessee. The following factors may affect the reported stormwater pollutant concentrations:

- Landuse: All of the watershed areas were separated into residential, commercial, industrial, open space and freeway land uses. Data are also available from mixed landuse areas which will be used later to verify the prediction methods.
- EPA Rain Zone: As shown in Figure 1, the country is divided in 9 rain/climatic regions representing all combinations of areas having warm summers, cold winters, large rainfalls, and little rain.
- Season: Four seasons were identified by the month when the samples were collected: Winter (December to February); Spring (March to May); Summer (June to August); and Fall (September to November).
- Percentage Imperviousness: About 2/3 of the monitoring sites currently have percentage imperviousness data.
- Rainfall: Almost all of the events have the rainfall amount associated with the monitored event.
- Type of sample collection: Some of the events represent special "first-flush" and composite sample pairs for the same event. These data were evaluated previously to identify these effects on runoff water quality. The type of sampler and sampling method has been identified for about ¼ of the sampling locations.
- Runoff amount: About 1/3 of the events have the runoff amounts associated with the monitored events.
- Watershed area: All of the monitored locations have the watershed areas identified.
- Date of sample collection: All of the data are associated with the date of sample collection. In addition to the seasonal effects, this information can be used to examine any trends in concentration that may have occurred during the 10 years of sample collection represented in the NSQD.
- Type of conveyance system: About 1/3 of the sites have the conveyance system identified.
- Aerial photographs and topographic maps have been obtained for almost all of the monitoring areas.

Figure 11 is a probability plot for the observed COD concentrations separated by land use. This plot is similar to the previously presented box and whisker plots for the different constituents separated by land use. These plots do show additional information that is useful for developing predictive models. As typically assumed, the COD values closely follow log-normal probability plots for much of the data range (Figure 2 illustrates log-normal probability plots for many of the constituents available in the NSQD, but grouped for all factors combined). Figure 11 shows significant differences by land uses. The open space COD concentrations are the lowest, and the freeway COD concentrations are the largest for most all of the data range. The residential, commercial, and industrial areas are very similar for the lower half of the distribution, while the residential areas are lower than the commercial and industrial areas in the upper portion of the distribution. The effects of some of the above listed factors on concentrations have been previously illustrated. The following shows how we plan to develop the predictive tool for the main watershed factors listed above. In this example, we will examine COD concentrations as a function of EPA rain zones and season, for the residential areas.

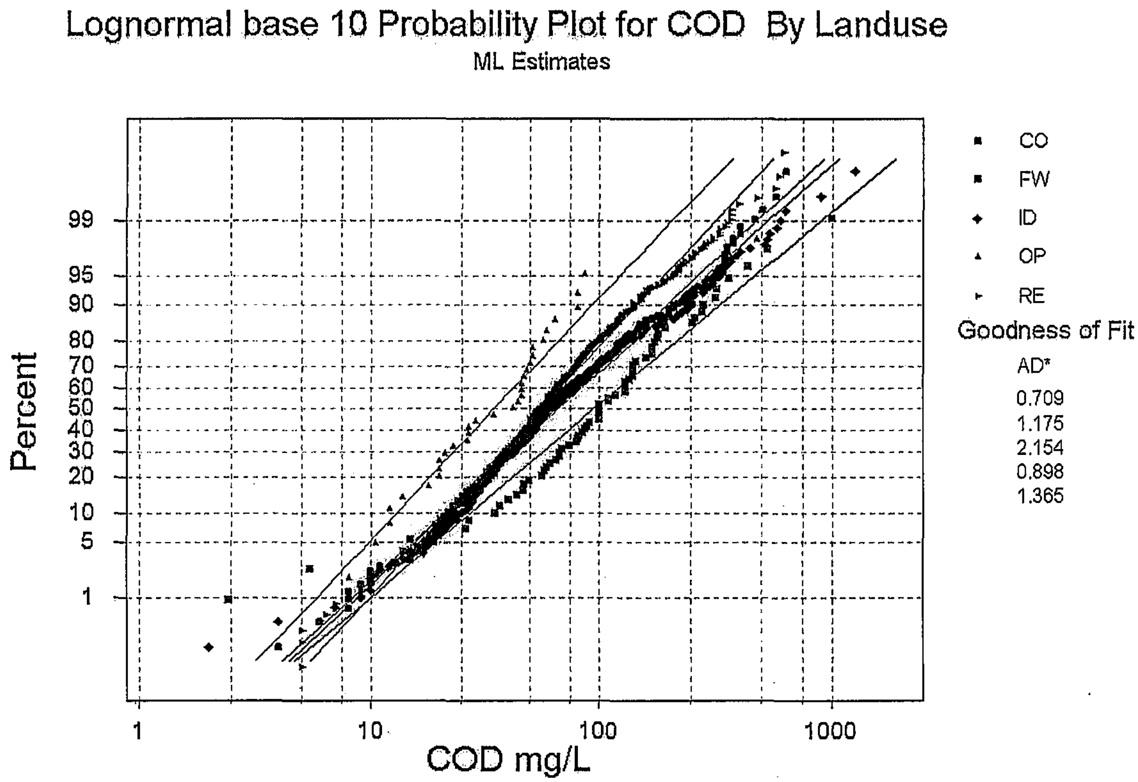


Figure 11. Probability plots of COD concentrations for different land uses.

It is possible to identify statistically significant differences in the COD concentrations for residential land uses in different EPA zones and seasons. Table 5 shows the total number of storm events collected which has residential COD values for the different rain zones and seasons.

Table 5. Number of Events with Detected COD Values in Residential Land Use Areas in the NSQD

EPA Rain Zone	Total	Spring	Summer	Fall	Winter
1	6	1	5	-	-
2	490	116	102	135	137
3	53	12	10	14	17
4	43	9	15	8	11
5	95	39	5	22	29
6	44	7	19	6	12
7	49	15	1	18	15
8	7	3	1	3	-
9	-	-	-	-	-

Table 5 shows that EPA rain zone 2 has about 62% of the total number of COD observations in the database. This unbalance of sample numbers can potentially lead to confusing results if the other areas do not adequately represent the actual conditions in their areas and is a violation of the data assumptions needed for a successful ANOVA test. It is possible to see if there is a difference in the COD concentrations for the different seasons in each zone during the four seasons using a one-way analysis of variance test, as the numbers of samples in each season for each main zone are relatively even.

The analysis of variance requires that the residuals are normally distributed and there is the same variance for each of the seasons. After log transforming the data, it was found that the residuals can be considered normal with a p-value of 0.8 using the Kolmogorov-Smirnov Goodness of fit test. To test if the variances are the same for the four seasons, Barlett's test was used. This test is powerful when the normality assumption of the residuals is achieved, as in this example. The results indicated that the variance can be considered the same for each season in EPA rain zone 2, with a p-value of 0.44. The results of the ANOVA found that there is a significant difference in the COD concentrations during the four seasons. The COD concentration in EPA rain zone two during winter seems to be smaller than summer and spring. The pooled standard deviation of the observations was calculated as 0.677

Power Calculations as a Function of Numbers of Data Observations

Figure 12 is a set of power curves showing the difference in the mean COD concentrations for the different subgroups that can be identified for different numbers of samples. If the ANOVA test indicated a significant difference with a confidence of five percent ($\alpha=0.05$), these mean differences can be detected for the noted sample sizes. Table 6 lists the sample sizes needed, for a power level of 0.8 and a confidence of 0.05, to detect the noted differences in mean concentrations. If a goal of at least a 25% difference was desired, then about 120 samples in each season would be needed. This is approximately the conditions for EPA rain zone 2 residential land uses. However, if only 10 samples are available for each season, then the "detectable" difference would be relatively large (larger than 50%).

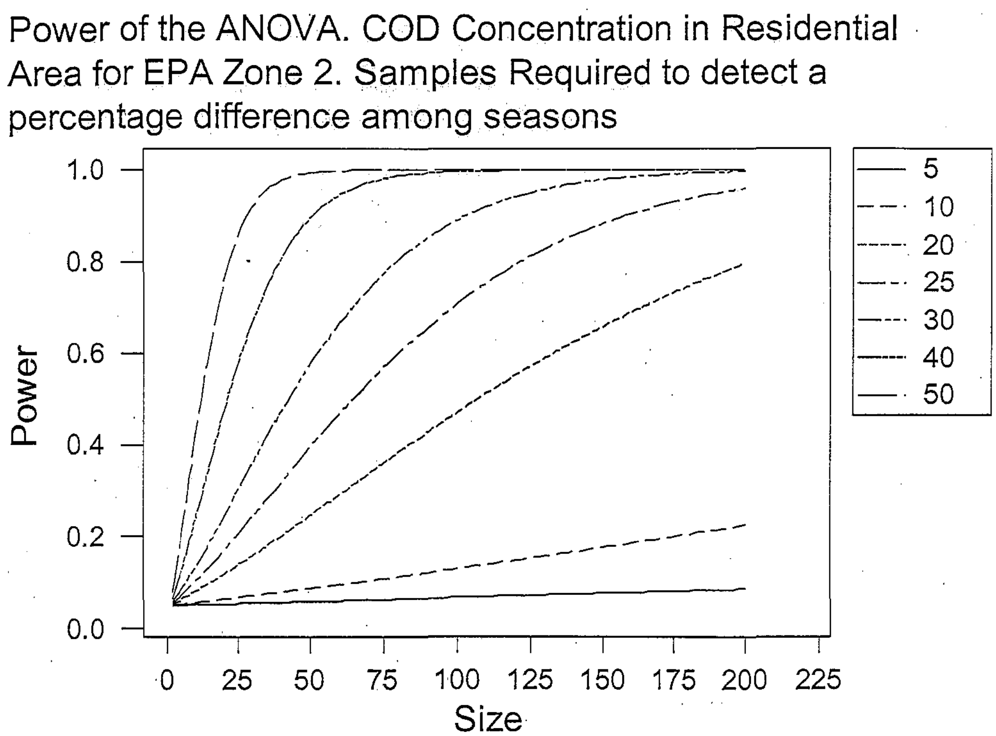


Figure 12. Power of the one way ANOVA test for COD in EPA rain zone 2.

Table 6. Samples required to detect specific differences in the COD for different seasons

Percentage difference between the mean values (%)	Samples Required
5	3844
10	908
20	202
25	122
30	80
40	40
50	22

Multivariate Analyses of Factors

A two-way analysis can also be conducted to examine the effects of both seasons and rain zones together, and their interaction. In following example, rain zones 3, 4, 5, 6, and 7 were evaluated for all four seasons. Rain zone 2 was excluded from this preliminary analysis because it had many more samples than the other regions and could have overly emphasized those conditions. The first step in this analysis is to check the distributions and variances of the data sets. The residuals (the differences of the observations from the mean) can be considered normal as they had a p-value higher than 15% (no significant difference from a normal distribution). Barlett's test also indicated that the variance for the different groups can be considered the same with a p-value of 0.35. A two-way ANOVA can therefore be used to identify any differences between the seasons and EPA rain zones, plus their interaction, because the data were normally distributed and they have the same variance within each group.

The 2-way ANOVA results indicated that there are no significant differences between the different seasons (p-value = 0.091), but that there is a difference between the EPA rain zones (p-value < 0.001). Figure 13 contains probability plots of the residential COD values for each season, showing no clear distinction of these concentrations for the different seasons. The ANOVA test also found no significant interaction between rain zone and season (p-value = 0.25).

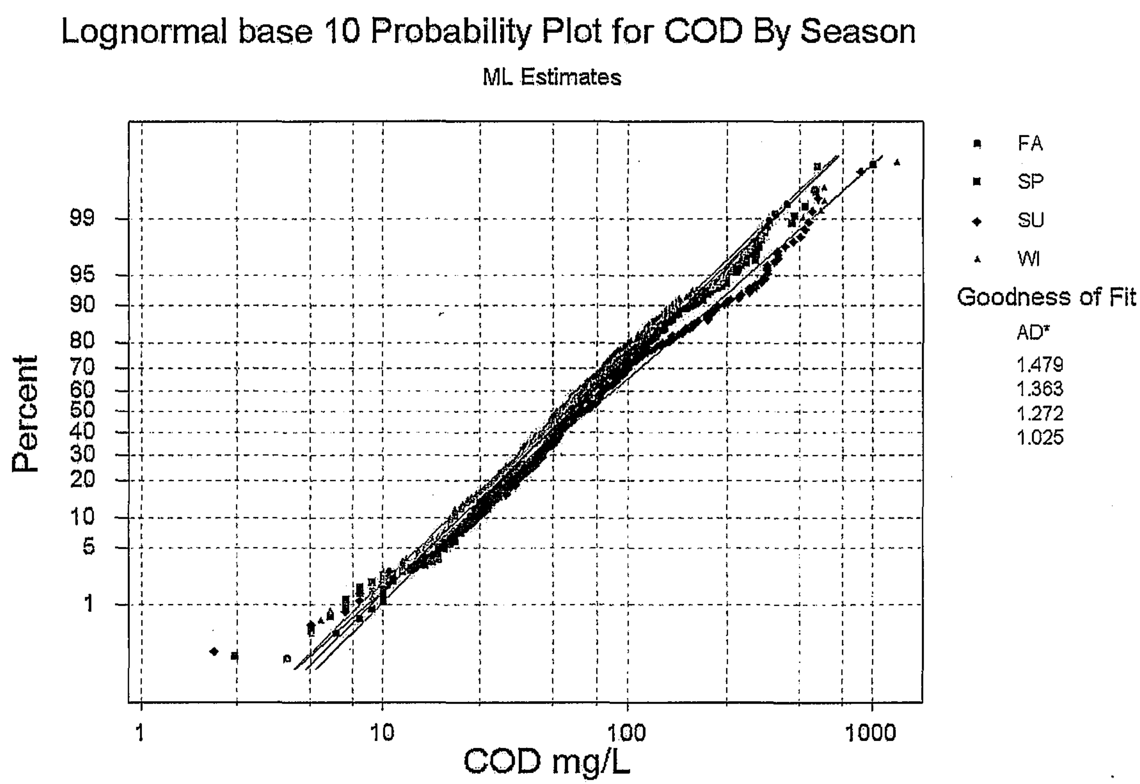


Figure 13. Probability plots of residential COD concentrations for different seasons.

Figure 14 shows probability plots of residential area COD concentrations for each EPA rain zone. There are likely three distinct groupings for residential COD values, based on their geographical location. Samples collected in zone 6 had the highest mean concentrations and were collected in Arizona. Samples collected in zones 2, 4 and 5 were intermediate in COD concentration and were collected in the mid Atlantic states and Texas. Samples collected in zones 3 and 7 had the lowest COD concentrations and were collected in Alabama, Georgia, and in Oregon.

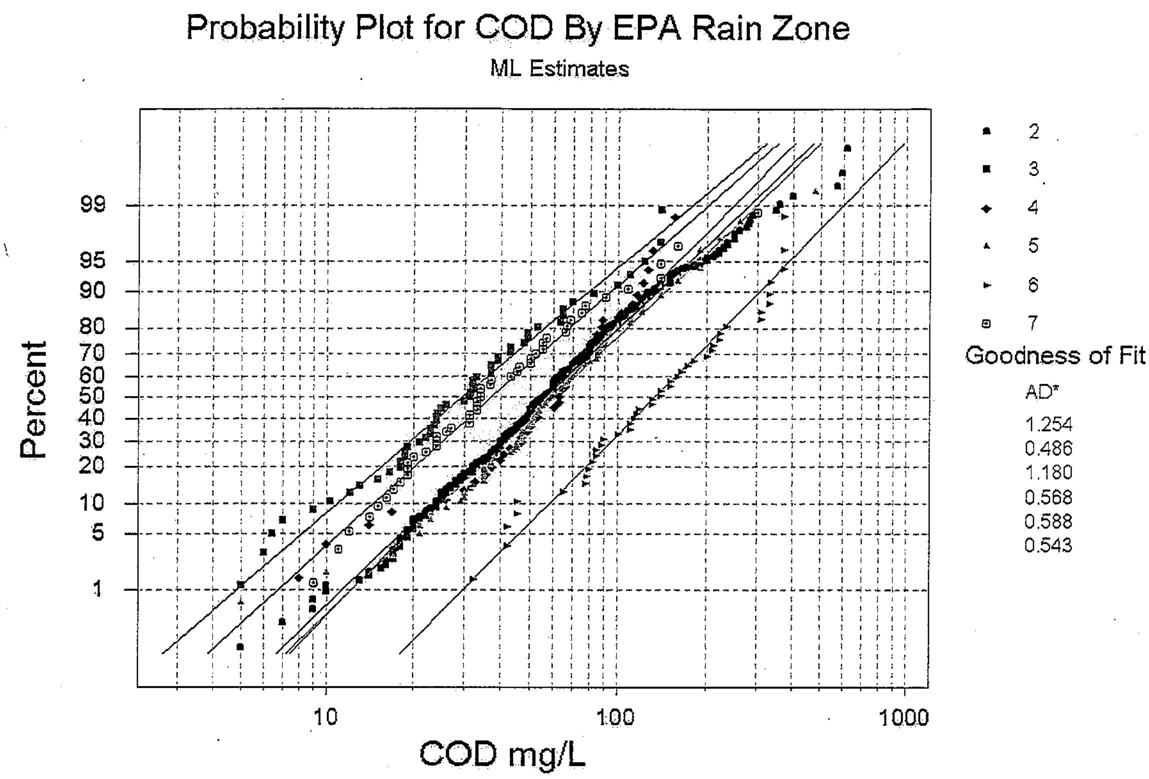


Figure 14. Probability plots of residential COD concentrations in different EPA Ran Zones.

Therefore, COD residential area concentrations can be divided into the following three groups, based on EPA rain zone:

Zones 3 and 7: average: 44.4 mg/L, standard deviation: 41.9 (102 observations)
Zones 2, 4 and 5: average: 72.8 mg/L, standard deviation: 61.6 (628 observations)
Zone 6: average: 162.1 mg/L, standard deviation: 100.0 (44 observations)

Overall residential COD: average: 74.1, standard deviation: 69.2 mg/L

The statistical analyses of the available NSQD COD residential area data did not identify any significant differences in any rain zones that can be explained by season. There was insufficient data in zones 1, 8, and 9 to be evaluated by season and the overall residential COD values should therefore be used for those areas until additional data is collected and evaluated.

Clustering and principal component analyses (PCA) are also being used to identify expected factors influencing sample variability. Figure 15 is an example dendogram from a cluster analysis of all of the preliminary data combined. However this analysis did not include most of the site characteristics when it was conducted; only rain depth, watershed size, and percentage imperviousness were included for this analysis, in addition to the runoff concentrations. This plot indicates very close relationships between rain depth and the nutrients (total phosphorus, dissolved phosphorus, nitrite plus nitrate, ammonia, and Total Kjeldahl Nitrogen). Some of the heavy metals (cadmium, nickel, and chromium) are closely related to each other, but copper, lead and zinc are much more independent. BOD_5, COD, dissolved solids, and suspended solids are poorly related to other pollutants for the pooled data. Pearson correlation analyses did show relatively strong relationships between suspended solids and the total forms of most of the heavy metals, substantiating the observation that most of the stormwater metals are not in filtered forms.

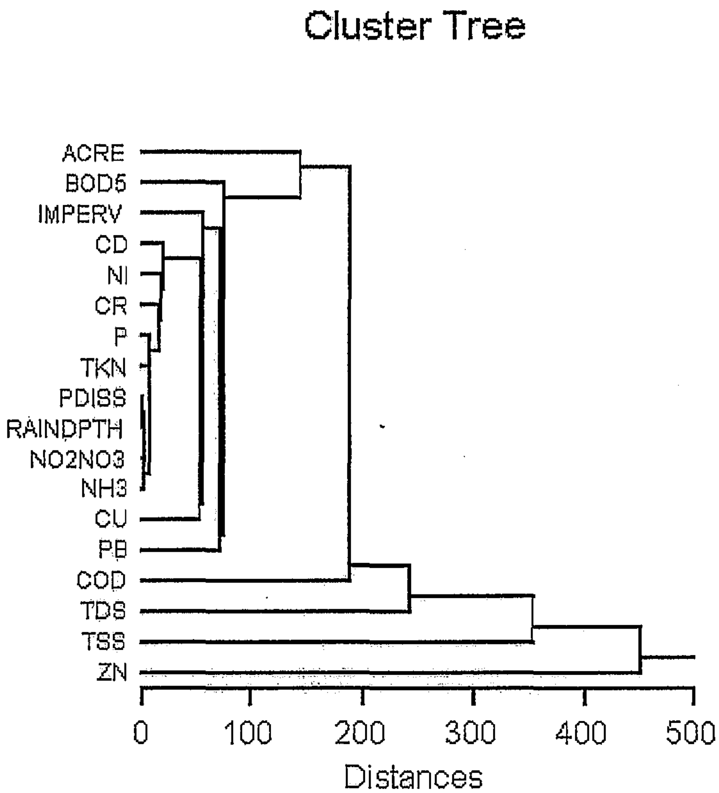


Figure 15. Cluster analysis (dendogram) showing relationships between stormwater pollutants.

Sampling Guidance for Stormwater Monitoring

A number of sampling issues can be statistically investigated using the information contained in the NSQD. The following discussion is a summary of the types of monitoring guidance that can be developed and refined using the database information.

Numbers of Samples Needed

An important aspect of any research is the assurance that the samples collected represent the conditions to be tested and that the number of samples to be collected are sufficient to provide statistically relevant conclusions. An experimental design process can be used that estimates the number of needed samples based on the allowable error, the variance of the observations, and the degree of confidence and power needed for each parameter. The number of samples needed is therefore dependent on the objectives of the data (characterization, comparison, trends, etc.), the variation of the concentrations in the category being investigated (typically described by the coefficient of variation, or the ratio of the mean to the standard deviation), and the allowable errors (the confidence and the power).

A basic equation that can be used to estimate the number of samples to characterize a set of conditions (given in Burton and Pitt 2001) is as follows:

$$n = [COV(Z_{1-\alpha} + Z_{1-\beta})/(error)]^2$$

where:

n = number of samples needed

α= false positive rate (1-α is the degree of confidence. A value of α of 0.05 is usually considered statistically significant, corresponding to a 1-α degree of confidence of 0.95, or 95%.)

β= false negative rate (1-β is the power. If used, a value of β of 0.2 is common, but it is frequently and improperly ignored, corresponding to a β of 0.5.)

$Z_{1-\alpha}$ = Z score (associated with area under normal curve) corresponding to 1-α. If α is 0.05 (95% degree of confidence), then the corresponding $Z_{1-\alpha}$ score is 1.645 (from standard statistical tables).

$Z_{1-\beta}$= Z score corresponding to 1-β value. If β is 0.2 (power of 80%), then the corresponding $Z_{1-\beta}$ score is 0.85 (from standard statistical tables). However, if power is ignored and β is 0.5, then the corresponding $Z_{1-\beta}$ score is 0.

error = allowable error, as a fraction of the true value of the mean

COV = coefficient of variation (sometimes noted as CV), the standard deviation divided by the mean (Data set assumed to be normally distributed.)

This equation assumes a normal distribution of the data, which would require a log transformation of most stormwater quality data. If an allowable error of about 25% is desired and the COV is estimated to be 0.4, then about 20 samples would have to be analyzed. The use of stratified random sampling can usually be used to advantage by significantly reducing the COV of the sub-population in the strata, requiring fewer samples for characterization.

Typical Numbers of Samples Needed for a Basic Stormwater Monitoring Program

The COV values for many constituents shown in Table 1 for the NPDES database range from unusually low values of about 0.1 (for pH) to highs between 1 and 2. There are a few COV values that are larger. One objective of a data analysis procedure is to categorize the data into separate stratifications, each having small variations in the observed concentrations. The only stratification in Table 1 is land use. However, Figure 6 shows many differences by geographical area (refer to Figure 1 for the EPA Rain Zone map). It is expected that the final data analyses for this project will identify separate stratifications of data (possibly considering the combination of land use, geographical area, and season factors) to significantly reduce the variations in each category. It is expected that COV values in the range of 0.5 to 1.0 will be common for many of these data stratifications. With a reasonable confidence of 95% (α= 0.05) and power of 80% (β= 0.20), and a commonly accepted allowable error of 25%, the number of samples needed to characterize conditions would likely range from about 25 to 50. If only 12 samples are obtained for each category (strata), the allowable errors would range from about 50% to 100%. Burton and Pitt (2001) present many additional experimental design equations and plots for other data quality objectives, including the effects of log transforming the data for more appropriate sampling effort approximations. In many cases, the actual errors in presenting data are larger than expected, due to relatively small numbers of samples. A continuing monitoring program (such as the Phase I stormwater NPDES permit monitoring effort) will result in better data as more samples are obtained with time.

Detection Limits of Analytical Methods

The NSQD can also be useful when selecting analytical methods. There are many important factors that must be considered when selecting an analytical method (availability, cost, detection limit, repeatability, safety and disposal problems, comparisons with historical data, etc.), but the detection limit is likely most important when ensuring the suitability of the data. In many cases, analytical methods are used that have detection limits that are actually larger than a criterion value, making accurate exceedence frequencies impossible (Burton and Pitt 2001).

Environmental researchers need to be concerned with many attributes of numerous analytical methods when selecting the most appropriate methods to use for analyses of their samples. The main factors that affect the selection of an analytical method include: cost, reliability (the "data quality objectives," or DQO which includes sensitivity, selectivity, repeatability), and safety. Most of these issues are not well documented in the literature for environmental sample analyses. Aspects of analytical reliability have received the most attention in the literature, but most of the other aspects noted above have not been adequately discussed for the many analytical alternatives available. It is therefore difficult for a water quality analyst to decide which methods to select, or even if a choice exists.

The selection of the appropriate analysis procedure is dependent on the use of the data and how false negatives or false positives would affect water use decisions or regulatory questions. The QA objectives for the method detection limit (MDL) and precision (RPD) for the compounds of interest have been shown to be a function of the anticipated median concentrations in the samples (Pitt, *et al.* 1993). The MDL objectives should generally be about 0.25, or less, of the median value for sample sets having typical concentration variation (COV values ranging from 0.5 to 1.25), based on many Monte Carlo evaluations to examine the rates of false negatives and false positives. Table 7 lists the typical median stormwater runoff constituent concentrations and the associated calculated MDL goals, for a typical stormwater monitoring project.

Using analytical methods having these detection limits, at least, will result in relatively few "non-detected" values. In most cases, analytical methods are available that can easily meet these goals. However, common problems are associated with some of the heavy metals, as most modern laboratories use ICP (inductively-coupled plasma) instruments that are capable of analyzing a broad range of metals simultaneously, but may not be able to meet these detection limit goals. When dissolved forms of the heavy metals need to be analyzed, the detection limits must be much smaller.

The NPDES stormwater database can be used to indicate the likely concentrations of interest for conditions similar to those that will be monitored. These expected values are a good start in determining the needed detection limits.

Sampling Methods

Details for all monitoring locations are desired for the database. Basic information (land use, season, geographic location, and if the sample is a first-flush or a composite sample) is available for all events in NSQD, and relatively complete site and monitoring descriptions are available for about 1/3 of the events. This data includes sampling methods (automatic samplers vs. manual samplers; manufacture and model of sampler; etc.). Investigations of how these factors may influence the monitoring results will be made, as illustrated in the initial evaluation of first-flush vs. composited samples. The effects of automatic vs. manual sampling will also be examined when sufficient information has been collected. One example of a previous investigation on stormwater sampling methods was conducted by Roa-Espinosa and Bannerman (1995). They collected samples from five industrial sites using different monitoring methods. They concluded that many time-composited subsamples combined for a single analysis can provide improved accuracy compared to fewer samples associated with flow-weighted samplers, and especially compared to samples only taken during a portion of an event.

Conclusions

A major goal of this project is to provide guidance to stormwater managers and regulators. Especially important will be the use of data as an updated benchmark for comparison with locally collected data. These comparisons will enable local monitoring data to be compared to typical values that should be expected for similar situations. If the local stormwater quality is significantly worse than expected, then it may be possible to quantify a treatment goal that should be attainable. In addition, this data may be useful for preliminary calculations when using the "simple method" for predicting mass discharges for unmonitored areas. This data can also be used as guidance when designing local stormwater monitoring programs (Burton and Pitt 2002), especially when determining the needed sampling effort based on expected variations. The final data analyses will expand on these preliminary examples and will also investigate other stormwater data and sampling issues.

Table 7. Example QA Objectives for a Stormwater Characterization Project

Constituent	Units	Typical COV category[1]	Typical Median Conc.	Estimated MDL Goal
Turbidity	NTU	low	5	4
COD	mg/L	medium	50	12
suspended solids	mg/L	medium	50	12
nitrates	mg/L	low	0.6	0.4
chromium	μg/L	medium	7	1.5
copper	μg/L	medium	15	3.5
lead	μg/L	medium	15	3.5
nickel	μg/L	medium	10	2.3
zinc	μg/L	medium	100	23
1,3-dichlorobenzene	μg/L	medium	10	2
benzo(a) anthracene	μg/L	medium	30	8
bis(2-ethylhexyl) phthalate	μg/L	medium	10	2.3
butyl benzyl phthalate	μg/L	medium	15	3

fluoranthene	µg/L	medium	6	1.4
pentachlorophenol	µg/L	medium	10	2
pyrene	µg/L	medium	5	1
lindane and chlordane	µg/L	medium	1	0.2

1 COV value: Multiplier for MDL

COV value	Multiplier for MDL
<0.5 (low)	0.8
0.5 to 1.25 (medium)	0.23
>1.25 (high)	0.12

from: Burton and Pitt 2001

The example investigation of first-flush conditions indicated that a first flush effect was not present in all the land uses and certainly not for all the constituents. Commercial and residential areas were more likely to show the phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that the effect will be more likely in watersheds with larger amounts of imperviousness. However, the industrial category had large amounts of imperviousness, but indicated first-flushes less than 50% of the time. All the metals evaluated show a higher concentration at the beginning of the event in the commercial land use category.

Suggested Role for Continued Stormwater Monitoring

The current data and information contained in NSQD indicates the potential value that a completed database (containing most of the NPDES stormwater data) can provide. The excellent U.S. national coverage, along with the broad representation of land uses, seasons, and other factors, makes this information highly valuable for numerous basic stormwater management needs. Monitoring with no specific objective, except for general characterization in an area, is not likely to provide any additional value beyond the data and information contained in NSQD. After a sufficient amount of data has been collected by a Phase 1 community for representative land uses and other conditions, outfall characterization monitoring resources should be re-directed to other specific data collection and evaluation needs. Burton and Pitt (2001) provide much additional information on determining an adequate outfall monitoring program. Similarly, communities that have not initiated a stormwater monitoring program (such as the Phase II NPDES small communities) may not require general characterization monitoring (monitoring is not specifically required as part of the Phase II regulations), if they can identify a regional Phase I community that has compiled extensive monitoring data as part of their required NPDES stormwater permit. Obviously, there will be some situations that are not well represented in NSQD and additional characterization monitoring may be warranted. These situations will be identified in the final data analyses.

This is not to say that stormwater quality monitoring has no role as part of a stormwater management program. Burton and Pitt (2001) present extensive examples and procedures showing the importance of a balanced monitoring program. This publication is available from CRC Press, and a version is available at:
http://civil.eng.ua.edu/~rpitt/Publications/BooksandReports/Stormwater%20Effects%20Handbook%20by%20%20Burton%20and%20Pitt%20book/MainEDFS_Book.html

Stormwater quality monitoring is a crucial component of local programs. Specific objectives for these include:

• Receiving water assessments to understand local problems. Receiving water monitoring is needed to identify local problems, especially when identifying beneficial use impairments. Assimilative capacity calculations (TMDLs) require knowledge of local source discharges. The NSQD data and information can be used for preliminary designs and cost estimates, but it is also important to invest a small amount of resources to accurately determine local discharge conditions before expensive controls are designed.

• Source area monitoring to identify critical sources. In many cases, source area controls may be more cost-effective than regional controls. The identification of critical source areas is therefore needed as part of a comprehensive stormwater management program. Monitoring within a critical drainage area should be conducted to identify the sources of pollutants, while simultaneous outfall monitoring is needed to verify these source area measurements.

• Detailed monitoring at selected outfalls, with complete monitoring of rainfall and runoff, with high-resolution data to examine time-variability characteristics of certain problem pollutants. This would be especially important at small, highly paved areas where "first-flush" conditions are most likely. This information is needed to evaluate the benefits and to quantify design approaches of critical source area controls.

• Treatability tests to verify performance of stormwater controls for local conditions. In areas where stormwater controls are being installed, local measurements of performance are a good investment. Before and after monitoring, or parallel monitoring, is usually needed to measure the performance of many types of stormwater controls. The ASCE National Stormwater BMP database (http://www.bmpdatabase.org/) is a good place to start in predicting the performance of controls, but site-specific validations in an area where the controls have not been previously used should be conducted.

• Assessment monitoring to verify success of stormwater management approach. Stormwater quality monitoring is a critical component of an assessment monitoring effort. Receiving water monitoring needs to focus on beneficial use impairments, and associated chemical, physical, and biological monitoring. In many cases, source area or outfall controls are being used as part of comprehensive management programs. Therefore, outfall monitoring may also be needed.

Acknowledgements

Many people and institutions need to be thanked for their help on this research project. Project support and assistance from Bryan Rittenhouse, the US EPA project officer for the Office of Water, is gratefully acknowledged. The many municipalities who worked with us to submit data and information were obviously crucial and the project could not be conducted without their help. Finally, the authors would like to thank a number of graduate students at the University of Alabama (especially Veera Rao Karri, Sanju Jacob, Sumandeep Shergill, Yukio Nara, and Soumya Chaturvedula) and employees of the Center for Watershed Protection (Ted Brown, Chris Swann, Karen Cappiella, and Tom Schueler) for their careful work on this project.

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ITEMS

SITE DESCRIPTION

ITEM	DESCRIPTION	EXAMPLE
Order	Key to identify the event, numeric, Integer	1
Landuse	Landuses that represent most of the watershed RE: Residential, CO: Comercial, ID: Industrial, IS:Institutional, OP: Open Space, FW: Freeway	RE_CO
Season	Season: WI: Winter (Dec-Jan-Feb); SP: Spring (Mar-Apr-May); SU: Summer (Jun-Jul-Aug); FA:Fall (Sep-Oct-Nov)	FA
Season_WI_1	WI = 1; SP = 2; SU = 3; FA = 4	4
COM_FF_XX	Composite, Flush or grab sample	COM
LOCATION_ID	Key to identify state, jurisdiction and site. The key has characters in the following order. Two capital letters for the state, two for the jurisdiction or municipality. The last characters identify the discharge.	ALBHA001
Jurisdiction	Name of the Jurisdistiction or Municipality. If spaces are necessary use _ instead.	San_Marcos
Site_ID	Use the ID used by the community. This is the last part of the ID that were used in LOCATION_ID	A001
Contact	Identify the name and phone number or e-mail of the office that create the record.	Gepeto@epa.gov
PLU_Residential	Percentage of Landuse residential in the drainage area	45
PLU_Institutional	Percentage of Landuse institutional in the drainage area	5
PLU_Commercial	Percentage of Landuse commercial in the drainage area	15
PLU_Industrial	Percentage of Landuse industrial in the drainage area	0
PLU_Open_Space	Percentage of Landuse open space in the drainage area	25
PLU_Freeway	Percentage of Landuse freeway in the drainage area	10
Drainage_Area	Drainage Area in acres	1.25
Latitude	Approximated Latitude North of the site in dd_mm_ss	38_54_09.09
Longitude	Approximated Longitude West of the site in dd_mm_ss	77_09_13.00
EPA_Rain_Zone	Zones according to: Methodology for Analyisis of Detention Basins for control of Urban Runoff Quality Prepared for the U.S. Environmental Protection Agency, Office of Water. 1986 [55 FR 48073 Nov 16 1990] 40 CFR part 122 appendix E	2
Per_Impervious	Percentage of impervious in the drainage area. Use 100 for complete impervious	45
Runoff_Vol_Coef	Volumetric runoff coefficient in the drainage area	0.25
Curve_Number	Curve number	75
Aged_Development	Age of the development in years	10.5

	Type_Conveyance	Use 2 capital letters in this field. CG for curb and gutter/seal drainage; GS for grass swale or OT for others. Use the comments column to add more information	CG
	Controls	Structure Control located above the discharge. Use WP for detention pond, DP for Dry Ponds, DT for detention structutes or OT for others. Use the comments field to add more information	WP
	Comments	Include all the comments that you consider relevant in the site.Don't use colons, semicolons, or commas. Use double underline instead period.	Low_Density_residential_in_Arlington_terms__Density_is_about_5_dwelling_units/acre__Garden_apts_and_low_rise_buildings
EVENT DESCRIPTION	EVENT_ID	use the code used for the community to identify the event	2001001
	Precipitation_Depth (in)	Precipitation depth of the EVENT_ID in inches.	1.6
	Q	Indicates where the precipitation was measured.	On Site
	Start_Date (mm/dd/yy)	Identify the start day of the EVENT_ID	4/12/1999
	Start_Time (min of day)	Identify the start time of the EVENT_ID	08_45
	End_Date (mm/dd/yy)	Identify the end day of the EVENT_ID.	4/13/1999
	End_Time (min of day)	Identify the end time of the EVENT_ID. **NOTE: If you don't have this information but have the duration, assign the start time at 00_00 of the storm day and assign the duration as end time. Additionally assign the start day as the end day.	23_30
	Maxr15	Maximum precipitation intensity in 15 minutes. (units in/hr)	0.85
	Runoff (in)	Total runoff of the EVENT_ID in inches.	0.89
	Q	Indicates if the runoff has base flow or not.	E_Base
	3H_TOT	Total runoff was evaluated for the complete event or the first 3 hours.	TOT
	FF_COM (First Flush or composite)	Identify with FF if the record corresponds to First Flush or COM for Composite	FF
	Type_Sample	MA: Manual; AU: Automatic	AU
	Type_Sampler	Indicate if the sample was time or flow weighted composite.	FLOW_COMP
	Type_Sa_An	DI: use for discrete analysis; COM: Used for composite analysis	DI
	BOD5 (mg/l)	Assign the value for each parameter in the corresponding units.	25.3
	Q	Qualifiers. Assign The following qualifiers according to the case: ND: Not Detected, don't assign any value to the cell value; NA: Not Available. The sample for this parameter was not available, please try to explain why in the comments; NZ: Not Analyzed; E:Estimated; C:Calculated	ND

Group	Subgroup	PARAMETER	X if included	Total Observations	Percentage Detected
Conventional Parameters	Commonly Used	Conductivity (uS/cm @ 25C)			
		DO (mg/L)			
		Hardness (mg/L CaCO3)			
		Oil and Grease (mg/L)			
		pH			
		Temperature (C)			
		Turbidity (NTU)			
	Sol	TDS (mg/L)			
		TS (mg/L)			
		TSS (mg/L)			
	O	BOD5 (mg/L)			
		COD (mg/L)			
	Bac	Fecal Coliform (colonies/100 ml)			
		Fecal Streptococcus (colonies/100 ml)			
		Total Coliform (colonies/100 ml)			
		Total E. Coli (colonies/100 ml)			
	Nutrients	Ammonia (mg/L)			
		N02+NO3 (mg/L)			
		Nitrogen Dissolved (mg/L)			
		Nitrogen Total (mg/L)			
		Nitrogen Kjeldahl Total (mg/L)			
		Phosphate Ortho (mg/L)			
		Phosphorous Dissolved (mg/L)			
		Phosphorous Total (mg/L)			
	Metals and Toxicants	Antimony Total (ug/L)			
		Antimony Dissolved (ug/L)			
		Arsenic Total (ug/L)			
		Arsenic Dissolved (ug/L)			
		Beryllium Total (ug/L)			
		Beryllium Dissolved (ug/L)			
		Cadmium Total (ug/L)			
		Cadmium Dissolved (ug/L)			
		Chromium Total (ug/L)			
		Chromium Dissolved (ug/L)			
		Copper Total (ug/L)			
		Copper Dissolved (ug/L)			
		Cyanide Total (ug/L)			
		Cyanide Dissolved (ug/L)			
		Lead Total (ug/L)			
		Lead Dissolved (ug/L)			
		Mercury Total (ug/L)			
		Mercury Dissolved (ug/L)			
		Nickel Total (ug/L)			
		Nickel Dissolved (ug/L)			
		Selenium Total (ug/L)			
		Selenium Dissolved (ug/L)			
		Silver Total (ug/L)			
		Silver Dissolved (ug/L)			
		Thallium Total (ug/L)			
		Thallium Dissolved (ug/L)			
		Toxicity Test Total (I25% RED)			
		Toxicity Test Dissolved (I25% RED)			
		Zinc Total (ug/L)			
		Zinc Dissolved (ug/L)			
	Volatiles	Acrolein (ug/L)			
		Acrylonitrile (ug/L)			
		Benzene (ug/L)			
		Bromoform (ug/L)			
		Carbon Tetrachloride (ug/L)			
		Chlorobenzene (ug/L)			
		Chlorodibromomethane (ug/L)			
		Chloroethane (ug/L)			
		2-Chloroethylvinyl ether (ug/L)			
		Chloroform (ug/L)			
		Dichlorobromoethane (ug/L)			
		1,1-Dichloroethane (ug/L)			
		1,2-Dichloroethane (ug/L)			
		1,1-Dichloroethylene (ug/L)			
		1,2-Dichloropropane (ug/L)			
		1,3-Dichloropropylene (ug/L)			

	Ethylbenzene (ug/L)
	Methylbromide (ug/L)
	Methylchloride (ug/L)
	Methylenechloride (ug/L)
	1,1,2,2-Tetrachloroethane (ug/L)
	Tetrachloroethylene (ug/L)
	Toluene (ug/L)
	1,2-Trans-dichloroetylene (ug/L)
	1,1,1-Trichloroethane (ug/L)
	1,1,2-trichloroethane (ug/L)
	Trichloroethylene (ug/L)
	Vinylchloride (ug/L)
Extra Parameters	Alkalinity, total as CaCO3 (mg/l)
	pH Field (S.U.)
	Fecal Coliform/Fecal Strep Ratio
	Oil and Grease Hidrocarbon (mg/l)
	Total_hydrocarbon_fingerprint (mg/l)
	Total_Petroleum_hydrocarbon (mg/l)
	Total_Organic_Carbon (mg/L)
	Chloride (mg/l)
	trans-1,3-Dichloropropene
	Bromomethane
	Chloromethane
	Trichlorofluoromethane
	Tetrachloroethene(ug/l)
	BOD5 Carbonaceous (mg/l)
	Hardness as calcium(mg/L)
	Hardness, Magnesium(mg/L)
	Nitrogen_Nitrate (mg/l)
	Nitrogen_Nitrite (mg/l)
	Nitrogen_Total_Organic (mg/l)
	Barium, total as Ba (ug/l)
	Iron, total as Fe (ug/l)
	Iron, Dissolved as Fe (ug/l)
	Days since last rain

		PARAMETER	X if included	Total Observations	Percentage Detected
Conventional Parameters	Commonly Used	Conductivity (uS/cm @ 25C)			
		DO (mg/L)			
		Hardness (mg/L CaCO3)			
		Oil and Grease (mg/L)			
		pH			
		Temperature (C)			
		Turbidity (NTU)			
	Sol	TDS (mg/L)			
		TS (mg/L)			
		TSS (mg/L)			
	O	BOD5 (mg/L)			
		COD (mg/L)			
	Bac	Fecal Coliform (colonies/100 ml)			
		Fecal Streptococcus (colonies/100 ml)			
		Total Coliform (colonies/100 ml)			
		Total E. Coli (colonies/100 ml)			
	Nutrients	Ammonia (mg/L)			
		N02+NO3 (mg/L)			
		Nitrogen Dissolved (mg/L)			
		Nitrogen Total (mg/L)			
		Nitrogen Kjeldahl Total (mg/L)			
		Phosphate Ortho (mg/L)			
		Phosphorous Dissolved (mg/L)			
		Phosphorous Total (mg/L)			
	Metals and Toxicants	Antimony Total (ug/L)			
		Antimony Dissolved (ug/L)			
		Arsenic Total (ug/L)			
		Arsenic Dissolved (ug/L)			
		Beryllium Total (ug/L)			
		Beryllium Dissolved (ug/L)			
		Cadmium Total (ug/L)			
		Cadmium Dissolved (ug/L)			
		Chromium Total (ug/L)			
		Chromium Dissolved (ug/L)			
		Copper Total (ug/L)			
		Copper Dissolved (ug/L)			
		Cyanide Total (ug/L)			
		Cyanide Dissolved (ug/L)			
		Lead Total (ug/L)			
		Lead Dissolved (ug/L)			
		Mercury Total (ug/L)			
		Mercury Dissolved (ug/L)			
		Nickel Total (ug/L)			
		Nickel Dissolved (ug/L)			
		Selenium Total (ug/L)			
		Selenium Dissolved (ug/L)			
		Silver Total (ug/L)			
		Silver Dissolved (ug/L)			
		Thallium Total (ug/L)			
		Thallium Dissolved (ug/L)			
		Toxicity Test Total (I25% RED)			
		Toxicity Test Dissolved (I25% RED)			
		Zinc Total (ug/L)			
		Zinc Dissolved (ug/L)			
	Volatiles	Acrolein (ug/L)			
		Acrylonitrile (ug/L)			
		Benzene (ug/L)			
		Bromoform (ug/L)			
		Carbon Tetrachloride (ug/L)			
		Chlorobenzene (ug/L)			
		Chlorodibromomethane (ug/L)			
		Chloroethane (ug/L)			
		2-Chloroethylvinyl ether (ug/L)			
		Chloroform (ug/L)			
		Dichlorobromoethane (ug/L)			
		1,1-Dichloroethane (ug/L)			
		1,2-Dichloroethane (ug/L)			
		1,1-Dichloroethylene (ug/L)			
		1,2-Dichloropropane (ug/L)			
		1,3-Dichloropropylene (ug/L)			

	Ethylbenzene (ug/L)
	Methylbromide (ug/L)
	Methylchloride (ug/L)
	Methylenechloride (ug/L)
	1,1,2,2-Tetrachloroethane (ug/L)
	Tetrachloroethylene (ug/L)
	Toluene (ug/L)
	1,2-Trans-dichloroetylene (ug/L)
	1,1,1-Trichloroethane (ug/L)
	1,1,2-trichloroethane (ug/L)
	Trichloroethylene (ug/L)
	Vinylchloride (ug/L)
Extra Parameters	Alkalinity, total as CaCO3 (mg/l)
	pH Field (S.U.)
	Fecal Coliform/Fecal Strep Ratio
	Oil and Grease Hidrocarbon (mg/l)
	Total_hydrocarbon_fingerprint (mg/l)
	Total_Petroleum_hydrocarbon (mg/l)
	Total_Organic_Carbon (mg/L)
	Chloride (mg/l)
	trans-1,3-Dichloropropene
	Bromomethane
	Chloromethane
	Trichlorofluoromethane
	Tetrachloroethene(ug/l)
	BOD5 Carbonaceous (mg/l)
	Hardness as calcium(mg/L)
	Hardness, Magnesium(mg/L)
	Nitrogen_Nitrate (mg/l)
	Nitrogen_Nitrite (mg/l)
	Nitrogen_Total_Organic (mg/l)
	Barium, total as Ba (ug/l)
	Iron, total as Fe (ug/l)
	Iron, Dissolved as Fe (ug/l)
	Days since last rain

ORDER	Landuse	Season	LOCATION_ID	Jurisdiction	Site_ID	Contact	PLU_Residential	PLU_Institutional	PLU_Commercial
39	ID	SP	VACHCOF1	esterfield County	unnamed OF1	Scott Flanigan	0	0	0
40	ID	FA	VACHCOF1	esterfield County	unnamed OF1	Scott Flanigan	0	0	0
41	ID	FA	VACHCOF1	esterfield County	unnamed OF1	Scott Flanigan	0	0	0
42	OP RE	SP	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
43	OP RE	FA	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
44	OP RE	WI	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
45	OP RE	FA	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
46	OP RE	SP	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
47	OP RE	FA	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
48	OP RE	SP	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
49	OP RE	FA	VACHCOF2	esterfield County	Oak river drive OF2	Scott Flanigan	20	0	0
50	RE	SP	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
51	RE	FA	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
52	RE	FA	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
53	RE	FA	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
54	RE	WI	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
55	RE	SP	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
56	RE	FA	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
57	RE	SP	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
58	RE	FA	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
59	RE	WI	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
60	RE	SP	VACHCOF3	esterfield County	Kings mill road OF3	Scott Flanigan	100	0	0
61	RE	SP	VACHCOF4	esterfield County	OF4	Scott Flanigan	100	0	0
62	RE	FA	VACHCOF4	esterfield County	OF4	Scott Flanigan	100	0	0
63	RE	WI	VACHCOF4	esterfield County	OF4	Scott Flanigan	100	0	0
64	RE	SP	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
65	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
66	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
67	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
68	RE	WI	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
69	RE	SP	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
70	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
71	RE	SP	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
72	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
73	RE	WI	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
74	RE	SP	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
75	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
76	RE	FA	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
77	RE	SU	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
78	RE	WI	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
79	RE	WI	VACHCOF5	esterfield County	Laurel oak road OF5	Scott Flanigan	100	0	0
80	RE	FA	VACHCN1A	esterfield County	Gates bluff 1A	Scott Flanigan	100	0	0
81	RE	FA	VACHCN1A	esterfield County	Gates bluff 1A	Scott Flanigan	100	0	0
82	RE	SU	VACHCN1A	esterfield County	Gates bluff 1A	Scott Flanigan	100	0	0
83	RE	WI	VACHCN1A	esterfield County	Gates bluff 1A	Scott Flanigan	100	0	0
84	RE	FA	VACHCN2A	esterfield County	Helmsley road 2A	Scott Flanigan	100	0	0
85	RE	FA	VACHCN2A	esterfield County	Helmsley road 2A	Scott Flanigan	100	0	0
86	RE	SU	VACHCN2A	esterfield County	Helmsley road 2A	Scott Flanigan	100	0	0
87	RE	WI	VACHCN2A	esterfield County	Helmsley road 2A	Scott Flanigan	100	0	0
88	CO	FA	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
89	CO	WI	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
90	CO	SP	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
91	CO	FA	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
92	CO	SP	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
93	CO	FA	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
94	CO	WI	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
95	CO	SP	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
96	CO	FA	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
97	CO	FA	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
98	CO	SU	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
99	CO	WI	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
100	CO	WI	VACHCCC4	esterfield County	CoverLeaf Mall CC4	Scott Flanigan	0	0	100
101	RE	FA	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
102	RE	WI	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
103	RE	SP	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
104	RE	FA	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
105	RE	SP	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
106	RE	FA	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
107	RE	WI	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
108	RE	SP	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
109	RE	FA	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
110	RE	FA	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
111	RE	SU	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
112	RE	WI	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0
113	RE	WI	VACHCCC5	esterfield County	Buck Rub Drive CC5	Scott Flanigan	100	0	0

ORDER	PLU_Industrial	PLU_Open_Space	PLU_Freeway	Drainage_Area	Latitude	Longitude	EPA_Rain_Zone	Per_Impervious	Q	Runoff_Vol_Coef
39	100	0	0	22.5			2			
40	100	0	0	22.5			2			
41	100	0	0	22.5			2			
42	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
43	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
44	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
45	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
46	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
47	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
48	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
49	0	80	0	19.05	37 13 54.12	77 32 10.68	2	10		0.14
50	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
51	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
52	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
53	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
54	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
55	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
56	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
57	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
58	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
59	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
60	0	0	0	13.5	37 31 24.24	77 38 57.12	2	20		0.23
61	0	0	0	38.5			2			
62	0	0	0	38.5			2			
63	0	0	0	38.5			2			
64	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
65	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
66	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
67	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
68	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
69	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
70	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
71	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
72	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
73	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
74	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
75	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
76	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
77	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
78	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
79	0	0	0	55.6	37 28 48.43	77 27 47.42	2	50		0.5
80	0	0	0	10	37 22 46.35	77 31 38.33	2	10		0.14
81	0	0	0	10	37 22 46.35	77 31 38.33	2	10		0.14
82	0	0	0	10	37 22 46.35	77 31 38.33	2	10		0.14
83	0	0	0	10	37 22 46.35	77 31 38.33	2	10		0.14
84	0	0	0	60	37 31 53.5	77 40 03.81	2	20		0.23
85	0	0	0	60	37 31 53.5	77 40 03.81	2	20		0.23
86	0	0	0	60	37 31 53.5	77 40 03.81	2	20		0.23
87	0	0	0	60	37 31 53.5	77 40 03.81	2	20		0.23
88	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
89	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
90	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
91	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
92	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
93	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
94	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
95	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
96	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
97	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
98	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
99	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
100	0	0	0	60	37 29 41.26	77 31 44.56	2	80		0.77
101	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
102	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
103	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
104	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
105	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
106	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
107	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
108	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
109	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
110	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
111	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
112	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5
113	0	0	0	10	37 24 0..35	77 39 08.53	2	50		0.5

ORDER	Curve_Number	Aged_Development	Type_Conveyance	Controls	Comments	EVENT_ID_Conventional	Precipitation_Depth (in)	Q	Start_Date (mm/dd/yy)	Start_Time (min of day)
39						4/16/1993	0.54	On Site	04/16/93	
40						8/6/1993	1.29	On Site	08/06/93	
41						10/26/1993		On Site	10/26/93	
42			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	4/16/1993	0.55	On Site	04/16/93	
43			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	8/6/1993	0.43	On Site	08/06/93	
44			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	12/15/1993	0.55	On Site	12/15/93	
45			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	8/12/1996	0.08	On Site	08/12/96	
46			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	3/14/1997	0.01	On Site	03/14/97	
47			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	8/4/1997	0.11	On Site	08/04/97	
48			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	2/3/1998	0.04	On Site	02/03/98	
49			GS		veyed via 48 inch RCP land use is 20 percent low density res and 80 percent agriculture	10/8/1998		On Site	10/08/98	
50			CG		drainage conveyed via 42 inch by 28 inch oval CMP	4/16/1993		On Site	04/16/93	
51			CG		drainage conveyed via 42 inch by 28 inch oval CMP	8/6/1993	1.1	On Site	08/06/93	
52			CG		drainage conveyed via 42 inch by 28 inch oval CMP	10/26/1993	0.02	On Site	10/26/93	
53			CG		drainage conveyed via 42 inch by 28 inch oval CMP	8/12/1996	0.2	On Site	08/12/96	
54			CG		drainage conveyed via 42 inch by 28 inch oval CMP	11/8/1996	0.07	On Site	11/08/96	
55			CG		drainage conveyed via 42 inch by 28 inch oval CMP	3/14/1997	0.02	On Site	03/14/97	
56			CG		drainage conveyed via 42 inch by 28 inch oval CMP	8/4/1997	0.06	On Site	08/04/97	
57			CG		drainage conveyed via 42 inch by 28 inch oval CMP	2/3/1998	0.02	On Site	02/03/98	
58			CG		drainage conveyed via 42 inch by 28 inch oval CMP	10/8/1998	1.3	On Site	10/08/98	
59			CG		drainage conveyed via 42 inch by 28 inch oval CMP	1/8/1999	0.04	On Site	01/08/99	
60			CG		drainage conveyed via 42 inch by 28 inch oval CMP	2/1/1999	0.125	On Site	02/01/99	
61						4/16/1993	0.65	On Site	04/16/93	
62						8/6/1993	0.91	On Site	08/06/93	
63						12/15/1993		On Site	12/15/93	
64			CG		drainage conveyed via 48 inch RCP	4/16/1993		On Site	04/16/93	
65			CG		drainage conveyed via 48 inch RCP	8/6/1993	1.38	On Site	08/06/93	
66			CG		drainage conveyed via 48 inch RCP	10/26/1993	0.32	On Site	10/26/93	
67			CG		drainage conveyed via 48 inch RCP	8/12/1996	0.07	On Site	08/12/96	
68			CG		drainage conveyed via 48 inch RCP	11/8/1996	0.6	On Site	11/08/96	
69			CG		drainage conveyed via 48 inch RCP	3/13/1997	0.03	On Site	03/13/97	
70			CG		drainage conveyed via 48 inch RCP	8/4/1997	0.16	On Site	08/04/97	
71			CG		drainage conveyed via 48 inch RCP	2/3/1998	0.04	On Site	02/03/98	
72			CG		drainage conveyed via 48 inch RCP	10/8/1998	0.13	On Site	10/08/98	
73			CG		drainage conveyed via 48 inch RCP	1/8/1999	0.05	On Site	01/08/99	
74			CG		drainage conveyed via 48 inch RCP	2/1/1999	0.05	On Site	02/01/99	
75			CG		drainage conveyed via 48 inch RCP	8/19/1999	0.8	On Site	08/19/99	
76			CG		drainage conveyed via 48 inch RCP	9/27/1999	0.9	Airport	09/27/99	
77			CG		drainage conveyed via 48 inch RCP	6/27/2000	0.41	On Site	06/27/00	
78			CG		drainage conveyed via 48 inch RCP	1/8/2001	0.65	On Site	01/08/01	
79			CG		drainage conveyed via 48 inch RCP	12/10/2001	0.2	On Site	12/10/01	
80			CG		drainage conveyed via 36 inch deep reinforced concrete trapezoidal channel	8/19/1999	1.45	On Site	08/19/99	
81			CG		drainage conveyed via 36 inch deep reinforced concrete trapezoidal channel	9/27/1999	0.9	Airport	09/27/99	
82			CG		drainage conveyed via 36 inch deep reinforced concrete trapezoidal channel	6/27/2000	0.56	On Site	06/27/00	
83			CG		drainage conveyed via 36 inch deep reinforced concrete trapezoidal channel	1/8/2001	0.08	On Site	01/08/01	
84			CG		drainage conveyed via 48 inch RCP	8/19/1999		On Site	08/19/99	
85			CG		drainage conveyed via 48 inch RCP	9/27/1999	0.9	Airport	09/27/99	
86			CG		drainage conveyed via 48 inch RCP	6/27/2000	1.25	On Site	06/27/00	
87			CG		drainage conveyed via 48 inch RCP	1/8/2001	0.19	On Site	01/08/01	
88			CG		drainage conveyed via 60 inch RCP	8/12/1996	0.27	On Site	08/12/96	
89			CG		drainage conveyed via 60 inch RCP	11/8/1996	0.06	On Site	11/08/96	
90			CG		drainage conveyed via 60 inch RCP	3/14/1997	0.06	On Site	03/14/97	
91			CG		drainage conveyed via 60 inch RCP	8/4/1997	0.29	On Site	08/04/97	
92			CG		drainage conveyed via 60 inch RCP	2/3/1998	0.02	On Site	02/03/98	
93			CG		drainage conveyed via 60 inch RCP	10/8/1998	0.21	On Site	10/08/98	
94			CG		drainage conveyed via 60 inch RCP	1/8/1999	0.06	On Site	01/08/99	
95			CG		drainage conveyed via 60 inch RCP	2/1/1999	0.13	On Site	02/01/99	
96			CG		drainage conveyed via 60 inch RCP	8/19/1999	0.26	On Site	08/19/99	
97			CG		drainage conveyed via 60 inch RCP	9/27/1999	0.9	Airport	09/27/99	
98			CG		drainage conveyed via 60 inch RCP	6/27/2000	0.89	On Site	06/27/00	
99			CG		drainage conveyed via 60 inch RCP	1/8/2001	0.09	On Site	01/08/01	
100			CG		drainage conveyed via 60 inch RCP	12/10/2001	0.24	On Site	12/10/01	
101			GS		drainage conveyed via 24 inch RCP	8/12/1996	0.15	On Site	08/12/96	
102			GS		drainage conveyed via 24 inch RCP	11/8/1996	0.1	On Site	11/08/96	
103			GS		drainage conveyed via 24 inch RCP	3/14/1997	0.03	On Site	03/14/97	
104			GS		drainage conveyed via 24 inch RCP	8/4/1997	0.16	On Site	08/04/97	
105			GS		drainage conveyed via 24 inch RCP	2/3/1998	0.19	On Site	02/03/98	
106			GS		drainage conveyed via 24 inch RCP	10/8/1998	0.2	On Site	10/08/98	
107			GS		drainage conveyed via 24 inch RCP	1/8/1999	0.02	On Site	01/08/99	
108			GS		drainage conveyed via 24 inch RCP	2/1/1999	0.08	On Site	02/01/99	
109			GS		drainage conveyed via 24 inch RCP	8/19/1999	1.5	On Site	08/19/99	
110			GS		drainage conveyed via 24 inch RCP	9/27/1999	0.9	Airport	09/27/99	
111			GS		drainage conveyed via 24 inch RCP	6/27/2000	0.74	On Site	06/27/00	
112			GS		drainage conveyed via 24 inch RCP	1/8/2001	0.07	On Site	01/08/01	
113			GS		drainage conveyed via 24 inch RCP	12/10/2001	0.38	On Site	12/10/01	

ORDER	End_Date (mm/dd/yy)	End_Time (min of day)	Maxr15	Runoff (in)	Q	3h or Total event? 3H - TOT	FF_COM (First Flush or composite)	Type_Sampler	Type_Sa_An	Days since last rain	Conductivity (uS/cm @25°C)	Q
39						3H	COM	MA	FLOW COM			
40						3H	COM	MA	FLOW COM			
41						3H	COM	MA	FLOW COM			
42						3H	COM	MA	FLOW COM			
43						3H	COM	MA	FLOW COM			
44						3H	COM	MA	FLOW COM			
45						3H	COM	MA	FLOW COM	3		
46						3H	COM	MA	FLOW COM	10		
47						3H	COM	MA	FLOW COM	11		
48						3H	COM	MA	FLOW COM	6		
49						3H	COM	MA	FLOW COM	7		
50						3H	COM	MA	FLOW COM			
51						3H	COM	MA	FLOW COM			
52						3H	COM	MA	FLOW COM			
53						3H	COM	MA	FLOW COM	3		
54						3H	COM	MA	FLOW COM	6		
55						3H	COM	MA	FLOW COM	10		
56						3H	COM	MA	FLOW COM	11		
57						3H	COM	MA	FLOW COM	6		
58						3H	COM	MA	FLOW COM	7		
59				0.019		3H	COM	MA	FLOW COM	5		
60				0.063		3H	COM	MA	FLOW COM	6		
61						3H	COM	MA	FLOW COM			
62						3H	COM	MA	FLOW COM			
63						3H	COM	MA	FLOW COM			
64						3H	COM	MA	FLOW COM			
65						3H	COM	MA	FLOW COM			
66						3H	COM	MA	FLOW COM			
67						3H	COM	MA	FLOW COM	3		
68						3H	COM	MA	FLOW COM	6		
69						3H	COM	MA	FLOW COM	10		
70						3H	COM	MA	FLOW COM	11		
71						3H	COM	MA	FLOW COM	6		
72						3H	COM	MA	FLOW COM	7		
73				0.04		3H	COM	MA	FLOW COM	5		
74						3H	COM	MA	FLOW COM	6		
75						3H	COM	MA	FLOW COM	4		
76				0.45		3H	COM	MA	FLOW COM	4		
77						3H	COM	MA	FLOW COM			
78						3H	COM	MA	FLOW COM			
79						3H	COM	MA	FLOW COM			
80				0.155		3H	COM	MA	FLOW COM	4		
81				0.125		3H	COM	MA	FLOW COM	4		
82						3H	COM	MA	FLOW COM			
83						3H	COM	MA	FLOW COM			
84				0.253		3H	COM	MA	FLOW COM	4		
85						3H	COM	MA	FLOW COM	4		
86						3H	COM	MA	FLOW COM			
87						3H	COM	MA	FLOW COM			
88						3H	COM	MA	FLOW COM	3		
89						3H	COM	MA	FLOW COM	6		
90						3H	COM	MA	FLOW COM	10		
91						3H	COM	MA	FLOW COM	11		
92						3H	COM	MA	FLOW COM	6		
93						3H	COM	MA	FLOW COM	7		
94				0.01		3H	COM	MA	FLOW COM	5		
95				0.034		3H	COM	MA	FLOW COM	6		
96				0.141		3H	COM	MA	FLOW COM	4		
97						3H	COM	MA	FLOW COM	4		
98						3H	COM	MA	FLOW COM			
99						3H	COM	MA	FLOW COM			
100						3H	COM	MA	FLOW COM			
101						3H	COM	MA	FLOW COM	3		
102						3H	COM	MA	FLOW COM	6		
103						3H	COM	MA	FLOW COM	10		
104						3H	COM	MA	FLOW COM	11		
105						3H	COM	MA	FLOW COM	6		
106						3H	COM	MA	FLOW COM	7		
107						3H	COM	MA	FLOW COM	5		
108						3H	COM	MA	FLOW COM	6		
109						3H	COM	MA	FLOW COM	4		
110						3H	COM	MA	FLOW COM	4		
111						3H	COM	MA	FLOW COM			
112.						3H	COM	MA	FLOW COM			
113						3H	COM	MA	FLOW COM			

ORDER	DO (mg/l)	Q	Hardness (mg/L CaCO3)	Q	Oil and Grease Total (mg/l)	Q	pH	Q	Turbidity (NTU)	Q	Temperature (C)	Q	TDS (mg/l)	Q	TS (mg/l)
39					<5	LD									
40					<5	LD									
41					<5	LD									
42					<5	LD							5		
43					<5	LD							100		
44					<5	LD							59		
45					1								50		
46			5		<1	LD							40		
47			30		<1	LD							110		
48			7		3								50		
49					<1	LD									
50					<5	LD							45		
51					<5	LD							37		
52					<5	LD							5		
53					2								20		
54			10		<1	LD							30		
55			20		<1	LD							60		
56			6		<1	LD							24		
57			28		<1	LD							60		
58			3		<1	LD							20		
59			11		<1	LD	6.2				4		50		
60			7		7		6.5				7		20		
61					<5	LD									
62					<5	LD									
63					<5	LD									
64					<5	LD							70		
65					<5	LD							<5	?	
66					<5	LD							<1	LD	
67					6								50		
68			12		<1	LD							40		
69			21		<1	LD							60		
70			22		<1	LD							74		
71			19		11								50		
72			12		<1	LD							30		
73			17		<1	LD	6.3				7		50		
74			15		9		5.9				12		50		
75			57.7		<1	LD	6.4				25		56		
76			15		8		6				23		50		
77			28.8		2								42		
78			16.5		10								90		
79			14.6		16								34		
80			48.1		1		7.2				24		72		
81			53.3		4		6.9				23		118		
82			365.2		2								102		
83			57.2		<1	LD							84		
84			33.7		<1	LD	6.9				23		82		
85			31		13		6.9				20		68		
86			25		<1	LD							56		
87			40.7		15								114		
88					3								40		
89			32		8								80		
90			38		<1	LD							90		
91			18		<1	LD							34		
92			54		4								110		
93			12		2								40		
94			31		<1	LD	7.4				7		150		
95			19		7		4.5				9		50		
96			16.8		1		8.3				22		12		
97			15		<1	LD	6.6				23		18		
98			17.3		<1	LD							24		
99			19.4		1								64		
100			21.9		18								98		
101					3								60		
102			21		13								70		
103					1										
104			16		<1	LD							43		
105			10		5								40		
106			14		<1	LD							40		
107			29		<1	LD	7.4				3		80		
108			18		7		7.2				7		50		
109			38.5		1		6.1				25		48		
110			20.8		17		7.1				24		57		
111			269.1		<1	LD							46		
112			33.9		52								78		
113			13.7		1								164		

ORDER	Q	TSS (mg/l)	Q	BOD5 (mg/l)	Q	COD (mg/l)	Q	Fecal Coliform (colonies/100 ml)	Q	Fecal Streptococcus (colonies/100 ml)	Q	Total Coliform (colonies/100 ml)	Q	Total E. Coli (colonies/100 ml)	Q	Ammonia (mg/l)	Q
39																	
40																	
41																	
42		23		3		24		50								<0.05	LD
43		29		8		55		4100								0.35	
44		20		9		55		900								<0.05	LD
45		58		1.3		33		40								0.1	
46		8		1.3		22		130								<0.05	LD
47		23		10		61		160000								<0.05	LD
48		<5	?		?		?	130								<0.05	LD
49								4									
50		52		10		45		7400								0.07	
51		51		4		33		23800								0.49	
52		5		2		10		500								0.46	
53		3		14		26		800								0.3	
54		19		9.4		38		1700								0.3	
55		4		7		42		40								<0.05	LD
56		3		4.4		56		9000								0.45	
57		9		7.9		<5	LD	80								0.1	
58		<1	LD	3.6		<5	LD									<0.05	LD
59		4		4.1		<5	LD	30								0.15	
60		3		2.2		16		1600								<0.05	LD
61																	
62																	
63																	
64		62		13		65		50								<0.05	LD
65		<5	?	2		7		41600								0.05	
66		10		16		23		200								0.27	
67		13		19		61		9000								0.3	
68		36		8.8		25		30000								0.2	
69		18		5.7		41		80								<0.05	LD
70		18		17		103		300								0.56	
71		6		7.9		<5	LD	40								0.06	
72		6		8.3		<5	LD	9000								0.3	
73		9		12		9		300								0.15	
74		19		6		27		5000								0.1	
75		36		28.5		58		>1600	UD							0.51	
76		<5	?	<6	LD	42		>1600	UD							0.37	
77		172.5		26		40		24000								0.315	
78		12.8		11.5		60		900								0.38	
79		11.6		14.5		63.5		30000								0.14	
80		380		10.9		90		>1600	UD							0.59	
81		54		9.4		60		>1600	UD							0.11	
82		166		21.6		108		>16000	UD							0.32	
83		42		12.8		60		<2	LD							0.31	
84		48		6.7		36		>1600	UD							0.29	
85		<0.5	LD	<6	LD	18		>1600	UD							0.01	
86		140.5		20.2		64		1600								0.16	
87		26.7		18.8		68		<2	LD							0.47	
88		13		5.8		32		16000								0.3	
89		15		32		43		160000								0.5	
90		14		11		57		20								<0.1	LD
91		5		5.3		52		9000								0.43	
92		9		30		<5	LD	170								0.24	
93		8		4.8		<5	LD									0.23	
94		20		24		50		170								0.4	
95		14		15		34		800								0.06	
96		20		100.2		136		>1600	UD							0.4	
97		<0.5	LD		?	32		>1600	UD							0.32	
98		9		7		32		1600								0.32	
99		30.6		10.1		80		1600								0.53	
100		42		<6	LD	30.8		130								0.16	
101		7		16		28		1700								0.2	
102		19		23		62		17000								0.2	
103								110									
104		19		10		74		22000								0.45	
105		12		8.9		22										0.15	
106		13		6.8		30										0.46	
107		17		21		66		500								0.16	
108		16		5.9		33		800								0.1	
109		193		8.7		48		>1600	UD							0.55	
110		10		9.4		63		>1600	UD							0.24	
111		314.5		23		80		24000								0.27	
112		24.6		12.6		80		1600								0.57	
113		48		55.8		69.2		30000								0.06	

ORDER	N02+NO3 (mg/l)	Q	Nitrogen Total (mg/l)	Q	Nitrogen Kjeldahl Total (mg/l)	Q	Phosphate Ortho (mg/l)	Q	Phosphorous Dissolved (mg/l)	Q	Phosphorous Total (mg/l)	Q	Antimony Total (ug/l)	Q
39													<50	LD
40													<50	LD
41													<60	LD
42	<0.1	LD			0.6				0.15				<60	LD
43	1.1				2.2				0.23		0.48		<60	LD
44	0.3				1.1				0.12		0.15		<60	LD
45	<0.05	LD			0.9						0.14			
46	<0.05	LD			<0.5	LD			0.02		0.02			
47	0.28				1.6				0.06		0.17			
48	<0.05	LD			<0.5	LD			<0.02	LD	<0.02	LD		
49														
50	0.8				1				0.13				<50	LD
51	1.2				1.5				0.13		0.17		<60	LD
52	0.1				1.1				0.05		0.05		<50	LD
53	0.63				1						0.09			
54	0.51				0.8				0.06		0.09			
55	1.95				0.9				0.08		0.09			
56	0.62				1				0.1		0.11			
57	1.64				0.7				<0.02	LD	0.02			
58					<0.5	LD			<0.05	LD				
59	1.52				1				<0.05	LD	<0.05	LD		
60	1.02				<0.5	LD			<0.05	LD	<0.05	LD		
61													<50	LD
62													<50	LD
63													<50	LD
64	1.3				2.2				0.23				<60	LD
65	0.6				0.5				0.05		0.05		<60	LD
66	0.5				0.8				<0.05	LD	0.14		<60	LD
67	0.06				1.4						0.19			
68	0.64				1.5				0.19		0.46			
69	1.34				1.1				0.02		0.13			
70	1				2.1				0.15		0.31			
71	1.31				<0.5	LD			<0.02	LD	0.03			
72					1				<0.05	LD				
73	2.06				0.9				<0.05	LD	0.11			
74	1.67				1.01				<0.05	LD	0.08			
75	0.7				2.17				0.29		0.41			
76	0.52				4.5				0.14		0.2			
77	0.49				0.39				0.245		0.448			
78	0.74				2.1				0.229		0.265			
79	0.91				1.52				0.196		0.249			
80	0.8				2.75				0.41		0.78			
81	0.42				1.45				0.29		0.43			
82	0.58				2.47				0.567		0.83			
83	0.94				2				0.232		0.404			
84	0.6				1.25				0.36		0.4			
85	0.36				0.15				0.04		0.09			
86	0.35				1.42				0.224		0.677			
87	1.31				2.2				0.495		0.627			
88	0.58				1						0.1			
89	0.8				1.6				0.11		0.18			
90	1.27				1.7				0.11		0.22			
91	0.61				1				0.09		0.12			
92	1.16				0.6				0.02		0.06			
93					0.9				0.05					
94	1.88				1.9				0.64		0.45			
95	1.15				0.9				0.09		0.12			
96	0.4				0.43				0.1		0.2			
97	0.29				3.2				0.08		0.1			
98	0.31				0.59				0.117		0.158			
99	0.67				1.7				0.125		0.245			
100	0.68				1.17				0.05		0.084			
101	0.63				1.1						0.09			
102	0.28				1.4				0.4		0.52			
103														
104	0.83				1.8				0.26		0.34			
105	0.33				0.6				0.05		0.06			
106					1.7				0.29					
107	1.67				1.7				0.11		0.19			
108	0.97				1.1				0.07		0.13			
109	0.5				1.08				0.2		0.41			
110	0.24				1.15				0.39		0.47			
111	0.86				1.37				0.158		0.493			
112	0.54				1.5				0.36		0.421			
113	0.43				0.87				0.313		0.48			

ORDER	Antimony Dissolved (ug/l)	Q	Arsenic Total (ug/l)	Q	Arsenic Dissolved (ug/l)	Q	Beryllium Total (ug/l)	Q	Beryllium Dissolved (ug/l)	Q	Cadmium Total (ug/l)	Q	Cadmium Dissolved (ug/l)	Q	Chromium Total (ug/l)
39			<5	LD			<4	LD			0.8				<10
40			<5	LD			<4	LD			1.2				<10
41			<5	LD			<4	LD			1.4				<10
42			<5	LD			<4	LD			<0.5	LD			<10
43			<5	LD			<4	LD			<0.5	LD			<10
44			<5	LD			<4	LD			<0.5	LD			<10
45															
46											<0.5	LD	<0.5	LD	
47											<0.5	LD	<0.5	LD	
48											<0.5	LD	<0.5	LD	
49													<0.5	LD	
50			<5	LD			<4	LD			<0.5	LD			<10
51			<5	LD			<4	LD			<0.5	LD			<10
52			<5	LD			<4	LD			<0.5	LD			20
53															
54											<0.5	LD	<0.5	LD	
55											<0.5	LD	<0.5	LD	
56											<0.2	LD	<0.2	LD	
57											<0.5	LD	<0.5	LD	
58											<0.5	LD	<0.5	LD	
59											<0.2	LD	<0.2	LD	
60											<0.2	LD	<0.2	LD	
61			<5	LD			<4	LD			<0.5	LD			<10
62			<5	LD			<4	LD			<0.5	LD			<10
63			<5	LD			<4	LD			<0.5	LD			<10
64			<5	LD			<4	LD			<0.5	LD			<10
65			<5	LD			<4	LD			<0.5	LD			<10
66			<5	LD			<4	LD			<0.5	LD			<10
67															
68											<0.5	LD	<0.5	LD	
69											<0.5	LD	<0.5	LD	
70											<0.2	LD	<0.2	LD	
71											<0.5	LD	<0.5	LD	
72											<0.5	LD	<0.5	LD	
73											<0.2	LD	<0.2	LD	
74											<0.2	LD	<0.2	LD	
75											<1	LD	<1	LD	
76											<1	LD	<1	LD	
77											<1	LD	<1	LD	
78											<1	LD	<1	LD	
79											<1	LD	<1	LD	
80											<1	LD	<1	LD	
81											<1	LD	<1	LD	
82											<1	LD	<1	LD	
83											<1	LD	<1	LD	
84											<1	LD	<1	LD	
85											<1	LD	<1	LD	
86											<1	LD	<1	LD	
87											<1	LD	<1	LD	
88															
89											<0.5	LD	<0.5	LD	
90											<0.5	LD	<0.5	LD	
91											0.3		0.2		
92											<0.5	LD	<0.5	LD	
93											<0.5	LD	<0.5	LD	
94											<0.2	LD	<0.2	LD	
95											<0.2	LD	<0.2	LD	
96												?		?	
97											0.1		<1	LD	
98											<1	LD	<1	LD	
99											<1	LD	<1	LD	
100											<1	LD	<1	LD	
101															
102											<0.5	LD	<0.5	LD	
103													<0.5	LD	
104											<0.2	LD	<0.2	LD	
105											<0.5	LD	<0.5	LD	
106											<0.5	LD	<0.5	LD	
107											<0.2	LD	0.2		
108											<0.2	LD	<0.2	LD	
109											<1	LD	<1	LD	
110											<1	LD	<1	LD	
111											<1	LD	0.5		
112											<1	LD	<1	LD	
113											<1	LD	<1	LD	

ORDER	Q	Chromium Dissolved (ug/l)	Q	Copper Total (ug/l)	Q	Copper Dissolved (ug/l)	Q	Cyanide Total (ug/l)	Q	Cyanide Dissolved (ug/l)	Q	Lead Total (ug/l)	Q	Lead Dissolved (ug/l)	Q
39	LD			<10	LD			<5	LD			<3	LD		
40	LD			<10	LD			<5	LD			7			
41	LD			<10	LD			<5	LD			9			
42	LD			<10	LD			<5	LD			<3	LD		
43	LD			<10	LD			<5	LD			23			
44	LD			20				<5	LD			4			
45				2		1		<5	LD			5		<1	LD
46				2		<1	LD	<5	LD			3		2	
47				2		<1	LD	<5	LD			8		2	
48				<5	LD	<5	LD	<5	LD			<5	LD	<5	LD
49						<5	LD	<5	LD					<5	LD
50	LD			<10	LD			<5	LD			<3	LD		
51	LD			20				<5	LD			23			
52				<10	LD			<5	LD			<3	LD		
53				40		24		<5	LD			2		<1	LD
54				29		16		<5	LD			10		8	
55				36		33		<5	LD			2		2	
56				60		58		<5	LD			5		2	
57				37		<5	LD	<5	LD			<5	LD	<5	LD
58				20		18		<5	LD			<5	LD	<5	LD
59				43		28						3		2	
60				21		20		<5	LD			1		<1	LD
61	LD			<10	LD			<5	LD			3			
62	LD			<10	LD			8				9			
63	LD			<10	LD			<5	LD			<3	LD		
64	LD			<10	LD			<5	LD			3			
65	LD			<10	LD			<5	LD			5			
66	LD			<10	LD			<5	LD			<3	LD		
67				7		5		<5	LD			2		<1	LD
68				7		2		<5	LD			28		19	
69				8		<1	LD	<5	LD			4		<1	LD
70				10		2		<5	LD			5		1	
71				6		<5	LD	<5	LD			44		<5	LD
72				16		<5	LD	<5	LD			<5	LD	<5	LD
73				7		3						4		3	
74				7		3		<5	LD			2		<1	LD
75				7		<5	LD	5				<5	LD	<5	LD
76				<5	LD	<5	LD	<5	LD			<5	LD	<5	LD
77				<5	LD	<5	LD	<10	LD			<5	LD	10	
78				5		6		<5	LD			11		<5	LD
79				8		10		<10	LD			<5	LD	<5	LD
80				6		<5	LD	<5	LD			12		<5	LD
81					?		?	<5	LD			6		<5	LD
82				7		2.5		<5	LD			10		<5	LD
83				8		7		<5	LD			<5	LD	<5	LD
84				<5	LD	<5	LD	5				<5	LD	<5	LD
85				<5	LD	14		<5	LD			<5	LD	6	
86				<5	LD	<5	LD	<10	LD			<5	LD	<5	LD
87				<5	LD	<5	LD	<5	LD			<5	LD	<5	LD
88				6		2		<5	LD			10		<1	LD
89				14		7		<5	LD			14		10	
90				13		11		<5	LD			8		5	
91				9		4		<5	LD			8		4	
92				13		<5	LD	<5	LD			6		<5	LD
93				10		9		<5	LD			6		<5	LD
94				13		8		<5	LD			14		10	
95				10		9		<5	LD			7		<2	LD
96				9		5		5				17		20	
97				8		5		<5	LD			24		<5	LD
98				8		<5	LD	<10	LD			16		6	
99				35		11		<5	LD			15		<5	LD
100				11		9		<10	LD			15		<5	LD
101				3		<1	LD	<5	LD			1		<1	LD
102				4		2		<5	LD			9		8	
103						3		<5	LD					1	
104				6		2		<5	LD			5		1	
105				9		<5	LD	<5	LD			<5	LD	<5	LD
106				<5	LD	<5	LD	<5	LD			<5	LD	<5	LD
107				5		2		<5	LD			2		2	
108				5		2		<5	LD			1		<1	LD
109				6		<5	LD	<5	LD			10		<5	LD
110				12		10		<5	LD				?		?
111				6		7		<10	LD			13		10	
112				6		9		<5	LD			<5	LD	<5	LD
113				9		6		<10	LD			<5	LD	<5	LD

ORDER	Mercury Total (ug/l)	Q	Mercury Dissolved (ug/l)	Q	Nickel Total (ug/l)	Q	Nickel Dissolved (ug/l)	Q	Selenium Total (ug/l)	Q	Selenium Dissolved (ug/l)	Q	Silver Total (ug/l)	Q	Silver Dissolved (ug/l)	Q
39	<0.2	LD			<20	LD			<5	LD			<10	LD		
40	<0.2	LD			<20	LD			<5	LD			<10	LD		
41	<0.2	LD			<20	LD			<5	LD			<10	LD		
42	<0.2	LD			<20	LD			<5	LD			<10	LD		
43	<0.2	LD			<20	LD			<5	LD			<10	LD		
44	<0.2	LD			<20	LD			<5	LD			<10	LD		
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50	<0.2	LD			<20	LD			<5	LD			<10	LD		
51	<0.2	LD			<20	LD			<5	LD			<10	LD		
52	<0.2	LD			<20	LD			<5	LD			<10	LD		
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61	<0.2	LD			<20	LD			<5	LD			<10	LD		
62	<0.2	LD			<20	LD			<5	LD			<10	LD		
63	<0.2	LD			<20	LD			<5	LD			<10	LD		
64	<0.2	LD			<20	LD			<5	LD			<10	LD		
65	<0.2	LD			<20	LD			<5	LD			<10	LD		
66	<0.2	LD			<20	LD			<5	LD			<10	LD		
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ORDER	Thallium Total (ug/l)	Q	Thallium Dissolved (ug/l)	Q	Zinc Total (ug/l)	Q	Zinc Dissolved (ug/l)	Q	Acrolein (ug/l)	Q	Acrylonitrile (ug/l)	Q	Benzene (ug/l)	Q	Bromoform (ug/l)
39	<100	LD			320				<100	LD					
40	<100	LD			320				<100	LD					
41	<100	LD			980				<100	LD					
42	<100	LD			60				<100	LD					
43	<100	LD			110				<100	LD					
44	<100	LD			380				<100	LD					
45					31		9								
46					23		15								
47					83		29								
48					18		14								
49							6								
50	<100	LD			200				<100	LD					
51	<100	LD			390				<100	LD					
52	<100	LD			310				<100	LD					
53					61		22								
54					48		48								
55					66		44								
56					94		85								
57					52		14								
58					42		28								
59					43		38								
60					30		27								
61	<100	LD			80				<100	LD					
62	<100	LD			330				<100	LD					
63	<100	LD			180				<100	LD					
64	<100	LD			110				<100	LD					
65	<100	LD			790				<100	LD					
66	<100	LD			350				<100	LD					
67					46		33								
68					40		25								
69					49		9								
70					120		30								
71					25		26								
72					43		36								
73					47		35								
74					40		16								
75					43		35								
76						?		?							
77					28		28								
78					23		28								
79					<10	LD	<20	LD							
80					39		10								
81					12		<10	LD							
82					31		<10	LD							
83					15		12								
84					15		12								
85					<10	LD	19								
86					15		<10	LD							
87					<10	LD	11								
88					154		56								
89					132		129								
90					193		139								
91					206		160								
92					163		34								
93					182		147								
94					187		100								
95					294		210								
96					134		123								
97					157		139								
98					109		63								
99					194		192								
100					310		269								
101					44		16								
102					51		34								
103							25								
104					79		24								
105					38		14								
106					35		33								
107					47		30								
108					33		19								
109					40		21								
110						?		?							
111					42		56								
112					36		54								
113					19		<10	LD							

ORDER	Q	Carbon Tetrachloride (ug/l)	Q	Chlorobenzene (ug/l)	Q	Chlorodibromomethane (ug/l)	Q	Chloroethane (ug/l)	Q	2-Chloroethylvinylether (ug/l)	Q	Chloroform (ug/l)	Q	Dichlorobromoethane (ug/l)	Q	1,1-Dichloroethane (ug/l)	Q
39												<2	LD				
40												<2	LD				
41												<2	LD				
42												<2	LD				
43												<2	LD				
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50												<2	LD				
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ORDER	1,2-Dichloroethane (ug/l)	Q	1,1-Dichloroethylene (ug/l)	Q	1,2-Dichloropropane (ug/l)	Q	1,3-Dichloropropylene (ug/l)	Q	Ethylbenzene (ug/l)	Q	Methylbromide (ug/l)	Q	Methylchloride (ug/l)	Q	Methylenechloride (ug/l)	Q
39									<3	LD					<2	LD
40									<3	LD					<2	LD
41									<3	LD					<2	LD
42									<3	LD					<2	LD
43									<3	LD					<2	LD
44									<3	LD					<2	LD
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50									<3	LD					<2	LD
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ORDER	1,1,2,2-Tetrachloroethane (ug/l)	Q	Tetrachloroethylene (ug/l)	Q	Toluene (ug/l)	Q
39					<5	LD
40					<5	LD
41					<5	LD
42					<5	LD
43					<5	LD
44					<5	LD
45						
46						
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50					<5	LD
51					<5	LD
52					<5	LD
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61					<5	LD
62					<5	LD
63					<5	LD
64					<5	LD
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Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1

	Area (acres)	% Impervious	Precipitation Depth (in)	Runoff Depth (in)	Conductivity (μS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Temperature (C)	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)
Overall Summary (3765)													
Number of observations	3765	2209	3316	1495	685	1082	1834	1665	861	2956	3493	3105	2750
% of samples above detection	100	100	100	100	100	98.7	66.1	100	100	99.0	97.9	96.2	98.4
Median	57.3	50.0	0.48	0.15	121	38.0	4.3	7.5	16.5	80	59	8.6	53
Coefficient of variation	3.7	0.4	1.0	1.9	1.6	1.4	9.7	0.1	0.4	3.4	1.8	7.4	1.1
Residential (1042)													
Number of observations	1042	614	919	372	104	215	483	286	181	814	978	908	748
% of samples above detection	100	100	100	100	100	100	54.9	100	100	99.1	98.3	97.1	98.7
Median	57.3	37.0	0.48	0.10	102	32.0	4.0	7.2	17.0	72.0	49	9.0	54.5
Coefficient of variation	4.8	0.4	1.0	1.5	1.6	1.1	7.8	0.1	0.4	1.1	1.8	1.5	0.93
Mixed Residential (611)													
Number of observations	611	278	491	262	105	168	283	333	137	491	582	549	465
% of samples above detection	100	100	100	100	100	98.2	70.3	100	100	99.2	98.3	94.2	99.6
Median	150.8	44.9	0.53	0.12	112	40.0	4.0	7.50	15.5	86	66	7.8	43
Coefficient of variation	2.1	0.3	0.8	1.3	1.2	1.1	2.6	0.1	0.3	5.2	1.6	1.3	1.2
Commercial (527)													
Number of observations	527	284	462	146	78	156	331	191	98	418	503	452	393
% of samples above detection	100	100	100	100	100	100	71.9	100	100	99.5	95.2	97.6	98.5
Median	38.8	84.5	0.42	0.29	107	36.5	4.6	7.4	16.0	72	43	11.0	58
Coefficient of variation	1.2	0.1	1.0	1.0	1.0	1.1	3.0	0.1	0.4	1.9	2.0	1.1	1.0
Mixed Commercial (324)													
Number of observations	324	237	305	118	59	98	134	156	98	265	297	277	267
% of samples above detection	100	100	100	100	100	99.0	79.9	100	100	99.6	99.7	98.9	99.6
Median	75.0	60.0	0.47	0.28	100	36.0	5.0	7.60	14.5	69.5	54.5	9.0	60
Coefficient of variation	1.4	0.3	1.0	0.9	0.8	1.8	2.9	0.1	0.4	1.9	1.3	1.7	1.0
Industrial (566)													
Number of observations	566	292	482	215	102	132	315	248	140	431	521	455	386
% of samples above detection	100	100	100	100	100	96.2	64.8	100	100	99.5	97.7	95.4	99.0
Median	39.5	75.0	0.50	0.16	139	39.0	4.8	7.50	17.9	86	81	9.0	58.6
Coefficient of variation	1.1	0.3	0.9	1.2	1.3	1.5	11.8	0.1	0.3	3.6	1.6	10.0	1.2

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 – *Continued*

	Area (acres)	% Impervious	Precipitation Depth (in)	Runoff Depth (in)	Conductivity (μS/cm @25°C)	Hardness (mg/L CaCO3)	Oil and Grease (mg/L)	pH	Tempe-rature (C)	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)
Mixed Industrial (218)													
Number of observations	218	118	193	117	56	75	72	152	57	186	207	178	175
% of samples above detection	100	100	100	100	100	93.3	80.6	100	100	99.5	100	95.5	98.9
Median	168.0	44.0	0.45	0.29	126	29.3	9.0	7.70	18.0	90	82	7.5	39.9
Coefficient of variation	1.8	0.3	0.9	1.2	0.8	0.6	1.8	0.1	0.3	0.8	1.4	1.8	1.2
Institutional (18)													
Number of observations	18	18	17	14						18	18	18	18
% of samples above detection	100	100	100	100						100	94.4	88.9	88.9
Median	36.0	45.0	0.18	0.00						52.5	17	8.5	50
Coefficient of variation	0	0	0.9	2.1						0.7	0.83	0.7	0.9
Freeways (185)													
Number of observations	185	154	182	144	86	127	60	111	31	97	134	26	67
% of samples above detection	100	100	100	100	100	100	71.7	100	100	99.0	99.3	84.6	98.5
Median	1.6	80.0	0.54	0.41	99	34.0	8.0	7.10	14.0	77.5	99	8	100
Coefficient of variation	1.4	0.13	1.1	1.7	1.0	1.9	0.6	0.1	0.4	0.8	2.6	1.3	1.1
Mixed Freeways (26)													
Number of observations	26		26		21	12	20	17	17	15	23	23	15
% of samples above detection	100		100		100	100	100	100	100	100	100	100.0	100.0
Median	63.1		0.47		353	83	4.5	7.7	16.0	177	88	8.2	47
Coefficient of variation	0.7		0.8		0.6	0.3	1.8	0.1	0.3	0.4	1.1	1.2	0.5
Open Space (49)													
Number of observations	49	37	41	11	2	8	19	19	2	45	44	44	43
% of samples above detection	100	100	100	100	100	100	36.8	100	100	97.8	95.5	86.4	76.74
Median	85	2.0	0.52	0.05	113	150	1.3	7.70	14.6	125	48.5	5.4	42.1
Coefficient of variation	1.5	1.0	1.2	1.4	0.5	0.6	0.7	0.08	0.7	0.7	1.5	0.7	1.5
Mixed Open Space (168)													
Number of observations	168	131	167	93	65	70	90	128	76	148	153	145	145
% of samples above detection	100	100	100	100	100	100	60.0	100	100	99.3	97.4	96.6	96.6
Median	115.4	33.0	0.51	0.10	215	64.2	8.5	7.9	16.0	109	78.0	6.0	34
Coefficient of variation	0.8	0.4	0.8	1.2	1.7	1.3	1.5	0.1	0.3	2.2	1.6	2.7	1.6

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 – *Continued*

	Fecal Coliform (mpn/100 mL)	Fecal Strepto-coccus (mpn/100 mL)	Total Coliform (mpn/100 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phospho-rus, filtered (mg/L)	Phospho-rus, total (mg/L)	Sb, total (μg/L)	As, total (μg/L)	As, filtered (μg/L)	Be, total (μg/L)
Overall Summary (3765)													
Number of observations	1704	1141	83	67	1908	3075	3191	2477	3285	874	1507	210	947
% of samples above detection	91.2	94.0	90.4	95.5	71.3	97.3	95.6	85.1	96.5	7.2	49.9	27.1	7.7
Median	5091	17000	12000	1750	0.44	0.60	1.4	0.13	0.27	3.0	3.0	1.5	0.4
Coefficient of variation	4.6	3.8	2.4	2.3	1.4	0.97	1.2	1.6	1.5	1.7	2.6	1.0	2.5
Residential (1042)													
Number of observations	402	257		14	572	889	922	690	926		395		282
% of samples above detection	87.8	87.9		100	82.2	97.6	96.5	83.5	96.8		40.8		7.8
Median	7000	24300		700	0.31	0.60	1.5	0.18	0.31		3.0		0.5
Coefficient of variation	5.2	1.7		1.6	1.1	1.1	1.1	0.9	1.1		2.2		2.5
Mixed Residential (611)													
Number of observations	336	178	26	11	282	531	517	430	552		158		97
% of samples above detection	94.3	97.8	84.6	90.9	58.5	97.9	95.0	83.3	96.2		65.9		11.3
Median	11210	27500	5667	1050	0.39	0.57	1.4	0.13	0.28		3.0		0.3
Coefficient of variation	3.2	2.1	1.3	2.1	1.6	0.78	1.7	1.1	1.7		3.9		2.7
Commercial (527)													
Number of observations	253	201			300	445	469	343	466		235		
% of samples above detection	88.9	92.5			83.3	98.0	97.4	81.0	95.9		33.6		
Median	4600	12000			0.50	0.6	1.5	0.11	0.22		2.3		
Coefficient of variation	3.0	2.7			1.2	1.1	0.9	1.3	1.2		2.9		
Mixed Commercial (324)													
Number of observations	116	95			173	284	276	221	290	89	139		
% of samples above detection	94.8	98.9			67.1	96.8	96.0	93.7	98.6	11.9	45.5		
Median	5400	11900			0.60	0.58	1.4	0.12	0.26	15.0	2.0		
Coefficient of variation	3.0	2.6			1.0	0.7	0.9	2.1	1.5	1.0	1.0		
Industrial (566)													
Number of observations	315	189			272	461	483	344	478	152	255		197
% of samples above detection	87.3	93.7			78.3	96.3	96.3	88.1	96.2	14.5	52.9		10.7
Median	2400	12000			0.42	0.69	1.4	0.10	0.25	3.7	4.0		0.38
Coefficient of variation	5.7	7.0			1.3	0.92	1.1	1.2	1.4	1.4	1.4		2.5

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 – *Continued*

	Fecal Coliform (mpn/100 mL)	Fecal Strepto-coccus (mpn/100 mL)	Total Coliform (mpn/100 mL)	Total E. Coli (mpn/100 mL)	NH3 (mg/L)	N02+NO3 (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phospho-rus, filtered (mg/L)	Phospho-rus, total (mg/L)	Sb, total (µg/L)	As, total (µg/L)	As, filtered (µg/L)	Be, total (µg/L)
Mixed Industrial (218)													
Number of observations	79	59	14		99	173	160	179	177		93		
% of samples above detection	98.7	96.9	71.4		30.3	98.8	92.5	84.4	95.5		88.2		
Median	3033	11000	2467		0.58	0.59	1.1	0.08	0.20		3.5		
Coefficient of variation	2.5	2.5	1.5		0.8	0.7	1.5	2.3	1.6		0.9		
Institutional (18)													
Number of observations					18	18	18	17	17				
% of samples above detection					88.9	100	100	82.4	94.1				
Median					0.31	0.6	1.35	0.13	0.18				
Coefficient of variation					0.5	0.6	0.5	0.5	1.0				
Freeways (185)													
Number of observations	49	25	16	13	79	25	125	22	128		61	72	
% of samples above detection	100	100	100	100	87.3	96.0	96.8	95.5	99.2		55.7	50.0	
Median	1700	17000	50000	1900	1.07	0.28	2.0	0.20	0.25		2.4	1.4	
Coefficient of variation	2.0	1.2	1.5	2.2	1.3	1.2	1.4	2.1	1.8		0.7	2.0	
Mixed Freeways (26)													
Number of observations	20	16				22	22	11	22		15		
% of samples above detection	85.0	93.8				100	100	100	100		80		
Median	2600	19000				0.9	2.3	0.03	0.34		3.0		
Coefficient of variation	2.3	1.1				0.7	1.3	0.9	0.7		0.7		
Open Space (68)													
Number of observations	23	22			32	44	45	44	46		19		
% of samples above detection	91.3	90.9			18.8	84.1	71.1	79.6	84.8		31.6		
Median	7200	24900			0.18	0.59	0.74	0.13	0.31		4.0		
Coefficient of variation	1.1	1.0			1.24	0.9	0.9	0.9	3.5		0.4		
Mixed Open Space (168)													
Number of observations	86	75			71	152	123	148	152		88		
% of samples above detection	97.7	100			22.5	97.4	90.2	85.8	96.1		44.3		
Median	3000	21000			0.51	0.7	1.1	0.09	0.25		3.0		
Coefficient of variation	2.3	2.4			1.2	0.8	0.9	1.1	1.1		0.9		

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 – *Continued*

	Cd, total (µg/L)	Cd, filtered (µg/L)	Cr, total (µg/L)	Cr, filtered (µg/L)	Cu, total (µg/L)	Cu, filtered (µg/L)	Pb, total (µg/L)	Pb, filtered (µg/L)	Hg, total (µg/L)	Ni, total (µg/l)	Ni, filtered (µg/L)	Zn, total (µg/L)	Zn, filtererd (µg/L)
Overall Summary (3765)													
Number of observations	2574	389	1598	261	2722	411	2949	446	1014	1430	246	3007	381
% of samples above detection	40.6	30.3	70.2	60.5	87.4	83	77.7	49.8	10.2	59.8	64.2	96.6	96.3
Median	1.0	0.50	7.0	2.1	16	8.0	17.0	3.0	0.20	8.0	4.0	116	52
Coefficient of variation	3.7	1.1	1.5	0.7	2.2	1.6	1.8	2.0	2.5	1.2	1.5	3.3	3.9
Residential (1042)													
Number of observations	695		404		771	90	762	108	275	392	25	784	87
% of samples above detection	31.1		53.2		83.1	63.3	69.4	33.3	6.9	44.1	44.0	96.2	89.7
Median	0.5		4.5		12	7.0	12.0	3.0	0.20	5.6	2.0	73	31.5
Coefficient of variation	3.4		1.2		1.8	2.0	1.9	1.9	0.9	1.2	0.5	1.3	0.8
ixed Residential (611)													
Number of observations	420	30	193	21	432	29	500	30	115	150	25	515	28
% of samples above detection	34.5	40.0	81.3	52.4	83.8	72.4	78.4	46.7	15.7	60	72.0	92.6	100
Median	0.9	0.30	7.0	2.0	16	5.5	16	3.0	0.20	7.8	5.5	95	48
Coefficient of variation	3.6	0.6	1.5	0.8	1.2	0.9	1.4	0.7	0.8	0.8	0.9	0.9	0.9
Commercial (527)													
Number of observations	379	47	257	27	408	48	399	59	170	242	23	414	49
% of samples above detection	41.7	23.4	60.7	40.7	92.9	79.2	85.5	52.5	6.5	60.3	47.8	99.0	100
Median	0.96	0.30	6.0	2.0	17	7.57	18.0	5.0	0.20	7.0	3.0	150	59
Coefficient of variation	2.7	1.3	1.3	0.6	1.5	0.8	1.6	1.6	0.8	1.2	0.8	1.2	1.4
Mixed Commercial (324)													
Number of observations	188	41	128	27	191	41	244	41		102	26	243	39
% of samples above detection	49.5	34.1	88.3	66.7	93.2	80.5	88.1	63.4		78.4	69.2	98.8	100
Median	0.9	0.35	5.0	2.5	17.5	10	17.0	3.5		5.1	3.5	131.4	73
Coefficient of variation	1.1	0.8	1.1	0.7	3.0	0.6	1.4	0.8		1.3	0.6	1.7	0.8
Industrial (566)													
Number of observations	435	42	250	36	455	42	452	51	199	237	36	473	42
% of samples above detection	49.0	54.8	72.0	55.6	88.6	90.5	75.0	52.9	13.9	61.6	58.3	98.9	95.2
Median	2.0	0.60	12.0	3.0	20.8	8.0	24.9	5.0	0.20	14.0	5.0	199	112
Coefficient of variation	2.2	1.1	1.2	0.7	2.0	0.7	1.9	1.6	2.7	1.0	1.4	1.5	3.6

Table 1. Summary of Available Stormwater Data Included in NSQD, version 1.1 – *Continued*

	Cd, total (µg/L)	Cd, filtered (µg/L)	Cr, total (µg/L)	Cr, filtered (µg/L)	Cu, total (µg/L)	Cu, filtered (µg/L)	Pb, total (µg/L)	Pb, filtered (µg/L)	Hg, total (µg/L)	Ni, total (µg/l)	Ni, filtered	Zn, total (µg/L)	Zn, filtererd

											(µg/L)		(µg/L)
Mixed Industrial (218)													
Number of observations	145	25	109	15	150	24	213	25	58	74	15	212	24
% of samples above detection	60.7	92.0	92.7	66.7	90.0	100.0	82.6	92.0	22.4	83.8	100.0	98.6	95.8
Median	1.6	0.60	8.0	2.0	23	6.0	20.0	5.0	0.3	12	5.0	172	2100
Coefficient of variation	1.9	0.6	1.7	0.7	0.8	0.6	1.4	1.0	0.6	0.8	0.6	3.1	1.2
Institutional (18)													
Number of observations							18					18	
% of samples above detection							77.8					100	
Median							5.75					305	
Coefficient of variation							0.8					0.8	
Freeways (185)													
Number of observations	95	114	76	101	97	130	107	126		99	95	93	105
% of samples above detection	71.6	26.3	98.7	78.2	99.0	99.2	100	50.0		89.9	67.4	96.8	99.1
Median	1.0	0.68	8.3	2.3	34.7	10.9	25	1.8		9.0	4.0	200	51
Coefficient of variation	0.9	1.0	0.7	0.7	1.0	1.5	1.5	1.7		0.9	1.4	1.0	1.9
Mixed Freeways (26)													
Number of observations	23		15		23		23					23	
% of samples above detection	56.5		100		100		56.5					100	
Median	0.5		6.0		14		10.0					130	
Coefficient of variation	2.2		1.0		1.0		1.3					0.9	
Open Space (68)													
Number of observations	38		36		39		45					45	
% of samples above detection	55.3		36.1		74.4		42.2					71.1	
Median	0.38		5.4		10		10.0					40	
Coefficient of variation	1.9		1.7		2.0		1.7					1.3	
Mixed Open Space (168)													
Number of observations	107		88		108		155		27	51		156	
% of samples above detection	18.7		81.8		89.8		74.2		14.8	72.5		98.1	
Median	2.0		6.0		9.0		10		0.15	8.0		80	
Coefficient of variation	1.4		1.3		1.0		2.3		0.4	1.1		1.1	

Implementation Guidance for Ambient Water Quality Criteria for Bacteria (Draft)

A draft of the *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* is available. When final, the *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* will guide state, territory, and authorized tribal water quality programs in adopting and implementing bacteriological water quality criteria to protect waters designated for recreation. We expect that this document will also serve as a valuable resource for state and local beach program managers and interested citizens. We expect to publish the final document soon.

- Cover Memo (PDF, 1 pp., 55K) (June 2002)
- Fact Sheet (PDF, 2 pp., 78K) (June 2002)
- Draft Guidance Document (PDF, 101 pp., 547K) (June 2002)

Ambient Water Quality Criteria for Bacteria - 1986 (PDF, 24 pp., 370K)

EPA
United States
Environmental Protection
Agency

Implementation Guidance for Ambient Water Quality Criteria for Bacteria

May 2002 Draft

U.S. Environmental Protection Agency
Office of Water (4305T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

EPA-823-B-02-003

Foreword

Our Nation's waters are a valuable recreational resource. We use them for swimming and recreating, to seek adventure through white water rafting, surfing, and kayaking, or simply enjoying their aesthetic qualities while hiking or birdwatching. Protection of these waterbodies begins with state, territory, and authorized tribal adoption of water quality standards. The draft *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* was written to provide guidance to state, territory, and authorized tribal water quality programs on the adoption and implemention of bacteriological water quality criteria for the protection of waters designated for recreation. This document may also serve as a useful resource for state and local beach program managers and interested members of the public.

This draft guidance takes into account feedback the Agency received on its previous February 2000 draft and subsequent interactions with interested stakeholders. In response to this feedback, the scope and detail of this document increased significantly in comparison to EPA's February 2000 version. Consequently, we are providing this additional opportunity for public review of the *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* to ensure that all interested parties have an opportunity to participate and offer comments on this important guidance.

Once finished, I believe you will find this document a useful resource. We look forward to receiving your comments and working with you to ensure continued protection of our recreational waters. Should you have any questions or concerns, please do not hesitate to contact me (202-566-0430) or Elizabeth Southerland, Director of the Standards and Health Protection Division (202-566-0400).

Geoffrey H. Grubbs, Director
Office of Science and Technology

NOTICE

The *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* is designed to address questions on implementing EPA's recommended water quality criteria for bacteria within state, territory, and authorized tribal water quality programs.

The guidance included in this document cannot impose legally binding requirements on EPA, states, territories, authorized tribes, or the regulated community. It cannot substitute for Clean Water Act (CWA) requirements, EPA's regulations, or the obligations imposed by consent decrees or enforcement orders. Further, this guidance might not apply to a particular situation based upon the circumstances.

Acknowledgments

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Executive Summary

The purpose of this document is to provide guidance for the implementation of water quality criteria for bacteria once adopted into state and tribal water quality standards. As part of these recommendations, EPA is encouraging states and authorized tribes to use *E. coli* or enterococci as the basis of their water quality criteria for bacteria to protect fresh recreational waters. For marine recreational waters, EPA recommends the use of enterococci as the basis for water quality criteria for bacteria. Further, for coastal recreational waters (i.e., marine waters, coastal estuaries, and the Great Lakes), states are required to adopt bacteriological criteria as protective as EPA's Clean Water Act §304(a) criteria recommendations by April 2004. EPA believes the use of *E. coli* and/or enterococci are best suited to prevent acute gastrointestinal illness caused by the incidental ingestion of fecally contaminated recreational waterbodies.

This document provides a summary of EPA's existing recommended water quality criteria for bacteria that it published in 1986 as well as recommendations on the implementation of bacteriological criteria for the protection of recreation uses once they have been adopted into a state or authorized tribe's water quality standards. The use of water quality standards to protect recreational waters encompasses a broad spectrum of waterbody types, from heavily-used ocean front beach areas, to remote mountain streams. This document attempts to acknowledge these different types of recreational uses and the different management choices that are available to states and tribes in managing these water resources.

States and authorized tribes must adopt primary contact recreation wherever attainable for all surface waters within their jurisdiction, and, in doing so, consider the use of the waterbody by children and other susceptible groups. To provide protection of human health, states and tribes should conduct sanitary surveys to identify sources of fecal pollution when high levels of bacteria are observed.

In many circumstances, waterbodies are impacted by not only human sources of fecal contamination, but also other animals, including wildlife. In these situations, based on ability of warm-blooded animals to harbor and shed human pathogens, EPA feels it is inappropriate to conclude that these sources present no risk to human health from waterborne pathogens. Consequently, states and authorized tribes should not use broad exemptions from the bacteriological criteria for waters designated for primary contact recreation based on the presumption that high levels of bacteria resulting from non-human fecal contamination present no risk to human health. This policy statement revises EPA's previous policy as stated in its 1994 *Water Quality Standards Handbook*, which allowed states and authorized tribes to justify a decision not to apply the bacteriological criteria to particular recreational waters when high concentrations of bacteria were found to be of animal origin.

For heavily-used beach areas and other well-known or popular recreational areas, EPA recommends a more conservative approach in the adoption and implementation of recreational water quality standards, such as adoption of criteria based on lower illness rates, consideration of the use of the 75% confidence level as a single sample maximum value, frequent monitoring, and the use of sanitary surveys to identify sources of fecal pollution.

For other types of waterbodies, states and authorized tribes may opt to use different approaches in the management of their recreational waterbodies. For example, those states and authorized tribes wishing to adopt bacteriological criteria based on the same illness rates for their fresh and marine waters may adopt both fresh and marine water criteria based on illness rates no greater than 14 illnesses per 1000 swimmers. For states and authorized tribes not opting for this approach, the maximum illness rate upon which fresh water criteria should be based is 14 illnesses per 1000 swimmers and the maximum illness rate upon which marine water criteria should be based is 19 illnesses per 1000 swimmers.

In some instances, particularly in northern climates, states and authorized tribes may choose to adopt seasonal recreation uses to protect primary contact recreation during the time of year it occurs and to prevent excessive disinfection by dischargers during the winter months. Residual chlorine in effluents can result in the formation of disinfection by-products, such as trihalomethanes in surface waters, which can have an adverse effect on human health and aquatic life. In other circumstances where a state or authorized tribe has determined that primary contact recreation is not an existing use as defined by federal and state (or tribal) regulations, nor attainable for one of the reasons identified in the federal and state (or tribal) regulations, states and authorized tribes may adopt other categories of recreation such as intermittent primary contact recreation, wildlife impacted recreation, or secondary contact recreation.

In addition to providing recommendations on the adoption of recreational uses and protective water quality criteria into water quality standards, the document also provides explanations of how states' and authorized tribes' recreational water quality standards should be used to form the basis for water quality-based National Pollutant Discharge Elimination System permits, assess and determine attainment of water quality standards, and develop subsequent Total Maximum Daily Loads and wasteload allocations.

While this document is focused primarily on the adoption and implementation of water quality criteria for bacteria as part of a states' or tribes' recreational water quality standards, there are some natural relationships between this topic and drinking water programs, shellfishing programs, and beach management activities. This document provides brief discussions of these relationships and, where appropriate, provides the reader with references where more information may be obtained.

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1. Background and Introduction

In 1986, the U.S. Environmental Protection Agency (EPA) published *Ambient Water Quality Criteria for Bacteria–1986.* That document contained EPA's recommended water quality criteria for bacteria for the protection of bathers from gastrointestinal illness in recreational waters. The water quality criteria established levels of indicator bacteria, namely *Escherichia coli* (*E. coli*) and enterococci, that demonstrate the presence of fecal pollution and which should not be exceeded in order to protect bathers in fresh and marine recreational waters. Indicator organisms such as these have long been used to protect bathers from illnesses that may be contracted from recreational activities in surface waters contaminated by fecal pollution. These organisms often do not cause illness directly, but have demonstrated characteristics that make them good indicators of harmful pathogens in waterbodies. Prior to its 1986 recommendations, EPA recommended the use of fecal coliforms as an indicator organism to protect bathers from gastrointestinal illness in recreational waters. Following epidemiological studies conducted by EPA that evaluated the use of several organisms as indicators, including fecal coliforms, *E. coli*, and enterococci, EPA recommended in 1986 the use of *E. coli* for fresh recreational waters and enterococci for fresh and marine recreational waters because they were better predictors of acute gastrointestinal illness than fecal coliforms. Some states and authorized tribes have replaced their fecal coliform criteria with water quality criteria for *E. coli* and/or enterococci; however, many other states and authorized tribes have not yet made this transition.

The main route of exposure to illness-causing organisms in recreational beach waters is through direct contact with polluted water while swimming, most commonly through accidental ingestion of contaminated water. In waters containing fecal contamination, potentially all of the waterborne diseases that are spread through fecal contamination and subsequent ingestion (the "fecal-oral route") may affect bathers. These illnesses result from the following:

- Bacterial infection (such as cholera, salmonellosis, shigellosis, and gastroenteritis).
- Viral infection (such as infectious hepatitis, gastroenteritis, and intestinal diseases caused by enteroviruses).
- Protozoan infections (such as cryptosporidiosis, amoebic dysentery, and giardiasis).

Although the most common effects of bathing in contaminated water are illnesses affecting the gastrointestinal tract, other illnesses and conditions affecting the eye, ear, skin, and upper respiratory tract can be contracted as well. With these conditions, infection often results when pathogenic microorganisms come into contact with small breaks and tears in the skin or ruptures in delicate membranes in the ear or nose resulting from diving into the water. These illnesses are not likely to be life-threatening for the majority of the population.

Microorganisms are ubiquitous in all terrestrial and aquatic ecosystems. Many types are beneficial, functioning as agents for chemical decomposition, food sources for larger animals, and essential components of the nitrogen cycle and other biogeochemical cycles. Some microorganisms reside in the bodies of animals and aid in the digestion of food; others are used for medical purposes such as providing antibiotics. Of the vast number of species of microorganisms present in the environment, only a small subset are human pathogens, capable of causing varying degrees of illness in humans. While some human pathogens are naturally occurring in the environment (e.g., Naeglaria or *Vibrio cholera*), the source of these microorganisms is usually the feces or other wastes of humans and various other warm-blooded animals. The pathogens most commonly identified and associated with waterborne diseases can be grouped into the three general categories: bacteria, viruses, and protozoa.

Bacteria are unicellular organisms that lack an organized nucleus and contain no chlorophyll. Waste from warm-blooded animals is a source of many types of bacteria found in waterbodies, including the coliform group and streptococcus, lactobacillus, staphylococcus, and clostridia. It is important to note, however, that most types of bacteria are not pathogenic.

Viruses are a group of infectious agents that are obligate intracellular parasites (i.e., require a host in which to live). The most significant virus group affecting water quality and human health originates in the gastrointestinal tract of infected animals. These enteric viruses are excreted in feces and include hepatitis A, rotaviruses, Norwalk-type viruses, adenoviruses, enteroviruses, and reoviruses.

Protozoa are unicellular organisms occurring primarily in the aquatic environment. Pathogenic protozoa constitute almost 30 percent of the 35,000 known species of protozoans. Pathogenic protozoa exist in the environment as cysts that hatch, releasing infective forms that attach to or invade cells, and then grow and multiply, causing associated illness. Encystation of protozoa facilitates their survival, protecting them from harsh conditions such as high temperature and salinity. Two protozoa of major concern as waterborne pathogens are *Giardia lamblia* and *Cryptosporidium parvum*.

The detection and enumeration of all pathogens of concern is impractical in most circumstances due to the potential for many different pathogens to reside in a single waterbody, lack of readily available and affordable methods, and the variation in likely pathogen concentrations. The use of indicators provides regulators and water quality managers with a means to ascertain the likelihood that human pathogens may be present in recreational waters. Specifically, the criteria published by EPA are intended, once adopted by states and authorized tribes, to control pathogens by keeping concentrations of indicator organisms at a level that corresponds with acceptable risks of acute gastrointestinal illness to recreational water users. Of the different illnesses that may be contracted during recreational activities, gastrointestinal illness occurs most frequently (CDC 2000; CDC 1998). Gastroenteritis is a term for a variety of diseases that affect the gastrointestinal tract and are rarely life-threatening. Symptoms of the illness include vomiting, diarrhea, stomach ache, nausea, headache, and fever. While other illnesses may be contracted from recreational activities, they are not specifically addressed by EPA's criteria recommendations. People who become ill as a result of bathing in contaminated water often do not associate their illness symptoms with swimming because symptoms often appear several days after exposure and are often not severe enough to cause individuals to go to the hospital or see a doctor. Most people afflicted by gastroenteritis will experience flu-like symptoms several days after exposure, rarely suspecting that ingestion of water while recreating is the cause of their illness and often assuming that the symptoms are a result of the flu or food poisoning. Consequently, disease outbreaks often are inconsistently detected and reported, leading to difficulty in ascertaining the total incidences of illness resulting from contact with recreational waters.

1.1 What is the purpose of this guidance?

This guidance provides recommendations to help states[1] and authorized tribes[2] implement EPA's recommended water quality criteria for bacteria for the protection of recreational waters. EPA strongly encourages states and authorized tribes that have not already done so, to adopt the recommendations set forth in *Ambient Water Quality Criteria for Bacteria* – 1986 or to adopt other scientifically defensible water quality criteria for bacteria into their recreational water quality standards to replace fecal or total coliform criteria.

EPA's *Ambient Water Quality Criteria for Bacteria*–1986 was developed for the protection of waters designated for recreational uses. Under section 304(a) of the Clean Water Act (CWA), EPA is required to publish water quality criteria accurately reflecting the latest scientific knowledge for the protection of human health and aquatic life. The scientific foundation of the criteria is based on studies conducted by EPA demonstrating that for fresh water, *E. coli* and enterococci are best suited for predicting the presence of gastrointestinal illness-causing pathogens, and for marine waters, enterococci is most appropriate. EPA believes the *E. coli* and enterococci indicators provide a better means of protecting recreators from contracting gastrointestinal illness than the use of fecal coliforms. The transition to *E. coli* and enterococci bacterial indicators continues to be an Agency priority for states' and authorized tribes' triennial reviews of water quality standards. Further, the recently-enacted amendments to the Clean Water Act, also known as the Beaches Environmental Assessment and Coastal Health Act (BEACH Act amendments), require coastal and Great Lakes states, by April 2004, to adopt EPA's recommended water quality criteria for bacteria or other criteria for pathogens or pathogen indicators demonstrated to be as protective as EPA's recommended water quality criteria for Great Lakes, marine, and estuarine waters. The BEACH Act amendments further direct EPA to propose and promulgate such standards for states that fail to do so. Appendix A contains the full text of the Beach Act.

1.2 Why is EPA publishing this guidance?

Despite EPA's and other studies (see Appendix B) demonstrating better correlation between swimming-associated illnesses and concentrations of *E. coli* and enterococci, many states and authorized tribes continue to use either fecal or total coliform criteria to protect and maintain

[1]Note: The term "states" will be used to denote states and U.S. territories.

[2]Pursuant to section 518(e) of the CWA, EPA is authorized to treat an Indian tribe in the same manner as a state for the purposes of administering a water quality standards program. 40 CFR 131.8 establishes the criteria by which the Agency makes such a determination. At this time, 23 tribes have requested and been granted program authorization, and 20 tribes have adopted, and EPA has approved, water quality standards pursuant to section 303(c) of the Act, and the implementing federal regulations at 40 CFR 131.

waterbodies designated for recreation. To date, only 18 states, 3 territories, and 6 authorized tribes[3] have adopted *E. coli* and/or enterococci criteria to protect all or part of their waters designated for recreation within their jurisdiction (Appendix C). EPA recognizes there has been some uncertainty among states and authorized tribes with regard to how EPA's recommended 1986 bacteriological water quality criteria should be implemented and how the transition should be made from fecal coliforms to *E. coli* and enterococci. This guidance addresses those issues identified by states and authorized tribes as impeding their progress toward adopting and implementing EPA's current recommended water quality criteria for bacteria. To assist states and authorized tribes in the adoption and implementation of EPA's recommended water quality criteria for bacteria, this document includes the following:

- Section 2 contains a reaffirmation of the scientific validity of the *Ambient Water Quality Criteria for Bacteria*–1986 through a summarization EPA's review of relevant peer-reviewed epidemiological studies conducted since EPA's 1984 epidemiological studies;

- Section 3 contains an explanation of the relationship among state and tribal water quality standards, the requirements of the BEACH Act amendments, and state and authorized tribal beach monitoring and advisory programs;

- Sections 4.2 and 4.4 contain recommendations on the application of EPA's recommended water quality criteria to waters contaminated by non-human sources;

- Section 4.3 provides recommendations for appropriate approaches for monitoring the safety of recreational waters in those tropical climates where *E. coli* and enterococci may exist naturally in the soil environment, possibly complicating the use of those organisms as indicators;

- Sections 4.4 and 4.5 provide recommendations for appropriate approaches for managing risk in waters that are not designated for primary contact recreation, including waters impacted by wildlife sources of fecal pollution or high levels of indicator organisms during wet weather events;

- Section 5.1 contains recommendations for making the transition from fecal coliforms to EPA's recommended water quality criteria, including the use of multiple indicators during a transition period;

[3]The states of Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Idaho, Indiana, Maine, Michigan, New Hampshire, New Jersey, Ohio, Oklahoma, Oregon, Tennessee, Texas, and Vermont; the territories of American Samoa, Commonwealth of the Northern Mariana Islands, and Puerto Rico; and the tribes of the Acoma Pueblo, the Colville Confederated Tribes, the Confederated Tribes of the Umatilla Indian Reservation of Oregon, the Fond du Lac Band of Lake Superior Chippewa, the Ft. Peck Assiniboine and Sioux Tribes, and the Warm Springs Tribe have adopted water quality criteria for bacteria based on *E. coli* and/or enterococci to protect part or all of their recreational waters. In some cases, because the jurisdiction over bathing beaches and administration of the state's water quality standards often resides with different departments or at different levels of government (i.e., state versus county), EPA's recommended water quality criteria may be used to manage beaches even though the state has not adopted the criteria into its water quality standards.

- Section 5.4 contains recommendations on the development of wasteload allocations for the purpose of calculating Total Maximum Daily Loads;
- Section 5.5 provides recommendations for the use of detection and enumeration methods in monitoring ambient and effluent water quality; and
- Sections 5.6 and 5.7 discuss the relationship of recommendations contained in this document to the protection of drinking water sources and shellfishing waters, respectively.

1.3 Who should use this guidance?

This guidance should be used by state and authorized tribal environmental agencies administering a water quality standards program. This guidance may also provide useful information for state, tribal, and local beach program managers and interested members of the public.

1.4 What are EPA's recommended water quality criteria for bacteria?

The tables in Appendix D contain EPA's recommended water quality criteria for the protection of primary contact recreation. The criteria consist of geometric mean and single sample maximum bacteria density value components derived from specific illness rates. When the criteria were published in 1986, they were based upon specified illness rates for fresh and marine recreational waters. Specific single sample maximum values were derived using percentiles (referred to as "confidence levels" in the criteria document) associated with the geometric mean and observed standard deviation and were given descriptive headings based on the suggested application of the maximum values to varying use intensities.

EPA's criteria recommendations include single sample maximum values targeted to various percentiles at the upper range of the observed distribution. In terms of criteria setting, the targeted level of protection is the illness rate, and the most direct relationship between measurements of bacterial levels and illness rate is the geometric mean of measurements taken over the course of a recreation season. The best way to interpret a series of measurements taken over a period of time is in comparison to the geometric mean, and the best way to interpret any single measurement is in comparison to the confidence level associated with the distribution around the geometric mean.

When EPA published its criteria in 1986, illness rates were established based on 8 illnesses per 1000 swimmers in fresh waters and 19 illnesses per 1000 in marine waters, an approximation of the protection previously afforded by the fecal coliform criterion. In this guidance EPA has determined that it would be appropriate for states and authorized tribes to protect marine waters at approximately the same level as fresh waters. This could entail adopting or retaining a fresh water criterion at a level based on 8 illnesses per 1000 swimmers and adopting a criterion for marine recreational waters at the same illness rate. Alternatively, a state or authorized tribe may elect to choose criteria associated with other illness rates to apply to both its fresh and marine recreational waters. While, in theory, states and authorized tribes could adopt criteria for both fresh and marine recreational waters associated with illness rates of up to 19 illnesses per 1000 swimmers to protect its waters designated for primary contact recreation (consistent with EPA's 1986 recommendations for marine waters) states and authorized tribes should be aware that the epidemiological data used to support the relationship between illness rates and fresh water bacteriological conditions is based on an observed illness rate range of up to 14 illnesses per 1000 swimmers, and thus, does not support extrapolation beyond that point. Consequently, EPA recommends that for states and authorized tribes choosing to adopt fresh and marine water criteria based on approximately the same illness rates, the criteria be based on illness rates below 14 illnesses per 1000 swimmers. In any case, for marine recreational waters, EPA recommends states and authorized tribes adopt criteria associated with 19 or fewer illnesses per 1000 swimmers for the protection of primary contact recreation waters. Further discussion on this topic is contained in section 4.1.1.

1.5 What is the basis for EPA's 1986 water quality criteria for bacteria?

Prior to publishing its recommended criteria in 1986, EPA conducted a series of epidemiological studies that examined the relationship between swimming-associated illness (namely, acute gastrointestinal illness) and the microbiological quality of the waters used by recreational bathers. The results of those studies demonstrated that fecal coliforms, the indicator originally recommended in 1968 by the Federal Water Pollution Control Administration of the Department of the Interior, are correlated less strongly with swimming-associated gastroenteritis than other possible indicator organisms. Two indicator organisms, *E. coli* and enterococci, exhibited a strong correlation to swimming-associated gastroenteritis, the former in fresh waters only and the latter in both fresh and marine waters (USEPA, 1986; USEPA, 1984; USEPA, 1983). The strong correlation may be due to the indicator organisms being more similar to the pathogens of concern in their ability to survive within the environment. In some cases, fecal coliforms are routinely detected where fecal contamination is absent, possibly resulting in inaccurate assessments of recreational safety. For example, *Klebsiella* spp., a bacterial organism that is part of the fecal coliform group and are generally not harmful to humans, are often present in pulp and paper and textile mill effluents (Archibald, 2000; Dufour et al., 1973). In contrast, *E. coli* and enterococci are less frequently found in environments where fecal contamination is known to be absent, making them more suitable as indicators of fecal contamination. Enterococci are also resistant to environmental factors, particularly saline environments, enhancing their utility as an indicator in marine waters.

Based on these studies, EPA's *Ambient Water Quality Criteria for Bacteria* - 1986, published under section 304(a) of the CWA, recommended the use of criteria based on the indicator organisms *E. coli* and enterococci rather than fecal coliforms.

1.5.1 How were EPA's epidemiological studies conducted?

The data supporting the water quality criteria were obtained from a series of studies (USEPA, 1984; USEPA, 1983) conducted by EPA examining the relationships between swimming-associated illness and the microbiological quality of waters used by recreational bathers. The EPA studies were unique at the time they were initiated because they attempted to relate swimmer illness to water quality at the time of swimming. This was done by approaching individuals as they were leaving the beach and asking if they would volunteer to be a part of the recreational water studies. Individuals who had been swimming during the previous week were excluded from the study. After seven to 10 days, the volunteers were contacted by telephone to determine their health status since the swimming event. Control non-swimmers, usually a member of the volunteer's family, were questioned in a similar manner. The water quality was measured on the day the volunteers swam. Multiple potential indicators were measured in each beach water sample. Multiple indicators were measured because it was unknown which one would best correlate to swimmer illness. The swimming-associated illness parameter was obtained by subtracting the non-swimmer illness rate from the swimmer illness rate using data collected over a summer trial. Additional study details may be obtained from *Health Effects Criteria for Marine Recreational Waters* (USEPA, 1983), *Health Effects Criteria for Fresh Recreational Waters* (USEPA, 1984), and the subsequent *Ambient Water Quality Criteria for Bacteria*–1986 (USEPA, 1986).

1.5.2 How were the data from EPA's epidemiological studies analyzed to provide EPA's recommended water quality criteria for bacteria?

These studies were conducted at three marine and two freshwater locations over several years. Data were collected on the bacteriological water quality and the incidents of gastrointestinal illness among swimmers as compared to non-swimmers. For the purpose of analysis, the data collected at each of these sites were grouped by location and then by season. Each season at a beach was then averaged into one paired data point consisting of an averaged illness rate and a geometric mean of the observed water quality. These data points were plotted to determine the relationships between illness rates and average water quality (expressed as a geometric mean). The resulting linear regression equations were used to calculate recommended geometric mean values at specific levels of protection (e.g., 8 illnesses per thousand). Using a generalized standard deviation of the data collected to develop the relationships and assuming a log normal distribution, various percentiles of the upper ranges of these distributions were calculated and presented as single sample maximum values.

EPA recognizes that the single sample maximum values in the 1986 criteria document are described as "upper confidence levels," however, the statistical equations used to calculate these values were those used to calculate percentile values. While the resultant maximum values would more appropriately be called 75^{th} percentile values, 82^{nd} percentile values, etc., this document will continue to use the historical term "confidence levels" to describe these values to avoid confusion.

As displayed in Appendix D tables, confidence levels were chosen ranging from 75% to 95% and assigned subjective, qualitative descriptions. For example, the most conservative single sample maximum value was assigned to beach areas because a more conservative approach should be taken in the protection of heavily-used recreational waterbodies. Conceivably, less intensively used areas may have the less restrictive single sample limits applied to them. EPA recommends the use of the single sample maximum value associated with a 75^{th} percentile for beach areas as a more conservative approach to assuring that the associated geometric mean is not exceeded in those areas regularly used for primary contact recreation activities.

The criteria were developed based on exposures incurred during swimming with head immersion and are thus intended to be adopted by states and authorized tribes to protect their primary contact recreation uses. Other criteria values may be used to protect surface waters that are not designated for primary contact recreation; however, such a designation must be supported by a use attainability analysis consistent with federal regulations at 40 CFR 131.10(g). See sections 4.4 and 4.5 for further discussion.

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2. Reaffirmation of EPA's Recommended Water Quality Criteria

The following sections describe the scientific rationale underlying EPA's 1986 guidance, EPA's re-evaluation of its recommended criteria, and subsequent research conducted following EPA's issuance of the 1986 guidance. The section also describes additional epidemiological research EPA plans to conduct in the future that may support development of new water quality criteria for bacteria.

2.1 Does EPA continue to support its *Ambient Water Quality Criteria for Bacteria* – 1986?

EPA reviewed its original studies supporting its recommended 1986 water quality criteria for bacteria and the literature on epidemiological research studies conducted since EPA performed its marine and freshwater research studies of swimming-associated health effects. Based on these reviews, EPA continues to believe that when appropriately applied and implemented, EPA's recommended water quality criteria for bacteria are protective of human health for acute gastrointestinal illness.

The epidemiological and statistical methods used to derive EPA's water quality criteria for bacteria represent a sound scientific rationale. As with all criteria, there are limitations and uncertainties. Aside from measuring pathogens directly, the use of bacterial indicators provides the best known approach to protecting swimmers against potential waterborne diseases that may be fecal in origin. Despite this fact, there are many known limitations of using indicators as the basis for protective criteria. The criteria published by EPA are targeted toward protecting recreators from acute gastrointestinal illness and may not provide protection against other waterborne diseases, such as eye, ear, skin, and upper respiratory infections, nor illnesses that may be transmitted from swimmer to swimmer. Also, certain subgroups of the population may contract illnesses more readily than the general population. These subgroups include children, the elderly, and immuno-compromised individuals. In addition, because pathogens are not being measured directly, the concentration of pathogens causing acute gastrointestinal illness may not be constant over time and at different locations relative to the measured concentrations of bacterial indicators. For instance, depending upon the type of source and the type and number of pathogens contributed by the source of fecal pollution, the actual number of illnesses realized for a given level of bacteria may be more or less than the rates observed in EPA's epidemiological studies that formed the basis of the criteria. On this topic, the *Ambient Water Quality Criteria for Bacteria*–1986 stated:

> ...the major limitations of the criteria are that the observed relationship may not be valid if the size of the population contributing the fecal wastes becomes too small or if epidemic conditions are present in a community. In both cases the pathogen to indicator ratio, which is approximately constant in a large population becomes unpredictable and therefore, the criteria may not be reliable under these circumstances.

Lastly, new pathogens and strains of antibiotic resistant bacteria capable of causing gastrointestinal illness have been identified since EPA's studies were conducted. The introduction of these new pathogens into the environment may cause a greater number of illnesses to occur at a given level of indicator organisms.

These uncertainties and limitations demonstrate the need for appropriate implementation of water quality criteria for bacteria. To assure protection of recreational water users, EPA recommends:

- frequent monitoring of known recreation areas to establish a more complete database upon which to determine if the waterbody is attaining the water quality criteria;
- assuring that where mixing zones for bacteria are authorized, they do not impinge upon known primary contact recreation areas; and
- conducting a sanitary survey when higher than normal levels of bacteria are measured. (See section 4 for additional information on conducting sanitary surveys.)

In addition to its re-evaluation of the original studies, EPA reviewed the literature for epidemiological research studies conducted after EPA performed its marine and freshwater studies of swimming-associated health effects. The review examined recent studies to determine if EPA's indicator relationship findings were supported or if different indicator bacteria were consistently shown to have quantitatively better predictive abilities. EPA's Office of Research and Development reviewed 11 separate peer-reviewed studies. This detailed review is contained in Appendix B. Following this review, EPA's Office of Research and Development concluded:

> The epidemiological studies conducted since 1984, which examined the relationships between water quality and swimming-associated health effects, have not established any new or unique principles that might significantly affect the current guidance EPA recommends for maintaining the microbiological safety of marine and freshwater bathing beaches. Many of the studies have, in fact, confirmed and validated the findings of the U.S. EPA studies. There would appear to be no good reason for modifying the Agency's current guidance for recreational waters at this time (Dufour, 1999).

As a result of this examination, EPA believes its 1986 water quality criteria for bacteria continue to represent the best available science and serve as a defensible foundation for protecting public health in recreational waters. EPA has no new scientific information or data justifying a revision of the Agency's recommended 1986 water quality criteria for bacteria at this time. EPA continues to believe that when appropriately applied and implemented, EPA's recommended *Ambient Water Quality Criteria for Bacteria*–1986 are protective of human health for acute gastrointestinal illness.

2.2 Have subsequent studies affected EPA's recommended water quality criteria for bacteria?

None of the epidemiological studies examined by EPA in its recent review presented compelling evidence that necessitate revising the 1986 water quality criteria for bacteria recommended by EPA. Most of the studies used a survey plan similar to that used by EPA in the

Agency's studies during the 1970's and 1980's. The study sites chosen by most of the investigators were similar to those studied by EPA. In the studies, one site was typically a beach with some fecal contamination, and the other site was usually a relatively unpolluted beach. Most of the bacteria loadings at the polluted beach sites came from known point sources. The results from these studies were similar to those found in the EPA studies, i.e., swimming in fecally contaminated water was associated with a higher rate of gastrointestinal illnesses in swimmers when compared to non-swimmers. This outcome was not observed in two of the reviewed studies. The reason for a negative finding is unclear, but could be related to factors such as the short length of time between the swimming event and the follow-up contact, the small numbers of children in the study groups, or the selection of a study site in which the pollution source was poorly defined.

Only a limited number of studies attempted to show a dose-response relationship between swimming water quality and gastrointestinal illness. Six of the studies (McBride et al., 1998; Kay et al., 1994; Cheung et al., 1990; Ferley et al., 1989; Seyfried et al., 1985) showed that as the level of pollution increased, there was also an increase in swimming-associated illness. Only two studies that looked for a relationship between swimming-associated illness and the level of water quality failed to find such a relationship (Kueh et al., 1995; Corbett et al., 1993). It is possible that these findings were related to the indicator organisms measured (i.e., fecal coliforms and fecal streptococci) or to the methodology used to detect the indicators. In general, the result of these studies was similar to the results found in the EPA studies; the swimming-associated illness rate increased with increasing water pollution levels.

It has been shown that some indicator organisms are superior predictors of gastrointestinal illness in swimmers. In the EPA studies, *E. coli* and enterococci exhibited the strongest relationships to swimming-associated gastrointestinal illness. Some of the studies reviewed describe other microbes having strong relationships with swimming-associated gastrointestinal illness, such as staphylococci (Seyfried et al., 1985), *Clostridium perfringens* (Kueh et al., 1995), and *Aeromonas* spp. (Kueh et al., 1995). Most of the studies, however, had findings similar to those of the EPA studies in which enterococci were shown to be the most efficient indicators for measuring marine water quality. One of the two fresh water studies indicated that *E. coli* and enterococci both exhibited very strong correlations with swimming-associated gastrointestinal illness. In general, the best indicator organisms for measuring water quality in the reviewed studies were *E. coli* and enterococci, results similar to those documented in EPA's studies.

In examining the relationships between water quality and swimming-associated gastrointestinal illness, the epidemiological studies conducted since 1984 offer no new or unique principles that significantly affect the current water quality criteria EPA recommends for protecting and maintaining recreational uses of marine and fresh waters. Many of the studies have, in fact, confirmed and validated the findings of EPA's studies. Thus, EPA has no new scientific information or data justifying a revision of the Agency's recommended 1986 water quality criteria for bacteria at this time.

2.3 Is EPA planning on conducting additional epidemiological studies in the future?

The recently enacted Beaches Environmental Assessment and Costal Health (BEACH) Act amendments to the Clean Water Act require EPA to perform an assessment of potential human health risks resulting from exposure to pathogens in coastal recreation waters. To meet this requirement, EPA is planning to conduct additional epidemiological studies that may be used to revise and develop new water quality criteria for pathogens and pathogen indicators. See CWA §§104, 304(a) (33 U.S.C. 1254; 33 U.S.C. 1314). Section 3 contains more information on the BEACH Act of 2000 and EPA's BEACH program. Appendix A contains the full text of the BEACH Act.

Future epidemiological studies and evaluation of new indicators and methods may provide new information to support protection of recreation waters. EPA plans to conduct epidemiological studies to support the development of new water quality indicators and associated guidelines for recreational waters. The epidemiological studies will examine the illness rates in families with children as they relate to microbial contaminant levels in fresh and marine recreational waters. The studies will evaluate exposure to and effects of illness from microbial pathogens in recreational waters. A range of water quality indicators will be monitored in fresh and marine recreational waters. The specific indicators that will be used have not been determined at this time. Recreational waters included in the study will be selected based on potential number of beach-goers, water quality, and sources of microbial pathogens to the water (domestic sewage versus animals). Pilot studies are scheduled to begin in summer 2002, with full-scale studies being completed by the end of the 2006 fiscal year. Pending their results, new criteria for the protection of recreation waters may be developed following the completion of these studies.

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3. Relationship Between Water Quality Standards and Beach Monitoring and Advisory Programs

CWA §303 requires states and authorized tribes to adopt water quality standards for waters of the United States within their jurisdiction sufficient to "protect the public health or welfare, enhance the quality of water and serve the purposes of [the CWA]." EPA has an oversight role in this process. EPA's implementing regulations at 40 CFR 131.11 require water quality criteria to be based on sound scientific rationale and to contain sufficient parameters to protect designated uses. Further, section 303(c) specifies that water quality standards shall include the designated use or uses to be made of the water and water quality criteria necessary to protect those uses. States and authorized tribes may adopt water quality criteria based on EPA's recommended water quality criteria developed under section 304(a) of the CWA or other scientifically defensible methods. Within the context of this guidance, states and authorized tribes may adopt EPA's recommended water quality criteria for bacteria, or other water quality criteria for bacteria based on scientifically defensible methods, to protect those waterbodies designated for primary contact recreation.

EPA's current 304(a) criteria are used as the basis for Agency decisions, both regulatory and nonregulatory, until EPA revises and reissues pollutant-specific 304(a) criteria. Two distinct purposes are served by the 304(a) criteria: (1) as guidance to states and authorized tribes in the development and adoption of water quality criteria which will protect designated uses, and (2) as the basis for promulgation of a superseding federal rule when such action is necessary. Once adopted by a state or authorized tribe into their water quality standards or promulgated by EPA for a state or authorized tribe, the water quality criteria are used to establish National Pollutant Discharge Elimination System (NPDES) water quality-based permit limits, to assess the attainment of water quality, and to provide the basis upon which Total Maximum Daily Loads (TMDLs) are developed.[4]

In addition to the uses for the state or tribal-adopted water quality criteria for bacteria listed above, some beach monitoring and advisory programs have used the state or authorized tribe's bacteriological criteria adopted into the state's or authorized tribe's water quality standards to issue beach advisories and make opening and closure decisions for identified beach areas. In general, waters designated for primary contact recreation within a state or authorized tribe's water quality standards comprise a much larger group of waterbodies than those falling under the purview of a state or tribe's beach program. While waters designated for primary contact recreation may consist of a majority of a state or tribe's waters and may vary in type from remote streams to well-known and highly managed beach areas, beach programs generally focus on the latter subset. EPA recommends beach programs use the state or tribal-adopted water quality standards for beach advisories (a requirement for those beaches covered under the BEACH Act) and encourages coordination between state and tribal water quality standards programs and beach monitoring and advisory programs.

Although these natural relationships exist between water quality standards and beach monitoring and advisory programs, the use of bacterial water quality monitoring data as part of beach

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[4]After a waterbody has been placed on a list by a state or authorized tribe for not attaining its water quality standards, a TMDL, which is an analysis apportioning pollutant loads to sources of the pollutant causing the impairment, is usually developed.

monitoring and advisory programs may differ slightly to account for some of the inherent differences between the two programs. For example, because a beach manager must make decisions based on water quality on a given day or weekend, he or she may focus more on recently collected data to determine whether a swimming advisory should be issued. This contrasts with the use of monitoring data for making a determination that a waterbody is not attaining water quality standards as specified under CWA §303(d). In this case, states and authorized tribes will usually consider data collected over a longer period of time. Further, for beach programs, beach managers may wish to consider other types of data in addition to water quality data. This may include the consideration of rainfall data when notifying the public that the standards have been exceeded or are expected to be exceeded. A recent EPA-funded study in Massachusetts at Boston Harbor beaches found that because the time necessary to obtain water quality monitoring results is at least 24 hours, levels of enterococci measured on the previous day were not always predictive of the water quality that existed when the monitoring results became available. The study found that using water quality data in conjunction with rainfall data as the basis for posting swimming advisories resulted in more accurate postings and fewer occasions when a swimming advisory would have otherwise been issued based on poor water quality associated with a previous day's measurements (MWRA, 2001).

EPA understands that the authority for administering beach programs varies among states and tribes and may rest with state, tribal, county, or municipal government. When the governmental body with the responsibility and authority for a beach monitoring and advisory program differs from the state or tribe's water quality standards program, EPA encourages coordination of these programs to ensure the greatest efficiency and consistency in monitoring and data collection. Additional information on the use of EPA's recommended criteria for bacteria in beach monitoring and notification programs will be found in EPA's *National Beach Guidance and Required Performance Criteria for Grants*, which is expected to be made available to the public in June 2002.

3.1 What are the BEACH Act amendments and how do they apply to waters designated for recreation under a state or tribe's water quality standards?

On October 10, 2000, the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) was passed, amending the Clean Water Act to provide for monitoring of coastal recreation waters and public notification when the applicable water quality standards are not met or are not expected to be met. As defined by the Act, coastal recreation waters are the marine, coastal estuaries, and Great Lakes waters. The amendments contain three significant provisions, summarized as follows:

1. The BEACH Act amended the CWA to include section 303(i), which requires states that have coastal recreation waters to adopt new or revised water quality standards by April 10, 2004, for pathogens and pathogen indicators that are as protective as the criteria published by EPA under CWA section 304(a). See CWA §303(i)(1)(A). The BEACH Act amendments further direct EPA to promulgate such standards for states that fail to do so. See CWA §303(i)(2)(A). For those states that have not adopted water quality standards as protective as EPA's water quality criteria, EPA intends to publish an Advance Notice of Proposed Rulemaking identifying those states not

adopting such criteria prior to its proposing federal water quality standards.

2. The BEACH Act amended the CWA to require EPA to study issues associated with pathogens and human health and, by October 10, 2005, to publish new or revised CWA section 304(a) criteria for pathogens and pathogen indicators based on these studies. See CWA §104(v). Within 3 years after EPA's publication of the new or revised section 304(a) criteria, states that have coastal recreation waters must then adopt new or revised water quality standards for all pathogens and pathogen indicators to which EPA's new or revised section 304(a) criteria apply. See CWA §303(i)(1)(B).

3. The BEACH Act amended the CWA to include a new section, section 406, which authorizes EPA to award grants to states and authorized tribes for the purpose of developing and implementing a program to monitor for pathogens and pathogen indicators in coastal recreation waters adjacent to beaches that are used by the public and to notify the public if water quality standards for pathogens and pathogen indicators are exceeded or likely to be exceeded. To be eligible for the implementation grants, states and authorized tribes must develop monitoring and notification programs that are consistent with performance criteria published by EPA under the Act. This performance criteria is contained in EPA's *National Beach Guidance and Required Performance Criteria for Grants.* Development grants were made available to all eligible states in 2001, and will be made available again in 2002. The BEACH Act also requires EPA to perform monitoring and notification activities for waters in states that do not have a program consistent with EPA's performance criteria, using grants funds that would otherwise have been available to those states. See CWA §406(h). For the full text of the BEACH Act, see Appendix A.

3.2 How will EPA determine if a state's water quality standards are as protective as EPA's 1986 water quality criteria for bacteria?

In determining whether a state's water quality standards are as protective as EPA's 1986 water quality criteria for bacteria for BEACH Act purposes, it is useful to review the development and analyses supporting the criteria. This analysis also applies to situations outside the context of the BEACH Act in evaluating and adopting the appropriate criteria to protect primary contact recreation uses. The water quality criteria for bacteria recommended by EPA consist of two elements: a geometric mean value and a single sample maximum. For each geometric mean value, four different single sample maximum values were developed based on the distribution of the observed data (See tables contained in Appendix C). These range from the 75% to the 95% confidence levels.

As discussed in section 1.5.2, the single maximum values calculated are more appropriately referred to as percentiles based on the equations used. The term "confidence levels" has been retained to avoid confusion; however, the manner in which the maximum values were derived has implications for the implementation of the criteria. Percentiles represent the predicted bounds of values surrounding the geometric mean. For example, 95 percent of the values used in calculating the recommended geometric means fell under the 95th percentile value, with only 5% of the values falling above the 95th percentile value. Likewise, 75 percent of the values used in calculating the recommended geometric mean fell below the 75th percentile value, with 25% of the values falling above the upper 75th percentile value. The percentile values are based on a standard deviation and an assumption of log normal shape of the distribution. In terms of statistics, a measurement falling above the 75th percentile value of the collected data is somewhat likely to lie beyond the distribution of values that constitute the geometric mean, whereas a measurement that falls above the 95th percentile value is very likely to lie beyond the distribution of values that constitute the geometric mean.

In terms of risk management, selecting a lower confidence level (e.g., 75%) for comparison to single measurements will result in a more conservative estimate of whether the measurement is associated with a given geometric mean value. This would result in a greater number of "false positive" determinations (i.e., bias toward concluding that criteria are not attained). In the case of beach advisories, this more conservative approach may be warranted. In contrast, selecting a higher confidence level (e.g., 95%) for comparison to single measurements will result in a less conservative estimate of whether the measurement is associated with a given geometric mean value. This would result in a fewer number of "false positive" determinations. EPA considers the range of the 75% to 95% confidence levels to represent an appropriate balance between "false positives" and "false negatives" for determining attainment of a geometric mean associated with a given illness rate.

Both the selection of a target illness rate within a certain range and the choice of a specific single sample maximum value within this range is a risk management decision at the discretion of the state or authorized tribe. In practice, the choice of a single sample maximum depends on several considerations, including the degree of confidence that the variability associated with the standard deviation accurately reflects the variability at the site [i.e., if the site (or group of recreational waters) exhibits enormous variability in bacteria levels, then a lower confidence level (e.g., 75%) may be more appropriate, at least until a site-specific standard deviation is determined]. Another important consideration is the consequence of the decision (e.g., the potential for more illnesses versus the loss of recreational use resulting from a beach advisory or closure). The table of single sample maximum values presented in the 1986 criteria document includes qualitative descriptors of beach usage associated with different confidence levels. This represents one approach to risk management, one that reflects a strong bias toward avoiding the potential for greater numbers of illnesses at more heavily used recreational waters.

EPA will consider a state's water quality standards to be as protective as its recommendations consistent with the requirements in CWA §303(i)(1)(A) applying to coastal and Great Lakes states if, for fresh waters, the state's criteria are

1. based on an illness rate equal to or less than 14 illnesses per 1000; and
2. uses a geometric mean *and* a single sample maximum;

and if, for marine waters, the state's criteria are

1. based on an illness rate equal to or less than 19 illnesses per 1000; and
2. uses a geometric mean *and* a single sample maximum value.

In either case, EPA would not consider a single sample maximum adopted exceeding the value associated with the 95% confidence level value to be as protective as its recommendations. EPA would also consider such criteria to be protective of primary contact recreation uses for waters not covered under the BEACH Act.

EPA recommends states and authorized tribes adopt both a geometric mean and single sample maximum for several reasons. Because the criteria form the basis for several purposes under the Clean Water Act, adoption of both a geometric mean and a single sample maximum will give states and authorized tribes the necessary components to best implement their adopted criteria for water quality-based effluent limits, determine whether a waterbody is attaining its water quality standards, and issue beach notifications and advisories. In some circumstances, states and authorized tribes may conclude that after evaluation of their monitoring data for a particular waterbody that, while the geometric mean is consistently met, the distribution of water quality data is such that the single sample maximum values are routinely exceeded. In this case, as described in the *Ambient Water Quality Criteria for Bacteria*–1986, a state or authorized tribe may re-calculate a standard deviation specific to the waterbody and subsequently adopt into water quality standards single sample maximum values specific to the observed distribution of criteria. For any state or authorized tribe choosing this option, data used should be sufficient in number and representative of the waterbody.

3.2.1 Once adopted by a state or authorized tribe into its water quality standards, how should the water quality criteria for bacteria be used in beach monitoring and notification programs?

States, authorized tribes, and local governments carrying out beach monitoring and notification programs under section 406 of the Clean Water Act monitor certain coastal recreation waters for attainment of applicable water quality standards and notify the public whenever those standards are exceeded or are likely to be exceeded.[5] Assuming that a geometric mean value and a single sample maximum have been adopted, both measures should be used in making public notification decisions.

Use of both the geometric mean and single sample maximum will enable beach managers to better evaluate the overall water quality of their beaches. For example, comparison of water quality data with the single sample maximum value will provide beach managers with the most recent information about the water quality of a beach and the information with which to post beach closings or issue advisories. In addition, frequent exceedances of the geometric mean will likely indicate that a chronic contamination problem exists and that a sanitary survey should be conducted to determine the cause.

[5] Note: For states and authorized tribes receiving grants under the BEACH Act, the requirements described in this section are elements that must be included in a state or authorized tribe's beach monitoring and advisory program in order to be eligible to receive funding. For other state and tribal beach programs for waters not covered by the BEACH Act, these provisions should be considered recommendations.

When bacteria concentrations exceed an applicable standard, the appropriate agency must immediately make a decision to either issue a public notification or to resample. A state, tribal, or local government can resample where there is reason to doubt the accuracy or certainty of the first sample, based on predefined quality assurance measures. The interpretation of the bacteria monitoring data with respect to notifying the public of an advisory or closing the beach should be clear and based on the decision rules established during the state or authorized tribe's planning process. (For more information, refer to the *National Beach Guidance and Required Performance Criteria for Grants* discussion in Section 4.2.1, When to Conduct Additional Sampling.)

EPA's *National Beach Guidance and Required Performance Criteria for Grants*, also contains detailed information and recommendations regarding when and how to provide public notification for beaches covered under the state or authorized tribe's program. EPA recommends a "tiered" beach classification system in which beaches are sorted into various tiers, depending on beach risk and/or amount of use. Further, CWA §406 requires states, authorized tribes, and local governments to prioritize the use of grant funds for monitoring and notification programs based on the use of the waterbody and the risk to human health presented by pathogens or pathogen indicators. Thus, "Tier 1" would include those beaches likely to have the greatest risk and/or highest use. Under this approach, the specific notification actions may be tailored to each category. (These recommendations are taken from Chapter 5 of the *National Beach Guidance and Required Performance Criteria for Grants*.)

EPA recommends that a tiered approach be used to determine the sampling frequency for the designated beaches. In general, EPA recommends that states, tribes, and local governments monitor at least once a week at the Tier 1 and Tier 2 beaches, resulting in the calculation of a 30-day geometric mean based on at least four samples.

Because the BEACH Act requires that states and authorized tribes notify the public whenever the water quality standards are exceeded or likely to be exceeded, some states, authorized tribes, and local governments have logically concluded that a situation may arise in which a beach would continue to be closed or advisories issued after the isolated high bacteria level was observed due to the continued exceedance of the geometric mean. Since the geometric mean is generally calculated based on data collected over the previous thirty days, a high bacteria level measured a week or two earlier could continue to cause the geometric mean value to remain high, even if subsequent samples are much lower. However, this type of situation can be prevented in the following ways. First, states, authorized tribes, and local governments that monitor more frequently than on a weekly basis will rarely encounter this situation. In areas where regular monitoring occurs less frequently, monitoring should be conducted as soon as possible after a single, very high sample is detected. If a state, authorized tribe, or local government has developed a good quality assurance/quality control plan, requiring the collection of replicate samples would provide the it with further information with which to assess whether the observed high bacteria level is representative of conditions or is an "outlier."

EPA has also proposed several ambient water quality monitoring methods for bacteria that are easily portable and relatively cheap, which should facilitate states', authorized tribes', and local governments' ability to conduct additional monitoring should the need arise. Additional samples taken following observance of a single high value will serve the dual purpose of identifying when the waterbody is safe again and showing that the geometric mean is being met based on increased sampling frequency.

EPA believes these approaches will meet the BEACH Act requirement that states adopt water quality standards for their coastal waters "as protective as" EPA's recommendations. In using any of these approaches, the state will achieve the protection of recreational waterbodies consistent with EPA's criteria recommendations.

References

Massachusetts Water Resources Authority (MWRA), prepared by Kelly Coughlin and Ann-Michelle Stanley. 2001. Water Quality at Four Boston Harbor Beaches: Results of Intensive Monitoring, 1996 - 1999. Boston, MA. US EPA Grant # X991712-01.

USEPA. 2002. National Beach Guidance and Required Performance Criteria for Grants. U.S. Environmental Protection Agency, Washington, DC. EPA-823- B-02-004

4. Appropriate Approaches for Managing Risk in Recreational Waters

Recreation occurs in many forms throughout the United States and frequently centers around waterbodies and activities occurring in and on the water. To protect the public while recreating in surface waters, states and authorized tribes have adopted primary contact recreation uses and bacteriological criteria for the majority of waterbodies in the United States. Pursuant to the federal regulations, primary contact recreation uses must be adopted for waterbodies unless such uses are shown not to be attainable. Further, primary contact recreation uses must be adopted wherever necessary to protect such uses downstream. See 40 CFR 131.10(b), 40 CFR 131.10(j).

As highlighted in section 2, states and authorized tribes may help assure protection of recreational waters through frequent monitoring of known recreation areas to establish a more complete database upon which to determine if the waterbody is attaining the water quality criteria; assuring that where mixing zones for bacteria are authorized, they do not impinge upon known primary contact recreation areas; and conducting sanitary surveys when higher than normal levels of bacteria are measured.

Sanitary surveys are an important element of protecting recreational waters and have long been used as a means to identify potential sources of contamination. A sanitary survey is an examination of a watershed to determine if unauthorized sanitary discharges are occurring from sources such as failed septic tank leach fields or cesspools, sewage leakage from broken pipes, sanitary sewer overflows from hydraulically overloaded sewers, or overflows from storm sewers that may contain illegal sanitary sewer connections. The survey should use available public health and public works departments' records to identify where such septic tanks and sewer lines exist so that observations are focused in the right places. A sanitary survey might also use dyes or other tracers in both dry and wet weather to see if unauthorized discharges are occurring from septic tanks and sewers. In addition, EPA recommends that sanitary surveys identify other possible sources, including confined animal areas, wildlife watering points, and recreational spots, such as dog running/walking areas, since these are also sources of fecal pollution. Additional guidance for conducting sanitary surveys may be found from several sources: The *National Beach Guidance and Required Performance Criteria for Grants* contains a section discussing the use of sanitary surveys in recreational waters and contains a summarization of recent publications on the subject. Additional resources include the *Guidance Manual for Conducting Sanitary Surveys of Public Water System* (USEPA, 1999), the *National Shellfish Sanitation Program Model Ordinance* (NSSP, 1999), and California's *Guidance for Saltwater Beaches* (draft) and *Guidance for Freshwater Beaches* (draft) (CA DHS, 2000a; CA DHS, 2000b).

Sanitary surveys, in addition to being a tool that can be used to identify sources of contamination, can provide useful data in characterizing a recreational waterbody and determining the relative contributions of fecal pollution sources. This type of information can be useful in deciding how to control sources as well as provide useful information to a state or authorized tribe that may be contemplating a change to the recreational use. While many waters are suitable for recreation of some sort, there are circumstances where primary contact recreation may not be attainable. This section identifies these situations and provides recommendations to appropriately protect these waters.

4.1 Where should the primary contact recreation use apply?

States and authorized tribes should designate primary contact recreation and adopt water quality criteria to support that use, unless shown to be unattainable, to reduce the risk of gastrointestinal illness in recreators. In particular, states and authorized tribes should assure that primary contact recreation uses are designated for waterbodies where people engage, or are likely to engage, in activities that could result in ingestion of water or immersion. These activities logically include swimming, water skiing, kayaking, and any other activity where contact and immersion in the water is likely. However, states and authorized tribes should also be aware that although conditions such as the location of a waterbody, high or low flows, safety concerns, or other physical conditions of the waterbody may make it unlikely that these activities would occur, EPA believes that people, particularly children, may swim or make other use of the waterbody such that ingestion may occur. Children are more likely to engage in activities where ingestion of water is likely, even in waterbodies where ingestion would not be likely for adults. Children splash and swim in shallow waters that may otherwise be considered too shallow for full body immersion. Other populations, such as kayakers or surfers, may actually seek out high flow or unsafe waters in which to recreate.

4.1.1 What water quality criteria for bacteria should states and authorized tribes adopt to protect waters designated for primary contact recreation?

In adopting criteria to protect primary contact recreation waters, EPA recommends states and authorized tribes use enterococci and/or *E. coli* criteria with a specified illness rate no greater than 14 illnesses per 1000 swimmers for fresh waters and no greater than 19 illnesses per 1000 swimmers for marine waters. These recommendations are contained in Appendix C. In adopting water quality criteria for bacteria to protect waters designated for primary contact recreation, states and authorized tribes should adopt both a geometric mean and a single sample maximum using the values or equations described in Appendix C to calculate the appropriate geometric mean and single sample maximum values. EPA believes that the objective of protecting primary contact recreation waters is best achieved through this approach. The rationale behind this recommendation is contained in section 3.2. For waters that are known to be heavily-used swimming areas and where necessary to protect downstream primary contact recreation uses, states and authorized tribes should consider using more conservative approaches, such as adopting criteria based on lower illness rates (e.g., 8 illnesses per 1000 swimmers for fresh waters) or a more conservative single sample maximum (e.g., single sample maximum values based on the 75% confidence level). For recommendations on refining recreation uses for waters where primary contact recreation is not attainable, see section 4.4.

States and authorized tribes that opt to protect primary contact recreation waters with criteria associated with illness rates within these ranges should recognize that this is a risk management decision by the state or authorized tribe similar to the selection of alternate risk levels when adopting human health criteria for carcinogens, and thus would not require a use attainability analysis as described by the federal regulations at 40 CFR 131.10. Exercising such discretion should assure, however, that downstream uses, including downstream uses across state or tribal boundaries, are protected. Further, like any other addition or revision to a state or authorized tribe's water quality standards, any subsequent change resulting from these risk management decisions are subject to the public participation requirements at 40 CFR 131.20(b).

In utilizing this risk management discretion, states and authorized tribes may wish to establish more than one category of primary contact recreation use. For example, Colorado has two categories of primary contact recreation use in addition to their secondary contact recreation designated use (CDPHE, 2001). The Recreation Class 1A use is the default use category, and is assigned an *E. coli* criterion of 126 colony forming units (cfu) per 100 milliliters (ml) based on EPA's recommended illness rate of 8 illnesses per 1000 swimmers. In these waters, primary contact recreation uses have been documented or are presumed to be present. The Recreation 1B use is intended to protect waters with the potential to support primary contact recreation uses and may be assigned only if a reasonable level of inquiry has failed to identify any existing primary contact recreation uses of the waterbody. This use category is assigned an *E. coli* criterion of 206 cfu per 100 ml based on an illness rate of 10 illnesses per 1000 swimmers. Finally, under Colorado regulation, the secondary contact recreation use (known as Recreation Class 2 in the Colorado water quality standards) may be assigned only where a use attainability analysis has been conducted consistent with 40 CFR 131.10 that further demonstrates there is no reasonable potential for primary contact recreation uses to occur within the next 20-year period. This use category is assigned an *E. coli* criterion of 630 cfu per 100 ml, which is five times the geometric mean criterion value associated with 8 illnesses per 1000 swimmers.

4.1.2 When is it appropriate to adopt seasonal recreational uses?

A seasonal recreation use may be appropriate in those states and authorized tribes where ambient air and water temperatures cool substantially during the winter months. For example, in many northern areas, primary contact recreation is possible only a few months out of the year. Several states and authorized tribes have adopted, and EPA has approved, primary contact recreation uses and the associated microbiological water quality criteria only for those months when primary contact recreation occurs and have relied on less stringent secondary contact recreation water quality criteria to protect for incidental exposure in the "non-swimming" season. The federal regulation allows for seasonal uses, provided the criteria adopted to protect such uses do not preclude the attainment and maintenance of a more protective use in another season. See 40 CFR 131.10(f).

EPA feels this is an appropriate approach, particularly where treatment of discharges sufficient to meet the primary contact recreation use would result in the use of disinfection by chlorine and thus, the release of residual chlorine in the effluent. Total residual chlorine in effluents discharging to surface waters can react with organic compounds to produce disinfection by-products such as trihalomethanes. Trihalomethanes have an adverse impact on human health and aquatic life, and are consequently of particular concern in waterbodies used for drinking water and areas where aquatic life may be adversely impacted. Thus, in some cases states and authorized tribes have adopted seasonal uses to allow for the reduction or suspension of effluent chlorination during the colder months and, consequently, to reduce risk to human health and aquatic life.

The rationale provided by states and authorized tribes to EPA to support a change in water quality standards resulting in adoption of a seasonal recreation use for a waterbody need not be burdensome. EPA's regulations do not require a formal use attainability analysis for the adoption of seasonal recreation uses. Generally, for a state or authorized tribe contemplating such a revision to its recreational water quality standards, EPA would expect that the state or authorized tribe provide information on why the particular season is being chosen. This information may include information relating to the times of year when the ambient air and water temperatures support primary contact recreation, activities in and use (or lack thereof) of the waterbody during the proposed non-recreation months, and other relevant information.

4.2 What is EPA's policy regarding high levels of indicator organisms from animal sources?

In the 1994 *Water Quality Standards Handbook*, EPA established a policy that states and authorized tribes may apply water quality criteria for bacteria to waterbodies designated for recreation with the rebuttable presumption that the indicators show the presence of human fecal contamination. As noted below, EPA is now revising this policy. This 1994 policy stated:

> States may apply bacteriological criteria sufficient to support primary contact recreation with a rebuttable presumption that the indicators show the presence of human fecal pollution. Rebuttal of this presumption, however, must be based on a sanitary survey that demonstrates a lack of contamination from human sources. The basis for this option is the absence of data demonstrating a relationship between high densities of bacteriological water quality indicators and increased risk of swimming-associated illness in animal-contaminated waters.

In short, under this policy a state or authorized tribe could justify a decision not to apply the criteria to a particular waterbody when bacterial indicators were found to be of animal origin. This policy was based on the absence of data correlating non-human sources of fecal contamination and human illness and on the belief that pathogens originating from animal sources present an insignificant risk of acute gastrointestinal illness in humans.

EPA no longer believes that the position taken in the 1994 Water Quality Standards Handbook is supported by the available scientific data. The available data suggest that there is some risk posed to humans as a result of exposure to microorganisms resulting from non-human fecal contamination. As a result, states and authorized tribes may no longer use broad exemptions from the bacteriological criteria for waters designated for primary contact recreation based on the presumption that high levels of bacteria resulting from non-human fecal contamination present no risk to human health.

Recent evidence indicates that warm-blooded animals other than humans may be responsible for transmitting pathogens capable of causing illness in humans. Examples include outbreaks of enterohemorrhagic *E. coli* O157:H7, *Salmonella, Giardia*, and *Cryptosporidium*, all of which are frequently of animal origin. Consequently, due to the potential for animal sources to contribute human pathogens to surface waters, EPA is changing its 1994 policy as stated in the Water Quality Standards Handbook through this guidance to recommend that states and authorized tribes apply their water quality criteria for bacteria to all waterbodies designated for primary contact recreation in order to ensure protection of human health from gastrointestinal illness. Livestock, wildlife, and domestic pets are carriers of human pathogens and can transmit these pathogens to surface waters as well as contribute significant numbers of indicator bacteria to waterbodies. The relative health risk from waters contaminated by human sources versus non-human sources has been the subject of recent debate, particularly related to the application and implementation of EPA's recommended water quality criteria for bacteria. Blanket exemptions for animal sources would not ensure protection of swimmers in waters designated for primary contact recreation.

Incidents where these pathogens have been spread to humans through water have been documented in recent years. In the case of *E. coli* O157:H7, several cases have been cited in which fecal contamination from animals was the probable source of the pathogen. The most prominent examples have included contamination of water supplies, including an outbreak in Alpine, Wyoming, in June 1998, affecting 157 people, and a major outbreak Walkerton, Ontario, in May and June of 2000 causing more than 2,300 people to become ill and causing seven deaths (CDC, 2002; CDC, 2000; Ontario's Ministry of the Attorney General, 2000). In the former case, contamination by wildlife of the community water supply is the suspected source, and in Walkerton, Ontario, heavy rains causing agricultural runoff to leak into city wells is suspected. The 1993 Milwaukee *Cryptosporidium* outbreak is a well-known example of water supply contamination that resulted in 403,000 illnesses and approximately 100 deaths. The source of the oocysts was not identified, but suspected sources include agricultural runoff from dairies in the region, wastewater from a slaughterhouse and meat packing plant, and municipal wastewater treatment plant effluent (Casman, 1996; USDA, 1993). In addition, *Cryptosporidium* was the known cause of 15 other outbreaks associated with drinking and recreational water affecting 5,040 individuals in the U.S. between 1991 and 1994 (Gibson et al., 1998). While many of the reported outbreaks have occurred through the consumption of contaminated drinking water, other incidences of *E. coli* O157:H7 infection from exposure to surface waters have been documented. For example, in the summer of 1991, 21 *E. coli* O157:H7 infections were traced to fecal contamination of a lake where people swam in Portland, Oregon (Keene et al., 1994)

These and other pathogens can cause significant gastrointestinal illness, although direct measurement of these organisms is not readily quantified by current conventional microbial methods. While EPA believes that non-human sources are capable of transmitting pathogens that can cause the specific kinds of gastrointestinal illness identified in EPA's original epidemiological studies, the specific risk from these sources has not been fully determined. The risk presented by fecal contamination of waters by non-human sources is possibly less significant; however, the increasing number of cases described above in which animals are the likely cause of the contamination and resulting illness present a compelling case to protect waters where human contact or consumption are likely to occur. In addition, because the presence of bacterial indicators may provide evidence of fecal pollution, high levels of these indicator organisms originating from animal sources may also indicate the presence of pathogens capable of causing other human illnesses in addition to acute gastroenteritis.

A study conducted by Calderon et al. (1991) sought to determine if the human health risk from animal sources could be quantified. The study was conducted on a small, three-acre pond in a semi-rural community in central Connecticut and examined the relationship between water quality degraded by dispersed, unidentified sources of animal fecal contamination and swimmer illness. It found that although large numbers of indicator organisms were contributed to the waterbody by animals, the resulting health risk was statistically insignificant at the 95% confidence interval to swimmers. This study concluded that EPA's currently recommended bacterial indicators are ineffective for predicting potential health effects associated with water contaminated by animal sources of fecal pollution.

Because of the relatively small sample size and the closeness of the statistical analyses to demonstrating that a relationship existed between enterococci concentrations and swimmer illness, EPA believes that this single study does not provide an adequate basis to conclude that non-human sources of fecal contamination have no potential to cause gastrointestinal illness in humans. (That is, the study p-value was 0.059 when analyzing the correlation between enterococci and swimmer illness. A p-value less than 0.05 would have indicated a strong relationship between the two parameters.)

Unless and until the time that the absence of a relationship between non-human sources of fecal contamination and human illness rates is established, EPA recommends that states and authorized tribes apply their water quality criteria for bacteria to all waterbodies designated with primary contact recreation in order to ensure protection of human health from gastrointestinal illness, and thus is changing its policy regarding non-human sources of fecal contamination from what was previously contained in the 1994 *Water Quality Standards Handbook* on this issue.

While EPA believes a change in this policy is necessary to ensure protection of human health, EPA acknowledges such a change may present states and authorized tribes with difficulties, such as the routine exceedance of the ambient water quality criterion due to natural sources of pollution. Changes to the designated use may be the most appropriate way to address these situations. Examples of natural (and potentially uncontrollable) sources are resident wildlife populations, migrating waterfowl, wildlife refuges, or lakes frequented by waterfowl. For waterbodies affected by natural sources such as these, where a significant portion of fecal contamination is shown to be from natural sources and a state or authorized tribe demonstrates the water quality criterion for bacteria and the primary contact recreation designated use is not attainable through the control of other sources, an intermittent, wildlife impacted, or secondary contact recreational use may be the most appropriate designated use. Section 4.4.2 discusses the process a state or authorized tribe would follow to refine recreational uses where contamination from natural sources is significant.

4.3 What is EPA's policy regarding high levels of indicator organisms originating from environmental sources in tropical climates?

Recent research has raised the possibility that EPA's recommended indicator bacteria, *E. coli* and enterococci, may not be appropriate indicators for assessing the risk of gastrointestinal illness in tropical recreational waters. *E. coli* and enterococci have been found to persist in soils and waterbodies (Fujioka et al., 1999; Fujioka and Byappanahalli, 1998; Lopez-Torres et al., 1987). Some researchers have hypothesized that these bacteria have developed mechanisms to maintain viable cell populations for significant periods of time under uniform tropical conditions (Fujioka, 1998). Because of these observations, some states and authorized tribes have expressed a concern that the use of EPA's recommended indicator organisms will result high observed concentrations of these bacteria that are not indicative of human health risks.

4.3.1 Does EPA recommend a different indicator for tropical climates?

At this time, EPA does not recommend that states and authorized tribes use different bacteria indicators for recreational waters in tropical climates. EPA's continued recommendation to apply *E. coli* and/or enterococci criteria for the protection of recreational waters in tropical climates is based on an expert workshop held recently on this issue and the scientific information available to date. In March 2001, an EPA-funded workshop was held in Hawaii to evaluate the existing scientific body of information on the adequacy of current indicators for tropical waters. International experts who either have conducted studies or who were otherwise very familiar with the scientific data base regarding *E. coli* or enterococci indicator persistence and growth in tropical environments were tasked to determine if these indicators remained appropriate for determining water quality and associated exposure risks for gastrointestinal disease in recreational waters. While the final report from this expert workshop has not yet been completed, EPA's preliminary assessment of the workshop's outcome is that the evidence is not compelling to change its recommendation for states and authorized tribes to use *E. coli* or enterococci criteria to ensure protection of their tropical recreational waters. The Agency believes there currently are insufficient data and information concerning possible adverse health implications to support a recommendation for the use of different tropical indicators. EPA will consider further research to determine whether or not environmental mechanisms favoring the persistence or growth of *E. coli* and enterococci indicators impact upon correctly determining the safety of tropical recreational waters. Also, EPA will review the tropical indicators workshop report, when completed, to determine research and policy needs and to pursue future research on alternative indicators that may be better suited for characterizing tropical recreational water quality.

4.3.2 What options are available to states and authorized tribes to address the applicability of EPA's recommended water quality criteria for bacteria in tropical climates?

States and authorized tribes have several options to modify their water quality standards and/or implementation procedures to address the potential for bacterial indicators to persist in tropical climates. First, a state or authorized tribe may develop water quality criteria applicable to recreational waters in tropical climate using alternative indicators. If a state or authorized tribe wishes to pursue this approach, they should apply a risk-based methodology to the development of the water quality criteria to establish a correlation between alternative indicator organism concentrations and gastrointestinal illness. This approach would be consistent with EPA's requirements for the development of scientifically defensible criteria. See 40 C.F.R. §131.11(b)(1)(iii). In addition to demonstrating a statistically significant relationship to gastrointestinal illness, an alternative indicator should be indicative of recent contamination and be detectable and quantifiable using acceptable peer-reviewed analytical methods.

Clostridium perfringens has been identified as a candidate organism having potential as a bacteriological tracer of fecal pollution. However, studies have yet to be conducted demonstrating a correlation between *C. perfringens* and the incidence of gastrointestinal illness. In addition, because *C. perfringens* forms spores that can survive for extended periods of time, EPA continues to have concerns regarding the ability of *C. perfringens* to indicate recent fecal contamination. However, for states and authorized tribes that do not wish to undertake resource-intensive epidemiological studies, *C. perfringens,* or another microorganism associated with fecal pollution may be adopted as an additional tracer of fecal pollution. EPA recommends the use of enterococci (expressed both as a geometric mean and single sample maximum) as the primary bacteriological indicator for marine and fresh waters (or *E. coli* for fresh waters), with a secondary tracer of human fecal contamination if desired. For a state or authorized tribe with tropical waters that chooses this approach, the use of the criteria and an additional tracer of fecal contamination in conjunction with site surveys should be adequate to protect the primary contact recreational uses. EPA will work with states and authorized tribes concerned about the applicability of EPA's recommended criteria in tropical waters on developing appropriate implementation procedures that take into account the behavior of indicator organisms in tropical climates.

Another option is the adoption of a subcategory of recreation use with appropriate criteria reflecting these natural conditions similar to the process described in section 4.4.2 for waterbodies impacted by high levels of wildlife fecal pollution. An approach such as this would be appropriate if it can be shown that the primary contact recreation is not an existing use, the source of pollution is not from anthropogenic sources, and that the primary contact designated use cannot be attained due to naturally-occurring pollutant concentrations preventing the attainment of the use. (See section 4.4.2 for additional details.)

EPA notes that states and authorized tribes should exercise caution in undertaking this latter approach; domestic pets and wildlife (especially waterfowl) can contribute significant numbers of indicator bacteria. While such non-human sources may be less significant in the transmission of the types of gastrointestinal illnesses identified in EPA's original epidemiological studies, the bacterial indicators may indicate risks of other illnesses. Recent outbreaks of enterohemorrhagic *E. coli* O157:H7, *Giardia*, and *Cryptosporidium*, which are frequently of animal origin, may cause significant illness. (See section 4.2 for information on human health risks from animal sources of fecal contamination.)

In addition to the approaches described here, other approaches may also be appropriate. EPA will work with states and authorized tribes interested in developing such approaches to assure they meet the requirements of the Clean Water Act and federal regulations. In general, the above approaches are applicable to any tropical area with high background concentrations of indicator bacteria. However, prior to any change to water quality standards or implementation procedures, EPA strongly recommends conducting sanitary surveys in addition to bacteria indicator monitoring, especially in areas where higher-than-normal bacteria densities are observed during monitoring. A discussion of sanitary surveys and additional related resources is provided at the beginning of section 4.

4.4 What options exist for adopting subcategories of recreation uses?

States and authorized tribes may adopt subcategories of recreation uses. More choices in subcategories of recreational uses will allow states and authorized tribes to better tailor the level of protection to the waterbody where it is most needed, while maintaining some protection for unanticipated recreation in waters where primary contact recreation is unattainable. Examples of such categories are primary contact recreation uses modified to reflect high flow situations or waterbodies significantly impacted by wildlife sources of fecal contamination. In determining the appropriate recreational use for a waterbody, states and authorized tribes should consider the fact that in certain circumstances people will use whatever waterbodies are available for recreation, regardless of the physical conditions, and that adopting a recreational use subcategory may necessitate a concurrent plan or actions by the state or authorized tribe to communicate to the public the potential risks or hazards associated with recreating in certain waterbodies.

In adopting recreational subcategories with criteria less stringent than that associated with primary contact recreation, some analysis will be required. While most recreational waters are designated for primary contact recreation to protect people engaged in water immersion activities, there are some waters where, if it can be shown that recreation is not an existing use pursuant to 40 CFR 131.10(h)(1), recreation uses may be removed altogether.[6] States and authorized tribes must justify a change to the primary contact recreation use for a waterbody through a use attainability analysis. See 40 CFR 131.10(g). The level of analysis required will vary depending upon the type of recreation use being designated. Table 4.1 provides a summary of EPA's recommendations and the types of analyses that should accompany any state or tribal revision to its recreational uses. These uses can include the designation of intermittent, secondary, or seasonal recreation uses. Subject to the provisions of 40 CFR 131.10, recreation uses other than primary contact recreation may be applicable to waters where, for example, human caused conditions combined with wet weather events cannot be remedied, or where meeting the primary contact recreation use at all times would result in substantial and widespread social and economic impact. Where states and authorized tribes have adopted uses less than primary contact recreation, federal regulations require a re-examination every three years to determine if any new information has become available to support the designation of a more protective recreation use. See 40 CFR 131.20.

4.4.1 When is it appropriate to modify primary contact recreation uses to reflect high flow situations?

An intermittent recreation use may be appropriate when the water quality criteria associated with primary contact recreation are not attainable for all wet weather events. Meeting the water quality criteria associated with the primary contact recreation use may be suspended during defined periods of time, usually after a specified hydrologic or climatic event. EPA intends this intermittent primary contact recreation use to be adopted for waterbodies in a limited number of circumstances,

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[6] 40 CFR 131.3(e) defines existing uses as "those uses actually attained in the waterbody on or after November 28, 1975, whether or not they are included in the water quality standards."

contingent upon a state or authorized tribe demonstrating that the primary contact recreation use is not an existing use, is not attainable through effluent limitations under CWA §301(b)(1)(A) and (B) and §306 or through cost effective and reasonable best management practices, and meets one of the six reasons listed under 40 CFR 131.10(g).[7] The length of time the water quality criteria (and, thus, the recreation uses) should be suspended during these events should be determined on a waterbody-by-waterbody basis, taking into account the proximity of outfalls to sensitive areas, the amount of rainfall, time of year, etc., and should not allow for any lowering of existing water quality.

EPA anticipates that the use of high flow cutoffs will be primarily applicable to flowing waterbodies and still waters impacted by flowing waterbodies, where high flows are accompanied by high levels of indicator bacteria that can not be controlled without substantial and widespread social and economic impact. When considering whether a high flow cutoff may be appropriate for a particular waterbody, states and authorized tribes should evaluate the effects of the wet weather events on the recreation use. For example, in some waterbodies, high flows routinely provide an attractive recreation environment (e.g., for kayakers), making such waters ineligible for a high flow cutoff because this type use of a waterbody constitutes an existing use which cannot be removed. See 40 CFR 131.10(h)(1). In other circumstances, high wet weather flows result in dangerous conditions physically precluding recreation (e.g., arroyo washes in the arid west), thus indicating that primary contact recreation is not or should not be occurring. Waterbody flow and velocity vary greatly among waterbodies depending on a combination of many factors, such as the amount of impervious surface, slope, soil texture, vegetative cover, soil compaction, and soil moisture. The conditions affecting velocity also vary with the depth and width of the waterbody's channel. These variables affect the relationship between wet weather events and the resulting levels of indicator bacteria.

Adoption of a high flow cutoff should be based on rigorous scientific assessment and needs to reflect public input. If the waterbody is impacted by combined sewer overflows, the supporting analysis for any water quality standards revision should be consistent with, or reflected in, the Long Term Control Plan (LTCP). Additionally, such a cutoff should apply on a case-by-case basis (rather than state-wide, for example), should be tailored to the waterbody (rivers, as distinct from lakes), and

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[7] One of the six conditions listed under 40 CFR 131.10(g) must be met in order to remove a designated use which is not an existing use, or to establish sub-categories of a use:

(1) Naturally occurring pollutant concentrations prevent the attainment of the use; or

(2) Natural, ephemeral, intermittent or low flow conditions or water levels prevent the atttainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or

(3) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

(4) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasibile to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use; or

(5) Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

(6) Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

should set the cutoff at a point where it only applies under certain limited conditions. For flowing waters, one approach is to specify the flow conditions when an exceedance may be allowed. Alternately, for either flowing or still waters, a state or authorized tribe may specify a certain number of events per year where the bacteriological criteria may be exceeded.

If a state or authorized tribe adopts a high flow cutoff, it should address several questions:

- Will other uses of the waterbody continue to be protected even when the high flow cutoff is triggered?
- What is the resulting velocity during the high flow events when the designated use would not be protected?
- Would the velocity during these events preclude all recreational uses (including kayaking) that typically occur during high velocity flows?
- Do the high flows have a minimal effect on the velocity of the flow, posing little or no danger to persons using the waters for recreation?
- For how many days would the cutoff apply and how was the length of time determined?
- Will the state or authorized tribe adopt the cutoff as a discharger-specific variance, or create recreational subcategories that correlate to the cutoff?
- Has a use attainability analysis shown that additional controls within the water watershed would result in substantial and widespread social and economic impact?
- What effect would the high flow cutoff have on implementing controls for all sources of bacterial contamination to the waterbody (e.g., CSOs, storm water, leaking septic systems, feed lots, row crops, etc.)?

States and authorized tribes implementing such a high flow cutoff should include scientifically valid methodologies for maintaining and protecting the primary contact recreational uses when normal flow returns and for protecting downstream uses. While EPA has not developed a national policy on a high flow/velocity cutoff for bacteria and recreational uses similar to its 4B3/7Q10 low flow recommendations for aquatic life criteria (e.g., the flow that results in a four-day exceedance of a chronic aquatic life criterion once every three years, which is approximately equal to the 7Q10, the lowest seven day flow that is likely to occur once every ten years), EPA envisions a methodology that states and authorized tribes could apply on a site-specific basis using the waterbody channel and landscape characteristics. States and authorized tribes could also create a subcategory of the recreational uses to which the cutoff would apply. Since use of a high flow/velocity cutoff reduces the level of protection for the waterbody, a use attainability analysis would be required for each waterbody to which the high flow/velocity cutoff applies. It would be particularly important to demonstrate that a community could not afford a higher level of control (or, for example, additional storm water or agricultural best management practices) without substantial and widespread social and economic impact. As with other changes in designated uses, the public must have an opportunity to comment on the proposed revision to the water quality standard before a state or authorized tribe adopts and submits it to EPA for approval or disapproval under CWA §303(c).

For states and authorized tribes using this approach, EPA encourages the development of a plan to communicate to the public the conditions under which recreation should not occur. For waterbodies that are known to be beaches or heavily used recreation areas, EPA encourages caution in adopting intermittent suspensions of the primary contact recreation use. If the state or authorized tribe finds after public comment that such a revision to water quality standards for a beach area is supported, EPA encourages beach managers to issue advisories during the cutoff conditions unless monitoring data are collected indicating it is safe to recreate. EPA feels this is the most appropriate implementation measure for those waters heavily used for recreation since the adoption of such a cutoff presumes that, under the conditions specified by the state or authorized tribe, the bacteriological criteria will be exceeded and, thus, may present a hazard to swimmers.

Further guidance on refining water quality standards specifically for combined sewer overflow receiving waterbodies is contained in the *Coordinating CSO Long-Term Planning With Water Quality Standards Reviews* (USEPA, 2001).

4.4.2 When is it be appropriate to adopt wildlife impacted recreation uses?

States and authorized tribes may refine designated uses if it can be demonstrated that primary contact recreation is not an existing use and natural sources preclude the attainment of water quality standards. Prior to exercising this option, a state or authorized tribe should gather data to address the following questions:

- Is the waterbody publicly identified, advertised, or otherwise regularly used or known by the public as a beach or swimming area where primary contact recreation activities are encouraged to occur?
- What is the existing water quality? If it is not currently meeting the applicable recreational water quality standards, do the exceedances occur on a seasonal basis, in response to rainfall events, or at other times due to other conditions or weather-related events?
- Is the primary contact recreation use attainable through the application of effluent limitations under CWA §301(b)(1)(A) and (B) and §306 or through cost effective and reasonable best management practices?
- What are the sources of fecal pollution within the waterbody? What are the relative contributions of these sources?

The first two questions will assist the state or authorized tribe in determining whether or not primary contact recreation is an existing use. In answering these questions, both water quality and the actual use that has occurred since November 28, 1975 should be considered. See 40 CFR 131.3(e). Information provided by the public should be considered by the state or authorized tribe in making this determination. The state or authorized tribe should provide documentation of the waterbody's historical water quality, if available, and the use of the waterbody for recreation in support of its conclusion that primary contact recreation is not an existing use.

Secondly, the state or authorized tribe should determine that natural sources, and not leaking septic tanks or other anthropogenic sources, prevent attainment of water quality standards. To ascertain whether natural sources are the cause of impairment, several tools are available. Sanitary surveys may be conducted to identify the sources contributing to a waterbody. Recommendations on conducting sanitary surveys and additional references are contained at the beginning of section 4. Detection of detergents, dyes, or caffeine may indicate human sewage as the source of fecal pollution. Knowledge of land use patterns within a watershed may also assist states and authorized tribes in determining the relative contribution sources of fecal contamination within a watershed. In addition, other analytical tools are becoming more common in identifying the sources of fecal contamination. While Bacterial Source Tracking methods such as ribotyping and Antibiotic Resistance Analysis are becoming more common, such methods may be cost prohibitive for many states and authorized tribes to use on a large scale (See, for example, Dombeck et al., 2000; Harwood et al., 2000, Wiggins et al., 1999).

The results of the sanitary survey or other methods demonstrating that natural sources preclude attainment of primary contact recreation should be sufficient to conclude that primary contact recreation is not attainable under 40 CFR 131.10(g)(1), on the grounds that naturally-occurring pollutant concentrations prevent the attainment of the use. When removing a CWA §101(a) goal use or adopting subcategories of those uses, under 40 CFR 131.10(g), states and authorized tribes are required to submit an analysis demonstrating that the use is not an existing use and justifying the removal of that use based on one of the six reasons listed in that section. When contemplating revisions to water quality standards based upon impacts from natural sources, EPA encourages states and authorized tribes to use scientifically defensible methods in their supporting analyses. EPA will review this information as part of its review and action on any revised water quality standards. EPA believes answering the questions identified above should assist the state or authorized tribe in making a scientifically defensible determination that natural sources preclude attainment of the primary contact recreation use.

Once the initial analysis has been completed, states and authorized tribes have several options for revising their recreational water quality standards. A state or authorized tribe could pursue adoption of a wildlife impacted recreation use as a recreational use subcategory, or, for waterbodies where water quality sufficient to support primary contact recreation is unattainable and location or barriers make recreation unlikely to occur, consider the adoption of a secondary contact recreation use or removal of recreation uses. Establishing a wildlife impacted recreation use would be appropriate for waters where limited recreational activities may still occur. EPA recommends that states and authorized tribes wishing to adopt a wildlife impacted recreation use adopt a criterion reflecting the natural levels of bacteria and, because the specific risk to people recreating in these waters is unknown, develop a plan to communicate to the public the potential risk of recreating in waters designated with this use. This communication could include public announcements or sign posting along the waterbody. Ideally, the state or authorized tribe should have monitoring and/or modeling data that would assist in identifying the natural levels of indicator organisms. Because such contributions are often correlated with rainfall events, the state or authorized tribe should consider the level of bacterial indicators present during dry and wet weather as well as any other spatial or temporal variability to assist in the establishment of an appropriate criterion. EPA envisions that a wildlife impacted recreation use category would provide greater protection than a secondary contact recreation use. However, wildlife sources of fecal contamination may still present some additional risk to recreators. Therefore, if the state or authorized tribe is adopting a less stringent criterion, the increment of change should correspond only to the estimated amount of the bacteria that is present due to natural sources.

Where it is shown that primary contact recreation is not an existing use and that the waterbody is significantly impacted by wildlife contamination, states and authorized tribes may adopt a secondary contact recreation use or remove the recreational use altogether. In determining whether recreation is an existing use, states and authorized tribes should consider the location of the waterbody and any barriers that may exist that would preclude the use of the waterbody for primary contact recreation. See section 4.5 for a discussion of secondary contact recreation uses and criteria.

Other water quality standards approaches beyond those described here may also be appropriate. EPA will work with states and authorized tribes interested in developing such approaches to assure they meet the requirements of the Clean Water Act and federal regulations. Regardless of the option a state or authorized tribe pursues, EPA emphasizes the importance of public participation in revising its water quality standards.

Use of this approach can provide states and authorized tribes with the means to acknowledge the type of fecal pollution that exists and its potential risk to recreators. Concern has been expressed that the use of this approach may provide existing NPDES permitted dischargers with relaxed effluent limitations. In the case where a discharger has a water quality based effluent limitation (WQBEL) for bacteriological criteria, it would not be eligible for less stringent effluent limitations unless an antidegradation analysis was performed consistent with the federal and state (or tribal) regulations. See 40 CFR 131.12. In addition, an analysis should be performed as part of the development of the WQBEL that considers the receiving waterbody's water quality and to determine whether of the discharge has the resonable potential to cause or contribute to the exceedance of applicable water quality standards. See 40 CFR 122.44(d).

4.5 What is EPA's policy regarding secondary contact recreation uses?

While recreational waters have been designated by states and authorized tribes for primary contact recreation to protect people engaged in recreational activities, there are some waters where a secondary contact recreation use with less stringent water quality criterion may be more appropriate. Activities that constitute secondary contact recreation include those in which contact and immersion with the water is unlikely. States and authorized tribes may justify the adoption of a secondary contact recreation use through a use attainability analysis. See 40 CFR 131.10(g). Subject to the provisions of 40 CFR 131.10, a secondary contact recreation use may be applicable to waters that are, for example, impacted by human caused conditions that cannot be remedied, or where meeting the criteria associated with the primary contact recreation use would result in substantial and widespread social and economic impact.

4.5.1. When is it appropriate to designate a secondary recreation use?

EPA considers waters designated for primary contact recreation and waters designated for secondary contact recreation with bacteriological water quality criteria sufficient to support primary contact recreation to be consistent with the CWA §101(a) goal uses. States and authorized tribes may designate other recreation uses after demonstrating that primary contact recreation is not an existing use and the water quality necessary to support the use is not attainable based on chemical, physical, and biological analyses, as well as economic considerations. See 40 CFR 131.10(g). Any adoption of a secondary contact recreation use with less stringent water quality criteria than required for primary contact recreation or the removal of recreation uses requires the state or authorized tribe to submit appropriate justification for the change in designated use to EPA for review and approval. See 40 CFR 131.10(j). Also, see section 4.5.3 for EPA's recommended water quality criteria for secondary contact recreation uses.

Where a primary contact recreation use and the water quality necessary to support the use is not attainable and primary contact recreation is not an existing use, the state or authorized tribe should evaluate whether the other subcategories of recreation described in the previous sections are appropriate. If not, a secondary contact recreation use with less stringent water quality criteria may be appropriate. An example would be a situation where flowing or pooled water is not present within a waterbody during the months when primary contact recreation would otherwise take place and the waterbody is not in close proximity to residential areas, thereby indicating that primary contact recreation is not likely to be an existing use. If it can also be demonstrated that natural, ephemeral, intermittent, or low flow conditions or water levels prevent attainment of the primary contact recreation use, a secondary contact recreation use may be appropriate. Another example would be a discharger that may not be able to meet limits necessary to protect the primary contact recreation use without causing substantial and widespread social and economic impact, but can meet limits that would assure protection of a secondary contact recreation use. These demonstrations would fulfill the requirements of and address one of the six conditions contained in 40 CFR 131.10(g) justifying the removal of a designated use. In addition, as discussed in section 4.4.2, designating a secondary contact recreation use may also be appropriate where primary contact recreation is not an existing use and high levels of natural and uncontrollable fecal pollution exist.

4.5.2 What information should be contained in a use attainability analysis to remove a primary contact recreation use?

States and authorized tribes should consult EPA guidance (USEPA, 1995; USEPA, 1994) for general guidelines on conducting use attainability analyses for recreation uses. The likely components of a use attainability analysis for recreation uses may include:

- physical analyses considering the actual use, public access to the waterbody, facilities promoting the use of recreation, proximity to residential areas, safety considerations, and substrate, depth, width, etc. of a waterbody;
- chemical analyses of existing water quality;

- potential for water quality improvements including an assessment of nutrients and bacteriological contaminants; and
- economic/affordability analyses.

(See also sections 4.4.1 for changes to recreation uses for waterbodies impacted by bacteria associated with high flow conditions and 4.4.2 for waterbodies impacted by non-human sources.)

On the subject of physical analyses, EPA has previously stated that, "Physical factors, which are important in determining attainability of aquatic life uses, may not be used as the basis for not designating a recreational use consistent with the CWA section 101(a)(2) goal" (USEPA, 1994). EPA continues to believe that physical factors alone would not be sufficient justification for removing or failing to designate a primary contact recreation use. EPA's suggested approach to the recreational use issue is for states and authorized tribes to look at a suite of factors such as whether the waterbody is actually being used for primary contact recreation, existing water quality, water quality potential, access, recreational facilities, location, safety considerations, and physical conditions of the waterbody in making any use attainability decision. Any one of these factors, alone, may not be sufficient to conclude that designation of the use is not warranted.

EPA continues to believe that downgrading or removing recreational uses due only to physical conditions is inappropriate when it is *otherwise feasible to meet water quality standards.* However, when considered with other data collected for a use attainability analysis, there are a few instances where physical considerations may play an important role in informing a state or authorized tribe's decision to refine a recreation use and, in particular, in determining whether or not primary contact recreation is an existing use. This may include a waterbody where access is prevented by fencing or in an urban waterbody that also serves as a shipping port or has close proximity to shipping lanes. It may also include waterbodies where primary contact recreation is not an existing use, it can be demonstrated that flowing or pooled water is not present during the months when recreation would otherwise take place, and that the waterbody is not in close proximity to residential areas. In instances such as these, the physical attributes help to ensure primary recreation does not and will not occur in these waterbodies.

EPA understands that substantial and widespread social and economic impacts are often determining factors in assessing whether or not the primary contact recreation use and water quality to support the use can be met. EPA has published guidance to assist states and authorized tribes in considering economic impacts when adopting water quality standards (USEPA, 1995). The cost of placing additional control measures on sources of fecal contamination are often cited as the reason a water cannot attain the primary contact recreation use and the associated water quality criteria in all waters at all times. In the use attainability analysis process, the federal regulation at 40 CFR 131.10(g) lists the factors that may be used to demonstrate that a primary contact recreation use cannot be met; these factors include substantial and widespread social and economic impact, and natural conditions. EPA reminds the reader that water quality criteria are derived to address the effects of pollution concentrations on the environment and human health. As such, water quality criteria do not reflect consideration of economic impacts or the technological feasibility of meeting the ambient criterion concentration in the waterbodies, while under the federal regulation, the setting of designated uses (and the associated protective criteria) may take into account social and economic considerations. See 40 CFR 131.10(g).

4.5.3 What water quality criteria should be applied to waters designated for secondary contact recreation?

For waterbodies where a state or authorized tribe demonstrates through a use attainability analysis that removing a primary contact recreation use is justified, adoption of a recreation use and water quality criteria to protect secondary contact activities may be appropriate. EPA defines secondary contact activities as those activities where most participants would have very little direct contact with the water and where ingestion of water is unlikely. Secondary contact activities may include wading, canoeing, motor boating, fishing, etc. Many states and authorized tribes have adopted secondary contact recreation uses for waterbodies. States and authorized tribes with bacteriological water quality criteria based on fecal coliforms have generally adopted a secondary contact water quality criterion of 1000 cfu/100ml geometric mean, which is five times the geometric mean value used by many states and authorized tribes to protect primary contact recreation. This water quality criterion has been applied to secondary contact uses and to seasonal recreation uses during the months of the year not associated with primary recreation. The *Ambient Water Quality Criteria for Bacteria*–1986 recommending *E. coli* and enterococci as indicators did not recommend water quality criteria for recreation uses other than primary contact recreation. States and authorized tribes have cited this as one reason why they have not adopted EPA's recommended water quality criteria.

During the development of this guidance document, EPA explored the feasibility of scientifically deriving criteria for secondary contact waters and found it infeasible for several reasons. In reviewing the data generated in the epidemiological studies conducted by EPA that formed the basis for its 1986 criteria recommendations, EPA found that these data would be unsuitable for the development of a secondary contact criterion. The exposure data collected were associated with swimming-related activities involving immersion. Secondary contact recreation activities generally do not involve immersion in the water, unless it is incidental (e.g., slipping and falling into the water or water being inadvertently splashed in the face). While the main illness likely to be contracted during primary contact recreation is gastrointestinal illness, illnesses contracted from secondary contact recreation activities may just as likely be diseases and conditions affecting the eye, ear, skin, and upper respiratory tract. Because of the different exposure scenarios and the different exposure routes that are likely to occur under the two different types of uses, EPA is unable to derive a national criterion for secondary contact recreation based upon existing data.

Despite the lack of information necessary to develop a risk-based secondary contact recreation criterion, EPA believes that waters designated for secondary contact recreation should also have in place an accompanying numeric criterion. Protecting waters designated for secondary contact recreation with a numeric criterion for bacteria provides the basis for the development of effluent limitations and, where applicable, the implementation of best management practices. Such an approach also provides a mechanism to assure that downstream uses are protected and, where adopted as part of a seasonal recreation use, help to assure that the primary contact recreation use is not precluded during the recreation season. Adoption of a numeric criterion is a straightforward approach, transparent to the public, and consistent with historical practices. In pursuing this approach, states and authorized tribes may wish to adopt a criterion five times that of the geometric mean component of the criterion adopted to protect primary contact recreation, similar to the approach states and authorized tribes have used historically in the adoption a secondary contact criterion for fecal coliforms. In evaluating attainment with this criterion, states and authorized tribes may wish to calculate geometric mean values based on samples taken over a 30 day period or on a seasonal or annual basis. Another approach would be the adoption of numeric criterion as a maximum value protective of the secondary contact recreation use. EPA feels that this would also be an appropriate approach, particularly for states and authorized tribes that are unable to collect sufficient monitoring data to calculate a geometric mean value. A narrative criterion along with implementation procedures may also form the basis for these measures. States and authorized tribes may also pursue an alternate approach to the protection of secondary contact recreation waters, and EPA will work with the state or authorized tribe to ensure the approach is protective of the designated use and meets the above objectives.

4.5.4 Will EPA publish risk-based water quality criteria to protect for "secondary contact" uses?

EPA's *Ambient Water Quality Criteria for Bacteria*–1986 are designed to protect the public from gastrointestinal illnesses associated with accidental ingestion of water. EPA has not developed any water quality criteria for secondary contact recreation to protect for other human health-based risks. Such additional water quality criteria could conceivably be based on the effects of dermal contact, such as rashes or other minor skin irritations or infections, and inhalation of water. As part of EPA's requirements under the BEACH Act amendments and commitments made in its Beach Action Plan, EPA intends to gather additional data and investigate the development of water quality criteria for transmission of organisms that cause skin, eye, ear, nose, respiratory illness, or throat infections. Some elements of such future water quality criteria may potentially be applicable to secondary contact uses.

Table 4.1 Recreation Uses, Criteria, and Supporting Analyses

Designated Use	Criterion	Supporting Analysis
Primary Contact Recreation		
Identified/Popular Beach Areas	Criteria based on risk levels of 8 or fewer illnesses/1000 swimmers (fresh waters) and 19 or fewer illnesses/1000 swimmers (marine waters).	None.
Other Primary Contact Recreation Waters	Criteria based on risk level not greater than 14 illnesses/1000 swimmers (fresh waters) and not greater than 19 illness/1000 swimmers (marine waters).	None.
Seasonal Recreation Use	Primary contact recreation criteria apply during specified recreational season; secondary contact recreation criteria apply rest of year.	Information explaining choice of recreation season (e.g., water & air temperatures, time of use, etc.).
Recreational Use Subcategories		
Exceptions for High Flow Events	Exception to criteria at high flows on a waterbody-by-waterbody basis based on flow statistic or number of exceedances allowed.	Use Attainability Analysis consistent with 40 CFR 131.10(g); demonstration that primary contact recreation is not an existing use.
Wildlife Impacted Recreation	Criteria to reflect the natural levels of bacteria while providing greater protection than criteria adopted to protect a secondary contact recreation use.	Use Attainability Analysis consistent with 40 CFR 131.10(g) and data demonstrating wildlife contributes a significant portion of fecal contamination; demonstration that primary contact recreation is not an existing use.
Other Categories of Recreation		
Secondary Contact Recreation	Criteria sufficient to protect the use. May use numeric criterion protective of secondary contact recreation(suggest specifying criterion expressed as maximum value or criterion expressed as geometric mean five times primary contact recreation geometric mean value) or narrative criterion.	Use Attainability Analysis consistent with 40 CFR 131.10(g); demonstration that primary contact recreation is not an existing use.

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5. Implementation of EPA's *Ambient Water Quality Criteria for Bacteria* – 1986 in State and Authorized Tribal Water Quality Programs

5.1 What is EPA's recommended approach for states and authorized tribes making the transition from fecal coliforms to *E. coli* and/or enterococci?

EPA recognizes that states and authorized tribes that have yet to adopt EPA's recommended 1986 water quality criteria for bacteria may be concerned about how to ensure consistency and continuity within their regulatory programs. Specifically, states and authorized tribes may have concerns about making regulatory decisions during this transition period while an adequate monitoring database is being established. To facilitate this period of transition, states and authorized tribes may include both fecal coliforms and *E. coli*/enterococci in their water quality standards for the protection of designated recreational waters for a limited period of time, generally one triennial review cycle. The dual sets of applicable criteria will enable regulatory decisions and actions to continue while collecting data for the newly adopted *E. coli* or enterococci criteria. For states and authorized tribes choosing this approach, EPA expects that during this limited period of time, states and authorized tribes will be actively collecting data on *E. coli* and/or enterococci and working to incorporate *E. coli* and/or enterococci water quality criteria into their water quality programs, e.g., National Pollutant Discharge Elimination System (NPDES), 305(b), and 303(d) programs. Alternatively, states and authorized tribes may elect to concurrently adopt a delayed effective date to allow for time in which to collect data on the newly adopted criteria. With these options available, lack of data should not delay states' and authorized tribes' adoption of *E. coli* and/or enterococci. Once *E. coli* and/or enterococci are adopted into state or tribal water quality standards, EPA encourages states and authorized tribes to remove the fecal coliform criterion as it applies to recreational waters during its next triennial review, since retaining the fecal coliform criterion for recreational waters may result in additional permitting and monitoring requirements.

Attainment of water quality criteria for bacteria is a critical component of ensuring assessing the attainment of primary contact recreation uses. Once adopted as water quality standards by states, authorized tribes, or EPA, these water quality criteria form the basis for water quality program actions, both regulatory and non-regulatory. For example, water quality criteria are used in establishing NPDES water quality-based effluent limitations (WQBELs), listing impaired waters under section 303(d), and beach monitoring and advisory programs. How the adopted criteria will be used in these different programs should be clearly explained in states' and authorized tribes' water quality standards or supporting implementation documents.

EPA recommends that states and authorized tribes adopt water quality criteria for bacteria containing both the geometric mean and single sample maximum components and use both components when assessing and determining attainment of waters designated for primary contact recreation. With regard to interpreting the geometric mean component of the criteria, there has been a common misconception of how water quality data should be used to determine whether or not a waterbody has attained the applicable geometric mean value. Some states and authorized tribes have mistakenly interpreted the water quality criteria as requiring a minimum number of samples in order to determine the attainment of the geometric mean component of the water quality criteria. The confusion may have arisen because the water quality criteria recommend a monitoring frequency of five samples taken over a 30-day period. The recommendation does not intend to imply that five samples are needed before a geometric mean can be calculated. The minimum number of samples used in the 1986 water quality criteria for bacteria is for accuracy purposes only; clearly, more frequent sampling yields more accurate results when determining the geometric mean. Further, in some instances averaging periods greater than 30 days may be appropriate. Unless specified otherwise in a state or authorized tribe's water quality standards or assessment methodology, the geometric mean should be calculated based on the *total number of samples collected* over the specified monitoring period in conjunction with a single sample maximum to determine attainment of the numeric water quality criteria (e.g., CWA §303(d) listing for fresh and marine waters), regardless of the number of samples collected. This interpretation encourages the collection and use of data and is what has always been intended. EPA notes that this interpretation was used by the Agency when promulgating water quality standards for the Colville Confederated Tribes (40 CFR 131.35).

5.2 How should states and authorized tribes implement water quality criteria for bacteria in their NPDES permitting programs[8]?

States and authorized tribes have discretion in how NPDES water quality-based effluent limits for bacteria are specified. The following sections describe how limits may be established by the permitting authority for different discharge types and consistent with the applicable federal requirements. Two scenarios are discussed: first, the period of time during which states and authorized tribes are making the transition from fecal coliform criteria to *E. coli* or enterococci criteria, and second, developing limits once the *E. coli*/enterococci criteria have been established in state and tribal water quality standards.

5.2.1 While transitioning from fecal coliforms to *E. coli* and/or enterococci, how should states and authorized tribes implement water quality criteria for bacteria in their NPDES permitting programs?

If a state or authorized tribe chooses to retain its fecal coliform criterion during a transitional period after adoption of *E. coli* and/or enterococci as water quality criteria, any new or reissued permits would need to contain water quality-based effluent limits, as appropriate and unless specified otherwise in a state or authorized tribe's water quality standards, reflecting both criteria to be consistent with the federal requirement at 40 CFR 122.44(d)(1)(i). This provision requires water quality-based permits containing limits for those pollutants (including all bacterial pollutants) the permitting authority determines are or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an exceedance of any applicable water quality standard. In this case, the existence of "reasonable potential" for fecal coliforms would also indicate the existence of

[8]Pursuant to section 518(e) of the CWA, EPA is authorized to treat an Indian tribe in the same manner as a state for the purposes of administering a NPDES program. 40 CFR 123.31-121.34 establishes the procedures and criteria by which the Agency makes such a determination. At this time, several tribes are in the process of requesting program authorization; however, to date no tribe has been granted authorization to administer an NPDES program.

reasonable potential for any other criterion for bacteria adopted by the state or authorized tribe. In most cases, wastewater treatment plants that have used secondary and tertiary treatment for fecal coliforms should find that this treatment also adequately addresses *E. coli* and enterococci (Miescier and Cabelli, 1982). However, wastewater treatment plants chlorinating their effluent may find enterococci more resistant to chlorination than fecal coliforms or *E. coli* (Oregon Association of Clean Water Agencies, 1993; Miescier and Cabelli, 1982).

5.2.2 Once *E. coli* and/or enterococci have been adopted by states and authorized tribes, how should the water quality criteria for bacteria be implemented in NPDES permits ?

Many states and authorized tribes have raised concerns regarding how state and tribal water quality standards based on EPA's 1986 water quality criteria for bacteria should be implemented through NPDES permits. Under the Clean Water Act and the implementing federal regulations, states and authorized tribes have flexibility in how they translate water quality standards into NPDES permit limits to ensure attainment of designated uses. In implementing state and tribal water quality standards that include both the geometric mean and single sample maximum components, there are multiple acceptable approaches. EPA recommends, but would not require, that states and authorized tribes use only the geometric mean component for NPDES water quality-based effluent limits. Alternatively, states and authorized tribes could use *both* the geometric mean and single sample maximum in the development of NPDES water quality-based effluent limits; or the single sample maximum value expressed as a daily average limit for NPDES water quality-based effluent limits. The Agency is aware that states have taken different approaches in deriving WQBELs for bacteria to ensure the ambient water quality criteria are met. For example, many states apply the ambient water quality criteria for bacteria directly to the discharge with no allowance for in-stream mixing (this is often referred to as "criteria end-of-pipe"). Alternatively, some states provide mixing zones for bacteria and derive permit limits that account for in-stream dilution. EPA has also stated that for certain types of regulated discharges (e.g., municipal separate storm sewer systems [MS4s] and concentrated animal feeding operations [CAFOs]), the most appropriate permit requirements may be non-numeric effluent limitations expressed in the form of best management practices (BMPs). The underlying principle, however, is that which ever approach is selected, the permitting authority must determine that permit limits and requirements derive from and comply with applicable water quality standards. See 40 CFR 122.44(d)(1)(vii)(A).

In determining a discharger's compliance with any effluent limitation, the federal regulation requires that monitoring for any pollutant should never occur less than once per year. Further, monitoring requirements should be established case-by-case based on the nature of the effluent. See 40 CFR 122.44(i)(2). More frequent sampling may be appropriate if the discharge is in close proximity to beach areas or known recreation areas.

With respect to determining whether WQBELs for bacteria are needed for a specific discharge, the Agency expects permitting authorities to use the same approach that applies to other pollutants. Thus, the permitting authority must include a WQBEL in the NPDES permit for a discharger if it determines that a pollutant (including all bacteria pollutants) is or may be discharged at a level which will cause, have reasonable potential to cause, or contribute to an exceedance of any state or tribal water quality standard. See 40 CFR 122.44(d)(1)(i). When a state or authorized tribe adopts, and EPA approves, new water quality criteria for *E. coli* and/or enterococci, the permitting authority (in most cases, the state) must immediately begin implementing these criteria through limits incorporated into any new or reissued NPDES permit, unless the state or tribal water quality standards authorize another approach. Additionally, if the state or authorized tribe chooses to retain an existing water quality criterion for fecal coliforms, the permitting authority must continue to implement this criterion in the form of a WQBEL as well, unless otherwise specified in the state or tribal water quality standards. In some cases where a discharge is released into a waterbody designated for both recreation and shellfishing, even after removal of the fecal coliform criterion for recreation, the permit will likely continue to contain effluent limitations for both parameters since the fecal coliform criterion will continue to apply to waters designated for shellfishing.

Following state or tribal adoption and EPA approval of water quality criteria for *E. coli* and/or enterococci, the Agency does not believe that permitting authorities will typically need to reopen existing permits prior to their expiration dates to incorporate WQBELs based on the newly-adopted water quality criteria. Instead the Agency expects that existing WQBELs for fecal coliforms will continue to be enforced through the existing permit's term, and that permitting authorities will incorporate WQBELs based on newly adopted water quality criteria (as needed) at the time of permit reissuance.

5.2.3 How do the antibacksliding requirements apply to NPDES permits with effluent limits for bacteria?

Dischargers that previously had NPDES water quality-based effluent limits for fecal coliforms, and subsequently have water quality-based effluent limits based on a state or authorized tribe's newly adopted *E. coli* and/or enterococci criteria should also be aware of federal NPDES "antibacksliding" provisions. The CWA and implementing NPDES federal regulations contain specific restrictions on when an existing WQBEL may be removed or replaced with a less stringent effluent limitation in a reissued NPDES permit. See CWA section 402(o); 40 CFR 122.44(l). When a state or authorized tribe replaces a fecal coliform criterion with water quality criteria for *E. coli* and/or enterococci, that replacement will not generally result in less stringent effluent limits in the permit (i.e., replacing a 200 cfu/100 ml fecal coliform criterion with an *E. coli* criterion of 126 cfu/100 ml or an enterococci criterion of 33 cfu/100 ml for fresh water or 35 cfu/100 ml enterococci criterion for marine water). In other words, if all other factors are unchanged, EPA expects that the WQBEL(s) based on the newly adopted water quality criteria for bacteria (for *E. coli* and/or enterococci), while perhaps expressed in a different form, will not be less stringent than the previous WQBEL (for fecal coliform) and that, therefore, the backsliding prohibitions in section 402 of the CWA and its implementing regulations will not apply.

If a state or authorized tribe chooses to adopt *E. coli* or enterococci water quality criteria greater than, for fresh waters, an *E. coli* criterion of 126 cfu/100 ml or an enterococci criterion of 33 cfu/100 ml or, for marine waters, an enterococci criterion of 35 cfu/100 ml (generally occurring through the adoption of a subcategory of primary contact recreation use, other recreational subcategories, or secondary contact recreation use), the antibacksliding elements of the CWA and federal regulations would apply. In these instances, the CWA and federal regulations would allow for backsliding in some circumstances as described below. EPA has consistently interpreted section 402(o)(1) of the CWA to allow relaxation of WQBELs if the requirements of CWA section 303(d)(4) are met. (While CWA §402(o)(2) allows for backsliding to occur when new information is present, revised water quality standards regulations do not constitute "new information" under this provision.)

Section 303(d)(4) has two parts: paragraph (A) which applies to "non-attainment waters" and paragraph (B) which applies to "attainment waters."

- **Non-attainment water**–Section 303(d)(4)(A) allows the establishment of less stringent WQBELs for waters identified under CWA §303(d)(1)(A) as not meeting applicable water quality standards (i.e., a "nonattainment water"), if two conditions are met. First, the existing WQBEL must be based on a total maximum daily load (TMDL) or other wasteload allocation. Second, relaxation of a WQBEL is only allowed if attainment of water quality standards will be assured.
- **Attainment water**–Section 303(d)(4)(B) applies to waters where the water quality equals or exceeds levels necessary to protect the designated use, or to otherwise meet applicable water quality standards (i.e., an "attainment water"). Under section 303(d)(4)(B), WQBELs may only be relaxed where the action is consistent with the state or authorized tribe's antidegradation policy.

It is important to note that these exceptions to the prohibition on antibacksliding as a result of a change to water quality standards are only applicable to permits with water quality-based effluent limitations. They are not applicable to relax limitations based on technology-based treatment standards for the pollutants at issue.

5.3 How should state and tribal water quality programs monitor and make attainment decisions for the water quality criteria for bacteria in recreational waters?

Monitoring protocols and assessment methodologies for recreational waters may differ depending upon the location of the waterbody, level of use, and program resources. The following sections describe appropriate approaches in the development and implementation of state and tribal monitoring and assessment programs for bacteria. Specifically, section 5.3.1 provides recommendations applicable to the period during which a state or authorized tribe may be transitioning from fecal coliforms to *E. coli* or enterococci. Section 5.3.2 focuses on general recommendations and examples for evaluating monitoring data, assessing water quality, and determining attainment of water quality standards.

5.3.1 While transitioning from fecal coliforms to *E. coli* and/or enterococci, how should states and authorized tribes monitor and make attainment decisions for their water quality criteria for bacteria?

Once a state or authorized tribe has adopted *E. coli* and/or enterococci into its water quality standards and EPA has approved the new standards, states and authorized tribes should not delay listing waterbodies for exceedances of water quality criteria for bacteria where historical data (whether for fecal coliforms or for the newly adopted criteria) indicate an impairment. Further, current Agency guidance and policy reject the notion that states and authorized tribes can avoid listing waters in anticipation of a change to a state or authorized tribe's water quality standards. Thus, if a state or authorized tribe has fecal coliform data that indicate a particular waterbody is not attaining the applicable water quality standards, the waterbody should still be listed even if the state or authorized tribe anticipates replacing its fecal coliform criteria with *E. coli* or enterococci in the near future.

For waterbodies previously listed under section 303(d) for not attaining water quality standards for fecal coliforms, EPA recommends that the waterbody continue to be included in the state or authorized tribe's 303(d) impaired waters list for bacteria until sufficient *E. coli*/enterococci data are collected to either develop a Total Daily Maximum Load (TMDL) for bacteria or support a de-listing decision. Where possible, states and authorized tribes may wish to assign these waterbodies a lower priority ranking for development of TMDLs to accommodate the collection of data on *E. coli* and/or enterococci. This would allow a waterbody listed for fecal coliforms to have additional data collected for *E. coli* and/or enterococci and, if needed, a TMDL written based on these newer criteria. In some instances states and authorized tribes may find that a waterbody not meeting its previous fecal coliform criterion may meet the newer *E. coli* or enterococci criterion. In a recent EPA-funded study conducted at Boston Harbor beaches in Massachusetts, it was found that the enterococci criterion was met more often than the fecal coliform criterion (MWRA, 2001). Proceeding in this manner to accommodate the collection of additional data would also preclude the need for a future TMDL revision if it had initially been written based on fecal coliforms.

Where there is an immediate threat to public health or where a waterbody has been listed under 303(d) on the basis of fecal coliform exceedances, and the waterbody is a priority due to court order or state (or tribal) statute or regulations, states and authorized tribes should not delay developing a TMDL. In these situations, the state or authorized tribe should develop the TMDL using the fecal coliform criterion, and monitor progress toward meeting all bacterial water quality standards, including the fecal coliform criterion (if it has been retained in the state or authorized tribe's water quality standards during a transition period) and *E. coli* and/or enterococci. Because data may not yet exist on the newly-adopted criteria, this would be one approach to meeting the requirement that TMDLs be based on the water quality criterion in effect at the time of development. If data collected over time indicate that the waterbody is meeting the *E. coli*/enterococci criteria, this would constitute an acceptable measure of attainment of the TMDL. Alternatively, if later data show a continuing problem under the *E. coli*/enterococci criterion that has not been adequately addressed under the fecal coliform TMDL, revisions to the TMDL may be necessary once data on *E. coli*/enterococci are collected.

After a state or authorized tribe adopts criteria for *E. coli* and/or enterococci, the amount of data necessary to support a listing or de-listing decision will vary among states' and authorized tribes' monitoring programs. This information should be contained either in states' and authorized tribes' assessment and listing methodologies or in their water quality standards. The design of the state or authorized tribe's monitoring program and the conclusiveness of the data collected will affect the length of time before a state or authorized tribe is able to make regulatory decisions and take appropriate actions. For example, if a state or authorized tribe routinely collects monitoring data and finds within a relatively short period of time that the data collected indicate an exceedance of the water quality criteria, EPA expects the state or authorized tribe to conclude that the waterbody is impaired. Further, monitoring designs should reflect the way in which the state or authorized tribe's water quality standards are expressed.

5.3.2 Once *E. coli* and/or enterococci have been adopted, how should recreational waters be assessed and attainment determined for waters where the bacteriological criteria apply?

Implementing water quality criteria for bacteria within a state or authorized tribe's monitoring and listing program is a recurring topic within the ongoing dialogue EPA has with states, authorized tribes, and other stakeholders, particularly during the recent development of the *Consolidated Assessment and Listing Methodology* (USEPA, 2002a). The upcoming Version 1 of the Methodology will address water quality monitoring strategies, data quality and data quantity needs, and data interpretation methodologies. This effort is focused on helping states and authorized tribes improve the accuracy and completeness of their CWA §303(d) lists and §305(b) reports as well as streamlining these two reporting requirements. In addition, this document provides recommendations for the listing and assessment of waters designated for primary contact recreation and specifically refines previous recommendations on assessing attainment of the water quality criteria for bacteria.

States and authorized tribes have questioned how the criteria should be interpreted when assessing waterbodies under CWA §305(b) and determining attainment under CWA §303(d). As discussed earlier, EPA recommends states and authorized tribes adopt both a geometric mean and a single sample maximum value. For states and authorized tribes that follow this approach, determining attainment would be based on an evaluation of the water quality data as they relate to both criteria components as specified in the state or authorized tribe's methodology.

Historically, states and authorized tribes have used simple descriptive statistics to determine attainment consistent with these recommendations. Using this approach, the geometric mean of the total number of samples taken over a certain period of time is calculated and the results compared to the geometric mean component of the criterion. In addition, the monitoring data are compared to the single sample maximum value to assure that no sample has exceeded the single sample maximum value. Using simple descriptive statistics such as this, while acceptable to EPA, has several drawbacks. Most notably, use of this approach assumes that the entire population was representatively sampled, i.e., that the samples fully captured the range and variability of the ambient concentrations existing over the period of time in which the samples were taken.

States and authorized tribes may also use what is known as inferential statistics (e.g., Students t-test, binomial and chi-square tests). The primary difference between the descriptive statistical approach described above and inferential statistics is how they handle uncertainty (i.e., decision error) and the likelihood that the sample data represent the population they are used to characterize. While descriptive statistics do not address uncertainty in the statistics used to describe the population of interest, inferential statistics assume a potential for error in using sample data to characterize the population and specifically address the likelihood that the sample data represent the population by setting targets for reasonable decision error. States and authorized tribes that define acceptable decision error have taken on a greater responsibility for monitoring programs, because these states and authorized tribes are systematically defining—and, it is hoped, committing the resources to collect—sufficient samples to support the tests.

Of these two general approaches, EPA prefers that, if sufficient data are collected, states and authorized tribes use inferential statistical models due to the ability of these models to provide the greatest certainty in making attainment decisions. Recommendations and discussions of the use of different statistical approaches will be provided in EPA's *Consolidated Assessment and Listing Methodology* (USEPA, 2002a) and are contained in EPA's *Guidance for Choosing a Sampling Design for Environmental Data Collection* (USEPA, 2000). Using statistical approaches enables the assessor to estimate, based on the samples taken and a specified confidence level, whether or not the criterion is being attained. In order for these approaches to provide reliable results, a certain amount of data must be collected as determined by data quality objectives, which in turn reflect individual state or tribal standards. Alternatively, states and authorized tribes have employed other statistical approaches. For example, some states and authorized tribes calculate confidence intervals, the upper limits of which are compared to the single sample maximum to determine compliance with that component of the criterion. Additional guidance on the use of alternate assessment approaches will be provided in the *Consolidated Assessment and Listing Guidance.*

In addition to these two approaches, states and authorized tribes may develop their own approaches; however, any monitoring protocol developed by the state or authorized tribe should be consistent with the relevant water quality standards. If the state or tribal water quality standards define how the standards are to be interpreted, the state or authorized tribe must follow its prescribed approach when assessing attainment. If the state or authorized tribe's standards are silent on how to interpret data to make ambient attainment decisions, the state or authorized tribe should describe its process. The state or authorized tribe may either follow EPA recommendations or develop implementation procedures that are consistent with its water quality standards. For example, if a state or authorized tribe's water quality criteria for bacteria consist of a geometric mean and a single sample maximum and specify that the geometric mean is to be calculated based on five samples taken over a thirty day period and that no sample may exceed the single sample maximum, the state or authorized tribe's monitoring and assessment protocol should be consistent with these water quality standards provisions. In some circumstances, states and authorized tribes may find that revisions need to be made to their water quality standards to clarify how the water quality standards will be interpreted for assessment and attainment determinations.

Many states' and authorized tribes' use information on bathing area restrictions and closures to determine attainment with recreation-based water quality standards. This information often comes from state, tribal, or local health departments and may be based on water quality monitoring, calibrated rainfall alert curves, or precautionary information. Before using this information on use restrictions and closures, it is important to document the basis for them. For example, the water quality agency may want to verify that the health department uses indicators and thresholds that are consistent with the state or authorized tribe's water quality standards.

In general, water quality-based bathing closures or restrictions that are consistent with the state or authorized tribe's water quality standards and assessment methodology and are in effect during the reporting period should be used as an indicator of water quality standards attainment. There are some exceptions, however. Bathing areas subject to precautionary administrative closures such as automatic closures after storm events of a certain intensity may not trigger an impairment decision if monitoring data show an exceedance of applicable water quality standards has not occurred. Similarly, closures or restrictions based on other conditions like rip-tides or sharks should not trigger a nonattainment decision (USEPA, 2002a).

Regardless of the monitoring protocol used by a state or tribe, EPA recommends, at a minimum, that primary contact recreation waters be monitored throughout the swimming season, ideally on a weekly basis, to ensure human health is adequately protected, particularly waters that are beach areas. EPA has prepared additional guidance contained in the *National Beach Guidance and Required Performance Criteria for Grants* recommending monitoring approaches for identified beach areas, as well as recommendations on how to use the data in making beach closures and advisories. This document is available through EPA's Beach Watch web site at www.epa.gov/waterscience/beaches.

EPA recognizes that there may be some waterbodies that merit less frequent monitoring. These waterbodies may include those where public access is purposely restricted or limited by location and other waterbodies that are not likely to be used for primary contact recreation. Due to resources or other constraints, states and authorized tribes may not be able to collect sufficient samples for these waterbodies to perform a robust statistical analysis or to collect five samples within a thirty day period to perform the recommended arithmetic analysis. In addition, for waterbodies where infrequent sampling occurs, the few samples that are taken may have only been collected during the swimming season.

Limited state or tribal resources may result in a state or tribe not being able to collect sufficient samples to calculate a meaningful geometric mean for comparison with the criterion. While EPA continues to encourage frequent monitoring of beaches and heavily-used recreation areas, for those waterbodies that are remote or, for other reasons, rarely used, EPA recommends states and authorized tribes develop monitoring protocols that describe how these waterbodies will be monitored. States and authorized tribes should assure that any alternate monitoring protocols developed are consistent with its water quality standards. In some cases, states and authorized tribes may wish to revise their water quality standards to clarify these approaches. Alternatively, states and authorized tribes may choose to specify their monitoring procedures in their CWA §303(d) listing methodology. Regardless of where this information is contained, states and authorized tribes should assure that their monitoring protocols and interpretation of the monitoring data are consistent with the expression of the applicable water quality standards. Examples of types of monitoring approaches that may be applied to infrequently used recreational waters are described in Table 5-1.

Table 5-1. Monitoring approaches for less frequently used primary contact recreation waters

Example #1
The sampling procedures for waters not identified as public or high use beaches specify that water quality data collected over a period of time longer than 30 days may be used to calculate geometric mean values. This may include calculation of seasonal geometric mean values or annual geometric mean values in addition to using the single sample maximum component.

Example #2
The sampling procedures for remote waters not identified as public or high use beaches specify the samples collected be compared to the single-sample maximum, serving as a trigger for collecting five samples within a 30-day period. If routine monitoring finds an exceedance of a single-sample maximum, then the state or tribe collects additional samples to calculate the geometric mean. The state or tribe then uses the geometric mean to make an attainment/nonattainment decision (i.e., both the geometric mean and the single-sample maximum need to exceed the state or tribal standards for the waterbody to be identified as impaired under CWA §§305(b) and 303(d)). This approach differs from Example #4 in that the assessment decision is made only after additional data are collected.

Example #3
The sampling procedures for remote waters not designated as public beaches specify sampling to occur periodically. On a rotating basin basis, sampling is conducted more intensively to confirm periodic sampling findings.

Example #4
The sampling procedures for remote waters not identified as public or high use beaches are compared to the single-sample maximum to determine attainment status. If any of the samples collected exceeds the single sample maximum, the waterbody is determined to be impaired. This approach differs from Example #2 in that the assessment decision is made after comparison only with the single sample maximum. An exceedance results in a nonattainment decision by the state or tribe as opposed to triggering more monitoring.

When considering the spectrum of different types of waterbodies designated for recreation, approaches states and authorized tribes take to monitor their waterbodies may vary with the uses assigned, since prioritization of monitoring resources may be directed more toward the heavily used recreation areas. For example, a state or authorized tribe may choose an inferential statistical approach for the monitoring and evaluation of data for high use or identified bathing areas since more data are likely to be collected in these areas. Alternatively, states and authorized tribes may choose an approach that relies on fewer data for other waterbodies that are primary contact recreation waters, but are not heavily used. (See section 4.1.1 for a discussion of how states and authorized tribes may bifurcate their primary contact recreation use designations.) Regardless of the approach used, states and authorized tribes should specify which monitoring approaches they will be using. Additionally, states and authorized tribes may find it useful to identify and provide to the public a list of recreation waters and the frequency with which they will be monitored.

5.4 How should a state or authorized tribe's water quality program calculate allowable loadings for TMDLs?

If a state or authorized tribe finds that its bacteriological criteria are not being attained, the state or authorized tribe will need to develop a TMDL consistent with CWA §303(d). A TMDL establishes the allowable loadings for specific pollutants that a waterbody can receive without exceeding water quality standards, thereby providing the basis for states and authorized tribes to establish water quality-based pollution controls. A TMDL identifies the loading capacity for a pollutant in a waterbody, the allocation of that pollutant to point and nonpoint sources contributing the pollutant, and the seasonal variation and margin of safety so that the TMDL will result in attaining the water quality standard.

For states and authorized tribes that have adopted *E. coli* and/or enterococci into their water quality standards, state and authorized tribe's water quality programs need to keep in mind the basis and assumptions inherent in the development of the applicable water quality standard when calculating a waterbody's total allowable load of the impairment-causing pollutant. The 1986 *E. coli* and enterococci criteria are generally expressed both as a 30-day geometric mean and as a single sample. The geometric mean is based on a comparison of the average summer exposure to the illness rate; the single sample is a calculation of a daily exposure that is statistically related to the geometric mean. The geometric mean characterizes an average exposure over 30 consecutive days; the single sample characterizes exposure for any given day. The calculated allowable load will need to reflect these, that is, the allowable load is a 30-day average load if based on the geometric mean, and a single day load if based on the single sample. Because the comparison of bacteriological indicator concentrations to illnesses was conducted on a daily basis, EPA recommends using the daily average effluent flow for calculating loads based on the single sample.

EPA has published guidance on how to calculate loadings that attain water quality standards for pathogens and pathogen indicators (USEPA, 2001a). This guidance identifies analytical methods that are appropriate to calculate these loads:

- **Empirical approaches** – Empirical approaches use existing data to determine the linkage between sources and water quality targets. In cases where there are sufficient observations to characterize the relationship between loading and exposure concentration across a range of loads, this information could be used to establish the linkage directly, using, for example, a regression approach.

- **Simple approaches** – Where the sole source of indicator bacteria are NPDES permitted sources, these sources are often required to meet water quality standards for indicator bacteria at the point of discharge or edge of the mixing zone, as specified in the state or tribal water quality standard. Simple dilution calculations and/or compliance monitoring (for existing discharges) are often adequate for this task.

- **Detailed modeling** – In cases where sources of bacteria are complex and subject to influences from physical processes, a water quality modeling approach is typically used to incorporate analysis of fate and transport issues. Modeling techniques vary in complexity, using one of two basic approaches: steady-state or dynamic modeling. Steady-state models use constant inputs for effluent flow, effluent concentration, receiving water flow, and meteorological conditions. Generally, steady-state models provide very conservative results when applied to wet weather sources. Dynamic models consider time-dependent variation of inputs. Dynamic models apply to the entire record of flows and loadings; thus the state or tribal water quality program does not need to specify a design or critical flow for use in the model. A daily averaging time is suggested for bacteria.

When detailed modeling is used, different types of models are required for accurate simulation for rivers and streams as compared to lakes and estuaries because the response is specific to the waterbody:

- **Rivers and Streams**. Prediction of bacteria concentrations in rivers and streams is dominated by the processes of advection and dispersion and the bacteria indicator degradation. One-, two-, and three-dimensional models have been developed to describe these processes. Waterbody type and data availability are the two most important factors that determine model applicability. For most small and shallow rivers, one-dimensional models are sufficient to simulate the waterbody's response to indicator bacteria loading. For large and deep rivers and streams, however, the one-dimensional approach falls short of describing the processes of advection and dispersion. Assumptions that the bacteria concentration is uniform both vertically and laterally are not valid. In such cases two- or three-dimensional models that include a description of the hydrodynamics are used.

- **Lakes and Estuaries.** Predicting the response of lakes and estuaries to bacteria loading requires an understanding of the hydrodynamic processes. Shallow lakes can be simulated as a simplified, completely mixed system with an inflow stream and outflow stream. However, simulating deep lakes with multiple inflows and outflows that are affected by tidal cycles is not a simple task. Bacteria concentration prediction is dominated by the processes of advection and dispersion, and these processes are affected by the tidal flow. The size of the lake or the estuary, the net freshwater flow, and wind conditions are some of the factors that determine the applicability of the models.

Given that most sources of bacteria are related to rainfall and higher river flow events, and that water quality standards apply over a wide range of flows, states and authorized tribes will most likely find that they need to calculate allowable loads for a wide variety of river flows. For this reason, EPA recommends that states and authorized tribes use dynamic modeling to calculate these loads. EPA recommends three dynamic modeling techniques to be used when an accurate estimate of the frequency distribution of projected receiving water quality is required: continuous simulation, Monte Carlo simulation, and log-normal probability modeling. These methods are described in detail in EPA's guidance (USEPA, 2001; USEPA, 1991b). Models capable of simulating bacterial concentrations are also described in EPA's guidance (USEPA, 2002b; USEPA, 1997).

In using dynamic modeling techniques, the state or authorized tribe will first develop, calibrate, and verify a water quality model for existing loads, and then will try different scenarios of load reductions until the water quality standards are attained. The wasteload allocations are then directly calculated from the dynamic model using the permit derivation techniques described in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991b). The load allocations are calculated from the percent reduction or pounds reduction used to attain the water quality standard.

If a state or authorized tribe elects not to use a dynamic model, generally because there are not sufficient data to develop such a model, then the program will need to use a steady state model approach. This entails specifying a design flow for riverine systems to apply to the water quality criterion in the standards. As discussed above, this flow will need to reflect the basis and assumptions inherent in the development of the water quality criterion. Specifying the flow will also be a challenge because the water quality standards must be attained over a range of flows, and where the loadings are rainfall related, a critical drought flow approach will not always be representative of the conditions when the standards might be exceeded. In lakes and estuaries, the flow is not as responsive to rainfall events, and an average water circulation can be used.

Most TMDLs for bacteria will include intermittent or episodic loading sources (e.g., surface runoff) that are rain-related and thus have serious water quality impacts under various flow conditions. Sometimes, maximum impacts from episodic loading occur at high flows instead of at low flows. For example, the elevated spring flows associated with snowmelt can contain high concentrations of bacteria, especially when snowmelt originates from agricultural areas where manure is spread in winter or from urban areas where residents practice poor pet curbing. As another example, a small tributary may deliver bacteria to a river. The river's bacteria load is positively, although not linearly, correlated with flow in the higher-order stream. (Both waters respond to regional precipitation patterns.) The in-stream concentration from the tributary load will be affected by the competing influences of increased load and increased dilution capacity, resulting in a peak impact at some flow greater than base flow. If a point source was also present, a dual design condition might be necessary.

For these reasons, if a state or authorized tribe elects to use a steady state model for a riverine system, EPA recommends a dual design approach where the loadings for intermittent or episodic sources are calculated using a flow duration approach and the loadings for continuous sources are calculated based on a low flow statistic. The flow duration approach has been used to establish a number of TMDLs for rivers in Kansas (Stiles, 2001).

The flow duration approach calculates a load duration curve by first calculating the cumulative frequency of the historical daily flow data over a period of time by the water quality criterion. This in essence calculates the allowable load for every flow event, and portrays those loads as the percentage of days that a loading can be exceeded without exceeding the water quality criterion. The geometric mean criterion should be multiplied by the 30-day average flow, and the single sample criterion should be multiplied by the daily flow. The flows used should reflect the long term history of a river, although those periods may be shortened due to major disruptions to rivers, such as reservoir operations or ground water depletion.

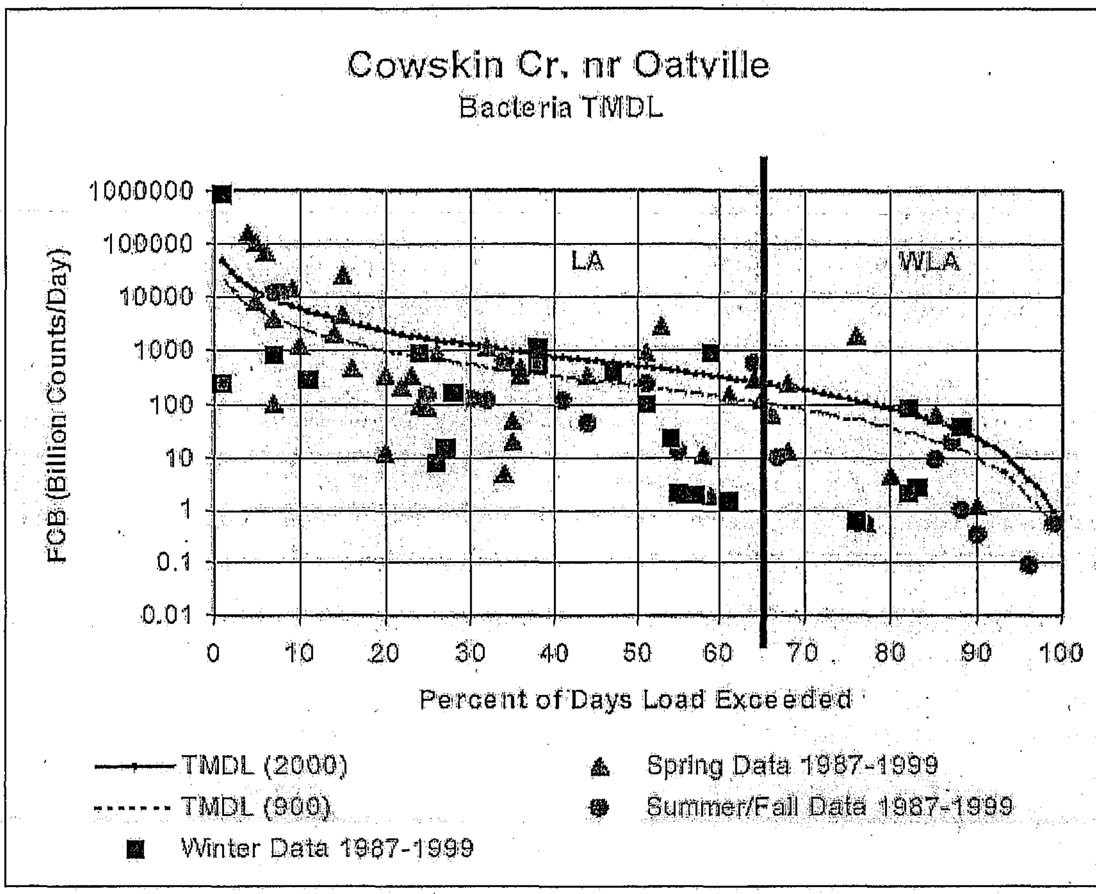
This approach requires the availability of long-term flow data to develop flow duration curves as well as daily flow values associated with dates of sampling. Where there are no gauging stations present at the sampling site, the state or authorized tribe may need to monitor flow itself or rely on USGS-developed methods to estimate flow duration curves from ungauged areas.

The distribution of existing loads is calculated by multiplying the sampled quality data by the daily flow on the date of sample, and plotting these calculations on the load duration curve above. The state or authorized tribe can then compare the actual loadings to what is needed to attain water quality standards. An example of this approach for Cowskin Creek near Oakville, Kansas, is shown in Figure 1 (Stiles, 2001). While this example has used the state's existing fecal coliform criterion, the approach is also applicable to either *E. coli* or enterococci criteria.

The overall reduction in loading necessary to attain the water quality standards is calculated as the reduction from the distribution of the existing loadings to that of the loadings necessary to attain the standards. This reduction also defines the necessary load reduction for nonpoint sources in the Load Allocation and intermittent or episodic point sources in the Wasteload Allocation.

Continuous loadings, that is, sources that discharge at about the same level regardless of the rainfall, often most greatly impact water quality under low-flow, dry-weather conditions, when dilution is minimal (USEPA, 1991a). For these sources, EPA recommends that the allowable loading and Wasteload Allocations be calculated for the geometric mean as the product of the geometric mean water quality criterion and the 30Q5 flow statistic (i.e., the highest 30-day flow occurring once every five years), and for the single sample as the product of the single sample water quality criterion and 1Q10 flow statistic (i.e., the highest one-day flow occurring once every 10 years) or the low flow specified in the state or tribal water quality standards, if one is so specified. These flows reflect the characteristics of the criteria, that is, a 30-day average flow for the 30-day average geometric mean and a one day flow for the single sample. By using extreme flow values, the loading calculation ensures that the criteria are rarely exceeded. The 30Q5 is EPA's recommendation for human health criteria for non-carcinogens and the 1Q10 is EPA's recommendation for calculating loadings for criteria that represent a daily or hourly averaging period (USEPA, 1991b).

FIGURE 1. EXAMPLE OF A TMDL LOAD DURATION CURVE FOR BACTERIA



Source: Stiles, 2001

5.5 What analytical methods should be used to quantify levels of *E. coli* and enterococci in ambient water and effluents?

The permit writer is responsible for specifying the analytical methods to be used for monitoring in an NPDES permit. Typically, the methods specified are those cited in 40 CFR 136 in the standard conditions of the permit, unless other test procedures have been specified. In the case of the development of permits for *E. coli* and enterococci, while EPA is planning to publish final methods in 40 CFR 136 for *E. coli* or enterococci in the near future, methods do not yet exist in 40 CFR 136 for these constituents. Pursuant to 40 *CFR* 122.41(j)(4), permit writers have the authority to specify methods that are not contained in 40 CFR 136. In addition to commercially available test methods there are several EPA-approved methods permit writers may specify in permits, including the mE and the mEI agar methods for enterococci and the modified mTEC and mTEC agar methods for *E. coli*.

5.6 How do the recommendations contained in this document affect waters designated for drinking water supply?

Waterbodies that are used as public (drinking) water supplies are an important resource that share many of the same human health concerns with recreational waterbodies. Both types of waterbodies have a need to be protected against contamination by sources of fecal pollution. Like recreational waterbodies, the primary route of exposure is through ingestion. However, unlike recreation, consumption and other uses of water are intended and typically in much larger quantities.

While the Safe Drinking Water Act requires public water systems that are served by surface water, or by groundwater under the direct influence of surface water, to provide a minimum level of drinking water treatment to remove microbial pathogens, the treatment technologies used to reduce microbial pathogens to safe levels in drinking water are not fully effective (i.e., they don't remove every single microbe). Because these technologies remove only a *percentage* of pathogens from the ambient water, higher pollutant loads in the ambient water will result in higher absolute levels of drinking water contamination and greater public health risk. Further, because drinking water treatment technologies are subject to operator error and occasional equipment failure, the prospect of treatment bypass poses a higher public health risk when the ambient water pollutant loads are higher than when they are lower. Treatment bypass is the suspected cause of the Milwaukee outbreak of cryptosporiasis in 1993 in which approximately 100 people died.

To date, EPA has not developed criteria recommendations under section 304(a) of the CWA specifically aimed at the protection of drinking water sources from microbiological contaminants. Some states and authorized tribes have adopted EPA's recommended water quality criteria for bacteria to protect waters designated for drinking water supplies. EPA believes that, in the absence of criteria specifically targeted to the microbiological organisms and exposure routes of concern in drinking water supplies, this is an appropriate approach. Even though public water systems are required to remove microbial pathogens to safe levels for consumption, the adoption of EPA's recommended water quality criteria for bacteria to protect drinking water supplies provides an additional and critical measure of public health protection. State and tribal adoption of EPA's bacteriological criteria recommendations into their water quality standards for the protection of drinking water supplies can provide a mechanism by which water quality may be maintained and protected and sources of fecal pollution controlled.

EPA is contemplating the development of water quality criteria specifically targeted toward the protection of waters designated for drinking water supplies. This is one area identified in EPA's forthcoming *Microbial Waterborne Disease Strategy* that EPA intends to pursue.

5.7 How do the recommendations contained in this document affect waters designated for shellfishing?

EPA's criteria recommendations for the use of fecal coliform criteria to protect designated shellfishing waters are contained in its *Quality Criteria for Water 1986* (also known as the Gold Book) (USEPA, 1986). While EPA continues to recommend states and authorized tribes use fecal coliform criteria to protect shellfishing waters, EPA's current recommendation that states and authorized tribes use enterococci for marine recreational waters and either enterococci or *E. coli* for fresh recreational waters, are causing states and authorized tribes that have adopted these criteria to now monitor for two different indicators. While EPA realizes that this may cause some inconvenience and additional resources to conduct monitoring, data and information do not yet exist that would support the use of *E. coli* or enterococci as criteria to protect waters designated for shellfishing.

The1986 *E. coli* and enterococci criteria were developed to protect against human health effects, namely acute gastroenteritis, that may be incurred due to incidental ingestion of water while recreating. These criteria do not account for exposure that may be incurred by the consumption of shellfish, and therefore, are not appropriate for waters designated for shellfish. If, at such time, data and information are compiled that support the use of these indicator organisms in shellfishing waters, EPA will revisit this issue and consider the development of a revised criterion that appropriately takes into account the exposure pathways associated with the consumption of shellfish. In the meantime, EPA continues to recommend the use of fecal coliforms for the protection of shellfishing waters.

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Appendix A: Beaches Environmental Assessment and Coastal Health Act of 2000

An Act

To amend the Federal Water Pollution Control Act to improve the quality of coastal recreation waters, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Beaches Environmental Assessment and Coastal Health Act of 2000".

SECTION 2. ADOPTION OF COASTAL RECREATION WATER QUALITY CRITERIA AND STANDARDS BY STATES.

Section 303 of the Federal Water Pollution Control Act (33 U.S.C. 1313) is amended by adding at the end the following:

(i) **Coastal Recreation Water Quality Criteria.**—

(1) **Adoption by States.**—

(A) **Initial Criteria and Standards.**—Not later than 42 months after the date of the enactment of this subsection, each State having coastal recreation waters shall adopt and submit to the Administrator water quality criteria and standards for the coastal recreation waters of the State for those pathogens and pathogen indicators for which the Administrator has published criteria under section 304(a).

(B) **New or Revised Criteria and Standards.**—Not later than 36 months after the date of publication by the Administrator of new or revised water quality criteria under section 304(a)(9), each State having coastal recreation waters shall adopt and submit to the Administrator new or revised water quality standards for the coastal recreation waters of the State for all pathogens and pathogen indicators to which the new or revised water quality criteria are applicable.

(2) **Failure of States to Adopt.**—

(A) **In General.**—If a State fails to adopt water quality criteria and standards in accordance with paragraph (1)(A) that are as protective of human health as the criteria for pathogens and pathogen indicators for coastal recreation waters published by the Administrator, the Administrator shall promptly propose regulations for the State setting forth revised or new water quality standards for pathogens and pathogen indicators described in paragraph (1)(A) for coastal recreation waters of the State.

(B) **Exception.**—If the Administrator proposes regulations for a State described in subparagraph (A) under subsection (c)(4)(B), the Administrator shall publish any revised or new standard under this subsection not later than 42 months after the date of the enactment of this subsection.

(3) **Applicability.**—Except as expressly provided by this subsection, the requirements and procedures of subsection (c) apply to this subsection, including the requirement in subsection (c)(2)(A) that the criteria protect public health and welfare.

SECTION 3. REVISIONS TO WATER QUALITY CRITERIA.

(a) **Studies Concerning Pathogen Indicators in Coastal Recreation Waters.**—Section 104 of the Federal Water Pollution Control Act (33 U.S.C. 1254) is amended by adding at the end the following:

(v) **Studies Concerning Pathogen Indicators in Coastal Recreation Waters.**—Not later than 18 months after the date of the enactment of this subsection, after consultation and in cooperation with appropriate Federal, State, tribal, and local officials (including local health officials), the Administrator shall initiate, and, not later than 3 years after the date of the enactment of this subsection, shall complete, in cooperation with the heads of other Federal agencies, studies to provide additional information for use in developing—

(1) an assessment of potential human health risks resulting from exposure to pathogens in coastal recreation waters, including nongastrointestinal effects;

(2) appropriate and effective indicators for improving detection in a timely manner in coastal recreation waters of the presence of pathogens that are harmful to human health;

(3) appropriate, accurate, expeditious, and cost-effective methods (including predictive models) for detecting in a timely manner in coastal recreation waters the presence of pathogens that are harmful to human health; and

(4) guidance for State application of the criteria for pathogens and pathogen indicators to be published under section 304(a)(9) to account for the diversity of geographic and aquatic conditions.

(b) **Revised Criteria.**—Section 304(a) of the Federal Water Pollution Control Act (33 U.S.C. 1314(a)) is amended by adding at the end the following:

(9) **Revised Criteria for Coastal Recreation Waters.**—

(A) **In General.**—Not later than 5 years after the date of the enactment of this paragraph, after consultation and in cooperation with appropriate Federal, State, tribal, and local officials (including local health officials), the Administrator shall publish new or revised water quality criteria for pathogens and pathogen indicators (including a revised list of testing methods, as appropriate), based on the results of the studies conducted under section 104(v), for the purpose of protecting human health in coastal recreation waters.

(B) **Reviews.**—Not later than the date that is 5 years after the date of publication of water quality criteria under this paragraph, and at least once every 5 years thereafter, the Administrator shall review and, as necessary, revise the water quality criteria.

SECTION 4. COASTAL RECREATION WATER QUALITY MONITORING AND NOTIFICATION.

Title IV of the Federal Water Pollution Control Act (33 U.S.C. 1341 et seq.) is amended by adding at the end the following:

SEC. 406. COASTAL RECREATION WATER QUALITY MONITORING AND NOTIFICATION.

(a) **Monitoring and Notification.**—

(1) **In General.**—Not later than 18 months after the date of the enactment of this section, after consultation and in cooperation with appropriate Federal, State, tribal, and local officials (including local health officials), and after providing public notice and an opportunity for comment, the Administrator shall publish performance criteria for—

(A) monitoring and assessment (including specifying available methods for monitoring) of coastal recreation waters adjacent to beaches or similar points of access that are used by the public for attainment of applicable water quality standards for pathogens and pathogen indicators; and

(B) the prompt notification of the public, local governments, and the Administrator of any exceeding of or likelihood of exceeding applicable water quality standards for coastal recreation waters described in subparagraph (A).

(2) **Level of Protection.**—The performance criteria referred to in paragraph (1) shall provide that the activities described in subparagraphs (A) and (B) of that paragraph shall be carried out as necessary for the protection of public health and safety.

(b) **Program Development and Implementation Grants.**—

(1) **In General.**—The Administrator may make grants to States and local governments to develop and implement programs for monitoring and notification for coastal recreation waters adjacent to beaches or similar points of access that are used by the public.

(2) **Limitations.**—

(A) **In General.**—The Administrator may award a grant to a State or a local government to implement a monitoring and notification program if—

(i) the program is consistent with the performance criteria published by the Administrator under subsection (a);

(ii) the State or local government prioritizes the use of grant funds for particular coastal recreation waters based on the use of the water and the risk to human health presented by pathogens or pathogen indicators;

(iii) the State or local government makes available to the Administrator the factors used to prioritize the use of funds under clause (ii);

(iv) the State or local government provides a list of discrete areas of coastal recreation waters that are subject to the program for monitoring and notification for which the grant is provided that specifies any coastal recreation waters for which fiscal constraints will prevent consistency with the performance criteria under subsection (a); and

(v) the public is provided an opportunity to review the program through a process that provides for public notice and an opportunity for comment.

(B) **Grants to Local Governments.**—The Administrator may make a grant to a local government under this subsection for implementation of a monitoring and notification program only if, after the 1year period beginning on the date of publication of performance criteria under subsection (a)(1), the Administrator determines that the State is not implementing a program that meets the requirements of this subsection, regardless of whether the State has received a grant under this subsection.

(3) **Other Requirements.**—

(A) **Report.**—A State recipient of a grant under this subsection shall submit to the Administrator, in such format and at such intervals as the Administrator determines to be appropriate, a report that describes—

(i) data collected as part of the program for monitoring and notification as described in subsection (c); and

(ii) actions taken to notify the public when water quality standards are exceeded.

(B) **Delegation.**—A State recipient of a grant under this subsection shall identify each local government to which the State has delegated or intends to delegate responsibility for implementing a monitoring and notification program consistent with the performance criteria published under subsection (a) (including any coastal recreation waters for which the authority to implement a monitoring and notification program would be subject to the delegation).

(4) **Federal Share.**—

(A) **In General.**—The Administrator, through grants awarded under this section, may pay up to 100 percent of the costs of developing and implementing a program for monitoring and notification under this subsection.

(B) **Nonfederal Share.**—The non-Federal share of the costs of developing and implementing a monitoring and notification program may be—

(i) in an amount not to exceed 50 percent, as determined by the Administrator in consultation with State, tribal, and local government representatives; and

(ii) provided in cash or in kind.

(c) **Content of State and Local Government Programs.**—As a condition of receipt of a grant under subsection (b), a State or local government program for monitoring and notification under this section shall identify—

(1) lists of coastal recreation waters in the State, including coastal recreation waters adjacent to beaches or similar points of access that are used by the public;

(2) in the case of a State program for monitoring and notification, the process by which the State may delegate to local governments responsibility for implementing the monitoring and notification program;

(3) the frequency and location of monitoring and assessment of coastal recreation waters based on—

(A) the periods of recreational use of the waters;

(B) the nature and extent of use during certain periods;

(C) the proximity of the waters to known point sources and nonpoint sources of pollution; and

(D) any effect of storm events on the waters;

(4) (A) the methods to be used for detecting levels of pathogens and pathogen indicators that are harmful to human health; and

(B) the assessment procedures for identifying short-term increases in pathogens and pathogen indicators that are harmful to human health in coastal recreation waters (including increases in relation to storm events);

(5) measures for prompt communication of the occurrence, nature, location, pollutants involved, and extent of any exceeding of, or likelihood of exceeding, applicable water quality standards for pathogens and pathogen indicators to—

(A) the Administrator, in such form as the Administrator determines to be appropriate; and

(B) a designated official of a local government having jurisdiction over land adjoining the coastal recreation waters for which the failure to meet applicable standards is identified;

(6) measures for the posting of signs at beaches or similar points of access, or functionally equivalent communication measures that are sufficient to give notice to the public that the coastal recreation waters are not meeting or are not expected to meet applicable water quality standards for pathogens and pathogen indicators; and

(7) measures that inform the public of the potential risks associated with water contact activities in the coastal recreation waters that do not meet applicable water quality standards.

(d) **Federal Agency Programs.**—Not later than 3 years after the date of the enactment of this section, each Federal agency that has jurisdiction over coastal recreation waters adjacent to beaches or similar points of access that are used by the public shall develop and implement, through a process that provides for public notice and an opportunity for comment, a monitoring and notification program for the coastal recreation waters that—

(1) protects the public health and safety;

(2) is consistent with the performance criteria published under subsection (a);

(3) includes a completed report on the information specified in subsection (b)(3)(A), to be submitted to the Administrator; and

(4) addresses the matters specified in subsection (c).

(e) **Database.**—The Administrator shall establish, maintain, and make available to the public by electronic and other means a national coastal recreation water pollution occurrence database that provides—

(1) the data reported to the Administrator under subsections (b)(3)(A)(i) and (d)(3); and

(2) other information concerning pathogens and pathogen indicators in coastal recreation waters that—

(A) is made available to the Administrator by a State or local government, from a coastal water quality monitoring program of the State or local government; and

(B) the Administrator determines should be included.

(f) **Technical Assistance for Monitoring Floatable Material.**— The Administrator shall provide technical assistance to States and local governments for the development of assessment and monitoring procedures for floatable material to protect public health and safety in coastal recreation waters.

(g) **List of Waters.**—

(1) **In General.**—Beginning not later than 18 months after the date of publication of performance criteria under subsection (a), based on information made available to the Administrator, the Administrator shall identify, and maintain a list of, discrete coastal recreation waters adjacent to beaches or similar points of access that are used by the public that—

(A) specifies any waters described in this paragraph that are subject to a monitoring and notification program consistent with the performance criteria established under subsection (a); and

(B) specifies any waters described in this paragraph for which there is no monitoring and notification program (including waters for which fiscal constraints will prevent the State or the Administrator from performing monitoring and notification consistent with the performance criteria established under subsection (a)).

(2) **Availability.**—The Administrator shall make the list described in paragraph (1) available to the public through—

(A) publication in the Federal Register; and

(B) electronic media.

(3) **Updates.**—The Administrator shall update the list described in paragraph (1) periodically as new information becomes available.

(h) **EPA Implementation.**—In the case of a State that has no program for monitoring and notification that is consistent with the performance criteria published under subsection (a) after the last day of the 3year period beginning on the date on which the Administrator lists waters in the State under subsection (g)(1)(B), the Administrator shall conduct a monitoring and notification program for the listed waters based on a priority ranking established by the Administrator using funds appropriated for grants under subsection (i)—

(1) to conduct monitoring and notification; and

(2) for related salaries, expenses, and travel.

(i) **Authorization of Appropriations.**—There is authorized to be appropriated for making grants under subsection (b), including implementation of monitoring and notification programs by the Administrator under subsection (h), $30,000,000 for each of fiscal years 2001 through 2005.

SECTION 5. DEFINITIONS.

Section 502 of the Federal Water Pollution Control Act (33 U.S.C. 1362) is amended by adding at the end the following:

(21) **Coastal Recreation Waters.**—

(A) **In General.**—The term 'coastal recreation waters' means—

(i) the Great Lakes; and

(ii) marine coastal waters (including coastal estuaries) that are designated under section 303(c) by a State for use for swimming, bathing, surfing, or similar water contact activities.

(B) **Exclusions.**—The term 'coastal recreation waters' does not include—

(i) inland waters; or

(ii) waters upstream of the mouth of a river or stream having an unimpaired natural connection with the open sea.

(22) **Floatable Material.**—

(A) **In General.**—The term 'floatable material' means any foreign matter that may float or remain suspended in the water column.

(B) **Inclusions.**—The term 'floatable material' includes—

(i) plastic;

(ii) aluminum cans;

(iii) wood products;

(iv) bottles; and

(v) paper products.

(23) **Pathogen Indicator.**—The term 'pathogen indicator' means a substance that indicates the potential for human infectious disease.

SECTION 6. INDIAN TRIBES.

Section 518(e) of the Federal Water Pollution Control Act (33 U.S.C. 1377(e)) is amended by striking ''and 404'' and inserting "404, and 406''.

SECTION 7. REPORT.

(a) **In General.**—Not later than 4 years after the date of the enactment of this Act, and every 4 years thereafter, the Administrator of the Environmental Protection Agency shall submit to Congress a report that includes—

(1) recommendations concerning the need for additional water quality criteria for pathogens and pathogen indicators and other actions that should be taken to improve the quality of coastal recreation waters;

(2) an evaluation of Federal, State, and local efforts to implement this Act, including the amendments made by this Act; and

(3) recommendations on improvements to methodologies and techniques for monitoring of coastal recreation waters.

(b) **Coordination.**—The Administrator of the Environmental Protection Agency may coordinate the report under this section with other reporting requirements under the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.).

Appendix B: Summary of Epidemiological Research Conducted Since 1984

A recent review by Pruss[1] of all studies since 1953 that examined the relationship between swimming-associated gastroenteritis and water quality, indicated that nine separate marine studies and at least two fresh water studies were conducted since the EPA studies were completed in 1984. In this review, each of the later studies is summarized with regard to the size of the study, study design, water quality indicator bacteria measured, and the results of the study with respect to gastrointestinal illness. Some of the studies looked only at whether an association existed between swimming and illness at a polluted beach or a non-polluted beach, while other studies attempted to determine the relationship between increasing levels of poor water quality and the levels of gastrointestinal illness associated with those increases. This review does not address studies that examined non-enteric illnesses or infections unrelated to gastrointestinal disease. The intent of the review is to carefully examine all of the studies conducted subsequent to the EPA studies and to determine if they have a significant impact on the current water quality criteria for bacteria recommended by the Agency.

Marine Water Studies

In 1987, Fattal et al.[2] reported on a study of health and swimming conducted at beaches near Tel-Aviv, Israel. The study design was the same that used by EPA. (In those studies described here using the same design as the epidemiological studies conducted by EPA in support of its 1986 water quality criteria for bacteria recommendations, it will state that the EPA design was used rather than describing it in detail each time.) Beach water quality was measured using fecal coliforms, enterococci, and *E. coli*. Three beaches with different water qualities were studied. Symptoms among bathers were analyzed according to high and low categories of bacterial indicator densities in the seawater. The high and low categories for fecal coliforms were above and below 50 colony forming units (cfu) per 100 ml. The limits for enterococci and *E. coli* were 24 cfu per 100 ml. Excess illness was observed only in swimmers 0-4 years old at low categories of the indicators. Significant differences in illness rates between swimmers and non-swimmers occurred only at high indicator densities. Enterococci were the most predictive indicator for enteric disease symptoms.

In 1990, Cheung and his co-workers[3] reported on a health effects study related to beach water pollution in Hong Kong. The basic EPA design was used in conducting this investigation. Nine microbial indicators were examined as potentially useful measures of water quality. They included fecal coliforms, *E. coli, Klebsiella* spp., fecal streptococci, enterococci, staphylococci, *Pseudomonas aeruginosa, Candida albicans*, and total fungi. The study was carried out at nine beaches that were polluted either by human sewage discharged from a submarine outfall or carried by storm water drains into the beaches. Two of the beaches were contaminated mainly by livestock wastes. Approximately nineteen thousand usable responses were obtained, of which about 77% were from swimmers. The enterococci densities at the beaches ranged from 31 to 248 cfu per 100 ml. The range for *E. coli* was from 69 to 1,714 cfu per 100 ml. The overall gastrointestinal illness rates were significantly higher in swimmers than in non-swimmers. Children under 10 years old were more likely to exhibit gastrointestinal illness (GI) and highly credible gastrointestinal illness (HCGI) symptoms than individuals older than 10 years. The best relationship between a microbial indicator density and swimming-associated health effects was between *E. coli* and HCGI.

Health risks associated with bathing in sea water in the United Kingdom were described by Balarajan et al.[4] in 1991. This study also used the EPA design for their trials. The study was conducted at one beach where 1,883 individuals participated (1,044 bathers and 839 non-bathers). The methods used to measure water quality were not given. Ratios of illness in swimmers to non-swimmers were developed. The rate of gastrointestinal illness was found to be significantly greater in bathers than in non-bathers. The risk of illness increased with the degree of exposure, ranging from 1.25 in waders, 1.31 in swimmers, to 1.81 in surfers or divers. The authors concluded that the increase was indicative of a dose-response relationship.

Von Schirnding and others[5] conducted a study to determine the relationship between swimming-associated illness and the quality of bathing beach waters. A series of discrete, prospective trials was carried out at a relatively clean and a moderately polluted beach following the methodology used in the EPA studies. The beaches were situated on the Atlantic coast of South Africa. The moderately polluted beach was affected by septic tank overflows, storm water run-off, and feces-contaminated river water. A number of potential indicator organisms were measured including enterococci, fecal coliforms, coliphages, staphylococci, and F-male-specific bacteriophages. A total of 1,024 people were contacted, of whom 733 comprised the final study population. The moderately polluted beach was characterized by fecal coliforms and enterococci. The median fecal coliform density was 77 cfu per 100 ml and the median enterococci density was 52 cfu per 100 ml. The median fecal coliform and enterococci densities at the relatively clean beach were 8 and 2 cfu per 100 ml, respectively. The rates for gastrointestinal symptoms were appreciably higher for swimmers than non-swimmers at the more polluted beach as compared with the less polluted beach, but the differences were not statistically significant, either for children less than ten years of age or for adults. The lack of statistical significance may have been due in part to the uncertain sources of fecal contamination.

In 1993, Corbett et al.[6] conducted a study to determine the health risks of swimming at ocean beaches in Sydney, Australia. The study used a design slightly modified from the EPA approach. First, no one under the age of 15 was recruited for the study and, second, multiple samples were taken at the time of swimming activity. The inclusion of families and social groups was minimized. Water quality was measured using fecal coliforms and fecal streptococci. A total of 2,869 individuals participated in the study. Of this group, 32.2% reported that they did not swim. In general, gastrointestinal symptoms in swimmers did not increase with increasing counts of fecal bacteria. However, fecal streptococci were worse predictors of swimming-associated illness than fecal coliforms. Although no relationship was observed between the measured indicators and gastrointestinal illness, swimmers who swam for more than 30 minutes were 4.6 times more likely to develop gastrointestinal symptoms than were those that swam for less than 30 minutes. The lack of a relationship between increasing fecal coliform densities and gastrointestinal symptoms was similar to results noted in the EPA marine and freshwater studies where increasing illness rates were not associated with increasing fecal coliform densities.

In 1994, Kay et al.[7] conducted a series of four trials at bathing beaches in the United Kingdom to examine the relationship between swimming-associated illness and water quality. The design of this study differed from previous studies in that the study population was selected prior to each trial. On the trial date, half of the participants were randomly assigned to be swimmers, with the remaining participants were non-swimmers. Each swimmer swam in a designated area that was monitored by taking a sample every 30 minutes. Samples were analyzed for total and fecal coliforms, fecal streptococci, *Pseudomonas aeruginosa,* and total staphylococci. The total number of participants in the study was 1,112, of which 46% were selected as swimmers. All of the study volunteers were older than 18 years of age. Analysis of the data indicated that the rates of gastroenteritis were significantly higher in the swimming group than in the non-swimming group. Only fecal streptococci showed a significant dose-response relationship with gastroenteritis. The analysis suggested that the risk of gastroenteritis did not increase until bathers were exposed to about 40 streptococci per 100 ml.

In 1995, Kueh et al,[8] reported a second study conducted at Hong Kong beaches. Only two beaches were examined in the second study, rather than the nine beaches examined in the 1990 Hong Kong study. The study design for collecting health data was similar to that followed in the EPA studies. The ages of study participants ranged from 10 to 49 years of age. Unlike the EPA studies, follow-up telephone calls were made two days after the swimming event rather than seven to 10 days. Another aspect of the Hong Kong study differing from the EPA studies was the collection of clinical specimens from ill participants with their consent. Stool specimens were analyzed for Rotavirus, *Salmonella* spp., *Shigella* spp., *Vibrio* spp., and *Aeromonas* spp. Throat swabs were examined for Influenza A and B; Parainfluenza virus types 1, 2 and 3; Respiratory Syncytial Virus, and Adenovirus. Water samples were examined for *E. coli,* fecal coliforms, staphylococci, *Aeromonas* spp., *Clostridium perfringens, Vibrio cholera, Vibrio parahemolyticus, Vibrio vulnificus, Salmonella* spp., and *Shigella* spp. A total of 18,122 individuals participated in the study. Although the levels of indicator densities were not reported for the beaches, the gastrointestinal illness rates were significantly higher at the more polluted beach. This study did not find a relationship between *E. coli* and swimming-associated illness as had been found in the original Hong Kong study. This may have been, as pointed out by the authors, due to the fact that only two beaches were examined rather than nine. The cause of the infections could not be ascertained from the clinical specimens obtained from ill individuals.

In 1998, McBride et al,[9] reported prospective epidemiological studies on the possible health effects from sea bathing at seven New Zealand beaches. A total of 1,577 and 2,307 non-swimmers participated in the studies. Although the EPA study design was used, it was slightly modified in that follow-up interviews were conducted three to five days after the swimming event rather than the seven to 10 days used in the U.S. studies. Fecal coliforms, *E. coli,* and enterococci were used to measure water quality. The results of the study showed that enterococci were most strongly and consistently associated with illness risk for the exposed groups. Risk differences between swimmers and non-swimmers were significantly increased if swimmers stayed in the water for more than 30 minutes as compared to those in the water less than 30 minutes. The risk differences were slightly greater for paddlers than for swimmers.

The most recent study of possible adverse health effects associated with swimming in marine waters was conducted at beaches on Santa Monica Bay, California, by Haile and others.[10] The objective of this study was to determine if excess swimming-associated illness could be observed in swimmers exposed to waters receiving discharges from a storm drain. The study design was patterned after the U.S. EPA studies. Water samples were taken at ankle depth and collected from sites at the storm drain, 100 yards up-coast, and 100 yards down-coast. Samples were also collected 400 yards up-coast or down-coast of the storm drain, depending on which location would be used as a control area. The samples were analyzed for total coliforms, fecal coliforms, enterococci, and *E. coli*. One sample was collected each Friday, Saturday, and Sunday during the study period at the mouth of the storm drain and analyzed for enteric viruses. Subjects of all ages participated in the study. A total of 11,686 subjects volunteered to take part in the study. The results of the study with regard to associations between bacterial indicators and health outcomes were presented in terms of thresholds of bacterial densities, which were somewhat arbitrarily chosen. No positive associations, as measured by risk ratios, were observed for *E. coli* at bacterial density thresholds of 35 and 70 cfu per 100 ml. A less arbitrary analysis using a continuous model showed more positive associations, especially for enterococci. The model for enterococci indicated positive associations with fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, and highly credible gastrointestinal illness. The associations of symptoms with indicators were very weak in the case of *E. coli* and fecal coliforms. However, the authors found that the total coliform to fecal coliform ratio was very informative. Using a ratio of 5.0 as a threshold, diarrhea and highly credible gastrointestinal illness were associated with a lower total coliform to fecal coliform ratio regardless of the absolute level of fecal coliforms. When their analysis was restricted to subjects where the total coliforms exceeded 5,000 cfu per 100 ml, significantly higher risks were detected for most outcomes. One of the general conclusions of the study was that excess gastrointestinal illness is associated with swimming in feces-polluted bathing water.

Fresh Water Studies

In 1985, Seyfried et al.[11] reported on a prospective epidemiological study of swimming-associated illness in Canada. These investigations used the EPA methodology in carrying out the study. Water quality was measured with the following bacterial indicators of swimming water quality: fecal coliforms, fecal streptococci, heterotrophic bacteria, *Pseudomonas aeruginosa*, and total staphylococci. A total of 4,537 individuals participated in the study, of which 2,743 were swimmers and 1,794 were non-swimmers. Swimmers were found to have significantly higher gastrointestinal illness rates than non-swimmers, and swimmers under the age of 16 had substantially higher rates than swimmers 16 and older. Logistic regression analysis was performed to determine the best relationship between water quality indicators and swimming-associated illness. A small degree of correlation was observed between fecal streptococci and gastrointestinal illness. The best correlation was between gastrointestinal illness and staphylococcus densities.

In 1989, Ferley et al.[12] described an epidemiological study conducted in France that examined health effects associated with swimming in a freshwater river. A total of 5,737 individuals participated in the study. The quality of the water was measured by assaying for fecal coliforms, fecal streptococci, and *Pseudomonas aeruginosa*. The study design for collecting health data was unique. The maximum latency period for the illness category groups examined in this study was three days. Illnesses occurring during the course of the study were assigned to the nearest day within the latency period on which a sample was taken. A weighted linear regression was performed to relate gastrointestinal morbidity incidence rates to different levels of exposure to indicator bacteria. Significant excess gastrointestinal illness was observed in swimmers. Furthermore, regression of gastrointestinal illness incidence to the concentration of indicator organisms showed a good relationship between swimming-associated illness for both fecal coliforms and fecal streptococci. The strongest correlations occurred between incidence rates of acute gastrointestinal disease and fecal streptococci densities. The authors indicated that their definition of fecal streptococci essentially included what the EPA studies call enterococci.

Summary of Research Conducted Since 1984					
Researcher	**Year**	**Location**	**Type of Water**	**Microorganisms Evaluated**	**Relevant Findings**
Fattal et al.[2]	1987	Israel	Marine	Fecal coliforms Enterococci *E. coli*	• Enterococci were the most predictive indicator for enteric disease symptoms
Cheung et al.[3]	1990	Hong Kong	Marine	Fecal coliforms *E. coli* *Klebsiella* spp. Enterococci Fecal streptococci Staphylococci *Pseudomonas aeruginosa* *Candida albicans* Total fungi	• Best relationship between a microbial indicator density and swimming-associated health effects was between *E. coli* and highly credible gastrointestinal illness.
Balarajan et al.[4]	1991	United Kingdom	Marine	Unknown	• Risk of illness increased with degree of exposure. If the non-exposed population risk ranked at 1, risk increased to 1.25 for waders, 1.31 for swimmers, and 1.81 in surfers or divers.
Von Schirnding et al.[5]	1992	South Africa (Atlantic coast)	Marine	Enterococci Fecal coliforms Coliphages Staphylococci F-male-specific bacteriophages	• Uncertainty in sources of fecal contamination may explain lack of statistically significant rates of illness between swimmers and non-swimmers.
Corbett et al.[6]	1993	Sydney, Australia	Marine	Fecal coliforms Fecal streptococci	• Gastrointestinal symptoms in swimmers did not increase with increasing counts of fecal bacteria. • Counts of fecal streptococci were worse predictors of swimming-associated illness than fecal coliforms.

Summary of Research Conducted Since 1984					
Researcher	**Year**	**Location**	**Type of Water**	**Microorganisms Evaluated**	**Relevant Findings**
Kay et al.[7]	1994	United Kingdom	Marine	Total coliforms Fecal coliforms Fecal streptococci *Pseudomonas aeruginosa* Total staphylococci	• Only fecal streptococci were associated with increased rates of gastroenteritis. • Risk of gastroenteritis did not increase until bathers were exposed to about 40 fecal streptococci per 100 ml.
Kueh et al.[8]	1995	Hong Kong	Marine	*E. coli* Fecal coliforms Staphylococci *Aeromonas* spp. *Clostridium perfringens* *Vibrio cholera* *Vibrio parahemolyticus* *Salmonella* spp. *Shigella* spp.	• Also analyzed stool specimens for rotavirus, *Salmonella* spp., *Shigella* spp., *Vibrio* spp., and *Aeromonas* spp.; throat swabs for Influenza A and B; Parainfluenza Virus types 1, 2, and 3; Respiratory Syncytial Virus; and Adenovirus. • Did not find a relationship between *E. coli* and swimming-associated illness [possibly due to low number of beaches sampled (only two)].
McBride et al.[9]	1998	New Zealand	Marine	Fecal coliforms *E. coli* Enterococci	• Enterococci were most strongly and consistently associated with illness risk for the exposed groups. • Risk differences significantly greater between swimmers and non-swimmers if swimmers remained in water for more than 30 minutes.

Summary of Research Conducted Since 1984

Researcher	Year	Location	Type of Water	Microorganisms Evaluated	Relevant Findings
Haile et al.[10]	1996	California, USA	Marine	Total coliforms Fecal coliforms Enterococci *E. coli*	• Results for enterococci indicate positive associations with fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, and highly credible gastro-intestinal illness. • Association of symptoms with both *E. coli* and fecal coliforms were very weak. • Total coliform to fecal coliform ratio very informative — below the cutpoint of 5.0, diarrhea and highly credible gastrointestinal illness were associated with a lower ratio regardless of the absolute level of fecal coliforms.
Seyfried et al.[11]	1985	Canada	Fresh	Fecal coliforms Fecal streptococci Heterotrophic bacteria *Pseudomonas aeruginosa* Total staphylococci	• Small degree of correlation observed between fecal streptococci and gastrointestinal illness. • Best correlation was between gastrointestinal illness and staphylococcus densities.
Ferley et al.[12]	1989	France	Fresh	Fecal coliforms Fecal streptococci *Pseudomonas aeruginosa*	• In this study, the definition of fecal streptococci is essentially the same as the U.S. definition of enterococci. • Good relationship between swimming associated illness and fecal coliform and fecal streptococci concentrations. • Strongest relationship was between gastrointestinal disease and fecal streptococci densities.

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Appendix C: Sample Calculations of *E. Coli*/Enterococci Water Quality Criteria Associated with Different Risk Levels

Table B.1 EPA's Recommended 1986 Water Quality Criteria for Bacteria

Indicator	Illness Rate (per 1000)	Geometric Mean Density	Single Sample Maximum Allowable Density			
			Designated Beach Area 75% C.L.*	Moderate Full Body Contact Recreation 82% C.L.	Lightly Used Full Body Contact 90% C.L.	Infrequently Used Full Body Contact 95% C.L.
freshwater						
enterococci	8	33	62	78	107	151
E. coli	8	126	235	298	410	576
marine water						
enterococci	19	35	104	158	276	501

*C.L. = confidence level. While more appropriately referred to as "percentiles", these values were originally described as "confidence levels" in EPA's 1986 criteria document.

Source: USEPA, 1986.

<u>Regression Equations Used to Calculate Geometric Mean Density</u>:

Freshwater

E. coli: log (geometric mean) = (0.1064 x illness rate) + 1.249

Enterococci: log (geometric mean) = (0.1064 x illness rate) + 0.668

Marine Water

Enterococci: log (geometric mean) = (0.0827 x illness rate) - 0.0164

<u>Equations Used to Calculate Single Sample Maximum Values</u>:

Log (SSM) = (Log (Geometric Mean Value)) + ((Confidence Level Factor) x (Log Standard Deviation))

Confidence Level Factors:
75% = 0.68
82% = 0.94
90% = 1.28
95% = 1.65

Log Standard Deviation:
Freshwater = 0.4
Marine Water = 0.7

Water Quality Criteria for Bacteria for Fresh Recreational Waters

Enterococci Criteria

Illness Rate (per 1000)	Geometric Mean Density	Single Sample Maximum Allowable Density			
		Designated Beach Area 75% C.L.	Moderate Full Body Contact Recreation 82% C.L.	Lightly Used Full Body Contact 90% C.L.	Infrequently Used Full Body Contact 95% C.L.
8	33	62	78	107	151
9	42	79	100	137	193
10	54	100	128	175	246
11	69	128	163	224	315
12	88	164	208	286	402
13	112	209	266	365	514
14	144	267	340	467	656

E. coli Criteria

Illness Rate (per 1000)	Geometric Mean Density	Single Sample Maximum Allowable Density			
		Designated Beach Area 75% C.L.	Moderate Full Body Contact Recreation 82% C.L.	Lightly Used Full Body Contact 90% C.L.	Infrequently Used Full Body Contact 95% C.L.
8	126	235	487	669	576
9	206	300	381	524	736
10	206	383	487	669	941
11	263	490	622	855	1202
12	336	626	795	1092	1536
13	429	799	1016	1396	1962
14	548	1021	1298	1783	2507

Water Quality Criteria for Bacteria for Marine Recreational Waters

Enterococci Criteria

Illness Rate (per 1000)	Geometric Mean Density	Single Sample Maximum Allowable Density			
		Designated Beach Area 75% C.L.	Moderate Full Body Contact Recreation 82% C.L.	Lightly Used Full Body Contact 90% C.L.	Infrequently Used Full Body Contact 95% C.L.
8	4	13	20	34	63
9	5	16	24	42	76
10	6	19	29	50	91
11	8	23	35	61	110
12	9	28	42	73	133
13	11	33	51	89	161
14	14	40	61	107	195
15	16	49	74	129	235
16	20	59	90	156	284
17	24	71	108	189	343
18	29	86	131	228	415
19	35	104	158	276	501

Appendix D: Summary of Water Quality Criteria for Bacteria Adopted by States, Authorized Tribes, and Territories

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
Region I		
Connecticut	**Inland, coastal and marine surface waters (A/SA and B/SB for enterococci):** GM = 33cfu/100 ml S.M. = 61cfu/100 ml	Enterococci criteria do not apply to all primary contact recreation waters, only established bathing waters.
Maine	**Freshwater (*E. coli*)** **Class B:** GM = 64 cfu/100ml S.M. = 427 cfu/100 ml **Class C:** GM = 142 cfu/100ml S.M. = 949 cfu/100 ml **Marine Waters (enterococci)** **Class SB** GM = 8 cfu/100 ml S.M. = 54 cfu/100 **Class SC** GM=14 cfu/100 ml S.M. = 94 cfu/100	Seasonal for both Class SB and SC: May 15-Sept. 30
New Hampshire	**Fresh Waters (*E. coli*)** **Class A** GM = 47 cfu/100ml S.M. = 153 cfu/100 ml **Class B** GM = 126 cfu/100ml S.M. = 406 cfu/100 ml **Class B (beaches)** GM = 47 cfu/100ml S.M. = 88 cfu/100 ml **Marine Waters (enterococci)** **Class A** GM = 35 cfu/100 ml S.M. = 104 cfu/100, for "beaches" S.M. = 88 cfu/100 **Class B** GM = 35 cfu/100 ml S.M. = 104 cfu/100, for "beaches" S.M. = 88 cfu/100	

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
Vermont	**Class A (*E. coli*)** S.M. = 18 cfu/100 (*E. coli*) **Class B (*E. coli*)** S.M. = 77 cfu/100 (*E. coli*)	Secretary may waive October 31-April 1.
Region II		
New Jersey	**Fresh waters** (enterococci) **FW2:** GM = 33 cfu/100 ml S.M. = 61 cfu/100 **Salt and estuarine waters (SE1) and saline coastal waters (SC) (enterococci):** GM = 35 cfu/100 ml S.M. = 104/100 ml	
PR	**Class SA:** May not be altered except by natural causes **Class SB (enterococci):** GM = 35 cfu/100 ml for "intensely used waters"	The criteria has only been adopted for certain marine waters (Class SB). Other marine waters (Class SC, which includes primary contact recreation) do not include these criteria.
Region III		
Delaware	**Fresh Waters (enterococci):** GM = 100 cfu/100 ml **Marine Waters (enterococci):** GM = 10 cfu/100 ml	
Region IV		
Tennessee	**Recreation waters (*E. coli*):** GM = 126 cfu/100 ml	
Region V		
Indiana	**Total Body Contact Recreation (*E. coli*):** GM = 125 cfu/100 ml S.M. = 235 cfu/100 ml	Seasonal: April - October
Michigan	**All waterbodies (*E. coli*):** GM = 130 cfu/100 ml S.M. = 300 cfu/100 ml	The criteria apply, at minimum, May1-Oct. 31 The *E. coli* value is used for ambient monitoring and fecal coliforms used for establishing effluent limitations.

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
Ohio	**Lake Erie & Ohio R. (*E. coli*):** GM = 126 cfu/100 ml No more than 10% samples exceed 235 cfu/100 ml **Rest of state (*E. coli*):** **primary contact:** GM = 126 cfu/100 ml No more than 10% samples exceed 298 cfu/100 ml **secondary contact:** GM = 126 cfu/100 ml No more than 10% samples exceed 576 cfu/100 ml	
Fond du Lac Band of Lake Superior Chippewa	**Primary Contact Recreation, Secondary Contact Recreation** **(*E. coli*)** GM = 126 cfu/100 ml	When fewer than five samples collected in 30-day period, *E. coli* is not to exceed 235 cfu/100 ml in any single sample.
Region VI		
Oklahoma	**Primary Body Contact Recreation** **(*E. coli*)** GM = 126 cfu/100 ml S.M. = 235 cfu/100 ml (lakes and high use waterbodies) S.M. = 406 cfu/100 ml **(enterococci)** GM = 33 cfu/100 ml S.M. = 61 cfu/100 ml (lakes and high use waterbodies) S.M. = 108 cfu/100 ml	Applies during recreation period of May 1 to September 30.
Texas	**Fresh Waters (*E. coli*)** **Contact Recreation Use** GM = 126 cfu/100 ml S.M. = 394 cfu/100 ml **Noncontact Recreation Use** GM = 605 cfu/100 ml **Marine Waters (enterococci)** **Contact Recreation Use** GM =35 cfu/100 ml S.M. = 89 cfu/100 ml **Noncontact Recreation Use** GM = 168 cfu/100 ml	

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
Acoma Pueblo	**Primary Contact Recreation** (*E. coli*) GM = 126 cfu/100 ml S.M. = 235 cfu/100 ml (Acomita Lake and high use waterbodies) S.M. = 406 cfu/100 ml (all other ceremonial and recreation use areas) (enterococci) GM = 33 cfu/100 ml S.M. = 61 cfu/100 ml (Acomita Lake and high use waterbodies) S.M. = 108 cfu/100 ml (all other ceremonial and recreation use areas) **Partial Body Contact** 10x criteria specified for primary contact recreation	Compliance for primary contact recreation based on meeting the criteria for one of the indicators.
Region VIII		
Colorado	**Recreation Use 1a** (*E. coli*) GM = 126 cfu/100 ml **Recreation Use 1b** (*E. coli*) GM = 205 cfu/100 ml **Secondary Contact Recreation Use** (*E. coli*) GM = 630 cfu/100 ml	
Ft. Peck Assiniboine and Sioux Tribes	**Primary Contact Recreation Use** (*E. coli*) GM = 126 cfu/100 ml S.M. = 235 cfu/100 ml **Secondary Contact Recreation Use** (*E. coli*) GM = 126 cfu/100 ml S.M. = 406 cfu/100 ml	
Region IX		
Arizona	**Full Body Contact** (*E. coli*) GM = 130 cfu/100 ml S.M. = 580 cfu/100 ml	

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
California	<u>REGIONAL BOARD 2</u> **Salt Waters REC-1 (enterococci):** Geometric mean (GM) =35 cfu/100 ml Single sample maxima (S.M.) range from 104-500 based on frequency of use **Fresh Waters REC-1:** **Enterococci** GM =33 cfu/100 ml S.M. range from 61-151 based on frequency of use *E. coli* GM =126 cfu/100 ml S.M. range from 235-576 based on frequency of use <u>REGIONAL BOARD 7</u> **REC-1:** **Enterococci** GM = 33 cfu/100 ml S.M. = 100 cfu/100 ml *E. coli* GM = 126 cfu/100 ml S.M. = 400 cfu/100 ml **REC-2:** **Enterococci** GM = 165 cfu/100 ml S.M. = 500 cfu/100 ml *E. coli* GM = 630 cfu/100 ml S.M. = 2000 cfu/100 ml <u>Colorado River</u> **REC-1:** **Enterococci** S.M. = 61 cfu/100 ml *E. coli* S.M. = 235 cfu/100 ml **REC-2:** **Enterococci** S.M. = 305 cfu/100 ml *E. coli* S.M. = 1175 cfu/100 ml	Regional Boards 2, 7, and 9 have adopted criteria based on EPA's recommended indicators. The other 6 Boards have not. The geometric means specified by Regional Board 7 for the REC-1 and REC-2 uses also apply to the Colorado River.

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
California (cont.)	**REGIONAL BOARD 9** **Salt Waters REC-1 (enterococci):** GM=35 cfu/100 ml S.M. range from 104-500 based on frequency of use **Fresh Waters REC-1** **Enterococci** GM=33 cfu/100 ml S.M. range from 61-151 based on frequency of use *E. coli* GM =126 cfu/100 ml S.M. range from 235-576 based on frequency of use **STATE OCEAN PLAN (enterococci)** GM = 24 cfu/100 ml for 30 day period GM = 12 cfu/100 ml for 6 month period	
Hawaii	**Marine Waters (enterococci):** GM = 7 cfu/100 ml	
American Samoa	**For all marine waters (enterococci):** GM = 33 cfu/100 ml **Open Ocean:** S.M. = 276 cfu/100 ml **Embayments:** S.M. = 104 or 124 cfu/100 ml **Open Coastal Waters:** S.M. = 124 cfu/100 ml	
CNMI	**Class AA (enterococci):** GM = 35 cfu/100 ml **Class A (enterococci):** GM = 125 cfu/100 ml	One element of the Class A use is primary contact recreation.
Hoopa Valley Tribe	**Primary Contact Recreation (enterococci)** GM = 16 cfu/100 ml S.M. = 35 cfu/100 ml **Secondary Contact Recreation (enterococci)** GM = 33 cfu/100 ml S.M. = 150 cfu/100 ml	Tribe has not yet completed WQS adoption process.

STATES	WATER QUALITY CRITERIA[1]	COMMENTS
Region X		
Idaho	**Primary Contract Recreation** (*E. coli*) GM = 126 cfu/100 ml S.M. = 406 cfu/100 ml **Secondary Contact Recreation** (*E. coli*) GM = 126 cfu/100 ml S.M. = 576 cfu/100 ml	
Oregon	**Fresh and Estuarine Waters** (*E. coli)* GM = 126 cfu/100 ml	
Washington	**Fresh waters (enterococci)** **Water Contact Recreation** GM = 33 cfu/100 ml S.M. = 61 cfu/100 **Marine Waters** (enterococci) **Water Contact Recreation** GM = 35 cfu/100 ml S.M. = 104/100 ml	In the process of adopting
Colville Confederated Tribes	**Class I (enterococci)** GM = 8 cfu/100 ml S.M. = 35 cfu/100 ml **Class II (enterococci)** GM = 16 cfu/100 ml S.M. = 75 cfu/100 ml **Class III (enterococci)** GM = 33 cfu/100 ml S.M. = 150 cfu/100 ml	
Warm Springs	**Public and private domestic water supply, Water Contact Recreation, Wildlife and Hunting, Fishing, Boating/Rafting** (*E. coli*) GM = 126 cfu/100 ml S.M. = 406 cfu/100 ml	
Confederated Tribes of the Umatilla Indian Reservation of Oregon	**Recreation** (*E. coli*) GM = 126 cfu/100 ml S.M. = 406 cfu/100 ml	

PPIC STATEWIDE SURVEY

NOVEMBER 2003

Special Survey on Californians and the Environment

in collaboration with

The William and Flora Hewlett Foundation

The James Irvine Foundation

The David and Lucile Packard Foundation

• • • • •

Mark Baldassare
Research Director & Survey Director

Public Policy Institute of California

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Preface

The PPIC Statewide Survey series provides policymakers, the media, and the general public with objective, advocacy-free information on the perceptions, opinions, and policy preferences of California residents. Inaugurated in April 1998, the survey series has generated a database that includes the responses of more than 80,000 Californians.

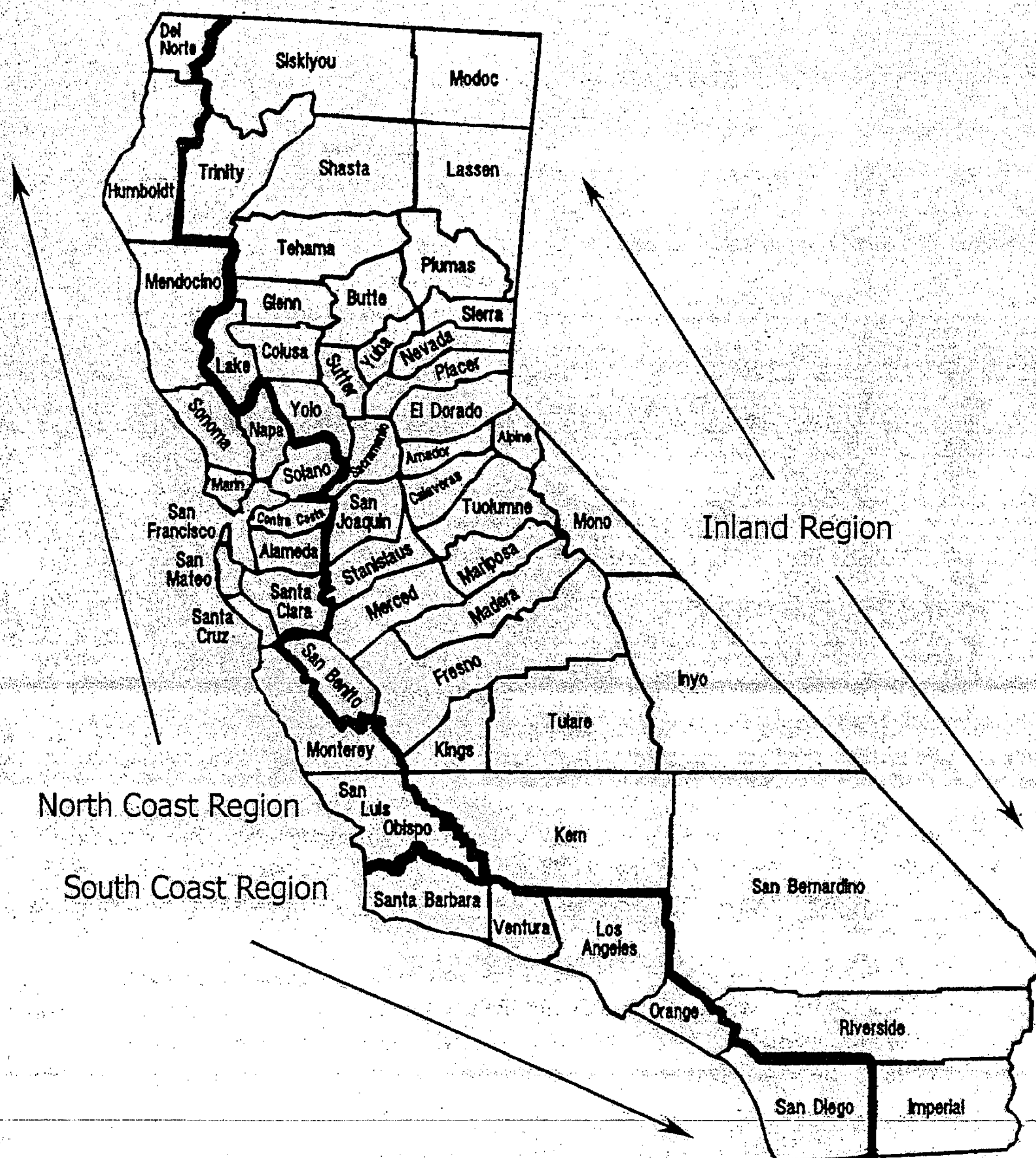
This survey on Californians and the environment—a collaborative effort of the Public Policy Institute of California and The William and Flora Hewlett Foundation, The James Irvine Foundation, and The David and Lucile Packard Foundation—is a special edition of the PPIC Statewide Survey. This is the sixth in a series of eight surveys—two per year for four years—launched in May 2001. The intent of the surveys is to inform policymakers, encourage discussion, and raise public awareness about a variety of growth and environmental issues facing the state. Previous statewide surveys have focused on land use and air quality issues. The current survey provides the first comprehensive analysis in our survey series of the public's perspectives on the wide range of marine and coastal issues confronting California today. The importance of coastal and marine issues for an environment survey series is derived from California's 1,100-mile shoreline, the state's history of controversy over coastal development and conflict over oil drilling off the coast, and the publication of recent reports by the Pew Oceans Commission and other national and international study groups on issues such as marine pollution and the depletion of coral reefs, fish, and marine mammals.

This special edition presents the responses of 2,004 adult residents throughout the state. It examines in detail the public's views on ocean and coastal conditions in California, their public policy preferences and lifestyle choices related to the ocean and coastal areas, and the state and national government's efforts in the environmental arena. Some of the questions are repeated from PPIC Statewide Surveys on Californians and the environment conducted since June 2000. More specifically, we examine the following issues:

- The public's perceptions of ocean and marine conditions, including their relative rankings of ocean and beach pollution compared to other environmental problems, rankings of ocean quality today, trends in ocean quality over time, the importance of ocean and beach conditions for California, and the specific problems affecting the marine and coastal environment.
- Public policy choices, including the public's support for policies aimed at the protection of the marine and coastal environment, ratings of the state government's efforts toward marine and coastal protection, the perceived importance of environmental policies for the new governor, ratings of the president on environmental policies, perceived importance of the candidates' positions on environmental issues in the 2004 presidential election, and the political party (i.e., Democrat, Republican) that is viewed as most trusted to handle environmental issues in the United States.
- California lifestyle issues related to the marine and coastal environments, including the use of beaches, the frequency of sports activities in the ocean and bays, the extent to which seafood is a part of the personal diet, health and environmental concerns related to seafood as part of the diet, and the extent to which Californians visit aquariums and have aquariums in their homes.
- Variations in marine and coastal perceptions, public policy choices, lifestyles, and political perspectives between residents living in coastal counties and inland counties, between Latinos and non-Hispanic whites, and across age, socioeconomic, and political spectrums.

Copies of this report may be ordered by e-mail (order@ppic.org) or phone (415-291-4400). Copies of this and earlier reports are posted on the publications page of the PPIC web site (www.ppic.org). For questions about the survey, please contact survey@ppic.org.

Subregions Used in This Report



Contents

Press Release

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SPECIAL SURVEY ON CALIFORNIANS AND THE ENVIRONMENT

IT'S A BEACH STATE ... OF MIND: DESPITE TUMULTUOUS TIMES, CALIFORNIA'S GOLDEN COAST STILL CAPTURES HEARTS

Most Residents Willing To Pay To Safeguard Ocean, Beaches; High Environmental Expectations for Schwarzenegger

SAN FRANCISCO, California, November 13, 2003 — Whether coastal or inland dwellers, Californians love the Pacific. In a time of budget woes, political turmoil, and catastrophic natural disaster, large majorities of residents still place an extraordinary value on the state's beaches and ocean, according to a survey released today by the Public Policy Institute of California (PPIC) and the Hewlett, Irvine, and Packard Foundations. Across geography and political ideology, Californians display a profound desire to protect the coast despite potential economic costs.

Affection for the shoreline is clear: A vast majority (88%) of Californians say the condition of the ocean and beaches is personally important to them, with 60 percent saying it is *very* important. In fact, Californians (72%) are far more likely than Americans as a whole (40%) to visit an ocean beach at least several times per year. Strong majorities of Californians also believe the coastline's condition is very important to the state's quality of life (69%) and economy (61%).

Wariness About Coast's Health Translates into Strong Public Policy Preferences

Consistent with the premium they place on the coastline, Californians express high levels of concern over coastal conditions and strong support for policies that protect the ocean and beaches. Over half (52%) believe the quality of the ocean along the state's shoreline has deteriorated in the past two decades, and 45 percent say ocean conditions are likely to worsen over the next twenty years.

Concerns about the coast top the list of environmental worries, with 53 percent of residents saying ocean and beach pollution is a big problem in California today. Specifically, 52 percent describe pollution from streets and storm drains and contamination of fish and seafood as *big* problems, while strong majorities say declining numbers of marine mammals (74%), commercial overfishing (71%), coastal development (71%), and limited public access to the beaches (58%) are at least *somewhat* of a problem.

But are Californians willing to turn their concern into action? Despite partisan divisions on many issues, state residents are surprisingly in step on their willingness to ante up for coastal protection. Two-thirds of Californians – including majorities of Democrats, Republicans, and independents – favor limiting the sale of fish and seafood to environmentally safe products, even if this results in higher consumer prices (67%), and support restricting private development along the coast, even if it results in less available housing (69%). Three in four residents support protecting wetlands and beach/bay habitats even if it means less commercial activity near the coast (77%), and favor creating more marine reserves, even if it limits commercial and recreational fishing (75%). "Californians see the coastline as a precious resource and an important part of their own lives," says survey director Mark Baldassare. "But the degree to which people are willing to protect the beaches and ocean, even at the expense of economic growth, is striking."

While half of Californians (50%) favor prohibiting new off-shore oil drilling along California's coast, even if it means higher gasoline prices, there is a notable partisan split on this issue: Democrats favor a ban on new drilling by almost two-to-one (60% to 35%), while independents are narrowly divided (49% to 46%) and Republicans are strongly opposed (39% to 55%).

Walk on Water? High Environmental Expectations of Schwarzenegger Administration

Nearly uniformly, residents agree that environmental protection should be a priority for Governor-elect Arnold Schwarzenegger. Almost one-third (32%) of Californians think it should be a top priority, while a large majority (57%) say it should be an important priority. Nearly half (49%) of all California residents say environmental protection should be a priority for state government even if it curbs economic growth, while fewer residents (42%) think economic growth should be the top priority even if the environment suffers. And despite the state's enormous budget deficit, 48 percent of Californians support funding environmental programs at current levels, even at the expense of other state programs, while only 35 percent support reducing environmental funding.

However, the state's likely voters are narrowly divided on the balance the new administration should strike between environmental and economic priorities: Forty-six percent favor protecting the environment even if it curbs economic growth, and 45 percent favor economic growth even if the environment suffers. There is a partisan divide on this issue, with Democrats (54%) and independents (50%) favoring environmental protection, and Republicans (61%) preferring economic growth.

According to Baldassare, balancing economic and environmental concerns will be a tall order for the new governor, but thus far, Schwarzenegger is in good standing with the public. "Although it's early in the game, Californians are generally supportive of Schwarzenegger's plans and policies for the state's future." Indeed, by nearly a two-to-one margin (47% to 25%), residents back the governor-elect, with Republicans (69%) and independents (53%) expressing greater support than Democrats (32%).

President George W. Bush's overall approval rating stands at 48 percent in California. Residents are critical of his performance on the environment, with nearly half of Californians (49%) and a majority of likely voters (53%) saying they disapprove of his handling of national environmental issues. A majority of residents (54%) also say the federal government is not doing enough to protect the country's coastal and marine environment, with Democrats and Republicans deeply split on the issue (70% to 33%).

Residents Trust State to Govern Coast, But Some Believe California Coastal Commission Too Lax

A smaller, but still significant, number of Californians (44%) also say the state is not doing enough to protect California's coastal environment. Despite their concern, more residents trust the state (42%) rather than local (30%) or federal (14%) governments to manage marine and coastal issues. However, they want to see more action: One-third (38%) of state residents say the California Coastal Commission is not strict enough in its regulation of development along California's coast, while only 11 percent say the commission's controls are too strict.

Levels of Coastal Concern Differ By Region, Ethnicity

Despite shared concern for their 1,100 mile-long coastline, there are regional and racial/ethnic differences in Californians' attitudes about coastal issues. In particular, residents of the South Coast region (Santa Barbara, Ventura, Los Angeles, Orange, and San Diego Counties) place greater importance on the shoreline, are more concerned about worsening coastal conditions, and are more personally connected to the ocean and beaches than those who live in the North Coast or Inland regions (see page ii for a map of the regions). More South Coast residents (74%) than residents of the North Coast and Inland regions (67% and 62%, respectively) believe the condition of the coastline is very important to California's quality of life. South Coast residents (66%) are also more likely than those in the North Coast (56%) or Inland (57%) regions to say the ocean and beaches are very important to the economy.

Consequently, South Coast residents are also more anxious about shoreline conditions: Fifty-seven percent think the condition of the ocean has grown worse in the past twenty years, while 44 percent of North Coast and 50 percent of Inland residents share this perception. Far more residents of the South Coast (62%) than of the North Coast (45%) or Inland (46%) regions think ocean and beach pollution in California is a big problem. "Recent beach contamination warnings as well as a prevailing beach ethos in southern coastal California heighten the concern of local residents," says Baldassare. Indeed, nearly half (46%) of South Coast residents say they visit a California beach at least once a month, significantly more than residents of the North Coast (39%), and far more than those Inland (16%).

Interestingly, Latinos are more concerned than non-Hispanic whites about many of the environmental problems affecting the coastline. For example, they are more likely to view as big problems ocean and beach pollution (66% to 49%), the contamination of seafood (64% to 46%), declining numbers of sea mammals (54% to 40%), overfishing (46% to 32%), and public access to the coast (27% to 17%).

More Key Findings

- **Safe Seafood?** (page 17)

Although 54 percent of Californians eat fish or seafood often, half of adults (50%) and most Latinos (62%) are very concerned that what they are consuming could be harmful due to contamination.

- **Finding Nemo** (page 18)

Almost one-third (30%) of households with children in California keep pet fish. Seventy-three percent of all Californians say they have visited an aquarium or other public place with live fish in the past year.

- **Surf's Up!** (page 14)

Ten percent of Californians and 13 percent of South Coasters have surfed in the state's ocean or bays in the past year, but far more residents have gone ocean or bay swimming (43%). Fewer older residents (55 and older) than younger ones (18-34) participated in an ocean or bay activity in the past year (20% to 31%).

About the Survey

The Californians and the Environment survey is a special edition of the PPIC Statewide Survey. It is the sixth in a four-year, multisurvey series on growth, land use, and the environment, produced in collaboration with The William and Flora Hewlett Foundation, The James Irvine Foundation, and The David and Lucile Packard Foundation. Findings of the current survey are based on a telephone survey of 2,004 California adult residents interviewed from October 24 to November 2, 2003. Interviews were conducted in English or Spanish. The sampling error for the total sample is +/- 2%. The sampling error for subgroups is larger. For more information on survey methodology, see page 19.

Mark Baldassare is research director at PPIC, where he holds the Arjay and Frances Fearing Miller Chair in Public Policy. He is founder of the PPIC Statewide Survey, which he has directed since 1998. His most recent book, *A California State of Mind: The Conflicted Voter in a Changing World*, is available at www.ppic.org.

PPIC is a private, nonprofit organization dedicated to improving public policy through objective, nonpartisan research on the economic, social, and political issues that affect Californians. The institute was established in 1994 with an endowment from William R. Hewlett. PPIC does not take or support positions on any ballot measure or on any local, state, or federal legislation, nor does it endorse, support, or oppose any political parties or candidates for public office.

This report will appear on PPIC's website (www.ppic.org) on November 13.

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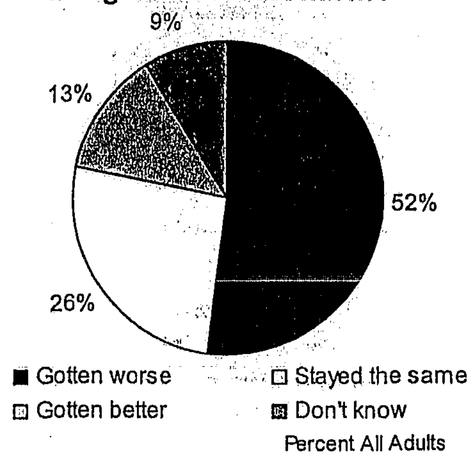
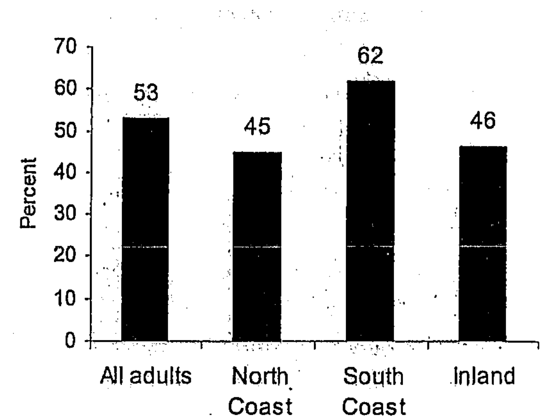
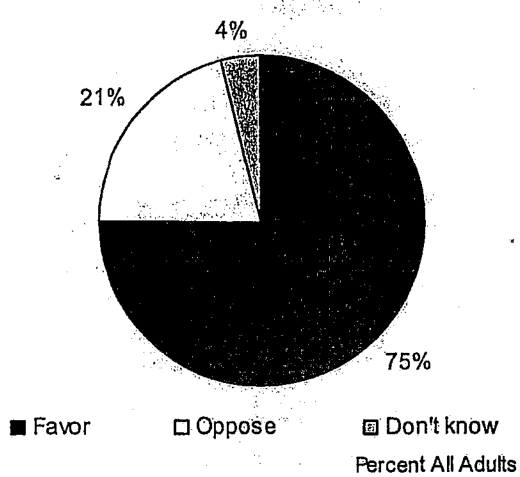
Over the past 20 years, do you think the condition of the ocean along the CA coast has...?



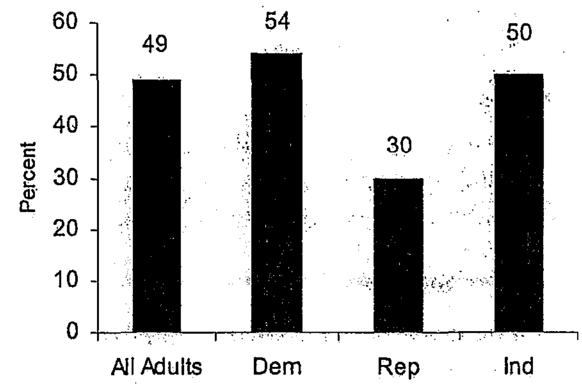
Percent who say ocean and beach pollution is a big problem



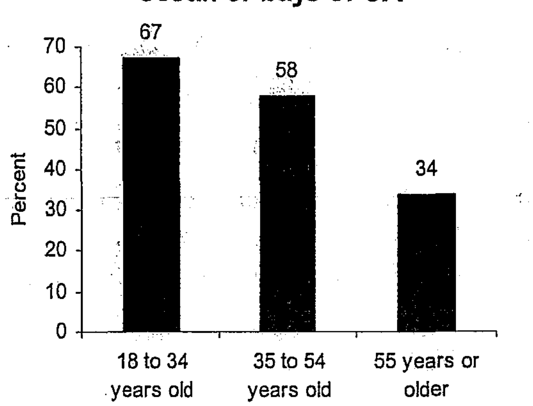
Creating more marine reserves off the CA coast



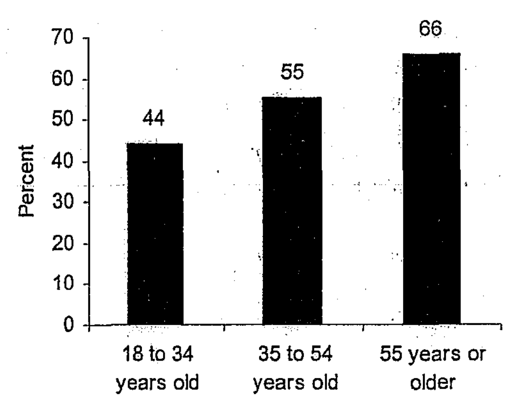
Percent who say environmental protection should be a priority for the Schwarzenegger Administration



Percent of those who do one water activity or more in the ocean or bays of CA



Percent who say they eat fish or seafood often



Perceived Conditions and Concerns

Ocean's Importance for California

Oceans and beaches have a special place in the hearts and minds of many Californians. Sixty-nine percent of them believe that the state's marine and coastal conditions are "very important" to California's quality of life. For another 26 percent, that condition is at least "somewhat important," and only 5 percent dismiss it as "not too" or "not at all" important.

The perceived importance of oceans and beaches for quality of life varies regionally and among population groups. Three in four South Coast residents[1] say they are very important, compared to two in three residents in other regions. Latinos (77%) are more likely than whites (67%) to see oceans and beaches as very important, and perception of their importance declines slightly with age but not with education nor income. Among political groups, Democrats (72%) and liberals (78%) are more likely than Republicans (58%) and conservatives (62%) to believe that ocean and beach conditions are very important for quality of life. However, a substantial majority of residents across the political spectrum think this is a very important factor.

"How important is the condition of the ocean and beaches to the quality of life in California?"

	All Adults	Region			Latinos
		North Coast	South Coast	Inland	
Very important	69%	67%	74%	62%	77%
Somewhat important	26	28	21	33	20
Not too important	4	5	3	4	2
Not important at all	1	0	2	1	1

The vast majority of Californians also believe that the condition of the ocean and beaches is very important (61%) or somewhat important (30%) to the state's economy. Across regions, 66 percent of South Coast, 57 percent of Inland, and 56 percent of North Coast residents believe it is very important. Latinos (70%) are more likely than whites (58%), and Democrats and liberals are more likely than Republicans and conservatives, to see coastal conditions as very important to the economy.

"How important is the condition of the ocean and beaches to the economy in California?"

	All Adults	Region			Latinos
		North Coast	South Coast	Inland	
Very important	61%	56%	66%	57%	70%
Somewhat important	30	34	25	34	23
Not too important	6	8	5	5	3
Not important at all	1	1	2	1	1
Don't know	2	1	2	3	3

[1] See the Methodology section (p. 19) for a description of the regional definitions used in this survey.

Trends in Ocean Quality

Looking at these resources they believe are so important for quality of life and the economy, 52 percent of Californians believe that the condition of the ocean along the state's coast has gotten worse in the past two decades. Twenty-six percent believe the condition is about the same, and only 13 percent believe it has gotten better. Regional perceptions differ: South Coast residents (57%) are more likely than Inland (50%) and North Coast (44%) residents to think that conditions have deteriorated. The perception of deteriorating conditions rises with age and education. It is also higher among women than among men and among whites than among Latinos. While Democrats and liberals are more likely than Republicans and conservatives to see a negative trend, the predominant perception across partisan and ideological lines is that ocean conditions have worsened.

"Over the past 20 years, do you think the condition of the ocean (along the California coast) has gotten better, stayed about the same, or gotten worse?"

	All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
Gotten worse	52%	44%	57%	50%	48%
Stayed about the same	26	28	23	29	28
Gotten better	13	17	12	11	14
Don't know	9	11	8	10	10

What about the overall health and quality of the ocean off California today? Twenty-eight percent of residents say it is excellent or good, 46 percent say it is fair, and 23 percent describe it as poor. Those living in the South Coast (30%) are more likely than those living in the North Coast (15%) or Inland areas (20%) to say that ocean conditions are poor. There are no major differences in current perceptions across age, education, income, gender, or racial/ethnic groups. However, Republicans (40%) and conservatives (35%) are more likely than Democrats (20%) and liberals (20%) to rate ocean conditions as excellent or good.

What do residents think the future holds? Almost half (45%) believe conditions along the coast will get worse over the next 20 years, 26 percent think they will stay the same, and 23 percent expect them to get better. Younger residents are the most likely to believe that ocean conditions will be worse, and Democrats and liberals are more pessimistic than Republicans and conservatives about the ocean's future. There are no major differences by region, education, income, or gender.

"Twenty years from now, do you think the condition of the ocean (along the California coast) will have gotten better, stayed about the same, or gotten worse than it is today?"

	All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
Gotten worse	45%	43%	46%	45%	49%
Stayed about the same	26	30	23	28	19
Gotten better	23	19	25	21	27
Don't know	6	8	6	6	5

Rating of Environmental Problems

Consistent with the value they place on the ocean and beaches and the conditions they perceive, half of California residents (53%) say that ocean and beach pollution along the coast is a big problem in the state today. Other environmental issues ranked about the same as a big problem are toxic substances contaminating soil and groundwater (53%), urban growth and air pollution damaging forests in the Sierra mountains (52%), and pollution from runoff affecting the water quality of rivers, streams, and lakes (51%). Fewer Californians expressed high levels of concern about the effects of development on endangered species and wildlife habitats (40%) and the logging of old-growth redwoods (38%).

Concern about ocean and beach pollution is about the same today as it was in the June 2000 PPIC Statewide Survey. There is slightly more concern today than three years ago about the effects of air pollution and urban growth on the forests, of toxic substances on soil and groundwater contamination, and of pollution runoff on rivers, lakes, and steams and about the logging of old-growth redwoods.

Problem rankings differ across regions: South Coast residents (62%) are the most likely to rate ocean and beach pollution as a big problem in the state. North Coast residents are more concerned than people in other regions about logging of old-growth redwoods. Latinos are more concerned than whites about all six of these environmental problems: Nearly seven in 10 Latinos rate ocean and beach pollution; pollution from runoff in rivers, lakes, and streams; and toxic contamination to groundwater and soil as big problems in the state today.

"Do you think ____________ is a big problem in California today?"

Percentage seeing the issue as a big problem	All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
Ocean and beach pollution along the California coast	53%	45%	62%	46%	66%
Toxic substances contaminating soil and groundwater	53	54	54	51	68
Urban growth and air pollution damaging the forests in the Sierra mountains	52	49	54	50	63
Urban and agricultural runoff polluting lakes, rivers, and streams	51	48	54	50	68
Urban development harming wildlife habitats and endangered species	40	39	43	38	54
The logging of old-growth redwoods in Northern California	38	44	37	34	43

Focusing on residents' concern with ocean and beach pollution, we find considerable differences across groups. There are large variations in the perception of "big problems" between younger and older residents, the non-college educated and college graduates, Latinos and whites, Democrats and Republicans, and liberals and conservatives. There are also modest differences between women and men, renters and homeowners, lower-income and upper-income residents, the native born and immigrants, those with and those without children at home, and those with shorter and longer stays at their residence.

"How about ocean and beach pollution along the California coast? Do you think this is a big problem, somewhat of a problem, or not a problem in California today?"

		Big problem	Somewhat of a problem	Not a problem	Don't know
All Adults		53%	34%	9%	4%
Age	18-34 years old	63	28	7	2
	35-54 years old	52	35	10	3
	55 years or older	43	40	12	5
Sex	Male	49	34	14	3
	Female	58	34	5	3
Education	High school only	58	29	9	4
	Some college	56	33	8	3
	College graduate	48	40	9	3
Income	Under $40,000	55	33	7	5
	$40,000 to under $80,000	53	34	10	3
	$80,000 or more	51	36	10	3
Race/ ethnicity	White	49	38	9	4
	Latino	66	25	7	2
Nativity	Native	52	36	9	3
	Immigrant	58	29	10	3
Homeownership	Own	50	37	10	3
	Rent	58	30	9	3
Children at home	Children under 18	56	34	9	1
	No children under 18	52	34	9	5
Years at current residence	Fewer than five years	57	32	8	3
	Five or more years	50	36	10	4
Party registration	Democrat	60	30	6	4
	Republican	39	43	14	4
	Independent	52	38	7	3
Political ideology	Liberal	65	26	6	3
	Moderate	52	38	7	3
	Conservative	44	39	13	4

Regional Coastal Concerns

When asked about coastal issues in the part of the California coast nearest to them, residents were most concerned about ocean and beach pollution from streets and storm drains: 52 percent say that this is a big problem in their part of the coast. However, it was more likely to be rated as a big problem by residents of the South Coast (63%) than by those who live Inland (48%) or on the North Coast (37%).

Perceptions of this problem vary widely across groups: Whites (47%) are much less likely than Latinos (66%) to see urban runoff as a big coastal problem; and concern about runoff tends to decline with education, income, and homeownership. While substantial proportions of residents across the political spectrum express some concern, Democrats (59%) and liberals (58%) are more likely than Republicans (40%) and conservatives (45%) to rate ocean and beach pollution from runoff as a big problem in their part of the California coast.

Fewer residents rate coastal development (36%) and limited public access to the coastline (20%) as big problems, compared to coastal pollution. Nevertheless, substantial majorities say these two issues are at least somewhat of a problem in their parts of California. Coastal development and public access concerns are similar across most regions. However, there is less concern in the North Coast than elsewhere about public access to the coastline. Latinos (27%) are much more likely than whites (17%) to rank limited public access as a big problem in their part of the state. Democrats and liberals are more likely than Republicans and conservatives to see both development and public access as major problems along their part of the coast.

"Do you think ____________ is a big problem, somewhat of a problem or not a problem in the part of the California coast closest to you?"

		All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
Ocean and beach pollution from streets and storm drains	Big problem	52%	37%	63%	48%	66%
	Somewhat of a problem	34	44	30	33	29
	Not a problem	9	14	5	13	4
	Don't know	5	5	2	6	1
Too much growth and development on the coast	Big problem	36%	34%	38%	36%	33%
	Somewhat of a problem	35	35	36	34	38
	Not a problem	24	27	22	25	22
	Don't know	5	4	4	5	7
Limited public access to the coast and beaches	Big problem	20%	15%	22%	22%	27%
	Somewhat of a problem	38	37	39	38	42
	Not a problem	37	43	35	35	26
	Don't know	5	5	4	5	5

Marine Concerns

When asked about three marine issues—that is, issues involving the California coastal waters nearest them—residents voiced the most concern about contamination of seafood: 84 percent see it as a big problem (52%) or somewhat of a problem (32%) in their coastal region. Perception of this as a big problem is high across all regions but higher in the South Coast (56%) than in the North Coast (51%) and Inland (47%). Whites (46%) are less likely than Latinos (64%) to rate this marine issue as a big problem in their region, and concerns tend to decline significantly with education and income but not with age. Democrats (59%) and liberals (61%) are much more likely than Republicans (37%) and conservatives (46%) to think seafood contamination is a big problem.

Although a decline in marine mammals does not concern residents quite as much, 74 percent see it as a big problem (44%) or somewhat of a problem (30%). There are no significant differences between South Coast, North Coast, or Inland residents on perceptions of this issue. Whites (40%) are less likely than Latinos (54%) to believe depletion of marine mammals is a big problem. The concern also declines with age, education, and income. There are also large differences in perceptions between Democrats (47%) and Republicans (30%) and liberals (54%) and conservatives (34%) in the extent to which this particular issue is a big problem in California's coastal waters.

Overfishing generates about the same level of concern as depletion of marine mammals: 71 percent of residents believe it is a big problem (36%) or somewhat of a problem (35%) in the ocean waters nearest them. There are more concerns about this issue on the coast than inland and in the North Coast than in the South Coast. Latinos (46%) are more likely than whites (32%) to say that overfishing on the coast near them is a big problem.

"Do you think ____________ is a big problem, somewhat of a problem or not a problem in the part of the California coast closest to you?"

		All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
The contamination of fish and seafood	Big problem	52%	51%	56%	47%	64%
	Somewhat of a problem	32	34	31	32	25
	Not a problem	12	12	10	15	8
	Don't know	4	3	3	6	3
Declining numbers of marine mammals such as whales and sea otters	Big problem	44%	43%	45%	43%	54%
	Somewhat of a problem	30	31	30	28	27
	Not a problem	19	19	17	21	13
	Don't know	7	7	8	8	6
Overfishing (depleting the fishing stock) by commercial fishing boats	Big problem	36%	39%	36%	31%	46%
	Somewhat of a problem	35	33	34	38	35
	Not a problem	20	20	20	21	13
	Don't know	9	8	10	10	6

Public Policies

The Schwarzenegger Administration and Environmental Protection

Overall, from what they know so far, Californians approve of Governor-elect Arnold Schwarzenegger's plans and policies for the state's future by about a two-to-one margin. Nearly half of state residents (47%) approve of his plans and policies, 25 percent disapprove, and almost three in 10 say they just don't know yet. A majority of Republicans (69%) and independents (53%) approve of the governor-elect's plans and policies, while Democrats are equally likely to disapprove (33%) as to approve (32%) of his ideas.

"From what you know so far, overall do you approve or disapprove of Governor-elect Arnold Schwarzenegger's plans and policies for California's future?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Approve	47%	32%	69%	53%	47%
Disapprove	25	33	7	19	21
Don't know	28	35	24	28	32

In terms of priorities for the Schwarzenegger administration, Californians nearly uniformly agree that environmental protection should be a priority. Thirty-two percent of Californians think that protecting the environment should be a *top* priority, and another 57 percent believe that it should be an important although not a top priority. Only one in 10 Californians thinks that environmental protection is not too important (8%) or should not be undertaken (2%). Thirty-seven percent of Democrats, 29 percent of independents, and 17 percent of Republicans think that protecting the environment should be a top priority for the new administration. Latinos are more likely than whites to consider environmental protection a top priority (41% to 29%).

Even relative to the state's economy, Californians think that the incoming administration should focus on environmental protection. Forty-nine percent of Californians think that protecting the environment should be a priority, even at the risk of curbing economic growth. Forty-two percent think that economic growth should be a priority, even if the environment suffers a bit. The state's likely voters are more narrowly divided on these priorities (46% favor the environment; 45% favor economic growth). While a majority of Democrats (54%) and half of independents (50%) think that environmental protection should be a priority even if it results in economic consequences, a majority of Republicans (61%) think that economic growth should be given priority, even at some expense to the environment.

"When it comes to the state policies that you would prefer from the Schwarzenegger administration, which comes closer to your views ..."

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Protection of the environment should be a priority, even at the risk of curbing economic growth	49%	54%	30%	50%	46%
Economic growth should be a priority, even if the environment suffers to some extent	42	37	61	41	45
Don't know	9	9	9	9	9

Governing California's Coast

Asked which branch of government they trust to do a better job in handling the state's marine and coastal issues, 42 percent of Californians say they trust the state government, 30 percent say local government, 14 percent say the federal government, and 2 percent volunteer that they do not trust any of these governments to handle these issues. Among the state's likely voters, 47 percent trust state government the most in marine and coastal matters. Among Democrats and Republicans, the state is clearly the most trusted government with respect to California's marine and coastal issues; but among independents, preference for the state and local governments is nearly even (41% to 37%). Coastal and inland residents do not differ in their assessments.

"Which branch of government ... do you trust to do a better job in handling marine and coastal issues in California?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
State government	42%	46%	46%	41%	47%
Local government	30	28	32	37	32
Federal government	14	13	13	12	11
None of them *(volunteered)*	2	3	2	2	3
Other / Don't know	12	10	7	8	7

Asked whether the state is currently doing more than enough, just enough, or not enough to protect the coastal and marine environment in California, 44 percent of Californians say that the state is not doing enough, 40 percent say just enough, and only 7 percent say more than enough. Democrats (54%) and independents (47%) are much more likely than Republicans (32%) to say that the state is *not* doing enough to protect the coastal and marine environment. There is almost no variation in attitude toward the state's current efforts to protect these environments between frequent and infrequent visitors to the California coast. However, those who believe that ocean and beach pollution along the coast is a big problem are much more likely than those who do not think it is a problem to say that the state is not doing enough (55% to 20%). Similarly, 65 percent of Californians who think that the health and quality of the ocean today is poor say that the state is not doing enough to protect these environments, compared to only 26 percent of those residents who rate the ocean's health and quality as excellent or good.

"Overall, do you think that the state government is currently doing more than enough, just enough, or not enough to protect the coastal and marine environment in California?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Not enough	44%	54%	32%	47%	46%
Just enough	40	35	45	39	37
More than enough	7	3	13	6	8
Don't know	9	8	10	8	9

Although recent estimates suggest that the state will again face a large budget deficit in the upcoming fiscal year, and that program cuts will be needed to balance the budget, 48 percent of all Californians and 48 percent of the state's likely voters want to continue to fund environmental programs at current levels, even if it means less funds for other state programs. Thirty-five percent of Californians would prefer to reduce funding for environmental programs, so that more funds would be available for other state programs. By wide margins, Democrats (56% to 28%) and independents (50% to 34%) favor continuing funding for environmental programs before other programs, while Republicans favor reducing current environmental funding (45% to 37%).

"The state government faces a large budget deficit, and program cuts are needed to balance the budget. Should the state ..."

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Continue to fund environmental programs at the current level, even if it means less funds for other programs	48%	56%	37%	50%	48%
Reduce funding for environmental programs, so that more funds are available for other programs	35	28	45	34	34
Other answer	5	6	6	5	7
Don't know	12	10	12	11	11

When it comes to the California Coastal Commission, four in 10 Californians (38%) say that the commission is not strict enough in its regulation of development along the California coast. One in three Californians (31%) believes the commission's restrictions are about right, 11 percent view them as too restrictive, and one in five either doesn't know or hasn't heard of the Coastal Commission. Thirty-eight percent of independents and 45 percent of Democrats—but only 28 percent of Republicans—say that the commission's control of development is not strict enough. Twenty-one percent of Republicans, 11 percent of independents, and 6 percent of Democrats think that the controls are too restrictive.

About four in 10 South Coast and Inland residents (42% and 37%, respectively) and 31 percent of North Coast residents say that the Coastal Commission is not strict enough in controlling development. Assessments of the commission's controls vary only slightly by race/ethnicity, education, or homeownership.

"Overall, what do you think of the California Coastal Commission when it comes to controls on development—are they too strict, about right, or not strict enough?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Not strict enough	38%	45%	28%	38%	38%
About right	31	30	30	30	29
Too strict	11	6	21	11	13
Don't know about California Coastal Commission / Don't know	20	19	21	21	20

Marine Policy Issues

In general, Californians respond positively to policies that have been proposed to help protect the ocean and marine life along the California shoreline, even when it comes to the most controversial issues. For example, with regard to the hotly contested environmental and energy issue of oil drilling off the California coast, majorities of Californians consistently oppose new drilling off the coast, even if it might reduce dependence on foreign oil (July 2003) or lead to lower gasoline prices for California drivers (June 2000 and June 2002). Fifty percent of Californians today say they favor prohibiting additional drilling off the coast, even if it means higher fuel prices for California drivers. Among California's likely voters, 53 percent would ban new drilling, even if it resulted in higher gas prices.

Public attitude toward increased drilling off the coast varies by partisanship, with Democrats favoring a ban almost two-to-one (60% to 35%), a majority of Republicans opposing a ban (55% to 39%), and independents nearly evenly divided (49% favor; 46% oppose). Support for the prohibition is strongest along the North Coast (58% favor; 36% oppose), while those along the South Coast (48% to 46%) and Inland (45% to 50%) are closely split on the question of allowing more oil drilling.

"How about prohibiting more oil drilling off the California coast, even if this means higher gasoline prices for California drivers?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Favor	50%	60%	39%	49%	53%
Oppose	45	35	55	46	42
Don't know	5	5	6	5	5

Three in four Californians (75%)—including large majorities of Democrats (80%), Republicans (66%), and independents (77%)—favor creating more marine reserves off the California coast, even if it means that some ocean areas will be off-limits to commercial and recreational fishing; twenty-one percent of California residents oppose new reserves.

Two-thirds of state residents also favor limiting the sale of fish and seafood to those products that have been caught or farmed in an environmentally safe manner, even if this means paying higher prices in California stores and restaurants. Seven in 10 Democrats (71%) and independents (67%) favor this restriction, as do 53 percent of Republicans. Support for selling only fish and seafood caught or farmed in an environmentally safe manner is unrelated to how often respondents eat fish or to annual household income.

"How about only selling fish or seafood that was caught or farmed in an environmentally safe manner, even if this means paying higher prices in California stores and restaurants?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Favor	67%	71%	53%	67%	64%
Oppose	28	25	42	28	31
Don't know	5	4	5	5	5

Coastal Policy Issues

Most Californians also favor a free and open coastline. For example, seven in 10 support restricting private development along the coast, even if it means less available housing in the coastal area. Majorities of Democrats (77%), Republicans (62%), and independents (71%) agree upon this matter. Similarly, majorities of North Coast (71%), South Coast (70%), and even Inland (66%) residents favor restricting private development along the coastline. Renters (68%) are nearly as likely as homeowners (71%) to support this restriction.

"How about restricting the private development of land along the California coast, even if this means that there will be less housing available near the ocean and beaches?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Favor	69%	77%	62%	71%	72%
Oppose	27	21	33	27	24
Don't know	4	2	5	2	4

Three-quarters of Californians (77%) also favor protecting wetlands and habitats near the bays and beaches, even if it means less commercial activity near the coast. While majorities of Californians across political parties favor protecting coastal wetlands and habitats, support is significantly higher among Democrats (83%) than Republicans (68%); about eight in 10 independents (79%) favor these environmental protections. Seventy-eight percent of North Coast, 79 percent of South Coast, and 72 percent of Inland residents favor protecting coastal wetlands and habitats, even if it means less commercial activity near the coast.

"How about protecting the wetlands and habitats near the bays and beaches, even if this means there will be less commercial activity near the California coast?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Favor	77%	83%	68%	79%	78%
Oppose	18	12	26	19	18
Don't know	5	5	6	2	4

In a similar vein, 72 percent of Californians favor improving the quality of the water feeding into the ocean from storm drains and sewage treatment plants, even if it means higher utility bills. Support for such improvement is strong across the coastal and inland regions and across partisan and age groups. Californians from households with incomes of $80,000 or more are somewhat more likely than those from households with incomes under $40,000 to favor improving the water quality from storm drains and sewage plants (77% to 71%), as are those with a college degree compared to those with a high school diploma or less (78% to 65%). Democrats (76%) and independents (75%) favor this effort more than Republicans (66%).

President Bush and National Politics

Forty-eight percent of Californians approve of the job that George W. Bush is doing as president of the United States, and 46 percent disapprove of his job performance. Among likely voters, 47 percent approve and 49 percent disapprove. Overall, Californians are more critical of the president's handling of environmental issues: Almost half of all Californians, and 53 percent of the state's likely voters disapprove of the way he is handling the country's environmental issues.

Bush's overall ratings and his environmental policy approval ratings are both strongly related to party affiliation. Eighty-three percent of Republicans approve of Bush's overall job performance, compared to 45 percent of independents and only one-quarter of Democrats. Similarly, 60 percent of Republicans, but only 31 percent of independents and 16 percent of Democrats, approve of the way he is handling the country's environmental issues. Latinos and whites are equally likely to approve of Bush's overall performance (51% to 50%), but Latinos are somewhat more likely than whites to approve of his handling of environmental issues (42% to 34%).

		All Adults	Party Registration			Likely Voters
			Dem	Rep	Ind	
Overall, do you approve or disapprove of the way that George W. Bush is handling his job as president of the United States?	Approve	48%	25%	83%	45%	47%
	Disapprove	46	70	14	49	49
	Don't know	6	5	3	6	4
And do you approve or disapprove of the way that President Bush is handling environmental issues in the United States?	Approve	35%	16%	60%	31%	34%
	Disapprove	49	70	23	54	53
	Don't know	16	14	17	15	13

Fifty-four percent of Californians say that the federal government is not doing enough to protect the coastal and marine environment of the United States. Seventy percent of Democrats and 64 percent of independents—but only 33 percent of Republicans—think that the federal government is not doing enough to protect these environments. Sixty percent of Californians who live along the North Coast think that the federal government is not doing enough to protect the coastal and marine environment in California, compared to 56 percent of those living along the South Coast and 47 percent of those in Inland areas.

"Overall, do you think that the federal government is doing more than enough, just enough, or not enough to protect the coastal and marine environment in the United States?"

	All Adults	Party Registration			Likely Voters
		Dem	Rep	Ind	
Not enough	54%	70%	33%	64%	57%
Just enough	32	22	46	26	30
More than enough	6	2	11	4	6
Don't know	8	6	10	6	7

Looking ahead to the 2004 presidential election, 42 percent of Californians and 38 percent of likely voters say that the candidates' positions on environmental issues will be very important in determining how they will vote. Only one in 10 of all Californians and of likely voters say that the candidates' positions on environmental issues will not be important to them in deciding how to vote in 2004.

Life Is a Beach

Californians believe that the condition of the oceans and beaches of the state is almost as important to them personally as it is to the state's quality of life and economy. Eighty-eight percent say that condition is very (60%) or somewhat (28%) important to them personally, while only 11 percent say it is not too important (7%) or not important at all (4%). More than 8 in 10 residents across every region of the state say it is at least somewhat important. However, those who live in the North Coast (61%) and South Coast (66%) are more likely than residents of the Inland region (50%) to say it is very important to them. It is more often rated as very important by Democrats (65%) than by Republicans (50%) or independents (57%) and by women (63%) than by men (57%). Whites and Latinos are about equally likely to rank it as at least somewhat important (88% to 90%).

"How important is the condition of the ocean and beaches in California to you personally?"

	All Adults	Region			Latinos
		North Coast	South Coast	Inland	
Very important	60%	61%	66%	50%	65%
Somewhat important	28	28	25	32	25
Not too important	7	7	5	10	5
Not important at all	4	3	3	7	3
Don't know	1	1	1	1	2

There is more truth than poetry in the myth of Californians' love affair with the beach. They are much more likely than Americans as a whole to visit an ocean beach at least several times a year (72% compared to 40%).[1] However, the frequency varies greatly across regions: 46 percent of South Coast residents go to the beach at least once a month, compared to 39 percent in the North Coast and 16 percent in the Inland region. Higher-income residents are more likely than those with lower incomes, and whites are more likely than Latinos, to visit the beach more frequently. Not surprisingly, Californians who frequent the beach several times a month are more likely than others to say that the ocean is very important to them personally.

"How often would you say you visit a beach on the coast of California for any purpose?"

	All Adults	Region			Latinos
		North Coast	South Coast	Inland	
Once a week	16%	15%	23%	5%	12%
Once a month	20	24	23	11	21
Several times a year	36	38	33	39	36
Once a year	15	12	11	23	20
Less than once a year	9	7	5	15	6
Never	4	4	5	7	5

[1] Statistic for Americans as a whole is derived from a 1999 national survey commissioned by Sea Web.

Water Sports

Among the six recreational uses of the ocean and bays that we asked about, swimming is by far the most common activity. Four in ten Californians say they have gone swimming in the ocean or bays in the past year.

Ocean and bay swimming varies across regions and demographic groups. It is higher for South Coast (49%) than for Inland (39%) and North Coast (35%) residents, for men (47%) than for women (38%), and for Latinos (48%) than for whites (42%). Younger residents are much more likely than older residents, and people with higher incomes are somewhat more likely than those with lower incomes, to say they swam in the ocean or bays in the past 12 months.

When it comes to recreational or sport fishing, only 17 percent of Californians say they have fished in the ocean or bays in the past year. While there are no differences across the state's three regions, men are more than twice as likely as women to have partaken in this activity (23% to 11%). Asked about sailing or kayaking in the ocean or bays in the last 12 months, 14 percent of state residents say they have done so. Coastal residents are twice as likely as those who live inland to say they have sailed or kayaked (16% to 8%). Those with a college degree are more likely than those with a high school diploma or less (20% to 6%), and those with an income of $80,000 or more are more likely than lower-income residents (24% to 10%), to say they have sailed or kayaked in the last year.

"In the past 12 months have you gone ____________ in the ocean or the bays of the California coast?"

Percentage saying they have done the following activities in 12 months	All Adults	Region: North Coast	Region: South Coast	Region: Inland	Latinos
Swimming	43%	35%	49%	39%	48%
Recreational or sport fishing	17	16	16	18	18
Sailing or kayaking	14	15	16	8	9
Motorboating or jet skiing	13	10	13	14	15
Surfing	10	6	13	9	8
Snorkeling or scuba diving	8	7	9	8	5

An even smaller percentage of state residents say they have been motorboating or jet skiing (13%), surfing (10%), or snorkeling (8%). These activities vary by region. Motorboating or jet skiing is slightly more popular in the Inland region (14%) and the South Coast (13%) than in the North Coast (10%). The South Coast region has a much higher percentage of residents (13%) than the North Coast (6%) or Inland region (9%) who say they have been surfing in the past year. Residents with an income of $80,000 or more are more than twice as likely as lower-income residents (14% to 6%) to say they have gone snorkeling or scuba diving. More men than women say they have been motorboating (17% to 9%), surfing (15% to 6%), and snorkeling or scuba diving (12% to 5%) in the ocean or bays of the California coast in the past 12 months.

Nearly half of state residents (45%) have not used the ocean or bays of the California coast for any of these six activities in the past 12 months. Twenty-seven percent have engaged in one water activity and 28 percent have engaged in two or more. Residents of the North Coast and the Inland regions (both 49%) are more likely than residents of the South Coast (40%) to say they have not used the ocean or bays for water activities in the past year. One in three of the South Coast's residents say they have engaged in at least two or more water activities along the coast in the past year.

The percentage of Californians who say they have engaged in a water activity declines with age and increases with household income and the presence of children. Latinos are somewhat more likely than whites, and men are much more likely than women, to say they have been involved in one or more water activities in the past year. Of the six in 10 Californians who say that the condition of oceans and beaches is personally very important to them, two in three have participated in water activities on the coast during the past twelve months. In contrast, the majority of residents who attach less importance to the state's beach and ocean conditions have not been involved in any of the six water activities along the California coast in the past year.

		Ocean/ Bay Activities[2]		
		Two or more	One	None
All Adults		28%	27%	45%
Region	South Coast	32	28	40
	North Coast	23	28	49
	Inland	25	26	49
Sex	Male	37	26	37
	Female	19	28	53
Age	18 to 34	36	31	33
	35 to 54	30	28	42
	55 or older	14	20	66
Race/ ethnicity	White	29	25	46
	Latino	27	33	40
Education	High school only	25	28	47
	Some college	29	27	44
	College graduate	30	26	44
Income	$40,000 or less	25	27	48
	$40,000 to under $80,000	27	29	44
	$80,000 or more	36	26	38
Children at home	Children under 18	31	33	36
	No children under 18	26	23	51
How important is the condition of the ocean and beaches in California to you personally?	Very important	33	30	37
	Somewhat important	23	26	51
	Not too important	18	13	69
	Not important at all	13	10	77

[2] Activities include swimming, recreational or sport fishing, sailing or kayaking, motor boating or jet skiing, surfing, and snorkeling or scuba diving.

Seafood Diet

The consumption of fish and seafood is also part of the California lifestyle but not out of line with national consumption: 54 four percent of adult Californians say they eat fish or seafood often (i.e., once a week or more) at home or in a restaurant, 24 percent say they eat fish or seafood sometimes, 16 percent say rarely, and 6 percent say they never do. These results are similar to those in a 1996 national survey conducted for Sea Web. However, consumption varies regionally and across population groups. South Coast residents (58%) often eat fish or seafood somewhat more than North Coast (55%) and Inland (47%) residents. More men than women (57% to 51%), and more people without children than with children in their households (57% to 50%), say they eat fish often at home or in restaurants. Eating fish or seafood tends to increases with income and education. Residents age 55 and older are much more likely than residents between the ages of 18 and 34 to say they often eat fish or seafood.

"How often would you say you eat fish or seafood at home or in a restaurant—often, sometimes, rarely, or never?"

		Region			Age		
	All Adults	North Coast	South Coast	Inland	18-34 years old	35-54 years old	55 years or older
Often	54%	55%	58%	47%	44%	55%	66%
Sometimes	24	25	23	24	29	25	15
Rarely	16	15	13	20	19	13	14
Never	6	5	6	9	8	7	5

Eighty-two percent of Californians believe eating fish or seafood is very (47%) or somewhat (35%) important for a healthy diet, while 17 percent say it is not too important or not at all important. Belief that the health benefits of eating fish are very important is higher among South Coast residents (51%) than North Coast (45%) and Inland (42%) residents. Although men are more likely than women to say they consume fish often, women are more likely than men to say it is very important for their having a healthy diet (50% to 43%). The belief that eating fish and seafood is very important for health reasons increases with age (38% for ages 18-34; 49% for ages 35-54; 56% for age 55 and older). Although consumption of fish or seafood increases with education and income, belief in its dietary importance is similar across education levels but not across income levels: People in households with incomes of $40,000 or less are the most likely to say the health benefits are very important. Overall, two in three of those who often eat fish say that seafood it is very important for having a healthy diet.

"How important would you say that eating fish or seafood is to your having a healthy diet—very important, somewhat important, not too important, or not at all important?"

		Frequency of eating fish or seafood				
	All Adults	Often	Sometimes	Rarely	Never	Latinos
Very important	47%	64%	30%	24%	20%	53%
Somewhat important	35	31	48	40	15	31
Not too important	11	4	18	24	7	9
Not at all important	6	1	2	11	52	5
Don't know	1	0	2	1	6	2

Seafood Safety

Many Californians worry that the fish or seafood they are eating might be harmful to their health: 83 percent say they are very (50%) or somewhat (33%) concerned that the fish or seafood for sale is contaminated by ocean pollution. People who frequently eat fish or seafood are more likely than those who rarely or never do to say they are very or somewhat concerned about contamination. Women are more likely than men (55% to 46%) and Latinos are more likely than whites (62% to 44%) to say they are very concerned about this contamination. Concern about contamination tends to decline with higher income and higher education.

"How concerned are you that the fish or seafood for sale are contaminated by ocean pollution?"

	All Adults	Frequency of eating fish or seafood				Latinos
		Often	Sometimes	Rarely	Never	
Very concerned	50%	53%	49%	48%	36%	62%
Somewhat concerned	33	31	36	33	37	29
Not too concerned	11	10	11	12	11	5
Not at all concerned	5	5	4	7	12	3
Don't know	1	1	0	0	4	1

Most Californians are more worried about contamination than about the possibility that the fish or seafood available for purchase is being commercially overfished. Yet, eight in ten state residents say they are at least somewhat concerned and nearly four in 10 residents are very concerned about this issue. Concern varies regionally and with consumption of fish: North Coast (42%) and South Coast (41%) residents are more likely than Inland residents (30%) to say they are very concerned about this issue. People who eat fish more frequently are slightly more likely than others to worry about overfishing.

"How concerned are you that the fish or seafood for sale are commercially overfished?"

	All Adults	Frequency of eating fish or seafood				Latinos
		Often	Sometimes	Rarely	Never	
Very concerned	38%	40%	38%	35%	32%	41%
Somewhat concerned	42	42	44	43	33	45
Not too concerned	11	10	12	14	15	7
Not at all concerned	5	5	3	6	13	4
Don't know	4	3	3	2	7	3

Fish Friendly

How much are pet fish part of the California lifestyle? Twenty-one percent of adult residents say they have an aquarium or other place where they keep pet fish at home. People who live inland (25%) are more likely than residents of the North (18%) or South Coast (21%) regions to have pet fish. Pet fish are twice as prevalent in households with children as in childless homes (30% to 14%). People ages 18 to 54 are more likely than those age 55 or older (26% to 12%) and Latinos are more likely than whites (25% to 19%) to be keeping pet fish.

"Do you currently have an aquarium or some other place at home where you keep pet fish?"

	All Adults	Region			Children at home		Latinos
		North Coast	South Coast	Inland	Yes	No	
Yes	21%	18%	21%	25%	30%	14%	25%
No	79	82	79	75	70	86	75

For most Californians, observing live fish in action is also an aspect of their leisure and educational activities. National surveys indicate a similar trend for all Americans. When asked whether they had visited an aquarium or other public place having live fish, nearly three-quarters of all Californians said they had. Majorities across all regional, demographic, and racial and ethnic groups say they have had this experience in recent years; but there are variations. For example, coastal residents from both the North (81%) and South (72%) are more likely than Inland residents (68%) to say they have visited an aquarium. Whites are more likely than Latinos to have visited such a place (77% to 61%). Similar numbers of residents across all age groups say they have visited an aquarium. However, visits to aquariums increase with education and income and the presence of children: People with children in their household are somewhat more likely than those who don't to say they have made these visits (76% to 71%).

"In the past few years, have you visited an aquarium or other public places with live fish?"

	All Adults	Region			Children at home		Latinos
		North Coast	South Coast	Inland	Yes	No	
Yes	73%	81%	72%	68%	76%	71%	61%
No	27	19	28	32	24	29	39

Survey Methodology

The PPIC Statewide Survey is directed by Mark Baldassare, research director at the Public Policy Institute of California, with assistance in research and writing from Jon Cohen, survey research manager, and Eliana Kaimowitz and Renatta DeFever, survey research associates. The survey was conducted in collaboration with The William and Flora Hewlett Foundation, The James Irvine Foundation, and The David and Lucile Packard Foundation and benefited from discussions with staff at the foundations and their grantees and colleagues at other institutions; however, the survey methods, questions, and content of the report were solely determined by Mark Baldassare.

The findings of this survey are based on a telephone survey of 2,004 California adult residents interviewed between October 24 and November 2, 2003. Interviewing took place on weekday nights and weekend days, using a computer-generated random sample of telephone numbers that ensured that both listed and unlisted telephone numbers were called. All telephone exchanges in California were eligible for calling. Telephone numbers in the survey sample were called up to six times to increase the likelihood of reaching eligible households. Once a household was reached, an adult respondent (age 18 or older) was randomly chosen for interviewing by using the "last birthday method" to avoid biases in age and gender. Each interview took an average of 18 minutes to complete. Interviewing was conducted in English or Spanish. Casa Hispana translated the survey into Spanish; and Schulman, Ronca & Bucuvalas, Inc. conducted the telephone interviewing.

We used recent U.S. Census and state figures to compare the demographic characteristics of the survey sample with characteristics of California's adult population. The survey sample was closely comparable to the census and state figures. The survey data in this report were statistically weighted to account for any demographic differences.

The sampling error for the total sample of 2,004 adults is +/- 2 percent at the 95 percent confidence level. This means that 95 times out of 100, the results will be within 2 percentage points of what they would be if all adults in California were interviewed. The sampling error for subgroups is larger. Sampling error is only one type of error to which surveys are subject. Results may also be affected by factors such as question wording, question order, and survey timing.

In this report, we divide the state into three geographic regions. The "North Coast" region (25% of the state's population) refers to the counties along the California coast from Del Norte through San Luis Obispo. This region also includes the San Francisco Bay Area counties of Napa, Solano, Contra Costa, Alameda, and Santa Clara. The "South Coast" region (47% of the state's population) includes Santa Barbara, Ventura, Los Angeles, Orange, and San Diego counties. All other counties are included in the "Inland" region (28% of the state's population).

We present specific results for Latinos because they account for about 28 percent of the state's adult population and constitute one of the fastest growing voter groups. The sample sizes for the African American and Asian subgroups are not large enough for separate statistical analysis. We do compare the opinions of registered Democrats, Republicans, and independents. The "independents" category includes only those who are registered to vote as "decline to state."

In some cases, we compare PPIC Statewide Survey responses to responses recorded in national surveys conducted by Mellman Group for Sea Web in 1996, 1997, 1999, and 2001; by Beldon Russonello & Stewart and American Viewpoint for the Ocean Project in 1999; and by a California voters' survey conducted by Edge Research for Sea Web in 2002. We used earlier PPIC Statewide Surveys to analyze trends over time in California.

PPIC STATEWIDE SURVEY: SPECIAL SURVEY ON THE ENVIRONMENT
OCTOBER 24—NOVEMBER 2, 2003
2,004 CALIFORNIA ADULT RESIDENTS; ENGLISH AND SPANISH
MARGIN OF ERROR +/- 2% AT 95% CONFIDENCE LEVEL FOR TOTAL SAMPLE

---

1. Do you think things in California are generally going in the right direction or the wrong direction?

    32% right direction
    52 wrong direction
    16 don't know

2. Do you think that during the next 12 months we will have good times financially or bad times?

    39% good times
    47 bad times
    14 don't know

Next, I am going to read to you a list of environmental issues in the state. Please tell me if you think each of the following is a big problem, somewhat of a problem, or not a problem in California today. *[rotate question 3 to 8]*

3. How about ocean and beach pollution along the California coast?

    53% big problem
    34 somewhat of a problem
    9 not a problem
    4 don't know

4. How about urban and agricultural runoff polluting lakes, rivers, and streams?

    51% big problem
    34 somewhat of a problem
    10 not a problem
    5 don't know

5. How about toxic substances contaminating soil and groundwater?

    53% big problem
    34 somewhat of a problem
    8 not a problem
    5 don't know

6. How about urban growth and air pollution damaging the forests in the Sierra mountains?

    52% big problem
    31 somewhat of a problem
    11 not a problem
    6 don't know

7. How about the logging of old-growth redwoods in Northern California?

    38% big problem
    29 somewhat of a problem
    20 not a problem
    13 don't know

8. How about urban development harming wildlife habitats and endangered species?

    40% big problem
    36 somewhat of a problem
    20 not a problem
    4 don't know

Next, I am interested in your views about ocean and marine life along the California coast.

9. Over the past 20 years, do you think the condition of the ocean (along the California coast) has gotten better, stayed about the same, or gotten worse?

    52% gotten worse
    26 stayed about the same
    13 gotten better
    9 don't know

10. Thinking about the overall health and quality of the ocean (along the California coast) today—would you rate them as excellent, good, fair, or poor?

    3% excellent
    25 good
    46 fair
    23 poor
    3 don't know

11. Twenty years from now, do you think the condition of the ocean (along the California coast) will have gotten better, stayed about the same, or gotten worse than it is today?

    45% gotten worse
    26 stayed about the same
    23 gotten better
    6 don't know

[rotate questions 12 and 13]

12. How important is the condition of the ocean and beaches to the quality of life in California—very important, somewhat important, not too important, or not important at all?

69%	very important
26	somewhat important
4	not too important
1	not important at all

13. How important is the condition of the ocean and beaches to the economy in California— very important, somewhat important, not too important, or not important at all?

61%	very important
30	somewhat important
6	not too important
1	not important at all
2	don't know

14. How important is the condition of the ocean and beaches in California to you personally—is it very important, somewhat important, not too important, or not important at all?

60%	very important
28	somewhat important
7	not too important
4	not important at all
1	don't know

Next, I am going to list some specific problems that some people say affect our ocean and marine life in California today. After each, please tell me whether you think it is a big problem, somewhat of a problem, or not a problem in the part of California coast that is closest to you. *[rotate question 15 to 20]*

15. How about ocean and beach pollution from streets and storm drains?

52%	big problem
34	somewhat of a problem
9	not a problem
5	don't know

16. How about too much growth and development on the coast?

36%	big problem
35	somewhat of a problem
24	not a problem
5	don't know

17. How about limited public access to the coast and beaches?

20%	big problem
38	somewhat of a problem
37	not a problem
5	don't know

18. How about overfishing (depleting the fishing stock) by commercial fishing boats?

36%	big problem
35	somewhat of a problem
20	not a problem
9	don't know

19. How about the contamination of fish and seafood?

52%	big problem
32	somewhat of a problem
12	not a problem
4	don't know

20. How about declining numbers of marine mammals such as whales and sea otters?

44%	big problem
30	somewhat of a problem
19	not a problem
7	don't know

Next, I am going to list some policies that people have proposed to help protect the ocean and marine life on the California coast. For each that I mention, please tell me if you would favor or oppose taking such an action. *[rotate question 21 to 26]*

21. How about prohibiting more oil drilling off the California coast, even if this means higher gasoline prices for California drivers?

50%	favor
45	oppose
5	don't know

22. How about creating more marine reserves off the California coast, even if this means that some ocean areas will be off-limits to commercial and recreational fishing?

75%	favor
21	oppose
4	don't know

23. How about only selling fish or seafood that was caught or farmed in an environmentally safe manner, even if this means paying higher prices in California stores and restaurants?

67%	favor
28	oppose
5	don't know

24. How about restricting the private development of land along the California coast, even if this means that there will be less housing available near the ocean and beaches?

69% favor
27 oppose
4 don't know

25. How about improving the water quality from storm drainage and sewer treatment plants that feed into the oceans, even if this means that Californians will be paying higher utility bills?

72% favor
24 oppose
4 don't know

26. How about protecting the wetlands and habitats near the bays and beaches, even if this means there will be less commercial and recreational activity near the California coast?

77% favor
18 oppose
5 don't know

27. Changing topics, overall do you approve or disapprove of the way that George W. Bush is handling his job as president of the United States?

48% approve
46 disapprove
6 don't know

28. And do you approve or disapprove of the way that President Bush is handling environmental issues in the United States?

35% approve
49 disapprove
16 don't know

29. Overall, do you think that the federal government is doing more than enough, just enough, or not enough to protect the coastal and marine environment in the United States?

54% not enough
32 just enough
6 more than enough
8 don't know

30. Next, in thinking about the presidential election in 2004, how important are the candidates' positions on environmental issues in determining your vote—very important, somewhat important, or not important?

42% very important
45 somewhat important
11 not important
2 don't know

31. Which political party —*[rotate]* the Republican Party or the Democratic Party—do you trust to do a better job in handling environmental issues in the United States?

47% Democratic Party
26 Republican Party
2 other answer *(specify)*
3 both equally *(volunteered)*
11 neither *(volunteered)*
11 don't know

32. Turning to the state, from what you know so far, overall do you approve or disapprove of Governor-elect Arnold Schwarzenegger's plans and policies for California's future?

47% approve
25 disapprove
28 don't know

33. In terms of priorities for Governor-elect Schwarzenegger, should protecting the environment in California be a top priority, important but lower priority, not too important, or should it not be done?

32% top priority
57 important but lower priority
8 not too important
2 should not be done
1 don't know

34. When it comes to the state policies that you would prefer from the Schwarzenegger administration, which comes closer to your views? *[rotate]* protection of the environment should be given a priority, even at the risk of curbing economic growth; or economic growth should be given a priority, even if the environment suffers to some extent.

49% protection of the environment should be a priority
42 economic growth should be a priority
9 don't know

35. Overall, do you think that the state government is currently doing more than enough, just enough, or not enough to protect the coastal and marine environment in California?

44% not enough
40 just enough
7 more than enough
9 don't know

36. The state government faces a large budget deficit, and program cuts are needed to balance the budget. Should the state *[rotate]* continue to fund environmental programs at the current level even if it means less funds for other programs; or reduce funding for environmental programs, so that more funds are available for other programs?

48%	continue to fund at current level
35	reduce funding
5	other answer *(specify)*
12	don't know

36b. Which branch of government —*[rotate]* the federal, state, or local government—do you trust to do a better job in handling marine and coastal issues in California?

42%	state government
30	local government
14	federal government
2	other answer *(specify)*
2	none *(volunteered)*
10	don't know

37. Overall, what do you think of the California Coastal Commission when it comes to controls on development—are they too strict, about right, or not strict enough?

38%	not strict enough
31	about right
11	too strict
3	never heard of the Commission *(volunteered)*
17	don't know

38. Next, how often would you say you eat fish or seafood at home or in a restaurant—several times a week, about once a week, sometimes, rarely, or never?

21%	several times a week
33	about once a week
24	sometimes
16	rarely
6	never

39. How important would you say that eating fish or seafood is to your having a healthy diet—very important, somewhat important, not too important, or not at all important?

47%	very important
35	somewhat important
11	not too important
6	not at all important
1	don't know

40. How concerned are you that the fish or seafood for sale are contaminated by ocean pollution—very concerned, somewhat concerned, not too concerned, or not at all concerned?

50%	very concerned
33	somewhat concerned
11	not too concerned
5	not at all concerned
1	don't know

41. How concerned are you that the fish or seafood for sale are commercially overfished—very concerned, somewhat concerned, not too concerned, or not at all concerned?

38%	very concerned
42	somewhat concerned
11	not too concerned
5	not at all concerned
4	don't know

42. Next, how often would you say you visit a beach on the coast of California for any purpose— once a week, once a month, several times a year, once a year, less than once a year, or never?

16%	once a week
20	once a month
36	several times a year
15	once a year
9	less than once a year
4	never

On another topic, please tell me if, in the past 12 months, you have done the following in or on the ocean or bays of the California coast.
[rotate question 43 to 48]

43. In the past 12 months, have you gone swimming in the ocean or bays of the California coast?

43%	yes
57	no

44. In the past 12 months, have you gone recreational or sport fishing on the ocean or bays of the California coast?

17%	yes
83	no

45. In the past 12 months, have you gone sailing or kayaking on the ocean or bays of the California coast?

14%	yes
86	no

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46. In the past 12 months, have you gone surfing on the ocean or bays of the California coast?

10% yes
90 no

47. In the past 12 months, have you gone snorkeling or scuba diving in the ocean or bays of the California coast?

8% yes
92 no

48. In the past 12 months, have you gone motorboating or jet skiing on the ocean or bays of the California coast?

13% yes
87 no

49. In the past few years, have you visited an aquarium or other public places with live fish?

73% yes
27 no

50. Do you currently have an aquarium or some other place at home where you keep pet fish?

21% yes
79 no

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Advisory Committee

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Article published Jan 16, 2006

'First flush' pollutants washed away

Testing after initial rain has been difficult

STOCKTON - Once a year, the first winter rains rinse a varied mix of pesticides, bacteria and other nasties through Stockton's storm-drain system and out to the Delta, poisoning fish and plants.

But exactly how much pollution swims through the city's drains and canals remains largely unknown.

City officials are required to sample what is known as "first flush" - heavy rains that wash away ground pollution built up for months. But often officials don't, because unpredictable weather makes it tricky, if not impossible, to capture the water that would show the true amount of pollution.

"We kind of sit in a strange situation in Stockton. You never know what storms are going to hit us," said Robert Murdoch, the city's stormwater manager. "They always come at the worst times."

Although the city has been monitoring stormwater since getting a permit from the state in 2002, it failed to capture first-flush samples during the 2003-04 rainy season and again in 2004-05.
A 2001 study found pesticides and other pollutants that built up on the city's lawns, streets and gutters were rinsing into the Delta and killing fish.

Although pollutants can be detected in stormwater throughout the rainy season, without first-flush data, officials lose a significant chunk of the puzzle.

"Especially here in California, where we have this nine months of accumulation without rain, that first flush can be loaded with pollutants of various types that would not occur in subsequent storm events," said G. Fred Lee, an environmental consultant based in El Macero, near Sacramento.

In the 2005-06 rainy season, officials managed to do better, snaring stormwater at two of its four stations during rains that fell Dec. 1. But there wasn't enough rainfall at the city's Duck Creek station; and at the American Legion Park station, a device failed that lets operators know when water is coming through.

The city needs at least a quarter-inch of rain after a dry period to measure runoff. But weather forecasts are deceiving, Murdoch said.

Sometimes forecasters predict a storm will dump an inch of rain on the city, but it doesn't come. Sometimes a tenth of an inch of rain is predicted, and the city gets doused. Sometimes storms split, and rain falls on one area of town and not another, Murdoch said.

"You physically have to have people in the field in these locations at different times and as needed," he said. "It can be labor-intensive for a very short period of time. ... There have been many, many times when you mobilize, you get everything set up and prepared and everything, and you don't get enough rain."

Although first-flush samples are considered important, the state does not require them.

According to its stormwater permit, th [illegible] water from two storm "events" each year,

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not just the first flush. But Stockton apparently has had trouble doing that, too.

In 2004, the city violated the conditions of its stormwater permit by missing a number of chances to capture samples during several rainy periods, according to the state Regional Water Quality Control Board. The city was required to correct the problem.

"They provided a really vague reason," said Brett Stevens, an environmental scientist with the state board. "Their argument was it took them five months to prepare for monitoring, and they couldn't do it any quicker. ... We felt they could."

The city also needs to make "a good-faith effort" to sample first-flush water even if there is no penalty, Stevens said.

"It's usually the storm event that is the worst water quality," he said.

Harry Morrow, water operations director for OMI-Thames, which runs Stockton's sewer and stormwater systems, said officials are being more diligent about capturing first-flush samples. "I would like to think we're monitoring things a lot more closely, and we're better able to react," he said.

It takes about an hour after officials hear a storm is coming to get people out to the monitoring stations, Morrow said.
Much of the city's stormwater drains into Smith Canal, which recently was listed as one of the most-polluted waterways in the state. A 2002 study by Lee, the El Macero consultant, which was sponsored by the environmental group DeltaKeeper, found the canal's levels of pathogens and pesticides were high enough to harm people and fish.

Randy Norman, a member of Friends of the Smith Canal, believes the city is making strides.

"I haven't really anything negative to say other than it's been pretty slow," Norman said. "The positive thing is we're moving forward, and we're seeing progress."

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Aquatic Processes and Systems in Perspective

DOI: 10.1039/b603613a

Introduction

This latest *Perspective on Aquatic Processes* focuses on a topic of great value but one that receives little attention—that of the need for water quality monitoring. Research often gets more attention from the public and from funding agencies, but it is monitoring—particularly long term programs—that provide the necessary data to determine trends in assessing ecosystem health. Monitoring programs have been receiving less and less support (and collecting fewer and fewer data), including those of the venerable U.S. Geological Survey (USGS), which has had water monitoring as central to its mission for 130 years. It is possible that there will not be sufficient data available to assess overall environmental quality trends in the near future. We cannot effectively manage or protect our environment without understanding its condition. Without the proper water monitoring data, we cannot develop models for management or forecasting. This Perspective is contributed by Dr Robert Hirsch and his colleagues at the USGS, and makes a strong case for the need for monitoring and discusses the erosion in support of these programs.

Robert M. Hirsch, PhD, has served as Associate Director for Water at the USGS since 1999, and is responsible for all USGS water science programs. He has served as the leader of USGS water programs since 1994. He represents the interests of the USGS in scientific, technical, and leadership aspects of hydrology and serves as the Director's principal advisor on water-related issues. In his capacity as spokesperson for the USGS and its water resources mission, Hirsch holds the title of Chief Hydrologist. He is Co-Chair of the inter-agency Subcommittee on Water Availability and Quality (SWAQ) of the National Science and Technology Council (NSTC). Dr Hirsch is a Fellow of the American Association for the Advancement of Science and an active member of the American Geophysical Union and the American Water Resources Association. Pixie A. Hamilton began her career as a hydrologist with the USGS in 1984 and served as the Water Science Director of USGS water programs in Virginia from 1994–1996. Since then she has served as a hydrologist and water information coordinator for USGS's National Water-Quality Assessment (NAWQA) program. Timothy L. Miller has worked for the USGS since 1973, and has been the Senior Advisor for Water Quality since 1997. Prior to coming to USGS Headquarters in 1987, Mr Miller worked for USGS in his native Oregon. He now serves as the Chief of the USGS Office of Water Quality. He served as Chief of the NAWQA program from 1995 to 2003. The NAWQA program have been collecting and analyzing data and information in more than 50 major river basins and aquifers across the US since 1991. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions.

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U.S. Geological Survey perspective on water-quality monitoring and assessment†

Introduction

Protecting and enhancing the quality of rivers and streams has become a high priority across the United States (U.S.), generating substantial discussion and many reports on the current status and needs for monitoring in the future. Several studies, for example, by the Government Accountability Office (2002, 2004),[1,2] and The H. John Heinz III Center for Science, Economics, and the Environment (2002)[3] have documented the inadequacy of current water-quality monitoring efforts in the U.S. in recent years, and point to the lack of consistent and comprehensive, national-level data (Box 1). The studies report that lack of data has lead to (a) possible serious problems that go undetected; (b) a limited ability to develop cost-effective management and regulations; and (c) an inability to determine whether water quality is getting better or worse. (These reports can be accessed directly at http://water.usgs.gov/wicp/acwi/monitoring/network/links.html.) While the U.S. Geological Survey (USGS) acknowledges the issues, and actively participates in many of the ongoing discussions, we would like to address some of the critical scientific considerations that are fundamental to successful water-quality monitoring programs, regardless of, and transcending any organizational and political agendas, regulatory responsibilities, and jurisdictional boundaries.

† The opinions expressed in the following article are entirely those of the author and do not necessarily represent the views of either the Royal Society of Chemistry, the Editor or the Editorial Board of *JEM*.

Box 1: Current status of U.S. water-quality monitoring

Several studies by the Government Accountability Office (GAO, 2002; 2004),[1,2] The H. John Heinz III Center for Science, Economics, and the Environment (2002),[3] National Research Council of the National Academies (2004),[4] and other organizations have documented the inadequacy of water-quality monitoring and assessment efforts in the U.S. Overall findings point to a lack of consistent and comprehensive, national-level data; the possibility that serious problems may go undetected; data gaps that limit cost-effective management and regulation; and a lack of information on whether water quality is getting better or worse. The most recent GAO study was done in response to the 2002 Heinz Center "State of the Nation's Ecosystems" report that identified 100 key indicators needed for monitoring ecosystem health and measuring the efficacy of environmental protection, and reported that high-quality data existed for only half of the indicators. The GAO study noted continued slow financial erosion of U.S. water-quality data, reporting that 6 of 20 Federal programs—including the USGS National Water-Quality Assessment and National Stream Quality Accounting Network Programs—that had produced high-quality environmental indicator data used in the 2002 Heinz report may not be able to continue producing data of comparable quality, quantity, and scope for the planned 2007 Heinz report and more generally over the medium-term future (Government Accountability Office, 2004).[2] Specific findings cited in the GAO report and other reports on monitoring can be accessed at http://water.usgs.gov/wicp/acwi/monitoring/network/links.html.

Changing issues, changing questions

Before the U.S. Clean Water Act was implemented in 1972, many rivers flowing through urban centers were subjected to "point" discharges of sewage and industrial waste. Point source contamination can be traced to specific "end-of-pipe" points of discharge or outfalls, such as from wastewater treatment plants, factories, or combined sewers. Water-quality issues generally were acute in nature, including biologically dead rivers, fish kills, gross contamination, and massive algal blooms. Such issues culminated on June 23, 1969, when Cleveland's oily, contaminated Cuyahoga River caught fire, attributed to wastes dumped into the river by the waterfront industries. The Cuyahoga River became a poster child for the Federal clean water legislation that followed.

Although water-quality violations still occur, the legislation and investments in wastewater-treatment technology that it spawned have had a positive effect on water-quality conditions. Today, the overwhelming majority of water-quality problems are caused by a myriad of "nonpoint" sources of pollution from agricultural, urban, and suburban land; forest harvesting; energy and mineral extraction; and the atmosphere. The U.S. reauthorization of the Clean Water Act in 1987 added some provisions to begin addressing nonpoint sources and storm water, but legislation can carry actions only so far. Monitoring and science must be adapted to support decisions in this predominantly nonpoint source context.

The nature of water-quality issues facing the U.S. has substantially changed, both in geographic scale and over time. First, nonpoint-source issues are larger in scale than more localized, site-specific point-source issues, and include many diffuse and widespread origins within a watershed and even across regions and the nation. Sources and delivery systems are more difficult to pinpoint, evaluate, and control. Second, the amount of pollution delivered is highly variable—from hour to hour and season to season—making it difficult to quantify nonpoint-source contributions over time. Third, the number of nonpoint-source contaminants is significantly larger than those of 30 years ago, when concerns about water quality focused mostly on the sanitary quality of rivers and streams, including bacteria, turbidity, temperature, nutrients, and dissolved-oxygen concentrations. While these factors are still important, over the last 25 years new and more complex issues have emerged. For example, hundreds of synthetic organic compounds, including pesticides and volatile organic compounds (VOCs) in solvents and gasoline have been introduced into the environment. Fourth, nonpoint-source contamination is subject to, and largely influenced by, the natural and altered landscape and the type of human activities that take place on that landscape as water and associated contaminants move over the land and into the ground. Even given similar nonpoint sources within a watershed, differences in hydrologic processes and delivery mechanisms, land-management activities, and natural features, such as soils, geology, topography, and climate may result in one watershed being more vulnerable to contamination than another, and thus require different management strategies to protect or improve water quality.

Successful implementation of nonpoint controls and support in the political and legal systems depends on monitoring systems that help to identify and quantify possible nonpoint sources. Equally important, monitoring must clearly link water-quality conditions with the causes of those conditions, which are in turn related to the natural landscape, hydrologic processes, and human activities—building towards an understanding of how, when, where, and why water-quality conditions vary among watersheds across the nation. Sustainable, high-quality water and effective decision-making depend greatly on this scientific understanding.

Monitoring for scientific understanding of how and why watersheds work

What does monitoring for scientific understanding really entail? Primarily, it requires a design (referred to here as "targeted") in which sites are selected because they represent certain human activities, environmental settings, or hydrologic conditions during different seasons or times of year. For example, sites may be selected to assess the effects of agriculture and urban land-use practices on pesticide and nutrient contamination in streams. A targeted monitoring design requires ancillary information on land use, chemical sources of contamination, natural landscape features, and hydrologic transport. Such a design also requires the collection of various data.

Data required for a targeted monitoring design

Over different seasons. USGS assessments generally show low concentrations of contaminants, such as pesticides, in streams for most of the year—lower than most standards and guidelines established to protect aquatic life and human health. However, the assessments also show pulses of elevated concentrations—commonly 100 to 1000 times higher—during times of the year associated with rainfall and chemical applications than during other times of the year (Gilliom *et al.*, 2006).[5] Such pulses could affect aquatic life at critical points in the life cycle and also affect drinking-water supplies for short periods. These conditions cannot be described in a meaningful way unless repetitive, time- and flow-dependent, monitoring is conducted at given sampling locations, with a substantial part of that sampling focused at times that are prone to large water-quality changes. Multiple samples are less critical in ground water as changes occur more slowly and generally are less influenced by seasonal conditions or individual hydrologic events.

Among different land uses. Water-quality conditions differ substantially among different land-use settings, such as agricultural, urban and more pristine settings that are relatively undeveloped. USGS studies show, for example, that insecticides occur more frequently and generally at higher concentrations in urban streams than in agricultural streams (Gilliom *et al.*, 2006).[5] Water-quality conditions also vary considerably within land-use settings by crop type and land-use practices. For example, USGS assessments show that concentrations of phosphorus, sediment, and selected pesticides are higher in streams draining agricultural fields with furrow irrigation than in streams draining agricultural fields with sprinkler irrigation (Hamilton *et al.*, 2004).[6]

In different geologic or climatic settings. The setting—whether it is sand and gravel or igneous rock—affects how readily water and associated contaminants move over the land and into the ground. USGS studies show, for example, that ground water underlying intensive agriculture in parts of the Upper Midwest is minimally contaminated where it is protected by relatively impermeable soils and glacial till that cover much of the region, and yet subsurface agricultural tile drains and ditches provide quick pathways for contaminant delivery to streams in this same area (U.S. Geological Survey, 1999).[7] Similarly, climate can have profound effects on water quality. Water-quality conditions associated with a particular land-use practice in a hot, dry climate can differ substantially from those associated with a similar practice in a cold, wet climate.

During different hydrologic conditions. A large part of the variation in water quality at a given location on a stream is determined by stream flow. Amounts of contaminants measured at a sampling location or entering a receiving water body, such as a lake, reservoir, or estuary can increase substantially from year to year simply because of high flows during wet environmental conditions.

Including biological characteristics. Water quality and biological systems are closely interconnected. Aquatic organisms, such as algae, macroinvertebrates, and fish are susceptible to water-quality degradation. Meaningful water-quality assessments therefore depend on biological monitoring and determinations of how the biological response varies among diverse hydrologic settings.

Over the long term. Water quality continually changes. The changes can be relatively quick—within days, weeks, or months, such as demonstrated in streams in the Midwest where the types of herbicides used on corn and soybeans have changed. Or, changes can be relatively slow, such as in aquifers where changes can take decades because of slow ground-water movement (Gilliom *et al.*, 2006).[5] Without comparable data collected over time, long-term trends cannot be distinguished from short-term fluctuations, and natural fluctuations cannot be distinguished from the effects of human activities. Consistent and systematic long-term monitoring also is critical to evaluating whether environmental and management strategies are working, and to choosing the most cost-effective resource-management strategies for the future.

Solving water-resource issues

Targeted monitoring and the resulting scientific understanding help to answer questions, such as "Why do water-quality conditions occur and when? Do certain natural features, land uses, human activities, and management actions affect the occurrence and movement of certain contaminants? Is water quality getting better or worse?" The information helps decision-makers to more cost-effectively: (1) identify and prioritize those streams, aquifers, and watersheds most vulnerable to contamination and in need of protection; (2) target management actions to specific sources and causes of pollution; and (3) evaluate the effectiveness of those actions over time.

The USGS recognizes that one monitoring design cannot solve all water-resource issues or questions (Box 2). For example, probabilistic monitoring, in which sites are selected randomly across a certain region, is a useful method for obtaining an unbiased, broad geographic snapshot of "whether there is a problem" and "how big the problem is." Many probabilistic monitoring programs currently being implemented by States and within the U.S. Environmental Protection Agency (EPA) are providing quantitative, statistically valid estimates of, for example, the number of impaired stream miles within a region or State. Targeted and probabilistic monitoring designs are both important for answering different types of questions and for providing different types of information that are critical for understanding the ambient resource. The two designs, therefore, should not be viewed as competitive or duplicative, and both need to be supported by adequate funding. In fact, these designs are so different that discussions should not focus on

Box 1: Current status of U.S. water-quality monitoring

Several studies by the Government Accountability Office (GAO, 2002; 2004),[1,2] The H. John Heinz III Center for Science, Economics, and the Environment (2002),[3] National Research Council of the National Academies (2004),[4] and other organizations have documented the inadequacy of water-quality monitoring and assessment efforts in the U.S. Overall findings point to a lack of consistent and comprehensive, national-level data; the possibility that serious problems may go undetected; data gaps that limit cost-effective management and regulation; and a lack of information on whether water quality is getting better or worse. The most recent GAO study was done in response to the 2002 Heinz Center "State of the Nation's Ecosystems" report that identified 100 key indicators needed for monitoring ecosystem health and measuring the efficacy of environmental protection, and reported that high-quality data existed for only half of the indicators. The GAO study noted continued slow financial erosion of U.S. water-quality data, reporting that 6 of 20 Federal programs—including the USGS National Water-Quality Assessment and National Stream Quality Accounting Network Programs—that had produced high-quality environmental indicator data used in the 2002 Heinz report may not be able to continue producing data of comparable quality, quantity, and scope for the planned 2007 Heinz report and more generally over the medium-term future (Government Accountability Office, 2004).[2] Specific findings cited in the GAO report and other reports on monitoring can be accessed at http://water.usgs.gov/wicp/acwi/monitoring/network/links.html.

Changing issues, changing questions

Before the U.S. Clean Water Act was implemented in 1972, many rivers flowing through urban centers were subjected to "point" discharges of sewage and industrial waste. Point source contamination can be traced to specific "end-of-pipe" points of discharge or outfalls, such as from wastewater treatment plants, factories, or combined sewers. Water-quality issues generally were acute in nature, including biologically dead rivers, fish kills, gross contamination, and massive algal blooms. Such issues culminated on June 23, 1969, when Cleveland's oily, contaminated Cuyahoga River caught fire, attributed to wastes dumped into the river by the waterfront industries. The Cuyahoga River became a poster child for the Federal clean water legislation that followed.

Although water-quality violations still occur, the legislation and investments in wastewater-treatment technology that it spawned have had a positive effect on water-quality conditions. Today, the overwhelming majority of water-quality problems are caused by a myriad of "nonpoint" sources of pollution from agricultural, urban, and suburban land; forest harvesting; energy and mineral extraction; and the atmosphere. The U.S. reauthorization of the Clean Water Act in 1987 added some provisions to begin addressing nonpoint sources and storm water, but legislation can carry actions only so far. Monitoring and science must be adapted to support decisions in this predominantly nonpoint source context.

The nature of water-quality issues facing the U.S. has substantially changed, both in geographic scale and over time. First, nonpoint-source issues are larger in scale than more localized, site-specific point-source issues, and include many diffuse and widespread origins within a watershed and even across regions and the nation. Sources and delivery systems are more difficult to pinpoint, evaluate, and control. Second, the amount of pollution delivered is highly variable—from hour to hour and season to season—making it difficult to quantify nonpoint-source contributions over time. Third, the number of nonpoint-source contaminants is significantly larger than those of 30 years ago, when concerns about water quality focused mostly on the sanitary quality of rivers and streams, including bacteria, turbidity, temperature, nutrients, and dissolved-oxygen concentrations. While these factors are still important, over the last 25 years new and more complex issues have emerged. For example, hundreds of synthetic organic compounds, including pesticides and volatile organic compounds (VOCs) in solvents and gasoline have been introduced into the environment. Fourth, nonpoint-source contamination is subject to, and largely influenced by, the natural and altered landscape and the type of human activities that take place on that landscape as water and associated contaminants move over the land and into the ground. Even given similar nonpoint sources within a watershed, differences in hydrologic processes and delivery mechanisms, land-management activities, and natural features, such as soils, geology, topography, and climate may result in one watershed being more vulnerable to contamination than another, and thus require different management strategies to protect or improve water quality.

Successful implementation of nonpoint controls and support in the political and legal systems depends on monitoring systems that help to identify and quantify possible nonpoint sources. Equally important, monitoring must clearly link water-quality conditions with the causes of those conditions, which are in turn related to the natural landscape, hydrologic processes, and human activities—building towards an understanding of how, when, where, and why water-quality conditions vary among watersheds across the nation. Sustainable, high-quality water and effective decision-making depend greatly on this scientific understanding.

Monitoring for scientific understanding of how and why watersheds work

What does monitoring for scientific understanding really entail? Primarily, it requires a design (referred to here as "targeted") in which sites are selected because they represent certain human activities, environmental settings, or hydrologic conditions during different seasons or times of year. For example, sites may be selected to assess the effects of agriculture and urban land-use practices on pesticide and nutrient contamination in streams. A targeted monitoring design requires ancillary information on land use, chemical sources of contamination, natural landscape features, and hydrologic transport. Such a design also requires the collection of various data.

Data required for a targeted monitoring design

Over different seasons. USGS assessments generally show low concentrations of contaminants, such as pesticides, in streams for most of the year—lower than most standards and guidelines established to protect aquatic life and human health. However, the assessments also show pulses of elevated concentrations—commonly 100 to 1000 times higher—during times of the year associated with rainfall and chemical applications than during other times of the year (Gilliom *et al.*, 2006).[5] Such pulses could affect aquatic life at critical points in the life cycle and also affect drinking-water supplies for short periods. These conditions cannot be described in a meaningful way unless repetitive, time- and flow-dependent, monitoring is conducted at given sampling locations, with a substantial part of that sampling focused at times that are prone to large water-quality changes. Multiple samples are less critical in ground water as changes occur more slowly and generally are less influenced by seasonal conditions or individual hydrologic events.

Among different land uses. Water-quality conditions differ substantially among different land-use settings, such as agricultural, urban and more pristine settings that are relatively undeveloped. USGS studies show, for example, that insecticides occur more frequently and generally at higher concentrations in urban streams than in agricultural streams (Gilliom *et al.*, 2006).[5] Water-quality conditions also vary considerably within land-use settings by crop type and land-use practices. For example, USGS assessments show that concentrations of phosphorus, sediment, and selected pesticides are higher in streams draining agricultural fields with furrow irrigation than in streams draining agricultural fields with sprinkler irrigation (Hamilton *et al.*, 2004).[6]

In different geologic or climatic settings. The setting—whether it is sand and gravel or igneous rock—affects how readily water and associated contaminants move over the land and into the ground. USGS studies show, for example, that ground water underlying intensive agriculture in parts of the Upper Midwest is minimally contaminated where it is protected by relatively impermeable soils and glacial till that cover much of the region, and yet subsurface agricultural tile drains and ditches provide quick pathways for contaminant delivery to streams in this same area (U.S. Geological Survey, 1999).[7] Similarly, climate can have profound effects on water quality. Water-quality conditions associated with a particular land-use practice in a hot, dry climate can differ substantially from those associated with a similar practice in a cold, wet climate.

During different hydrologic conditions. A large part of the variation in water quality at a given location on a stream is determined by stream flow. Amounts of contaminants measured at a sampling location or entering a receiving water body, such as a lake, reservoir, or estuary can increase substantially from year to year simply because of high flows during wet environmental conditions.

Including biological characteristics. Water quality and biological systems are closely interconnected. Aquatic organisms, such as algae, macroinvertebrates, and fish are susceptible to water-quality degradation. Meaningful water-quality assessments therefore depend on biological monitoring and determinations of how the biological response varies among diverse hydrologic settings.

Over the long term. Water quality continually changes. The changes can be relatively quick—within days, weeks, or months, such as demonstrated in streams in the Midwest where the types of herbicides used on corn and soybeans have changed. Or, changes can be relatively slow, such as in aquifers where changes can take decades because of slow ground-water movement (Gilliom *et al.*, 2006).[5] Without comparable data collected over time, long-term trends cannot be distinguished from short-term fluctuations, and natural fluctuations cannot be distinguished from the effects of human activities. Consistent and systematic long-term monitoring also is critical to evaluating whether environmental and management strategies are working, and to choosing the most cost-effective resource-management strategies for the future.

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Box 2: Collaboration and cooperation

The USGS adheres to rigorous scientific standards and national quality-assurance programs with uniform methods of sampling and analysis. This approach is crucial for successful comprehensive regional and national assessments that identify current conditions and trends in water-quality conditions. However, no single agency can advance these goals alone, and therefore, the USGS strongly supports the coordination in which the wider water-quality monitoring community is heading. Much of the coordination is spearheaded by the National Water-Quality Monitoring Council (NWQMC) of the Advisory Committee on Water Information (ACWI); information on specific efforts can be accessed at http://water.usgs.gov/wicp/acwi/monitoring/index.html. Primary goals of the NWQMC are to: increase collaboration and partnerships among agencies and non-governmental organizations; standardize sampling and analytical methodology and quality assurance and quality control protocols; promote metadata to allow exchange and integration of data from a variety of organizations; develop stable national monitoring networks; and, integrate data management and data accessibility.

whether one design can substitute for another, but rather on how to integrate the two in order to go beyond what each can provide individually. Ideally, data-collection and laboratory analytical methods should be consistent and comparable so that findings can be integrated.

Hydrologic tenets that underpin successful monitoring

Water monitoring has been central to the USGS mission for nearly 120 years (Box 3). The USGS experience has shown that water information that supports effective decision-making requires recognition of, and commitment to, several fundamental hydrologic tenets that underpin all monitoring.

First, hydrology is a cycle

Water-quality data must be evaluated in a "total resource" context, including all components of the hydrologic cycle. Surface water, ground water, and the atmosphere are all connected, and the interactions among them are crucial to determining water flow, fate and transport of contaminants, and chemical and biological quality. Water quality and watersheds are too often considered solely in terms of rivers and streams and the land draining to those surface-water bodies. Yet, ground water can be a major contributor to rivers, streams, and other surface-water bodies; contaminated aquifers that discharge to waterways can, therefore, become nonpoint-pollution sources. For example, USGS studies show that in the Chesapeake Bay, more than half of the water and the nutrients it carries first travels through the ground-water system, and then is delivered as baseflow to tributary streams or directly into the bay (Bachman *et al.*, 1998).[8]

Quantifying ground-water contribution to surface water is essential to developing total maximum daily loads (TMDLs), issuing permits, and meeting Clean Water Act goals. To ensure that water-quality standards can be attained, for example, Clean Water Act Section 303(d) requires states to identify water bodies impaired by pollution and to establish a TMDL of selected pollutants for each water body. Yet, the percentage of the total contaminant load that is contributed by ground-water inputs rarely is evaluated in estimating stream contaminant loads. Exclusion of ground-water monitoring may prevent a full accounting of all available sources and may limit the effectiveness that TMDLs could have in future stream protection and restoration efforts. Similarly, surface water can be a major contributor to ground water and, therefore, a major nonpoint-contamination source for aquifers, particularly where high-capacity, public-supply wells are located near rivers and streams.

Second, hydrology controls the quality of our waters

Water-quality data must be evaluated in concert with water quantity. Concentrations and types of contaminants and their potential effects on ecosystems and drinking-water supplies vary over time,

Box 3: Mission of the U.S. Geological Survey

The U.S. Geological Survey (USGS) has monitored and assessed the quantity and quality of U.S. streams and ground water since its inception in 1879. Today, the USGS provides information on issues such as availability and suitability of water for public supply and irrigation, aquatic ecosystem health, effects of agriculture and urbanization on water resources, and disposal of radioactive waste. Through its programs, the USGS continues its mission to provide timely and relevant water-resources data and information that is freely available to all levels of government, non-governmental organizations, industry, academia, and the general public. The information provides a scientific basis for decision-making related to resource management and restoration, and how we as individuals interact with our environment. The USGS has no regulatory responsibilities and focuses on monitoring and evaluating the ambient water resource, which is the source of the nation's drinking water and water used for industry, irrigation, and recreation. The USGS monitoring programs thereby complement much of the compliance and regulatory monitoring conducted at the state level. The USGS monitors and assesses a multitude of chemicals, including some that are regulated and some that are unregulated, which helps to address new and emerging water-quality issues. Consistent methodology is used across States, which allows regional and national assessments.

and depend largely on the amount of water flowing in streams and the amounts and directions of ground-water flow. Contaminant concentrations vary greatly between low and high flows, during different seasons of a year, and during different hydrologic regimes—such as periods when snowmelt or ground-water inflow dominates river flow. It is critical to monitor water quality under these different hydrologic conditions, and to evaluate the load of material that is transported in a stream and river and delivered to receiving bodies, such as lakes, reservoirs, estuaries, and bays (this is referred to as the "mass flux", which is the concentration of a compound multiplied by stream flow).

Only part of the water-quality story can be told from monitoring for concentrations of chemical constituents in water without the quantitative hydrologic context and calculation of fluxes. Using the Chesapeake Bay as an example, USGS monitoring from 1985 through 2003 showed that concentrations of nitrogen and phosphorus decreased at 55 and 75 percent, respectively, of the stream sites along the major rivers entering the bay (Langland *et al.*, 2004; Cohn *et al.*, 1989).[9,10] An important conclusion from the concentration data and analysis is that management actions in the bay watershed are having some positive effect in reducing nutrients. However, the "flux story" of the bay is somewhat different, in large part because of high stream flows during 2003. USGS findings indicated that in 2003, fluxes of nitrogen and phosphorus were the second highest since 1990 in some of the large rivers (such as the Potomac and Susquehanna) entering the bay. These fluxes were influenced by near-record river flows from elevated precipitation—2003 represented the third-highest amount of river flow to enter the bay since 1937 when USGS record-keeping began for these rivers. More than twice the amount of river flow entered the bay in 2003 than in 2002, which marked the end of a 3-year drought. As a result, about 3 times the amount of nitrogen, 5 times the amount of phosphorus, and 11 times the amount of sediment entered the bay in 2003 compared to drier times in 2002. High stream flow and resulting high fluxes in 2003 may help to explain why the bay experienced periods of low concentrations of dissolved oxygen (hypoxia) and loss of submerged aquatic vegetation (Langland *et al.*, 2004).[9]

Third, hydrology controls much of the timing of our water issues

We must be patient, persistent, and committed to monitoring over long time scales, remaining mindful of placing our monitoring data within a historical, hydrologic context. This is particularly true for changes in ground-water and sediment quality, which may not be evident for years or even decades. Continuing with the Chesapeake Bay as an example, USGS studies show that dissolved nitrogen associated with ground-water discharge to streams may have a transport time through the ground-water system of years to decades, with a median time of about 10 years. Nutrients associated with sediment can have even longer transport times (several decades) in the watershed because of their storage in soil and stream corridors, both of which are greatly influenced by yearly rainfall. This is in contrast to dissolved nitrogen associated with surface runoff that has a transport time of hours to months in the watershed (Phillips and Lindsey, 2003).[11]

A long-term, hydrologic context is important when evaluating effects of management practices. For example, the effects of management practices to reduce nutrient inputs to ground water, which have been implemented in many agricultural areas on the Delmarva Peninsula (in Delaware, Maryland, and Virginia) over the last 10 years, are not generally apparent in the deep parts of the aquifer used for domestic supply. Because ground water typically moves slowly, about 0.25–2 feet per day, decreases in nutrient concentrations deep within the aquifer may not be apparent for decades (Hamilton *et al.*, 2004).[6]

The long-term, hydrologic context is also important to sort out the effects of natural variability from the effects of man's activities. Natural events such as floods or drought often can mask shorter term, human actions as suggested above in the case of Chesapeake Bay where we noted a pattern of particularly wet or dry years. Only after understanding the patterns within the historic hydrologic record are we likely to recognize any underlying changes that are taking place due to man's activities.

Moving from monitoring to prediction

The development and verification of predictive tools and models is an essential step in understanding and successfully managing U.S. waters in the future. Such tools are needed to extrapolate or forecast conditions to unmonitored, yet comparable areas, both in space and in time. In light of increasingly diminishing resources, we simply cannot expect to monitor our water resources directly in all places and at all times. We therefore must get smarter, enhancing the value of data collected at individual sites, and applying our understanding of the hydrologic system and water-quality conditions to broader areas, including entire stream reaches and aquifers, large river basins, ecoregions, states, and even the nation. Moving from monitoring to modeling ultimately gives us state-wide, regional, and even national assessments of water quality.

The development of predictive tools helps to prioritize contaminant sources and to tease out the importance of factors affecting water quality, including landscape features and hydrologic transport. These predictive tools can help estimate conditions that often cannot be directly measured, such as the effects of specific management practices or the percentage of contamination in a stream that originates from different sources. For example, the Gulf of Mexico experiences low concentrations of dissolved oxygen each spring and summer largely as a result of large amounts of nitrogen delivered by the Mississippi River, which in turn promotes excessive growth of algae and other nuisance plants and potentially can harm the fisheries. The USGS model SPARROW (SPAtially Referenced Regression On Watershed attributes) shows that a considerable amount of the nitrogen delivered to the Gulf of Mexico originates in distant watersheds in the Mississippi River Basin, such as in Ohio and Tennessee (Alexander *et al.*, 2000).[12]

In addition, models can be used to estimate probabilities that concentrations of selected compounds will exceed a specific value, such as a drinking-water standard or an aquatic-life guideline, at a particular location. The SPARROW model has been applied, for example, to predict in-stream concentrations of phosphorus in streams across the U.S. that meet the EPA recommended goal of 0.1 milligrams per litre to control excessive growth of algae and other nuisance plants. The USGS WARP (Watershed Regressions for Pesticides) model (developed from measured pesticide concentrations in streams, together with information on pesticide use and land use, climate and soil characteristics, and other natural features) has been used to estimate concentrations of atrazine in streams and, specifically, to predict the likelihood that annual average atrazine concentrations in any particular stream in the U.S. would exceed the EPA drinking-water standard of 3 micrograms per litre (Larson *et al.*, 2004).[13] A USGS ground-water model has been used to predict the presence of atrazine in shallow ground water within agricultural areas across the nation; model results show the highest detection frequencies of atrazine in parts of the Midwest, Great Plains, Pacific Northwest, and Mid-Atlantic regions where atrazine is heavily used in hydrologic settings that favor the transport of pesticides to ground water (Stackelberg *et al.*, 2006).[14] Similarly, a USGS nitrate model used to assess the risk of nitrate contamination in shallow ground water across the U.S. shows that nitrate concentrations are expected to be lowest in shallow ground water underlying areas with low inputs of nitrogen and poorly drained soils, such as in parts of the southeastern Coastal Plain, and highest in areas with high nitrogen inputs and well-drained soils that overlie unconsolidated sand and gravel aquifers, such as in the High Plains of northeastern Nebraska and the western U.S. (Nolan *et al.*, 2002).[15] Although results from these models may not be used directly when making policy decisions, they provide critical insights into the locations of our more vulnerable water resources, and help to prioritize where and how we spend our future monitoring dollars.

Continued advancements in predicting and modeling water-quality conditions will depend on two important components. First, we must dedicate resources to gather ancillary data necessary to interpret water-quality data, including better information on the use of chemicals, land-use changes, water use, land-management practices, geomorphology and stream networks, geologic setting, and also point-source discharges. Unfortunately, many of these spatial data are lacking. For example, current chemical-use information is generally insufficient—and in urban areas essentially unavailable—for local and regional water-resource management and decision-making, and yet, information on chemical use is needed to definitely attribute specific pollutants to different sources in nonpoint runoff and support management actions. Unless we continue to improve relevant geospatial data sets, we will make little progress in understanding and managing water quality. Advances in remote sensing may provide cost-effective ways to enhance and spatially extend selected compilations of data associated with the landscape, human activities, and environmental settings.

Second, we must continue to integrate monitoring with predictive tools. The direction for future model development is towards better representation of the physical, chemical and biological processes in the models, coupled with powerful statistical techniques to estimate the importance of various factors used in the models. Credible, comparable, and comprehensive information must continue to be generated—by means of "on-the-ground" monitoring, assessment, and research—that can be used to validate and verify model predictions. Continued monitoring and data collection will reduce the overall uncertainty of model predictions and estimates. In turn, uncertainty analyses associated with each prediction will help to guide future monitoring and data-collection needs.

Advancing monitoring technology

Advances related to monitoring technology also are needed to successfully support future water-quality issues. These advancements include, for example, continued development and testing of water-quality probes, monitors, data recorders, and telemetry equipment that allow us to monitor water-quality properties on a real-time or near real-time basis. Real-time sensors of water quality can allow a high density of measurements over relatively short periods, which is critical because water-quality conditions can vary widely, such as before, during, and after storms. Sensors can be cost-effective because they minimize costly field visits by scientists and technicians. In addition, real-time measurements for temperature, conductance, and turbidity can be correlated with other important properties, such as bacteria, that are more costly and difficult to monitor and analyze. Development, testing, and deployment of a new generation of real-time sensors for water quality have the potential to greatly increase the level of information available at a given level funding.

In summary

Water-quality issues have increased in complexity as we have moved from point-source controls, focusing on "end of pipe" site-specific data, to investments in water-quality protection and enhancement, focusing on nonpoint-source pollution and a whole-watershed approach. Given the increased complexity, achieving sustainable high-quality water supplies across the nation requires recognition of certain hydrologic tenets that drive water-quality conditions, and firm commitments to: (1) understanding the relations between water-quality conditions and the natural landscape, hydrologic processes, and the human activities that take place on the landscape within watersheds; (2) assessing water quality in a "total resource" context; (3) evaluating water quality in concert with water quantity; (4) evaluating water quality in concert with biological systems; (5) monitoring over long time scales, remaining mindful of placing measurements in a historical, hydrologic context; (6) moving from monitoring to prediction and applying our understanding of the hydrologic system and water-quality conditions to unmonitored, yet comparable areas; (7) investing resources to gather ancillary information on landscape and human factors controlling water quality; and (8) advancing monitoring technology, such as that for measuring water quality in real time.

This commitment will provide the critical and improved scientific basis for decision-makers to effectively manage and protect water resources across the nation and in specific geographic areas, now and in the future. The science will provide the needed basis to prioritize the multitude of decisions involving the increasing number of competing demands for safe drinking water, irrigation, aquatic ecosystem health, wetland protection, native and endangered species preservation, and recreation.

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science for a changing world

Selected Findings and Current Perspectives on Urban and Agricultural Water Quality by the National Water-Quality Assessment Program

Studies by the USGS National Water-Quality Assessment (NAWQA) program in the last decade describe water-quality conditions in nearly 120 agricultural and 35 urban watersheds ("urban" primarily refers to residential and commercial development over the last 50 years). The findings show that for both urban and agricultural areas, nonpoint chemical contamination is an issue. Much work still needs to be done in urban areas with point source contamination as well, including infrastructure improvements. Appreciable improvements in overall water quality, however, will depend upon effective management of point and nonpoint sources. The findings also show that water-quality conditions and aquatic health reflect a complex combination of land and chemical use, land-management practices, population density and watershed development, and natural features, such as soils, geology, hydrology, and climate. Contaminant concentrations vary from season to season and from watershed to watershed. Even among seemingly similar land uses and sources of contamination, different areas can have very different degrees of vulnerability and, therefore, have different rates at which improved treatment or management can lead to water-quality improvements.

Water Quality in Agricultural Watersheds

- Nitrogen and phosphorus in surface water commonly exceed levels that contribute to excessive algae. For example, average annual concentrations of phosphorus in nearly 80 percent of streams sampled in agricultural areas were greater than the U. S. Environmental Protection Agency (USEPA) desired goal for preventing nuisance plant growth in streams. Excessive plant growth can lead to low dissolved oxygen, which can be harmful to fish and other aquatic life.
- Nitrate is often elevated above background levels in shallow ground water underlying farmland. Concentrations in about 20 percent of shallow wells sampled in agricultural areas exceeded the USEPA drinking water standard. This result is a concern in rural areas where shallow ground water is used for domestic supply; these domestic wells are not regulated and owners often do not know the quality of their well water or whether their wells are vulnerable to contamination. Nitrate is most often elevated in karst (carbonate) areas or where soils and aquifers consist of sand and gravel. These natural features enable rapid infiltration and downward movement of water and chemicals. Some of the more vulnerable areas are the Central Valley of California, and parts of the Pacific Northwest, the Great Plains, and the Mid-Atlantic region. In contrast, ground-water contaminants underlying farmland in parts of the upper Midwest are barely detectable, despite similar high rates of chemical use. In these areas ground-water contamination may be limited because of relatively impermeable, poorly drained soils and glacial till that cover much of the region, and because tile drains provide quick pathways for runoff to streams.
- Pesticides are widespread. At least one pesticide was detected in more than 95 percent of stream samples. Pesticides were detected in more than 60 percent of shallow wells sampled in agricultural areas.
- Pesticides commonly occur in mixtures. Two-thirds of stream samples collected in agricultural areas contained 5 or more pesticides, and more than one-quarter of the samples contained 10 or more. Ground water contained fewer pesticides; about 30 percent of the wells sampled contained 2 or more.
- Concentrations of pesticides generally are low and below drinking-water standards. However, the risk to humans and the environment from present-day low levels of contaminant exposure remains unclear. For example, current standards and guidelines do not yet account for exposure to mixtures, and many pesticides and their breakdown products do not have standards or guidelines.
- Herbicides—most commonly atrazine and its breakdown product desethylatrazine, and metolachlor, cyanazine, and alachlor—occur more frequently and usually at higher concentrations in agricultural streams and ground water than in urban waters. Their occurrence is linked to their use; they rank in the top five in national herbicide use for agriculture.
- Insecticides that were used in the past still persist in agricultural streams and sediment. DDT was the most commonly detected organochlorine compound, followed by dieldrin and chlordane. Their uses were restricted in the 1970s and 1980s and, yet, more than 20 years later, one or more sediment-quality guidelines were exceeded at more than 20 percent of agricultural sites.

U.S. Geological Survey
U.S. Department of the Interior

FS–047–01
April, 2001

Water Quality in Urban Watersheds

- Concentrations of fecal coliform bacteria commonly exceed recommended standards for water-contact recreation.
- Concentrations of total phosphorus are generally as high in urban streams as in agricultural streams. More than 70 percent of sampled urban streams exceeded the USEPA desired goal for preventing nuisance plant growth.
- Insecticides, such as diazinon, carbaryl, chlorpyrifos, and malathion, occur more frequently, and usually at higher concentrations in urban streams than in agricultural streams. Concentrations are low in urban streams, rarely exceeding USEPA drinking-water standards. However, effects on aquatic life may be more of a concern. Concentrations of insecticides exceeded at least one guideline established to protect aquatic life in every sampled urban stream.
- Herbicides are widespread in surface water (detected in 99 percent of urban stream samples) and ground water (detected in more than 50 percent of sampled wells). Most common are those applied to lawns, golf courses, and road right-of-ways, such as atrazine, simazine, and prometon.
- Similar to agricultural areas, pesticides in urban waters commonly occur in mixtures; nearly 80 percent of stream samples contained 5 or more pesticides. Two of the most commonly detected insecticides in mixtures were diazinon and chlorpyrifos; common herbicides detected were simazine and prometon.
- Sediment in urban streams is associated with higher frequencies of occurrence of DDT, chlordane, and dieldrin and higher concentrations of chlordane and dieldrin than sediment in agricultural streams. Sediment-quality guidelines for organochlorine pesticides were exceeded at 36 percent of sampled urban sites.
- Volatile organic compounds, which are used in plastics, cleaning solvents, gasoline, and industrial operations, occur widely in shallow urban ground water. Some of the most frequently detected of the 60 analyzed compounds were the commercial and industrial solvents trichloroethene (TCE), tetrachloroethene (PCE), and methylene chloride; the gasoline additive methyl tert-butyl ether (MTBE); and the solvent and disinfection by-product of water treatment, trichloromethane (also known as chloroform).
- Concentrations of selected trace elements, such as cadmium, lead, zinc, and mercury, are elevated above background levels in populated urban settings, most likely caused by emissions from industrial and municipal activities and motor vehicles. Sediment cores from streambeds and reservoirs, which can be used to track changes over long time periods, indicate that lead increased from 1940s to the 1970s, and began to decrease after it was removed from gasoline. Concentrations are not yet down to background levels. Decreases also are noted for DDT and chlordane.
- In contrast to lead, DDT, and chlordane, sediment cores indicate that zinc and polycyclic aromatic hydrocarbons (PAHs, which result from fossil fuel combustion) are increasing. These increases most likely relate to increasing motor vehicle traffic in watersheds. Sediment-quality guidelines for PAHs were exceeded at more than 40 percent of urban sites.
- Toxic compounds in streambed sediment in urban areas, such as DDT, chlordane, dieldrin, and PCBs, also were found in fish tissue, often at higher concentrations than in the sediment. One or more organochlorine compounds were detected in 97 percent of whole fish samples collected at urban sites, and PCBs were detected in more than 80 percent of whole fish samples. Concentrations of organochlorine compounds exceeded guidelines to protect wildlife at more than 10 percent of urban sites; wildlife guidelines for PCBs were exceeded at nearly 70 percent of urban sites. These findings have contributed to decisions by some states to issue fish-consumption advisories.
- Deteriorated water quality and sediment, as well as habitat disturbances, contribute to degraded biological communities in urban streams. The greatest effects are seen in areas with the highest human population densities and watershed development. Pollution-tolerant algae and aquatic invertebrates (such as worms and midges), as well as omnivorous fish communities, prevail at the affected sites.

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Monitoring in the 21st Century to Address our Nation's Water-Resource Questions

By Timothy L. Miller
February 25, 2005

A time of increasing complexity

Water-quality monitoring has become a high priority across the Nation, in large part because the issues are more complex and money is tighter. The demand for high-quality water is increasing in order to support a complex web of human activities and fishery and wildlife needs. This increasing demand for water, along with population growth and point and nonpoint sources of pollution, threatens the quality *and* quantity—and therefore the availability—of all our water resources.

This is a challenge all across the country. Areas once thought of as "water rich"—mostly in terms of limitless availability—are now considered "water challenged," such as in southern Florida, where available water must support 6 million people along their coasts, extensive agriculture south of Lake Okeechobee, and ecosystems in the Everglades and the Florida Bay. No longer is only the arid western U.S. challenged to manage its water needs for drinking, irrigation, aquatic ecosystems, and recreation.

As was acknowledged more than 30 years ago when the Clean Water Act was implemented, monitoring is fundamental to successful management of water resources. However, the nature of monitoring must adapt to increasingly complex water demands and issues. Monitoring is no longer limited to "end of pipe" site-specific data on dissolved oxygen or suspended solids, collected for day-to-day evaluations of compliance or decisions about permitting. Three specific challenges force a shift in monitoring since the implementation of the Clean Water Act.

- Most water-quality problems are caused by diffuse "nonpoint" sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These sources are more difficult to monitor, evaluate, and control than point sources, such as discharges of sewage and industrial waste. The amount of pollution from nonpoint sources varies from hour-to-hour and season-to-season, making it difficult to monitor and quantify the sources over time.
- Water-quality issues themselves have become more complex. Forty years ago, concerns about water quality focused largely on the sanitary quality of rivers and streams—in bacteria counts, nutrients, dissolved oxygen for fish, and a few measures like temperature and salinity. While these factors are still important, new and more complex issues have emerged. Hundreds of synthetic organic compounds, like pesticides and volatile organic compounds (VOCs) in solvents and gasoline have been introduced into the environment. Over the last 10 years, improved laboratory techniques have led to the "discovery" in our waters of microbial and viral contaminants, pharmaceuticals, and hormones that weren't measured before.
- Evaluation and monitoring of pollution sources and of the condition of our water resources have been limited because available information is fragmented. Inconsistency in the types of data collected, the standards and analytical methods used, and the selection of monitoring sites makes it difficult to integrate the findings.

Different questions require different kinds of monitoring

It's important to understand that one monitoring design cannot solve all of our water-resource issues or questions. For example, depending on specific interests or responsibilities, one might ask:

- Is the water meeting beneficial uses; that is, is it acceptable for drinking or swimming or irrigation or for sustaining aquatic habitat?

- What percentage of streams is impaired within a State?
- Are regulatory requirements being met? Are concentrations or loads below those allowed in discharge permits?
- How does the water quality of one water body compare with those nearby or across the Nation?
- Is water quality getting better or worse? Does water quality change during certain times of the year?
- What are the sources of contaminants and causes of the problems?
- How do changes in land use or management practices affect water quality?

None of these questions is easy to answer, and each requires a different kind of monitoring—a specific set of data collected in certain places and at certain times. So, undoubtedly, monitoring designs end up being unique or different—varying in the timescales and spatial scales covered. The process, however, is always the same. The process begins with clearly defining the water-resource questions; outlining the decisions that will be made from the data; and then identifying the data (or monitoring) needed to make the decision.

Water-resource issues or questions determine monitoring objectives. And the objectives determine the monitoring design. No design, therefore, is "better" or "more successful" than another. Success is measured by whether the monitoring design addresses the specific objectives.

Different types of monitoring—such as "probabilistic" and "targeted" designs—answer different sets of questions. Although both of these designs can contribute to statewide, regional, or national assessments, and improve understanding of the general or "ambient" water resource, they provide different types of information. Both types of monitoring are important, and therefore, should not be viewed as competitive or duplicative, and both need support with adequate funding. In fact, these designs are so different that discussions should not focus on whether one design can substitute for another but on how to integrate the two in order to go beyond what each can provide individually, particularly in predicting conditions in unmonitored areas. This can be illustrated by addressing an overarching question driving many discussions "What is the quality of our Nation's waters?"

Monitoring the quality of our Nation's waters

What monitoring design best answers ***"What is the quality of our Nation's waters?"*** Again, it depends on specific objectives and questions.

To some, this may reflect an overall assessment of the resource as required in the Clean Water Act section 305(b): "What percentage of the Nation's waters is impaired? What percentage is in good condition? What percentage of streams is meeting their beneficial uses?"

Such questions require a broad-based probabilistic monitoring design, in which sites are chosen randomly and are distributed across a certain region. This type of monitoring provides a quantitative, statistically valid estimate of, for example, the number of impaired stream miles within a region or State.

Probabilistic monitoring and assessments help to document what is going well (how much of the resource is in good condition) and what is not (how much is in poor condition). The data collected help decision makers prioritize regions having the most degraded waters and assess which stressors—such as nutrients, sedimentation, and habitat disturbance—are of most importance in that region or State. Many probabilistic monitoring programs are currently implemented by States and within the U.S. Environmental Protection Agency, such as the Environmental Monitoring and Assessment Program (EMAP).

Probabilistic monitoring is a useful and cost-effective method for getting an unbiased, broad geographic snapshot of "whether there is a problem" and "how big the problem is."

To others, "assessing the Nation's waters" leads to other questions, including "Why are water-quality conditions happening and when? Do certain natural features, land uses, or human activities, and management actions affect the occurrence and movement of certain contaminants? Are water conditions changing over time? "

These are equally important questions, but require a "targeted" monitoring design that focuses on understanding the relations between water-quality conditions and the natural and human factors that cause those conditions. Monitoring sites are therefore not selected randomly within a grid, but because they represent certain human activities, environmental settings, or hydrologic conditions during different seasons or times of year. For example, sites may be selected to assess the effects of agriculture and urban development on pesticide and nutrient contamination in streams.

A "targeted" monitoring design requires data collection . . .

- **Over different seasons.** This is important because, for example, USGS assessments generally show low concentrations of contaminants, such as pesticides, in streams for most of the year—lower than most standards and guidelines established to protect aquatic life and human health. However, the assessments also show pulses of elevated concentrations—often 100 to 1,000 times greater in magnitude, exceeding standards and guidelines—during times of the year associated with rainfall and applications of chemicals. Such pulses could affect aquatic life at critical points in the life cycle and also could affect drinking water.

- **In different land uses**, including agricultural, urban, and more pristine land-use settings. USGS assessments show that water conditions are very different among the different settings; insecticides, for example, are more frequently detected at higher concentrations in urban streams than in agricultural streams. Water conditions also are different among different land-use practices; phosphorus, sediment, and selected pesticides, for example, are at higher concentrations in streams draining agricultural fields with furrow irrigation than in agricultural fields with sprinkler irrigation.

- **In different geologic settings.** The setting—whether it is sand and gravel or volcanic rock, for example—affects how readily water moves over the land and into the ground.

- **During different hydrologic conditions.** The amount of streamflow and the timing of high and low flows determine how contaminants are carried in streams, and the connections between streams and ground water determine how the ground water will be affected.

- **Over the long term.** Without comparable data collected over time, assessments cannot distinguish long-term trends from short-term fluctuations and natural fluctuations from effects of human activities. USGS assessments show that water quality continually changes. The changes can be relatively quick—within days, weeks, or months, such as in streams in the Midwest where types of herbicides used on corn and soybeans have changed, or relatively slow, such as in ground water beneath the Delmarva Peninsula where nitrate concentrations are beginning to decrease after 10 years of improved management of nitrogen fertilizers.

Targeted sampling brings an understanding of the causes of water-quality conditions. It establishes relations between water quality and the natural and human factors that affect water quality.

Targeted monitoring and assessments help decision makers to (1) identify streams, aquifers, and watersheds most vulnerable to contamination; (2) target management actions based on causes and sources of pollution; and (3) monitor and measure the effectiveness of those actions over time. Such monitoring would not be necessary if all streams and watersheds responded the same over time. But they *are* different. As shown by targeted assessments across the Nation, such as through the USGS National Water-Quality Assessment (NAWQA) Program, even among similar land uses, the differences in sources, land-use practices, hydrology and other natural factors make one watershed more vulnerable to contamination than another and result in different ways that management strategies can improve water quality.

Integrating the two designs

Neither probabilistic nor targeted monitoring designs answer all questions about the Nation's water resources. While the targeted design cannot provide a quantified estimate of, for example, percentage of streams impaired within a broad geographic region, a probabilistic design cannot account for sources, seasonal differences, varying streamflow and ground-water contributions, or processes that control the movement and quality of water.

Ideally, data collection and monitoring should be consistent and comparable so that the findings can be integrated. National investments and partnerships must commit to increasing the comparability and integration of monitoring in order to enhance our ability to answer critical questions about water resources and understand the quality of the Nation's waters.

Moving from monitoring to predicting

An equally important step in understanding and successfully managing our Nation's waters requires a recognition of and commitment to development and verification of predictive tools and models. Such tools and models are needed to extrapolate or forecast conditions to unmonitored, yet comparable areas—both in space and in time. This is a critical step for cost-effective protection of water resources, particularly in light of diminishing financial resources, which requires more information than can be measured directly in all places and at all times.

Development of predictive tools has come a long way, resulting in improved broad-based assessments of conditions (such as through probabilistic and targeted monitoring), as well as of key factors and processes that affect water quality—including land use, chemical sources of contamination, natural landscape features, and hydrologic transport.

Success will depend on the integration of monitoring and assessment with the predictive models. In other words, it is critical that credible, comparable, and comprehensive information continues to be generated—by means of "on-the-ground" monitoring, assessment, and research—that can be used to validate and verify the predictions. Such integration will lead to more cost-effective and grounded protection and restoration of water resources and more efficient monitoring designs in the future.

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Briefing notes were prepared for a Congressional Briefing in Washington D.C., sponsored by the Water Environment Federation, Environmental and Energy Study Institute, and U.S. Geological Survey.

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Moving from Monitoring to Prediction: The Quality of the Nation's Streams

By Richard B. Alexander and Richard A. Smith

Successful management of our Nation's water resources requires a commitment not only to monitoring but also to the development of predictive tools such as models. Such tools are needed to extrapolate measured water-quality conditions to unmonitored, comparable areas.

This ability to extrapolate or make predictions is critical for cost-effective assessment of our Nation's streams, which requires more information than can be measured directly in all places and at all times. The expense of monitoring limits the number of stream miles that can be measured. As noted in the most recent 305b reports, for example, States have assessed only about 20 percent of the more than 3.7 million stream miles in the Nation.

Models are powerful tools. They can be used to assess water quality over broad regions and the Nation. In addition, models can establish linkages between water-quality conditions and contaminant sources on land; track contaminants from their upstream origins to downstream destinations; and simulate changes in water quality resulting from management actions or trends in human activities. Such information provides estimates of conditions that often cannot be directly measured, such as the percentage of contamination in a stream that originates from different sources or the effects of specific pollution controls.

However, models are incomplete tools without monitoring—i.e., direct measurements or observations of water-quality conditions, contaminant sources, and factors that control the movement of contaminants on land and in water. Model predictions are only reliable and successful if they are developed and verified on the basis of credible, comparable, and comprehensive data from "on-the-ground" monitoring, assessment, and research.

SPARROW—A USGS model used to assess water quality

USGS scientists developed the SPARROW (SPAtially Referenced Regression On Watershed attributes) model to better understand the linkages between monitoring data collected at a large network of sampling stations and the watershed factors that determine water quality. The model correlates *contaminant loads* (or the mass of contaminants transported downstream past a point on a river) with

- *upstream sources,* such as fertilizer, manure application, wastewater discharges, and the atmosphere, and
- *watershed characteristics* affecting contaminant transport, including soil permeability, stream channel size, and streamflow.

Model predictions reflect repeated sampling of hydrologic and contaminant conditions over multiple years (reported as long-term annual average conditions).

Examples of SPARROW results presented in this briefing sheet include (1) in-stream concentrations of phosphorus that meet the recommended goal of the U.S. Environmental Protection Agency (USEPA); (2) sources of nitrogen pollution and their relative impacts on nitrogen concentrations in the Mississippi River basin and the Gulf of Mexico; and, (3) effects of changes in livestock production on concentrations of fecal coliform bacteria in streams and rivers.

Phosphorus concentrations related to the USEPA-recommended goal

SPARROW is used to predict concentrations of phosphorus in streams and rivers across the Nation that meet the USEPA recommended goal (0.1 milligrams per liter) to control excessive growth of algae

Briefing sheet prepared for Congressional Briefing, sponsored by
Water Environment Federation, Environmental and Energy Study Institute, and U.S. Geological Survey
Washington, D.C., March 4, 2005 (Revised March 7, 2005)

WATER RESOURCE REGIONS

Modified from Seaber and others, 1987

Model estimates show that the percentage of stream miles meeting the USEPA recommended goal for phosphorus varies regionally (presented by water-resource regions). Note that the margin of error associated with model findings tends to be smaller for larger regions; for example, compare the margin of error for the entire U.S. (+/- 2.5 percentage points) to that for New England (+/- 7.5 percentage points) and in the Great Basin (+/- 12.3 percentage points) (Smith and others, 1997).

Water resource region	Percentage of stream miles meeting USEPA recommended goal (0.1 milligrams per liter)	Margin of error (+/- percentage)
U.S. (48 States)	39.4	2.5
New England	83.8	7.5
Mid-Atlantic	59.8	6.8
South Atlantic	58.0	5.0
Great Lakes	56.2	5.2
Ohio	51.1	6.3
Tennessee	70.9	10.9
Upper Mississippi	18.5	3.8
Lower Mississippi	47.1	8.0
Souris-Red-Rainy	21.7	7.0
Missouri	18.0	3.7
Arkansas-White-Red	18.9	5.0
Texas Gulf	21.2	5.1
Rio Grande	34.4	8.2
Upper Colorado	33.9	8.1
Lower Colorado	10.8	4.7
Great Basin	24.1	12.3
Pacific Northwest	67.3	3.9
California	45.3	5.7

and other nuisance plants. The phosphorus model was developed with USGS data on total phosphorus collected from 419 monitoring stations between 1975 and 1992.

Model results indicate that only about 40 percent of U.S. stream miles meet the recommended goal. Concentrations vary regionally; for example, about 20 percent of stream miles in the Upper Mississippi River basin meet the goal versus nearly 85 percent in New England. Such findings help to identify regions that are most vulnerable to elevated concentrations of phosphorus and contribute scientifically defensible information to the development of regional water-quality criteria for nutrients.

Nitrogen delivered to the Gulf of Mexico

SPARROW is used to quantify the relative contributions of sources of nitrogen to the Gulf of Mexico from the Mississippi River basin. Nitrogen in the Mississippi River that reaches the Gulf of Mexico has been cited as the leading cause of excessive algal growth and low dissolved oxygen in the Gulf.

Model results indicate that fertilizers contribute about 50 percent of the nitrogen; livestock, municipal wastewater, and the atmosphere each contribute from 10 to 20 percent.

Agricultural sources (i.e., fertilizers and livestock wastes) in the Midwest contribute some of the highest quantities of nitrogen. Municipal wastewater sources—some as far away as Pittsburgh—also can contribute large quantities.

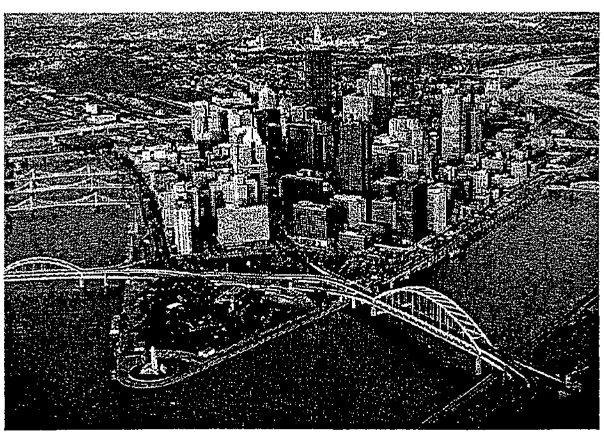
However, only about 15 percent of nitrogen released in the Mississippi River basin ultimately reaches the Gulf. The remaining nitrogen is taken up by crops or is stored or removed from soils and streams and rivers by a process called denitrification—the conversion of nitrogen to an innocuous gas by bacteria. Understanding where nitrogen loss occurs is, therefore, critical to quantifying sources and identifying watersheds that are primarily responsible for nitrogen delivery to the Gulf of Mexico.

Model results show that nitrogen loss in streams decreases rapidly as channel size increases. Therefore, despite long travel times, sources in watersheds close to large rivers—even those more than 1,500 miles from the Gulf—contribute a much larger percentage of nitrogen to the Gulf as compared to those watersheds located on smaller streams only a few hundred miles from the Gulf. The delivery of nitrogen to coastal waters from both point and nonpoint sources, therefore, is not simply a function of the distance of these sources from coastal waters.

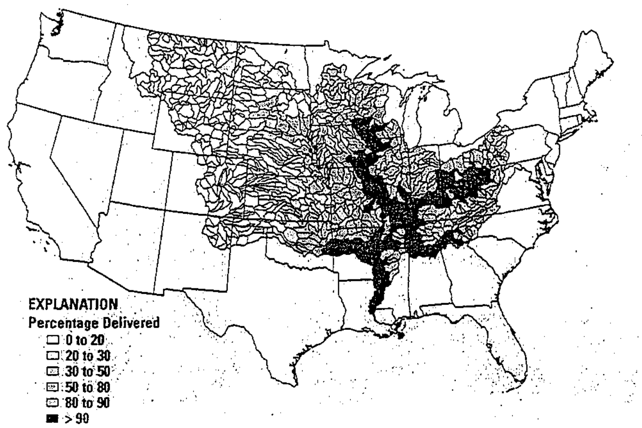
These findings have important implications for nutrient management. The information can help States, Federal agencies, and other stakeholders target types of sources—such as from agricultural fields, livestock operations, urban runoff, and wastewater discharges—in the implementation of nutrient loss strategies.

In addition, model findings can be used to identify watersheds where it would be most cost effective to implement such strategies. For example, when the State of Kansas was developing its 2004 Nutrient Reduction Plan (as required by Section 204a of the Clean Water Act), USGS model results helped with identifying watersheds where nitrogen reductions would likely have the most beneficial effects on deliveries to the Gulf of Mexico (Kansas Department of Health and Environment, 2004).

Overall, the model suggests that it would be most efficient to control nitrogen in watersheds drained by large rivers with low rates of natural nitrogen loss (shown in red on the map). Removal of one pound of nitrogen in these larger rivers would cause a similar reduction in nitrogen delivered to the Gulf of Mexico. By contrast, removal of 2 to 3 pounds of nitrogen would be required in smaller watersheds with higher



Agricultural sources in the Midwest contribute some of the highest quantities of nitrogen to the Gulf of Mexico from the Mississippi River Basin. Municipal wastewater sources—some as far away as Pittsburgh—also can contribute large quantities.



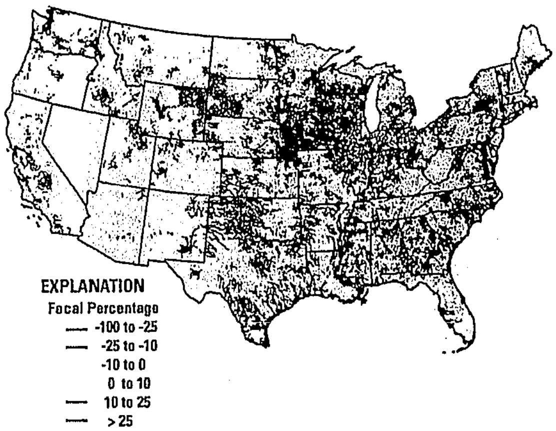
Model findings show that the delivery of nitrogen to coastal waters from both point and nonpoint sources is not simply a function of the distance of these sources from coastal waters. In-stream nitrogen delivered to the Gulf of Mexico is greatest in those watersheds located along large rivers, as far as 1,500 miles away, as compared to those watersheds located on smaller streams only a few hundred miles from the Gulf (Alexander and others, 2000).

natural rates of nitrogen loss (shown in green on the map) to achieve a one-pound reduction in nitrogen delivery to the Gulf.

Fecal coliform concentrations related to livestock production

Models can be used to simulate water-quality conditions given a change in human activities, including those reflecting business or economic trends. For example, animal agriculture has undergone major structural changes in the United States over the past two decades. While the total number of animal units on farms has remained nearly unchanged (only about a 7 percent increase), the number of livestock producers has declined dramatically and the average size of the operations has increased substantially. This trend raises obvious questions about the effects of animal agriculture on water quality in regions where livestock production has become more intense.

SPARROW was used to predict the effects of changing the number and size of livestock operations, holding all other sources of fecal coliform constant. Model results showed that, nationally, fecal coliform contamination in U.S. streams and rivers from livestock waste remained relatively constant between the early 1980s and late 1990s. Annual average concentrations



Model simulations show that concentrations of fecal coliform bacteria increased in many areas of the Great Plains, Ozarks, and the Carolinas as a result of changes in confined and unconfined livestock production from 1982 to 1997 (Smith, Alexander, and Schwarz, 2004).

exceeded 1,000 colonies per 100 milliliters in about half of total U.S. stream miles throughout the period (a common State standard for recreational waters is 200 colonies per 100 milliliters).

The effects of changes in the livestock industry varied regionally, however; model simulations indicated that fecal coliform concentrations increased in many areas of the Great Plains, Ozarks, and the Carolinas, and decreased in most of the Upper Mississippi Basin and in parts of the Deep South and Northeast.

Model results also indicated that, on average across the Nation, a unit of animal waste from confined operations introduced only about 40 percent of the fecal coliform bacteria to streams that is introduced by the same amount of waste from unconfined operations. The difference may be, in part, because unconfined animals are free to wander close to, and even in, streams; and because the relatively large and concentrated amount of waste generated in confined operations is managed and stored through more tightly controlled systems, such as lagoons. These findings, although preliminary, may eventually help to lessen the effects of animal agriculture on water quality.

In summary

Models play an essential role in the assessment of water quality over broad regions and the Nation. They provide a cost-effective approach—particularly when the expense of monitoring limits the number of streams that can be measured during varying streamflow conditions—for prioritizing water resources for protection and restoration; targeting sources of pollution, and designing more efficient and integrated monitoring programs. As models are used to assess other pollutants, such as suspended sediment and pesticides, it is critical to remember that models are successful only if they are developed and verified on the basis of "on-the-ground" monitoring. The integration of monitoring and modeling is the key to our future understanding of the Nation's water quality.

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This briefing sheet is available on the Web at http://water.usgs.gov/nawqa

Details and publications on SPARROW can be accessed at http://water.usgs.gov/nawqa/sparrow

A Comprehensive Approach to Urban Stormwater Impact Assessment

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Abstract

Stormwater monitoring has been conducted in Greensboro, North Carolina, since April 1994 as required by the City's National Pollutant Discharge Elimination System (NPDES) municipal stormwater permit. Runoff sampling is conducted quarterly at storm sewer outfall pipes from seven sites, which generally represent the City's land uses. Over thirty water quality parameters are tested in grab and composite storm event samples. As part of the permit requirement, results are evaluated and pollutant loading estimates are calculated to determine pollutant specific annual and seasonal loads for each site and the entire city. To complement and expand upon this data, City staff also monitored ambient stream water quality under baseflow conditions, evaluated wet weather runoff for acute toxicity, and collected benthic macroinvertebrates for biological assessment in order to characterize stormwater impacts.

The results of the stormwater runoff sampling and load estimates are sufficient to characterize the discharges of varying land uses in the City. However, these data do not provide relevant information on the impact to the receiving waters. Since there are currently no end-of-pipe regulatory limits on stormwater nor wet weather criteria for streams, a tiered approach to impact assessment is needed. Although the runoff data show significant pollutant loads, the baseflow stream s[illegible]ling and toxicity testing results indicated no major problems. The benthic data, however, show a stressed aquatic co[illegible]unity. These studies point to a need for further monitoring including wet weather stream sampling and sediment sampling and/or instream toxicity testing. The data collected to date indicate that the City's urban stream system is stressed due to stormwater runoff quantity and quality impacts.

Introduction

Stormwater monitoring has been conducted in Greensboro, North Carolina, since April 1994 as required by the NPDES municipal stormwater permit conditions. The only stormwater monitoring explicitly required by the NPDES permits is the storm event sampling. Municipalities larger than 100,000 persons (NPDES Phase I stormwater regulations) sample runoff from five to ten representative drainage areas to characterize runoff for their locale. However, these data do not provide relevant information on the impact to the receiving waters. In order to characterize impacts to the receiving waters, a more comprehensive study and approach is needed. In Greensboro, the Storm Water Services Division is examining many facets of its stream and aquatic environment to monitor and quantify the impacts of stormwater runoff so that a watershed-based management program can be developed to mitigate those impacts.

Methods

In the first five years of its NPDES stormwater permit, Greensboro's staff developed a monitoring program both to meet the permit requirements and to make initial assessments of stormwater impacts to the City's stream resources. The staff sampled storm event runoff, stream quality, and the biological community, assessed habitat, and collected samples for toxicity tests. This approach has shown that stormwater impacts are diverse and a range of control measures within the watershed must be used for urban water quality improvement.

St[illegible] Event Runoff Monitoring

Storm event sampling characterizes the quality of stormwater runoff from urban nonpoint sources feeding the municipal storm sewer system during wet weather. In general, the quality and quantity of stormwater runoff depends on the land use type and impervious surface area. In developed urban areas such as Greensboro, there is significant impervious are wl water will not infiltrate and which causes runoff to increase over predevelopment flows. Industrial, commerc , and residential activities bring pollutants into contact with stormwater runoff, which are then carried into receiving streams and lakes. Wet weather sampling enables the City to determine pollutant concentrations and loadings from urban nonpoint sources and provides data to assist in the development and location of effective best management practices for minimizing urban pollutant discharges to area receiving waters.

Wet weather monitoring in Greensboro currently focuses on characterization of discharges from various land use types. Staff performs quarterly monitoring of representative storms (0.1 to 0.8 inches of rainfall within 3 hours) to measure the quality of runoff from 7 sites (see Table 1). Each site represents a different land use type. These data provide a baseline for comparison with special study areas and provide data for estimates of city-wide pollutant concentrations and loads.

Each wet weather site is sampled by a team of two monitoring technicians who are on 24-hour call for storm events. Samples are taken manually from each storm sewer pipe outfall and delivered to a contract lab for analysis. Two types of samples are taken during a storm event: first a grab sample to measure the "first flush" of stormwater runoff and then a time-weighted composite sample is taken over a three-hour period to measure average runoff quality. Field parameters including water temperature, pH, conductivity, and turbidity are measured in addition to site specific rainfall and flow depths. Samples are analyzed for an extensive list of parameters per the NPDES requirements (see Table 2).

Ambient Stream Monitoring

To augment the storm event runoff monitoring and to establish a general baseline for determining impacts to the receiving streams, an ambient instream monitoring program was developed. Since July 1996, staff has monitored seven stream sites on monthly basis (see Table 3). (North and South Buffalo Creeks and their tributaries represent the major stream sy as in the most urbanized areas of Greensboro.) Similar to the storm event sampling process, samples are colle by a team of two monitoring technicians and delivered to a contract lab for analysis. Field parameters including flow level, water temperature, pH, conductivity, and turbidity are also measured. Conventional parameters are sampled monthly while metals are added on a quarterly basis (see Table 4). Samples are taken on the second Tuesday of each month, generally under baseflow conditions.

This stream monitoring provides water quality data and information on the health of the stream during dry weather. The data will provide a reference point for determining stormwater impact under wet weather conditions.

Toxicity Testing

To estimate the toxic impact of stormwater runoff on the receiving stream, toxicity testing of runoff was conducted. Due to the sporadic nature of stormwater runoff events, the State of North Carolina recommended acute toxicity testing. During the winter quarter of 1997 (January - March 1997) grab samples were collected during the first flush of storm events at each of the seven land use characterization outfalls. Samples were delivered to a contract lab where a 48-hour test was run on each sample using fathead minnows (*Pimephales promelas*). Sample dilutions (0, 12.5, 25, 50, 75, and 100 percent) were fabricated and mortality of minnows measured over a 48-hour period.

Biological Monitoring - Benthic Macroinvertebrates

During the summer of 1997, staff sampled the aquatic benthic invertebrate communities at 31 stream sites across Greensboro to further assess the impacts from urban stormwater. Sites were selected to complement wet weather sampling si ambient stream sampling sites, and to provide a comprehensive coverage of the city including streams drainir the city's drinking water supply reservoir. Samples were taken using a kicknet in riffle area habitats. Subsamples o organisms were taken from each sample and sent to a contractor for taxonomic identification.

bitat Assessment

Along with the biological assessment of the city's streams, habitat assessments were also conducted. Urban streams typically become degraded once contributory drainage impervious area exceeds approximately ten percent (Schueler, 1995). In addition, prior to 1994 and implementation of the municipal NPDES stormwater permit, the City dredged some local streams as part of its routine drainage maintenance. These factors have contributed to degrade the aquatic habitat and impact the biological community. With an improved understanding of the local impacts of past stream channel maintenance practices, the City no longer performs routine dredging of streams.

Two assessment methods have been used to evaluate stream channel conditions and habitat. The first was a qualitative survey of a subsample of city streams to assess stream channel stability, vegetation, and maintenance practices. A quantitative survey was done in conjunction with the biological monitoring study using the format provided by EPA's Rapid Bioassessment Protocol. This assessment created a numerical score for localized sites including substrate characterization, channel sinuosity, channel alteration, streambank vegetation and stability, and riparian vegetation.

Results and Discussion

Urban Stormwater Runoff

The characterization of receiving streams as impaired varies depending on the amount of impervious area and land uses in the drainage basin. Sites with little impervious area and restricted land uses, undeveloped or low-density residential sites have few problems. Age and quality of the drainage system and maintenance of the land uses appear to play a role in runoff quality. Sites with large quantities of pavement and roof area generate significantly more runoff and more ·· tants. On these sites, there is greater area for pollutants to accumulate between rain events.

Pollutants of concern identified in the City of Greensboro's sampling program include:

- suspended and dissolved solids,
- oxygen consuming wastes,
- bacteria,
- nutrients, and
- heavy metals.

A significant finding of the runoff sampling has been that stormwater contains pollutants similar to wastewater discharges to streams and in some cases with concentrations that are higher. Also, the findings from Greensboro's storm event sampling program are generally comparable to the national NURP study.

Elevated levels of suspended and dissolved solids and turbidity are found in nearly all samples except the undeveloped site (Country Park). The TSS data average about 200 mg/l during the first flush of runoff but drop to below 80 mg/l in the composite samples. For comparison, wastewater discharges must meet a limit of 30 mg/l, but in Greensboro are usually less than 10 mg/l due to stringent treatment requirements. Turbidity frequently exceeds the state standard of 50 NTU in the first flush of stormwater runoff.

recal coliform and fecal streptococcus have been present at all sampling locations. Exceedances of the state standard for fecal coliform (200 colonies/100 ml) have occurred at all sites. The only site that is occasionally within the standard is the undeveloped site. Most fecal data is far above the required levels for wastewater discharges (200 colonies /100 ml). Some sites have exhibited exceptionally high values, which may indicate leaks from the sanitary sewer lines to the storm [illegible] sys[illegible].

Although the dissolved oxygen (DO) of runoff itself does not appear to be of concern, the BOD and COD levels are generally much higher in urban runoff than domestic wastewater discharges. This is especially true locally in Greensboro, where due to the low flow streams and high temperatures, wastewater discharges are required to meet very stringent BOD limits of less than 5 - 10 mg/l. Though wastewater discharges are continuous and stormwater discharges are sporadic, the BOD in urban stormwater runoff is exerted over a longer period of time than in many other wastewaters (Field and Pitt, 1990). The long-term BOD of some storm runoff may be much higher than that of domestic wastewater; and sediments may store BOD which become resuspended and move the area of DO deficit further downstream.

Greensboro is located at the headwaters of the Cape Fear River Basin in an area that has been designated by the State as Nutrient Sensitive Waters (NSW). This stream classification requires wastewater discharges to meet a phosphorus limit of 2 mg/l to protect Jordan Lake, a major regional water supply and flood control reservoir, from more frequent algal blooms. The runoff data indicates that nutrient loading from urban sources is less severe than from wastewater discharges. However, the nutrient levels (phosphorus and nitrogen) from the Athena (90% impervious) first flush runoff are greater than or equal to the required wastewater discharge limits. The nutrient loading levels are approximately 50% lower in the composite sampling. A more important consideration may be the total nutrient loading from nonpoint sources as compared to the point sources.

Metals have been detected at all sites. Higher concentrations are present at sites with greater amounts of impervious area and with more industrial land uses. Copper, lead, and zinc exceed the state standards (7 μ g/l, 25 μ g/l, and 50 μ g/l respectively) at all sites except the low density residential and undeveloped sites. Other studies (e.g., Moran, 1998) ind[illegible]ate that significant sources of these metals, particularly copper, include automotive wear and tear (including au[illegible]otive brake pads) and roof runoff.

Annual Pollutant Loading Estimates

Annual pollutant loading estimates have been calculated using the "Simple Method" (MWCOG, 1987), where: pollutant load (lbs/yr) = [runoff (acre-ft/yr) * event mean concentration of pollutant (mg/l) * conversion factor]. An effective annual rainfall of 38.3 inches per year (based on the average for Greensboro) was used to estimate runoff for each sampling site. At the end of the sampling year, the actual annual rainfall is converted to effective annual rainfall and the load estimates are revised accordingly. The estimates attached as Table 5 are annual pollutant loading averages based on analysis of local storm event sampling results between June 1995 and June 1997. Table 5 also provides the loadings based on pollutant event mean concentrations from the EPA NURP study for comparison to the local findings. The estimates are comparable, but the local pollutant concentrations and loadings are generally lower than findings and estimates based on the national NURP study.

Ambient Stream Monitoring

Monitoring results to date indicate that during dry weather the water quality of the city streams is only slightly impaired. There are no significant instream problems during dry weather except in areas with dry weather discharges. One site is located in an industrial corridor which has both stormwater runoff problems and dry weather discharges. Fecal coliform levels consistently exceed state standards. A master plan is currently under development for the largest of the industrial sites, which will address containment and treatment of stormwater runoff and dry weather discharges.

V[illegible]r quality is consistently uniform during baseflow conditions. The most noticeable changes during or immedia[illegible] fo[illegible]owing wet weather is the sediment load from upstream construction areas. Turbidity levels exceed the state sta[illegible]d when there is soil loss from construction sites. There are also significant differences between sediment loads in North and South Buffalo Creeks. South Buffalo carries a much higher load, which can be largely attributed to increased construction ~~ivities in the South Buffalo Creek watershed.

The instream baseflow water quality data contrasts with wet weather data, which indicates that significant levels of pollutants are entering the streams via stormwater runoff. In July 1998, baseflow monitoring will be reduced to quarterly and wet weather monitoring will be conducted twice during the year. Stream monitoring will also be added at six United States Geological Survey (USGS) flow-gaged stream sites in order to correlate water quality and flow information for future watershed modeling and master planning efforts.

Acute Toxicity Tests

The results of the acute toxicity tests indicated that the first flush samples were not toxic according to the standards of the test. No acute toxicity (48-hour, fathead minnow) was found at any site. The LC50 was greater than 100% at all sites. The LC50 is a measure of the strength of a sample in which 50% of the population is found to die after a 48-hour exposure (Standard Methods, 1994). For the samples obtained in the city, even full strength or the 100% dilution did not cause a 50% mortality. Very little mortality was seen at the storm sites. Merritt (75% impervious, commercial site) had limited mortality of 35% at the full strength sample. The cause of this mortality is unclear. The water quality data for Merritt were generally better than the other sampled sites. However, conductivity was higher and dissolved oxygen was lowest of all the samples. This is consistent with a study in Kentucky that found that mortality in the bioassays of stormwater runoff was most affected by low DO concentrations in the runoff (Marsh, 1993).

The tests indicate that the first flushes of stormwater runoff were not acutely toxic. However, reviews of the data show exceedances of water quality standards for copper, lead and zinc as well as detectable levels of other metals. Therefore it is likely that stormwater may have a chronic impact. Acute toxicity testing was selected because storm events are short-t m events. Yet, these events occur frequently with an average of four significant events per month. Some of the effects rmwater discharges are associated with organic and toxic pollutant accumulations over a long time and are not associated with individual runoff events (Field and Pitt, 1990). The true impact on the stream then can become a chronic impact. Chronic toxicity testing could determine whether the stormwater runoff itself has a toxic impact.

Other studies suggest that the toxic impact from stormwater runoff is manifested in the interface between the sediment and water column. Pollutants bound to suspended particles in the water accumulate in the bottom sediment and are readily available to aquatic organisms or may be resuspended during storms. Sampling by Wisconsin DNR found that petroleum byproducts and heavy metals were present in bottom sediment (Masterson, 1994). Another researcher, Dr. G.J. Pesecreda of North Carolina, has conducted instream toxicity tests using the Stonefly (*Pteronarcys dorsata*) to determine their response to urban runoff and wastewater in comparison to a control site. He found that mortality in sites receiving urban runoff experienced greater mortality than an instream reference site. In addition, there was no significant difference in mortality to the test organisms exposed above and below a wastewater plant when both were exposed to urban stormwater runoff (Pesecreda, 1997). Sediment sampling and sediment toxicity tests may be needed to evaluate the relationships of pollutant transport and storage in sediments to water quality impairment as measured by the biological community.

Biological Community

Results from benthic macroinvertebrate samples indicated that biotic communities are relatively tolerant to periodic storm events and are more severely impacted by degradation in habitat and continuous water quality problems. Thirteen of the 31 sites sampled rated "good-fair" using the North Carolina Biotic Index (NCBI). This "good-fair" rating was supported by similar ratings from taxa richness and EPT abundance values. Only two sites had "poor" biotic communities. These two sites were located in the North Buffalo Creek basin and had no Ephemeroptera, Tricoptera, and Plecoptera (EPT) and h percentages of Chironomids. Both of these sites receive runoff from old industrial and commercial areas and also had aded habitat.

Overall, South Buffalo Creek indicated less impaired biotic communities and water quality than North Buffalo. An in-stream site (Big Tree) actually indicated "excellent" NCBI and had a high habitat score. Even the highly industrialized Gillespie site had "fair" NCBI rating and 15 EPT species. However, water quality and stream degradation was obser- d as the uth Buffalo Creek traversed downstream through the city.

As expected, water quality and biotic communities in the water supply watersheds were less impaired than North and South Buffalo Creeks due to better habitat and less urban runoff. In general, the water supply watershed areas are less developed than the North and South Buffalo basins. However, Bryan Park, which was selected as a reference site, received only a "good-fair" biotic rating but had a high habitat score. Although little urban development is present in the Bryan Park drainage area, agricultural activities in the area are believed to have contributed to the stream degradation.

Macroinvertebrate samples are useful to determine short-term changes in habitat and water quality changes. They would be useful to determine the effects of stream restoration or changes in riparian buffers as well as the effects of new construction or point source discharges. Habitat, water chemistry and biotic communities interact to form the aquatic ecosystem; therefore, there is a need to study and identify all three to manage aquatic resources properly.

- **Aquatic Habitat**

The assessment of stream channels to evaluate maintenance practices and channel stability indicated that the past City maintenance practices in combination with high velocity and increased volume of storm flows resulted in stream channels that are unstable and highly erodible. The historical practice of maintaining stream channels as a drainage network included routine dredging to remove sandbars and widen channels, and routine mowing up to and including the stream banks using a boom mower. These practices have disturbed habitat within the stream and removed most vegetative cover. In 1994, the routine dredging ceased. While some mowing has continued, the City continues to evaluate its vegetative maintenance practices to develop an optimum balance between the environment and other public concerns related to str m systems. Wildlife studies conducted by the Audubon Society in Greensboro compared stretches of the same st n, North Buffalo Creek, with and without vegetative cover. Their findings indicate that there is a more diverse songbird community where there is more cover. This study also found that radio-tagged turtles would not enter areas without vegetative cover (Audubon, 1998). As noted, the City continues to evaluate its maintenance practices to provide a better balance between flood routing, aquatic habitat, and related stream system issues.

Habitat assessment was conducted at 31 locations throughout the city. All locations indicated some impact from human development. Some sites, especially in parks and the water supply watershed, had very good riparian buffer zones, channel flow and pool variability but lacked streambank stabilization and had high sediment deposition. Conversely, other sites no longer have meanders, canopy cover, or epifaunal substrate cover but have stabilized banks and low sediment deposition. However, all sites were able to support aquatic communities. Schueler states that stream degradation occurs at 10-20% impervious (Schueler, 1995). However, stream alteration takes place any time the watershed is disturbed. Habitat should always be evaluated when assessing water quality. Future monitoring is planned to evaluate restoration of riparian vegetative zones along stream reaches that had previously been mowed and/or dredged.

Conclusions

The monitoring of stormwater runoff required by the NPDES permits is not sufficient to determine the overall impact of stormwater on the City's receiving waters. And, without this determination, the City cannot develop a complete strategy for improving water quality in the city streams. A more comprehensive approach to urban stormwater monitoring and determining the impacts of urban stormwater runoff upon receiving waters includes:

- a storm event outfall monitoring program (as required by the NPDES permit),
- an ambient stream monitoring program,
- wet weather acute toxicity testing at storm sewer outfalls,

- a biological monitoring and habitat assessment program,
- an instream wet weather monitoring program,
- sediment sampling, and
- chronic toxicity testing.

While meeting its NPDES requirements, the City of Greensboro has begun implementation of a comprehensive program for water quality monitoring and stormwater impact assessment. In 1998, a network of USGS stream gages will be added to allow continuous tracking of rainfall, streamflow, and provide early warning of potential flooding. The city's monitoring staff will sample the streams at the USGS sites at least six times per year during variable flow regimes in order to develop a database for model calibration.

A watershed-based stormwater runoff and stream model will be developed during 1998 and 1999 to predict both water quality and quantity impacts including a determination of the impacts of future land use changes. With this tool, the City can develop watershed-based strategies for reducing the impacts of future urban development, as well as mitigating impacts of existing development and other factors within the watershed. Comprehensive and proactive watershed management, including improved water quality, is the goal of the City of Greensboro's stormwater program.

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Table 1. Wet Weather Monitoring Sites in the City of Greensboro

Site	Drainage Area	Land Use	% Impervious

Athena Court	21 acres	Commercial – Heavy	90
Country Park	20 acres	Open	2
Husbands St.	13 acres	Industrial	74
Merritt Dr.	23 acres	Commercial – Light	75
Randleman Rd.	26 acres	Residential – High	50
Union St.	33 acres	Mixed	75
Willoughby Blvd.	13 acres	Residential – Low	20

Table 2. Sampled Parameters

Ammonia Nitrogen (NH3)	Total Kjeldahl Nitrogen (TKN)	Selenium*
BOD, 5-day (BOD5)	Chlorides	Silver *
Chemical Oxygen Demand (COD)	Antimony *	Thallium *
Cyanide, Total *	Arsenic *	Zinc, Total
Fecal Coliform, MF *	Beryllium *	EPA 624 *
Fecal Streptococcus – Tube *	Cadmium	EPA 625 *
Nitrate + Nitrite, Nitrogen	Chromium	EPA 608 *
Phosphorus, Total Dissolved (TDP)	Copper, Total	
Phosphorus, Total (TP)	Lead	
Solids, Total Dissolved (TDS)	Mercury, Total *	
Solids, Total Suspended (TSS)	Nickel	
* *These parameters apply only to the grab sample. Other parameters apply to both grab and composite samples.*		

Table 3. Stream Monitoring Sites

Site Location and Stream Order	Land Use
South Buffalo Creek at Big Tree Way (2nd order stream)	High density residential
South Buffalo Creek at Hillsdale Park (3rd order stream)	Residential
Tributary to Mile Run Creek at Gillespie Golf Course (2nd order stream)	Industrial
South Buffalo Creek at McConnell Creek (4th order stream)	Agricultural, low density residential
North Buffalo Creek at City Arboretum (3rd order stream)	Residential
North Buffalo Creek at Lake Daniel Park (4th order stream)	Residential
Tributary to Richland Creek at Battleground Park (1st order stream)	Undeveloped

Table 4. Sampled Parameters in Ambient Stream Monitoring Program

Monthly Parameters		Quarterly Parameters	
Dissolved Oxygen	Ammonia Nitrogen	Aluminum	Silver
Temperature	Nitrate/Nitrite	Arsenic	Zinc
PH	TKN	Cadmium	Nickel
Turbidity	TP	Chromium	
Conductivity	TDP	Copper	
Chlorides	TSS and TDS	Iron	
BOD5	Fecal Coliform	Lead	
COD	Fecal Streptococcus	Mercury	

Table 5. Comparison of Annual Pollutant Loadings Based on NURP and Local Sampling Data

Parameter	Estimated annual loadings based on NURP data (lbs / yr)	Estimated annual loadings based on local sampling data (lbs / yr)
TSS	39,933,876	8,531,186
TDS	13,366,988	15,744,167
TP	83,544	46,172
TDP	25,063	37,111
TN	551,388	118,112
BOD5	2,005,048	2,874,528
COD	15,706,211	10,391,131
Cadmium	167	72
Copper	8,354	3,382
Lead	39,767	3,372
Zinc	58,982	23,391

Rapid Bioassessment of Benthic Macroinvertebrates Illustrates Water Quality in Small Order Urban Streams in a North Carolina Piedmont City

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Abstract

Rapid bioassessment of macroinvertebrates was conducted at thirty-one sites within the urban watershed of Greensboro, North Carolina during the summer of 1997. Assessment at each site included physicochemical parameters, habitat score, and the following indices: total taxa richness, North Carolina biotic index value (NCBI), EPT (Ephemeroptera, Plecoptera, and Trichoptera) abundance, EPT richness, ratio of EPT and Chironomidae, percent Tubificidae, and percent dominant species. Sites up-stream of urban activity showed high diversity and richness of aquatic communities and overall good water quality. Poor to fair water quality ratings were seen downstream of urban activity. However, the condition of biotic communities was directly related to habitat and water chemistry. Habitat is degraded in urban areas due to dredging, channelization, and impaired riparian buffer zones that contribute to poor species diversity. The results of the bioassessment monitoring program lead us to the conclusion that physical and chemical data of storm events and baseflow stream conditions cannot fully assess the effects of urbanization on small order streams.

We have been monitoring storm water runoff for four years and ambient in-stream conditions for two years to establish water quality history. Storm water runoff from developed land showed elevated levels of pollution whereas ambient in-stream conditions showed much lower levels. Using benthic macroinvertebrates as indicators of localized conditions aids ... eting water quality data because they lead stationary lives and respond quickly to stress from storm events and illegal dumpings. This study illustrates the importance of biological data in conjunction with physicochemical data to assess water quality and to characterize impacts from urban runoff.

Introduction

Greensboro, North Carolina is located at the headwaters of the Cape Fear River Basin in the Piedmont ecoregion and has 509 linear miles of streams (NCDEHNR 1995). Greensboro is a rapidly growing city with a population of over 200,000 and an area of 109 square miles. The City of Greensboro was issued a National Pollutant Discharge Elimination System (NPDES) Permit in 1994. This permit requires the monitoring of storm water runoff within the city to characterize pollutant loading from different land uses and to estimate annual pollutant loading. In addition, the permit focuses on the elimination of non-point source pollutants through identification of every outfall in the city with a focus on industrial areas. The City of Greensboro also conducted monitoring of ambient in-stream conditions to establish baseline water quality and conducted acute toxicity testing on storm water. However, the effects of spills, illegal discharges and other episodic events cannot be qualified or quantified by any of these methods.

Data on runoff from storm events indicated high levels of pollutants entering into the small streams of Greensboro, but baseline in-stream data showed relatively low amounts of chemical pollutants. It was determined that benthic macroinvertebrate would be good indicators of localized conditions. In addition, many sites throughout the city could be studied with relative ease. Macroinvertebrates integrate the short-term environmental variations because they respond quickly to stress from spills and storm events and lead stationary lives. Macroinvertebrates, rather than fish, were selected because many of the first and second order streams in Greensboro might not be able to support fish assemblages whereas invertebrates are present in most streams (EPA 1996).

Materials and Methods

Study Area and Site Selection

We sampled benthic macroinvertebrates at 31 sites within and draining into the watershed of the City of Greensbor Nc Buffalo Creek and South Buffalo Creek are located in the heart of the oldest and most urbanized areas of the city with the highest amount of development and impervious area. Streams in these sections often have been channelized and dredged in the past. South Buffalo Creek has the most recent construction activity and as a result more sediment loading. Reedy Fork Creek is located in the north reaches of the city limits and drains primarily undeveloped or agricultural areas. A series of five reservoirs have been built on this stream to provide drinking water to Greensboro. In the last ten years, urban sprawl has started spreading into these basins with increased residential, commercial and industrial activities. In addition, the East Fork Deep River and Bull Run are within Greensboro City limits and discharge to the City of High Point's water supply.

Emphasis was placed on the major tributaries supplying Greensboro's and High Point's drinking water supplies. Efforts were made to spatially distribute sites over the entire area within the city limits of Greensboro. Macroinvertebrate samples were collected on the North and South Buffalo Creeks at sites that are monitored for storm water runoff and in-stream baseflow conditions. In addition, tributaries were selected to provide basinwide coverage. Very little monitoring had been conducted on the Reedy Fork Creek. All the main tributaries to the reservoirs and downstream of the reservoirs were sampled. In addition, one site on East Fork Deep River and Bull Run were sampled to estimate the condition of these streams as they leave the city limits of Greensboro.

Three sites were selected as reference sites in relatively undeveloped locations: Bryan Park, Battleground, and McKnight Mill. Each is a first, second, and third order stream, respectively. These sites are important since replicate sampling was not conducted and will be used for comparison.

Invertebrate Sampling

Benthic sampling followed a modified version of the EPA Rapid Bioassessment Protocol II using single habitat approach with 1-meter kick net with 500-μ m mesh openings (EPA 1996). A 100-m reach representative of the stream was selected. All samples were collected from the riffle zones of streams in areas where there was the best canopy coverage and side bank vegetation to portray the best overall sample results. Whenever possible, the site was at least 100 meters upstream of roads or bridge crossings and had no major tributaries discharging to the site. Two or three kicks were sampled at various velocities within in the stream reach. Large rocks and logs in the area where dislodged and washed off within the net. From the net, the sample was placed into a 500-μ m opening sieve bucket where leaves, twigs and other large debris were washed off and discarded. The remaining debris and sample was placed in plastic containers and preserved in 90% ethanol. All organisms were sorted from debris in the laboratory and then 100-organism sub-sample was randomly selected from a standardized grid. The one-hundred organism sub-sample was properly labeled and preserved in glass containers in 90 % ethanol. Three of the sites were samples twice to provide quality assurance.

Identification

Sorted samples were sent to a qualified contracted laboratory where organisms were identified to the lowest practical taxon, usually species. Specimens too immature or damaged to identify below the level of genus were reported to the lowest known level. Identifications were checked by having 10% of the samples randomly selected and identified by another biologist. Tolerance values and functional feeding groups were reported. Hilsenhoff tolerance values were used when North Carolina's tolerance values were not available. North Carolina's tolerance values range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant to organic wastes.

Metrics

The following statistics were calculated for each site: total taxa richness, North Carolina biotic index value (NCBI), EPT

Abundance, EPT Richness, Ratio of EPT and Chironomidae, Percent Chironomidae, Percent Tubificidae, and Percent dominant species (EPA 1996, NCDEHNR 1997, MCDEP 1996).

R... ess

Taxa richness is the simplest measure of diversity. The total number of species collected in the 100-organism subsample was recorded to measure taxa richness. Taxa richness decreases with a decrease in water quality as the less tolerant species are eliminated. Bioclassification criteria developed by North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR) for the North Carolina Piedmont for the standard qualitative sampling method is listed in Table 1. This bioclassification criterion is based on values from summer collection (June - September). These ratings reflect effects of chemical pollution but poorly assess the effects of sediment pollution.

Biotic Index Criteria

NCDEHNR developed the NCBI which accounts for differences in stream size, seasonal variations and ecoregions to complement taxa richness (NCDEHNR 1997, Lenat 1993). The NCBI is intended to examine the general level of pollution, regardless of source.

The NCBI is derived using the following formula:

$$NCBI = \frac{\Sigma Tv_i N_i}{Total N}$$

where Tv_i is the tolerance value of the ith taxa, N_i is the abundance of the ith taxa (1,3 or 10) and N is the sum of the ...ance values. The abundance information for each taxon is tabulated at either RARE (1-2 specimens), COMMON (3-9 specimens) or ABUNDANT (> 10 specimens) and given the value of 1, 3, or 10 respectively. The bioclassification criteria developed by NCDEHNR for the NCBI (after seasonal corrections) for the North Carolina Piedmont are listed in Table 2 (Lenat 1993).

Ratio of EPT and Chironomidae Abundance

Good biotic conditions would be reflected in communities with an even distribution among all four major groups. Skewed populations having a disproportionate number of Chironomidae relative to the more sensitive organisms (Ephemeroptera, Plecoptera, and Trichoptera) indicate environmental stress (EPA 1989).

Percent Chironomidae

The percentage of the family Chironomidae in the sample represents whether a stream is oligotrophic or eutrophic. A sample in which greater than 50% is Chironomidae suggests eutrophic conditions. Some species of Chironomidae are also tolerant to heavy metals. Percentage of Chironomidae will increase with a decrease in water quality.

Percent Tubificidae

An abnormally high percentage of Tubificidae accompanied by abnormally low values for percent Chironomidae indicates toxicity form urban runoff or insecticides that are toxic to arthropods. High tubified percentages accompanied by large Chironomidae populations indicate a serious organic problem.

...ent Contribution of Dominant Species

A community dominated by relatively few species would indicate environmental stress. Dominant species greater than 35% indicates poor water quality, between 23%-35% indicates fair water quality and less than 25% indicates good water quality (EPA 1996).

Physical, Chemical, and Habitat Sampling

Water samples were collected in plastic containers from locations at the middle of stream prior to macroinvertebrate sampling. Samples were preserved on ice and analyzed within 24 hours for nitrate-nitrogen and reactive phosphorus using the Hach Portable DR2000 Spectrophotometer. Turbidity, conductivity, pH, temperature and dissolved oxygen where measured at each site. Upon completion of sampling, a habitat assessment of each site was conducted using a format developed by EPA Rapid Bioassessment Protocol (EPA 1996). A numerical habitat score was calculated for each site. Habitat assessments were summed to obtain overall habitat score: optimal (260-201), sub-optimal (200-136), marginal (135-71), and poor (<70). Stream order for each site was determined using USGS topographic maps.

Results

Baseline and Storm Data

Greensboro, NC annually receives over 38 inches of rain. Input of pollutants from storm water runoff is frequent and a source of pollutant loading in our streams and waterways. This was evident in the results from four years of land use storm water quality data that showed heavy metals, fecal bacteria, and solids were the greatest impacts from urban runoff. These parameters frequently exceeded NCDEHNR action limits and standards for in-stream concentrations. However, acute toxicity of first flush samples using the fat head minnow (*Pimephales promelas*) showed no mortality. To complement this information, two years ago monthly sampling of ambient stream conditions was started to determine baseflow conditions. These samples were taken on the second Tuesday of each month to reflect any weather conditions but most likely reflected dry weather conditions in the stream. Fecal coliform levels continued to be elevated during baseflow conditions. Aluminum and iron, which were not tested in storm water runoff, were at levels above the NCDEHNR's criteria, but were attributed to local soil types. The heavy metals, copper, lead, and zinc, which were prevalent in storm runoff, were much lower in ambient conditions. It is hypothesized that these particles quickly settle out of the water column into the sediment. As expected, solids were much lower in ambient stream conditions as was biochemical and chemical oxygen demand (BOD and COD, respectively).

Biological and Habitat Data

Selected results and the associated metrics are listed in Table 3. The purpose of biological sampling was to sample citywide and to help determine the areas where more in-depth monitoring could be conducted or sites where future development may adversely affect stream conditions.

Physicochemical Data

At each site where macroinvertebrates were sampled, nitrate-nitrogen and reactive phosphorus, pH, conductivity, turbidity, dissolved oxygen, and temperature was taken. Results were consistent with ambient in-stream data. Nutrient levels were found at very low concentrations. Phosphorus ranged between 0.0 mg/l to 0.75 mg/l and nitrate ranged from 0.2 mg/l and 1.5 mg/l. Temperatures were slightly elevated at sites with little canopy cover in comparison with site that had vegetative cover. Dissolved oxygen (DO) was not below 4 mg/l at any the sites. The lowest DO was 4.99 mg/l and as high as 9.73 mg/l. Turbidity was below 25 NTU at all sites except three sites that ranged between 90 to 102 NTU. These sit re associated with construction activities. Conductivity generally ranged from 64 μ mhos/cm to 506 μ mhos/c nd one site with 996 μ mhos/cm. Sites with high conductivity were observed to be associated with industrial activities.

Discussion

dequacy of Chemical Data

The purpose of the storm water monitoring program is to assess the overall health of the streams in Greensboro. NPDES permit requires monitoring of storm water runoff for the purpose of land use characterization and pollutant load estimates. However, this does not adequately characterize the health or condition of city streams. It does not take into account stream habitat or biological communities. This monitoring provides instantaneous chemical and physical data but does not indicate long term or continuous effects. Biological communities are directly affected by these parameters in addition to upstream and downstream activities such as piping of streams, dams, impoundments, construction activities, and stream crossings.

Role of Habitat

Great variation in habitat was seen throughout the city. For this study, the best overall habitat area was sampled in the different stream reaches. Habitat scores were lower at sites that received good-fair and fair biotic ratings in comparison to sites rated good and excellent. Some sites had good riparian buffers and canopy cover but lacked adequate substrate and bank stability. Historic practice in the urban setting was to channelize and dredge city streams to convey the water as quickly as possible out of the city to minimize flooding. In addition, riparian zones were maintained mowed lawns and bank vegetation was scarce. These practices have led to the destruction of biological communities. Current City policy is to restore vegetative riparian zones and to stop dredging stream channels. Unfortunately, we are still left with the damage from the past. Now the latest problem seems to be the result of construction and development activities that continues to increase sediment and flow to the streams.

Evaluation of the Metrics

L...ss number of metrics and indices exist to analyze macroinvertebrate samples (Resh et al 1995, Thorne and Willliams 1997, Washington 1984). We have chosen to follow the procedures outlined by NCDEHNR (1995). In particular, bioclassifications have been based on the NCBI to support water quality assessment. Other metrics were used to help interpret the overall quality of the site. Of all the metrics calculated, the most useful were NCBI, taxa richness, EPT abundance, and percent Chironomidae.

EPT Richness showed very little difference between individual site with NCBI ratings good, good-fair, and fair. However, impaired and poor sites had EPT richness and abundance values of 1 and 0 indicating absence of mayflies, stoneflies and caddisflies. However, this absence was already noted in the NCBI and taxa richness. Therefore, we would not recommend using these metrics alone.

Tubificidae populations were rare, only being found at seven sites comprising less than 5% of the community. Since Tubificidae were not present at many of the sites this metric is not useful. Similarly, percent dominant species and ratio of EPT to Chironomidae did not produce distinct results. The greatest tubificidae population was 26% of the community at Caesar, which had poor ratings from all metrics. These results indicated the site suffers from sever organic pollution and eutrophic conditions.

Water Quality and Macroinvertebrates

South Buffalo Creek exemplifies the degradation of macroinvertebrate communities along the stream continuum. Big Tree is a second order stream location on South Buffalo Creek with an excellent NCBI rating influenced by residential land use. Its habitat score was rated sub-optimal with no channel alterations. Boston Road is slightly downstream where Buffalo Creek is a third order stream. This site had a NCBI rating of good even though it is located downstream of two heavy construction areas with high amount of sediment loading. Hillsdale is further downstream on South Buffalo

Creek, which receives runoff from an older commercial area with shopping mall, restaurants and office parks. The stream channel has been dredged and the buffer zone and banks are mowed regularly. The NCBI value at the Hillsdale site was only rated fair. Slight improvement was seen downstream at the Trestle site where the NCBI rating was good-fair. M t lik the reason the NCBI rating was improved was better habitat conditions and changes in land use. However fu downstream on South Buffalo Creek at the McConnell site, the location was rated fair with impaired substrate and quality even though the surrounding land use was not developed. This site suffers from the affects of upstream urban activities.

Sites along North Buffalo Creek and its tributaries also showed degradation along the stream continuum. The Arboretum site is the farthest site upstream on the main channel. This site location is a third order stream where the NCBI rating was good-fair with habitat rating of sub-optimal. The stream degraded slightly at Lake Daniel where the NCBI rating was only fair and the habitat score was reduced. Surprisingly, the NCBI rating upstream of the City's wastewater treatment plant (WWTP) was rated good-fair. Previous investigation by the NCDEHNR reported a poor NCBI rating. Water quality data showed dissolved oxygen of 4.99 mg/l and conductivity of 996 µ mhos/cm. Two tributaries draining into North Buffalo Creek at Caesar Park and White Street indicated poor NCBI ratings. Both are affected by industrial as well as commercial runoff.

Sites located in the various tributaries to the water supply lakes were rated excellent, good and good-fair by NCBI. EPT species were well represented and Chironomidae percentages were low at all sampling locations. Development was restricted in these areas requiring best management practices on new development. However, development has steadily increased. This preliminary data on benthic communities serves as a baseline for change as development continues and the watershed changes.

Sediment loading occurs from construction activities especially during storm events. Benthic macroinvertebrates are able to withstand short-term increases in suspended sediments; however, continuous high levels of sediment may have adverse effects. The sediment effects macroinvertebrates by changing substrate, causing respiration difficulties, lowering oxygen concentrations and reducing food value. Chironomidae may increase because they use fine sediments in the constru n of es and tubes (Wood and Armitage 1997). Therefore, higher percentage of Chironomidae would be expected in South Buffalo downstream of construction activities. However, Boston, Hillsdale, and Trestle, which had high turbidity, had relatively low Chironomidae percentages. Sediment was evident at most sites even in the upper reaches of the water supply watershed that had almost no cobble substrate. Sediment in these areas was from some construction and bank erosion. The effect of sediment and erosion of biota still needs to be studied.

Conclusions

It is not surprising that urbanization causes degradation of water quality, habitat and biotic communities in streams. However, we have concluded that historic water chemistry monitoring does not provide enough information to assess completely the condition of aquatic ecosystems. The rapid bioassessment protocol indicated if water quality, substrate, riparian buffer, or channel alterations have impacted the site. Sites thought to be severely degraded from the appearance and perceived water quality actually indicated good-fair biotic communities. Conversely, sites in the water supply watershed of the City thought to be relatively pristine having good water quality showed lower water quality, habitat and biotic community diversity than expected. Macroinvertebrates are an important monitoring tool to measure continuous and chronic effects from pollution, stream degradation from storm water runoff and point source discharges, and indicators of stream recovery. Data on invertebrate communities in conjunction with habitat and water chemistry data will provide the necessary tools for monitoring impacts to streams and other aquatic systems.

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Table 1. Bioclassification Criteria for Taxa Richness Values for the

North Carolina Piedmont for Standard Qualitative Sampling Methods

(Lenat 1988, NCDEHNR 1997)

Bioclassification	Standard Method
Excellent	>31
Good	24-31
Good-Fair	16-23
Fair	8-15
Poor	0-7

Table 2. Bioclassification Criteria for North Carolina Biotic Index for the North Carolina Piedmont (NCDEHNR 1995)

Bioclassification	Biotic Index Value
Excellent	< 5.19
Good	5.19 - 5.78
Good - Fair	5.79 - 6.48
Fair	6.49 - 7.49
Poor	> 7.48

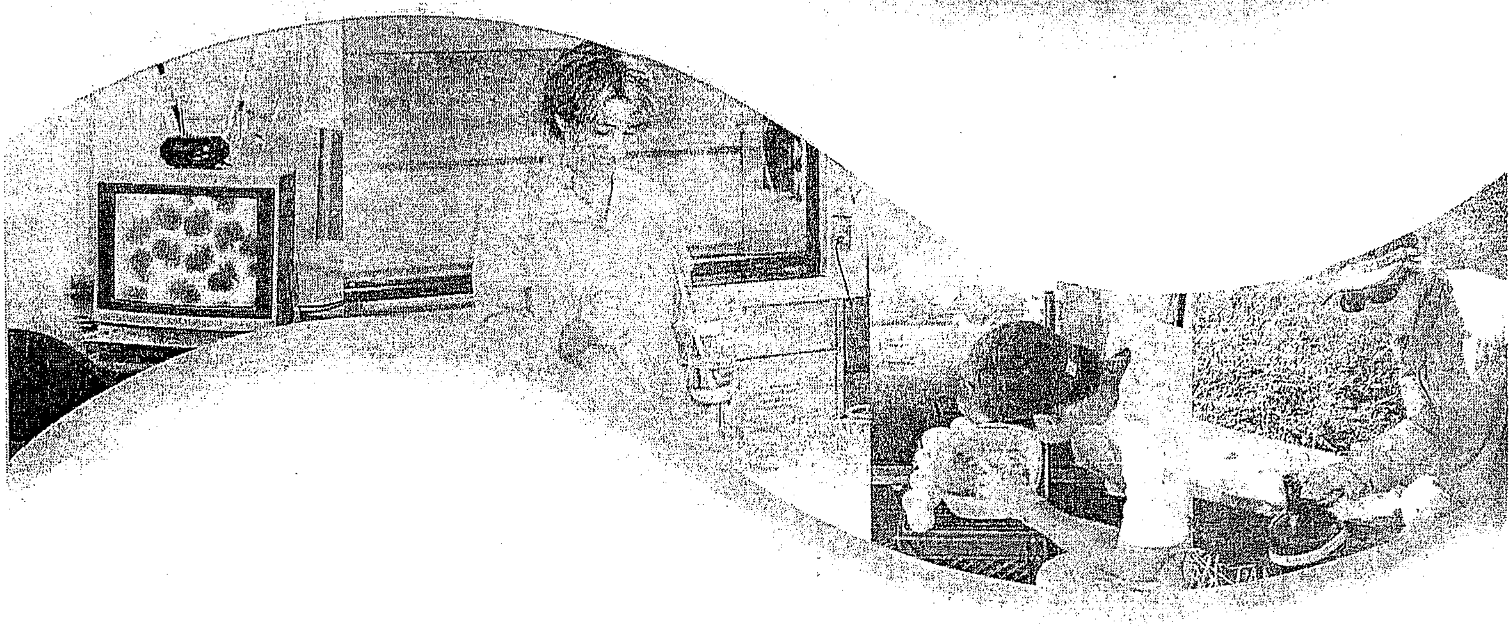
Table 3: Selected Results of Biological Monitoring and Habitat Assessment

Site	Taxa Richness	EPT Abundance	NCBI	NCBI Classification	EPT:C	% Chironomidae	Stream Order	Habitat Score
North Buffalo Creek								
Willoughby	45	23	5.46	Good	16.33	3.33	1	178
Caesar Park	50	0	7.73	Poor	0	61.8	1	162
Benjamin	60	33	6.01	G-F	8	8.94	2	191
Arboretum	72	33	6.16	G-F	2.3	18.18	3	170
White Street	30	6	7.67	Poor	0.16	80	3	151
*McKnight Mill	44	16	5.44	Good	2.5	12.8	3	183
Lake Daniel	52	0	6.84	Fair	0	76.74	4	144
WWTP	54	23	6.46	G-F	6.24	11.81	4	180
South Buffalo Creek								
Randleman	35	16	5.96	G-F	5.53	13.48	1	140
McColluck	42	16	6.48	G-F	3.2	15	1	157
Florida	38	16	6.72	Fair	3.16	19	1	144
Big Tree	36	25	4.36	Excellent	19	4.46	2	181
Meadowview	43	21	5.82	G-F	1.97	30.36	2	121

Cypress Park	56	26	5.77	Good	11	6.14	2	141
Gillespie	40	15	6.83	Fair	0.54	57.14	2	109
Boston	57	26	5.78	Good	3.56	16.22	3	160
Hillsdale	41	16	7.30	Fair	1.73	28.57	3	155
RR Trestle	37	27	5.90	G-F	6.23	13.27	4	181
McConnell	33	1	7.43	Fair	0.01	72.16	4	138
Water Supply Waters								
King Edward	65	20	5.81	G-F	1.05	33.04	1	168
*Battleground	62	16	5.24	Good	1.95	18.27	1	177
Church St.	60	18	5.00	Excellent	1.05	34.55	2	152
*Bryan Park	62	13	5.88	G-F	2.32	19.53	2	170
Chimney Rock	54	22	6.29	G-F	3.05	17.54	2	137
Cotswald	62	13	5.73	Good	3.22	7.44	3	130
Quaker Run	50	18	5.5	Good	10.6	4.55	3	120
Bunch Road	31	1	6.3	G-F	0.09	25.58	3	119
Cardinal CC	37	13	6.46	G-F	1	37.93	3	110
I-29	54	23	5.54	Fair	1.05	26.87	4	170
Addams Farm	44	25	5.54	Good	0	0	3	198
Piedmont Pkwy	50	23	6.08	G-F	5.75	12.21	2	193

*Reference Sites

EPA Region 9 and 10 Toxicity Training Tool



A069282

ACKNOWLEDGMENTS

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CHAPTER 6. AMBIENT TOXICITY TESTING AND WATERSHED ASSESSMENT

6.1 Overview

This chapter provides guidance to permit writers who are including stormwater or ambient conditions in permits. Although, WET tests are used as the primary tool for stormwater and ambient monitoring, the conditions under which they are used are generally different from monitoring continuous effluent discharges. Procedures which should be considered include:

- Experimental design – sample collection location, single vs. multiple concentrations
- Sampling – frequency, volume, container material, holding time
- Toxicity test method – organism selection, renewal frequency

Additionally, this chapter provides a broad overview of tools to be considered for stormwater and ambient monitoring, and provide examples of programs that have utilized tools including sediment toxicity testing, bioassessments, and in situ testing.

6.2 Introduction

Permitting authorities are, by the very nature of what they do, stewards of the nation's water resources. As such, their ultimate goal is to maintain those resources in a condition that, "meets the needs of the present without compromising the ability of future generations to meet their needs" (Bruntland 1987). The Clean Water Act (CWA) states, "The objective of this act is to restore, and maintain the chemical, physical, and biological integrity of the nation's waters." It is no longer sufficient to think about aquatic ecosystems from a single perspective like point sources, non-point sources, sediment, stormwater, or the air/water interface. A holistic approach, using the watershed as the integrating unit, has clearly been recognized by EPA as the focal point for measuring how well the objectives of the CWA are being met.

According to the Watershed Information Network (www.epa.gov/owow/watershed/), a watershed is an area of land that drains to a common place, such as a stream, lake, estuary, wetland, aquifer, or the ocean. Since the goal of permitting authorities is to maintain healthy water resources, they are increasingly not only required to monitor effluent discharges, but potential watershed pollution in the form of stormwater discharges and non-point source toxicity to receiving waters, or ambient waters. Much like effluent outfalls are monitored with toxicity and chemistry, stormwater outfalls and receiving waters can be monitored with similar tools, but with specific considerations for their use.

Once, the Permitting Authority identifies the questions to be addressed, the development of the Quality Assurance Project Plan (QAPP) integrates all technical and data quality aspects of a project including planning, implementation, and assessment. EPA requires that all environmental data used in decision-making be supported by an approved QAPP. EPA requirements for QAPPs can be found at http://www.epa.gov/quality/qs-docs/rsfinal.pdf. Ambient water quality monitoring conducted in California using state funds must be compatible with the State's Surface Water Ambient Monitoring Program (SWAMP). The objective of

SWAMP is to provide high quality data that is comparable and accessible. The current requirements necessary to be considered SWAMP-compatible are detailed in the links found at www.swrcb.ca.gov/swamp. Before any study is undertaken, there are certain common steps, regardless of the study, that should be performed. These steps are outlined in Figure 6-1.

Figure 6-1. Recommended Steps in Development and Implementation of Environmental Monitoring Studies

Develop a Problem Statement

- Review all relevant historical information
- Define spatial and temporal boundaries
- Identify collaborators to maximize benefit of limited funding

↓

Identify a Study Approach

- Define approach, purpose and objectives
- Include a conceptual model (if appropriate)
- Optimize sampling design - consult a statistician

↓

Develop a QAPP and Monitoring Plan

- Establish measurement quality objectives (MQOs)
- Develop a rigorous QA/QC program
- Include SOPs for all toxicity testing and chemical analyses

↓

Collect and Analyze Data

- Collect and analyze data according to the QAPP and Monitoring Plan
- Review data frequently and alter approach, if appropriate
- Identify stressor(s) using Stressor Identification Procedures and/or TIEs
- Include discussion of BMPs

↓

Synthesize and Report Data

- Make draft report available for review by stakeholders
- Provide responses to all comments
- Publish report, preferably in peer-reviewed journal

6.3 Use of WET Testing in Stormwater and Ambient Monitoring

Toxicity testing procedures that are typically used in WET testing compliance, coupled with other biological assessments, have become increasingly important tools for identification of waterbodies which fail to meet goals of the CWA. In general the same organisms, testing protocols and sampling methods used in WET testing can be used in stormwater and ambient water monitoring. However, stormwater and ambient water study designs may need to incorporate different test organisms and sampling strategies to meet the goals of the study.

Monitoring in freshwater ecosystems typically employs EPA three-species toxicity tests with freshwater algae (*Selenastrum capricornutum*), the cladoceran (*Ceriodaphnia dubia*), and the fathead minnow (*Pimephales promelas*) (USEPA 2002a, 2002b). There are numerous advantages in using established WET test species for ambient monitoring including well understood life history and husbandry of the test organism, and established test protocols with a robust statistical basis for endpoint interpretation. Depending on site-specific water quality conditions, it may be appropriate to utilize other species. For example, standard WET species may not tolerate high TDS waters characteristic of some ambient and storm waters. In cases where water quality characteristics are not compatible with standard test species, the permitting authority should use best scientific judgment within local and state agencies and EPA to select alternate species and/or testing approaches.

For testing of estuarine environments, EPA has published short-term chronic toxicity test methods for several West Coast species which could be used for environmental monitoring in estuarine and marine environments (USEPA 1995a). The estuarine species include topsmelt (*Atherinops affinis*) and mysid (*Holmesimysis costata*). For testing marine waters, protocols for Pacific oyster (*Crassostrea gigas*), mussel (*Mytilus* sp.), red abalone (*Haliotis rufescens*), giant kelp (*Macrocystis pyrifera*), sea urchin (*Strongylocentrotus purpuratus*), and sand dollar (*Dendraster excentricus*) are available. Monitoring programs may be conducted in areas that contain species of special concern. EPA has provided guidance on selection of standard test organisms that would predict responses of species that are threatened or endangered (USEPA 2003b).

6.4 Stormwater Monitoring

Stormwater monitoring for toxicity is really a special case of effluent monitoring, the main difference being that stormwater is episodic. There are special conditions associated with stormwater monitoring in cities and towns where collected stormwater is conveyed through separate storm sewer systems or through combined sewers to a treatment plant prior to discharge. In most cases, stormwater is directly discharged to the receiving system without treatment. Ultimately, a successful stormwater program minimizes the level of contaminants in the stormwater. The most severe receiving water problems due to wet weather flows are likely associated with chronic exposures to contaminated sediment and to habitat destruction.

Since 1990, EPA has developed Phase I of the NPDES Stormwater Program (http://cfpub.epa.gov/npdes/home.cfm?program_id=6). Most stormwater discharges are considered point sources and require coverage by an NPDES permit. The Phase I program addressed sources of stormwater runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required NPDES permit coverage for stormwater discharges from medium and large separate stormwater systems, eleven categories of industrial activity, and construction activity that disturb five or more acres of land. Phase II of the program requires NPDES coverage for stormwater from certain regulated small municipal separate storm sewer systems and construction activity disturbing between 1 and 5 acres of land.

The "quality" of the wet weather flow is dependent in large part on the use designations of the land it flows over. There are differences between constituents in wet weather flows originating in high mountain forested areas and those originating in fully developed urban areas. According to Pitt (2003) urban receiving waters may have many beneficial goals, including:

- stormwater conveyance (flood protection),
- biological uses (warm water fishery, biological integrity, etc.),
- noncontact recreation (linear parks, aesthetics, boating, etc.),
- contact recreation (swimming), and
- water supply.

However, with full-scale development and lack of stormwater controls, severely degraded streams will be commonplace in highly urbanized areas. Some studies have shown significant aquatic life impacts even in watersheds that are less than 10% urbanized (Pitt 2003; Booth and Jackson 1997). In the Pacific Northwest, Horner et al. (1997) found that when imperviousness reached about 8% in the watershed, there was a rapid decline in the biological conditions in the receiving water. Severe problems were found when imperviousness reached 30%. Claytor (1996) found that when only conventional water quality measures are used to evaluate the status of non-tidal streams, 87% supported their designated biological uses. However, when biological assessments were included, only 13% of the streams supported their designated biological uses. According to the EPA Stormwater website designed to provide guidance for reducing contaminant input into receiving waters, the primary method to control stormwater discharges is through the use of Best Management Practices (BMPs). EPA maintains a web site http://www.bmpdatabase.org/index.htm that contains a database of roughly 200 BMPs.

6.5 Ambient Monitoring

The receiving waters of either an effluent or stormwater discharge are monitored to achieve a greater understanding of the potential effects of the discharge. Standard effluent monitoring tools, such as toxicity testing and water chemistry are used gather data on receiving water impacts, but other tools include in situ toxicity tests, bioassessments, and sediment toxicity testing. The experimental design of the ambient monitoring study will be based on the study questions and the tools that are chosen. Water column toxicity tests will pick up more ephemeral toxicity, and therefore should be used in fewer places, but perhaps more often. In situ water column toxicity tests can integrate toxicity over time, and could probably be used more sparingly, at least temporally. Sediment acts as a sink for many chemicals, particularly hydrophobic contaminants, and sediment toxicity testing tends to monitor the potential for longer term effects. Sediment toxicity tests could be used less often temporally, but over a wider spatial range. Bioassessment also monitors long term trends, and is not generally considered a diagnostic tool, but could be used to assess long term impacts.

Several studies in California have successfully used ambient toxicity testing to identify and regulate frequently occurring toxic chemicals (Foe and Sheipline 1993; Kuivila and Foe 1995; de Vlaming et al. 2000). In these studies integral sampling locations were selected and ambient waters were collected to be assessed acute and chronic toxicity If toxicity was detected, additional samples were collected for testing to determine spatial and temporal patterns, as well as for conducting toxicity identification evaluations (TIEs) to identify the causative agents. This approach has led to the listing of chemicals broader than the 126 priority pollutants commonly tested. For example, diazinon was identified as causing water quality impairments and lead to 303(d) listings in several watersheds in California.

6.6 Special Considerations

Unlike effluents, where the constituents in the discharge remain fairly consistent, the constituents in stormwater and ambient samples can be ephemeral. Storm events are episodic, and depending on land use, a variety of contaminants can be present in the runoff. Receiving waters are similarly dynamic depending on inputs from point and non-point sources. Because of their inherent differences from effluents, toxicity testing of stormwater and receiving water have some specific method considerations. Areas which need to be considered differently for stormwater or ambient testing than the effluent testing program include: (1) sampling location and sample type, (2) sample containers, (3) sample initiation test, (4) sample renewals, and (5) experimental test design (single vs. multiple concentration testing).

6.6.1 Sampling Location

Selection of appropriate sample sites and sampling regimes are critical to the success of environmental monitoring studies. Sampling design in environmental monitoring programs is inevitably a compromise between cost/effort and accurately reproducing the regimen to which the organisms are actually exposed in the environment. Many sampling scenarios involve the use of integrator sites where multiple discharges and/or tributary flows combine. The United States Geological Survey's (USGS) "Seamless Data Distribution System" (http://seamless.usgs.gov) enables a user to view and download many geospatial layers, such as the National Evaluation Data set, National Land Cover Data set, and High Resolution Orthoimagery. If toxicity is detected at the integrator site, each of the contributing sources is tested to determine the source of the toxicity. Although this seems intuitive, care must be taken to assure that the samples are taken in such a way that takes into account the hydrology of the system being studied. USGS maintains a web site (http://water.usgs.gov/waterwatch) that reports in real time flows in mainstem rivers and major tributaries. In addition, real-time stream flows for California are posted the California Department of Water Resources website (http://cdec.water.ca.gov), which is useful in developing sampling plans. Land use information is critical for designing monitoring studies when it is important to know the contribution of flows from agricultural and urban areas. In addition, for agricultural areas, knowledge of crop type (http://gis.ca.gov) and pesticide use in specific areas (http://calpip.cdpr.ca.gov) can be useful in tracing sources of toxicity from agricultural chemicals.

6.6.2 Timing of Sample Collection

Monitoring stormwater for toxicity requires a special understanding of what needs to be monitored (Herricks and Milone 1998) although the methods used to test stormwater may not be any different from those used to test ambient/receiving waters. The challenge associated with stormwater testing is in developing sampling strategies that incorporate realistic exposure scenarios. Routine stormwater monitoring can differ from a "first flush" event that is generally more toxic because of contaminant buildup on impervious surfaces during the dry season. Similarly, first flush events from agricultural settings can occur after winter dormant spraying and pesticide applications in the spring. The greater the period between rainfall events, the greater is the potential for build-up of contaminants.

Timing of sampling of stormwater discharge depend on the intensity of the storm as well as preexisting conditions surrounding the site such as amount of impervious surfaces, characteristics of the collection system and soil saturation. The effect of these factors on discharge volume can be monitored using a hydrograph plot (flow vs. time). Contaminants will usually move into the receiving water as the storm hydrograph increases (Burton and Pitt 2001). Depending on the purpose of the study, multiple samples can be collected and tested throughout the runoff event to assess short-term effects and contaminant loading.

If a study objective was to monitor the toxicity associated with a particular storm event in a particular watershed at a particular site, or multiple sites, then samples collected over the period of the storm, based on the watershed characteristics and hydrograph would provide the most realistic time-scale for exposure. Herricks and Milone (1998) discuss a variety of approaches for determining the appropriate time scale of exposure for a given watershed. Miller et al. 2005 present results of flow-through toxicity studies for studying stormwater in an urban creek using *C. dubia.*

At the other extreme of exposure would be water column organisms that are picked up and carried for an extended, but unknown, period of time with the first flush of water that enters the receiving system. In this case, samples of the first flush of water can be used to expose organisms in the laboratory using WET test methods with or without renewals, depending on what the investigator is attempting to mimic.

For ambient sampling, knowledge of land use, pesticide application patterns and timing, and system hydrology is required to select sample site locations and timing. For both stormwater and ambient samples, sites that demonstrate adverse effects, timely collection of additional site samples is essential to establish the frequency, magnitude, and duration of the toxicity at the site.

6.6.3 Sample Collection

Effluent monitoring generally utilizes composite sampling to collect water during a discreet period of discharge. Depending on the objectives of the study, composite sampling can also be used for stormwater and ambient monitoring, but grab samples are used most often. The use of grab samples, the episodic nature of storm events, and the level of effort involved in the collection of receiving water samples can often lead to difficulties in adhering to a 36-hour sample holding time and the ability to collect multiple samples for renewals in an individual test. All tests should be conducted as soon as possible following sample collection. EPA has allowed exceptions to the 36-hour holding time, for example, when effluents are shipped overseas for testing (Denton and Narvaez 1996). The primary reason for an extension of the holding time would be the consideration of the sampling and laboratory technicians safety (Burton and Pitt 2001; see page 255), and logistics of coordinating collection and transport of multiple samples within a short period. Since, storm events are not pre-determined and typically are occurring rapidly throughout a watershed; therefore, many site samples must be coordinated with short notification. The 36-hour holding time for test initiation should be targeted, but no more than 72 hours should elapse before initial use of a sample. Typically, environmental monitoring programs use a single sample for all toxicity test renewals. For acute studies (typically 96 hours), a single test sample is usually collected and used to renew test solutions daily or at 48 hrs. EPA specifies the use of a minimum of 3 samples for chronic toxicity studies with fish and invertebrates (USEPA 1995a, 2002b, 2002c), but depending on the study question, sampling for storm events, might occur only once, or several times throughout the hydrograph. Another solution is to renew the test solutions with a mixture of ambient waters and stormwaters, if such waters could be collected following test initiation while meeting WET test holding time specifications (Katznelson and Mumley 1997).

During sample collection, it is critical to confirm and record the site location using GPS coordinates, note site characteristics, measure basic water chemistry (temperature, dissolved oxygen, conductivity), and estimate flow velocity and volume. The latter information may be challenging to obtain but is critical for estimating toxicant loading. Generally, glass sample containers are recommended for ambient and stormwater samples. Samples must be immediately placed on wet ice and transported to the testing lab, where testing should be initiated as soon as possible. Even assuming that all conditions of sample holding (36 hrs maximum at ≤ 6° C) are met, significant quantities of some chemical classes of constituents (e.g., organophosphates, pyrethroid insecticides and surfactants) may sorb to sample containers during the holding period. Vigorous shaking of sample containers prior to distributing to test containers to re-dissolve sorbed constituents is recommended (Wheelock et al. 2005).

6.6.4 Data Analysis

Initially, samples are tested at without dilution such as 100% concentration. The test endpoint data is analyzed using a standard t-test approach as described in the test methods manual (see USEPA 2002a, page 86). Many sampling plans specify that if toxicity is detected, the site shall be re-sampled and retested using a dilution series to determine the duration, frequency and magnitude of the toxicity. Toxic samples should immediately be subjected to TIE procedures to attempt to identify the toxic chemical(s).

6.6.5 Stormwater *In Situ* vs. First Flush

There are potentially two entirely different kinds of exposure from stormwater events. For sessile organisms (e.g., organisms which do not move with the discharge flow), the exposure is the culmination of all the water and constituents that pass over them during an event. In this case, *in situ* monitoring, using methods that can withstand the changes in the flow regime, can characterize that exposure. The effects of that exposure may be more difficult to predict, as they may not occur until some time after the exposure. One way to address this is to remove the *in situ* systems after the storm event and monitor their responses in clean water. Herricks and Milone (1998) studied time-varying exposures in the laboratory using the cladoceran *C. dubia*, the fish *P. promelas*, and the amphipod *H. azteca*. Their work showed the need for appropriate time-scales of exposure. Organisms that reside in the water column would move with the stormwater flows. Therefore, exposing *C. dubia* to the first flush sample in a storm event would probably not represent the exposure most of these sorts of organisms would receive.

6.7 Additional Monitoring Tools

There are additional tools that can be utilized for monitoring of stormwater and ambient water. Three of these tools are discussed below: in situ toxicity testing, sediment toxicity testing, and bioassessments. The use of these tools, and others, can either lead to the identification of an impairment, or monitor a currently impaired waterbody. Once impairment has been identified, identification of the primary stressors is pursued through the EPA stressor identification process (USEPA 2000c). This process was developed to identify any type of stressor or combination of stressors that cause biological impairment. The Stressor Identification (SI) process entails critically reviewing the available environmental information, analyzing potential exposure scenarios, and developing monitoring programs to fill in data gaps. The reader is encouraged to review the SI document prior to developing or reviewing environmental monitoring programs. Some types of monitoring approaches and their applications are shown in Table 6-1.

Table 6-1. Types of Monitoring Approaches and Their Applications

Type	*Approach*	*Applications*
Chemical Condition	Water quality sampling	Screen for impairment; identify specific pollutants of concern; identify water quality trends; determine support of designated contact recreation uses; identify potential pollution sources.
Physical Condition	Watershed survey	Determine land use patterns; determine presence of current and historical pollution sources; identify gross pollution problems; identify water uses, users, diversions, and stream obstructions
	Habitat assessment	Determine and isolate impacts of pollution sources, particularly land use activities; interpret biological data; screen for impairments
Biological Condition	Macroinvertebrate sampling	Screen for impairment; identify impacts of pollution and pollution control activities; determine the severity of the pollution problem and rank stream sites; identify water quality trends; determine support of designated aquatic life uses.

Source: USEPA 1997a.

6.7.1 *In-Situ* Testing

Toxicity tests using standard WET organisms and performed on ambient water samples are considered surrogate exposures for environmental realism. Exposing these organisms *in situ* can increase the environmental relevance. The test organisms used for *in situ* biomonitoring range from the same organisms used in WET toxicity testing to a wide array of other organisms. The list of references that follow are only a small number of articles on *in situ* toxicity testing: WET test organisms (Anderson 2002; Dickson et al. 1996; Hemming et al. 2001) amphipods (Maltby et al. 2003; Rainbow and Kwan 1995; Gerhardt et al. 1998); algae (Twist et al. 1997); real-time biomonitors (Allen et al. 1996; Waller et al. 1995; Kuster et al. 2004; Gerhardt et al. 1998; Kieu et al. 2001; Charoy et al. 1995).

Organisms can also be exposed in situ for bioaccumulation studies. Freshwater and marine mussels bioaccumulate both metals and organics and have been used extensively to evaluate sources of environmental pollution . Mussels can be placed in the field for varying periods and have the additional endpoints of growth and survival. Strategically located mussels can identify chemical inputs.

Several large monitoring programs have used mussels to monitor contaminants and determine contaminant bioavailability in the water column. The San Francisco Estuary Institute (SFEI) has a long history of using bivalves (resident clams and transplanted oysters and mussels) as sentinel species. Davis and Taberski (2002) reported on the use of mussels as part of a regional monitoring program of water quality in San Francisco Bay. California's Department of Fish and Game State Mussel Watch Program (SMWP) has been in effect since 1976. The Mussel Watch program is part of a worldwide monitoring effort designed to detect the presence and concentration of toxic pollutants in estuarine and marine waters (Martin and Severeid 1984). California has also employed mussels in the freshwater toxic substances monitoring program (SWRCB 1990).

6.7.2 Sediments

Because sediments can be sinks for many contaminants, they are potentially impacted by discharges to a receiving waters. The Contaminated Sediment Management Plan (USEPA 1998) has as its goal, "to reduce fragmentation, duplication, and increase more holistic approaches to pollution prevention." For example, NPDES permitted facilities may be meeting all their chemical-specific, parameter-specific, and WET requirements and yet sediment contamination could result from releases from these facilities. There are more than ten Federal statutes that provide authority to EPA program offices to address the problem of contaminated sediment. The EPA (1998) studied data from 1,372 of 2,111 watersheds in the continental United States and, based on the approach discussed below, identified 96 watersheds that contain "areas of probable concern" (APC). Four goals have been established to address the problem of contaminated sediment (USEPA 1998). These goals are:

- prevent the volume of sediment from increasing,
- reduce the volume of existing contaminated sediment,

- ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner, and
- develop scientifically sound sediment management tools for use in pollution prevention, source control, and dredged material management.

It is important to note that these 96 watersheds have been identified from existing databases and do not represent all the watersheds or portions of watersheds that might meet the criteria for APCs. A complete inventory of contaminated sediments in the United States has not as yet been established (USEPA 1997b). It is also important to note that the time span covered by the database from which these 96 APC watersheds were developed was 1980 to 1993. An updated report that is in draft form (USEPA 2001d) will provide new estimates for data up to and including 1999 as to the number and distribution of APCs.

Through the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA), EPA has the authority to ban or restrict the use of pesticides that have the potential to contaminate sediments if the risk is judged to be unreasonable. However, sediment toxicity has not been a part of routine test procedures and risk assessments for pesticide registration, re-registration or special review, even though prevention is clearly a better strategy than remediation.

Sediment has been functionally defined as all of the detrital, organic and inorganic particles that settle to the bottom of a body of water. In many sediment types (depositional sediments), water is found between the particles in the sediment and is termed interstitial or porewater. This water becomes very important in consideration of toxicity of contaminated sediment. Power and Chapman et al. (1992) divide sediment into four main compartments: interstitial water, organic, inorganic, and anthropogenically derived materials, including contaminants and eroded topsoil. According to their classification scheme, the largest volume is occupied by interstitial water that may occupy over 50% by volume of surface sediments. The inorganic phase includes the rock and shell fragments and mineral grains that originate from natural erosion of terrestrial materials. Organic matter is a variable, but small, fraction that occupies a low volume but is an important component because it can regulate the sorption and bioavailability of many contaminants.

Sediment toxicity tests are utilized much like WET tests, but their focus is on evaluating ambient sediment conditions. Freshwater and marine sediment testing protocols are described fully by the EPA (USEPA 1994d, 1994e, 2000d). The objective of sediment toxicity testing is to determine if chemicals in the sediment are harmful to, or accumulated by, benthic organisms. Sediment toxicity tests can be used to (1) determine the relationship between toxic effects and bioavailability, (2) investigate interactions among chemicals, (3) compare the sensitivities of different organisms, (4) determine spatial and temporal distribution of contamination, (5) evaluate dredge material, (6) measure toxicity as part of product licensing or safety testing or chemical approval, (7) rank areas for cleanup, and (8) set cleanup goals and estimate the effectiveness of remediation or management practices (USEPA 2000d). In addition to the methods in EPA 2000d, standard methods for assessing the toxicity of contaminants associated with sediments have been developed using amphipods, midges, polychaetes, oligochaetes, mayflies, and cladocerans (ASTM 1999a, 1999b, ASTM 1999c; USEPA 1994d, 1994e; Environment Canada 1997a, 1997b).

The sediment quality triad is an integrative approach for evaluating sediments (Chapman et al. 1992). This process is defined as any three-component integrative assessment that includes sediment toxicity, sediment chemistry and some measure of *in situ* bioeffects (often benthic infaunal community structure). The sediment quality triad is based on a ***weight of evidence*** approach for determining impact. For example, if chemistry indicates a potential impact, and toxicity tests show adverse effects, then the weight of evidence is strong that contaminants are impacting the sediment. Multiple toxicity tests on a variety of species do not substitute for other part of the triad, but do increase the strength of the toxicity leg. Detection of resident community alterations through bioassessments also reinforces the possibility of an impact.

Often, when information is gathered for assessing impacts, a tiered approach is used. By starting with the least complex and least expensive testing methodologies, a weight-of-evidence can be built over multiple metrics. If the metrics of the triad provide mixed results, then additional information may be needed to resolve the conflicts. However, some conclusions from mixed effect results can guide additional studies (Table 6-2). As with most assessments of environmental quality, the more quality information that is available, the greater is the likelihood that the assessment will be accurate.

Table 6-2. Information Provided by Differential Triad Response

Contamination	*Toxicity*	*Alteration*	*Possible Conclusions*
+	+	+	Strong evidence for pollution-induced degradation
-	-	-	Strong evidence that there is no pollution-induced degradation
+	-	-	Contaminants are not bioavailable
-	+	-	Unmeasured chemicals or conditions exist with the potential to cause degradation
-	-	+	Alteration is not due to toxic chemicals
+	+	-	Toxic chemicals are stressing the system
-	+	+	Unmeasured toxic chemicals are causing degradation
+	-	+	Chemicals are not bioavailable or alteration is not due to toxic chemicals

Source: Chapman et al. 1992

6.7.3 Sediment Collection

Procedures for collecting, storing, and manipulating sediments for chemical and toxicological analyses are well documented (USEPA 2001d; ASTM 2000). The EPA test methods manual represents a compilation of information from governmental documents to peer-reviewed literature and is an important source of information regarding the sediment phase of the aqueous environment. ASTM has also published a guide for the collection, storage, characterization and manipulation of sediments for toxicological testing (ASTM 2000).

The goal of any sediment sampling program should be to collect sediment in a manner that produces minimally disturbed sediment. The methods used to sample, transport, handle, and store and manipulate sediments and interstitial waters can influence the physicochemical properties and the results of chemical, toxicity and bioaccumulation analyses (USEPA 2001d). Many of the areas covered in EPA's technical manual are subjects of active research programs and, while the intent of the manual is to provide methodologies that minimize sampling impact, the authors recognize that methods are likely to evolve and that new additions of the technical guidance will reflect those advances. To keep pace with the changes visit www.epa.gov and search on sediment sampling and sediment testing.

There are many devices that have been used to collect whole sediments. The choice of sampling method is dependent to a large degree on what the sample is to be used for. The EPA sediment technical manual (USEPA 2001d) has a good discussion of the various collection methods and their strengths and weaknesses. Sampling sediments to determine the average concentration of chemical contaminants can be problematic. For monitoring and assessment studies, the upper 10-15 cm of sediment is normally collected because this is the area where most of the epibenthic and benthic organisms and the most recently deposited sediments are found. These samples can be used for physical and chemical analyses, benthic community analysis, and toxicity tests. In many instances, sub-samples of equal size from sediment samples can eliminate or reduce the influence of unequal sized grab samples.

Interstitial water, or pore water, is the liquid contained within every sediment sample. This water is may occupy up to 50% by volume in silt and depositional sediments (Sarda and Burton 1995; USEPA 2001d). Because interstitial water is in intimate contact with the sediment, it is assumed to be in thermodynamic equilibrium with contaminants in the sediment, and is generally to be considered the route of exposure for many sediment contaminants. In addition, contaminants in interstitial water can be transported to overlying waters through diffusion, bioturbation and re-suspension (Sarda and Burton 1995).

Interstitial water can be used to evaluate sediment toxicity with organisms that are normally used in aquatic toxicity tests (Carr and Nipper 2003). To evaluate interstitial water it must be separated from the sediment matrix. It should be noted that extraction of interstitial water can alter the chemistry of the sample (Sarda and Burton 1995). There are several methods used to isolate interstitial water from sediment including centrifugation, pressurization, or suction. *In situ* sampling devices for interstitial water have also been used. The most commonly used methods are "peepers" and suction devices. Peepers are samplers that have a rigid body with openings covered with permeable membranes. Prior to deployment, the openings are filled with a medium consistent with sample objectives. The peeper is then placed in the sediment and the medium in the openings is allowed to come into equilibrium with the surrounding interstitial water. The equilibration time varies, but multiple-week exposures are not unusual (USEPA 2001d; Sarda and Burton 1995). These methods generally produce smaller volumes of water (<500 mL) compared to centrifugation and pressurization and are often limited to shallower water depths. A variety of peeper designs along with diffusion samplers, vapor diffusion samplers, and semi-permeable membrane devices are discussed on the EPA website (http://clu-in.org/programs/21m2/sediment/). Regardless of the method of collection porewater samples should be processed as soon as possible after collection.

6.7.4 Freshwater Sediment Test Organisms

The EPA sediment test methods manual (USEPA 2000d) describes five methods for three organisms to measure the toxicity and bioaccumulation of contaminants from freshwater sediments. Two of the methods, one for the amphipod *Hyalella azteca* and one for the insect *Chironomus tentans*, measure survival and growth over a 10-day exposure period. One of the methods measures survival, growth and reproduction of *H. azteca* over a 42-day test, and one measures effects on *C. tentans* over the life-cycle of the insect. A bioaccumulation test with *Lumbriculus variegatus* is also presented.

Recently, sediment toxicity has been documented in urban waterways (Amweg et al. 2006) and agriculturally dominated waterways (Weston et al. 2004). The reader is encouraged to consult these published studies prior to designing or reviewing sediment toxicity. Phillips et al. (2006) and Anderson et al. (2006) describe TIE procedures for identification of the causes of toxicity in sediments from agriculturally dominated watersheds in California.

6.7.5 Bioassessments

Benthic infauna surveys can be accurate indicators of ecosystem health, and benthic surveys are frequently used as biocriteria to assess ecological integrity (Gibson et al. 2000; Borja 2005). Benthic data can be evaluated against historical data, reference conditions, models and indices, and with consensus professional judgment. Although standard benthic evaluation tools exist, the interpretation of benthic data is often subjective and based on best professional judgment (SCCWRP 2006). Moreover, because the presence of resident biota is region-specific, interpretation of bioassessment data must be based on the ecoregion.

Rapid Bioassessment Protocols (RBPs) were developed for freshwater environments as inexpensive screening tools for determining if a stream was supporting its designated aquatic life use (Plafkin et al. 1989). EPA guidance for marine bioassessments is provided in Gibson et al. (2000), but there are also a number of published marine bioassessment studies (e.g. Thompson and Lowe 2004; Weisberg et al. 1997; Smith et al. 2001). As these protocols were applied and modified, the areas in which the protocols provided useful information expanded to include:

- Characterizing the existence and severity of impairment to the water resource
- Helping to identify sources and causes of impairment
- Evaluating the effectiveness of control actions and restoration activities
- Supporting use attainability studies and cumulative impact assessments
- Characterizing regional biotic attributes of reference conditions.

The revised RBPs have been adopted and modified by various states to meet their monitoring needs (Barbour et al. 1999). Once adapted to the characteristics of a state, consistent reproducible procedures can be used to evaluate the status of a wadeable river or stream. One of the goals of the application of RBPs is to develop ***biocriteria*** that can be tailored to reflect the kind of biological system that should be found in waters that have a particular designated use (public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes). Once biocriteria are developed, a biosurvey of a receiving system with a particular designated use can be performed to determine if that system meets the requirements for that designated use. There are only a few places in the country that have developed biocriteria.

Implementing biocriteria in California is the responsibility of the State Water Resources Control Board and the Regional Water Quality Control Boards. In California, there is not one single entity responsible for developing statewide bioassessment protocols. As a consequence, five candidate programs exist in California that could provide the framework for the implementation of statewide bioassessment methods (SWRCB 2003). Bioassessments have been conducted at over 3000 sites in California by a variety of agencies. The California Department of Fish and Game (CDFG) bioassessment methodology has been used the most, with over 2500 sites sampled (SWRCB 2003). The more recent organization of California's Surface Water Ambient Monitoring Program (SWAMP) should provide the impetus to implement a better organized and standardized biological and assessment program (SWRCB 2003).

The California DFG is a leader in establishing taxonomic standards for statewide bioassessment efforts, an immense undertaking, given the size and diversity of ecoregions in California. The CABW was established as a forum for researchers, agency personnel and private consultants working in the field of freshwater biology. In 1995 the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet http://www.dfg.ca.gov/cabw/camlnetste.pdf) workgroup was started to develop consistent, sound methodological approaches to aquatic bioassessment, to provide mentoring and support, and to facilitate communication by promoting discussion of findings and bioassessment programs.

In 1999, CAMLnet produced the first edition of the CAMLnet List of Standard Taxonomic Effort (LSTE). This document defines the basic level of taxonomic resolution to be used by all CSBP data analyses. To conform to the CSBP standard effort levels, taxa may be identified to more, but not less precise, levels than those listed in the LSTE. The latest version (2003) of the list can be found at www.dfg.ca.gov/cabw/camlnetste.pdf. These protocols fit the essentials of the wadeable protocol to these specialized habitats.

An important and difficult step that is being pursued is the establishment of reference conditions for each of the types of waterbodies. The reference sites are, in theory, pristine sites for that waterbody type. Once the bioassessments of the reference conditions are in place, all streams of the same physical attributes (e.g., wadeable steams in a particular hydrologic unit) should have conditions equal to the reference site's conditions. In practice, it is difficult to find pristine sites for any given waterbody type, so the use of "least impacted" sites are often used instead. Regardless of the final choice of bioassessment protocols chosen for use, they will become an important tool in the arsenal of tools water quality managers have at their disposal.

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CHAPTER 7. ENFORCEMENT PROCEDURES FOR WET

7.1 Overview

The following discussion provides guidance on determining appropriate enforcement responses to violations of WET limits and conditions. This guidance incorporates the two main goals of EPA's NPDES compliance and enforcement program which are (1) to compel or require the permittee to expeditiously achieve and maintain compliance; and (2) to serve as a deterrent.

7.2 Background

CWA Section 309(a) states that any violation of a permit condition or limitation is subject to enforcement. Through EPA's 1989 national NPDES enforcement guidance, Enforcement Management System (EMS) guidance, the EPA Regional or State enforcement authority is encouraged to initiate an appropriate enforcement response to all permit violations. EPA's overall approach to enforcement applies to all parameters, including WET. Once a facility has been identified as having an apparent permit violation(s), the Permitting Authority reviews all available data on the seriousness of the violation, the compliance history of the facility, and other relevant facts to determine whether to initiate an enforcement action and the type of action that is appropriate. **The EMS recommends an escalating response to continuing violations of any parameter. Regions 9 and 10's enforcement follows the EMS.**

In a joint memorandum issued by EPA Headquarters Office of Regulatory Enforcement and Office of Wastewater Management (USEPA 1995b), EPA clarified National policy with regard to the two most common issues raised by the regulated community involving the enforcement of WET requirements in NPDES permits: 1) single exceedance of WET limits, and 2) inconclusive toxicity reduction evaluations (TREs).

EPA does not recommend that the initial response to a single exceedance of a WET limit, causing no known harm, be a formal enforcement action with a civil penalty. The regulated community has expressed concern about the potential for third party lawsuits for single exceedance of WET. Citizens cannot sue a permittee on the basis of a single violation of a permit limit. Under section 505(a) of the CWA, citizens are allowed to take a civil action against anyone who is alleged to "be in violation" of any standard or limit under the CWA. In Gwaltney of Smithfield, Ltd., v. Chesapeake Bay Foundation, Inc., 484 U.S. 49, 1008 S.Ct. 376, 98 L.Ed.2d 306 (1987), the Supreme Court held that the most natural reading of "to be in violation" is "a requirement that citizen-plaintiffs allege a state of either continuous or intermittent violation--that is, a likelihood that a past polluter will continue to pollute in the future." A State may have its own enforcement policy which may be more stringent.

In the case of inconclusive TREs, EPA recommends that solutions in these cases be pursued jointly with expertise from EPA and/or the States as well as the permittee. Solutions may involve special technical evaluation, as well as relief of civil penalties. The primary corrective action required for violations of WET limits is completion of a TRE, including, if necessary, a TIE. This requirement is incorporated into the Regions' NPDES permits. The permit language addressed in this document contains provisions requiring the permittee to: implement the generic

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

September 13, 2007

Steven Bay
Principal Scientist, Toxicology Department
Southern California Coastal Water Research Project
3535 Harbor Blvd., Suite 110
Costa Mesa, CA 92626-1437

Subject: SMBRC Technical Memorandum on Toxicity Testing of Wet and Dry Weather Runoff draft dated August 17, 2007

Dear Steven,

I appreciate the opportunity to review and comment on the Technical memorandum on toxicity testing of wet and dry weather runoff draft dated August 17, 2007. As we initially discussed on the phone, I suggest that the document have a technical tone only with no policy implications. Therefore, when the document states the objective of this memorandum is to provide guidance, it should be re-state the document is providing technical input to the LA Regional Water Resources Control Board for use in developing MS4 permit toxicity monitoring and reporting requirements.

I am enclosing your document with track changes and these additional comments and discussion. Storm events are episodic, and depending on land use, a variety of contaminants can be present in the runoff. Receiving waters are similarly dynamic depending on inputs from point and non-point sources. Because of their inherent differences from effluents, toxicity testing of stormwater and receiving water have some specific method considerations. Areas which need to be considered differently for stormwater or ambient testing than the effluent testing program include: (1) sampling location and sample type, (2) sample containers, (3) sample initiation test, (4) sample renewals, and (5) experimental test design - single vs. multiple concentration testing (Denton et al. 2007 and Denton and Narvaez 1996). I can provide the chapter within this document titled "Ambient toxicity testing and watershed assessment, and the pertinent frequently asked questions regarding stormwater and ambient toxicity testing.

In addition, issues such as timing of sample collection to flow and sample renewals should be discussed in the document. Taken from Denton et al., 2007, "As the timing of sample collection to a flow measurement important. A measurement of flow should coincide with the collection of stormwater samples for WET testing. This typically entails measuring flow discharge from the site, in addition to the amount of rainfall causing the discharge event. It is important to establish when sampling occurred relative to the streamflow hydrograph (and subsequent chemograph) (Ward and Elliot 1995). Scientists must consider the magnitude of a toxic response in relation to flow of receiving waters when making chemical or toxicity assessments of receiving or stormwaters in the regulatory arena (permitting and TMDL development) and when developing study designs. Therefore, if assessment and quantification of the mass loadings are of interest, then concurrent flow measurements from a US Geological Survey gauging station located near the point of interest and within the same watershed should be collected (USGS 1999, 2000). Measurement of flow concurrent with sample collection should be considered if a nearby and representative gauging station is not available." Additionally, how is the standard test renewal practices specified in the test method manuals followed, given that storm events may be of short duration? The EPA 5th edition acute test methods (USEPA 2002a) specify that test solutions be renewed after 48 hours for a 96-hour test. However, for storm events in short duration, this is not always feasible. A more realistic option, in cases when a second stormwater sample may not be available, would be to renew the test solutions with a mixture of ambient waters and stormwaters if such waters could be collected following test initiation while meeting WET test holding time specifications (Katznelson and Mumley 1997). Another option would be to collect sufficient volume during the storm event to use for the start of the test and at the 48-hour renewal".

Any questions call me at (916) 341-5520 or email at denton.debra@epa.gov.

Sincerely,

Debra L. Denton, PhD
Environmental Scientist

cc: Emily Reyes, State Water Resources Control Board
Terry Fleming, USEPA Region 9
Xavier Swamikannu, LA Regional Water Quality Control Board

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SMBRC Technical Memorandum on Toxicity Testing of Wet and Dry Weather Runoff

Draft August 17, 2007

Background

Toxicity testing of urban runoff toxicity in southern California has been incorporated into monitoring programs relatively recently; most monitoring programs have been in place for less than 10 years. (This needs to be restated to reflect the fact that monitoring programs have been in existences for the past 2 decades). There is still much to be learned regarding the magnitude, characteristics, and causes of toxicity in wet and dry weather runoff. A diversity of methods and study designs are currently used in toxicity monitoring programs.

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The primary objectives of toxicity monitoring for urban runoff are similar to those for other types of discharges, such as municipal wastewaters: to describe the magnitude and frequency of toxicity within watersheds and to determine the cause of toxicity. These monitoring programs may also have secondary objectives, such as determining the sources of pollutants and to implement best management programs (BMPs).

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Toxicity tests provide unique information that complements chemical analysis and other monitoring methods. Measurements of toxicity integrate the combined effect of all contaminants in a sample, including priority pollutants and contaminants of emerging concern. Because they use a biological response, toxicity tests take into account various factors that can affect the bioavailability and potency of contaminants, such as changes in water hardness, suspended particles, and interactions among contaminant mixtures. Toxicity tests often use exposure conditions and types of organisms likely to be encountered in the environment and thus provide an ecologically relevant measure of the biological impact of runoff discharge on receiving water. These characteristics make toxicity data especially relevant for prioritizing sites for management action and evaluating the effectiveness of BMPs.

Toxicity tests have several limitations that affect their utility for monitoring purposes. First, a diversity of species are used for testing, each with potentially different sensitivities to contaminants. Because toxicity is defined operationally as an adverse response in an organism and there is no standard reference material for toxicity, it is difficult to compare results between species (what is the meaning of this sentence?, there is no need for a standard reference material for toxicity). Second, the toxicity of a sample may change over a relatively short period of storage. As a result, toxicity tests must be completed rapidly and there is little opportunity to repeat the analysis in order to correct a technical problem. Finally, toxicity tests do not usually indicate the cause of toxicity and toxicity identification evaluation (TIEs) are needed to be conducted to identify the

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cause(s). (I suggest that this paragraph to be deleted as it is not germane to the topic).

Discharges of stormwater and dry weather runoff are different from continuous flow effluent discharges and therefore different applications of the test methods need to be considered and discussed within this document. Continuous effluent discharges are present year-round, relatively consistent from day to day, and originate from a treatment plant that provides convenient access for sampling. Runoff discharges differ in that the flow characteristics and composition are unpredictable and highly variable. Access to safe and representative runoff sampling points may be limited, requiring the location of sampling sites in areas that do not allow the use of sophisticated sampling methods or are not representative of the entire watershed. There is some guidance available to assist with the design of runoff monitoring programs, especially with regard to toxicity assessment (Denton et al., 2007; Burton and Pitt 2001). Areas which need to be considered differently for stormwater or ambient testing than the effluent testing program include: (1) sampling location and sample type, (2) sample containers, (3) sample initiation test, (4) sample renewals, and (5) experimental test design (single vs. multiple concentration testing).

The objective of this memorandum is to provide technical input to the LA RWQCB for use in developing MS4 permit toxicity monitoring and reporting requirements. This guidance is intended for application to sites used to characterize runoff mass emissions from a watershed into marine/estuarine waters. Some aspects of this guidance may not be appropriate for other types of monitoring sites, such as inland water bodies that do not discharge directly into coastal waters. Information and guidance on key aspects of study design, testing, data interpretation, and toxicity identification are presented. This guidance takes the form of recommendations, rather than absolute requirements, in recognition of the diverse situations that may be encountered in a monitoring program. The authors encourage the user to follow this technical input to the extent possible, so that greater comparability and success of toxicity monitoring can be obtained.

This memo was developed by the Technical Advisory Committee of the Santa Monica Bay Restoration Commission through consultation with the following agencies:

Sanitation Districts of Los Angeles County
[Please add your agency name as you would like it to appear in the memo]

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Sampling/Study Design Considerations

Study Design

- Test site locations should be determined on a site-specific basis. At least one site should be included in each watershed of interest and this site should represent a location as close to the bottom of the watershed as feasible (e.g., mass emission station).
- The number of sites should be determined for each monitoring program based on considerations such as the objectives of the study, watershed characteristics, and accessibility of sampling locations.

Multiple concentrations should be tested so that the relative toxicity of the sample can be determined with the greatest accuracy. A minimum of three concentrations should be tested: 100%, 50%, and 25%. Additional concentrations may be included that are based on a 0.5x series. At a minimum, replicates of each concentration should be tested as specified for the specific test method. (I suggest looking at Denton et al., 2007. "Initially, samples are tested at without dilution such as 100% concentration. The test endpoint data is analyzed using a standard t-test approach as described in the test methods manual (see USEPA 2002a, page 86). Many sampling plans specify that if toxicity is detected, the site shall be re-sampled and retested using a dilution series to determine the duration, frequency and magnitude of the toxicity. Toxic samples should immediately be subjected to TIE procedures to attempt to identify the toxic chemical(s)".

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- Salinity of the test samples should be adjusted as needed to eliminate salinity stress on marine test organisms if marine organism testing is conducted. Adjustments should be made using hypersaline brine or concentrated sea salts in order to minimize sample dilution. The dilution created by salinity adjustment should be included when reporting the concentration of the sample tested.

Manipulation of the sample prior to testing, such as the removal of particulates, should be conducted only as a last resort and using the most minimally invasive method available. These manipulations should be done in the testing laboratory, rather than in the field. According to Section 9.1.2 of the acute test methods manual (USEPA 2002a), filtering the sample through a 60 um mesh is only a requirement when the sample contains indigenous organisms that will interfere with the test. For example, some predatory invertebrates could eat the test organisms. If these interfering organisms are not present, the sample does not have to be filtered.

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Frequency and Timing

- Dry and wet weather events should be sampled from each watershed because different sources and magnitudes of toxicity may be present. A subsample of every toxicity sample should be analyzed for all of the chemical analytes specified in the permit.

Wet weather samples

- Two wet weather (storm) events should be sampled per year. The first sample should represent the first storm of the season that meets the sampling critical criteria. The second storm sample should be collected at least 30 days after the first, but generally no later than February. (I'm not sure that you want to be so prescriptive that another sample can't be collected within 30 days of the first event).

- Criteria for triggering wet weather sampling and criteria for sample acceptance should be defined in the permit. Suggested sampling criteria are: a predicted 0.25" of precipitation & 72 hr antecedent to the previous rainfall. Suggested sample acceptance criteria are: at least 0.1" recorded precipitation and at least 50% increase in flow relative to base flow. The precipitation criterion is intended to maximize success in obtaining sufficient sample for testing. However, the sample should not be discarded as unacceptable solely on the basis of a lower than predicted precipitation. Greater importance should be placed on obtaining a sample during the desired time frame (especially the first storm of year). If sufficient sample was collected and it represents primarily wet weather runoff, it should be tested. Note that greater than 0.1" of rainfall will typically be needed in less developed watersheds in order to provide adequate wet weather runoff.

Dry weather samples

- One dry weather sample should be tested per year, generally sampled April-October (or when dry weather flow is present).
- The suggested critical conditions for dry weather sample collection are: at least 14 days antecedent to the previous rainfall and sufficient flow to permit collection of a representative sample.

Sample Type and Handling

- A composite sample, matched with a chemistry sample of identical composition, should be collected. Compositing methods may vary due to site and weather considerations, but should produce a sample that is representative of the discharge during the sampling period. Flow-weighted compositing should be used for wet weather samples. Dry weather composite samples should represent a 24 hour period and be either time- or flow-weighted. Need to include a discussion on the utility of grab samples should be considered for stormwater toxicity testing as sampling logistics may not lend themselves to composite sampling.
- Volume needed is determined by specific test methods to be used. Generally, up to 5 gallons may be needed for baseline testing, with up to an additional 5 gallons for TIE studies.
- Glass containers should be used for both sample collection and storage. Plastic containers may accelerate changes in toxicity due to sorption and loss. Samples should be sealed with a minimum of head space and stored in the dark.

Samples must be stored on ice or under refrigeration (4 °C) between the end of sampling and the start of the test. This needs to be changed to reflect the sample temperature range that is specified in the test methods manual, according to the test method

Formatted: Indent: Left: 0", Hanging: 0.25", No bullets or numbering, Keep with next, Tabs: 0.25", Left manuals the storage and shipping temperature of samples is in the range of 0-6 degree C (USEPA 2002a, 2002b, 2002c).

Baseline toxicity tests should be started with 36 h of the end of sample collection. Tests started within 72h are acceptable for wet weather samples, but must be flagged and the reason for delay explained. These storage limits do not apply to TIE studies, but an effort should be made to conduct the TIEs as quickly as possible in order to minimize changes in toxicity. This paragraph needs to be revised to reflect this information. All tests should be conducted as soon as possible following sample collection. EPA has allowed exceptions to the 36-hour holding time, for example, when effluents are shipped overseas for testing (Denton and Narvaez 1996). The primary reason for an extension of the holding time would be the consideration of the sampling, laboratory technician safety (Burton and Pitt 2001; see page 255), and l. ogistics of coordinating collection and transport of multiple stormwater samples within a short period of time. Storm events are not pre-determined events and typically occur rapidly throughout a watershed; therefore, many site samples must be coordinated and processed with short notification to the toxicity testing laboratories. It is encouraged that the 36-hour holding time for test initiation be targeted; however, the Permitting Authorities may allow an exception beyond the 36-hours. However, no more than 72 hours should elapse before initial use of a sample.

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Toxicity Test Methods

Test method selection

- The selection of toxicity test species and methods should take into consideration several factors: comparability with other programs, sensitivity to contaminants of concern, logistics with respect to the monitoring program design. Ecological relevance has been discussed, addressed and not germane to technical input on methodology applications to wet and dry weather stormwater testing (USEPA 1999). Each of these factors is discussed in the following sections.
- Full comparability with other programs can only be achieved through the use of the same test species. It is recommended that a widely used and sensitive test method such as the *Ceriodaphnia dubia* 7 day survival and reproduction test be used to test all samples. If so, then document needs to address how to handle the second and third renewals within this seven-day test (see cover letter).
- No single test can provide a sensitive measure of toxicity for the variety of runoff samples likely to be encountered. A minimum of two sensitive species should be used to test each sample in order to address uncertainties in sample toxicant composition and test method sensitivity. It is recommended that one test species be a crustacean and the other test species include a sensitive invertebrate from a different phylum (e.g., mollusc or echinoderm). Prior experience has shown that fish and algae are relatively less sensitive to most runoff samples; use of these taxa should be limited to monitoring programs where site-specific concerns indicate that fish or algae are preferred test organisms.
- The selection of test species can usually be based on prior data for similar sites and consideration of other factors. Screening tests with several species should be

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conducted to inform test method selection for sites where there is insufficient information available to guide test selection.

- The feasibility (I suggest using a different word than "feasibility" has to do more with "logistics") of toxicity tests is determined by factors such as sample volume requirements, organism availability. Tests having the greatest feasibility are those using invertebrates, especially those using Ceriodaphnia, red abalone, and mussels.
- Table 1 summarizes the key characteristics and recommendations regarding some of the more commonly used runoff toxicity test species.

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QA/QC

- Required elements to be evaluated in each test batch include acceptable test acceptability criteria (TAC), review of within test variability (PMSD), performance of reference toxicant, salinity controls (if needed) and water quality measurements such as salinity, hardness, dissolved oxygen, and pH, water quality within acceptable method ranges, and sample and collection holding times.
- Response to a QA exceedance should be contingent upon nature of failure, potential impact on data, and prospects for repeated testing. Some exceedances will render data invalid, others may prompt a QA flag but still be sufficient to evaluate monitoring objectives. (see section on QA/QC within the testing manuals)
- The lack of ability to repeat wet weather toxicity tests should be considered in judging data acceptability. In general, a QA exceedance that is likely to result in a failure of the test to detect the presence of toxicity should be considered a test failure and invalid data.

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Data analysis and interpretation

- For the purposes of this program, any sample exhibiting effects relative to the control in excess of the minimum pMSD value specified in the permit should be identified as being toxic. Samples exhibiting effects less than the pMSD should be identified as being nontoxic. (I suggest rewriting this to accurately reflect chapter 10 from the testing manuals). The pMSD value should be based upon a species-specific statistical analysis of test data. Sources for PMSD values include EPA test methods manual see chapter 10 "Test Review and Report Preparation) is the specify the review of within-test variability PMSD's and the lower and upper bounds (USEPA 2002b, 2002c, USEPA 1995).
- Statistical analysis methods should be consistent with EPA test method manuals (USEPA 2002a, 2002b, 2002c, 1995).
- Toxicity results should be reported in the following formats: mean response (e.g., growth rate), control adjusted response (% of control), statistical significance of response relative to the control, NOEC, PMSD, and EC25/IC25. Comparisons of the magnitude of toxicity between samples should be based either on the control adjusted response at a specific test concentration (e.g., 100% runoff) or a point estimate of effect (EC25/IC25).

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Toxicity Identification Evaluations

The purpose of toxicity identification evaluations (TIEs) is to determine the principal cause(s) of the toxicity in a particular sample. The purpose of a toxicity reduction evaluation (TRE) is to determine the principal cause(s) of the toxicity and reduce the identified toxicity-causing constituent(s) to non-toxic levels. While TIE guidance is available it must be recognized that a TIE should be flexible, in order to adapt to unexpected events or to preliminary results. Stormwater and dry weather runoff TIEs present a challenge because the available sample volume is often limited and additional sample collection may not be possible or no longer representative of the conditions observed in the original sample. For these reasons, some TIEs may be unsuccessful due to the lack of toxicity or inability to conduct some analyses. Such events should be anticipated by both the regulator and permitee and do not necessarily indicate a failure to comply with the monitoring program requirements.

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Triggers

- Any sample exhibiting an effect greater than 50% relative to the control during baseline testing should be immediately tested using phase 1 TIE procedures. A sample trigger is a policy decision and should be decided by the regional water quality control board.
- Phase 1 TIE procedures should be conducted concurrently with initial baseline testing if prior testing indicated the presence of toxicity that is lost during sample storage.
- TIE testing should be considered for a sample if effects exceeding the minimum pMSD but below 50% are observed consistently.
- If a trigger is exceeded at multiple locations, at a minimum, the TIE should be conducted on the sample exhibiting the largest magnitude of effect. Additional prioritization of sites for TIE analysis should be established by the regulatory agency, in collaboration with the permittee.

Methods

- The TIE should be conducted on test species, generally demonstrating the most sensitive toxicity response at a site. However, a TIE(s) may be conducted on an additional test species with the caveat that once the toxicant(s) has been identified then the most sensitive test species triggering the TIE event needs to be tested additionally to verify that the toxicant has been identified and addressed.
- EPA guidance should be followed in conducting the TIE. The specific methods to be used vary depending on whether the species is marine or freshwater.
- The minimum methods (Phase I) to be applied to each TIE sample must include: 1) particle removal, 2) metal chelation by EDTA, 3) organics removal by SPE column, 4) assessment of confounding factors (ammonia, hardness, pH), and 5) baseline toxicity measurement. A suggested initial TIE study design is described in Appendix 1.
- Additional TIE methods are contingent upon the nature of the Phase I TIE results. A study plan for these methods should be developed by the analytical lab and approved by monitoring program coordinator before sampling begins.

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- Sample storage time criteria for toxicity characterization shall not apply for TIEs, but the samples should still be stored in glass containers and under refrigeration.

Interpretation

- A completed TIE sample is one that has been tested, at minimum, following the specified phase 1 manipulations. In addition, an initial TIE of a sample is considered complete if the sample no longer exhibits toxicity during subsequent testing.
- TIE testing should continue as often as a trigger is exceeded in order to determine the variability in the type of toxic constituents. If after multiple TIEs, a consistent pattern of toxicity (TIE fingerprint) is observed, the phase 1 manipulations could be streamlined to focus on the suspected constituent(s).

Recommendations for Future Investigations

The guidance described here is limited to selected aspects of toxicity testing. Additional guidance and data are needed to address other issues related to the evaluation of the toxic impacts of stormwater. Following are several areas recommended for further investigation.

- **Comprehensive multi-species screening studies.** There is limited information available to evaluate the comparative sensitivity to runoff for some of the species listed in Table 1. A study is needed to address this data gap, which would provide better information on which to base test species recommendations. It is suggested that stormwater management agencies work together to screen several runoff samples using all of the Tier 1 & 2 species listed in Table 1.
- **Develop guidance for evaluating impacts of runoff on sediment toxicity.** The use of sediment toxicity testing to evaluate runoff impacts is highly variable among southern California agencies. Guidance similar to that described here should be developed to address monitoring for sediment toxicity.
- **Investigate links to receiving water impacts.** Runoff toxicity tests are conducted under controlled conditions, use a very limited number of test species, and often utilize worst-case assumptions that might not correspond to exposure conditions in the field. Little is known about how well these laboratory tests correspond to actual receiving water impacts. Additional studies are needed to examine the correspondence between laboratory toxicity tests of runoff and impacts on populations and communities in the receiving environment. Such studies could be incorporated into regional watershed monitoring programs that are currently under development.

Table 1. Characteristics of toxicity tests relative to use in runoff monitoring.

Species/Name	Endpoint	Duration (days)	Use[1]	Sensitivity[1]	Availability[2]	Volume[3]	Method Difficulty[4]	H.	
Ceriodaphnia dubia (daphnid)	Survival/Repro.	7	Common	High	All	High	Moderate	F	
Holmesimysis costata (mysid)	Survival/Growth	7	Rare	Moderate?	Limited	Moderate	Moderate	N	
Americamysis bahia (mysid)	Survival/G/rowth	7	Some	Moderate	All	Moderate	Moderate	N	
Hyallela azteca (amphipod)	Survival	4	Some	Moderate	All	Moderate	Low	F	
Red abalone	Embryo Develop.	2	Rare	High?	All	Low	Low	N	
Mussel	Embryo Develop.	2	Rare	High?	All	Low	Low	N	
Purple sea urchin	Fertilization	1	Common	High	Most	Low	Moderate	N	
Purple sea urchin	Embryo Develop.	3	Rare	High?	Most	Low	Low	N	
Green alga	Growth	4	Some	Low	All	Moderate	Moderate	F	
Giant kelp	Growth	2	Rare	Low?	Limited	Moderate	Moderate	N	
Fathead minnow	Survival/Growth	7	Common	Low	All	High	Moderate	F	
Topsmelt	Survival/Growth	7	Rare	Low	All	High	Moderate	N	
Silverside	Survival/Growth	7	Rare	Low	All	High	Moderate	N	
					All				

1. Relative to other species in the table, when used for runoff monitoring. Based on local experience and judgment.
2. All: available at any time of year; Limited: availability unpredictable due to field collection; Most: Good availabil May, advance preparations needed for rest of year.
3. Approximate volume needed for initial and phase 1 TIE tests. High: >20 L : Moderate: 4-20 L; Low: <4 L
4. Moderate: Additional labor for water changes and feeding needed, specialized techniques needed to achieve high Low: High test success rate usually obtained, no water changes or feeding required during test.
5. Tier1: Use as benchmark species in all programs where feasible; Tier 2: Recommended use as a second sensitive Potential use depending on program-specific considerations; Tier 4: Not recommended due to low feasibility.

I suggest that using the word feasibility and instead logistics. Steve, as you and I discussed on the phone, but questi feasibility, but whether the organisms for certain methods may not be as available, such as giant kelp due to the natu field broodstock, which may not be available because of the nature of collecting broodstock concurrently while a sto

Appendix 1
Suggested Initial TIE Approach for Runoff Samples

If a toxicity trigger is exceeded, Phase 1 Tier 1 TIE manipulations should be initiated as soon as possible using remaining stored sample. If the magnitude of effects in 100% sample is less than 50% of the control, all TIE manipulations should be conducted using a control and only 100% sample using the method specified minimum number of replicates. If greater effects are observed, all TIE manipulations should be conducted using a control and a minimum of two concentrations in the range of 1% to 100% sample (e.g., 50%, and 100%).

Complete Phase 1, Tier 1 manipulations will include:

Treatment	Freshwater	Marine
Baseline (no manipulation)	X	X
EDTA Additions	X	X
Thiosulfate Additions	X	X
pH = 6.5	X	
pH = 8.5	X	
Filtration	X	X
Aeration	X	X
SPE	X	X
PBO addition	Optional[1]	Optional[1]
Carboxyl esterase addition	Optional[1]	Optional[1]

1. Highly recommended if pyrethroid or organophosporus pesticides are of concern.

If characterization of toxicity is unsuccessful or inconsistent using the Tier 1 manipulations, the following Tier 2 manipulations should be conducted as soon as possible using remaining sample and the previously used method specifications. Some of these methods may not be feasible for use with marine species.

Phase 1, Tier 2 manipulations (if necessary) will include:
Baseline (no manipulation)
Aeration at pH = 3 and pH = 10
Filtration at pH = 3 and pH = 10
SPE at pH = 3 and pH = 10

The following limited phase 2 manipulations should be conducted if appropriate based on the phase 1 characterization using EPA/600/R-92/080 (Methods for Aquatic Toxicity Identifications Evaluations – Phase II Toxicity Identification Procedures for Samples Exhibiting Acute and Chronic Toxicity:

Phase 2 Manipulations:

Non-polar Organics (toxicity removed in the SPE pass through manipulation) – sequential methanol elution of C18 column followed by reconstitution at 2X the original concentration to determine if toxicity is recovered..

Ammonia (pH = 7.0 removes or reduces toxicity) – zeolite filtration and ammonia add back

Metals (removal or reduction of toxicity in EDTA and/or STS addition manipulation) – Analytical quantification and subsequent add back confirmations.

California Regional Water Quality Control Board
Los Angeles Region
(50 Years Serving Coastal Los Angeles and Ventura Counties)

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Gray Davis
Governor

May 9, 2002

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Claim No. 7001 1140 0002 0364 8452

REVIEW OF THE VENTURA COUNTYWIDE STORMWATER MONITORING PROGRAM'S, 2000/2001 MONITORING REPORT, JULY 2001.

Dear Ms. Coleman:

In November 2001 the Ventura County Flood Control District (VCFCD) submitted its final Stormwater Monitoring Report to the Regional Water Quality Control Board. Subsequent comments are based on our review of the November and July 2001 monitoring status reports, and Regional Board staff meeting with VCFCD staff on April 11, 2002. We have been discussing these issues with you over the last few months, and we hope future monitoring reports will meet our expectations.

General Comments:

- Minimum Levels (MLs) for priority toxic pollutants from Appendix 4 of the policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SIP) shall be used in future monitoring. These MLs have replaced the existing Method Detection Limits (MDLs) for priority pollutants in the constituent list. Any approved USEPA analytical method may be used to achieve the MLs. If the principal permittee can demonstrate that a particular ML is not attainable in accordance with procedures set forth in 40 CFR 136, the lowest quantifiable concentration of the lowest calibration standard analyzed by a specific analytical procedure may be used instead of the listed ML. We hope this direction addresses the issue you raised in your letter dated November 13, 2001.
- The QA/QC plan for collecting field samples is missing from the report. The Ventura Countywide Stormwater Monitoring Program: Standard Operating Procedures 2000-2005 Stormwater Monitoring has not been updated to reflect current procedures. Please correct this deficiency in future reports.

- Information from duplicate samples criterion and tolerances are missing from the report. . Please correct this deficiency in future reports.

Constituents:

- Temperature data were not reported and are required to be recorded for all future sampling events in order to analyze parameters for the monitoring and reporting program.
- Nitrite as N data were not reported and need to be analyzed for and recorded for all future sampling events.
- E. Coli data were not reported and needs to be sampled and recorded for all fresh water stations during all sampling events.
- Sample, analyze and report for enterococcus rather than fecal streptococcus to be consistent with other bacteria monitoring and existing standards.
- Please provide information on what species of chromium, phosphorous, and ammonia were analyzed for in all future sampling events.
-

Metal Samples- Please provide information:

- Where the metal blanks originated;
- Level of detection at which the metal blanks were considered contaminated;
- What the quantity/level of metals was in the metal blanks;
- What metal(s) were found in the blanks; and
- The QA/QC plan procedure for handling metal banks (from origin to lab analysis).

Toxicity Results:

- A Toxicity Identification Evaluation (TIE) shall be performed when acute toxicity results are greater than 1 TUa. Please explain why no TIE was performed for 2000/01. Although you have three instances of exceedences. Freshwater acute toxicity testing shall be conducted on the most sensitive of the two species- Pimephales promelas (Fathead minnow) and Ceriodaphnia dubia (water flea).
- Chronic toxicity tests shall be conducted using the most sensitive marine species for two wet weather events and one dry weather flow sample per monitoring season. Strongylocentrotus purpuratus (purple sea urchin) fertilization is recognized as the most sensitive marine species. If it can be demonstrated that a specific species of the silverside (Menidia) is the most sensitive marine species, then it can be used; and
- The receiving water limitations (Permit, part 2.C) and the TIE procedures (II. Monitoring Requirements, section 2.g) must be fully addressed in future reports. When it is determined that storm water discharges are contributing to an exceedance of a water quality standard, the principal co-permittee shall submit a Receiving Water Limitation Compliance Report as an attachment to the Annual Report. The Compliance Report shall include the following:

(i) A plan to comply with the Receiving Water Limitations in the permit;
(ii) Changes to the Management Plan to eliminate or reduce exceedances;
(iii) Enhanced monitoring to demonstrate compliance; and
(iv) Results of implementation.

Data Analysis/Monitoring Results:

- Future monitoring reports shall include a comparison of storm water quality data to applicable water quality criteria that are found in the Basin Plan for Ventura County, California Toxic Rule (CTR), and the California Ocean Plan. The most stringent applicable criteria shall be used as a comparison for use in the general interpretation of the significance of the results;
- The report shall include a general interpretation of the significance of the results for all sampling station data (Permit part 3.E.1.c). Please explain why this was not done; and
- The Storm Water Monitoring Report due on July 15, 2001, is to be the final complete report containing:
  1) status of implementation of the monitoring program;
  2) results of the monitoring program;
  3) a general interpretation of the results;
  4) both tabular and graphical summaries of the monitoring data obtained during the previous year; and

  The Discharger shall submit by October 1st of each year, an integrated summary of the results of analyses from the monitoring program under Part II.B.
- Please note that the Permit's Monitoring and Reporting Program, Part II, Monitoring Requirements, section 2.g, states "The Discharger shall monitor a total of three mass emission stations to **establish baseline conditions and load estimates**, for the Ventura River and Calleguas Creek, beginning with the 2000-2001 monitoring season, and for the Santa Clara River beginning with the 2001-2002 monitoring season". In order to "establish baseline conditions and load estimates" analysis of the data collected will have to be performed.
- Attachments: Sampling results for two monitoring stations (W-4 Revolon Slough and ME-CC Calleguas Creek) were taken and analyzed for exceedences based on their Beneficial Uses. A similar procedure is recommended for analysis of results obtained at the County's monitoring stations. If the Beneficial Use designation MUN has an asterisk (*), then the designation does not apply until it has been reevaluated by the Regional Board. If the Beneficial Use designation GWR is listed and the Beneficial Use designation MUN does not have an asterisk (*), then Title 22 applies.

- The Los Angeles County 1999-2000 Stormwater Monitoring Report is located on their web site at http://ladpw.org/wmd/npdes/report_directory.cfm. Reviewing this document may benefit the Ventura County's effort in developing its Storm Water Monitoring Report.

If you have any questions concerning this matter, please call me at (213) 620-2120.

Sincerely,

Ejigu Solomon
Ventura Storm Water Chief

Enclosure

California Regional Water Quality Control Board
Los Angeles Region
(50 Years Serving Coastal Los Angeles and Ventura Counties)

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July 31, 2002

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REVIEW OF THE VENTURA COUNTYWIDE STORMWATER MONITORING PROGRAM'S, 2000/2001 MONITORING REPORT, JULY 2001.

Dear Ms. Coleman:

Thank you for your response letter dated June 28, 2002. In November 2001 the Ventura County Flood Control District (VCFCD) submitted its final Stormwater Monitoring Report (Report) to the Regional Water Quality Control Board (Board). We have been discussing issues raised following our review of the Report with you over the last few months. Following our discussions, on May 9, 2002, we sent you a letter outlining our critique of the Report and requesting additional information. In your letter of June 28, 2002 you provided responses to our concerns and supplied additional information, however there are several issues that have not been fully resolved. The following comments and directives address these outstanding concerns. We trust that future monitoring reports will meet our expectations.

Metal Field Blank:

- It is understood that the VCFCD will ensure that their lab recognizes the severity of field blank contamination, and that the lab has taken steps to resolve its QA/QC problem.

Toxicity Test Species:

- Freshwater acute toxicity testing shall be conducted on the most sensitive of the two species- Pimephales promelas (Fathead minnow) and Ceriodaphnia dubia (water flea). This Permit requirement intended that toxicity testing for both fish and invertebrates would initially be conducted to determine which species was the most sensitive. Subsequent testing would then use only the more sensitive of the two species. Freshwater acute toxicity testing on only Ceriodaphnia dubia does not meet the requirements of the Permit.
- The Board does concur with minimizing sample manipulation as much as possible, but in determining the most sensitive species for chronic marine testing, the question that you are trying to answer such as, does the discharge enter an estuary near shore or directly to

the ocean, and what Beneficial Use(s) need(s) to be protected, must be kept in mind. It may be appropriate for some samples to be tested using Menidia beryllina whereas for others it would be appropriate to use Strongylocentrotus purpuratus. When the concern is for toxicity to marine life, then the Strongylocentrotus purpuratus test is better. When the concern is for toxicity to freshwater or estuarine life, then the Menidia beryllina test is better. VCFCD has not fully justified their selection of the most sensitive species for chronic marine testing.

Receiving Water Limitation Compliance Report:

- Your proposed method for determining when a Receiving Water Compliance Limitation Report is required is not appropriate for the following reasons:
  - For the 90th percentile concentration to have any real value, data would have to be analyzed separately for each sampling location, and would require a fairly large number of samples due to the wide variability of storm water samples.
  - It is redundant to require exceedance of the 90th percentile of historic levels to trigger a water quality compliance report. By definition, if the 90th percentile concentration for a given constituent is greater than the applicable water quality standard, then the standard has been and will be exceeded for more than 10% of the samples, demonstrating a statistical exceedance of the standard. (Given your assumption that the 90th percentile equates to the concentration that will be exceeded more than once in three years, the applicable water quality standard would also be exceeded more than once in three years.) If the 90th percentile concentration is lower than the water quality standard, then it will be exceeded every time the standard is exceeded.
- Water quality compliance reports are triggered by a determination by either the Discharger or the Regional Board that discharges are causing or contributing to an exceedance of an applicable water quality standard(s). You shall perform the data analysis and comparison to applicable water quality criteria so possible exceedances will be detected.
- If required, the water quality compliance report may be included with the Annual Storm Water Report and Assessment, unless the Regional Board directs an earlier submittal. The Compliance Report shall include the following:

  (i) A plan to comply with the Receiving Water Limitations in the permit;
  (ii) Changes to the Management Plan to eliminate or reduce exceedances;
  (iii) Enhanced monitoring to demonstrate compliance; and
  (iv) Results of implementation.

Data Analysis and Monitoring Results:

- It is not clear what the statement "future storm water data will be combined with historic data" means. If future storm water data and historic data will be mixed together, then this is unacceptable. If future storm water data will be identifiable from and listed as separate data from the historic data then this will be acceptable.

- The most stringent applicable criteria shall be used as a comparison for use in the general interpretation of the significance of the results.
- The Report's data analysis must consider the applicable Beneficial Uses of the receiving water to determine the applicable water quality standards.
- The Regional Board recognizes that the County is under a tight timeframe for producing a complete and comprehensive Report in July. It is difficult to produce a report based on the analysis and interpretation of data due at the end of your sampling season, but this is the nature of a sampling program.
- As stated in the Permit and in the Board's letter dated May 9, 2002, the Storm Water Monitoring Report due in July is to be the final complete report. The County is not required to produce two reports per year, documenting six monitoring events. The County is required to produce a single report for its monitoring events titled "Storm Water Monitoring Report" due in July, which is to summarize the year's sampling events. The Annual Storm Water Monitoring Report and Assessment due in October is to include an integrated summary of the results of analyses from the monitoring program that is documenting the status of the general program and individual tasks contained in the Countywide Storm Water Quality Management Plan. The County's request to submit a single report to summarize the year's sampling events and submit only one annual water quality report per year in October of each year is denied at this time.

If you have any questions concerning this matter, please call me at (213) 620-2120.

Sincerely,

Ejigu Solomon
Ventura Storm Water Chief

California Regional Water Quality Control Board
Los Angeles Region
(50 Years Serving Coastal Los Angeles and Ventura Counties)

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Gray Davis
Governor

August 20, 2002

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PRELIMINARY COMMENTS ON THE VENTURA COUNTYWIDE STORMWATER MONITORING PROGRAM'S 2001/2002 MONITORING REPORT, JULY 2002.

Dear Ms. Coleman:

Thank you for the Ventura Countywide Storm Water Monitoring Program's 2001/02 Monitoring Report (Report), which we received on July 15, 2002. We have reviewed the Report and the following are our comments based on our review.

In general, the Report was much more clearly written than previous reports, and was found to be more "user friendly" for our purposes. We recognize the difficulty in producing these reports, and appreciate the effort you have made towards improving it. Please note that these are preliminary comments, and should the need arise, a final comment letter might follow.

Issues from previously reviewed reports

- There is still disagreement over the appropriate test species for chronic marine toxicity testing. The Permit requires chronic toxicity testing using the most sensitive marine species. We believe that the purple sea urchin, Strongylocentrotus purpuratus, is the most sensitive marine species. This species (S. purpuratus) is also specified in the Water Quality Control Plan for Ocean Waters of California as a Tier 1, or preferred, toxicity test species. The Ventura County Flood Control District (VCFCD) has so far chosen to use the silverside minnow, Menidia Beryllina, based on a recommendation from the testing laboratory. We would prefer that VCFCD conduct side-by-side tests to establish the species that is most sensitive.

- It is understood that in the future VCFCD will test samples for a) nitrite as N, b) E. Coli and enterococcus rather than streptococcus, and c) report temperature data, although these changes were not reflected in this Report.

- Data were collected from sampling events in June and July of 2002, however these results were not presented in the Report. VCFCD intends to present these new data in the Annual Report, due October 1, 2002. This plan deviates from the requirements that the annual report will contain "an integrated summary of the results of analyses from the monitoring program". In the future, sampling should be planned around the reporting dates, so that the July report can include an analysis of all the data for the previous years monitoring.

Water quality standard comparison

The comparison of sampling data to water quality standards showed numerous exceedances, for metals, some organics and indicator bacteria. The Permit states that:

> *"Upon a determination by either the Discharger or the Regional Board that the discharges are causing or contributing to an exceedance of an applicable water quality standard, the discharger shall promptly notify and thereafter submit a report to the Regional Board\...to prevent or reduce...exceedances of water quality standards"* (Part 2 – Receiving Water Limitations, p. 9).

The exceedances identified in the Report are a potential trigger for the above requirement. However, more information is required to assess the significance of these results because data from dry and wet weather events were lumped together in the analysis, and only acute standards were used for comparison.

We do not understand the rationale provided in the Report for selection of acute criteria for the comparison. Please explain the following statement further:

> *"The CTR acute and chronic criteria are associated with one another, the acute objectives are used since both acute and chronic criteria are associated with one another. The presence of an acute criterion also means the presence of a chronic criterion in which only one criterion is necessary."* (Report, p. 47) *

It is not sufficient to use only acute or instantaneous objectives for the comparison. Acute criteria may be appropriate to assess impacts to receiving waters for storm events due to their episodic nature and typically short duration. However, some storm events have a longer duration and criteria such as the daily maximum would be appropriate. Dry weather flows represent a continuous, chronic condition in the streams and therefore chronic criteria are appropriate for receiving waters under these conditions. Beneficial uses should also be considered when determining the appropriate water quality objective for comparison.

To make a meaningful comparison it will also be necessary to consider dry weather flows separately from storm flows. In future reports, we expect that dry weather sample data will be considered separately and compared to chronic criteria, and that storm flow data will be compared to appropriate acute criteria. *

The comparison also did not identify which particular events caused the exceedances, so the Report does not allow us to determine when they occurred. Did they occur in all years, or only during some years? For storm samples, were the exceedances related to storms early in the year, or did they occur late in the storm season as well? For dry weather samples, how often do the exceedances occur? The Report does not list the concentrations of the criteria to which data are being compared, or show the magnitude of the exceedance. The report also does not explain or demonstrate how CTR criteria for total metals were calculated. Future reports should clearly list the concentrations for comparison and provide the dates and concentrations of samples exceeding the criteria.

Sampling/laboratory issues

- Although the QA/QC procedures were clearly explained, there were continuing problems with blanks, recoveries, and problems with the controls for the growth portion of the chronic toxicity tests. VCFCD has indicated continuing contact with the laboratories to eliminate the problems to the extent possible. The Report states that the laboratories are investigating the reason(s) for the problems, however, we are concerned with the continued laboratory failures. We request that VCFCD provide a brief report outlining the laboratory's findings and steps taken to resolve these problems. We also suggest that equipment field blanks be done for the automatic samplers to determine whether they contribute contaminants to the samples. *

- There is some confusion in the description of sample qualification. For example, the metals Cr, Cu, Pb, Ni, and Zn are qualified with an asterisk in Table 16, and the footnote refers to Appendix B for the description of qualifiers. Even though Appendix B does have a table containing information on blanks, it does not define the qualifiers given in the last column (e.g., NDB, (a), and (b)). All data tables should be self-contained with the necessary descriptors--data qualifiers should be presented with the data themselves.

- The Report states that "no data were rejected based on field blank results". What does it mean to have a 667 percent difference as in the case of total cadmium at ME-CC on 4/11/02? What value does the environmental sample result have in this case? It appears that these data may be being considered as non-detects. Please provide an explanation. *

- No sample was taken at receiving water station W-3 (La Vista Ave.). It is understood that there was insufficient flow for a sample to be collected. We realize that 2001/2002 was an exceptionally dry year, and expect that this location will be sampled in the coming year provided sufficient flow is present.

- The Report states that laboratory data are provided to VCFCD in hardcopy form. We recommend that they be provided in electronic files, as these would be easier to handle and less prone to error.

Other issues

- A very high ammonia concentration was detected in a sample collected from Calleguas Creek on 11/21/01, and the sample demonstrated high toxicity. We appreciate the initiative taken to investigate the cause of this event. The agricultural use of ammonia may well be the cause, but a more rapid follow-up would be necessary to confirm this. Reliable data from an incident such as this one might prove to be important in the implementation of future total maximum daily loads (TMDLs). Perhaps other data sources (independent water quality studies) could be consulted as part of the analysis. It may be appropriate to provide outreach to the farmers and inquire whether they use best management practices.

- In the future, please provide hydrographs of the sampled events, and clarify the definition of "event volume", is it a 48-hour volume? It is also not clear what is meant by "averaging flow throughout the event" for the wet weather flow measurements. *

- The Report states that:

  "Mass loadings are calculated strictly for Permit requirements" (Report, p. 40).

  We remind you that estimated mass loadings, such as those in the Report, are a measure of the water quality of the watershed. We trust that this information serves a purpose beyond meeting a permit requirement, and should be beneficial to the management efforts in Ventura County. Such estimates might be more useful if they were apportioned among the contributing land uses.

  It is not clear how the mass load estimates were calculated. Please provide example calculations in future reports. *

- In Appendix C, the rightmost column labeled "Note" has designations (e.g., a, b, etc.), but these are not defined. Please provide explanations or definitions for all descriptors or data qualifiers. *

Please provide your response by October 1, 2002. Your response should address, at a minimum, our comments with asterisks.

If you have any questions concerning this matter, please call me at (213) 620-2120.

Sincerely,

Ejigu Solomon
Ventura Storm Water Chief

Winston H. Hickox
Secretary for Environmental Protection

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September 17, 2003

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REVIEW OF THE VENTURA COUNTYWIDE STORMWATER MONITORING PROGRAM 2002/ 03 MONITORING REPORT, JULY 2003.

Dear Ms. Coleman:

Thank you for the Ventura Countywide Storm Water Monitoring Program's 2002/03 Monitoring Report (Report), which we received on July 15, 2003. We have reviewed the Report and the following are our comments based on our review and they were discussed with Ms. Darla Wise of your staff on September 9, 2003.

We appreciate the effort you have made towards improving the County Monitoring Program and its associated Report.

Record of Monitoring Information

- The time of sampling does not appear to have been included with the data sheets for Laboratory Analysis Results or within the text of the Monitoring Report. It would be useful information to have it included with the data sheets for Laboratory Analysis Results. A requirement of the Permit is the recording of the time of sampling or measurements.

- It was understood that temperature data was going to be included in the list of analysis, and this year's Monitoring Report didn't include it.

Toxicity Testing Issues:

- There is still a misunderstanding over the freshwater acute toxicity testing. The Permit requires that freshwater acute toxicity testing shall be conducted on the most sensitive of the two species- Fathead minnow (*Pimephales promelas*) **and** Water flea *(Ceriodaphnia* *dubia*). The Permit is not stating that there is a testing choice between the two species, both species are to be tested.

- The Permit states that chronic toxicity tests shall be conducted using the most sensitive marine species. Chronic toxicity testing should be conducted on the most sensitive of the two species using USEPA West Coast marine and estuarine species. Testing should be performed using: Topsmelt (*Atherinops affinis*) **and** between Red abalone (*Haliotis rufescenis*), Mussels (*Mytilus spp.*) and Oyster (*Crassostrea gigas*), Purple urchin (*Strongylocentrotus purpuratus*) and Sand dollar (*Dendraster excentricus*), or Mysid (*Holmesimysis costata*).

- It should be noted that the sliverside minnow (*Menidia beryllina*) is an East Coast species not USEPA approved for West Coast marine chronic toxicity testing. The sliverside is not an appropriate choice for chronic toxicity testing and is not a recognized species to use for West Coast marine chronic toxicity testing, it does not fulfill the requirement of Ventura's Monitoring Report requirements.

Water Quality Results

- The sampling date for toxicity is not listed within the report and a requirement of the Permit is the recording of the date of sampling or measurements.

- New analytes, such as perchlorate, may be added in the revised permit and we strongly recommend that you include perchlorate in your Sampling and Analysis Plan for next year.

Metals Results

- Your Lab's, FGL's, recommendation to raise the reporting limits for lead, chromium, copper, and zinc to reduce the possibility of false blanks should be considered after the results of the SCCWRP Regional Intercalibration Study.

Data Analysis and Discussion

- The Basin Plan has been amended to include AB411 criteria (Board adoption date was October 25, 2001 and EPA Region IX approved the amendment September 25, 2002) , it is to be used for the analysis of Total and Fecal Coliform, and Enterococcus.

- Land use sites have a high probability of discharging concentrated pollutants, but water quality standards apply to all tributaries. Without data to support the statement "Once the discharges enter the waterbody (where the objectives apply), the higher flow rates dilute the discharge and result in lower concentrations of the pollutant" (*Land Use Discharge Analysis*, pg.65, 2nd paragraph) which in this case may be organic compounds, it can not be assumed.

If you have any questions concerning this matter, please call me at (213) 620-2120.

Sincerely,

Ejigu Solomon
Ventura Storm Water Chief

Enclosure

California Regional Water Quality Control Board
Los Angeles Region
(50 Years Serving Coastal Los Angeles and Ventura Counties)

Winston H. Hickox
Secretary for Environmental Protection

320 W. 4th Street, Suite 200, Los Angeles, California 90013
Phone (213) 576-6600 FAX (213) 576-6640
Internet Address: http://www.swrcb.ca.gov/rwqcb4

Gray Davis
Governor

October 29, 2004

Mr. Jeff Pratt, P.E., Director
Ventura County Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93009-1600

Certified Mail
Return Receipt Requested
Claim No. 7002 2030 0002 1673 2223

REVIEW OF THE VENTURA COUNTYWIDE STORMWATER MONITORING PROGRAM 2003/ 04 MONITORING REPORT, JULY 2004.

Dear Mr. Pratt:

Thank you for the Ventura Countywide Storm Water Monitoring Program's 2003/04 Monitoring Report (Report), which we received on July 12, 2004. We have reviewed the Report and the following are our comments based on our review.

Monitoring

- The Report is to have represented the County's Storm Water Monitoring Program during the 2003/2004 water year. Data represented in the Report does not fully show storm water monitoring for the 2003/2004 water year. For mass emission stations, the NPDES Permit CAS004002 (Permit) states: "Up to six station events per year, including a minimum of 2 dry weather samples must be monitored." This is interpreted to mean that at least 6 samples are to be taken each water year (4 wet weather samples and 2 dry weather samples). Data from the county's mass emission stations shows 3 wet weather samples collected in 2004 (February 2nd, 18th and 25th). The wet season is from October 1st through April 15th as defined in the Permit. The required 2 dry weather sampling events are to be taken during the water year also, one prior to the onset of wet weather (2003) and once wet weather events have subsided (2004). The Report does not contain data for the required 6 events per year, and this is a violation of the County's Permit.

Precipitation and Flow

- The 8 monitoring stations storm water sampling dates show that the 2003 first storms of the season were not sampled. In a storm event, the first flush of runoff typically contains relatively high concentrations of contaminants which may then fall and fluctuate at lower levels for the remainder of the storm event. As a result of this contaminant concentration pattern through an event, the highest levels of toxicity are expected to be associated with this first flush. The first .25 inches of rain from a storm event creates runoff in channels (See, *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report. Appendix D, Low Flow Study.* It has been shown those water quality constituents such as nitrate, total phosphorus, turbidity, TSS and hardness are higher in the smaller storms than larger storm events. Ventura County did not collect sampling data accurately representing storm water contaminants within its watersheds. The Permit does not contain "blackout dates".

- The first storms of the year generally produce the most toxic storm water, showing the need to sample these storms (See, *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report. Appendix C, Executive Summary of the Santa Monica Bay Receiving Waters Study by Southern California Coastal Waters Research Project.* Excerpted from the *Study of the Impact of Stormwater Discharge on the Beneficial Uses of Santa Monica Bay,* July 8, 1999 (SCCWRP, 1999), Pg. 11.

Toxicity Testing Issues:

- The presence of a particular contaminant should lead to the use of organisms with known sensitivity to that contaminant. For example, where ammonia is considered to be the causative agent of toxicity, fish should be used rather than invertebrates due to their greater sensitivity. In contrast, invertebrates would be more appropriate where pesticides are the suspected causative agent of toxicity. If the County of Ventura would like to perform a study to evaluate the selection of organisms to use when performing acute and chronic toxicity testing, then a plan will have to be submitted to the Regional Board prior to the onset of the study for evaluation. Alternatively, the County of Ventura may use the toxicity methods as explained in- Lau, S.-L., M.K. Stenstrom and S. Bay. 1994, *Assessment of storm drain sources of contaminants to Santa Monica Bay. Volume V, Toxicity of Dry Weather Urban Runoff,* prepared for Santa Monica Bay Restoration Project, Monterey Park, CA, Pg. 129, water flea (*Ceriodaphnia dubia*) reproduction and survival test (freshwater), and the purple sea urchin (*Strongylocentrotus purpuratus*) fertilization test (marine), shall continue to be used.

- The next Permit will re-evaluate the testing procedures for both acute and chronic toxicity testing. In the interim, it is recommend that Ventura County review the toxicity testing sections of the Storm Water Monitoring Program's Reports for both Los Angeles and Long Beach Counties. The County of Long Beach's Report, section 4.5.2.3- Sea Urchin Fertilization Test, should be reviewed for adjusting sample salinity. The County may also want to use the October 2002 EPA toxicity testing methods, EPA-821-R-02-012 for acute and EPA-821-R-02-013 for chronic.

- Chronic toxicity testing was not performed for water flea (*Ceriodaphnia dubia*) reproduction.

- Data sheets showing toxicity test results have to be included with the Report. Aquatic Bioassay & Consulting Laboratories, Inc.'s ToxCalc output for the 2003/2004 monitoring year is to be submitted to the Regional Board immediately.

<u>Water Quality Objective Comparisons:</u>

- The Water Quality Control Plan for Ocean Waters of California (Ocean Plan), which contains water quality objectives for the coastal waters of California, is to be used in comparing the County's monitoring data to water quality exceedances. Section C.1 of the *California Ocean Plan* states: "Nonpoint sources of waste discharges to the ocean are subject to Chapter I Beneficial Uses, Chapter II – WATER QUALITY OBJECTIVES (wherein compliance with water quality objectives shall, in all cases, be determined by direct measurements in the receiving waters) and Chapter III – PROGRAM OF IMPLEMENTATION Parts A.2, D, E, and H."

- During storm events, freshwater flows into the Ocean where a plume can persist for several days after a storm. Information on the properties of storm water plumes in terms of characterization and biological effects can be found in the report - *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report. Appendix C, Executive Summary of the Santa Monica Bay Receiving Waters Study by Southern California Coastal Waters Research Project.* . Excerpted from the *Study of the Impact of Stormwater Discharge on the Beneficial Uses of Santa Monica Bay, July 8, 1999* (SCCWRP, 1999).

- Monitoring data are to be compared to both acute and chronic criteria in the California Toxics Rule. In toxicity testing, it is the sub-lethal effect of the exposure that is being tested rather than the duration of exposure. Sub-lethal effects include damage to reproductive rates, growth, etc. Acute testing is showing lethal effects- death.

Potential Problematic Constituents

- Constituents exceeding water quality objectives are considered Pollutants of Concern (POC) and should be discussed within the Report. For these POCs, besides "continued monitoring" and "track[ing] for further analysis", they should be identified in the Ventura County Storm Water Management Plan (SMP) as requiring additional investigation. Based on the POC source identification, additional target businesses may be identified to be included in the industrial/commercial inspection program. And co-permittees shall report on the types and proposed actions to be taken in regard to the additional target businesses in annual reports.

- Also, in light of upcoming Total Maximum Daily Loads (TMDLs), the monitoring program should be geared towards selecting and prioritizing appropriate BMPs to target the identified POC.

Continued TSS Underreporting

- We continue to be concerned about the low results of TSS from your monitoring. These low results may be related to sampling large rainfall events and sampling methods. There are a multiple of sources of TSS from nearly all land uses. The significance of reducing TSS cannot be understated given the fact that a few other POC adsorb onto sediments.

- Therefore, as suggested in prior correspondence please review your testing methods, and we would like also to take split samples if given sufficient notification time.

If you have any questions concerning this matter, please call me at (213) 620-2237.

Sincerely,

Ejigu Solomon
Ventura Storm Water Chief

cc: Mr. Lawrence Jackson, Division Manager, Ventura County Watershed Protection District
Ms. Darla Wise, Ventura County Watershed Protection District

>>> "Arne Anselm" <Arne.Anselm@ventura.org> 10/29/2007 3:28 PM >>>
Tracy,

I want to let you know about the toxicity results of a storm sampled on September 22. The chronic toxicity for Ventura River was reported at >16.00 TUc. The storm was very small, just over 0.25 inch and over a long enough period that very little runoff was observed. In fact, two of our sites had no flow for the whole storm.

We have not received any other analytical data and currently have no idea what could have caused this. This site will be analyzed for chronic toxicity at the next sampling event, and a Toxicity Identification Evaluation will be performed if elevated toxicity is observed.

Give me a call if you have any questions,
Arne

Arne Anselm
Water Quality Monitoring Manager
Ventura County Watershed Protection District
805.654.3942
www.vcstormwater.org

From: "Gerhardt Hubner" <Gerhardt.Hubner@ventura.org>
To: "Deborah Smith" <Dsmith@waterboards.ca.gov>, "Tracy Woods" <twoods@waterboards.ca.gov>, "Xavier Swamikannu" <Xswamikannu@waterboards.ca.gov>
Date: 10/31/2007 9:45:53 AM
Subject: Fwd: Re: September 22th storm water monitoring event

Tracy,

No problem. As soon as we received it we will forward it to you.

Gerhardt

>>> "Tracy Woods" <twoods@waterboards.ca.gov> 10/31/2007 9:35 AM >>>
Hello Gerhardt,

Thanks for sending the lab results for bacteria and toxicity testing, I am still interested in reviewing the rest of the chemical analyses data, as soon as it comes available.

Thanks - Tracy Woods
LA-RWQCB / Storm Water Permitting
320 W. 4th Street, #200
Los Angeles, CA 90013
Phone: 213/620-2095
Fax: 213/576-5777
E-mail: twoods@waterboards.ca.gov

>>> "Gerhardt Hubner" <Gerhardt.Hubner@ventura.org> 10/31/2007 9:02 AM >>>
Hello All,

As promised, see attachments containing available lab reports and summary of data so far

Gerhardt

>>> Arne Anselm 10/31/2007 8:44 AM >>>
Gerhardt,

Here are the data sheets for the toxicity tests. As I mentioned in my first email we have not received all the analytical data, only bacteria and bioassays. The laboratory's long turn around for reporting data is typical and the reason we are concerned about the draft permit requirement to report results in 45 day. We will forward the rest of the data as soon as it is received, but it will not have gone through our internal QA/QC procedures.

Here is a summary of the data so far:
ME-CC
Toxicity - TUc = 1.00 (lowest possible result for chronic test)
Fecal - 16,000
Total - 579,400
E. coli - 11,199
Enterococcus - 4,060

ME-SCR
Toxicity -TUc = 1.00
Fecal - 170
Total - 21,870
E. coli - 120

Enterococcus - 406

ME-VR2
Toxicity - TUc >16.00
Fecal - 130
Total - 4,611
E. coli - 109
Enterococcus - 99

W-4
Toxicity - TUa = 0.91
Fecal - 24,000
Total - 8,664,000
E. coli - 7,270
Enterococcus - 3,440

W-3
No flow

A-1
No flow

>>> Gerhardt Hubner 10/30/2007 5:01 PM >>>
Tracy,

Upon Arne's return tomorrow morning we will have the reports sent to you.

Gerhardt

>>> "Tracy Woods" <twoods@waterboards.ca.gov> 10/30/2007 3:06 PM >>>
Hello Gerhardt,

Yesterday, Arne e-mailed me about the toxicity results of a storm water sample taken on September 22nd. The chronic toxicity for the Ventura River was reported at >16.00 TUc.

Would you send the results of the chemical analyses including the chronic and acute toxicity lab reports for the Ventura River September 22nd monitoring event, to the Water Board, as soon as possible?

Thanks-Tracy Woods
LA-RWQCB / Storm Water Permitting
320 W. 4th Street, #200
Los Angeles, CA 90013
Phone: 213/620-2095
Fax: 213/576-5777
E-mail: twoods@waterboards.ca.gov

RUN DATE: 09/26/07 PAGE 1
RUN TIME: 1315

VENTURA COUNTY PUBLIC HEALTH DEPARTMENT LABORATORY
2240 E. Gonzales Rd, Ste 160, Oxnard, CA 93036 (805) 981-5131
Brett Austin, PHM, Laboratory Director

Public Health Laboratory Report - WATER REPORT

Name: PW,A ME-CC Location: PUBLIC WORKS AGENCY

Specimen: 07:W0002813R Collected: 09/22/07-0815 Status: COMP Req#: 02558088
Received: 09/22/07-1100 Sub By: PUBLIC WORKS AGENCY
Source: ENVIRONMENTAL
Description: OTHER
Ordered: MPN EXP (WASTE), ENV.WATER QT
Comments: ME-CC
SAMPLE TESTED USING COLILERT 24.

Procedure	Result
> MPN EXPANDED (WASTE/SEWAGE) Final	
FECAL COLIFORMS	PRESENT 16,000 MPN INDEX/100ml
DATE COMPLETED:	09/26/07
TIME COMPLETED:	1218
TOTAL COLIFORMS (MMO-MUG) Final	
MPN/100 ML	>24,192
MPN - 1:100 DILUTION	>241,920
MPN - 1:1000 DILUTION	579,400
MPN - 1:10,000 DILUTION	663,000
E.COLI (MMO-MUG) Final	
MPN/100 ML	11,199
MPN - 1:100 DILUTION	10,710
MPN - 1:1000 DILUTION	9,600
MPN - 1:10,000 DILUTION	20,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1330
ENTEROCOCCUS (ENTEROLERT) Final	
MPN/100 ML	>2,005
MPN - 1:100 DILUTION	4,060
MPN - 1:1000 DILUTION	< 1,000
MPN - 1:10,000 DILUTION	< 10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1250

RUN DATE: 09/26/07
RUN TIME: 1315

PAGE 1

VENTURA COUNTY PUBLIC HEALTH DEPARTMENT LABORATORY
2240 E. Gonzales Rd, Ste 160, Oxnard, CA 93036 (805) 981-5131
Brett Austin, PHM, Laboratory Director

Public Health Laboratory Report - **WATER REPORT**

Name: PW,A ME-SCR Location: PUBLIC WORKS AGENCY

Specimen: 07:W0002814R Collected: 09/22/07-0900 Status: COMP **Req#:** 02558089
Received: 09/22/07-1100 Sub By: PUBLIC WORKS AGENCY
Source: ENVIRONMENTAL
Description: OTHER
Ordered: MPN EXP (WASTE), ENV.WATER QT
Comments: ME-SCR
SAMPLE TESTED USING COLILERT 24.

Procedure	Result
> MPN EXPANDED (WASTE/SEWAGE) Final	
FECAL COLIFORMS	PRESENT 170 MPN INDEX/100ml
DATE COMPLETED:	09/26/07
TIME COMPLETED:	1220
TOTAL COLIFORMS (MMO-MUG) Final	
MPN/100 ML	>24,192
MPN - 1:100 DILUTION	21,870
MPN - 1:1000 DILUTION	27,500
MPN - 1:10,000 DILUTION	31,000
E.COLI (MMO-MUG) Final	
MPN/100 ML	120
MPN - 1:100 DILUTION	740
MPN - 1:1000 DILUTION	2,000
MPN - 1:10,000 DILUTION	< 10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1330
ENTEROCOCCUS (ENTEROLERT) Final	
MPN/100 ML	406
MPN - 1:100 DILUTION	530
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	< 10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1250

Name: PW,A ME-SCR Acct No: H000898478

RUN DATE: 09/26/07 PAGE 1
RUN TIME: 1315

VENTURA COUNTY PUBLIC HEALTH DEPARTMENT LABORATORY
2240 E. Gonzales Rd, Ste 160, Oxnard, CA 93036 (805) 981-5131
Brett Austin, PHM, Laboratory Director

Public Health Laboratory Report - WATER REPORT

Name: PW/A ME-VR2 Location: PUBLIC WORKS AGENCY

Specimen: 07:W0002815R Collected: 09/22/07-1000 Status: COMP Req#: 02558090
Received: 09/22/07-1100 Sub By: PUBLIC WORKS AGENCY

Source: ENVIRONMENTAL
Description: OTHER
Ordered: MPN EXP (WASTE), ENV.WATER QT
Comments: ME-VR2
SAMPLE TESTED USING COLILERT 24.

Procedure	Result
> MPN EXPANDED (WASTE/SEWAGE) Final	
FECAL COLIFORMS	PRESENT 130 MPN INDEX/100ml
DATE COMPLETED:	09/26/07
TIME COMPLETED:	1221
TOTAL COLIFORMS (MMO-MUG) Final	
MPN/100 ML	4,611
MPN - 1:100 DILUTION	6,830
MPN - 1:1000 DILUTION	5,400
MPN - 1:10,000 DILUTION	<10,000
E.COLI (MMO-MUG) Final	
MPN/100 ML	109
MPN - 1:100 DILUTION	<100
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	<10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1335
ENTEROCOCCUS (ENTEROLERT) Final	
MPN/100 ML	99
MPN - 1:100 DILUTION	200
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	<10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1252

Name: PW/A ME-VR2 Acct No: H000898486

RUN DATE: 09/25/07 PAGE 1
RUN TIME: 1024

VENTURA COUNTY PUBLIC HEALTH DEPARTMENT LABORATORY
2240 E. Gonzales Rd, Ste 160, Oxnard, CA 93036 (805) 981-5131
Brett Austin, PHM, Laboratory Director

Public Health Laboratory Report - WATER REPORT

Name: PW,A MB-1 Location: PUBLIC WORKS AGENCY

Specimen: 07:W0002816R Collected: 09/22/07-1000 Status: COMP Req#: 02558092
Received: 09/22/07-1100 Sub By: PUBLIC WORKS AGENCY

Source: ENVIRONMENTAL
Description: OTHER
Ordered: MPN EXP (WASTE), ENV.WATER QT
Comments: MB-1
SAMPLE TESTED USING COLILERT 24.

Procedure	Result
> MPN EXPANDED (WASTE/SEWAGE) Final	
TOTAL COLIFORMS	ABSENT <2 MPN INDEX/100ml
DATE COMPLETED:	09/24/07
TIME COMPLETED:	1145
TOTAL COLIFORMS (MMO-MUG) Final	
MPN/100 ML	<10
MPN - 1:100 DILUTION	<100
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	<10,000
E.COLI (MMO-MUG) Final	
MPN/100 ML	<10
MPN - 1:100 DILUTION	<100
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	<10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1335
ENTEROCOCCUS (ENTEROLERT) Final	
MPN/100 ML	<10
MPN - 1:100 DILUTION	<100
MPN - 1:1000 DILUTION	<1,000
MPN - 1:10,000 DILUTION	<10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1253

RUN DATE: 09/26/07 PAGE 1
RUN TIME: 1340

VENTURA COUNTY PUBLIC HEALTH DEPARTMENT LABORATORY
2240 E. Gonzales Rd, Ste 160, Oxnard, CA 93036 (805) 981-5131
Brett Austin, PHM, Laboratory Director

Public Health Laboratory Report - WATER REPORT

Name: PW,A W-4 Location: PUBLIC WORKS AGENCY

Specimen: 07:W0002817R Collected: 09/22/07-1145 Status: COMP Req#: 02558101
Received: 09/22/07-1215 Sub By: PUBLIC WORKS AGENCY
Source: ENVIRONMENTAL
Description: OTHER
Ordered: MPN EXP (WASTE), ENV.WATER QT
Comments: W-4
SAMPLE TESTED USING COLILERT 24.

Procedure	Result
> MPN EXPANDED (WASTE/SEWAGE) Final	
FECAL COLIFORMS	PRESENT 24,000 MPN INDEX/100ml
DATE COMPLETED:	09/26/07
TIME COMPLETED:	1226
TOTAL COLIFORMS (MMO-MUG) Final	
MPN/100 ML	>24,192
MPN - 1:100 DILUTION	>241,920
MPN - 1:1000 DILUTION	>2,419,200
MPN - 1:10,000 DILUTION	8,664,000
E.COLI (MMO-MUG) Final	
MPN/100 ML	7,270
MPN - 1:100 DILUTION	6,830
MPN - 1:1000 DILUTION	50,400
MPN - 1:10,000 DILUTION	20,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1334
ENTEROCOCCUS (ENTEROLERT) Final	
MPN/100 ML	>2,005
MPN - 1:100 DILUTION	3,440
MPN - 1:1000 DILUTION	2,000
MPN - 1:10,000 DILUTION	<10,000
DATE COMPLETED:	09/23/07
TIME COMPLETED:	1336

AQUATIC BIOASSAY & CONSULTING
LABORATORIES, INC.

TOXICITY TESTING • OCEANOGRAPHIC RESEARCH

October 17, 2007

Mr. Arnie Anselm
Ventura County Watershed Protection District
800 South Victoria Ave
Ventura, CA 93009

Dear Mr. Anselm:

We are pleased to present the enclosed revised bioassay report. The test was conducted under guidelines prescribed in *Short-Term Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms, EPA-600/R95/136, 1995.* Results were as follows:

CLIENT:	County of Ventura
SAMPLE I.D.:	ME-CC
DATE RECEIVED:	22 Sept - 07
ABC LAB. NO.:	VCF0907.212

CHRONIC SEA URCHIN FERTILIZATION BIOASSAY

NOEC	=	100.00 %
TUc	=	1.00
IC25	=	>100.00 %
IC50	=	>100.00 %

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	VCF0907212	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-CC				

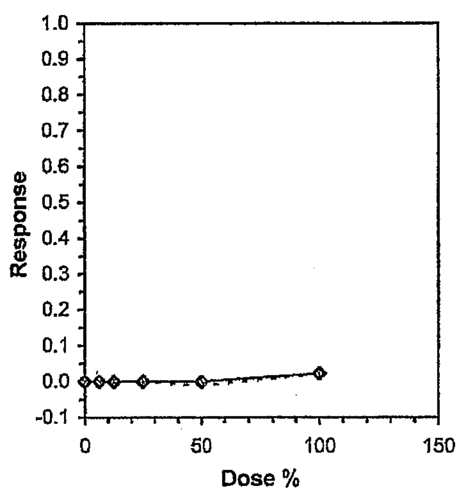
Conc-%	1	2	3	4
N Control	0.9200	0.9100	0.9400	0.9300
6.25	0.9100	0.9200	0.9300	0.9200
12.5	0.9300	0.9200	0.9100	0.9400
25	0.9100	0.9500	0.9300	0.9100
50	0.9400	0.9300	0.9200	0.9500
100	0.9200	0.9100	0.9000	0.8900

			Transform: Arcsin Square Root					1-Tailed			Isotonic	
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
N Control	0.9250	1.0000	1.2941	1.2661	1.3233	1.903	4				0.9260	1.0000
6.25	0.9200	0.9946	1.2843	1.2661	1.3030	1.174	4	0.535	2.410	0.0442	0.9260	1.0000
12.5	0.9250	1.0000	1.2941	1.2661	1.3233	1.903	4	0.000	2.410	0.0442	0.9260	1.0000
25	0.9250	1.0000	1.2951	1.2661	1.3453	2.911	4	-0.055	2.410	0.0442	0.9260	1.0000
50	0.9350	1.0108	1.3139	1.2840	1.3453	2.006	4	-1.078	2.410	0.0442	0.9260	1.0000
100	0.9050	0.9784	1.2580	1.2327	1.2840	1.755	4	1.969	2.410	0.0442	0.9050	0.9773

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.93723		0.884		0.34682	-0.7207
Bartlett's Test indicates equal variances (p = 0.81)					2.2436		15.0863			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**
Dunnett's Test	100	>100		1	0.02488	0.02689	0.00135	0.00067	0.12636	5, 18
Treatments vs N Control										

Linear Interpolation (200 Resamples)

Point	%	SD	95% CL(Exp)	Skew
IC05	>100			
IC10	>100			
IC15	>100			
IC20	>100			
IC25	>100			
IC40	>100			
IC50	>100			



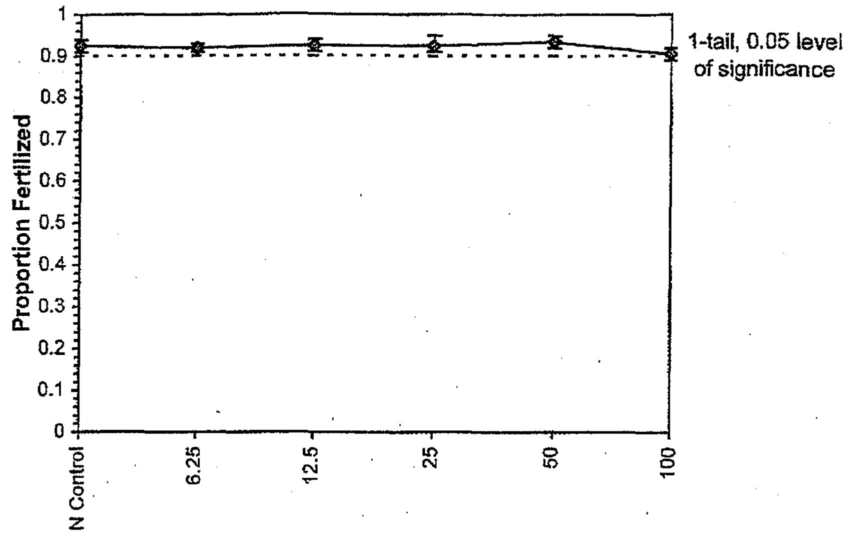
 ToxCalc v5.0.23 Reviewed by: [signature]

A009352

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID: VCF0907212		Sample ID:	CA000000
End Date:	9/24/2007	Lab ID: CAABC		Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol: EPA/600/R		Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-CC				

Dose-Response Plot



ToxCalc v5.0.23

Reviewed by: [signature]

A009353

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	VCF0907212	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-CC				

		Auxiliary Data Summary					
Conc-%	Parameter	Mean	Min	Max	SD	CV%	N
N Control	Temp C	15.15	15.00	15.30	0.21	3.04	2
6.5		15.30	15.30	15.30	0.00	0.00	1
6.25		15.00	15.00	15.00	0.00	0.00	1
12.5		15.15	15.00	15.30	0.21	3.04	2
25		15.15	15.00	15.30	0.21	3.04	2
50		15.15	15.00	15.30	0.21	3.04	2
100		15.15	15.00	15.30	0.21	3.04	2
N Control	pH	7.70	7.70	7.70	0.00	0.00	2
6.5		7.70	7.70	7.70	0.00	0.00	1
6.25		7.70	7.70	7.70	0.00	0.00	1
12.5		7.70	7.70	7.70	0.00	0.00	2
25		7.70	7.70	7.70	0.00	0.00	2
50		7.70	7.70	7.70	0.00	0.00	2
100		7.70	7.70	7.70	0.00	0.00	2
N Control	DO mg/L	6.10	5.90	6.30	0.28	8.72	2
6.5		6.50	6.50	6.50	0.00	0.00	1
6.25		5.70	5.70	5.70	0.00	0.00	1
12.5		6.15	5.70	6.60	0.64	12.97	2
25		6.25	5.80	6.70	0.64	12.76	2
50		6.20	5.90	6.50	0.42	10.51	2
100		6.30	5.90	6.70	0.57	11.94	2
N Control	Salinity ppt	34.00	34.00	34.00	0.00	0.00	2
6.5		34.00	34.00	34.00	0.00	0.00	1
6.25		34.00	34.00	34.00	0.00	0.00	1
12.5		34.00	34.00	34.00	0.00	0.00	2
25		34.00	34.00	34.00	0.00	0.00	2
50		34.00	34.00	34.00	0.00	0.00	2
100		34.00	34.00	34.00	0.00	0.00	2

AQUATIC BIOASSAY & CONSULTING LABORATORIES, INC.

TOXICITY TESTING • OCEANOGRAPHIC RESEARCH

October 17, 2007

Mr. Arnie Anselm
Ventura County Watershed Protection District
800 South Victoria Ave
Ventura, CA 93009

Dear Mr. Anselm:

We are pleased to present the enclosed revised bioassay report. The test was conducted under guidelines prescribed in *Short-Term Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms, EPA-600/R95/136, 1995*. Results were as follows:

CLIENT:	County of Ventura
SAMPLE I.D.:	ME-VR2
DATE RECEIVED:	22 Sept - 07
ABC LAB. NO.:	VCF0907.214

CHRONIC SEA URCHIN FERTILIZATION BIOASSAY

NOEC	=	<6.25 %
TUc	=	>16.00
IC25	=	60.09 %
IC50	=	76.95 %

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	VCF0907214	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-VR2				

Conc-%	1	2	3	4
N Control	0.9800	1.0000	1.0000	1.0000
6.25	0.9500	0.9600	0.9400	0.9400
12.5	0.9400	0.9300	0.9300	0.9300
25	0.9200	0.9400	0.9200	0.9100
50	0.8800	0.9100	0.9000	0.8900
100	0.1200	0.1600	0.1800	0.1700

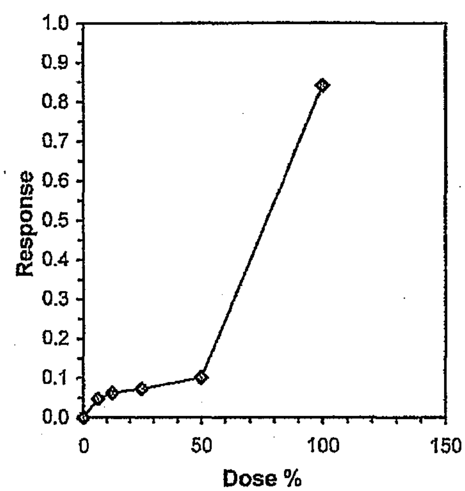
			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
N Control	0.9950	1.0000	1.4978	1.4289	1.5208	3.067	4				0.9950	1.0000
*6.25	0.9475	0.9523	1.3403	1.3233	1.3694	1.640	4	7.631	2.410	0.0497	0.9475	0.9523
*12.5	0.9325	0.9372	1.3081	1.3030	1.3233	0.776	4	9.193	2.410	0.0497	0.9325	0.9372
*25	0.9225	0.9271	1.2894	1.2661	1.3233	1.874	4	10.101	2.410	0.0497	0.9225	0.9271
*50	0.8950	0.8995	1.2412	1.2171	1.2661	1.700	4	12.434	2.410	0.0497	0.8950	0.8995
*100	0.1575	0.1583	0.4071	0.3537	0.4381	9.137	4	52.858	2.410	0.0497	0.1575	0.1583

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	0.91594	0.884	-0.997	1.1182
Bartlett's Test indicates equal variances (p = 0.29)	6.13894	15.0863		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	<6.25	6.25			0.00967	0.00972	0.60497	0.00085	5.2E-20	5, 18
Treatments vs N Control										

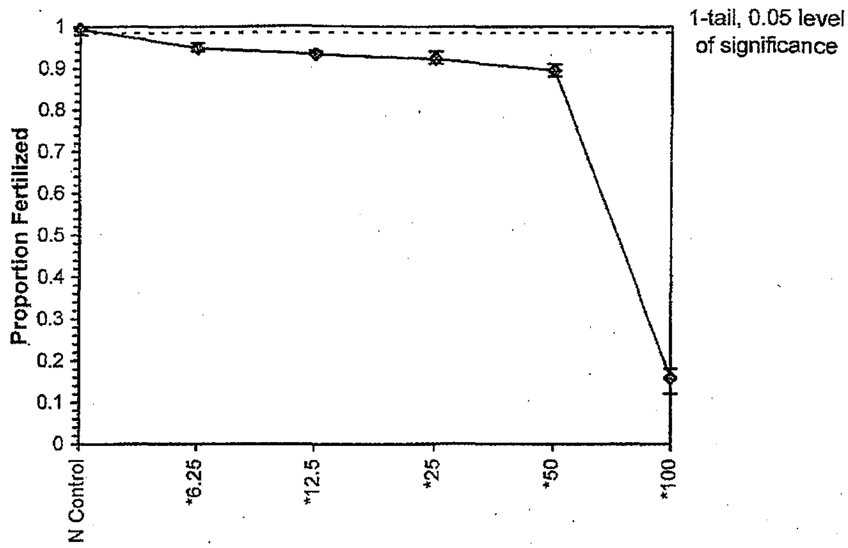
Linear Interpolation (200 Resamples)

Point	%	SD	95% CL(Exp)		Skew
IC05	7.188	1.998	4.383	13.110	2.3943
IC10	49.545	3.353	34.244	52.020	-1.2516
IC15	53.339	0.483	52.038	55.062	0.1013
IC20	56.712	0.464	55.464	58.359	0.0799
IC25	60.085	0.453	58.864	61.759	0.0368
IC40	70.203	0.467	68.921	71.535	-0.1923
IC50	76.949	0.513	75.404	78.402	-0.3326



Sperm Cell Fertilization Test-Proportion Fertilized					
Start Date:	9/24/2007	Test ID:	VCF0907214	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-VR2				

Dose-Response Plot



Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	VCF0907214	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-VR2				

Conc-%	Parameter	Mean	Min	Max	SD	CV%	N
		Auxiliary Data Summary					
N Control	Temp C	15.10	15.00	15.20	0.14	2.49	2
6.5		15.20	15.20	15.20	0.00	0.00	1
6.25		15.00	15.00	15.00	0.00	0.00	1
12.5		15.15	15.00	15.30	0.21	3.04	2
25		15.15	15.00	15.30	0.21	3.04	2
50		15.20	15.00	15.40	0.28	3.50	2
100		15.20	15.00	15.40	0.28	3.50	2
N Control	pH	7.70	7.70	7.70	0.00	0.00	2
6.5		7.70	7.70	7.70	0.00	0.00	1
6.25		7.70	7.70	7.70	0.00	0.00	1
12.5		7.70	7.70	7.70	0.00	0.00	2
25		7.70	7.70	7.70	0.00	0.00	2
50		7.70	7.70	7.70	0.00	0.00	2
100		7.70	7.70	7.70	0.00	0.00	2
N Control	DO mg/L	6.10	5.90	6.30	0.28	8.72	2
6.5		6.30	6.30	6.30	0.00	0.00	1
6.25		6.10	6.10	6.10	0.00	0.00	1
12.5		6.10	6.00	6.20	0.14	6.16	2
25		6.20	6.00	6.40	0.28	8.58	2
50		6.20	5.90	6.50	0.42	10.51	2
100		6.25	6.00	6.50	0.35	9.51	2
N Control	Salinity ppt	34.00	34.00	34.00	0.00	0.00	2
6.5		34.00	34.00	34.00	0.00	0.00	1
6.25		34.00	34.00	34.00	0.00	0.00	1
12.5		34.00	34.00	34.00	0.00	0.00	2
25		34.00	34.00	34.00	0.00	0.00	2
50		34.00	34.00	34.00	0.00	0.00	2
100		34.00	34.00	34.00	0.00	0.00	2

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October 17, 2007

Mr. Arnie Anselm
Ventura County Watershed Protection District
800 South Victoria Ave
Ventura, CA 93009

Dear Mr. Anselm:

We are pleased to present the enclosed revised bioassay report. The test was conducted under guidelines prescribed in *Short-Term Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms, EPA-600/R95/136, 1995*. Results were as follows:

CLIENT:	County of Ventura
SAMPLE I.D.:	ME-SCR
DATE RECEIVED:	22 Sept - 07
ABC LAB. NO.:	VCF0907.213

CHRONIC SEA URCHIN FERTILIZATION BIOASSAY

NOEC	=	100.00 %
TUc	=	1.00
IC25	=	>100.00 %
IC50	=	>100.00 %

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID: VCF0907213		Sample ID:	CA000000
End Date:	9/24/2007	Lab ID: CAABC		Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol: EPA/600/R		Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-SCR				

Conc-%	1	2	3	4
N Control	1.0000	1.0000	1.0000	1.0000
6.25	1.0000	1.0000	1.0000	1.0000
12.5	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000
50	1.0000	1.0000	1.0000	1.0000
100	1.0000	1.0000	1.0000	1.0000

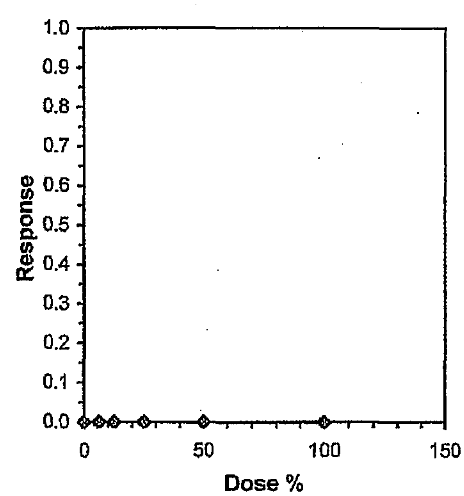
			Transform: Arcsin Square Root					Rank	1-Tailed	Isotonic	
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
N Control	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4			1.0000	1.0000
6.25	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4	18.00	10.00	1.0000	1.0000
12.5	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4	18.00	10.00	1.0000	1.0000
25	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4	18.00	10.00	1.0000	1.0000
50	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4	18.00	10.00	1.0000	1.0000
100	1.0000	1.0000	1.5208	1.5208	1.5208	0.000	4	18.00	10.00	1.0000	1.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)	1	0.884		
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	100	>100		1
Treatments vs N Control				

Linear Interpolation (200 Resamples)

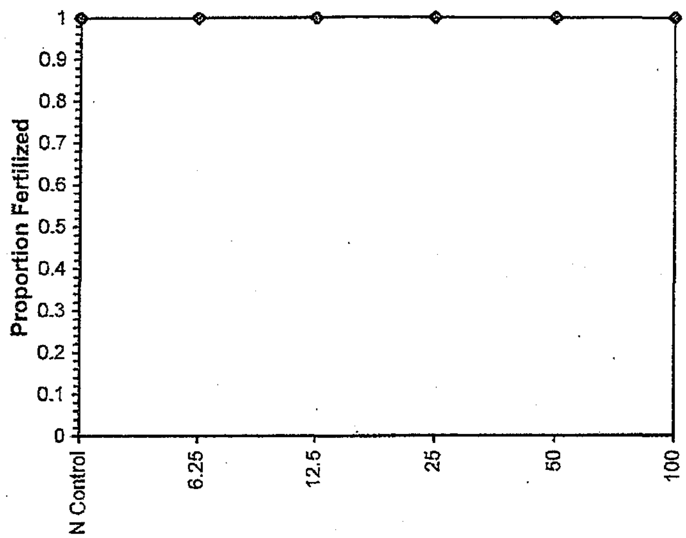
Point	%	SD	95% CL(Exp)	Skew
IC05	>100			
IC10	>100			
IC15	>100			
IC20	>100			
IC25	>100			
IC40	>100			
IC50	>100			



Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID: VCF0907213		Sample ID:	CA000000
End Date:	9/24/2007	Lab ID: CAABC		Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol: EPA/600/R		Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-SCR				

Dose-Response Plot



ToxCalc v5.0.23

Reviewed by: [signature]

A009361

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	VCF0907213	Sample ID:	CA000000
End Date:	9/24/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	ME-SCR				

		Auxiliary Data Summary					
Conc-%	Parameter	Mean	Min	Max	SD	CV%	N
N Control	Temp C	15.10	15.00	15.20	0.14	2.49	2
6.5		15.20	15.20	15.20	0.00	0.00	1
6.25		15.00	15.00	15.00	0.00	0.00	1
12.5		15.10	15.00	15.20	0.14	2.49	2
25		15.10	15.00	15.20	0.14	2.49	2
50		15.10	15.00	15.20	0.14	2.49	2
100		15.10	15.00	15.20	0.14	2.49	2
N Control	pH	7.70	7.70	7.70	0.00	0.00	2
6.5		7.70	7.70	7.70	0.00	0.00	1
6.25		7.70	7.70	7.70	0.00	0.00	1
12.5		7.70	7.70	7.70	0.00	0.00	2
25		7.70	7.70	7.70	0.00	0.00	2
50		7.70	7.70	7.70	0.00	0.00	2
100		7.70	7.70	7.70	0.00	0.00	2
N Control	DO mg/L	6.10	5.90	6.30	0.28	8.72	2
6.5		6.70	6.70	6.70	0.00	0.00	1
6.25		6.10	6.10	6.10	0.00	0.00	1
12.5		6.30	6.10	6.50	0.28	8.44	2
25		6.20	6.00	6.40	0.28	8.58	2
50		6.10	5.90	6.30	0.28	8.72	2
100		6.10	5.90	6.30	0.28	8.72	2
N Control	Salinity ppt	34.00	34.00	34.00	0.00	0.00	2
6.5		34.00	34.00	34.00	0.00	0.00	1
6.25		34.00	34.00	34.00	0.00	0.00	1
12.5		34.00	34.00	34.00	0.00	0.00	2
25		34.00	34.00	34.00	0.00	0.00	2
50		34.00	34.00	34.00	0.00	0.00	2
100		34.00	34.00	34.00	0.00	0.00	2

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October 17, 2007

Mr. Arnie Anselm
Ventura County Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93009

Dear Mr. Anselm:

We are pleased to present the enclosed revised bioassay report. The test was conducted under guidelines prescribed in *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, EPA-821-R-02-012.* Results were as follows:

CLIENT:	Ventura County Watershed Protection District
SAMPLE I.D.:	W-4 Revolon
DATE RECEIVED:	22 Sept - 07
ABC LAB. NO.:	VCF0907.218

ACUTE CERIODAPHNIA SURVIVAL BIOASSAY

Survival = 65 % Survival in 100% Sample
TU (a) = 0.91
LC50 = >100.00 %

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Ceriodaphnia Survival and Reproduction Test-96 Hr Survival

Start Date:	9/22/2007	Test ID:	VCF0907218	Sample ID:	CA0000000
End Date:	9/26/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPAA 85-EPA Acute	Test Species:	CD-Ceriodaphnia dubia
Comments:	W-4 Revolon				

Conc-%	1	2	3	4
N Control	1.0000	1.0000	1.0000	1.0000
6.25	1.0000	1.0000	1.0000	1.0000
12.5	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000
50	1.0000	1.0000	0.8000	0.8000
100	0.2000	0.6000	0.8000	1.0000

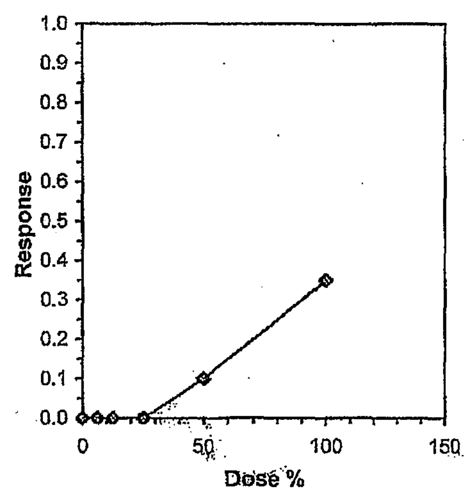
			Transform: Arcsin Square Root					Rank	1-Tailed	Isotonic	
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
N Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4			1.0000	1.0000
6.25	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
12.5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
25	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
50	0.9000	0.9000	1.2262	1.1071	1.3453	11.212	4	14.00	10.00	0.9000	0.9000
100	0.6500	0.6500	0.9505	0.4636	1.3453	39.437	4	12.00	10.00	0.6500	0.6500

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)	0.70751	0.884	-0.7963	7.25985
Equality of variance cannot be confirmed				

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	100	>100		1
Treatments vs N Control				

Linear Interpolation (200 Resamples)

Point	%	SD	95% CL(Exp)	Skew
IC05	37.500			
IC10	50.000			
IC15	60.000			
IC20	70.000			
IC25	80.000			
IC40	>100			
IC50	>100			



ToxCalc v5.0.23

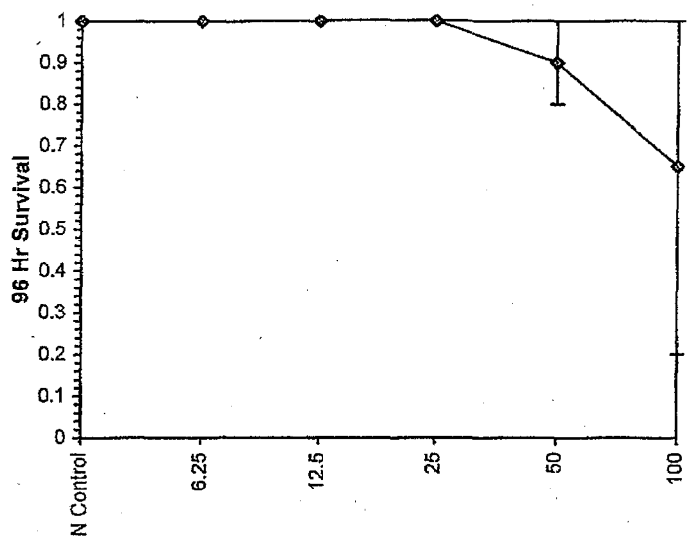
Reviewed by:_____

A009364

Ceriodaphnia Survival and Reproduction Test-96 Hr Survival

Start Date:	9/22/2007	Test ID:	VCF0907218	Sample ID:	CA0000000
End Date:	9/26/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date:	9/22/2007	Protocol:	EPAA 85-EPA Acute	Test Species:	CD-Ceriodaphnia dubia
Comments:	W-4 Revolon				

Dose-Response Plot



Ceriodaphnia Survival and Reproduction Test-96 Hr Survival

Start Date: 9/22/2007	Test ID:	VCF0907218	Sample ID:	CA0000000
End Date: 9/26/2007	Lab ID:	CAABC	Sample Type:	EFF1-POTW
Sample Date: 9/22/2007	Protocol:	EPAA 85-EPA Acute	Test Species:	CD-Ceriodaphnia dubia
Comments: W-4 Revolon				

		Auxiliary Data Summary					
Conc-%	Parameter	Mean	Min	Max	SD	CV%	N
N Control	Temp C	24.00	24.00	24.00	0.00	0.00	3
6.25		24.00	24.00	24.00	0.00	0.00	3
12.5		24.00	24.00	24.00	0.00	0.00	3
25		24.00	24.00	24.00	0.00	0.00	3
50		24.00	24.00	24.00	0.00	0.00	3
100		24.00	24.00	24.00	0.00	0.00	3
N Control	pH	8.23	8.20	8.30	0.06	2.92	3
6.25		8.23	8.20	8.30	0.06	2.92	3
12.5		8.23	8.20	8.30	0.06	2.92	3
25		8.20	8.20	8.20	0.00	0.00	3
50		8.10	8.10	8.10	0.00	0.00	3
100		8.07	8.00	8.10	0.06	2.98	3
N Control	DO mg/L	6.73	6.30	7.50	0.67	12.12	3
6.25		6.77	6.00	8.10	1.16	15.91	3
12.5		6.70	5.90	8.00	1.14	15.91	3
25		6.70	5.90	8.00	1.14	15.91	3
50		6.73	6.10	8.00	1.10	15.55	3
100		6.70	6.10	7.90	1.04	15.22	3
N Control	Hardness mg/L	93.00	90.00	95.00	2.65	1.75	3
6.25		0.00	0.00	0.00	0.00		0
12.5		0.00	0.00	0.00	0.00		0
25		0.00	0.00	0.00	0.00		0
50		0.00	0.00	0.00	0.00		0
100		250.00	250.00	250.00	0.00	0.00	3
N Control	Alkalinitymg/L	65.00	61.00	69.00	4.00	3.08	3
6.25		0.00	0.00	0.00	0.00		0
12.5		0.00	0.00	0.00	0.00		0
25		0.00	0.00	0.00	0.00		0
50		0.00	0.00	0.00	0.00		0
100		190.00	190.00	190.00	0.00	0.00	3
N Control	Conductivity	360.67	341.00	371.00	17.04	1.14	3
6.25		593.00	591.00	597.00	3.46	0.31	3
12.5		747.00	741.00	755.00	7.21	0.36	3
25		1081.33	1080.00	1083.00	1.53	0.11	3
50		1744.00	1740.00	1751.00	6.08	0.14	3
100		2929.00	2919.00	2937.00	9.17	0.10	3

AQUATIC
BIOASSAY &
CONSULTING
LABORATORIES, INC.

TOXICITY TESTING • OCEANOGRAPHIC RESEARCH

CHRONIC SEA URCHIN FERTILIZATION BIOASSAY

DATE:	24 September - 07
STANDARD TOXICANT:	Copper Chloride
NOEC =	56.00 ug/l
IC25 =	88.81 ug/l
IC50 =	138.52 ug/l

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	URC092407	Sample ID:	REF-Ref Toxicant
End Date:	9/24/2007	Lab ID:	ABC LABORA	Sample Type:	CUCL-Copper chloride
Sample Date:	9/24/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	Standard Toxicant				

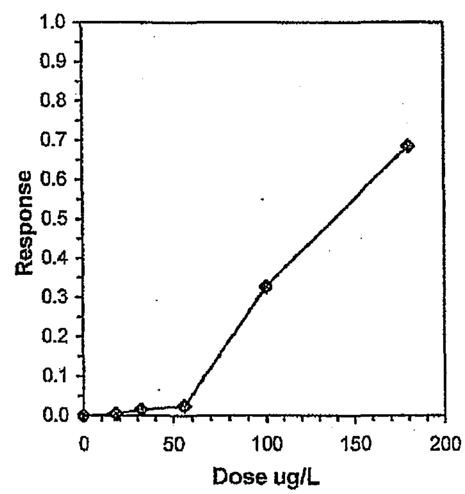
Conc-ug/L	1	2	3	4
Control	1.0000	0.9000	0.9200	0.9400
18	0.9100	0.9600	0.9200	0.9500
32	0.9600	0.8600	0.9400	0.9400
56	0.9200	0.8600	0.9600	0.9300
100	0.6400	0.6100	0.8700	0.4100
180	0.8800	0.0900	0.1200	0.0900

			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
Control	0.9400	1.0000	1.3443	1.2490	1.5208	9.038	4				0.9400	1.0000
18	0.9350	0.9947	1.3162	1.2661	1.3694	3.728	4	0.186	2.410	0.3640	0.9350	0.9947
32	0.9250	0.9840	1.3008	1.1873	1.3694	6.054	4	0.288	2.410	0.3640	0.9250	0.9840
56	0.9175	0.9761	1.2860	1.1873	1.3694	5.853	4	0.386	2.410	0.3640	0.9175	0.9761
*100	0.6325	0.6729	0.9301	0.6949	1.2019	22.412	4	2.742	2.410	0.3640	0.6325	0.6729
*180	0.2950	0.3138	0.5450	0.3047	1.2171	82.306	4	5.292	2.410	0.3640	0.2950	0.3138

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.01)					0.82227		0.884		1.9591	6.39287
Bartlett's Test indicates unequal variances (p = 3.16E-03)					17.8355		15.0863			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**
Dunnett's Test	56	100	74.8331		0.25956	0.27335	0.41255	0.04562	1.9E-04	5, 18
Treatments vs Control										

Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL(Exp)		Skew
IC05	59.78	10.04	0.36	71.95	-2.1803
IC10	67.04	5.86	54.80	94.79	1.6224
IC15	74.29				
IC20	81.55				
IC25	88.81				
IC40	116.24				
IC50	138.52				

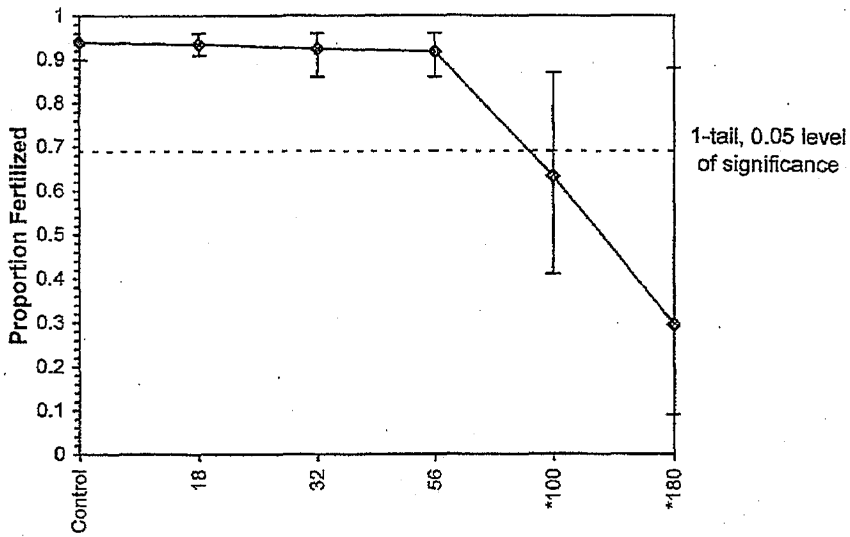


ToxCalc v5.0.23
Reviewed by: [signature]

A009368

Sperm Cell Fertilization Test-Proportion Fertilized					
Start Date:	9/24/2007	Test ID:	URC092407	Sample ID:	REF-Ref Toxicant
End Date:	9/24/2007	Lab ID:	ABC LABORA	Sample Type:	CUCL-Copper chloride
Sample Date:	9/24/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	Standard Toxicant				

Dose-Response Plot



ToxCalc v5.0.23

Reviewed by: [signature]

Sperm Cell Fertilization Test-Proportion Fertilized

Start Date:	9/24/2007	Test ID:	URC092407	Sample ID:	REF-Ref Toxicant
End Date:	9/24/2007	Lab ID:	ABC LABORA	Sample Type:	CUCL-Copper chloride
Sample Date:	9/24/2007	Protocol:	EPA/600/R	Test Species:	SP-Strongylocentrotus purpuratus
Comments:	Standard Toxicant				

		Auxiliary Data Summary					
Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
Control	Temp C	15.10	15.00	15.20	0.14	2.49	2
18		15.10	15.00	15.20	0.14	2.49	2
32		15.10	15.00	15.20	0.14	2.49	2
56		15.10	15.00	15.20	0.14	2.49	2
100		15.15	15.00	15.30	0.21	3.04	2
180		15.15	15.00	15.30	0.21	3.04	2
Control	pH	7.70	7.70	7.70	0.00	0.00	2
18		7.70	7.70	7.70	0.00	0.00	2
32		7.70	7.70	7.70	0.00	0.00	2
56		7.70	7.70	7.70	0.00	0.00	2
100		7.70	7.70	7.70	0.00	0.00	2
180		7.70	7.70	7.70	0.00	0.00	2
Control	Diss Oxygen	6.10	5.90	6.30	0.28	8.72	2
18		6.45	5.90	7.00	0.78	13.67	2
32		6.50	6.10	6.90	0.57	11.57	2
56		6.40	6.00	6.80	0.57	11.75	2
100		6.20	5.90	6.50	0.42	10.51	2
180		6.15	5.80	6.50	0.49	11.44	2
Control	Salinity ppt	34.00	34.00	34.00	0.00	0.00	2
18		34.00	34.00	34.00	0.00	0.00	2
32		34.00	34.00	34.00	0.00	0.00	2
56		34.00	34.00	34.00	0.00	0.00	2
100		34.00	34.00	34.00	0.00	0.00	2
180		34.00	34.00	34.00	0.00	0.00	2

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TOXICITY TESTING • OCEANOGRAPHIC RESEARCH

CHRONIC CERIODAPHNIA SURVIVAL AND REPRODUCTION BIOASSAY

DATE: 5 September - 07

STANDARD TOXICANT: Copper Chloride

ENDPOINT: SURVIVAL

NOEC = 10.00 ug/l

IC25 = 10.71 ug/l
IC50 = 14.29 ug/l

ENDPOINT: REPRODUCTION

NOEC = 5.00 ug/l

IC25 = 7.30 ug/l
IC50 = 10.72 ug/l

Yours very truly,

Thomas (Tim) Mikel
Laboratory Director

29 NORTH OLIVE STREET, VENTURA, CA 93001 • (805) 643-5621

Ceriodaphnia Survival and Reproduction Test-7 Day Survival

Start Date:	9/5/2007	Test ID:	CER090507	Sample ID:	CA0000000
End Date:	9/12/2007	Lab ID:	CAABC	Sample Type:	CUCL-Copper chloride
Sample Date:	9/5/2007	Protocol:	EPAF 91-EPA Freshwater	Test Species:	CD-Ceriodaphnia dubia
Comments:	Standard Toxicant				

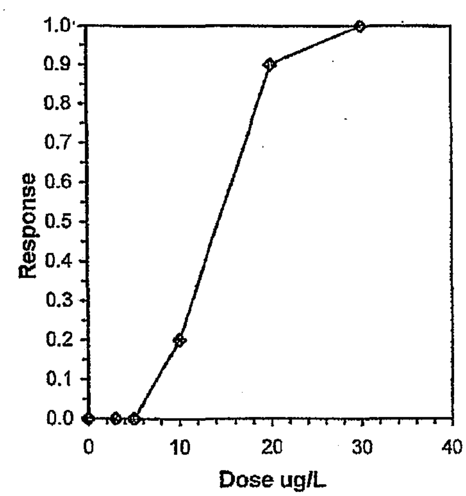
Conc-ug/L	1	2	3	4	5	6	7	8	9	10
N Control	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Conc-ug/L	Mean	N-Mean	Resp	Not Resp	Total	N	Fisher's Exact P	1-Tailed Critical	Isotonic Mean	Isotonic N-Mean
N Control	1.0000	1.0000	0	10	10	10			1.0000	1.0000
3	1.0000	1.0000	0	10	10	10	1.0000	0.0500	1.0000	1.0000
5	1.0000	1.0000	0	10	10	10	1.0000	0.0500	1.0000	1.0000
10	0.8000	0.8000	2	8	10	10	0.2368	0.0500	0.8000	0.8000
*20	0.1000	0.1000	9	1	10	10	0.0001	0.0500	0.1000	0.1000
30	0.0000	0.0000	10	0	10	10			0.0000	0.0000

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Fisher's Exact Test	10	20	14.1421	
Treatments vs N Control				

Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL		Skew
IC05	6.250	1.429	5.625	10.625	1.4289
IC10	7.500	1.691	6.250	11.250	0.1024
IC15	8.750	1.558	6.875	11.875	-0.1222
IC20	10.000	1.466	7.500	12.500	-0.4560
IC25	10.714	1.421	8.125	13.125	-0.5313
IC40	12.857	1.348	10.000	15.000	-0.7351
IC50	14.286	1.287	11.667	16.667	-0.5811



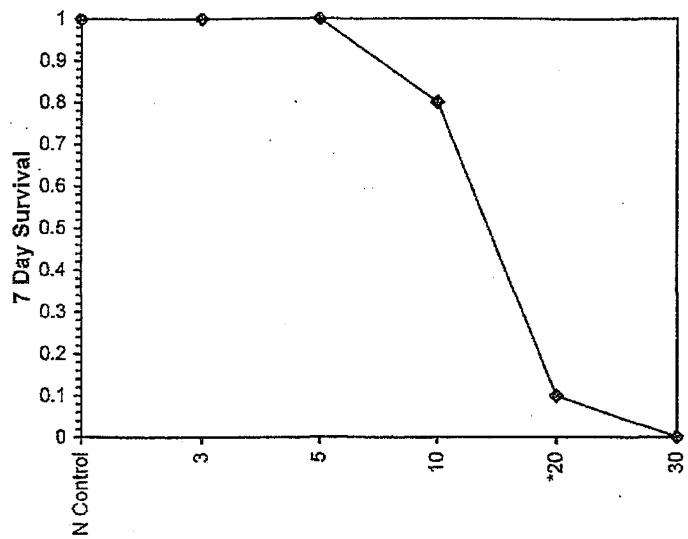
 ToxCalc v5.0.23 Reviewed by: [signature]

A009372

Ceriodaphnia Survival and Reproduction Test-7 Day Survival

Start Date:	9/5/2007	Test ID:	CER090507	Sample ID:	CA0000000
End Date:	9/12/2007	Lab ID:	CAABC	Sample Type:	CUCL-Copper chloride
Sample Date:	9/5/2007	Protocol:	EPAF 91-EPA Freshwater	Test Species:	CD-Ceriodaphnia dubia
Comments:	Standard Toxicant				

Dose-Response Plot



Ceriodaphnia Survival and Reproduction Test-Reproduction

Start Date:	9/5/2007	Test ID:	CER090507	Sample ID:	CA0000000
End Date:	9/12/2007	Lab ID:	CAABC	Sample Type:	CUCL-Copper chloride
Sample Date:	9/5/2007	Protocol:	EPAF 91-EPA Freshwater	Test Species:	CD-Ceriodaphnia dubia
Comments:	Standard Toxicant				

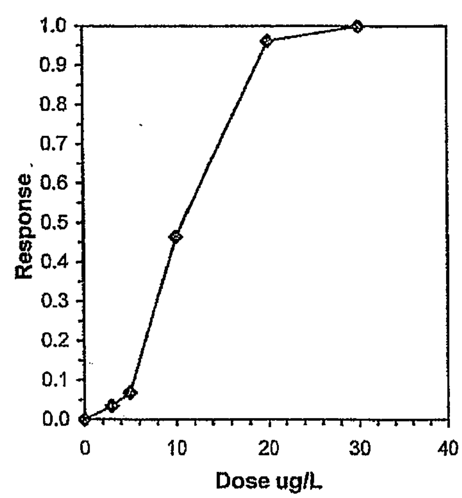
Conc-ug/L	1	2	3	4	5	6	7	8	9	10
N Control	33.000	36.000	35.000	26.000	31.000	23.000	29.000	29.000	30.000	21.000
3	25.000	28.000	29.000	28.000	22.000	27.000	30.000	30.000	35.000	29.000
5	28.000	24.000	32.000	34.000	32.000	38.000	29.000	15.000	24.000	17.000
10	0.000	0.000	20.000	23.000	23.000	19.000	16.000	19.000	25.000	12.000
20	0.000	0.000	0.000	11.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			Transform: Untransformed						1-Tailed		Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
N Control	29.300	1.0000	29.300	21.000	36.000	16.646	10				29.300	1.0000
3	28.300	0.9659	28.300	22.000	35.000	12.018	10	0.369	2.223	6.027	28.300	0.9659
5	27.300	0.9317	27.300	15.000	38.000	26.920	10	0.738	2.223	6.027	27.300	0.9317
*10	15.700	0.5358	15.700	0.000	25.000	57.760	10	5.017	2.223	6.027	15.700	0.5358
*20	1.100	0.0375	1.100	0.000	11.000	316.228	10	10.403	2.223	6.027	1.100	0.0375
30	0.000	0.0000	0.000	0.000	0.000	0.000	10				0.000	0.0000

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.01)					0.93728		0.93		-0.7243	1.04174
Bartlett's Test indicates equal variances (p = 0.01)					13.0119		13.2767			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**
Dunnett's Test	5	10	7.07107		6.02683	0.20569	1459.48	36.74	3.2E-14	4, 45
Treatments vs N Control										

Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL		Skew
IC05	3.930	1.572	1.156	5.638	-0.0968
IC10	5.401	1.272	2.312	6.297	-0.5083
IC15	6.032	1.053	3.401	6.972	-0.3758
IC20	6.664	1.032	4.363	7.631	0.0560
IC25	7.295	1.050	4.871	8.923	0.1363
IC40	9.190	1.124	7.510	11.551	0.4894
IC50	10.719	1.305	8.682	13.056	0.0998



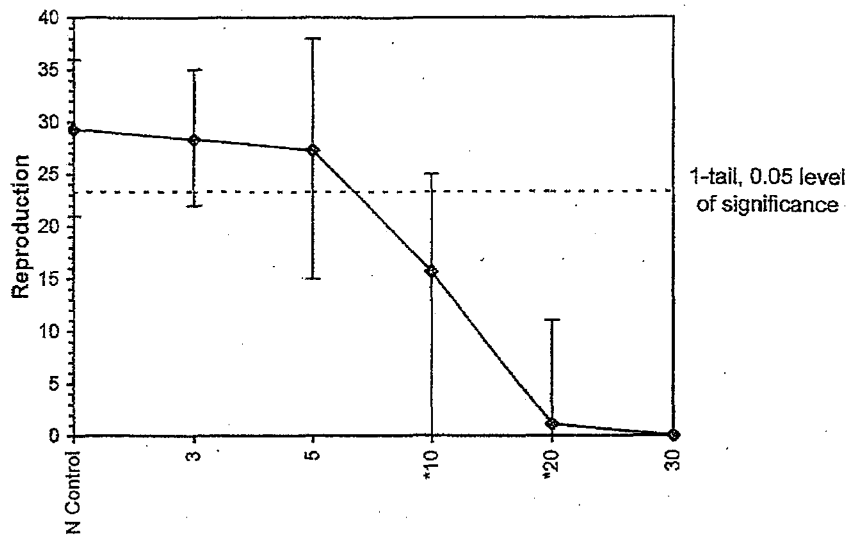
 ToxCalc v5.0.23 Reviewed by: [signature]

A009374

Ceriodaphnia Survival and Reproduction Test-Reproduction

Start Date:	9/5/2007	Test ID:	CER090507	Sample ID:	CA0000000
End Date:	9/12/2007	Lab ID:	CAABC	Sample Type:	CUCL-Copper chloride
Sample Date:	9/5/2007	Protocol:	EPAF 91-EPA Freshwater	Test Species:	CD-Ceriodaphnia dubia
Comments:	Standard Toxicant				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by: ______

Ceriodaphnia Survival and Reproduction Test-Reproduction

Start Date:	9/5/2007	Test ID:	CER090507	Sample ID:	CA0000000
End Date:	9/12/2007	Lab ID:	CAABC	Sample Type:	CUCL-Copper chloride
Sample Date:	9/5/2007	Protocol:	EPAF 91-EPA Freshwater	Test Species:	CD-Ceriodaphnia dubia
Comments:	Standard Toxicant				

		Auxiliary Data Summary					
Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
N Control	Temp C	24.48	24.00	25.80	0.70	3.42	8
3		24.48	24.00	25.80	0.70	3.42	8
5		24.48	24.00	25.80	0.70	3.42	8
10		24.48	24.00	25.80	0.70	3.42	8
20		24.48	24.00	25.80	0.70	3.42	8
30		24.48	24.00	25.80	0.70	3.42	8
N Control	pH	8.29	8.20	8.30	0.04	2.27	8
3		8.23	7.80	8.30	0.18	5.09	8
5		8.21	7.80	8.30	0.17	5.06	8
10		8.21	7.80	8.30	0.17	5.06	8
20		8.21	7.80	8.30	0.17	5.06	8
30		8.21	7.80	8.30	0.17	5.06	8
N Control	DO mg/L	7.26	5.80	7.70	0.61	10.79	8
3		6.89	6.20	7.60	0.48	10.08	8
5		6.86	6.30	7.50	0.40	9.25	8
10		6.88	6.30	7.50	0.39	9.11	8
20		6.86	6.20	7.50	0.40	9.25	8
30		6.88	6.20	7.50	0.40	9.19	8
N Control	Hardness mg/L	93.88	92.00	95.00	1.55	1.33	8
3		0.00	0.00	0.00	0.00		0
5		0.00	0.00	0.00	0.00		0
10		0.00	0.00	0.00	0.00		0
20		0.00	0.00	0.00	0.00		0
30		94.00	94.00	94.00	0.00	0.00	8
N Control	Cond umhos	346.75	338.00	359.00	6.30	0.72	8
3		346.88	341.00	357.00	5.33	0.67	8
5		338.25	337.00	341.00	1.39	0.35	8
10		336.63	333.00	341.00	2.45	0.46	8
20		336.25	334.00	338.00	1.75	0.39	8
30		335.63	331.00	338.00	2.20	0.44	8
N Control	Alkalinity mg/L	63.13	60.00	68.00	3.31	2.88	8
3		0.00	0.00	0.00	0.00		0
5		0.00	0.00	0.00	0.00		0
10		0.00	0.00	0.00	0.00		0
20		0.00	0.00	0.00	0.00		0
30		68.00	68.00	68.00	0.00	0.00	8

Ventura CountyWatershed Protection District
NPDES Stormwater Monitoing Program
Grab Toxicity Samples - ABC

CHAIN-OF-CUSTODY RECORD 1 OF 1

CLIENT: Ventura County Watershed Protection District

SAMPLING DATE: EVENT #1 (Wet)

SAMPLERS:

SAMPLE INFORMATION FOR GRAB SAMPLES

SAMPLE ID	DATE/TIME COLLECTED	Acute Ceriodaphnia - 6.25, 12.5, 25, 50, 100%	Chronic Echinoderm Fertilization - 6.25, 12.5, :						NOTES	Field H_2O Temp
ME-CC	9-22-07 8:15		X						See Note 1	19.2°C
ME-SCR	9:00		X						See Note 1	19.6°C
ME-VR2	10:00		X						See Note 1	17.6°C
~~A-1 Wood~~	DRY	~~X~~							See Note 2	
~~W-3 La Vista~~	DRY	~~X~~							See Note 2	
~~W-4 Revolon~~	9-22-07 11:45	~~X~~							See Note 2	19.6°C

	Relinquished By:	Date/Time
Signature	[signature]	9-22-07 10:20
Printed Name	DAVID F THOMAS	9-22-07 12:38 W-4
Affiliation	VCWPD	

	Received By:	Date/Time
	[signature]	9/22/07 1020
Printed Name	Arnel Ramos	9/22/07 1230 W-4
Affiliation	Aquatic Bioassay	

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

1. **Mass Emmission: No TIE for Chronic Samples.**
2. **Land Use: Run TIE if Tua (Acute) is >1 for any wet or dry weather event.**

CALLED 9-19-07 @ 09:50 x10 (BETH) = LEFT MESSAGE ; x12 (ARNEL) TALK W/ HIM.

5. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2006/07 monitoring season consisted of the capturing of the first flush storm event in Ventura County on December 9, 2006, followed by the monitoring of two mid-season storms on January 27, 2007 and February 22, 2007. A late season storm was captured on April 20, 2007. Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation. The two dry weather events were monitored on May 15, 2007 and June 12, 2007. Dry weather events are monitored when there has been at least a 72-hour antecedent dry period without measurable rainfall (< 0.01 inches).

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR2) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1) and Receiving Water (W-3, W-4) sites. Receiving Water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. Only aquatic toxicity grab samples were collected at the Ortega Street (I-2) and Swan Street (R-1) Land Use sites during Event 1 (12/9/06) because the Stormwater Monitoring Program had already satisfied its NPDES permit condition stating that these two Land Use sites must be monitored a minimum of three times per permit term with respect to the collection of water chemistry samples. However, the Stormwater Monitoring Program is still under a regulatory obligation to collect aquatic toxicity grab samples at these sites in order to amass baseline toxicity information related to land use discharges.

The Santa Clara River (ME-SCR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Ventura River (ME-VR2) site also possesses an electrical connection and refrigerated sampling unit, but communication with the sampling equipment is made possible via a cellular phone connection. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2 and R-1. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR.

The sampling methods and sample handling procedures used during the 2006/07 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water Guide*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission Guide*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388. The Stormwater Monitoring Program produces an *event sample matrix* for each event prior to its monitoring as a means of documenting the specific environmental and QA/QC samples to be collected at any given monitoring site for a particular event, as well as the specific sample container to be used when collecting a certain sample. All event sample matrices associated with the 2006/07 monitoring season are presented in Appendix C.

At Mass Emission, Receiving Water, and Land Use sites, both composite and grab samples are collected. Composite samples are collected in glass containers and then delivered to the lab where they are split by pouring off with a tipper. When the splitting of a composite sample is performed, the composite sample is continually rocked in a sample-pouring stand to provide as much "non-invasive" mixing as possible. Sample splitting allows homogeneous aliquots of a single, large water sample to be divided into several smaller samples for the purpose of delivering these smaller volumes of water to individual analytical laboratories as necessary. The volume of sample collected depends upon the volume required by the lab to perform requested water quality and QA/QC analyses.

Figure 20: Grab Sample Collection using EPA Sampling Protocols

In an effort to maintain quality control for the sampling program, the sampling crew, in cooperation with the analytical laboratories, has minimized the number of laboratories and sample bottles used for analysis. This has minimized bottle breakage, increased efficiency, and reduced the chances for contamination of the samples. Also, a dedicated monitoring team is used to provide consistent sample collection and handling. Remote access capability at all but two Land Use monitoring sites (I-2 and R-1) also provides data-on-demand which allows immediate onsite evaluation of stream conditions.

For constituents analyzed from samples required to be collected as "grabs", samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak flow. It should be noted that peak flow times vary for each monitoring station due to the size and inherent characteristics of the watershed in which the site is located. All grab and composite wet weather samples collected during the 2006/07 monitoring season are considered best available estimates of storm EMCs. During dry weather, time-paced composite samples are collected at each site over a 24 to 48-hour period. Dry weather grab samples are collected during this composite sample period. Table 7 summarizes the samples collected at each of the monitoring locations during the 2006/07 monitoring season. It should be noted that no composite sample was analyzed for the ME-CC station during Event 2 (1/27/07) because the 20-L bottle inside the sampler was broken and the water sample lost.

As a means of documenting all preparatory, operational, observational, and concluding activities of a monitoring event, the Stormwater Monitoring Program produces an *event summary* for each monitoring event it conducts. These event summaries include, but are not limited to information related to event duration, predicted and actual precipitation, weather conditions, the programming of sampling equipment, equipment malfunctions, sample collection and handling, and sample tracking with respect to delivery to an analytical laboratory. All event summaries associated with the 2006/07 monitoring season are presented in Appendix D.

Table 7: 2006/07 Monitoring Event Summary

Event Number	Event Date	A-1 Wood Road	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR2 Ventura River-OVSDTP
1	12/9/06	CGT	T	T	CGT	CGT	CGT	CGT	CGT
2	1/27/07	—	—	—	—	—	*GT	CGT	CGT
3	2/22/07	—	—	—	—	—	CGT	CGT	CGT
4	4/20/07	—	—	—	—	—	CG	CG	CG
5	5/15/07	—	—	—	—	—	CGT	CGT	CGT
6	6/12/07	—	—	—	—	—	CG	CG	CG

Notes:

"G" indicates that a grab sample was collected.

"C" indicates that a composite sample was collected.

"T" indicates that toxicity samples were collected.

"—" indicates that no sample was collected.

"*" No composite sample was taken at ME-CC during Event 2 because the 20-L bottle inside the sampler was broken and the water sample lost.

In addition to documenting the water quality samples scheduled for collection during an event through the generation of an event sample matrix, the Stormwater Monitoring Program also documents the actual samples it collects – and their date and time of collection – during the course of an event by completing a chain of custody (COC) form for each sampling event conducted at a monitoring site. The COC form not only documents sample collection, but also notifies an analytical laboratory that a particular sample should be analyzed for a certain constituent or group of constituents, oftentimes specifying the analytical method to be employed. Finally, the COC form acts as an evidentiary document noting how many samples were relinquished – and at what date and time – to a particular laboratory by the Stormwater Monitoring Program. All chain of custody forms associated with the 2006/07 monitoring season are presented in Appendix E.

For the analysis of wet weather (storm) data (Events 1 – 4), the Basin Plan objectives and the acute, freshwater objectives in the California Toxics Rule (CTR) were used. For some constituents, the California Toxics Rule does not contain acute objectives. In these cases, the California Toxics Rule Human Health (Organisms Only) objectives were used in the wet weather comparisons. The CTR Human Health (Organisms Only) objectives were used here because these constituents have no other objectives for comparison. These objectives were used even though they are based on long-term risks to human health that cannot be directly correlated to stormwater discharges. CTR chronic criteria were not used for wet weather analyses because acute criteria better reflect the short-term storm event exposure experienced by organisms, as compared to the long-term exposure considered by chronic criteria.

For the analysis of dry weather data (Events 5 and 6), the Basin Plan objectives and the chronic, freshwater objectives in the CTR were used. For some constituents, the CTR does not contain chronic objectives. In these cases, the CTR Human Health (Organisms Only) objectives were used in the dry weather comparisons. The CTR Human Health (Organisms Only) objectives were used here because these constituents have no other objectives for comparison.

Objectives in the CTR for metals are calculated based on the hardness of the water in which metals concentrations are being evaluated. This analysis used the hardness value measured at a particular site during a particular monitoring event for calculating a certain metals objective, except when the measured hardness was greater than 400 mg/L. The CTR sets a hardness cap of 400 mg/L for calculating the objectives, so any measured hardness value above 400 mg/L was set equal to 400 mg/L for the purposes of the calculation.

Table 57 through Table 59 present water quality objective exceedances at Mass Emission stations based on an analysis of the 2006/07 wet weather and dry weather stormwater monitoring data. Table 60 through Table 62 show water quality objective exceedances at the Mass Emission stations during dry weather monitoring events. Table 63 and Table 64 present water quality objective exceedances detected at Receiving Water sites W-3 and W-4, respectively, based on an analysis of the Event 1 wet weather monitoring data collected at these locations.

Table 57: Water Quality Objective Exceedances at Mass Emission Site ME-CC Observed During Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Event 2 1/27/07 Result	Event 3 2/22/07 Result	Event 4 4/20/07 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	15531	2481	3448	3255	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	24000	700	2400	1400	400	
Metal	Aluminum – Total	2466		1349		1000	
Metal	Mercury – Total	0.08288					0.051^
Organic	Benzo(b)fluoranthene	0.0582		0.0521			0.049^
Organic	Benzo(k)fluoranthene	0.0582					0.049^
Organic	Bis(2-ethylhexyl)phthalate			35.3401	14.0783	4	5.9^
Organic	Chrysene	0.0569		0.0544	0.0544		0.049^
Organic	Indeno(1,2,3-cd)pyrene	0.0542					0.049^
Pesticide	4,4'-DDD	0.0287		0.0142	0.0209		0.00084^
Pesticide	4,4'-DDE	0.1059		0.0783	0.0763		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 58: Water Quality Objective Exceedances at Mass Emission Site ME-VR2 Observed During Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Event 2 1/27/07 Result	Event 3 2/22/07 Result	Event 4 4/20/07 Result	Basin Plan Objective	CTR FW Acute Objective
Anion	Chloride (mg/L)	256.02	123.2	62.92	78.72	60	
Bacteriological	E. coli (MPN/100 mL)		1467	4611	598	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	500	1100	11000	9000	400	
Conventional	Total Dissolved Solids (mg/L)	1123				1000	
Organic	Bis(2-ethylhexyl)phthalate	6.7482	4.4671		5.4605	4	
Organic	Hexachlorobenzene	0.0013					0.00077^
Pesticide	4,4'-DDD	0.1902					0.00084^
Pesticide	4,4'-DDE	0.6256					0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 59: Water Quality Objective Exceedances at Mass Emission Site ME-SCR Observed During Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Event 2 1/27/07 Result	Event 3 2/22/07 Result	Event 4 4/20/07 Result	Basin Plan Objective	CTR FW Acute Objective
Anion	Chloride (mg/L)	91.13				80	
Bacteriological	E. coli (MPN/100 mL)	2613			2489	235	
Bacteriological	Fecal Coliform (MPN/100 mL)				1100	400	
Conventional	Total Dissolved Solids (mg/L)	31448		1320		1300	
Metal	Aluminum – Total	3573	1783	17330	1722	1000	
Metal	Cadmium – Total			13.7		5	
Organic	Benzo(a)anthracene				0.0639		0.049^
Organic	Benzo(b)fluoranthene				0.0632		0.049^
Organic	Bis(2-ethylhexyl)phthalate			17.7682	5.422	4	5.9^
Organic	Chrysene			0.0697	0.1615		0.049^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 60: Water Quality Objective Exceedances at Mass Emission Site ME-CC Observed During Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 5 5/15/07 Result	Event 6 6/12/07 Result	Basin Plan Objective	CTR FW Chronic Objective
Anion	Chloride (mg/L)	181.26	172.21	150	
Conventional	Total Dissolved Solids (mg/L)	860		850	
Organic	Bis(2-ethylhexyl)phthalate	5.7094	3.5941	4	
Pesticide	4,4'-DDE		0.0148		0.00059

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 61: Water Quality Objective Exceedances at Mass Emission Site ME-VR2 Observed During Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 5 5/15/07 Result	Event 6 6/12/07 Result	Basin Plan Objective	CTR FW Chronic Objective
Organic	Bis(2-ethylhexyl)phthalate	6.1251	5.742	4	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 62: Water Quality Objective Exceedances at Mass Emission Site ME-SCR Observed During Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 5 5/15/07 Result	Event 6 6/12/07 Result	Basin Plan Objective	CTR FW Chronic Objective
Anion	Chloride (mg/L)	81.44	87.44	80	
Metal	Selemium – Total	6.3	6.5		5^
Organic	Bis(2-ethylhexyl)phthalate		5.079	4	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 63: Water Quality Objective Exceedances at Receiving Water Site W-3 Observed During Wet Weather Monitoring Event

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	54750	235	
Conventional	Total Dissolved Solids (mg/L)	567	500	
Metal	Aluminum – Total	5036	1000	
Metal	Cadmium – Total	6	5	
Metal	Mercury – Total	0.5831		0.051^
Nutrient	Nitrate as N	53.49	10	
Organic	Benzo(a)pyrene	0.0674		0.049^
Organic	Benzo(b)fluoranthene	0.0678		0.049^
Organic	Benzo(k)fluoranthene	0.0601		0.049^
Organic	Bis(2-ethylhexyl)phthalate	16.7484	4	5.9^
Organic	Chrysene	0.1383		0.049^
Organic	Hexachlorobenzene	0.0039		0.00077^
Organic	Indeno(1,2,3-cd)pyrene	0.0539		0.049^
Pesticide	4,4'-DDD	0.5489		0.00084^
Pesticide	4,4'-DDE	3.046		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 64: Water Quality Objective Exceedances at Receiving Water Site W-4 Observed During Wet Weather Monitoring Event

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	3654	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	7000	400	
Conventional	Total Dissolved Solids (mg/L)	2099	500	
Metal	Aluminum – Total	4116	1000	
Metal	Mercury – Total	0.0522		0.051^
Nutrient	Nitrate as N	52.04	10	
Organic	Benzo(a)anthracene	0.3281		0.049^
Organic	Benzo(a)pyrene	0.5126		0.049^
Organic	Benzo(b)fluoranthene	0.7874		0.049^
Organic	Benzo(k)fluoranthene	0.5702		0.049^
Organic	Bis(2-ethylhexyl)phthalate	22.2727	4	5.9^
Organic	Chrysene	1.2274		0.049^
Organic	Dibenz(a,h)anthracene	0.1282		0.049^
Organic	Hexachlorobenzene	0.0093		0.00077^
Organic	Indeno(1,2,3-cd)pyrene	0.6393		0.049^
Pesticide	4,4'-DDD	0.994		0.00084^
Pesticide	4,4'-DDE	6.1746		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land User discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2006/07 monitoring data from the Agricultural Land Use station A-1 were compared to the Basin Plan and California Toxics Rule objectives previously described. Although the Stormwater Monitoring Program's Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters.

Table 65 presents water quality objective exceedances at agricultural Land Use site A-1 based on an analysis of the wet weather stormwater monitoring data collected there during Event 1.

Table 65: Water Quality Objective Exceedances at Agricultural Land Use Site A-1 Observed During Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)l	609	235	
Conventional	Total Dissolved Solids (mg/L)	2865	500	
Metal	Aluminum – Total	3056	1000	
Organic	Bis(2-ethylhexyl)phthalate	12.0772	4	5.9^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

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Potential Problematic Constituents

A review of Table 57 through Table 65 provides the following observations with respect to potential problematic constituents measured in wet weather runoff.

Anion

Chloride concentrations above Basin Plan objectives were observed at the Mass Emission sites during both wet and dry monitoring events. Two exceedances at the ME-CC station occurred during dry weather Events 5 and 6, while four exceedances at the ME-VR2 site occurred during the four monitored wet weather events. Site ME-SCR had exceedances during both wet (Event 1) and dry (Events 5 and 6) monitoring events. Chloride was not observed at concentrations greater than site-specific Basin Plan objectives for most monitoring events of the 2006/07 season. Chloride was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list presented in the 2002/03 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate chloride at Mass Emission and Receiving Water monitoring sites as a means of assessing any future trends exhibited by this pollutant.

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for *E. coli* and/or Fecal Coliform during one or more wet weather events. Likewise, runoff from the A-1 agricultural Land Use site exceeded the 235 MPN/100 mL Basin Plan objective for *E. coli*.. Dry weather monitoring at the three Mass Emission sites revealed no E. coli or Fecal Coliform concentrations exceeding their respective Basin Plan objectives. Consistent with previous pollutant of concern identification efforts by the Ventura Countywide Stormwater Quality Program (presented most recently in the 2002/03 Annual Monitoring Report) bacteria pose a potential problem for water quality protection and warrant special consideration by the Program.

Conventionals

Mass Emission stations ME-VR2 and ME-SCR, Receiving Water sites W-3 and W-4, and the agricultural Land Use site A-1 showed total dissolved solids concentrations during one or more wet weather events above Basin Plan objectives. A single dry weather exceedance above the Basin Plan site-specific objective for total dissolved solids was observed at Mass Emission site ME-CC. Total dissolved solids was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list contained in the 2002/03 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate total dissolved solids at its monitoring sites as a means of augmenting its database and tracking site-specific and seasonal trends in observed Basin Plan exceedances for this water quality parameter.

Metals

All Mass Emission, Receiving Water and Land Use sites monitored during wet weather events, with the exception of ME-VR2, showed concentrations of total aluminum in excess of Basin Plan water quality objectives during one or more events. This is the fourth year that aluminum has been monitored by the Stormwater Monitoring Program, and the fourth time that a comparison to Basin Plan objectives has revealed exceedances for total aluminum. It should be noted that aluminum is found as a ubiquitous natural element in sediments throughout Ventura County geology. Mass Emission station ME-CC also recorded concentrations of total mercury above the 0.051 µg/L CTR Human Health water quality objective during wet weather Event 1, while ME-SCR possessed total cadmium levels above the 5 µg/L Basin Plan objective during wet weather Event 3. Dry weather monitoring revealed two exceedance of the 5 µg/L CTR freshwater chronic objective for total selenium at Mass Emission station ME-SCR. Mass Emission site ME-VR2 recorded no metals concentration above water quality objectives during wet or dry weather events. Both Receiving Water sites exhibited exceedances for total mercury above the CTR Human Health water quality standard, in addition to an exceedance of the Basin Plan total cadmium objective at La Vista (W-3)..

Nutrients

Water quality objective exceedances were recorded for nitrate (as nitrogen) at two Receiving Water sites, La Vista (W-3) and Revolon Slough (W-4), but not at the agricultural Land Use site Wood Road (A-1). Given that these Basin Plan exceedances appear to be an issue most pertinent to fertilizer use by agriculture, the Stormwater Monitoring Program will continue to monitor for nutrients at these sites to augment the database. Consistent with the most recent POC analysis (see 2002/03 Annual Monitoring Report), the runoff contributions of nitrogen compounds will need to be analyzed by the Stormwater Management Program in more detail via trend analyses, source identification, and potential source control measures.

Organics

Organic compound exceedances observed during 2006/07 wet weather events were limited to the phthalate compound, Bis(2-ethylhexyl)phthalate, and various polynuclear aromatic hydrocarbons (PAHs). All monitoring stations recorded one or more exceedances of the 4 µg/L Basin Plan water quality objective for Bis(2-ethylhexyl)phthalate, while several sites showed concentrations of the phthalate compound above the 5.9 µg/L CTR Human Health objective . Dry weather exceedances of water quality objectives for trace organic compounds were limited to Bis(2-ethylhexyl)phthalate exceedances at all Mass Emission sites. As mentioned in Section 7, phthalate compounds originating from plastics are present in the environment at relatively high concentrations. The use of low detection limits achieved by the analytical laboratory employed by the Stormwater Monitoring Program to analyze for trace organics has resulted in the measurement of phthalate compounds at all monitoring stations in recent years.

All Mass Emission and Receiving Water sites recorded wet weather concentrations of one or more polynuclear aromatic hydrocarbon (PAH) in excess of CTR Human Health water quality objectives. No PAH concentrations were observed to exceed CTR Human Health objectives at Mass Emission stations during dry weather monitoring. The presence of individual PAH compounds above CTR objectives at particular monitoring sites are listed as follows:

- Benzo(a)anthracene: ME-SCR, W-4
- Benzo(a)pyrene: W-3, W-4
- Benzo(b)fluoranthene: ME-CC, ME-SCR, W-3, W-4
- Benzo(k)fluoranthene: ME-CC, W-3, W-4
- Chrysene: ME-CC, ME-SCR, W-3, W-4
- Dibenz(a,h)anthracene: W-4
- Hexachlorobenzene: ME-VR2, W-3, W-4
- Indeno(1,2,3-cd)pyrene: ME-CC, W-3, W-4

PAHs are found in the combustion products of wood, coal, and internal combustion engines, and are ubiquitous in the environment. Wildfires that burned in the region in recent years could also have served as a source of PAH compounds that were measured in water quality samples. With reference to both phthalates and PAHs, the CTR Human Health criteria for which these exceedances were observed were based on long-term exposure human health protection. Comparing short-term discharges with the human health criterion is only useful as a screening tool and not for assessing the impact of the stormwater discharge on the waterbody and compliance with water quality standards.

Pesticides

Pesticide exceedances observed during 2006/07 wet weather events were limited to two DDT-related compounds: 4,4'-DDD and 4,4'-DDE. All monitoring stations, except for the Mass Emission site ME-SCR and Land Use site A-1, showed one or more exceedances of the CTR Human Health objectives for 4,4'-DDD (0.00084 µg/L) and 4,4'-DDE (0.00059 µg/L) during wet weather events. Mass Emission station ME-CC recorded an exceedance of the CTR Human Health objective for 4,4'-DDE during dry weather Event 6.

The two DDT-related compounds for which CTR Human Health exceedances were recorded at Program monitoring sites were the legacy pesticides 4,4'- DDD and 4,4'-DDE. These legacy pesticides are associated with Ventura County's extensive farming history. These compounds are currently being addressed in the Calleguas Creek watershed through the implementation of the Calleguas Creek Watershed OC Pesticides and PCBs Total Maximum Daily Load (TMDL), adopted by the Los Angeles Regional Water Quality Control Board in July 2005. The Ventura Countywide co-permittees located in the Calleguas Creek watershed were actively involved in the TMDL development and are participating in its implementation. Legacy pesticides, such as DDT, will be further monitored over the course of the TMDL's implementation phase, and if high concentration areas (i.e., "hotspots") of these pesticides are identified, special studies will be implemented to address these hotspots.

Overall Conclusions for 2006/07 Stormwater Monitoring Season

This report summarizes the events of the 2006/07 monitoring season in which the Stormwater Monitoring Program successfully collected and analyzed water quality samples from four wet weather storm events and two dry weather events. The Stormwater Monitoring Program subsequently conducted a thorough QA/QC evaluation of the environmental and QA/QC results generated from its analysis of water quality samples and found the resultant data set to have achieved a 95.8% success rate in meeting program data quality objectives. Overall, the four wet weather and two dry weather events monitored during the current season produced a high quality data set in terms of the low percentage of qualified data, as well as the low reporting levels achieved by all laboratories analyzing the Stormwater Monitoring Program's water quality samples.

Acute toxicity was observed at Receiving Water sites A-1 (Wood), W-3 (La Vista), and W-4 (Revolon) for the samples collected during Event 1. ABC was unable to identify the toxicant(s) for the W-4 sample because the sample's toxicity dissipated by the time the TIE was initiated. At the A-1 site, ABC concluded that particulate-associated compounds and non-polar organic compounds contributed to the toxicity observed in the sample. At the W-3 site, ABC determined that particulate-associated compounds, non-polar organic compounds, and chlorine or other oxidants contributed to the toxicity observed in the sample.

Chronic toxicity was observed during one wet weather event and one dry weather event at Mass Emission stations ME-SCR and ME-VR2. Results from the February 2007 wet event did not trigger TIE initiation because two consecutive wet weather samples did not exhibit toxicity. Results from the May 2007 dry event triggered a TIE, but the time the baseline test for the TIE was performed, toxicity in both samples was reduced and the TIEs were aborted

The September 2006 BMI survey was preceded by a winter in which slightly more than average rainfall was recorded in the watershed. As a result of the unusually large amount of rain during the winter of 2004-05 and the above-average winter of 2005-06, 14 of the 15 BMI sampling locations had sufficient flow for sample collection (as compared to nine sites during the 2004 BMI survey possessing sufficient flow to allow sample collection). Physical habitat conditions at the 14 sampling sites ranged from poor to optimal. The best (highest) habitat scores were at locations on the upper main stem of the Ventura River, upper San Antonio Creek and Matilija Creek. The worst (lowest) scores were at locations on the lower Ventura River and Canada Larga Creek. Based on the Southern California Index of Biological Integrity (So CA IBI), the aquatic health of the Ventura Watershed during 2006 ranged from poor to good. One site on Matilija Creek ranked in the good range, while two sites on the Ventura River and one site each on Canada Larga and San Antonio Creek ranked in the poor range. The remaining ten sites in the watershed ranked in the fair range. The sites that ranked in the poor range were located in areas of the watershed that were impacted by either a large transient human population on the Ventura River or was located downstream of an erosion control project in the vicinity of grazing and stables.

4. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2006/07 monitoring season at the time of this report consisted of the capturing of the first flush storm event in Ventura County on December 9, 2006, followed by the monitoring of two mid-season storms on January 27, 2007 and February 22, 2007. Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation.

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR2) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1) and Receiving Water (W-3, W-4) sites. Receiving Water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. Only aquatic toxicity grab samples were collected at the Ortega Street (I-2) and Swan Street (R-1) Land Use sites during Event 1 (12/9/06) because the Stormwater Monitoring Program had already satisfied its NPDES permit condition stating that these two Land Use sites must be monitored a minimum of three times per permit term with respect to the collection of water chemistry samples. However, the Stormwater Monitoring Program is still under a regulatory obligation to collect aquatic toxicity grab samples at these sites in order to amass baseline toxicity information related to land use discharges.

The Santa Clara River (ME-SCR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Ventura River (ME-VR2) site also possesses an electrical connection and refrigerated sampling unit, but communication with the sampling equipment is made possible via a cellular phone connection. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2 and R-1. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR.

The sampling methods and sample handling procedures used during the 2006/07 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water Guide*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission Guide*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388. The Stormwater Monitoring Program produces an *event sample matrix* for each event prior to its monitoring as a means of documenting the specific environmental and QA/QC samples to be collected at any given monitoring site for a particular event, as well as the specific sample container to be used when collecting a certain sample. All event sample matrices associated with the 2006/07 monitoring season are presented in Appendix C.

At Mass Emission, Receiving Water, and Land Use sites, both composite and grab samples are collected. Composite samples are collected in glass containers and then delivered to the lab where they are split by pouring off with a tipper. When the splitting of a composite sample is performed, the composite sample is continually rocked in a sample-pouring stand to provide as much "non-invasive" mixing as possible. Sample splitting allows homogeneous aliquots of a single, large water sample to be divided into several smaller samples for the purpose of delivering these smaller volumes of water to individual analytical laboratories as necessary. The volume of sample collected depends upon the volume required by the lab to perform requested water quality and QA/QC analyses.

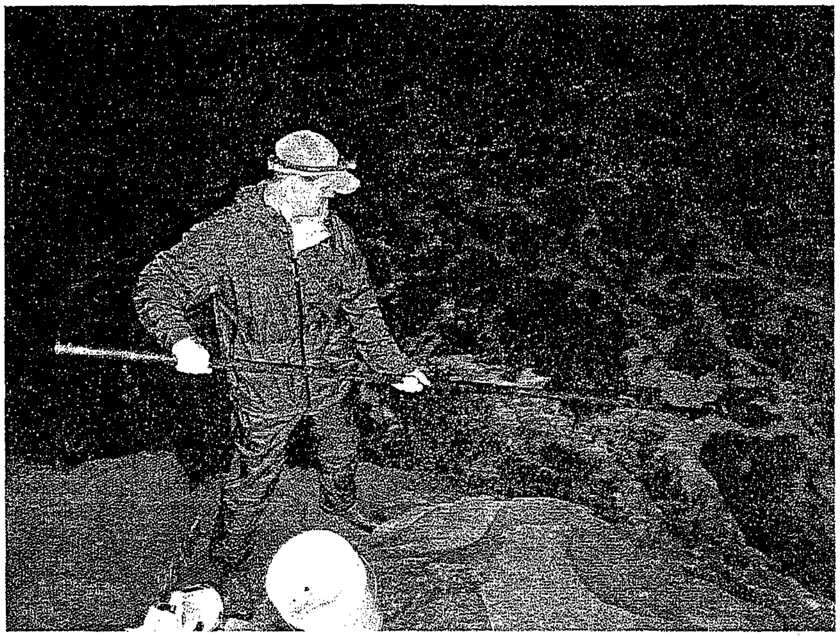

Figure 14: Grab Sample Collection using EPA Sampling Protocols

In an effort to maintain quality control for the sampling program, the sampling crew, in cooperation with the analytical laboratories, has minimized the number of laboratories and sample bottles used for analysis. This has minimized bottle breakage, increased efficiency, and reduced the chances for contamination of the samples. Also, a dedicated monitoring team is used to provide consistent sample collection and handling. Remote access capability at all but two Land Use monitoring sites (I-2 and R-1) also provides data-on-demand which allows immediate onsite evaluation of stream conditions.

For constituents analyzed from samples required to be collected as “grabs”, samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak flow. It should be noted that peak flow times vary for each monitoring station due to the size and inherent characteristics of the watershed in which the site is located. All grab and composite wet weather samples collected during the 2006/07 monitoring season are considered best available estimates of storm EMCs. Table 6 summarizes the samples collected at each of the monitoring locations during the 2006/07 monitoring season's wet weather events. It should be noted that no composite sample was analyzed for the ME-CC station during Event 2 (1/27/07) because the 20-L bottle inside the sampler was broken and the water sample lost.

As a means of documenting all preparatory, operational, observational, and concluding activities of a monitoring event, the Stormwater Monitoring Program produces an *event summary* for each monitoring event it conducts. These event summaries include, but are not limited to information related to event duration, predicted and actual precipitation, weather conditions. the programming of sampling equipment, equipment malfunctions, sample collection and handling, and sample tracking with respect to delivery to an analytical laboratory. All event summaries associated with the 2006/07 monitoring season are presented in Appendix D.

Table 6: 2006/07 Monitoring Event Summary

Event Number	Event Date	A-1 Wood Road	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR2 Ventura River-OVSDTP
1	12/9/06	CGT	T	T	CGT	CGT	CGT	CGT	CGT
2	1/27/07	-	-	-	-	-	*GT	CGT	CGT
3	2/22/07	-	-	-	-	-	CGT	CGT	CGT

Notes:
"G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"T" indicates that toxicity samples were collected.
"-" indicates that no sample was collected.
"*" No composite sample was taken at ME-CC during Event 2 because the 20-L bottle inside the sampler was broken and the water sample lost.

In addition to documenting the water quality samples scheduled for collection during an event through the generation of an event sample matrix, the Stormwater Monitoring Program also documents the actual samples it collects – and their date and time of collection – during the course of an event by completing a chain of custody (COC) form for each sampling event conducted at a monitoring site. The COC form not only documents sample collection, but also notifies an analytical laboratory that a particular sample should be analyzed for a certain constituent or group of constituents, oftentimes specifying the analytical method to be employed. Finally, the COC form acts as an evidentiary document noting how many samples were relinquished – and at what date and time – to a particular laboratory by the Stormwater Monitoring Program. All chain of custody forms associated with the 2006/07 monitoring season are presented in Appendix E.

Table 45: Bacteriological Results from Mass Emission Site ME-CC

Constituent ~ MPN/100 mL	Event 1 12/9/06	Event 2 1/27/07	Event 3 2/22/07
E. Coli	15,531	2,481	3,448
Enterococcus	1,650	4,060	11,840
Fecal Coliform	24,000	700	2,400
Total Coliform	307,600	261,300	290,900

Table 46: Bacteriological Results from Mass Emission Site ME-VR2

Constituent ~ MPN/100 mL	Event 1 12/9/06	Event 2 1/27/07	Event 3 2/22/07
E. Coli	203	1,467	4,611
Enterococcus	41	1,013	11,840
Fecal Coliform	500	1,100	11,000
Total Coliform	1,789	17,329	19,890

Table 47: Bacteriological Results from Mass Emission Site ME-SCR

Constituent ~ MPN/100 mL	Event 1 12/9/06	Event 2 1/27/07	Event 3 2/22/07
E. Coli	2,613	173	73
Enterococcus	1,124	478	344
Fecal Coliform	350	50	300
Total Coliform	72,700	27,550	57,940

Aquatic Toxicity Results

Samples for acute and chronic aquatic toxicity testing were collected during two wet weather events (December 2006 and January 2007). Results for acute and chronic toxicity tests for samples collected at the Land Use, Receiving Water, and Mass Emission monitoring stations are summarized in Table 48 and Table 49. Full results are available in Appendix N.

Acute Toxicity

Acute toxicity testing was performed using *Ceriodaphnia dubia* as the test species. Results for acute toxicity are reported as the LC50, which is the concentration of sample that produces death in 50% of test organisms exposed. Since the concentration of pollutants is unknown in environmental samples, concentration is measured as a dilution percentage of the original sample, with 100% equal to the undiluted sample. An LC50 concentration, or dilution percentage, reported as less than 100% indicates that the undiluted sample caused >50% mortality to exposed test organisms and required dilution to achieve LC50. An LC50 dilution result of greater than 100% indicates that the sample would have to be more concentrated than it was at the time of sample collection to achieve the LC50. Results are also reported in units of TUa[5], which the analyzing laboratory calculated using the following equation from the California Ocean Plan[6]:

$$TUa = \frac{\log(100-S)}{1.7}$$

where: S = percent survival in 100% sample. If S > 99, TUa shall be reported as zero.

[5] Historically, acute toxicity has been calculated using the following equation: TUa = 100/LC50

[6] California Ocean Plan. State Water Resources Control Board. 2005.

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Acute toxicity (as demonstrated by a TUa >1.0) was observed at Receiving Water sites A-1 (Wood), W-3 (La Vista), and W-4 (Revolon) for the samples collected during Event 1, as shown in Table 48. These sites are all in agriculture-dominated watersheds. In accordance with permit requirements, a TIE was initiated for each of these sites. The toxicity testing laboratory, Aquatic Bioassay & Consulting Laboratories, Inc. (ABC), was unable to identify the toxicant(s) for the W-4 (Revolon) sample because the sample's toxicity dissipated by the time the TIE was initiated. For that sample, ABC concluded that "the toxicant was most likely associated with volatile compound(s)." It is noteworthy that common environmental mechanisms other than volatilization may be causing degradation or loss of toxicant(s) over time, including photochemical (light) reactions, chemical reactions (oxidation/reduction, hydrolysis, etc.) or biochemical (microbial) transformations.

Table 48: Acute Toxicity Results from Land Use and Receiving Water Sites

Station	*Sample Date*	*Percent Survival in 100% Sample*	*Acute Ceriodaphnia Survival*	
			LC50 – Dilution %	*TUa*
A-1	12/9/06	0%	7.10%	14.08
I-2	12/9/06	100%	>100%	0.00
R-1	12/9/06	95%	>100%	0.41
W-3	12/9/06	0%	36.11%	2.77
W-4	12/9/06	0%	36.21%	2.76

The toxic signal persisted in the samples collected at A-1 (Wood) and W-3 (La Vista), enabling the laboratory to conduct Phase I TIEs for these sites following sample manipulation and testing procedures prescribed in Methods for Aquatic Toxicity Identification Evaluations, Phase I Toxicity Characterization Procedures (Second Edition), EPA/600/6-91/003. Results for the TIEs are as follows:

- A-1 (Wood): Particle removal and C^{18} extraction reduced sample toxicity, whereas piperonyl butoxide (PBO), EDTA and sodium thiosulfate addition did not. The analyzing laboratory therefore concluded that particulate-associated compounds and non-polar organic compounds contributed to the toxicity observed in the A-1 (Wood) sample.

- W-3 (La Vista): Particle removal, C18 extraction and sodium thiosulfate addition reduced sample toxicity, whereas piperonyl butoxide (PBO) and EDTA addition did not. The analyzing laboratory therefore concluded that particulate-associated compounds, non-polar organic compounds, and chlorine or other oxidants contributed to the toxicity observed in the W-3 (La Vista) sample. EPA's Phase I TIE manual states the following with regard to the sodium thiosulfate manipulation: "However, this oxidant reduction test does not simply affect chlorine toxicity. Also neutralized in this test are other chemicals used in disinfection (such as ozone, and chlorine dioxide), chemicals formed during chlorination (such as mono and dichloramines), bromine, iodine, manganous ions, and some electrophile organic chemicals...thiosulfate can also be a chelating agent for some cationic metals. Consequently, reductions in effluent toxicity observed with this test may be due to the formation of metal complexes with the thiosulfate anion."

Chronic Toxicity

Chronic toxicity tests are performed using Purple Sea Urchin (*Strongylocentrotus purpuratus*) as the test species. Results are reported in several ways: the IC50 is the sample concentration, or dilution percentage, at which an inhibitory response – in this case, lack of fertilization – is observed in 50% of the exposed test organisms. The NOEC is the concentration of sample at which there exists no observable effect on test organisms. An IC50 dilution or NOEC dilution reported as greater than 100% indicates that the sample would have to be more concentrated than it was at the time of sample collection to achieve the indicated effect. Results are also reported in units of TUc, which is calculated as 100 divided by the NOEC.

The NPDES permit specifies that a TIE must be initiated if two consecutive wet weather samples (or a single dry weather sample) exhibit toxicity; however, a numeric trigger for chronic toxicity is not

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specified in the permit. For the purposes of the Stormwater Monitoring Program, a numeric chronic toxicity trigger of TUc >1.0 was selected.

While chronic toxicity was not detected in any wet-weather samples collected at Mass Emission stations, several difficulties were encountered during the 2006/07 monitoring season. According to the NPDES permit, these tests are to be performed on water quality samples gathered during the first two wet-weather sampling events. However, while water quality samples were gathered in the field during Event 1 (grab sample date – 12/9/06), the sea urchins that were to be used for the tests failed to spawn. Therefore, ABC was unable to proceed with the testing. A make-up sample was collected during Event 3 (grab sample date – 2/22/07).

Furthermore, due to miscommunication between VCWPD staff and ABC during Event 2, concentrations of greater than 70% were not run. This resulted in toxicity units reported as less than 1.43, but without resolution on whether or not the toxicity units were below 1.0. ABC performed a statistical analysis and determined these samples to be not statistically different than the control, thereby rendering a TIE unnecessary. Results of the testing are summarized in Table 49. ABC Laboratory's toxicity testing reports from the 2006/07 monitoring season are provided in Appendix N.

Table 49: Chronic Toxicity Results from Mass Emission Sites

Station	Sample Date	Chronic Purple Sea Urchin Fertilization Bioassay		
		IC50 Dilution	NOEC Dilution	TUc
ME-CC	1/27/07	>70%	70%	≤1.43
ME-CC	2/22/07	>100%	100%	1.00
ME-SCR	1/27/07	>70%	70%	≤1.43
ME-SCR	2/22/07	>100%	50%	2.00
ME-VR2	1/27/07	>70%	70%	≤1.43
ME-VR2	2/22/07	>100%	50%	2.00

Dry weather monitoring for chronic toxicity is scheduled to be conducted later in the current monitoring season, and results from those tests will be reported in the October 2007 Annual Monitoring Report.

For this analysis of wet weather (storm) data, the Basin Plan objectives, the acute, freshwater objectives in the California Toxics Rule (CTR), and the 2005 California Ocean Plan (Ocean Plan) daily maximum objectives were used. For some constituents, the California Toxics Rule does not contain acute objectives. In these cases, the California Toxics Rule Human Health (Organisms Only) objectives were used in the wet weather comparison. The CTR Human Health (Organisms Only) objectives were used here because these constituents have no other objectives for comparison. These objectives were used even though they are based on long-term risks to human health that cannot be directly correlated to stormwater discharges. CTR chronic criteria were not used for wet weather analyses because acute criteria better reflect the short-term storm event exposure experienced by organisms, as compared to the long-term exposure considered by chronic criteria. With respect to the Ocean Plan, a 30-day Average objective (for protection of human health) was used when a Daily Maximum objective was not provided for a particular constituent. Objectives in the CTR for metals are calculated based on the hardness of the water. This analysis used the hardness value measured at a particular site during a particular monitoring event for calculating a certain metals objective, except when the measured hardness was greater than 400 mg/L. The CTR sets a hardness cap of 400 mg/L for calculating the objectives, so any measured hardness value above 400 mg/L was set equal to 400 mg/L for the purposes of the calculation.

Table 52 through Table 56 present water quality objective exceedances at Mass Emission and Receiving Water stations based on an analysis of the 2006/07 wet weather stormwater monitoring data.

Table 52: Water Quality Objective Exceedances at Mass Emission Site ME-CC

Classification	*Constituent (in µg/L except where noted)*	*Event 1 12/9/06*	*Event 2 1/27/07*	*Event 3 2/22/07*	*Basin Plan Obj.*	*Ocean Plan Daily Max*	*CTR FW Obj.*
Bacteriological	E. Coli (MPN/100 mL)	15531	2481	3448	235		
Bacteriological	Enterococcus (MPN/100 mL)	1650	4060	11840		104	
Bacteriological	Fecal Coliform (MPN/100 mL)	24000	700	2400	400	400	
Bacteriological	Total Coliform (MPN/100 mL)	307600	261300	290900		10000	
Metal	Aluminum - Total	2466		1349	1000		
Metal	Copper - Total	21.2		13.2		12	
Metal	Mercury - Total	0.08288					0.051^
Metal	Zinc - Total	90.8				80	
Organic	Benzo(b)fluoranthene	0.0582		0.0521			0.049^
Organic	Benzo(k)fluoranthene	0.0582					0.049^
Organic	Bis(2-ethylhexyl)phthalate			35.3401	4	3.5	5.9^
Organic	Chrysene	0.0569		0.0544			0.049^
Organic	Indeno(1,2,3-cd)pyrene	0.0542					0.049^
Organic	PAHs	0.4636		0.3463		0.0088	
Pesticide	4,4'-DDD	0.0287		0.0142			0.00084^
Pesticide	4,4'-DDE	0.1059		0.0783			0.00059^
Pesticide	Chlordane	0.007		0.0069		0.000023	
Pesticide	DDT	0.1456		0.1001		0.00017	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 53: Water Quality Objectives Exceedances at Mass Emission Site ME-VR2

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06	Event 2 1/27/07	Event 3 2/22/07	Basin Plan Obj.	Ocean Plan Daily Max	CTR FW Obj.
Anion	Chloride	256.02	123.195	62.92	60		
Bacteriological	E. Coli (MPN/100 mL)		1467	4611	235		
Bacteriological	Enterococcus (MPN/100 mL)		1013	11840		104	
Bacteriological	Fecal Coliform (MPN/100 mL)	500	1100	11000	400	400	
Bacteriological	Total Coliform (MPN/100 mL)		17329	19890		10000	
Conventional	Total Dissolved Solids	1123			1000		
Organic	Bis(2-ethylhexyl)phthalate	6.7482	4.4671		4	3.5	5.9^
Organic	Hexachlorobenzene	0.0013				0.00021	0.00077^
Organic	PAHs	0.1925				0.0088	
Pesticide	4,4'-DDD	0.1902					0.00084^
Pesticide	4,4'-DDE	0.6256					0.00059^
Pesticide	Chlordane	0.0165				0.000023	
Pesticide	DDT	1.1047				0.00017	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 54: Water Quality Objective Exceedances at Mass Emission Site ME-SCR

Classification	Constituent (in µg/L except where noted)	Event 1 12/9/06	Event 2 1/27/07	Event 3 2/22/07	Basin Plan Obj.	Ocean Plan Daily Max	CTR FW Obj.
Anion	Chloride	91.13			80		
Bacteriological	E. Coli (MPN/100 mL)	2613			235		
Bacteriological	Enterococcus (MPN/100 mL)	1124	478	344		104	
Bacteriological	Total Coliform (MPN/100 mL)	72700	27550	57940		10000	
Conventional	Total Dissolved Solids	31448		1320	1300		
Metal	Aluminum - Total	3573	1783	17330	1000		
Metal	Cadmium - Total			13.7	5	4	
Metal	Chromium - Total			31		8	
Metal	Copper - Total	15.1		148.7		12	
Metal	Lead - Total			25.62		8	
Metal	Nickel - Total	22.2		185.9		20	
Metal	Zinc - Total			300.1		80	
Organic	Bis(2-ethylhexyl)phthalate			17.7682	4	3.5	5.9^
Organic	Chrysene			0.0697			0.049^
Organic	PAHs	0.2506	0.0251	0.429		0.0088	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 55: Water Quality Objective Exceedances for Receiving Water Site W-3

Classification	*Constituent (in µg/L except where noted)*	*Event 1 12/9/06*	*Basin Plan Obj.*	*Ocean Plan Daily Max*	*CTR FW Obj.*
Bacteriological	E. Coli (MPN/100 mL)	54750	235		
Bacteriological	Enterococcus (MPN/100 mL)	6570		104	
Bacteriological	Total Coliform (MPN/100 mL)	307600		10000	
Conventional	Total Dissolved Solids	567	500		
Metal	Aluminum - Total	5036	1000		
Metal	Cadmium - Total	6	5	4	
Metal	Copper - Total	37.5		12	
Metal	Mercury - Total	0.58311		0.16	0.051^
Metal	Nickel - Total	67.3		20	
Metal	Zinc - Total	237.7		80	
Nutrient	Nitrate as N	53.49	10		
Organic	Benzo(a)pyrene	0.0674			0.049^
Organic	Benzo(b)fluoranthene	0.0678			0.049^
Organic	Benzo(k)fluoranthene	0.0601			0.049^
Organic	Bis(2-ethylhexyl)phthalate	16.7484	4	3.5	5.9^
Organic	Chrysene	0.1383			0.049^
Organic	Hexachlorobenzene	0.0039		0.00021	0.00077^
Organic	Indeno(1,2,3-cd)pyrene	0.0539			0.049^
Organic	PAHs	0.7227		0.0088	
Pesticide	4,4'-DDD	0.5489			0.00084^
Pesticide	4,4'-DDE	3.046			0.00059^
Pesticide	Chlordane	0.0637		0.000023	
Pesticide	DDT	4.2919		0.00017	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 56: Water Quality Objective Exceedances for Receiving Water Site W-4

Classification	*Constituent (in µg/L except where noted)*	*Event 1 12/9/06*	*Basin Plan Obj.*	*Ocean Plan Daily Max*	*CTR FW Obj.*
Bacteriological	E. Coli (MPN/100 mL)	3654	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	7000	400	400	
Bacteriological	Total Coliform (MPN/100 mL)	138500		10000	
Conventional	Total Dissolved Solids	2099	500		
Metal	Aluminum - Total	4116	1000		
Metal	Copper - Total	21.2		12	
Metal	Lead - Total	8.67		8	
Metal	Mercury - Total	0.0522			0.051^
Metal	Zinc - Total	112.5		80	
Nutrient	Nitrate as N	52.04	10		
Organic	Benzo(a)anthracene	0.3281			0.049^
Organic	Benzo(a)pyrene	0.5126	0.2		0.049^
Organic	Benzo(b)fluoranthene	0.7874			0.049^
Organic	Benzo(k)fluoranthene	0.5702			0.049^
Organic	Bis(2-ethylhexyl)phthalate	22.2727	4	3.5	5.9^
Organic	Chrysene	1.2274			0.049^
Organic	Dibenz(a,h)anthracene	0.1282			0.049^
Organic	Hexachlorobenzene	0.0093		0.00021	0.00077^
Organic	Indeno(1,2,3-cd)pyrene	0.6393			0.049^
Organic	PAHs	6.6753		0.0088	
Pesticide	4,4'-DDD	0.994			0.00084^
Pesticide	4,4'-DDE	6.1746			0.00059^
Pesticide	Chlordane	0.4142		0.000023	
Pesticide	DDT	7.7757		0.00017	

Blank cells denote no exceedance of a water quality objective.

"^" – CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land User discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2006/07 monitoring data from the Agricultural Land Use station A-1 were compared to the Basin Plan, California Toxics Rule, and California Ocean Plan objectives previously described. Although the Stormwater Monitoring Program's Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters.

Table 57 presents water quality objective exceedances at agricultural Land Use site A-1 based on an analysis of the wet weather stormwater monitoring data collected there during Event 1.

Table 57: Water Quality Objective Exceedances at Agricultural Land Use Site A-1

Classification	*Constituent (in µg/L except where noted)*	*Event 1 12/9/06*	*Basin Plan Obj.*	*Ocean Plan Daily Max*	*CTR FW Obj.*
Bacteriological	E. Coli	609	235		
Bacteriological	Enterococcus	373		104	
Bacteriological	Total Coliform	173290		10000	
Conventional	Total Dissolved Solids	2865	500		
Metal	Aluminum - Total	3056	1000		
Metal	Chromium - Total	8.4		8	
Metal	Copper - Total	18.6		12	
Metal	Nickel - Total	25.6		20	
Organic	Bis(2-ethylhexyl)phthalate	12.0772	4	3.5	5.9^
Organic	PAHs	0.0096		0.0088	

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Potential Problematic Constituents

A review of Table 52 through Table 57 provides the following observations with respect to potential problematic constituents measured in wet weather runoff.

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for E. Coli, Enterococcus, Fecal Coliform, and Total Coliform. Likewise, runoff from the A-1 agricultural Land Use site exceeded bacteriological objectives for these same four bacteria. It should be noted that the inclusion of new Enterococcus (104 MPN/100 mL) and Fecal Coliform (400 MPN/100 mL) objectives in the revised 2005 California Ocean Plan resulted in the recording of these two parameters as existing at concentrations above their respective Ocean Plan objective at most monitoring locations. Consistent with previous pollutant of concern identification efforts by the Ventura Countywide Stormwater Quality Program (presented most recently in the 2002/03 Annual Monitoring Report) bacteria pose a potential problem for water quality protection and warrant special consideration by the Program.

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Conventionals

Mass Emission stations ME-VR2 and ME-SCR, Receiving Water sites W-3 and W-4, and the agricultural Land Use site A-1 showed total dissolved solids concentrations during wet weather events above Basin Plan objectives. Total dissolved solids was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list contained in the 2002/03 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate total dissolved solids at its monitoring sites as a means of augmenting its database and tracking site-specific and seasonal trends in observed Basin Plan exceedances for this water quality parameter.

Metals

All Mass Emission, Receiving Water and Land Use sites monitored during wet weather events, with the exception of ME-VR2, showed concentrations of total aluminum in excess of Basin Plan water quality objectives. This is the fourth year that aluminum has been monitored by the Stormwater Monitoring Program, and the fourth time that a comparison to Basin Plan objectives has revealed exceedances for total aluminum. It should be noted that aluminum is found as a ubiquitous natural element in sediments throughout Ventura County geology. Mass Emission station ME-CC also recorded concentrations of copper, mercury, and zinc above water quality objectives, while ME-SCR had cadmium, chromium and copper (all total fractions) levels above these objectives. Mass Emission site ME-VR2 recorded no metals concentration above water quality objectives. Both Receiving Water sites exhibited exceedances for copper, mercury, and zinc (all total fractions) above water quality standards, in addition to exceedances for total cadmium and total nickel at La Vista (W-3) and total lead at Wood Rd. (W-4). Total chromium and copper concentrations measured at the agricultural Land Use site A-1 exceeded their respective Ocean Plan Daily Maximum objectives.

The Basin Plan total aluminum exceedances notwithstanding, it should be noted that most metals exceedances observed during 2006/07 wet weather events were for metals concentrations above Ocean Plan objectives, with the exception of CTR mercury exceedances. Consistent with the most recent POC analysis (see 2002/03 Annual Monitoring Report), the runoff contributions of copper, lead, and zinc will need to be analyzed by the Stormwater Management Program in more detail via trend analyses, source identification, and potential source control measures (see Pollutant of Concern Assessment below).

Nutrients

Water quality objective exceedances were recorded for nitrate at two Receiving Water sites, La Vista (W-3) and Revolon Slough (W-4), but not at the agricultural Land Use site Wood Road (A-1). Given that these Basin Plan exceedances appear to be an issue most pertinent to fertilizer use by agriculture, the Stormwater Monitoring Program will continue to monitor for nutrients at these sites to augment the database. Consistent with the most recent POC analysis (see 2002/03 Annual Monitoring Report), the runoff contributions of nitrogen compounds will need to be analyzed by the Stormwater Management Program in more detail via trend analyses, source identification, and potential source control measures (see Pollutant of Concern Assessment below).

Organics

Organic compound exceedances observed during 2006/07 wet weather events were limited to the phthalate compound, Bis(2-ethylhexyl)phthalate, and various polynuclear aromatic hydrocarbons (PAHs). All monitoring stations recorded exceedances of the Ocean Plan objective for Bis(2-ethylhexyl)phthalate (3.5 µg/L), and often also exceeded the Basin Plan (4 µg/L) and CTR Human Health objectives (5.9 µg/L) for this constituent. As mentioned in Section 6, phthalate compounds originating from plastics are present in the environment at relatively high concentrations. The use of low detection limits achieved by the analytical laboratory employed by the Stormwater Monitoring Program to analyze for trace organics has resulted in the measurement of phthalate compounds at all monitoring stations in recent years.

All monitoring sites recorded concentrations of polynuclear aromatic hydrocarbons (PAHs) above the Ocean Plan's objective for PAH compounds[8]. Additionally, all Mass Emission stations and the Receiving Water site W-4 exhibited one or more PAH compound (see Footnote 8 for list of constituents) concentrations in excess of CTR Human Health water quality objectives. The presence of individual PAH compounds above CTR objectives at particular monitoring sites are listed as follows:

- Benzo(a)anthracene: W-4
- Benzo(a)pyrene: W-3, W-4
- Benzo(b)fluoranthene: ME-CC, W-3, W-4
- Benzo(k)fluoranthene: ME-CC, W-3, W-4
- Chrysene: ME-CC, ME-SCR, W-3, W-4
- Dibenz(a,h)anthracene: W-4
- Hexachlorobenzene: ME-VR2, W-3, W-4
- Indeno(1,2,3-cd)pyrene: W-3, W-4

PAHs are found in the combustion products of wood, coal, and internal combustion engines, and are ubiquitous in the environment. Wildfires that burned in the region in recent years could also have served as a source of PAH compounds that were measured in water quality samples. With reference to both phthalates and PAHs, the CTR Human Health criteria for which these exceedances were observed were based on long-term exposure human health protection. Comparing short-term discharges with the human health criterion is only useful as a screening tool and not for assessing the impact of the stormwater discharge on the waterbody and compliance with water quality standards.

Pesticides

Pesticide exceedances observed during 2006/07 wet weather events were limited to Chlordane-related compounds[9] and two DDT-related compounds: 4,4'-DDD and 4,4'-DDE. The Ocean Plan's Chlordane objective was exceeded at the ME-CC station during Event 1, and at the Mass Emission station ME-VR2 and Receiving Water sites, W-3 and W-4, during Event 1. All monitoring stations, except for the Mass Emission sites ME-SCR and Land Use site A-1, showed an exceedance of the Ocean Plan's DDT compound[10] objective. The two DDT-related compounds for which CTR Human Health exceedances were recorded at all monitoring sites possessing detectable DDT concentrations were the legacy pesticides 4,4'- DDD and 4,4'-DDE. These legacy pesticides are associated with Ventura County's extensive farming history. These compounds are currently being addressed in the Calleguas Creek watershed through the implementation of the Calleguas Creek Watershed OC Pesticides and PCBs Total Maximum Daily Load (TMDL), adopted by the Los Angeles Regional Water Quality Control Board in July 2005. The Ventura Countywide co-permittees located in the Calleguas Creek watershed were actively involved in the TMDL development and are participating in its implementation. Legacy pesticides, such as DDT and Chlordane compounds, will be further monitored over the course of the TMDL's implementation phase, and if high concentration areas (i.e., "hotspots") of these pesticides are identified, special studies will be implemented to address these hotspots.

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[8] The California Ocean Plan requires that the concentrations of the following individual PAH constituents be summed when comparing discharge concentrations to the Ocean Plan's 0.0088 µg/L PAH objective: Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluorene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene.

[9] The California Ocean Plan requires that the concentrations of the following individual Chlordane-related compounds be summed when comparing discharge concentrations to the Ocean Plan's 0.000023 µg/L Chlordane objective: alpha-Chlordane, alpha-Chlordene, alpha-Nonachlor, Chlordane, gamma-Chlordane, gamma-Chlordene, gamma-Nonachlor, and Oxychlordane.

[10] The California Ocean Plan requires that the concentrations of the following individual DDT-related compounds be summed when comparing discharge concentrations to the Ocean Plan's 0.00017 µg/L DDT objective: 2,4'-DDD, 2,4'-DDE, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

Conclusions

This report summarizes the first three events of the 2006/07 monitoring season in which the Stormwater Monitoring Program successfully collected and analyzed water quality samples from three wet weather storm events. The Stormwater Monitoring Program subsequently conducted a thorough QA/QC evaluation of the environmental and QA/QC results generated from its analysis of water quality samples and found the resultant data set to have achieved a 95% success rate in meeting program data quality objectives. Overall, the three wet weather events monitored during the current season produced a high quality data set in terms of the low percentage of qualified data, as well as the low reporting levels achieved by all laboratories analyzing the Stormwater Monitoring Program's water quality samples.

Data from one wet weather and two dry weather monitoring events remain to be reported for the 2006/07 monitoring season by the Stormwater Monitoring Program. Water quality samples collected from these events will be analyzed and their data evaluated in the same manner as the wet weather samples described in this report. The results of the Stormwater Monitoring Program's remaining wet and dry weather monitoring activities will be presented in the October 2007 Annual Monitoring Report along with the present wet weather monitoring results.

5. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2005/06 monitoring season consisted of the capturing of the first flush storm event in Ventura County on October 17, 2005, followed by the monitoring of one early-season (November) and two mid-season (February) storms. Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation. The two dry weather events were monitored during the months of May (Event 5) and June (Event 6). Dry weather events are monitored when there has been at least a 72-hour antecedent dry period without measurable rainfall (< 0.01 inches).

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR2) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet and dry weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Due to the absence of permit requirements specifying the collection of flow proportional samples, time-paced composite samples were collected at the Land Use (A-1) and Receiving Water (W-3, W-4) sites. Only aquatic toxicity grab samples were collected at the Ortega Street (I-2) and Swan Street (R-1) Land Use sites during Event 1 (10/17/05) because the Stormwater Monitoring Program had already satisfied its NPDES permit condition stating that these two Land Use sites must be monitored a minimum of three times per permit term with respect to the collection of water chemistry samples. However, the Stormwater Monitoring Program is still under a regulatory obligation to collect aquatic toxicity grab samples at these sites in order to amass baseline toxicity information related to land use discharges.

The Santa Clara River (ME-SCR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Ventura River (ME-VR2) site also possesses an electrical connection and refrigerated sampling unit, but communication with the sampling equipment is made possible via a cellular phone connection. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2 and R-1. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR.

The sampling methods and sample handling procedures used during the 2005/06 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water SOP*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission SOP*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388. The Stormwater Monitoring Program produces an *event sample matrix* for each event prior to its monitoring as a means of documenting the specific environmental and QA/QC samples to be collected at any given monitoring site for a particular event, as well as the specific sample container to be used when collecting a certain sample. All event sample matrices associated with the 2005/06 monitoring season are presented in Appendix C.

sites W-3 and W-4, respectively, based on an analysis of the Event 1 wet weather monitoring data collected at these locations.

Table 57: Water Quality Objective Exceedances at Mass Emission Site ME-CC observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	12033	9208	1313	10462	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	16000	1700	30000	400	
Metal	Aluminum – Total	1480	4300	5720	12200	1000	
Metal	Mercury – Total				0.0796		0.051^
Organic	Benzo(a)-anthracene				0.0495		0.049^
Organic	Benzo(a)pyrene				0.0665		0.049^
Organic	Benzo(b)-fluoranthene				0.0708		0.049^
Organic	Benzo(k)-fluoranthene				0.0724		0.049^
Organic	Bis(2-ethyl-hexyl)phthalate				6.3	4	5.9^
Organic	Chrysene	0.0607	0.0652		0.0894		0.049^
Pesticide	4,4'-DDD	0.0328			0.0205		0.00084^
Pesticide	4,4'-DDE	0.136	0.069		0.0891		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 58: Water Quality Objectives Exceedances at Mass Emission Site ME-VR2 observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objective	CTR FW Acute Objective
Anion	Chloride (mg/L)			66.5		60	
Bacteriological	E. coli (MPN/100 mL)	2613	327		11199	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	5000			17000	400	
Conventional	Total Dissolved Solids (mg/L)			1004		1000	
Metal	Aluminum – Total			1713	10100	1000	
Metal	Mercury – Total				0.0649		0.051^
Organic	Bis(2-ethyl-hexyl)phthalate				6.48	4	5.9^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 59: Water Quality Objective Exceedances at Mass Emission Site ME-SCR observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	256	1722		5794	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	900	9000		5000	400	
Metal	Aluminum – Total	8580	12060	8390	43600	1000	
Metal	Cadmium – Total				14.8	5	
Metal	Mercury – Total	0.0545	0.0875		0.174		0.051^
Metal	Nickel – Total				161	100	
Organic	Bis(2-ethylhexyl)phthalate				4.95	4	
Organic	Chrysene				0.0576		0.049^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 60: Water Quality Objective Exceedances at Mass Emission Site ME-CC observed during Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 5 5/31/06 Result	Event 6 6/13/06 Result	Basin Plan Objective	CTR FW Chronic Objective
Anion	Chloride (mg/L)	178	191	150	
Bacteriological	E. coli (MPN/100 mL)	1000		235	
Bacteriological	Fecal Coliform (MPN/100 mL)		1600	400	
Conventional	Total Dissolved Solids (mg/L)	972	1020	850	
Metal	Aluminum – Total	3170		1000	
Pesticide	4,4'-DDD	0.0022			0.00084
Pesticide	4,4'-DDE	0.0299			0.00059
Pesticide	4,4'-DDT	0.0187			0.001

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 61: Water Quality Objective Exceedances at Mass Emission Site ME-SCR observed during Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	Event 5 5/31/06 Result	Event 6 6/13/06 Result	Basin Plan Objective	CTR FW Chronic Objective
Bacteriological	Fecal Coliform (MPN/100 mL)		470	400	
Metal	Aluminum – Total	3800	1085	1000	
Metal	Selenium – Total	5.47	6.1		5

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 62: Water Quality Objective Exceedances for Receiving Water Site W-3

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	32550	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	400	
Conventional	Total Dissolved Solids (mg/L)	881	500	
Metal	Aluminum – Total	28600	1000	
Metal	Mercury – Total	0.129		0.051^
Pesticide	4,4'-DDD	0.114		0.00084^
Pesticide	4,4'-DDE	0.742		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 63: Water Quality Objective Exceedances for Receiving Water Site W-4

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	3873	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	2400	400	
Conventional	Total Dissolved Solids (mg/L)	16240	500	
Metal	Aluminum – Total	8850	1000	
Nutrient	Nitrate as N (mg/L)	22.4	10	
Organic	Benzo(a)pyrene	0.056		0.049^
Organic	Benzo(b)fluoranthene	0.115		0.049^
Organic	Benzo(k)fluoranthene	0.0713		0.049^
Organic	Chrysene	0.162		0.049^
Organic	Indeno(1,2,3-cd)pyrene	0.0673		0.049^
Pesticide	4,4'-DDD	0.3		0.00084^
Pesticide	4,4'-DDE	1.45		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land User discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2005/06 monitoring data from the Agricultural Land Use station A-1 were compared to the Basin Plan and CTR objectives previously described. Although the Stormwater Monitoring Program's Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters.

Table 64 presents water quality objective exceedances at agricultural Land Use site A-1 based on an analysis of the wet weather stormwater monitoring data collected there during Event 1.

Table 64: Water Quality Objective Exceedances at Agricultural Land Use Site A-1

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective
Bacteriological	E. coli (MPN/100 mL)	4611	235	
Bacteriological	Fecal Coliform (MPN/100 mL)	5000	400	
Conventional	Total Dissolved Solids (mg/L)	3158	500	
Nutrient	Nitrate as N (mg/L)	48.7	10	
Pesticide	4,4'-DDD	0.049		0.00084^
Pesticide	4,4'-DDE	0.197		0.00059^

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Potential Problematic Constituents

A review of Table 57 through Table 64 provides the following observations with respect to potential problematic constituents measured in wet weather runoff.

Anions

Chloride concentrations above Basin Plan objectives were observed at Mass Emission sites ME-CC and ME-VR2 during both wet and dry monitoring events. The two exceedances at the ME-CC station occurred during dry weather Events 5 and 6, while the one exceedance at the ME-VR2 site occurred during wet weather Event 3. Chloride was not observed at concentrations greater than site-specific Basin Plan objectives for most monitoring events of the 2005/06 season. Chloride was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list presented in the 2002/03 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate chloride at Mass Emission and Receiving Water monitoring sites as a means of assessing any future trends exhibited by this pollutant.

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for *E. coli* and fecal coliform during wet weather events. Likewise, runoff from the A-1 agricultural Land Use site exceeded bacteriological objectives for these same two bacteria during wet weather Event 1. Dry weather monitoring at the three Mass Emission sites revealed fecal coliform concentrations above the Basin Plan objective at ME-CC and ME-SCR during Event 6, along with an E. coli exceedance recorded at ME-CC during Event 5. Consistent with previous pollutant of concern identification efforts by the Management Program (presented most recently in the 2002/03 Annual Monitoring Report) bacteria pose a potential problem for water quality protection and warrant special consideration by the Program (see Pollutant of Concern Assessment below).

Conventionals

Mass Emission station ME-VR2, Receiving Water sites W-3 and W-4, and the agricultural Land Use site A-1 showed total dissolved solids concentrations during wet weather events above Basin Plan objectives. A single dry weather exceedance above the Basin Plan site-specific objective for total dissolved solids was observed at Mass Emission site ME-CC. Total dissolved solids was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list contained in the 2002/-3 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate total dissolved solids at its monitoring sites as a means of augmenting its database and tracking site-specific and seasonal trends in observed Basin Plan exceedances for this water quality parameter.

4. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2005/06 monitoring season consisted of the capturing of the first flush storm event in Ventura County on October 17, 2005, followed by the monitoring of one early-season (November) and two mid-season (February) storms. Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation.

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR2) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1) and Receiving Water (W-3, W-4) sites. Receiving Water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. Only aquatic toxicity grab samples were collected at the Ortega Street (I-2) and Swan Street (R-1) Land Use sites during Event 1 (10/17/05) because the Stormwater Monitoring Program had already satisfied its NPDES permit condition stating that these two Land Use sites must be monitored a minimum of three times per permit term with respect to the collection of water chemistry samples. However, the Stormwater Monitoring Program is still under a regulatory obligation to collect aquatic toxicity grab samples at these sites in order to amass baseline toxicity information related to land use discharges.

The Santa Clara River (ME-SCR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Ventura River (ME-VR2) site also possesses an electrical connection and refrigerated sampling unit, but communication with the sampling equipment is made possible via a cellular phone connection. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2 and R-1. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR.

The sampling methods and sample handling procedures used during the 2005/06 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water Guide*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission Guide*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388. The Stormwater Monitoring Program produces an *event sample matrix* for each event prior to its monitoring as a means of documenting the specific environmental and QA/QC samples to be collected at any given monitoring site for a particular event, as well as the specific sample container to be used when collecting a certain sample. All event sample matrices associated with the 2005/06 monitoring season are presented in Appendix C.

At Mass Emission, Receiving Water, and Land Use sites, both composite and grab samples are collected. Composite samples are collected in glass containers and then delivered to the lab where they are split by pouring off with a tipper. When the splitting of a composite sample is performed, the composite sample is continually rocked in a sample-pouring stand to provide as much "non-invasive" mixing as possible. Sample splitting allows homogeneous aliquots of a single, large water sample to be divided into several smaller samples for the purpose of delivering these smaller volumes of water to individual analytical laboratories as necessary. The volume of sample collected depends upon the volume required by the lab to perform requested water quality and QA/QC analyses.

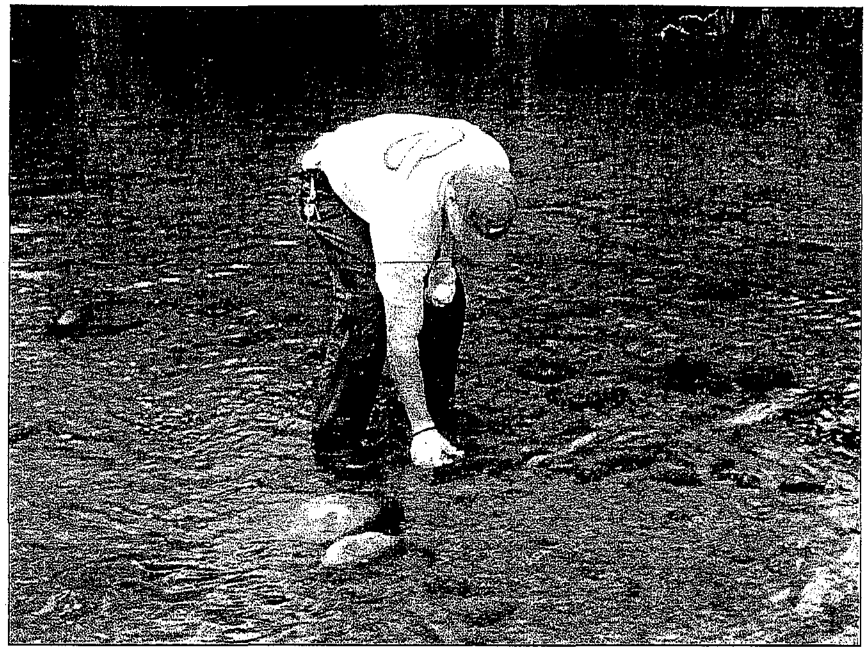

Figure 15: Grab Sample Collection in the Ventura River using EPA Sampling Protocols

In an effort to maintain quality control for the sampling program, the sampling crew, in cooperation with the analytical laboratories, has minimized the number of laboratories and sample bottles used for analysis. This has minimized bottle breakage, increased efficiency, and reduced the chances for contamination of the samples. Also, a dedicated monitoring team is used to provide consistent sample collection and handling. Remote access capability at all but two Land Use monitoring sites (I-2 and R-1) also provides data-on-demand which allows immediate onsite evaluation of stream conditions.

For constituents analyzed from samples required to be collected as "grabs", samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak flow. It should be noted that peak flow times vary for each monitoring station due to the size and inherent characteristics of the watershed in which the site is located. All grab and composite wet weather samples collected during the 2005/2006 monitoring season are considered best available estimates of storm EMCs. Table 6 summarizes the samples collected at each of the monitoring locations during the 2005/06 monitoring season's wet weather events. As a means of documenting all preparatory, operational, observational, and concluding activities of a monitoring event, the Stormwater Monitoring Program produces an *event summary* for each monitoring event it conducts. These event summaries include, but are not limited to information related to event duration, predicted and actual precipitation, weather conditions, the programming of sampling equipment, equipment malfunctions, sample collection and handling, and sample tracking with respect to delivery to an analytical laboratory. All event summaries associated with the 2005/06 monitoring season are presented in Appendix D.

Table 6: 2005/06 Monitoring Event Summary

Event Number	Event Date	A-1 Wood Road	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR2 Ventura River-OVSDTP
1	10/17/05	CGT	T	T	CGT	CGT	CGT	CGT	CGT
2	11/9/05	-	-	-	-	-	CGT	CGT	CGT
3	2/17/06	-	-	-	-	-	CG	CG	CG
4	2/27/06	-	-	-	-	-	CG	CG	CG

Notes:
"G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"T" indicates that toxicity samples were collected.
"-" indicates that no sample was collected.

In addition to documenting the water quality samples scheduled for collection during an event through the generation of an event sample matrix, the Stormwater Monitoring Program also documents the actual samples it collects – and their date and time of collection – during the course of an event by completing a chain of custody (COC) form for each sampling event conducted at a monitoring site. The COC form not only documents sample collection, but also notifies an analytical laboratory that a particular sample should be analyzed for a certain constituent or group of constituents, oftentimes specifying the analytical method to be employed. Finally, the COC form acts as an evidentiary document noting how many samples were relinquished – and at what date and time – to a particular laboratory by the Stormwater Monitoring Program. All chain of custody forms associated with the 2005/06 monitoring season are presented in Appendix E.

Table 45: Bacteriological Results from Mass Emission Site ME-CC

Constituent ~ MPN/100 mL	Event 1 10/17/05	Event 2 11/9/05	Event 3 2/17/06	Event 4 2/27/06
E. Coli	12033	9208	1313	10462
Enterococcus	43300	16520	2005	19200
Fecal Coliform	50000	16000	1700	30000
Total Coliform	5475000	770100	198630	344800

Table 46: Bacteriological Results from Mass Emission Site ME-VR2

Constituent ~ MPN/100 mL	Event 1 10/17/05	Event 2 11/9/05	Event 3 2/17/06	Event 4 2/27/06
E. Coli	2613	327	74	11199
Enterococcus	12980	207	111	10910
Fecal Coliform	5000	130	50	17000
Total Coliform	104620	3076	3448	241920

Table 47: Bacteriological Results from Mass Emission Site ME-SCR

Constituent ~ MPN/100 mL	Event 1 10/17/05	Event 2 11/9/05	Event 3 2/17/06	Event 4 2/27/06
E. Coli	256	1722	122	5794
Enterococcus	288	1298	453	14450
Fecal Coliform	900	9000	110	5000
Total Coliform	34480	198630	12997	686700

Aquatic Toxicity Results

Samples for acute and chronic aquatic toxicity testing were collected during two wet weather events (October and November) in 2005. Results for acute and chronic toxicity tests for samples collected at the Land Use, Receiving Water, and Mass Emission monitoring stations are summarized in Table 48 and Table 49.

Acute Toxicity

Acute toxicity testing was performed using *Ceriodaphnia dubia* as the test species. Results for acute toxicity are reported as the LC50, which is the concentration of sample that produces death in 50% of test organisms exposed. Since the concentration of pollutants is unknown in environmental samples, concentration is measured as a dilution percentage of the original sample, with 100% equal to the undiluted sample. An LC50 concentration, or dilution percentage, reported as less than 100% indicates that the undiluted sample caused >50% mortality to exposed test organisms and required dilution to achieve LC50. An LC50 dilution result of greater than 100% indicates that the sample would have to be more concentrated than it was at the time of sample collection to achieve the LC50. Results are also reported in units of TUa[4], which the analyzing laboratory calculated using the following equation from the California Ocean Plan[5]:

$$TUa = \frac{\log(100-S)}{1.7}$$

where: S = percent survival in 100% sample. If S > 99, TUa shall be reported as zero.

[4] Historically, acute toxicity has been calculated using the following equation: TUa = 100/LC50

[5] California Ocean Plan. State Water Resources Control Board. 2005.

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Acute toxicity (as demonstrated by a TUa >1.0) was observed at Receiving Water site W-3 for the sample collected during Event 1 (grab sample date – 10/18/05) as shown in Table 48. In accordance with permit requirements, a TIE was initiated for this sample. The toxicity testing laboratory, Aquatic Bioassay & Consulting Laboratories, Inc. (ABC), was unable to identify the toxicant(s) because the toxicity dissipated in the sample by the time the TIE was initiated.

Table 48: Acute Toxicity Results from Land Use and Receiving Water Sites

Station	Sample Date	Percent Survival in 100% Sample	Acute Ceriodaphnia Survival	
			LC50 – Dilution %	TUa
A-1	10/18/05	90	>100%	0.59
I-2	10/18/05	100	>100%	0.00
R-1	10/18/05	85	>100%	0.69
W-3	10/18/05	10	55.56%	2.00
W-4	10/18/05	80	>100%	0.77

Chronic Toxicity

Chronic toxicity tests were performed using the Purple Sea Urchin (*Strongylocentrotus purpuratus*) as the test species; results are summarized in Table 49.

Results are reported in several ways: the IC50 is the sample concentration, or dilution percentage, at which an inhibitory response – in this case, lack of fertilization – is observed in 50% of the exposed test organisms. The NOEC is the concentration of sample at which there exists no observable effect on test organisms. An IC50 dilution or NOEC dilution reported as greater than 100% indicates that the sample would have to be more concentrated than it was at the time of sample collection to achieve the indicated effect. Results are also reported in units of TUc, which is calculated as 100 divided by the NOEC.

Table 49: Chronic Toxicity Results from Mass Emission Sites

Station	Sample Date	Chronic Purple Sea Urchin Fertilization Bioassay		
		IC50 Dilution	NOEC Dilution	TUc
ME-CC	10/18/05	>100%	100%	1.00
ME-CC	11/09/05	>100%	100%	1.00
ME-SCR	10/18/05	>100%	100%	1.00
ME-SCR	11/09/05	>100%	100%	1.00
ME-VR2	10/18/05	>100%	100%	1.00
ME-VR2	11/09/05	>100%	100%	1.00

The NPDES permit specifies that a TIE must be initiated if two consecutive wet weather samples (or a single dry weather sample) exhibit toxicity; however, a numeric trigger for chronic toxicity is not specified in the permit. For the purposes of the Stormwater Monitoring Program, a numeric chronic toxicity trigger of >1.0 TUc was selected. Chronic toxicity (defined herein as a TUc >1.0) was not detected in any wet-weather samples collected at Mass Emission stations in 2005. ABC Laboratory's toxicity testing reports from the 2005/06 monitoring season are provided in Appendix F.

Dry weather monitoring for chronic toxicity is scheduled to be conducted later in the current monitoring season, and results from those tests will be reported in the October 2006 Annual Monitoring Report.

Table 52: Water Quality Objective Exceedances at Mass Emission Site ME-CC

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Bacteriological	E. Coli (MPN/100 mL)	12033	9208	1313	10462	235		
Bacteriological	Enterococcus (MPN/100 mL)	43300	16520	2005	19200			104
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	16000	1700	30000	400		400
Bacteriological	Total Coliform (MPN/100 mL)	5475000	770100	198630	344800			10000
Metal	Aluminum – Total	1480	4300	5720	12200	1000		
Metal	Cadmium – Total		4.58		4.32			4
Metal	Chromium – Total		13.8	23.8	26.2			8
Metal	Copper – Total	13.6	22.3	21.9	59.1			12
Metal	Lead – Total	11.7			16.1			8
Metal	Mercury – Total				0.0796		0.051^	
Metal	Nickel – Total		27.8	28.4	56.5			20
Metal	Zinc – Total				168			80
Organic	Benzo(a)-anthracene				0.0495		0.049^	
Organic	Benzo(a)-pyrene				0.0665		0.049^	
Organic	Benzo(b)-fluoranthene				0.0708		0.049^	
Organic	Benzo(k)-fluoranthene				0.0724		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate				6.3	4	5.9^	3.5
Organic	Chrysene	0.0607	0.0652		0.0894		0.049^	
Organic	PAHs	0.3419	0.2635		0.6309			0.0088
Pesticide	4,4'-DDD	0.0328			0.0205		0.00084^	
Pesticide	4,4'-DDE	0.136	0.069		0.0891		0.00059^	
Pesticide	Chlordane compounds				0.0105			0.000023
Pesticide	DDTs	0.1688	0.069		0.1209			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 53: Water Quality Objectives Exceedances at Mass Emission Site ME-VR2

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Anion	Chloride (mg/L)			66.5		60		
Bacterio-logical	E. Coli (MPN/100 mL)	2613	327		11199	235		
Bacterio-logical	Enterococcus (MPN/100 mL)	12980	207	111	10910			104
Bacterio-logical	Fecal Coliform (MPN/100 mL)	5000			17000	400		400
Bacterio-logical	Total Coliform (MPN/100 mL)	104620			241920			10000
Conven-tional	Total Dissolved Solids (mg/L)			1004		1000		
Metal	Aluminum – Total			1713	10100	1000		
Metal	Chromium – Total				16.9	50		8
Metal	Copper – Total				26.8			12
Metal	Lead – Total				9.77			8
Metal	Mercury – Total				0.0649		0.051^	
Metal	Nickel – Total				43.8			20
Organic	Bis(2-ethyl-hexyl)phthalate				6.48	4	5.9^	3.5
Organic	PAHs				0.2108			0.0088

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

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Table 54: Water Quality Objective Exceedances at Mass Emission Site ME-SCR

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Event 2 11/9/05 Result	Event 3 2/17/06 Result	Event 4 2/27/06 Result	Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Bacteriological	E. Coli (MPN/100 mL)	256	1722		5794	235		
Bacteriological	Enterococcus (MPN/100 mL)	288	1298	453	14450			104
Bacteriological	Fecal Coliform (MPN/100 mL)	900	9000		5000	400		400
Bacteriological	Total Coliform (MPN/100 mL)	34480	198630	12997	686700			10000
Metal	Aluminum – Total	8580	12060	8390	43600	1000		
Metal	Cadmium – Total				14.8	5		4
Metal	Chromium – Total	17.1	20.1	13.1	43.6			8
Metal	Copper – Total	21.7	38	18	149			12
Metal	Lead – Total		11.6		35.7			8
Metal	Mercury – Total	0.0545	0.0875		0.174		0.051^	0.16
Metal	Nickel – Total	27.7	40.2	23.5	161	100		20
Metal	Zinc – Total		96.4		341			80
Organic	Bis(2-ethyl-hexyl)phthalate				4.95	4		3.5
Organic	Chrysene				0.0576		0.049^	
Organic	PAHs	0.1162	0.0245	0.0165	0.3032			0.0088

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 55: Water Quality Objective Exceedances for Receiving Water Site W-3

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	32550	235		
Bacteriological	Enterococcus (MPN/100 mL)	59100			104
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	400		400
Bacteriological	Total Coliform (MPN/100 mL)	120330			10000
Conventional	Total Dissolved Solids (mg/L)	881	500		
Metal	Aluminum – Total	28600	1000		
Metal	Chromium – Total	45.6			8
Metal	Copper - Total	170			12
Metal	Lead – Total	50.3			8
Metal	Mercury – Total	0.129		0.051^	
Metal	Nickel – Total	77.6			20
Metal	Zinc – Total	302			80
Organic	PAH compounds	0.2782			0.0088
Pesticide	4,4'-DDD	0.114		0.00084^	
Pesticide	4,4'-DDE	0.742		0.00059^	
Pesticide	Chlordane compounds	0.0178			0.000023
Pesticide	DDTs	1.1108			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 56: Water Quality Objective Exceedances for Receiving Water Site W-4

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	3873	235		
Bacteriological	Enterococcus (MPN/100 mL)	20500			104
Bacteriological	Fecal Coliform (MPN/100 mL)	2400	400		400
Bacteriological	Total Coliform (MPN/100 mL)	1986300			10000
Conventional	Total Dissolved Solids (mg/L)	16240	500		
Metal	Aluminum – Total	8850	1000		
Metal	Chromium – Total	17.4			8
Metal	Copper - Total	34.1			12
Metal	Lead – Total	17.6			8
Metal	Nickel – Total	24.4			20
Metal	Zinc – Total	115			80
Nutrient	Nitrate as N (mg/L)	22.4	10		
Organic	Benzo(a)pyrene	0.056		0.049^	
Organic	Benzo(b)fluoranthene	0.115		0.049^	
Organic	Benzo(k)fluoranthene	0.0713		0.049^	
Organic	Chrysene	0.162		0.049^	
Organic	Indeno(1,2,3-cd)pyrene	0.0673		0.049^	
Organic	PAH compounds	0.868			0.0088
Pesticide	4,4'-DDD	0.3		0.00084^	
Pesticide	4,4'-DDE	1.45		0.00059^	
Pesticide	Chlordane compounds	0.0573			0.000023
Pesticide	DDTs	1.8565			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land User discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2005/06 monitoring data from the Agricultural Land Use station A-1 were compared to the Basin Plan, California Toxics Rule, and California Ocean Plan objectives previously described. Although the Stormwater Monitoring Program's Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters.

Table 57 presents water quality objective exceedances at agricultural Land Use site A-1 based on an analysis of the wet weather stormwater monitoring data collected there during Event 1.

Table 57: Water Quality Objective Exceedances at Agricultural Land Use Site A-1

Classification	Constituent (in µg/L except where noted)	Event 1 10/17/05 Result	Basin Plan Objective	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	4611	235		
Bacteriological	Enterococcus (MPN/100 mL)	165200			104
Bacteriological	Fecal Coliform (MPN/100 mL)	5000	400		400
Bacteriological	Total Coliform (MPN/100 mL)	2481000			10000
Conventional	Total Dissolved Solids (mg/L)	3158	500		
Metal	Copper - Total	15.9			12
Metal	Nickel – Total	26.4			20
Nutrient	Nitrate as N (mg/L)	48.7	10		
Organic	PAH compounds	0.0917			0.0088
Pesticide	4,4'-DDD	0.049		0.00084^	
Pesticide	4,4'-DDE	0.197		0.00059^	
Pesticide	DDT compounds	0.3509			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Potential Problematic Constituents

A review of Table 52 through Table 57 provides the following observations with respect to potential problematic constituents measured in wet weather runoff.

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for E. Coli, Enterococcus, Fecal Coliform, and Total Coliform. Likewise, runoff from the A-1 agricultural Land Use site exceeded bacteriological objectives for these same four bacteria. It should be noted that the inclusion of new Enterococcus (104 MPN/100 mL) and Fecal Coliform (400 MPN/100 mL) objectives in the revised 2005 California Ocean Plan resulted in the recording of these two parameters as existing at concentrations above their respective Ocean Plan objective at all monitoring locations. Consistent with previous pollutant of concern identification efforts by the Ventura Countywide Stormwater Quality Program (presented most recently in the 2002/03 Annual Monitoring Report) bacteria pose a potential problem for water quality protection and warrant special consideration by the Program (see Pollutant of Concern Assessment below).

Conventionals

Mass Emission station ME-VR2, Receiving Water sties W-3 and W-4, and the agricultural Land Use site A-1 showed total dissolved solids concentrations during wet weather events above Basin Plan objectives. Total dissolved solids was included in the Stormwater Monitoring Program's 2002/03 Pollutant of Concern (POC) Prioritization List, but was not ultimately included in the top-ranked POC list contained in the 2002/-3 Annual Monitoring Report. The Stormwater Monitoring Program will continue to evaluate total dissolved solids at its monitoring sites as a means of augmenting its database and tracking site-specific and seasonal trends in observed Basin Plan exceedances for this water quality parameter.

Metals

All Mass Emission and Receiving Water sites monitoring during wet weather events showed concentrations of total aluminum in excess of Basin Plan water quality objectives. The one Land Use site monitoring this season, A-1, did not show any such exceedance. This is the third year that aluminum has been monitored by the Stormwater Monitoring Program, and the third time that a comparison to

9.6 Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2004/05 monitoring season consisted of the capturing of the first flush storm event in Ventura County on October 16, 2004, followed by the monitoring of two early-season and one mid-season storm. A total of four wet weather events were monitored during the months of October 2004 (Events 1 and 2), December 2004 (Event 3), and January 2005 (Event 4). Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation. The two dry weather events were monitored during the months of May (Event 5) and June (Event 6). Dry weather events are monitored when there has been at least a 72-hour antecedent dry period without measurable rainfall (< 0.01 inches).

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. As mentioned previously, the two dry weather events monitoring in the Ventura River at the new ME-VR2 station were sampled using a portable sampler programmed to collect composite samples on a time-paced basis. Time-paced composite samples were also collected at the Land Use (A-1, I-2, R-1) and Receiving Water (W-3, W-4) sites. Receiving Water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available.

The Santa Clara River (ME-SCR), Ventura River (ME-VR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2, R-1, and ME-VR. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR. The new relocated Ventura River (ME-VR2) Mass Emission station will feature an automated refrigerated sampler, automated data logging, a tipping bucket rain gauge, and electric power supplied by the Ojai Valley Sanitation District once equipment installation is complete. Hard line phone access is still being investigated for this site.

The sampling methods and sample handling procedures used during the 2004/05 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water Guide.* The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD,

Table 9-73: Water Quality Objective Exceedances from the Mass Emission Station ME-CC Observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	10/26/04 Result	12/4/04 Result	1/7/05 Result	L.A. Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Bacteriological	E. Coli (MPN/100 mL)	10000	10000	246	4100	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	16000	16000		1400	400		
Metal	Aluminum – Total	8820	24300	1400	33600	1000		
Metal	Cadmium – Total				8.33	5		4
Metal	Chromium – Total	28.1	39		83.8	50		8
Metal	Copper – Total	29.1	30.4		84.7			12
Metal	Lead – Total	10.9	17.4		24.8			8
Metal	Mercury – Total	0.115			0.147		0.051^	
Metal	Nickel – Total	31.2	37.5		130	100		20
Metal	Zinc – Total	101	96.7		265			80
Organic	Benzo(a)-anthracene				0.0542		0.049^	
Organic	Benzo(a)-pyrene				0.0873		0.049^	
Organic	Benzo(b)-fluoranthene				0.0762		0.049^	
Organic	Benzo(k)-fluoranthene				0.0893		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate			7.92	7.8	4	5.9^	3.5
Organic	Chrysene				0.093		0.049^	
Organic	Indeno(1,2,3-cd)pyrene				0.0619		0.049^	
Organic	PAHs	0.2707	0.0642	0.0491	0.7114			0.0088
Nutrient	Nitrate as N (mg/L)			12.1		10		
Pesticide	4,4'-DDD	0.038			0.0542		0.00084^	
Pesticide	4,4'-DDE	0.127		0.0899			0.00059^	
Pesticide	Aldrin			0.136				0.000022
Pesticide	DDT	0.165		0.131	0.6902			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-74: Water Quality Objective Exceedances from the Mass Emission Station ME-SCR Observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	10/26/04 Result	12/4/04 Result	1/7/05 Result	L.A. Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Bacterio-logical	E. Coli (MPN/100 mL)	10000	10000		1750	235		
Bacterio-logical	Fecal Coliform (MPN/100 mL)	16000	11000		1100	400		
Conven-tional	Total Dissolved Solids (mg/L)			1230		1200		
Metal	Aluminum – Total	8530	15900		69900	1000		
Metal	Cadmium – Total				8.65	5		4
Metal	Chromium – Total	21.1	24.9		125	50		8
Metal	Copper – Total	16.6	27.2		133			12
Metal	Lead – Total		16.3		57.8			8
Metal	Mercury – Total		0.522		0.459		0.051^	0.16
Metal	Nickel – Total	24.8	29.5		185	100		20
Metal	Zinc – Total		82.1		473			80
Organic	Benzo(a)-anthracene				0.0521		0.049^	
Organic	Benzo(b)-fluoranthene				0.06		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate				8.61	4	5.9^	3.5
Organic	Chrysene		0.0609		0.133		0.049^	
Organic	PAHs	0.0242	0.2537		0.4458			0.0088

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-75: Water Quality Objective Exceedances from the Mass Emission Station ME-VR Observed during Wet Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	10/26/04 Result	12/4/04 Result	1/7/05 Result	L.A. Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Anion	Chloride (mg/L)	108	76.1	62.8		60		
Bacteriological	E. Coli (MPN/100 mL)	3000	4100		310	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	5000	9000			400		
Metal	Aluminum – Total		1300		30300	1000		
Metal	Cadmium – Total	4.26			4.3	5		4
Metal	Chromium – Total				55.5	50		8
Metal	Copper – Total				46.8			12
Metal	Lead – Total				26.6			8
Metal	Mercury – Total				0.169		0.051^	0.16
Metal	Nickel – Total				107	100		20
Metal	Zinc – Total	531			208			80
Metal	Zinc – Dissolved	456					316.32	
Organic	Benzo(a)-pyrene				0.0515		0.049^	
Organic	Benzo(b)-fluoranthene				0.156		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate	9.5		22.2	12	4	5.9^	3.5
Organic	Chrysene				0.273		0.049^	
Organic	PAHs		0.04238		1.0789			0.0088
Pesticide	DDT				0.167			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-76: Water Quality Objective Exceedances from the Mass Emission Station ME-CC Observed during Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	5/3/05 Result	6/22/05 Result	L.A. Basin Plan Objtv	CTR FW Chronic Objtv	Ocean Plan 6-Month Median Objtv
Anion	Chloride (mg/L)	390	162	150		
Conventional	Total Dissolved Solids (mg/L)	1140	900	850		
Metal	Cadmium – Dissolved	10.9			6.22	
Metal	Cadmium – Total	11.4		5		1
Metal	Chromium – Total	2.68				2
Metal	Copper – Total	5.47	3.86			3
Metal	Nickel – Total	7.48	6.15			5
Metal	Selenium – Total	5.3	7.67		5	
Nutrient	Nitrate as N (mg/L)	11.3	12.3	10		
Organic	PAHs		0.0132			0.0088

Blank cells denote no exceedance of a water quality objective.

Table 9-77: Water Quality Objective Exceedances from the Mass Emission Station ME-SCR Observed during Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	5/3/05 Result	6/22/05 Result	L.A. Basin Plan Objtv	CTR FW Chronic Objtv	Ocean Plan 6-Month Median Objtv
Anion	Chloride (mg/L)	250		150		
Bacteriological	E. Coli (MPN/100 mL)	410		235		
Metal	Aluminum – Total	1150		1000		
Metal	Chromium – Total	2.38				2
Metal	Copper – Total	3.96				3

Blank cells denote no exceedance of a water quality objective.

Table 9-78: Water Quality Objective Exceedances from the Mass Emission Station ME-VR2 Observed during Dry Weather Monitoring Events

Classification	Constituent (in µg/L except where noted)	5/3/05 Result	6/22/05 Result	L.A. Basin Plan Objtv	CTR FW Chronic Objtv	Ocean Plan 6-Month Median Objtv
Metal	Chromium – Total	2.05	2.71			2
Metal	Copper – Total		4.31			3
Metal	Nickel – Total		8.43			5

Blank cells denote no exceedance of a water quality objective.

Table 9-79: Water Quality Objective Exceedances from the Receiving Water Station W-3

Classification	Constituent (in µg/L except where noted)	10/17/04 Result	L.A. Basin Plan Objtv	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	52000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	30000	400		
Conventional	Total Dissolved Solids (mg/L)	930	500		
Metal	Aluminum – Total	10200	1000		
Metal	Chromium – Total	18.9			8
Metal	Copper - Total	36.4			12
Metal	Lead – Total	12.6			8
Metal	Mercury – Total	0.162		0.051^	0.16
Metal	Nickel – Total	20.4			20
Nutrient	Nitrate as N (mg/L)	11.4	10		
Organic	PAHs	0.0282			0.0088
Pesticide	4,4'-DDE	0.128		0.00059^	
Pesticide	DDT	0.1895			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-80: Water Quality Objective Exceedances from the Receiving Water Station W-4

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	L.A. Basin Plan Objtv	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	20000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	30000	400		
Conventional	Total Dissolved Solids (mg/L)	1500	500		
Metal	Chromium – Total	20.6			8
Metal	Copper - Total	26.7			12
Metal	Lead – Total	11.7			8
Metal	Mercury – Total	0.104		0.051^	
Metal	Nickel – Total	21.7			20
Metal	Zinc – Total	88			80
Nutrient	Nitrate as N (mg/L)	23.4	10		
Organic	Bis(2-ethylhexyl)-phthalate	4.57	4		3.5
Organic	PAHs	0.038			0.0088
Pesticide	4,4'-DDD	0.0337		0.00084^	
Pesticide	4,4'-DDE	0.174		0.00059^	
Pesticide	DDT	0.2958			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

9.10.5 Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land Use discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2004/05 monitoring data from Land Use sites (R-1, I-2, A-1) were compared to the Basin Plan, CTR, and California Ocean Plan objectives previously described. Although the Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters. Table 9-81 through Table 9-83 present water quality objective exceedances at Land Use sites based on an analysis of the 2004/05 wet weather stormwater monitoring data.

Table 9-81: Water Quality Objective Exceedances from the Land Use Station R-1

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	L.A. Basin Plan Objtv	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	31000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	16000	400		
Metal	Aluminum – Total	1860	1000		
Metal	Copper - Total	21.7			12
Metal	Copper - Dissolved	15.2		8.67	
Metal	Zinc – Total	126			80
Organic	Benzo(b)fluoranthene	0.0711		0.049^	
Organic	Benzo(k)fluoranthene	0.0541		0.049^	
Organic	Bis(2-ethylhexyl)-phthalate	5.14	4		3.5
Organic	Chrysene	0.113		0.049^	
Organic	Indeno(1,2,3-cd)pyrene	0.0599		0.049^	
Organic	PAHs	0.6754			0.0088
Pesticide	4,4'-DDE	0.0757		0.00059^	
Pesticide	DDT	0.0757			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-82: Water Quality Objective Exceedances from the Land Use Station I-2

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	L.A. Basin Plan Objtv	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	288000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	400		
Conventional	Total Dissolved Solids (mg/L)	760	500		
Metal	Aluminum – Total	2460	1000		
Metal	Chromium – Total	8.42			8
Metal	Copper - Total	43.5			12
Metal	Zinc – Total	138			80
Organic	Benzo(b)fluoranthene	0.0907		0.049^	
Organic	Benzo(k)fluoranthene	0.0851		0.049^	
Organic	Bis(2-ethylhexyl)-phthalate	13.4	4	5.9^	3.5
Organic	Chrysene	0.103		0.049^	
Organic	PAHs	0.6008			0.0088
Pesticide	4,4'-DDE	0.0819		0.00059^	
Pesticide	DDT	0.0819			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 9-83: Water Quality Objective Exceedances from the Land Use Station A-1

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*L.A. Basin Plan Objtv*	*CTR FW Acute Objective*	*Ocean Plan Daily Max Objective*
Bacteriological	E. Coli (MPN/100 mL)	1000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	1100	400		
Conventional	Total Dissolved Solids (mg/L)	860	500		
Metal	Aluminum – Total	8630	1000		
Metal	Chromium – Total	23.7			8
Metal	Copper - Total	42.1			12
Metal	Lead – Total	10.9			8
Metal	Mercury – Total	0.0621		0.051^	
Metal	Nickel – Total	30.7			20
Metal	Zinc – Total	136			80
Nutrient	Nitrate as N (mg/L)	22.7	10		
Organic	PAHs	0.0678			0.0088
Pesticide	4,4'-DDD	0.0799		0.00084^	
Pesticide	4,4'-DDE	0.546		0.00059^	
Pesticide	DDT	1.3362			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

9.10.6 Potential Problematic Constituents

A review of Table 9-73 through Table 9-83 provides the following observations:

9.10.6.1 Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for E. Coli and Fecal Coliform during wet weather events. Similarly, stormwater runoff from the R-1, I-2, and A-1 Land Use sites exceeded bacteriological objectives for E. Coli and Fecal Coliform. Dry weather concentrations of E. Coli were only greater than Basin Plan objectives during Event 5 at ME-SCR. No other bacteriological water quality objective exceedances were observed during dry events. Consistent with previous efforts by the Ventura Countywide Stormwater Quality Program (presented most recently the 2002/03 Annual Monitoring Report) bacteria pose a potential problem for water quality protection and warrant special efforts by the Program (see Pollutant of Concern Assessment below).

9.10.6.2 Metals

All Mass Emission and Land Use sites, as well as Receiving Water station W-3, showed concentrations of total aluminum in excess of Basin Plan water quality objectives during wet weather events. Dry weather concentrations of total aluminum were only greater than Basin Plan objectives during Event 5 at ME-SCR. This is the second year that aluminum has been monitored by the Stormwater Monitoring Program, and the second time that a comparison to Basin Plan objectives has revealed exceedances for total aluminum. It should be noted that aluminum is found as a ubiquitous natural element in sediments throughout Ventura County geology (Richard Gossett, CRG Marine Laboratories, Inc., personal communication). All Mass Emission stations also recorded concentrations of cadmium, chromium, copper, lead, mercury, nickel, and zinc (all total fractions) above water quality objectives during wet weather monitoring. Dry weather monitoring similarly revealed total chromium and total copper concentrations above Ocean Plan 6-Month Median objectives at all Mass Emission sites during one or more events. Total nickel concentrations exceeded Ocean Plan objectives during one or more dry events at ME-CC and ME-VR2. Additionally, Mass Emission station

4. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during the 2004/05 monitoring season consisted of the capturing of the first flush storm event in Ventura County on October 16, 2004, followed by the monitoring of two early-season and one mid-season storm. A total of four wet weather events were monitored during the months of October 2004 (Events 1 and 2), December 2004 (Event 3), and January 2005 (Event 4). Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain shall occur during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation.

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1, I-2, R-1) and Receiving Water (W-3, W-4) sites. Receiving Water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available.

The Santa Clara River (ME-SCR), Ventura River (ME-VR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2, R-1, and ME-VR. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR..

The sampling methods and sample handling procedures used during the 2004/05 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use and Receiving Water Guide*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission Guide*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388.

At Mass Emission, Receiving Water, and Land Use sites, both composite and grab samples are collected. Composite samples are collected in glass containers and then delivered to the lab where they are split by pouring off with a tipper. When the splitting of a composite sample is performed, the composite sample is continually rocked in a sample-pouring stand to provide as much "non-invasive" mixing as possible. Sample splitting allows homogeneous aliquots of a single large water sample to be divided into several smaller samples for the purpose of delivering these smaller volumes of water to individual analytical laboratories as necessary. The volume of sample collected depends upon the volume required by the lab to perform requested water quality and QA/QC analyses.

In an effort to maintain quality control for the sampling program, the sampling crew, in cooperation with the analytical laboratories, has minimized the number of laboratories and sample bottles used for analysis. This has minimized bottle breakage, increased efficiency, and reduced the chances for contamination of the samples. Also, a dedicated monitoring team is used to provide consistent sample collection and better quality control. All sites now feature automated flow measurement and sample collection that help to streamline the monitoring program and centralize sample collection. Remote access capability at all but two Land Use monitoring sites (I-2 and R-1) also provides data-on-demand which allows immediate onsite evaluation of stream conditions.

For constituents analyzed from samples required to be collected as "grabs", samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak flow. It should be noted that peak flow times vary for each monitoring station due to the size and inherent characteristics of the watershed in which the site is located. All grab and composite wet weather samples collected during the 2004/2005 monitoring season are considered best available estimates of storm EMCs. Table 6 summarizes the samples collected at each of the monitoring locations during the 2004/05 monitoring season's wet weather events.

Table 6: 2004/05 Monitoring Event Summary

(Storm/ Dry) Event Number	*(Storm/ Dry) Event Date*	*A-1 Wood Road*	*I-2 Ortega Street*	*R-1 Swan Street*	*W-3 La Vista Avenue*	*W-4 Revolon Slough*	*ME-CC Calleguas Creek-CSUCI*	*ME-SCR Santa Clara River*	*ME-VR Ventura River-Foster Park*
1	10/16/04	CGT	CGT	CGT	CGT	CGT	CGT	CGT	CGT
2	10/26/04	-	-	-	-	-	CGT	CGT	CGT
3	12/4/04	-	-	-	-	-	CG	CG	CG
4	1/7/05	-	-	-	-	-	CG	CG	CG

Notes:
"G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"T" indicates that toxicity samples were collected.
"-" indicates that no sample was collected.

Figure 14: Grab Sample Collection in the Ventura River using EPA Sampling Protocols

hardness cap of 400 mg/L for calculating the objectives, so any measured hardness value above 400 mg/L was set equal to 400 mg/L for the purposes of the calculation.

The usually large mass loadings calculated for Mass Emission stations ME-CC (see Table 59) and ME-VR (see Table 60) during Event 4 are the result of (1) the extremely large average flows (see Table 5) calculated for these extended runoff events, and (2) the elevated concentration of most constituents (especially total suspended solids, metals, organics, and pesticides) measured in the water quality samples collected at these sites. The elevated constituent concentrations were likely produced by the flushing of watersheds and the scouring of streambeds and adjacent riparian habitat that occurred as a result of the prolonged runoff and high flows observed during Event 4. The net result of these flushing and scouring effects can be seen in the increased number of water quality objective exceedances observed during Event 4 at the Mass Emission sites as compared to the exceedances reported during Events 1–3 at these stations. Table 61 through Table 65 present water quality objective exceedances at Mass Emission and Receiving Water sites based on an analysis of the 2004/05 wet weather stormwater monitoring data.

Table 61: Water Quality Objective Exceedances at Mass Emission Site ME-CC

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*10/26/04 Result*	*12/4/04 Result*	*1/7/05 Result*	*Basin Plan Objtv*	*CTR FW Acute Objtv*	*Ocean Plan Daily Max Objtv*
Bacteriological	E. Coli (MPN/100 mL)	10000	10000	246	4100	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	16000	16000		1400	400		
Metal	Aluminum – Total	8820	24300	1400	33600	1000		
Metal	Cadmium – Total				8.33	5		4
Metal	Chromium – Total	28.1	39		83.8	50		8
Metal	Copper – Total	29.1	30.4		84.7			12
Metal	Lead – Total	10.9	17.4		24.8			8
Metal	Mercury – Total	0.115			0.147		0.051^	
Metal	Nickel – Total	31.2	37.5		130	100		20
Metal	Zinc – Total	101	96.7		265			80
Organic	Benzo(a)-anthracene				0.0542		0.049^	
Organic	Benzo(a)-pyrene				0.0873		0.049^	
Organic	Benzo(b)-fluoranthene				0.0762		0.049^	
Organic	Benzo(k)-fluoranthene				0.0893		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate			7.92	7.8	4	5.9^	3.5
Organic	Chrysene				0.093		0.049^	
Organic	Indeno(1,2,3-cd)pyrene				0.0619		0.049^	
Organic	PAHs	0.2707	0.0642	0.0491	0.7114			0.0088
Nutrient	Nitrate as N (mg/L)			12.1		10		
Pesticide	4,4'-DDD	0.038			0.0542		0.00084^	
Pesticide	4,4'-DDE	0.127		0.0899			0.00059^	
Pesticide	Aldrin			0.136				0.000022
Pesticide	DDT	0.165		0.131	0.6902			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 62: Water Quality Objective Exceedances at Mass Emission Site ME-SCR

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	10/26/04 Result	12/4/04 Result	1/7/05 Result	Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Bacteriological	E. Coli (MPN/100 mL)	10000	10000		1750	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	16000	11000		1100	400		
Conventional	Total Dissolved Solids (mg/L)			1230		1200		
Metal	Aluminum – Total	8530	15900		69900	1000		
Metal	Cadmium – Total				8.65	5		4
Metal	Chromium – Total	21.1	24.9		125	50		8
Metal	Copper – Total	16.6	27.2		133			12
Metal	Lead – Total		16.3		57.8			8
Metal	Mercury – Total		0.522		0.459		0.051^	0.16
Metal	Nickel – Total	24.8	29.5		185	100		20
Metal	Zinc – Total		82.1		473			80
Organic	Benzo(a)-anthracene				0.0521		0.049^	
Organic	Benzo(b)-fluoranthene				0.06		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate				8.61	4	5.9^	3.5
Organic	Chrysene		0.0609		0.133		0.049^	
Organic	PAHs	0.0242	0.2537		0.4458			0.0088

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 63: Water Quality Objective Exceedances at Mass Emission Site ME-VR

Classification	Constituent (in µg/L except where noted)	10/16/04 Result	10/26/04 Result	12/4/04 Result	1/7/05 Result	Basin Plan Objtv	CTR FW Acute Objtv	Ocean Plan Daily Max Objtv
Anion	Chloride (mg/L)	108	76.1	62.8		60		
Bacteriological	E. Coli (MPN/100 mL)	3000	4100		310	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	5000	9000			400		
Metal	Aluminum – Total		1300		30300	1000		
Metal	Cadmium – Total	4.26			4.3	5		4
Metal	Chromium – Total				55.5	50		8
Metal	Copper – Total				46.8			12
Metal	Lead – Total				26.6			8
Metal	Mercury – Total				0.169		0.051^	0.16
Metal	Nickel – Total				107	100		20
Metal	Zinc – Total	231			208			80
Metal	Zinc – Dissolved	456					316.32	
Organic	Benzo(a)-pyrene				0.0515		0.049^	
Organic	Benzo(b)-fluoranthene				0.156		0.049^	
Organic	Bis(2-ethyl-hexyl)phthalate	9.5		22.2	12	4	5.9^	3.5
Organic	Chrysene				0.273		0.049^	
Organic	PAHs		0.04238		1.0789			0.0088
Pesticide	DDT				0.167			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 64: Water Quality Objective Exceedances for Receiving Water Site W-3

Classification	Constituent (in µg/L except where noted)	10/17/04 Result	Basin Plan Objective	CTR FW Acute Objective	Ocean Plan Daily Max Objective
Bacteriological	E. Coli (MPN/100 mL)	52000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	30000	400		
Conventional	Total Dissolved Solids (mg/L)	930	500		
Metal	Aluminum – Total	10200	1000		
Metal	Chromium – Total	18.9			8
Metal	Copper - Total	36.4			12
Metal	Lead – Total	12.6			8
Metal	Mercury – Total	0.162		0.051^	0.16
Metal	Nickel – Total	20.4			20
Nutrient	Nitrate as N (mg/L)	11.4	10		
Organic	PAHs	0.0282			0.0088
Pesticide	4,4'-DDE	0.128		0.00059^	
Pesticide	DDT	0.1895			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 65: Water Quality Objective Exceedances for Receiving Water Site W-4

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*Basin Plan Objective*	*CTR FW Acute Objective*	*Ocean Plan Daily Max Objective*
Bacteriological	E. Coli (MPN/100 mL)	20000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	30000	400		
Conventional	Total Dissolved Solids (mg/L)	1500	500		
Metal	Chromium – Total	20.6			8
Metal	Copper - Total	26.7			12
Metal	Lead – Total	11.7			8
Metal	Mercury – Total	0.104		0.051^	
Metal	Nickel – Total	21.7			20
Metal	Zinc – Total	88			80
Nutrient	Nitrate as N (mg/L)	23.4	10		
Organic	Bis(2-ethylhexyl)-phthalate	4.57	4		3.5
Organic	PAHs	0.038			0.0088
Pesticide	4,4'-DDD	0.0337		0.00084^	
Pesticide	4,4'-DDE	0.174		0.00059^	
Pesticide	DDT	0.2958			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land Use discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2004/05 monitoring data from Land Use sites (R-1, I-2, A-1) were compared to the Basin Plan, California Toxics Rule, and California Ocean Plan objectives previously described. Although the Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters. Table 66 through Table 68 present water quality objective exceedances at Land Use sites based on an analysis of the 2004/05 wet weather stormwater monitoring data.

Table 66: Water Quality Objective Exceedances at Land Use Site R-1

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*Basin Plan Objective*	*CTR FW Acute Objective*	*Ocean Plan Daily Max Objective*
Bacteriological	E. Coli (MPN/100 mL)	31000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	16000	400		
Metal	Aluminum – Total	1860	1000		
Metal	Copper - Total	21.7			12
Metal	Copper - Dissolved	15.2		8.67	
Metal	Zinc – Total	126			80
Organic	Benzo(b)fluoranthene	0.0711		0.049^	
Organic	Benzo(k)fluoranthene	0.0541		0.049^	
Organic	Bis(2-ethylhexyl)-phthalate	5.14	4		3.5
Organic	Chrysene	0.113		0.049^	
Organic	Indeno(1,2,3-cd)pyrene	0.0599		0.049^	
Organic	PAHs	0.6754			0.0088
Pesticide	4,4'-DDE	0.0757		0.00059^	
Pesticide	DDT	0.0757			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 67: Water Quality Objective Exceedances at Land Use Site I-2

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*Basin Plan Objective*	*CTR FW Acute Objective*	*Ocean Plan Daily Max Objective*
Bacteriological	E. Coli (MPN/100 mL)	288000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	50000	400		
Conventional	Total Dissolved Solids (mg/L)	760	500		
Metal	Aluminum – Total	2460	1000		
Metal	Chromium – Total	8.42			8
Metal	Copper - Total	43.5			12
Metal	Zinc – Total	138			80
Organic	Benzo(b)fluoranthene	0.0907		0.049^	
Organic	Benzo(k)fluoranthene	0.0851		0.049^	
Organic	Bis(2-ethylhexyl)-phthalate	13.4	4	5.9^	3.5
Organic	Chrysene	0.103		0.049^	
Organic	PAHs	0.6008			0.0088
Pesticide	4,4'-DDE	0.0819		0.00059^	
Pesticide	DDT	0.0819			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Table 68: Water Quality Objective Exceedances at Land Use Site A-1

Classification	*Constituent (in µg/L except where noted)*	*10/16/04 Result*	*Basin Plan Objective*	*CTR FW Acute Objective*	*Ocean Plan Daily Max Objective*
Bacteriological	E. Coli (MPN/100 mL)	1000	235		
Bacteriological	Fecal Coliform (MPN/100 mL)	1100	400		
Conventional	Total Dissolved Solids (mg/L)	860	500		
Metal	Aluminum – Total	8630	1000		
Metal	Chromium – Total	23.7			8
Metal	Copper - Total	42.1			12
Metal	Lead – Total	10.9			8
Metal	Mercury – Total	0.0621		0.051^	
Metal	Nickel – Total	30.7			20
Metal	Zinc – Total	136			80
Nutrient	Nitrate as N (mg/L)	22.7	10		
Organic	PAHs	0.0678			0.0088
Pesticide	4,4'-DDD	0.0799		0.00084^	
Pesticide	4,4'-DDE	0.546		0.00059^	
Pesticide	DDT	1.3362			0.00017

Blank cells denote no exceedance of a water quality objective.
"^" – CTR Human Health objective for consumption of organisms only.

Potential Problematic Constituents

A review of Table 61 through Table 68 provides the following observations:

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for E. Coli and Fecal Coliform. Likewise, runoff from the R-1, I-2, and A-1 Land Use sites

9.5 Sample Collection

Sampling conducted by the Stormwater Monitoring Program during previous years has consisted of a first-flush/early-season storm and other mid-season or late-season storms. This year only mid-season storm events were captured since the first storms of the monitoring season occurred during the Stormwater Monitoring Program's "blackout" dates, the Thanksgiving and Christmas holidays. Additionally, little precipitation has fallen during the 2003/04 monitoring season, and thus produced few wet weather events suitable for monitoring. A total of three wet weather events were monitored during the month of February 2004: February 2-3 (**Event 1**), February 18-19 (**Event 2**), and February 25-27 (**Event 3**). Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain occurs during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation. The three dry weather events were monitored on April 13-15 (**Event 4**), May 27-28 (**Event 5**), and June 14-15 (**Event 6**). Dry weather events are monitored when there has been at least 72 hours since the last measurable rainfall (0.01 inches).

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station during wet weather monitoring. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on 60 years of historic precipitation data used to develop runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis during wet weather monitoring because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1, I-2, R-1) and Receiving Water (W-3, W-4) sites. Receiving water site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. All water quality samples collected during 2003/04 dry weather monitoring at the Mass Emission stations were collected as time-paced composites.

The Santa Clara River (ME-SCR), Ventura River (ME-VR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2, R-1, and ME-VR. Additionally, all sites except for I-2 and R-1 can be exist, the CTR Human Health (Organisms Only) objectives were used in the dry weather comparison. The CTR Human Health (Organisms Only) objective was included here because these constituents have no other objectives for comparison. These objectives are used even though they are based on long-term risks to human health that cannot be directly correlated to stormwater discharges or periodic "snapshots" of baseline dry weather conditions.

Objectives in the CTR for metals are calculated based on the hardness of the water. This analysis used the hardness value measured at a particular site during a particular monitoring event for calculating a certain metals objective, except when the measured hardness was greater than 400 mg/L. The CTR sets a hardness cap of 400 mg/L for calculating metals objectives, so any measured hardness value above 400 mg/L was set equal to 400 mg/L for the purposes of the calculation. Table 9–70 through Table 9–77 (shown on pages 9-125 through 9-128) present water quality objective exceedances at Mass Emission and Receiving Water sites based on an analysis of the 2003/04 monitoring data. Table 9–73 through Table 9–75 (shown on page 9-127) specifically show water quality objectives exceedances observed at Mass Emission sites during dry weather monitoring events.

Table 9–70: Water Quality Objective Exceedances at Mass Emission Station ME-CC Observed during Wet Weather Monitoring Events 2003/2004

Classification	Constituent	Units	2/2/04 Result	2/18/04 Result	2/25/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	20000		10000	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	9000		50000	400	
Metal	Aluminum - Total	µg/L		3450	55500	1000	
Metal	Barium - Total	µg/L	1290		1990	1000	
Metal	Beryllium - Total	µg/L	4.44		5.31	4	
Metal	Cadmium - Total	µg/L	27.3		52.6	5	
Metal	Chromium - Total	µg/L	169		232	50	
Metal	Mercury - Total	µg/L	0.263		0.435		0.051^
Metal	Nickel - Total	µg/L	324		513	100	
Pesticide	4,4'-DDE	µg/L	0.0443	0.0592	0.126		0.00059^
Organic	Chrysene	µg/L			0.0535		0.049^

Blank cells denote no exceedance of a water quality objective.
^ CTR Human Health objective for consumption of organisms only.

Table 9-71: Water Quality Objective Exceedances at Mass Emission Station ME-SCR Observed during Wet Weather Monitoring Events

Classification	Constituent	Units	2/2/04 Result	*	2/25/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	10000		6300	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	2800		7000	400	
Metal	Aluminum - Total	µg/L	2450		17200	1000	
Metal	Arsenic - Total	µg/L	84.7			50	
Metal	Barium - Total	µg/L	1400			1000	
Metal	Cadmium - Total	µg/L	101		6.74	5	
Metal	Mercury - Total	µg/L	0.631		0.365		0.051^
Metal	Nickel - Total	µg/L	173			100	
Metal	Selenium - Total	µg/L	154			50	
Organic	Benzo(a)anthracene	µg/L	0.254				0.049^
Organic	Benzo(a)pyrene	µg/L	0.238			0.2	0.049^
Organic	Benzo(b)fluoranthene	µg/L	0.822				0.049^
Organic	Benzo(k)fluoranthene	µg/L	0.739				0.049^
Organic	Bis(2-ethylhexyl)phthalate	µg/L	9.88			4	5.9^
Organic	Chrysene	µg/L	0.737				0.049^
Organic	Indeno(1,2,3-cd)pyrene	µg/L	0.207				0.049^
Pesticide	4,4'-DDE	µg/L	0.153				0.00059^

Blank cells denote no exceedance of a water quality objective.
*No Basin Plan or CTR exceedances were observed for the second monitoring event (2/18/04) conducted at this site.
^CTR Human Health objective for consumption of organisms only.

Table 9-72: Water Quality Objective Exceedances at Mass Emission Station ME-VR Observed during Wet Weather Monitoring Events

Classification	Constituent	Units	2/2/04 Result	*	2/25/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	2000		1430	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	1600		1700	400	
Metal	Aluminum - Total	µg/L	2300		3970	1000	
Organic	Bis(2-ethylhexyl)phthalate	µg/L			20.7	4	5.9^

Blank cells denote no exceedance of a water quality objective.
*No Basin Plan or CTR exceedances were observed for the second monitoring event (2/18/04) conducted at this site.
^CTR Human Health objective for consumption of organisms only.

Table 9-73: Water Quality Objective Exceedances at Mass Emission Station ME-CC Observed during Dry Weather Monitoring Events

Classification	Constituent	Units	4/13/04 Result	5/27/04 Result	6/14/04 Result	Basin Plan Objective	CTR Objective
Anion	Chloride	mg/L	152	169		150	
Bacteriological	E. Coli	MPN/ 100 mL	1000	980	860	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	500		1100	400	
Conventional	Total Dissolved Solids	mg/L		950	910	850	
Organic	Bis(2-ethylhexyl)-phthalate	µg/L	4.65		5.45	4	
Pesticide	4,4'-DDE	µg/L			0.0085		0.00059^

Blank cells denote no exceedance of a water quality objective.
^ CTR Human Health objective for consumption of organisms only.

Table 9-74: Water Quality Objective Exceedances at Mass Emission Station ME-SCR Observed during Dry Weather Monitoring Events

Classification	Constituent	Units	4/13/04 Result	5/27/04 Result	6/14/04 Result	Basin Plan Objective	CTR Objective
Conventional	Total Dissolved Solids	mg/L		1430	1440	1200	
Metal	Selenium – Total	µg/L	10.1	10.5	8.21		5**
Organic	Bis(2-ethylhexyl)-phthalate	µg/L	5.87			4	

Blank cells denote no exceedance of a water quality objective.
**CTR Chronic Freshwater objective.

Table 9-75: Water Quality Objective Exceedances at Mass Emission Station ME-VR Observed during Dry Weather Monitoring Events

Classification	Constituent	Units	4/13/04 Result	5/27/04 Result	6/14/04 Result	Basin Plan Objective	CTR Objective
Anion	Chloride	mg/L		71.8		60	
Metal	Selenium – Total	µg/L	6.6				5**
Organic	Bis(2-ethylhexyl)-phthalate	µg/L	11		9.57	4	5.9^

Blank cells denote no exceedance of a water quality objective.
**CTR Chronic Freshwater objective.
^ CTR Human Health objective for consumption of organisms only.

Table 9-76: Water Quality Objective Exceedances for Receiving Water Site W-3 (WET) 2003/04

Classification	Constituent	Units	2/2/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	630	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	460	400	
Metal	Chromium - Total	µg/L	87.2	50	
Metal	Copper - Dissolved	µg/L	29.1		14.96*
Metal	Mercury - Total	µg/L	0.477		0.051^
Nutrient	Nitrite as N	mg/L	1.06	1	
Pesticide	4,4'-DDD	µg/L	0.0489		0.00084^
Pesticide	4,4'-DDE	µg/L	0.348		0.00059^

Blank cells denote no exceedance of a water quality objective
* CTR Acute Freshwater objective.
^ CTR Human Health objective for consumption of organisms only.

Table 9-77: Water Quality Objective Exceedances for Receiving Water Site W-4 (WET) 2003/04

Classification	Constituent	Units	2/2/04 Result	Basin Plan Objective	CTR Objective
Conventional	Residual Chlorine	µg/L	130	100	
Metal	Aluminum - Total	µg/L	17700	1000	
Nutrient	Nitrite as N	mg/L	6.14	1	
Pesticide	4,4'-DDD	µg/L	0.0266		0.00084^
Pesticide	4,4'-DDE	µg/L	0.181		0.00059^

Blank cells denote no exceedance of a water quality objective
^ CTR Human Health objective for consumption of organisms only.

9.9.5 Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land Use discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2003/04 wet weather monitoring data from Land Use sites were compared to the Basin Plan and California Toxics Rule objectives previously described. Although the Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban, industrial, and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters. Table 9-

78 through Table 9–80 (shown on pages 9-129 and 9-130) present water quality objective exceedances at Land Use sites based on an analysis of the 2003/04 wet weather stormwater monitoring data.

Table 9–78: Water Quality Objective Exceedances at Land Use Site R-1 (WEST)

Classification	Constituent	Units	2/2/04 Result	2/18/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	4100	1000	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	3000	500	400	
Conventional	pH (result < 6.5)	pH Units	6.11	6.35	6.5	
Metal	Aluminum - Total	µg/L	2620	1440	1000	
Metal	Copper - Dissolved	µg/L	10.9^A	11.1^B		6.74^A, 5.21^B*
Metal	Zinc - Dissolved	µg/L		70.9		49.99
Organic	Benzo(a)-anthracene	µg/L	0.0777	0.315		0.049^
Organic	Benzo(a)pyrene	µg/L	0.0815	0.392	0.2	0.049^
Organic	Benzo(b)-fluoranthene	µg/L	0.111	0.366		0.049^
Organic	Benzo(k)-fluoranthene	µg/L	0.109	0.336		0.049^
Organic	Chrysene	µg/L	0.172	0.415		0.049^
Organic	Dibenz(a,h)-anthracene	µg/L		0.0956		0.049^
Organic	Indeno(1,2,3-cd) pyrene	µg/L	0.0829	0.56		0.049^
Pesticide	4,4'-DDE	µg/L	0.0312	0.0275		0.00059^

Blank cells denote no exceedance of a water quality objective.
*CTR Acute Freshwater objective.
^CTR Human Health objective for consumption of organisms only.
A. CTR objective calculated when measured Total Hardness = 48.1 mg/L.
B. CTR objective calculated when measured Total Hardness = 36.6 mg/L.

Table 9–79: Water Quality Objective Exceedances at Land Use Site I-2

Classification	Constituent	Units	2/2/04 Result	2/18/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	8400	1730	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	8000	1100	400	
Conventional	pH (result < 6.5)	pH Units	6.46	6.44	6.5	
Metal	Aluminum - Total	µg/L	1630	1650	1000	
Metal	Mercury - Total	µg/L		0.0629		0.051^
Metal	Selenium - Total	µg/L	253		50	
Organic	Benzo(a) anthracene	µg/L	0.0532	0.208		0.049^
Organic	Benzo(a)pyrene	µg/L	0.082	0.403		0.049^
Organic	Benzo(b) fluoranthene	µg/L	0.158	0.576		0.049^
Organic	Benzo(k) fluoranthene	µg/L	0.136	0.425		0.049^
Organic	Chrysene	µg/L	0.186	0.412		0.049^
Organic	Dibenz(a,h) anthracene	µg/L		0.155		0.049^
Organic	Indeno(1,2,3-cd) pyrene	µg/L	0.115	0.784		0.049^
Pesticide	4,4'-DDE	µg/L	0.0241	0.0308		0.00059^

Blank cells denote no exceedance of a water quality objective.
^CTR Human Health objective for consumption of organisms only.

Table 9–80: Water Quality Objective Exceedances at Land Use Site A-1

Classification	Constituent	Units	2/2/04 Result	Basin Plan Objective	CTR Objective
Metal	Aluminum –Total	µg/L	11980	1000	
Nutrient	Nitrate as N	mg/L	12	10	
Organic	Hexachlorobenzene	µg/L	0.0043		0.00077^
Organic	Pentachlorophenol	µg/L	1.22	1	
Pesticide	4,4'-DDD	µg/L	0.0776		0.00084^
Pesticide	4,4'-DDE	µg/L	0.433		0.00059^

Blank cells denote no exceedance of a water quality objective.
^ CTR Human Health objective for consumption of organisms only.

4. Sample Collection

Sampling conducted by the Stormwater Monitoring Program during previous years has consisted of a first-flush/early-season storm and other mid-season or late-season storms. This year only mid-season storm events were captured since the first storms of the monitoring season occurred during the Stormwater Monitoring Program's "blackout" dates, the Thanksgiving and Christmas holidays. Additionally, little precipitation has fallen during the 2003/04 monitoring season, and thus produced few wet weather events suitable for monitoring. A total of three wet weather events were monitored during the month of February 2004: February 2-3, February 18-19, and February 25-27. Storm event sampling criteria contained in the NPDES permit specify that not more than 0.1 inch of rain occurs during the 72 hours preceding a monitored event. Storms are selected for monitoring based on the antecedent conditions (72-hour dry period), fulfillment of the dry period, and predicted precipitation.

At the Calleguas Creek (ME-CC) and Ventura River (ME-VR) sites automated composite samplers are programmed to collect flow-proportional samples based on water volume passing by the station. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific period of time and the estimated volume of runoff from the watershed. These values are based on historic precipitation and runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a time-paced basis because flow-proportional compositing is not possible due to the diversion of Santa Clara River water by the United Water Conservation District. The Stormwater Monitoring Program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather, as well as a flow meter on top of the Freeman Diversion Dam to measure flow during wet weather. Time-paced composite samples were collected at the Land Use (A-1, I-2, R-1) and Receiving Water (W-3, W-4) sites.
Site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. The Santa Clara River (ME-SCR), Ventura River (ME-VR), Wood Road (A-1), and both Receiving Water (La Vista, W-3, and Revolon Slough, W-4) monitoring sites have hard line phone and electrical connections and refrigerated sampling units. The Calleguas Creek (ME-CC) station possesses a cellular phone connection and runs on solar/battery power. The Ortega Street (I-2) and Swan Street (R-1) Land Use sites do not possess phone or power connections, and utilize portable refrigerated samplers for sample collection. Automated data logging is available at all sites, while tipping bucket rain gauges are installed at all sites except for I-2, R-1, and ME-VR. Additionally, all sites except for I-2 and R-1 can be remotely accessed via telemetry, including the area velocity flow meter installed in the infiltration channel at ME-SCR.

The sampling methods and sample handling procedures used during the 2003/04 monitoring year are based on EPA Method 1669 and are described in the revised *Ventura Countywide Stormwater Monitoring Program: Water Quality Monitoring Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) – a document also referred to as the *Land Use an Receiving Water Guide*. The sampling methods and sample handling procedures employed at Mass Emission monitoring sites are also based on EPA Method 1669 and are described in *Ventura Countywide Stormwater Monitoring Program: Mass Emission Stations Water Quality Monitoring Standard Operating Procedures 2000-2005* (VCWPD, 2003) – a document also referred to as the *Mass Emission Guide*. The parameters required to be monitored by the Stormwater Monitoring Program are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388.

At Mass Emission, Receiving Water, and Land Use sites, both composite and grab samples are collected. Composite samples are collected in 20-liter containers and then delivered to the lab where they are split by pouring off with a tipper. When the splitting of a composite sample is performed, the composite sample is continually rocked in a sample-pouring stand to provide as much "non-invasive" mixing as possible. Sample splitting allows homogeneous aliquots of a single large water sample to be divided into several smaller samples for the purpose of delivering these smaller volumes of water to individual analytical laboratories as necessary. The volume of sample collected depends upon the volume required by the lab to perform requested QA/QC analyses.

In an effort to maintain quality control for the sampling program. the sampling crew, in cooperation with the analytical laboratories, has minimized the number of laboratories and sample bottles used for analysis. This has minimized bottle breakage, increased efficiency, and reduced the chances for contamination of the samples. Also, a dedicated monitoring team is used to provide consistent sample collection and better quality control. All sites now feature automated flow measurement and sample collection that help to streamline the monitoring program and centralize sample collection. Remote access capability at all but two Land Use monitoring sites (I-2 and R-1) also provides data-on-demand which allows immediate onsite evaluation of stream conditions.

For constituents analyzed from samples required to be collected as "grabs", samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak flow. It should be noted that peak flow times vary for each monitoring station due to the size and inherent characteristics of the watershed in which the site is located. All grab and composite wet weather samples collected during the 2003/2004 monitoring season are considered best available estimates of storm EMCs.

The following table summarizes the samples collected at each of the monitoring locations during the 2003/04 monitoring season.

Table 6: 2003/04 Monitoring Event Summary

(Storm/ Dry) Event Number	*(Storm/ Dry) Event Date*	*A-1 Wood Road*	*I-2 Ortega Street*	*R-1 Swan Street*	*W-3 La Vista Avenue*	*W-4 Revolon Slough*	*ME-CC Calleguas Creek-CSUCI*	*ME-SCR Santa Clara River*	*ME-VR Ventura River-Foster Park*
1	2/2/04	CGT	CGT	CGT	CGT	CGT	CGT	CGT	CGT
2	2/18/04	-	CGT	CGT	-	-	CGT	CGT	CGT
3	2/25/04	-	-	-	-	-	CGT	CGT	CGT

Notes:
"G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"T" indicates that toxicity samples were collected.
"-" indicates that no sample was collected.

Figure 14: Grab Sample Collection in the Ventura River using EPA Sampling Protocols

A009440

Table 61: Water Quality Objective Exceedances at Mass Emission Site ME-CC

Classification	Constituent	Units	*2/2/04 Result*	*2/18/04 Result*	*2/25/04 Result*	*Basin Plan Objective*	*CTR Objective*
Bacteriological	E. Coli	MPN/ 100 mL	20000		10000	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	9000		50000	400	
Metal	Aluminum - Total	µg/L		3450	55500	1000	
Metal	Barium - Total	µg/L	1290		1990	1000	
Metal	Beryllium - Total	µg/L	4.44		5.31	4	
Metal	Cadmium - Total	µg/L	27.3		52.6	5	
Metal	Chromium - Total	µg/L	169		232	50	
Metal	Mercury - Total	µg/L	0.263		0.435		0.051^
Metal	Nickel - Total	µg/L	324		513	100	
Pesticide	4,4'-DDE	µg/L	0.0443	0.0592			0.00059^
Organic	Chrysene	µg/L			0.0535		0.049^

Blank cells denote no exceedance of a water quality objective
^ CTR Human Health objective for consumption of organisms only.

Table 62: Water Quality Objective Exceedances at Mass Emission Site ME-SCR

Classification	Constituent	Units	*2/2/04 Result*	*	*2/25/04 Result*	*Basin Plan Objective*	*CTR Objective*
Bacteriological	E. Coli	MPN/ 100 mL	10000		6300	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	2800		7000	400	
Metal	Aluminum - Total	µg/L	2450		17200	1000	
Metal	Arsenic - Total	µg/L	84.7			50	
Metal	Barium - Total	µg/L	1400			1000	
Metal	Cadmium - Total	µg/L	101		6.74	5	
Metal	Mercury - Total	µg/L	0.631		0.365		0.051^
Metal	Nickel - Total	µg/L	173			100	
Metal	Selenium - Total	µg/L	154			50	
Organic	Benzo(a)anthracene	µg/L	0.254				0.049^
Organic	Benzo(a)pyrene	µg/L	0.238			0.2	0.049^
Organic	Benzo(b)fluoranthene	µg/L	0.822				0.049^
Organic	Benzo(k)fluoranthene	µg/L	0.739				0.049^
Organic	Bis(2-ethylhexyl)phthalate	µg/L	9.88			4	5.9^
Organic	Chrysene	µg/L	0.737				0.049^
Organic	Indeno(1,2,3-cd)pyrene	µg/L	0.207				0.049^
Pesticide	4,4'-DDE	µg/L	0.153				0.00059^

Blank cells denote no exceedance of a water quality objective
*No Basin Plan or CTR exceedances were observed for the second monitoring event conducted at this site (i.e., 2003/04-2)
^CTR Human Health objective for consumption of organisms only.

Table 63: Water Quality Objective Exceedances at Mass Emission Site ME-SCR

Classification	Constituent	Units	2/2/04 Result	*	2/25/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	2000		1430	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	1600		1700	400	
Metal	Aluminum - Total	µg/L	2300		3970	1000	
Organic	Bis(2-ethylhexyl)phthalate	µg/L			20.7	4	5.9^

Blank cells denote no exceedance of a water quality objective
*No Basin Plan or CTR exceedances were observed for the second monitoring event conducted at this site (i.e., 2003/04-2)
^CTR Human Health objective for consumption of organisms only.

Table 64: Water Quality Objective Exceedances for Receiving Water Site W-3

Classification	Constituent	Units	2/2/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	630	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	460	400	
Metal	Chromium - Total	µg/L	87.2	50	
Metal	Copper - Dissolved	µg/L	29.1		14.96*
Metal	Mercury - Total	µg/L	0.477		0.051^
Nutrient	Nitrite as N	mg/L	1.06	1	
Pesticide	4,4'-DDD	µg/L	0.0489		0.00084^
Pesticide	4,4'-DDE	µg/L	0.348		0.00059^

Blank cells denote no exceedance of a water quality objective
* CTR Acute Freshwater objective.
^ CTR Human Health objective for consumption of organisms only.

Table 65: Water Quality Objective Exceedances for Receiving Water Site W-4

Classification	Constituent	Units	2/2/04 Result	Basin Plan Objective	CTR Objective
Conventional	Residual Chlorine	µg/L	130	100	
Metal	Aluminum - Total	µg/L	17700	1000	
Nutrient	Nitrite as N	mg/L	6.14	1	
Pesticide	4,4'-DDD	µg/L	0.0266		0.00084^
Pesticide	4,4'-DDE	µg/L	0.181		0.00059^

Blank cells denote no exceedance of a water quality objective
^ CTR Human Health objective for consumption of organisms only.

Land Use Discharge Analysis

In order to assess whether or not discharges from the stormwater system are contributing to the exceedances of objectives identified in the receiving waters, Land Use discharge data were analyzed in the same manner as the Mass Emission and Receiving Water data.

The 2003/04 monitoring data were compared to the Basin Plan and California Toxics Rule objectives previously described. The following tables provide comparisons for sites R-1, I-2, and A-1. Although the Land Use stations are not always located in each of the watersheds for which Receiving Water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the Land Use objective exceedances are compared to the receiving water objectives exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the Stormwater Monitoring Program to determine whether certain land use types may be contributing to the objectives exceedances in receiving waters. Tables 66 through 68 present water quality objective exceedances at Land Use sites based on an analysis of the 2003/04 wet weather stormwater monitoring data.

Table 66: Water Quality Objective Exceedances at Land Use Site R-1

Classification	Constituent	Units	2/2/04 Result	2/18/04 Result	Basin Plan Objective	CTR Objective
Bacteriological	E. Coli	MPN/ 100 mL	4100	1000	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	3000	500	400	
Conventional	pH (result < 6.5)	pH Units	6.11	6.35	6.5	
Metal	Aluminum - Total	µg/L	2620	1440	1000	
Metal	Copper - Dissolved	µg/L	10.9[A]	11.1[B]		6.74[A], 5.21[B]*
Metal	Zinc - Dissolved	µg/L		70.9		49.99
Organic	Benzo(a)-anthracene	µg/L	0.0777	0.315		0.049^
Organic	Benzo(a)pyrene	µg/L	0.0815	0.392	0.2	0.049^
Organic	Benzo(b)-fluoranthene	µg/L	0.111	0.366		0.049^
Organic	Benzo(k)-fluoranthene	µg/L	0.109	0.336		0.049^
Organic	Chrysene	µg/L	0.172	0.415		0.049^
Organic	Dibenz(a,h)-anthracene	µg/L		0.0956		0.049^
Organic	Indeno(1,2,3-cd) pyrene	µg/L	0.0829	0.56		0.049^
Pesticide	4,4'-DDE	µg/L	0.0312	0.0275		0.00059^

Blank cells denote no exceedance of a water quality objective.
*CTR Acute Freshwater objective.
^CTR Human Health objective for consumption of organisms only.

Table 67: Water Quality Objective Exceedances at Land Use Site I-2

Classification	*Constituent*	*Units*	*2/2/04 Result*	*2/18/04 Result*	*Basin Plan Objective*	*CTR Objective*
Bacteriological	E. Coli	MPN/ 100 mL	8400	1730	235	
Bacteriological	Fecal Coliform	MPN/ 100 mL	8000	1100	400	
Conventional	pH (result < 6.5)	pH Units	6.46	6.44	6.5	
Metal	Aluminum - Total	µg/L	1630	1650	1000	
Metal	Mercury - Total	µg/L		0.0629		0.051^
Metal	Selenium - Total	µg/L	253		50	
Organic	Benzo(a) anthracene	µg/L	0.0532	0.208		0.049^
Organic	Benzo(a)pyrene	µg/L	0.082	0.403		0.049^
Organic	Benzo(b) fluoranthene	µg/L	0.158	0.576		0.049^
Organic	Benzo(k) fluoranthene	µg/L	0.136	0.425		0.049^
Organic	Chrysene	µg/L	0.186	0.412		0.049^
Organic	Dibenz(a,h) anthracene	µg/L		0.155		0.049^
Organic	Indeno(1,2,3-cd) pyrene	µg/L	0.115	0.784		0.049^
Pesticide	4,4'-DDE	µg/L	0.0241	0.0308		0.00059^

Blank cells denote no exceedance of a water quality objective.
^CTR Human Health objective for consumption of organisms only.

Table 68: Water Quality Objective Exceedances at Land Use Site A-1

Classification	*Constituent*	*Units*	*2/2/04 Result*	*Basin Plan Objective*	*CTR Objective*
Metal	Aluminum -Total	µg/L	11980	1000	
Nutrient	Nitrate as N	mg/L	12	10	
Organic	Hexachlorobenzene	µg/L	0.0043		0.00077^
Organic	Pentachlorophenol	µg/L	1.22	1	
Pesticide	4,4'-DDD	µg/L	0.0776		0.00084^
Pesticide	4,4'-DDE	µg/L	0.433		0.00059^

Blank cells denote no exceedance of a water quality objective.
^ CTR Human Health objective for consumption of organisms only.

Potential Problematic Constituents

A review of Tables 61 through 68 provides the following observations:

Bacteriological

All Receiving Water and Mass Emission sites recorded concentrations greater than water quality objectives for E. Coli and Fecal Coliform. Likewise runoff from the R-1 and I-2 Land Use sites exceeded bacteriological objectives for E. Coli and Fecal Coliform. Consistent with previous efforts by the Ventura Countywide Stormwater Quality Program (most recently the 2002/03 Annual Monitoring

Ventura Stormwater Monitoring Chapter 2002/2003
Executive Summary

This chapter provides an investigation of stormwater program effectiveness, characterizes the surface water quality of Ventura County, and summarizes water quality data for monitoring conducted during the 2002/03 monitoring season. Analysis of samples collected at various sites throughout the watershed provides information to assess the impact of stormwater discharges and helps characterize the status of surface water quality for watersheds within Ventura County. The monitoring aids in the identification of pollutant sources as well as the evaluation of stormwater program effectiveness. Considering program effectiveness in the evaluation allows for changes to be made in the stormwater program to resolve any problems that may exist. This adaptive management strategy improves the quality and effectiveness of the stormwater program and minimizes the impact of stormwater pollutant discharges on the watershed.

For the 2002/03 monitoring season, a number of key points have been identified and are highlighted below.

- For the 2002/03 monitoring season, there were a total of 6 monitoring events (3 wet weather and 3 dry weather. Samples were collected in accordance with permit requirements for the 2002/03 monitoring season. There was a successful collection of samples at all stations and events as shown in the table below:

	Wet Weather Events			Dry Weather Events		
Station	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6
A-1	-	-	X	-	-	-
R-1	-	-	X	-	-	-
I-2	-	-	X	-	-	-
W-3	-	-	X	-	-	-
W-4	-	-	X	-	-	-
ME-CC	X	X	X	X	X	X
ME-SCR	X	X	X	X	X	X
ME-VR	X	X	X	X	X	X

10.8.3 Toxicity Results

Acute and chronic toxicity tests collected at the discharge, receiving water, and mass emission monitoring stations are summarized in Table 10-48 through Table 10-50.

Table 10-48. Acute Toxicity Results from the Land Use and Receiving Water Stations

			Acute Ceriodaphnia Survival	
Station	**Event Type**	**Event Number**	**LC50**	**TUa**
A-1	Wet	3	37.50%	2.67
I-2	Wet	3	>100%	0
R-1	Wet	3	>100%	0
W-3	Wet	3	>100%	0.41
W-4	Wet	3	72.20%	1.39
ME-CC	Wet	1	36.84%	2.71
ME-CC	Wet	2	>100%	0
ME-CC	Wet	3	75.00%	1.33
ME-CC	Dry	4	>100%	0
ME-CC	Dry	5	>100%	0
ME-CC	Dry	6	>100%	0
ME-SCR	Wet	1	>100%	0
ME-SCR	Wet	2	>100%	0
ME-SCR	Wet	3	>100%	0
ME-SCR	Dry	4	>100%	0
ME-SCR	Dry	5	>100%	0
ME-SCR	Dry	6	>100%	0
ME-VR	Wet	1	>100%	0
ME-VR	Wet	2	100%	1
ME-VR	Wet	3	>100%	0
ME-VR	Dry	4	>100%	0
ME-VR	Dry	5	>100%	0
ME-VR	Dry	6	>100%	0

• Table 10-58. Hardness Values Used Calculate CTR Metals Criteria

SiteID	EventType	Average	Minimum	Maximum
A-1	Wet	360	139	790
I-2	Wet	71	22	206
R-1	Wet	53	12	288
W-3	Wet	194	90	358
W-4	Wet	547	212	1530
ME-CC	Wet	220	24	424
ME-SCR	Wet	576	388	684
ME-VR	Wet	272	122	393
ME-CC	Dry	358	319	408
ME-SCR	Dry	652	553	698
ME-VR	Dry	392	370	414

The following tables provide summary statistics and percent exceedances for constituents exceeding at least one objective. Percentages denote the fraction of the total number of samples that have exceeded that particular objective. For example, if three out of 10 samples exceeded an objective, the constituent would have a 30% exceedance rate for the site.

• Table 10-59. Mass Emissions Sites - Objective Exceedances Dry Weather (ME-CC)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Cadmium	Total	10	0%	10%	
Copper	Dissolved	10		90%	0%
Copper	Total	10		90%	
E. Coli	Total	5	60%		
Fecal Coliform	Total	6	67%		
Nickel	Dissolved	10	0%	90%	0%
Nickel	Total	10	0%	90%	
Nitrate+Nitrite as N	Total	5	100%		
Nitrate Nitrogen	Total	10	70%		
Total Dissolved Solids	Total	10	100%		
Zinc	Dissolved	10		20%	0%
Zinc	Total	10		80%	
Total DDT	Total	9		22%**	

**30-Day Carcinogen
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-60. Mass Emissions Sites - Objective Exceedances Dry Weather (ME-VR)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Copper	Dissolved	10		20%	0%
Copper	Total	9		44%	
Fecal Coliform	Total	6	17%		
Nickel	Dissolved	10	0%	40%	0%
Nickel	Total	9	0%	56%	
Total Dissolved Solids	Total	10	100%		
Zinc	Total	9		22%	
Total DDT	Total	9		11%**	

**30-Day Carcinogen
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-61. Mass Emissions Sites - Objective Exceedances Dry Weather (ME-SCR)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Copper	Dissolved	7		57%	0%
Copper	Total	7		86%	
Fecal Coliform	Total	3	67%		
Lead	Total	7		14%	
Nickel	Total	7	0%	29%	
Selenium	Total	7	0%	0%	
Total Dissolved Solids	Total	7	100%		

Blanks denote no standard available for comparison

• Table 10-62. Mass Emissions Sites - Objective Exceedances Wet Weather (ME-CC)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	8			38%
4,4-DDE	Total	8			38%
Ammonia-N	Total	8		13%	
Cadmium	Total	8	13%	13%	
Chromium	Total	8	25%	0%*	
Copper	Total	8		38%	
E. Coli	Total	6	50%		
Fecal Coliform	Total	5	40%		
Lead	Total	8		38%	
Mercury	Total	8	0%	13%	
Nickel	Total	8	0%	25%	
Nitrate Nitrogen	Total	5	40%		
Nitrite Nitrogen	Total	6	50%		
Thallium	Total	8	38%	38%*	
Total Dissolved Solids	Total	8	25%		
Zinc	Total	8		25%	
Total DDT	Total	8		38%**	

*30-Day Non Carcinogen

**30-Day Carcinogen

Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-63. Mass Emissions Sites - Objective Exceedances Wet Weather (ME-SCR)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
Chromium	Total	5	40%	0%*	
Copper	Dissolved	5		20%	0%
Copper	Total	5		60%	
E. Coli	Total	6	50%		
Lead	Total	5		80%	
Nickel	Total	5	0%	40%	
Total Dissolved Solids	Total	5	100%		
Zinc	Total	5		60%	

*30-Day Non Carcinogen

Blanks denote no standard available for comparison

• Table 10-64. Mass Emissions Sites - Objective Exceedances Wet Weather (ME-VR)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
Ammonia-N	Total	8		13%	
Copper	Total	8		25%	
E. Coli	Total	6	50%		
Fecal Coliform	Total	5	40%		
Nickel	Dissolved	8	0%	0%	0%
Nickel	Total	8	0%	13%	
Nitrite Nitrogen	Total	6	50%		
Thallium	Total	8	13%	13%*	
Total Dissolved Solids	Total	8	50%		
Zinc	Dissolved	8		25%	0%
Zinc	Total	8		25%	
Total DDT	Total	8		25%**	

*30-Day Non Carcinogen

**30-Day Carcinogen

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-65. Receiving Water Sites - Objective Exceedances (W-3) 2002/2003

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	11			82%***
4,4-DDE	Total	12			92%***
Arsenic	Total	14	29%	50%	
Benzo(a)pyrene	Total	5	0%		20%***
Benzo(b)fluoranthene	Total	6			17%***
Cadmium	Dissolved	14	7%	7%	0%
Cadmium	Total	14	21%	21%	
Chromium	Total	14	57%	0%*	0%
Chrysene	Total	7			14%***
Copper	Dissolved	13		92%	92%
Copper	Total	14		100%	
Fecal Coliform	Total	12	100%		
Lead	Dissolved	14		43%	0%
Lead	Total	14		93%	
Mercury	Total	14	0%	36%	
Nickel	Dissolved	14	0%	21%	0%
Nickel	Total	14	43%	86%	
Nitrite Nitrogen	Total	13	92%		
Silver	Dissolved	14		7%	0%
Silver	Total	14		21%	
Total Dissolved Solids	Total	14	14%		
Zinc	Dissolved	14		14%	0%
Zinc	Total	14		93%	
Total DDT	Total	12		92%**	

*30-Day Non Carcinogen
**30-Day Carcinogen
***CTR Human Health
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

•Table 10-66. Receiving Water Sites - Objective Exceedances (W-4) 2002/2003

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	11			73%***
4,4-DDE	Total	11			91%***
Arsenic	Total	11	0%	18%	
Cadmium	Total	11	18%	18%	
Chromium	Total	11	64%	0%*	
Copper	Dissolved	10		30%	0%
Copper	Total	11		91%	
Fecal Coliform	Total	10	100%		
Lead	Dissolved	10		20%	0%
Lead	Total	11		73%	
Mercury	Total	10	0%	40%	
Nickel	Total	11	18%	73%	
Nitrate Nitrogen	Total	3	67%		
Nitrite Nitrogen	Total	9	89%		
Silver	Dissolved	10		10%	0%
Silver	Total	11		18%	
Total Dissolved Solids	Total	11	64%		
Zinc	Dissolved	10		20%	10%
Zinc	Total	11		91%	
Total DDT	Total	11		91%**	

*30-Day Non Carcinogen

**30-Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-67. Land Use Sites - Objective Exceedances (A-1)

Constituent	Fraction	Total Samples	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	12			75%***
4,4-DDE	Total	14			100%***
Ammonia-N	Total	19		16%	
Benzo(a)anthracene	Total	8			13%***
Benzo(a)pyrene	Total	7	0%		14%***
Benzo(b)fluoranthene	Total	8			13%***
Benzo(k)fluoranthene	Total	8			25%***
Cadmium	Total	19	42%	47%	
Chromium	Total	19	74%	0%*	
Chrysene	Total	10			50%***
Copper	Dissolved	19		68%	5%
Copper	Total	19		95%	
Dieldrin	Total	6		50%**	0%
Fecal Coliform	Total	19	95%		
Indeno(1,2,3-c,d)pyrene	Total	6			33%***
Lead	Dissolved	19		26%	0%
Lead	Total	19		84%	
Mercury	Total	20	0%	25%	
Nickel	Dissolved	19	0%	42%	0%
Nickel	Total	19	37%	95%	
Nitrite Nitrogen	Total	15	93%		
Silver	Dissolved	19		11%	0%
Silver	Total	19		32%	
Total Dissolved Solids	Total	18	72%		
Zinc	Dissolved	19		21%	0%
Zinc	Total	19		89%	
Total DDT	Total	14		100%**	

*30-Day Non Carcinogen
***CTR Human Health
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

• Table 10-68. Land Use Sites - Objective Exceedances (I-2)

Constituent	Fraction	Total Number	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	3			100%***
4,4-DDE	Total	4			100%***
Benzo(a)anthracene	Total	4			75%***
Benzo(a)pyrene	Total	3	67%		100%***
Benzo(b)fluoranthene	Total	4			75%***
Benzo(k)fluoranthene	Total	3			100%***
bis(2-ethylhexyl)phthalate	Total	4	75%	75%**	75%***
Cadmium	Total	22	9%	9%	
Chromium	Total	22	5%	0%*	
Chrysene	Total	4			75%***
Copper	Dissolved	18		56%	78%
Copper	Total	22		91%	
Dibenzo(a,h)Anthracene	Total	3			67%***
Fecal Coliform	Total	20	100%		
Indeno(1,2,3-c,d)pyrene	Total	3			100%***
Lead	Dissolved	19		37%	5%
Lead	Total	22		64%	
Mercury	Total	21	0%	10%	
Nickel	Dissolved	19	0%	37%	0%
Nickel	Total	22	5%	64%	
Nitrite Nitrogen	Total	19	53%		
Silver	Total	21		14%	
Zinc	Dissolved	19		26%	26%
Zinc	Total	22		86%	
Total DDT	Total	4		100%**	

*30-Day Non Carcinogen

**30-Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 10-69. Land Use Sites - Objective Exceedances (R-1)

Constituent	Fraction	Total Number	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDE	Total	4			100%***
Ammonia-N	Total	24		4%	
Benzo(a)anthracene	Total	5			80%***
Benzo(a)pyrene	Total	5	0%		40%***
Benzo(b)fluoranthene	Total	6			67%***
Benzo(k)fluoranthene	Total	6			67%***
bis(2-ethylhexyl)phthalate	Total	6	17%	33%**	0%***
Cadmium	Total	24	4%	8%	
Chromium	Total	24	8%	0%*	
Chrysene	Total	6			100%***
Copper	Dissolved	20		60%	70%
Copper	Total	24		71%	
Dibenzo(a,h)Anthracene	Total	3			33%***
Fecal Coliform	Total	22	100%		
Indeno(1,2,3-c,d)pyrene	Total	6			33%***
Lead	Dissolved	21		48%	5%
Lead	Total	24		71%	
Mercury	Total	21	0%	10%	
Nickel	Dissolved	21	0%	33%	0%
Nickel	Total	24	0%	42%	
Nitrite Nitrogen	Total	24	33%		
Silver	Total	23		13%	
Total Dissolved Solids	Total	24	4%		
Zinc	Dissolved	21		24%	29%
Zinc	Total	24		75%	
Total DDT	Total	4		100%**	

*30-Day Non Carcinogen

**30-Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Although the land use stations are not located in each of the watersheds for which receiving water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the land use objective exceedances are compared with the receiving water objective exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the program to determine whether certain land use types may be contributing to the objectives exceedances in the receiving waters.

4. Sample Collection

Flow-based composite samples were collected at all sites except for the Santa Clara River (ME-SCR) and Revolon Slough (W-4). Site ME-SCR is sampled using time-based composite samples due to flow diversion at the dam. Site W-4 currently does not have sample to volume (runoff) tables to determine the flow volume intervals necessary for flow-based composite sampling during wet events. Runoff tables will be calculated and included in the next update of the Standard Operating Procedures. Grab samples are collected for some constituents at all sites.

Sampling during each year of the monitoring program has consisted of at least a first-flush/early-season and other mid-season or late-season storms. A total of three wet weather events were collected on November 7-9, 2002, December 16-17, 2002 and February 11-13,2003. Storm event sampling criteria specify that not more than 0.1 inch of rain occurs during the 72 hours preceding a monitored event. Storms are selected for sampling based on the antecedent conditions (e.g. first-flush, early-season, etc.), fulfillment of the 72 hour "dry period," and weather forecasts.

At mass emissions, receiving water, and land use sites, both composite and grab samples are collected. Composite samples are collected in 20-liter containers, then delivered to the lab where they are split by pouring off with a tipper. When splitting of a composite sample is performed, the composite sample is continually rocked in the sample-pouring stand to provide as much "non-invasive" mixing as possible. The volume of sample collected depends upon the volume required by the lab to perform analytical tests.

In an effort to maintain quality control for the sampling program the sampling crew, in cooperation with the labs, has minimized the number of analytical labs and sample bottles used for analysis. This has increased efficiency and reduced the chances for contamination of the sample. Also, a dedicated monitoring team is used to prevent inconsistent data gathering and better quality control. All sites now have automated flow and sampling with data logging and remote access capabilities to streamline the monitoring program and centralize sample collection. Remote access capability also provides data on demand allowing for onsite evaluation of stream conditions.

At all sites except ME-SCR and W-4, automated composite samplers are programmed to collect flow proportional samples based on volume intervals passing by the station. The flow volume necessary to trigger sample collection is determined based on the predicted amount of precipitation over a specific time frame and the estimated volume of runoff of the watershed. These values are based on historic precipitation and runoff tables included in the Standard Operating Procedures. Samples at ME-SCR are collected on a timed interval basis because flow proportional compositing is not possible due to the diversion by United Water Conservation District. The VCWPD stormwater program has installed a flow gauge in the diversion channel to monitor flow diverted to infiltration ponds during dry weather. As discussed previously, another flow meter is planned to be installed at the river diversion gate at ME-SCR. Site W-4 collects samples on a time interval basis because sample to volume (runoff) tables are not available. Also, all stations except Calleguas have hard line phone and electrical connections and refrigerated sampling units. Calleguas Creek station is using cellular phone connection and solar/battery power. Automated data logging, rain gauges, and remote access are also installed at these sites.

For constituents requiring a grab sample, samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak river flow. All grab and composite wet weather samples in the 2002/2003 monitoring year are considered best available estimates of storm EMCs.

The following table summarizes the samples collected at each of the monitoring locations for the current period. Unless specified in the table, all sites were sampled for water chemistry and toxicity.

Table 6: 2002/03 Monitoring Event Summary

(Storm/Dry) Event Number	(Storm/Dry) Event Date	A-1 Wood Road	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR Ventura River-Foster Park
1	11/7/02	-	-	-	-	-	CG	CG	CG
2	12/16/02	-	-	-	-	-	CG	CG	CG
3	2/11/03	CG	Tox	Tox	CG	CG	CG	CG	CG

Notes:
"G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"Tox" indicates that only toxicity samples were collected.
"-" indicates that no sample was collected.

5. Analyses Performed

Sampling methods and sample handling procedures used in the 2002/03 monitoring year are based on the procedures described in the revised *Ventura Countywide Stormwater Monitoring Program: Standard Operating Procedures 2000-2005 Stormwater Monitoring* (LWA, 2001) and *Ventura Countywide Stormwater Monitoring Program: Standard Operating Procedures Mass Emission Monitoring* (VCWPD, 2003). The monitored parameter requirements are described as a part of NPDES Permit No. CAS004002 Section No. CL 7388.

FGL Environmental of Santa Paula performed all tests except mercury, TRPH, toxicity, bioassessment and bacteria. Monitoring program tests include: conventionals, microbiological, toxicity, bioassessment, and nutrient analyses, metals (except mercury), EPA 8141 and 8151 analyses for pesticides, EPA 8020 analyses for MTBE, 8270 analyses for chlorinated pesticides, PCBs, semi and non-volatile organics, TOC, and oil & grease analyses. Associated Laboratories was used to perform TRPH lab analysis. Frontier Laboratories performed low detection limit analysis for mercury samples. The Ventura County Health Care Agency Laboratory performed bacteriological tests for E.Coli, Enterococcus, and Total and Fecal Coliform. Analytical methods comply with those outlined in the permit. The methods allow the laboratories to achieve the lowest possible detection limits.

The toxicity tests were conducted by Aquatic Bioassay & Consulting of Ventura under the guidelines prescribed in *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (EPA 600/4-85/013). The toxicity tests include Acute *Ceriodaphnia dubia* and Chronic *Menidia beryllina*. Aquatic Bioassay & Consulting also performs the macroinvertebrate bioassessment testing in addition to toxicity.

Objectives in the CTR for metals are calculated based on the hardness of the water. For the purpose of this analysis, average hardness from the dataset at each site were used for the analysis. The following table summarizes the hardness at each site. The CTR sets a cap of 400 mg/L for calculating the objectives. For those sites with an average hardness of greater than 400 mg/L (ME-SCR and W-4), 400 mg/L was used to calculate the objectives.

Table 46: Hardness Values Used Calculate CTR Metals Criteria

Site	Average	Minimum	Maximum
A-1	350	19	790
R-1	53	12	288
I-2	71	22	206
W-3	177	27	358
W-4	547	212	1530
ME-CC	287	24	424
ME-SCR	616	388	684
ME-VR	317	122	402

Percentages denote the fraction of the total number of samples that have exceeded that particular objective. For example, if 3 out of 10 samples exceeded an objective, the constituent would have a 30% exceedance rate for the site. The following tables provide summary statistics and percent exceedances for constituents exceeding at least one objective.

Table 47: Mass Emissions Sites - Objective Exceedances Dry Weather (ME-CC)

Constituent	Fraction	Total	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Cadmium	Total	7	0%	14%	0%
Copper	Dissolved	7		86%	0%
Copper	Total	7		86%	0%
Fecal Coliform	Total	6	66%		
Nickel	Dissolved	7	0%	86%	0%
Nickel	Total	7	0%	86%	0%
Nitrate Nitrogen	Total	7	57%		
Total Dissolved Solids	Total	7	100%		
Zinc	Dissolved	7		29%	0%
Zinc	Total	7		86%	0%
Total DDT	Total	6		33%**	

**30-Day Carcinogen
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 48: Mass Emissions Sites - Objective Exceedances Dry Weather (ME-VR)

Constituent	Fraction	Total	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Copper	Dissolved	7		14%	0%
Copper	Total	6		33%	0%
Fecal Coliform	Total	6	17%		
Nickel	Dissolved	7	0%	43%	0%
Nickel	Total	6	0%	50%	0%
Total Dissolved Solids	Total	7	100%		
Zinc	Dissolved	6		17%	0%
Total DDT	Total	6		17%**	

**30 Day Carcinogen

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 49: Mass Emissions Sites - Objective Exceedances Dry Weather (ME-SCR)

Constituent	Fraction	Total	Basin Plan	Ocean Plan 6 Month Median	CTR Chronic
Copper	Dissolved	4		75%	0%
Copper	Total	4		100%	0%
Fecal Coliform	Total	3	66%		
Lead	Total	4		25%	0%
Nickel	Total	4	0%	50%	0%
Selenium	Total	4	0%	0%	50%
Total Dissolved Solids	Total	4	100%		

Blanks denote no standard available for comparison

Table 50: Mass Emissions Sites - Objective Exceedances Wet Weather (ME-CC)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	8			38%
4,4-DDE	Total	8			38%
Ammonia-N	Total	8		13%	
Cadmium	Total	8	13%	13%	0%
Chromium	Total	8	25%	0%*	0%
Copper	Total	8		38%	25%
Fecal Coliform	Total	5	60%		
Lead	Total	8		38%	0%
Mercury	Total	8	0%	13%	
Nickel	Total	8	0%	25%	0%
Nitrate Nitrogen	Total	5	40%		
Nitrite Nitrogen	Total	6	50%		
Thallium	Total	8	38%	38%*	
Total Dissolved Solids	Total	8	25%		
Zinc	Total	8		25%	13%
Total DDT	Total	8		38%**	

*30Day Non Carcinogen

**30Day Carcinogen

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 51: Mass Emissions Sites - Objective Exceedances Wet Weather (ME-SCR)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
Chromium	Total	5	40%	0%*	0%
Copper	Dissolved	5		20%	0%
Copper	Total	5		60%	0%
Lead	Total	5		80%	0%
Nickel	Total	5	0%	40%	0%
Total Dissolved Solids	Total	5	100%		
Zinc	Total	5		60%	0%

*30Day Non Carcinogen

Blanks denote no standard available for comparison

Table 52: Mass Emissions Sites - Objective Exceedances Wet Weather (ME-VR)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
Ammonia-N	Total	8		13%	
Copper	Total	8		25%	0%
Fecal Coliform	Total	5	40%		
Nickel	Dissolved	8	0%	0%	0%
Nickel	Total	8	0%	13%	0%
Nitrite Nitrogen	Total	6	50%		
Thallium	Total	8	13%	13%*	
Total Dissolved Solids	Total	8	50%		
Zinc	Total	8		25%	0%
Zinc	Total	8		25%	0%
Total DDT	Total	8		25%**	

*30 Day Non Carcinogen

**30 Day Carcinogen

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 53: Receiving Water Sites - Objective Exceedances (W-3)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	11			82%***
4,4-DDE	Total	12			92%***
Arsenic	Total	14	29%	50%	0%
Benzo(a)pyrene	Total	5	0%		20%***
Benzo(b)fluoranthene	Total	6			17%***
Cadmium	Dissolved	14	7%	7%	0%
Cadmium	Total	14	21%	21%	7%
Chromium	Total	14	57%	0%*	0%
Chrysene	Total	7			14%***
Copper	Dissolved	13		92%	92%
Copper	Total	14		100%	100%
Fecal Coliform	Total	12	100%		
Lead	Dissolved	14		43%	0%
Lead	Total	14		93%	7%
Mercury	Total	14	0%	36%	
Nickel	Dissolved	14	0%	21%	0%
Nickel	Total	14	43%	86%	0%
Nitrite Nitrogen	Total	13	92%		
Silver	Dissolved	14		7%	0%
Silver	Total	14		21%	7%
Total Dissolved Solids	Total	14	14%		
Zinc	Dissolved	14		14%	0%
Zinc	Total	14		93%	50%
Zinc	Total	14		93%	50%
Total DDT	Total	12		92%**	

*30Day Non Carcinogen
**30 Day Carcinogen
***CTR Human Health
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

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Table 54: Receiving Water Sites - Objective Exceedances (W-4)

[illegible] Constituent	[illegible] Fraction	[illegible] Total	[illegible] Basin Plan	Ocean Plan Daily Max	[illegible] CTR Acute
4,4-DDD	Total	11			73%***
4,4-DDE	Total	11			91%***
Arsenic	Total	11	0%	18%	0%
Cadmium	Total	11	18%	18%	0%
Chromium	Total	11	64%	0%*	0%
Copper	Dissolved	10		30%	0%
Copper	Total	11		91%	73%
Fecal Coliform	Total	10	100%		
Lead	Dissolved	10		20%	0%
Lead	Total	11		73%	0%
Mercury	Total	10	0%	40%	
Nickel	Total	11	18%	73%	0%
Nitrate Nitrogen	Total	3	67%		
Nitrite Nitrogen	Total	9	89%		
Silver	Dissolved	10		10%	0%
Silver	Total	11		18%	0%
Total Dissolved Solids	Total	11	64%		
Zinc	Dissolved	10		20%	10%
Zinc	Total	11		91%	27%
Total DDT	Total	11		91%**	

*30Day Non Carcinogen

**30 Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Based on this analysis, metals and bacteria appear to frequently exceed objectives in the receiving waters in the Ventura County watershed. However, fecal coliform limits in the Basin Plan describe the criteria as being the log mean of 200 MPN/100ml based on a minimum of 4 samples over a 30 day period. Although bacteriological samples for the program are collected once per event instead of over a 30 day period, this criteria of 200MPN/100ml was used since no other fecal coliform criterion was available.

A small number of organic constituents exceed a water quality objective at the mass emission and receiving water stations. As shown in the tables above, these constituents include: benzo(a)pyrene, benzo(b)fluoranthene and DDT associated compounds. When performing a comparison to a water quality objective, all available data (1993 to present) for a constituent is compared to the objective. The total number of data points that exceed the objective are counted and used to calculate the percent exceedance.

As the stormwater program became more effective over time, the data shows that the number of detected organic constituents decreases significantly. In the case of benzo(a)pyrene and benzo(b)fluoranthene, most of these data points that exceeded an objective did so at the earlier part of the program (1993-1999). In recent years (1999 to present), the number of organic compounds detected in the stormwater samples has declined.

Although the detection rate for DDT and associated compounds has also declined in the past few years, concentrations of these pollutants are still found during stormwater monitoring at levels that exceed objectives. DDT was historically used in agricultural areas in the watershed and is a highly persistent compound. The concentrations seen in the current monitoring are likely a result of this historic use the amount of DDT remaining in the sediments in the County.

Table 55 through Table 57 below summarizes objective exceedances at land use sites.

Table 55: Land Use Sites - Objective Exceedances (A-1)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	12			75%***
4,4-DDE	Total	14			100%***
Ammonia-N	Total	19		16%	
Benzo(a)anthracene	Total	8			13%***
Benzo(a)pyrene	Total	7	0%		14%***
Benzo(b)fluoranthene	Total	8			13%***
Benzo(k)fluoranthene	Total	8			25%***
Cadmium	Total	19	42%	47%	0%
Chromium	Total	19	74%	0%*	0%
Chrysene	Total	10			50%***
Copper	Dissolved	19		68%	5%
Copper	Total	19		95%	84%
Dieldrin	Total	6		50%**	0%
Fecal Coliform	Total	19	95%		
Indeno(1,2,3-c,d)pyrene	Total	6			33%***
Lead	Dissolved	19		26%	0%
Lead	Total	19		84%	0%
Mercury	Total	20	0%	25%	
Nickel	Dissolved	19	0%	42%	0%
Nickel	Total	19	37%	95%	0%
Nitrite Nitrogen	Total	15	93%		
Silver	Dissolved	19		11%	0%
Silver	Total	19		32%	0%
Total Dissolved Solids	Total	18	72%		
Zinc	Dissolved	19		21%	0%
Zinc	Total	19		89%	21%
Total DDT	Total	14		100%**	

*30Day Non Carcinogen
***CTR Human Health
Blanks denote no standard available for comparison
Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 56: Land Use Sites - Objective Exceedances (I-2)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDD	Total	3			100%***
4,4-DDE	Total	4			100%***
Benzo(a)anthracene	Total	4			75%***
Benzo(a)pyrene	Total	3	67%		100%***
Benzo(b)fluoranthene	Total	4			75%***
Benzo(k)fluoranthene	Total	3			100%***
bis(2-ethylhexyl)phthalate	Total	4	75%	75%**	75%***
Cadmium	Total	22	9%	9%	9%
Chromium	Total	22	5%	0%*	0%
Chrysene	Total	4			75%***
Copper	Dissolved	18		56%	78%
Copper	Total	22		91%	91%
Dibenzo(a,h)Anthracene	Total	3			67%***
Fecal Coliform	Total	20	100%		
Indeno(1,2,3-c,d)pyrene	Total	3			100%***
Lead	Dissolved	19		37%	5%
Lead	Total	22		64%	9%
Mercury	Total	21	0%	10%	
Nickel	Dissolved	19	0%	37%	0%
Nickel	Total	22	5%	64%	0%
Nitrite Nitrogen	Total	19	53%		
Silver	Total	21		14%	14%
Zinc	Dissolved	19		26%	26%
Zinc	Total	22		86%	82%
Total DDT	Total	4		100%**	

*30Day Non Carcinogen

**30Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Table 57: Land Use Sites - Objective Exceedances (R-1)

Constituent	Fraction	Total	Basin Plan	Ocean Plan Daily Max	CTR Acute
4,4-DDE	Total	4			100%***
Ammonia-N	Total	24		4%	
Benzo(a)anthracene	Total	5			80%***
Benzo(a)pyrene	Total	5	0%		40%***
Benzo(b)fluoranthene	Total	6			67%***
Benzo(k)fluoranthene	Total	6			67%***
bis(2-ethylhexyl)phthalate	Total	6	17%	33%**	0%***
Cadmium	Total	24	4%	8%	17%
Chromium	Total	24	8%	0%*	0%
Chrysene	Total	6			100%***
Copper	Dissolved	20		60%	70%
Copper	Total	24		71%	83%
Dibenzo(a,h)Anthracene	Total	3			33%***
Fecal Coliform	Total	22	100%		
Indeno(1,2,3-c,d)pyrene	Total	6			33%***
Lead	Dissolved	21		48%	5%
Lead	Total	24		71%	25%
Mercury	Total	21	0%	10%	
Nickel	Dissolved	21	0%	33%	0%
Nickel	Total	24	0%	42%	0%
Nitrite Nitrogen	Total	24	33%		
Silver	Total	23		13%	17%
Total Dissolved Solids	Total	24	4%		
Zinc	Dissolved	21		24%	29%
Zinc	Total	24		75%	75%
Total DDT	Total	4		100%**	

*30Day Non Carcinogen

**30Day Carcinogen

***CTR Human Health

Blanks denote no standard available for comparison

Total DDT is the sum of 2,4-DDD, 4,4-DDD, 2,4-DDE, 4,4-DDE, 2,4-DDT and 4,4-DDT

Although the land use stations are not located in each of the watersheds for which receiving water samples are collected, the sites were chosen to provide representative data to be used to describe the water quality of discharges from urban and agricultural areas in Ventura County. As a result, for this analysis, the land use objective exceedances are compared with the receiving water objective exceedances in all watersheds even if they are not specifically located in that watershed. This comparison allows the program to determine whether certain land use types may be contributing to the objectives exceedances in the receiving waters.

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A total of seven monitoring events (two wet and five dry) were collected at the mass emission stations during 2001/02. The dates of sample collection at each site are shown in Table 10-5 (on page 10-9). Mass emission monitoring stations are shown in Figure 10-1. The site characteristics are summarized below in Table 10-4 (on page 10-6).

Table 10-4 Mass Emission Site Characteristics Monitoring Program

Station Code	Location	Land Uses	Watershed Area (acres)	Rain Gauge
ME-CC	Calleguas Creek – CSUCI north side of Hueneme Road, just east of Lewis Road at the old Camarillo State Hospital bridge	Mixed Use	160,640	Camarillo-Adohr
ME-SCR	Santa Clara River – at Freeman diversion dam	Open Space	1,003,524	Fillmore Fish Hatchery
ME-VR	Ventura River – Foster Park west of State Highway 33, on the south side of Casitas Vista Road, just west of the Foster Park Bridge	Open Space	119,680	Ojai-Stewart Canyon

The mass emission stations, ME-CC and ME-VR, were installed and monitored for the first time in 2000/01. ME-SCR was first installed and monitored in 2001/02. ME-CC and ME-VR mass emission samples are collected using automated flow proportional composite samplers (ISCO 6712). ME-SCR mass emission samples are collected on automated time proportional composite samplers. ME-SCR station is located at a diversion dam where water is diverted by United Water Conservation District for ground water infiltration. Because of this, flow proportional composite sample collection is not possible. The stations are also configured for remote access monitoring using state of the art telemetry equipment. Rain gauges are available at ME-SCR and ME-CC. ME-VR and ME-SCR stations are also equipped with refrigeration units.

10.3.4 Sample Collection-Water Chemistry and Toxicity Monitoring

For the 2001/02 monitoring season, there were a total of seven monitoring events, consisting of two wet weather events and five dry weather events. Samples were collected at the mass emissions sites for all seven events. The first wet weather event occurred on Nov. 12, 2001 and the second wet weather event occurred on March 7-8, 2002. Wet weather samples were collected only from the mass emissions sites. Five dry weather monitoring events were monitored at the mass emission monitoring stations and one dry weather event at the land use and receiving water sites. Dry weather samples were collected as time-based composite samples over a 48-hour period. Dry weather monitoring was conducted on August 7-8, 2001, April 11, 2002, April 25, 2002, June 18, 2002 and July 9, 2002. On April 11, 2002, a dry weather sample was collected at both the land use and receiving water sites. Due to insufficient flow at the La Vista receiving water site, only one receiving water site, Revolon Slough, was sampled for the 2001/02 monitoring season.

Table 10-5 2001/02 Monitoring Event Summary
Monitoring Program

(Storm/Dry) Event Number	(Storm/Dry) Event Date	A-1 Wood Road	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR Ventura River-Foster Park
1(Dry)	8/9/01						CG	-	CG
2 (Wet)	11/12/01	-	-	-	-	-	CG	CG	CG
3 (Wet)	3/8/02	-	-	-	-	-	CG*	CG*	CG*
4 (Dry)	4/11/02	CG*	-2	-2	-2	CG*	CG*	CG*	CG*
5 (Dry)	4/25/02	-	-	-	-	-	CG*	CG*	CG*
6 (Dry)	6/18/02	-	-	-	-	-	CG*	CG*	CG*
7 (Dry)	7/9/02	-	-	-	-	-	CG*	CG*	CG*

Notes:
1) "G" indicates that a grab sample was collected.
"C" indicates that a composite sample was collected.
"-" indicates that no sample was collected.
" * " indicates that dry monitoring sample was collected.
2) Insufficient Flow Available

10.3.5 Bioassessment

The Ventura County Storm Water Monitoring Program also includes the bioassessment-monitoring program. A Work Plan for in-stream bioassessment monitoring in the Ventura River watershed was developed and submitted in January 2001 to the Regional Board as part of the revised Stormwater Management Plan. In addition to the preparation of the work plan, the County conducted a March 2001 training session on bioassessment monitoring techniques and participated in the Heal the Bay bioassessment training program. The Sustainable Land Stewardship Land Institute (Monique Borne) has also provided assistance to this program. The actual bioassessment monitoring was accomplished on September 24-26, 2001 and is included in the 2001/02 Annual Report. Figure 10-2 (on page 10-10) shows the bioassessment monitoring sites.

For most metals, objectives listed in the CTR are for dissolved metals. In order to perform a comparison with total metals data, the conversion factors identified in the CTR were used to convert a dissolved metal objective to a total metal objective.

10.9 Comparison and Discussion of Results

10.9.1. Mass Emission and Receiving Water Analysis

Data from the mass emission and receiving water stations were analyzed and compared to the objectives to determine the frequency of exceedances of objectives and identify potential pollutants of concern. The following tables describe the percent exceedance of acute or chronic objectives for constituents exceeding one or more objectives at the mass emission and receiving water sites. A summary of all the constituents analyzed with summary statistics for those with sufficient data is included in Appendix C.

Also, listed in the following tables (on pages 10-60 through 10-63) are the minimum **(min)** and maximum **(max)** concentrations detected of the constituent. **N** denotes the total number of samples analyzed for the detected constituent. Dry weather events were compared with CTR Chronic Freshwater, Ocean Plan 6 month median and Basin Plan objectives whereas wet weather events were compared to CTR Acute, Ocean Plan Daily Maximum, and Basin Plan objectives. For constituents that do not have any acute CTR, Ocean Plan or Basin Plan objectives to compare with, the California Toxics Rule Human Health Objectives for Organisms only is used for both wet and dry weather events. The California Toxics Rule Objectives for Organisms only is included here because these constituents have no other objectives for comparison in CTR. This objective is used even though human health objectives are based on long term risks to human health that cannot be directly correlated to stormwater discharges.

Percentages denote the fraction of the total number of samples that have exceeded that particular objective. For example, out of a total of 10 samples, total copper at ME-CC has a 30% exceedance rate for the CTR Acute objective. This would mean that 3 out of the 10 samples exceeded the California Toxics Rule Acute Freshwater objective for total copper.

Table 10-34 Mass Emissions Sites - Objective Exceedances Monitoring Program

ME-VR Dry

Constituent	Fraction	N	Units	Min	Max	CTR Chronic	CTR Chronic Objective	OP 6 Month	OP 6 Mth Objective	Basin Plan	BP Objective
Copper	Total	6	µg/L	2	7	0%	28	83%	3	*	*
Lead	Total	6	µg/L	ND	12.6	0%	23	17%	2	*	*
Mercury**	Total	6	µg/L	ND	0.128	17%	0.051	17%	40	0%	2
Nickel	Total	6	µg/L	4	18	0%	140	83%	5	0%	100
Fecal Coliform	Total	7	MPN/ 100ml	ND	16000	*	*	*	*	17%	400
Zinc	Total	5	µg/L	ND	20	0%	322	60%	20	*	*

ME-VR Wet

Constituent	*Fraction*	*N*	*Units*	*Min*	*Max*	*CTR Acute*	*CTR Acute Objective*	*OP Daily Max*	*OP Daily Max Objective*	*Basin Plan*	*BP Objective*
Ammonia-Nitrogen	Total	5	Mg/L	0.1	3.1	*	*	20%	2.4	*	*
bis(2-ethylhexyl)phthalate**	Total	5	µg/L	ND	331	60%	5.9	60%	3.5	60%	4
Cadmium	Total	5	µg/L	ND	5.45	0%	15	20%	4	20%	5
Chromium	Total	5	µg/L	1	151	0%	3870 [1]	0%	190000 [1]	40%	50 [2]
Copper	Total	5	µg/L	3	104	40%	35	40%	12	*	*
Copper	Dissolved	5	µg/L	2	84	20%	33.8	*	*	*	*
Lead	Total	5	µg/L	0.3	52.6	0%	284	20%	8	*	*
Lead	Dissolved	5	µg/L	ND	31.7	0%	184	*	*	*	*
Fecal Coliform	Total	5	MPN/ 100 ml	800	16000	*	*	*	*	100%	400
Zinc	Total	5	µg/L	10	450	20%	274.485	40%	80		
Nickel	Total	5	µg/L	3	137	0%	1073	40%	20	20%	100

ME-CC Dry

Constituent	*Fraction*	*N*	*Units*	*Min*	*Max*	*CTR Chronic*	*CTR Chronic Objective*	*OP 6 Month*	*OP 6 Mth Objective*	*Basin Plan*	*BP Objective*
4,4'-DDD**	Total	7	µg/L	ND	0.006	14%	0.00084	14%	0.0017	*	*
4,4'-DDE**	Total	7	µg/L	ND	0.003	14%	0.00059	14%	0.0017	*	*
beta-BHC	Total	7	µg/L	ND	0.047	14%	0.046	*	*	*	*
Cadmium	Total	7	µg/L	ND	4	0%	7.5	14%	1	0%	5
Copper	Total	7	µg/L	ND	7	0%	26	57%	3	*	*
Lead	Total	7	µg/L	ND	12.6			14%	2		
Nickel	Total	7	µg/L	ND	7	0%	128	71%	5	0%	100
Nitrate Nitrogen	Total	7	µg/L	9.35	66.9	*	*	*	*	57%	10
Zinc	Total	7	µg/L	20	60	0%	296	71%	20	*	*
Chloride	Total	7	µg/L	162	185	*	*	*	*	100%	150
Fecal Coliform	Total	6	MPN/ 100ml	80	5000	*	*	*	*	50%	400
TDS	Total	7	mg/L	820	944	*	*	*	*	850	86%

* Have no applicable objectives
** Compared with CTR Human Health Objectives

1. CTR and Ocean Plan objectives for Chromium are for Chromium III
2. Basin Plan objectives for Chromium are for Total Chromium.

Table 10-34 Mass Emissions Sites - Objective Exceedances (continued)
Monitoring Program

ME-CC Wet

Constituent	Fraction	N	Units	Min	Max	CTR Acute	CTR Acute Objective	OP Daily Max	OP Daily Max Objective	Basin Plan	BP Objective
4,4'-DDD**	Total	5	µg/L	ND	0.015	60%	0.00084	60%	0.00017	*	*
4,4'-DDE**	Total	5	µg/L	ND	0.12	60%	0.00059	60%	0.00017	*	*
4,4'-DDT**	Total	5	µg/L	ND	0.013	60%	0.00059	60%	0.00017	*	*
Ammonia-Nitrogen	Total	5	Mg/L	0.1	52			20%	2.4		
Benzo(a)anthracene**	Total	5	µg/L	ND	19	60%	0.049	*	*	*	*
Benzo(a)pyrene**	Total	5	µg/L	ND	26	60%	0.049	*	*	60%	0.2
Benzo(b)fluoranthene**	Total	5	µg/L	ND	36	60%	0.049	*	*	*	*
Benzo(k)fluoranthene**	Total	5	µg/L	ND	12	60%	0.049	*	*	*	*
bis(2-ethylhexyl)phthalate**	Total	5	µg/L	ND	402	60%	5.9	60%	3.5	60%	3.5
Cadmium	Total	5	µg/L	ND	5.3	0%	14	40%	4	20%	5
Chromium	Total	5	µg/L	ND	140	0%	3666 [1]	0%	190000 [1]	60%	50 [2]
Chrysene**	Total	5	µg/L	ND	36	60%	0.049	*	*	*	*
Chloride	Total	5	Mg/L	18	171					20%	150
Copper	Total	5	µg/L	5	93	60%	33	80%	12	*	*
Copper	Dissolved	5	µg/L	4	35	20%	31.7	*	*	*	*
Fluoranthene**	Total	5	µg/L	ND	44	0%	370	60%	15	*	*
Indeno(1,2,3-c,d)pyrene**	Total	5	µg/L	ND	27	60%	0.049	*	*	*	*
Lead	Total	5	µg/L	0.6	39.6	0%	261	60%	8	*	*
Mercury**	Total	5	µg/L	0.002	0.265	80%	0.051	20%	0.16	0%	2
Nickel	Total	5	µg/L	6	112	0%	1015	60%	20	40%	100
Nitrate Nitrogen	Total	5	µg/L	2.2	44.6	*	*	*	*	20%	10
Zinc	Total	5	µg/L	20	273	40%	260	60%	80	*	*
Fecal Coliform	Total	5	MPN/ 100ml	5	*	*	*	*	*	100%	400
TDS	Total	5	Mg/L	216	900	*	*	*	*	850	20%
ME-SCR Dry											
Constituent	Fraction	N	Units	Min	Max	CTR Chronic	CTR Chronic Objective	OP 6 Month	OP 6 Month Objective	Basin Plan	BP Objective
Copper	Total	4	µg/L	4	10	0%	52	100%	12	*	*
Lead	Total	4	µg/L	ND	12.6	0%	477	25%	8	*	*
Nickel	Total	4	µg/L	3	18	0%	1516	50%	20	0%	100
Chloride	Total	4	µg/L	81	98	*	*	*	*	100%	80
Selenium	Total	4	µg/L	ND	7	50%	5	0%	60	0%	50
Fecal Coliform	Total	3	MPN/ 100ml	160	16000	*	*	*	*	67%	400
TDS	Total	4	mg/L	1310	1400	*	*	*	*	1200	100%

* Have no applicable objectives ** Compared with CTR Human Health Objectives
1. CTR and Ocean Plan objectives for Chromium are for Chromium III.
2. 2. Basin Plan objectives for Chromium are for Total Chromium.

Table 10-35 Receiving Objective Exceedances[3]
Monitoring Program

	Constituent	Units	Fraction	Min	Max	N	CTR Acute	CTR Acute Objectives	OP Daily Max	OP Daily Max Objective	Basin Plan	BP Objective
W-3 (Agricultural Land Use)	Arsenic	µg/L	Total	8.8	188	17	0%	340	53%	32	27%	50
	Cadmium	µg/L	Total	ND	15.7	17	13%	9	20%	4	20%	5
	Copper	µg/L	Total	77	1750	17	100%	22	100%	12	*	*
	Copper	µg/L	Dissolved	12	188	17	93%	21.3	*	*	*	*
	Lead	µg/L	Total	ND	448	17	13%	152	93%	8	*	*
	Mercury**	µg/L	Total	0.024	0.275	17	80%	0.051	73%	0.16	0%	2
	Nickel	µg/L	Total	16	570	17	0%	709	93%	20	40%	100
	Silver	µg/L	Total	ND	13	17	7%	9	27%	2.8	*	*
	Silver	µg/L	Dissolved	ND	9.6	17	7%	7.99	*	*	*	*
	Zinc	µg/L	Total	68	2900	17	67%	181	93%	80	*	*
	Zinc	µg/L	Dissolved	68	1150	17	7%	177.27	*	*	*	*
	4,4' - DDD **	ng/l	Total	ND	77.9	17	77%	0.00084	*	*	*	*
	4,4' - DDE **	ng/l	Total	ND	892	17	100%	0.00059	*	*	*	*
	4,4' - DDT **	ng/l	Total	ND	184	17	82%	0.00059	*	*	*	*
	alpha-Chlordane	µg/L	Total	ND	17.4	17	45%	2.4	45%	0.000023	45%	0.1
	gamma-Chlordane	µg/L	Total	ND	12.1	17	45%	2.4	45%	0.000023	45%	0.1
	Benzo(a)pyrene **	µg/L	Total	ND	64	17	45%	0.049	*	*	45%	0.2
	bis(2-ethylhexylphthalate) **	µg/L	Total	ND	2180	17	11%	5.9	*	3.5	77%	4
	Fecal Coliform	MPN/ 100ml	Total	13000	500000	17	*	*	*	*	100%	400
	Benzo(b)fluoranthene**	µg/L	Total	ND	91	17	45%	0.049	*	*	*	*
	Chrysene**	µg/L	Total	ND	98	17	73%	0.049	*	*	*	*
	Fluoranthene**	µg/L	Total	ND	114	17	*	*	57%	15	*	*

* Have no applicable objectives
** Compared with CTR Human Health Objectives
ND – Not Detected

1. CTR and Ocean Plan objectives for Chromium are for Chromium III.
2. Basin Plan objectives for Chromium are for Total Chromium.
3. The one dry weather event collected at this site in 2001/02 was included with the wet weather samples for this analysis because it is the only dry weather sample available.

Table 10-35 Receiving Objective Exceedances[3] (continued)
Monitoring Program

	Constituent	Units	Fraction	Min	Max	N	CTR Acute	CTR Acute Objectives	OP Daily Max	OP Daily Max Objective	Basin Plan	BP Objective
W-4 (Mixed Land Use)	Arsenic	µg/L	Total	ND	33	14	0%	340	15%	32	0%	50
	Cadmium	µg/L	Total	ND	6.6	14	*	*	15%	4	15%	5
	Chromium	µg/L	Total	3	171	14	0%	54051	0%	1900001	69%	502
	Copper	µg/L	Total	8	187	14	77%	52	92%	12	*	*
	Lead	µg/L	Total	0.4	69.8	14	0%	477	69%	8	*	*
	Mercury**	µg/L	Total	0.001	0.282	14	100%	0.051	36%	0.16	0%	2
	Nickel	µg/L	Total	15	145	14	0%	1516	77%	20	15%	100
	Silver	µg/L	Total	ND	9.9	14	0%	44	23%	2.8	*	*
	Zinc	µg/L	Total	20	670	14	23%	388	50%	80	*	*
	Zinc	µg/L	Dissolved	10	429	14	8%	380	*	*	*	*
	4,4' – DDD **	ng/l	Total	ND	148	14	85%	0.00084	79%	17	*	*
	4,4' – DDE **	ng/l	Total	ND	812	14	100%	0.00059	93%	17	*	*
	4,4' – DDT **	ng/l	Total	ND	247	14	92%	0.00059	79%	17	*	*
	bis(2-ethylhexyl-phthalate**	µg/L	Total	ND	744	14	77%	5.9	77%	3.5	77%	4
	alpha-Chlordane	µg/L	Total	ND	13	14	46%	2.4	54%	0.000042	54%	0.1
	gamma-Chlordane	µg/L	Total	ND	8.9	14	46%	2.4	54%	0.000042	54%	0.1
	Benzo(a)pyrene **	µg/L	Total	ND	23	14	62%	0.049	62%	0.0088	62%	0.2
	Nitrate Nitrogen	mg/l	Total	2.4	214	14	*	*	*	*	23%	10
	Fecal Coliform	MPN/100ml	Total	8000	28000	*	*	*	*	*	100%	400
	Total Dissolved Solids	mg/L	Total	254	3490	14	*	*	*	*	23%	850
	Chloride	mg/L	Total	20	178	14	*	*	*	*	8%	150
	Benz(a)anthracene**	µg/L	Total	ND	17	14	54%	0.049	*	*	*	*
	Benzo(b)fluoranthene**	µg/L	Total	ND	33	14	77%	0.049	*	*	*	*
	Benzo(k)fluoranthene**	µg/L	Total	ND	32	14	77%	0.049	*	*	*	*
	Chrysene**	µg/L	Total	ND	41	14	85%	0.049	*	*	*	*
	Fluoranthene	µg/L	Total	ND	80	14	0%	370	92%	15	*	*
	Indeno(1,2,3-c,d)pyrene**	µg/L	Total	ND	35	14	46%	0.049	*	*	*	*

* Have no applicable objectives
** Compared with CTR Human Health Objectives
ND – Not Detected
1.CTR and Ocean Plan objectives for Chromium are for Chromium III.
2.Basin Plan objectives for Chromium are for Total Chromium.
3.The one dry weather event collected at this site in 2001/02 was included with the wet weather samples for this analysis because it is the only dry weather sample available.

For constituents requiring a grab sample, samples are ideally taken at the peak runoff flow to provide the best estimate for an event mean concentration (EMC). In practice it is difficult to both predict the peak flow and to allocate manpower such that all sites are grab-sampled at the storm event peak river flow. All grab and composite wet weather samples in the 2001/2002 monitoring year are considered best available estimates of storm EMCs.

For the 2001/02 monitoring season, there were a total of seven monitoring events, consisting of two wet weather events and five dry weather events. Included in this report are five monitoring events consisting of two wet weather and three dry weather events. Samples were collected at the mass emissions sites for all five events. The first wet weather event monitored occurred on Nov. 12, 2001 and the second wet weather event occurred on March 7-8, 2002. Wet weather samples were collected only from the mass emissions sites. Three dry weather monitoring events were monitored at the mass emission monitoring stations and from land use and receiving water sites for one dry weather event. Dry weather samples were collected as time-based composite samples over a 48-hour period. Dry weather monitoring was conducted on August 7-8, 2001, April 11, 2002, and April 25, 2002. On April 11, 2002, a dry weather sample was collected at both the land use and receiving water sites. Due to insufficient flow at the La Vista receiving water site, only receiving water site, Revolon Slough, was sampled for the 2001/02 monitoring season. Two other dry weather events were sampled on June 18th, 2002 and July 9th, 2002. Results of these events will be included in the October 2002 annual report.

The following table summarizes the samples collected at each of the monitoring locations.

Table 4: 2001/02 Monitoring Event Summary

(Storm/Dry) Event Number	(Storm/Dry) Event Date	A-1 Wood Road*	I-2 Ortega Street	R-1 Swan Street	W-3 La Vista Avenue	W-4 Revolon Slough	ME-CC Calleguas Creek-CSUCI	ME-SCR Santa Clara River	ME-VR Ventura River-Foster Park
1	8/9/01						CG	-	CG
2	11/12/01	-	-	-	-	-	CG	CG	CG
3	3/8/02	-	-	-	-	-	CG*	CG*	CG*
4	4/11/02	CG*	-	-	-[2]	CG*	CG*	CG*	CG*
5	4/25/02	-	-	-	-	-	CG*	CG*	CG*

Notes:

1) "G" indicates that a grab sample was collected.
   "C" indicates that a composite sample was collected.
   "-" indicates that no sample was collected.
   " * " indicates that dry monitoring sample was collected.
2) Insufficient Flow Available

__Flow Rates__

Flow rates were calculated at each of the mass emissions sites to establish baseline conditions and load estimates. Flow rate was measured on an hourly basis at each mass emission station and averaged over a 48 hour period for dry weather samples. Wet weather flow rates were calculated by averaging flow throughout the event. Table 5 summarizes flow rate at the mass emissions stations:

Table 5: Average Daily Flow Rate and Volume for Mass Emissions Sites

Event	Date	ME-CC (Calleguas Creek) (GPM)	ME-VR (Ventura River) (GPM)
1	8/9/2001*	11,643	43,354
2	11/12/01	27,410	32,644
3	3/8/02	10,344	26,490
4	4/12/2002*	15,925	27,513
5	4/25/2002*	12,469	26,400

* Dry Weather Sample

Flow rates were calculated using flow volume data collected from ISCO data logging equipment. This data was then processed through ISCO Flowlink software to determine total volume over a 48 hour period. This total volume was then averaged to determine a 24 hour (daily) average flow. Flow was not determined at the Santa Clara River mass emission station due to the irregular flowrates caused by the diversion dam. As described before, United Water Conservation District diverts water away from Santa Clara River at times for their infiltration facilities. There is no fixed time schedule for diverting water which makes it difficult to determine a daily average flow.

Event 1 at ME-VR had some problems with the flow rate being calculated as zero. These zeroes were not included in the 24 hour (daily) flow rate calculations. Reasons for zero flow rate calculated is the broad ratings curves used to determine flow rate. To calculate flow rate using the ratings curves, the level of the river is measured and extrapolated against the ratings curve to determine flow rate. The resolution of the ratings curve during Event 1 was broad meaning that accuracy of flow rate calculation was not very good. A combination of low river levels (summer season) and broad resolution of the ratings curve calculated the flow rate to be close to zero. For subsequent events, a more accurate narrow resolution ratings curve was used to determine flow rate.

Table 40: Mass Emissions Sites - Objective Exceedances

Site	Constituent	Units	Fraction	Min	Max	N	CTR Acute	OP Inst.	Basin Plar
ME-CC	Copper	ug/l	Total	ND	93	10	30%	30%	*
	Copper	ug/l	Dissolved	4	35	10	0%	0%	*
	Lead	ug/l	Total	ND	39.1	10	0%.	30%	*
	Total Dissolved Solids	mg/l	Total	216	944	10	*	70%	*
	bis(2-ethylhexyl)phthalate)	ug/l	Total	203	402	10	*	50%	*
	Fecal Coliform	MPN/100ml	Total	80	30000	10	*	*	90%
ME-SCR	Fecal Coliform	MPN/100ml	Total	1600	16000	4	*	*	100%
	Copper	ug/l	Total	4	42	4	0%	25%	*
	Total Dissolved Solids	mg/l	Total	ND	1260	4	*	*	50%
ME-VR	Copper	ug/l	Total	ND	104	10	10%	20%	*
	Copper	ug/l	Dissolved	1	84	10	10%	0%	*
	Zinc	ug/l	Total	ND	450	10	0%	10%	*
	Total Dissolved Solids	mg/l	Total	172	690	10	*	*	70%
	Fecal Coliform	MPN/100ml	Total	ND	16000	10	*	*	60%
	bis(2-ethylhexyl)phthalate)	ug/l	Total	158	388	10	*	50%	*

* Have no applicable objectives
ND – Not Detected

Table 41: Receiving Water Sites - Objective Exceedances

Site	Constituent	Units	Fraction	Min	Max	N	CTR Acute	OP Inst.	CTR Organisms Only	Basin Plan
W4	Chromium	ug/l	Total	3	171	14	0%	0%	*	64%
	Copper	ug/l	Total	8	187	14	77%	0%	*	77%
	Lead	ug/l	Total	0.4	69.8	14	0%	0%	*	62%
	Nickel	ug/l	Total	15	145	14	0%	0%	*	43%
	Silver	ug/l	Total	ND	9.9	14	0%	0%	*	7%
	Zinc	ug/l	Total	20	670	14	0%	0%	*	50%
	Fecal Coliform	MPN/100ml	Total	8000	28000	14	*	*	*	100%
	4,4' – DDD	ng/l	Total	ND	148	14	*	*	79%	*
	4,4' – DDE	ng/l	Total	ND	812	14	*	*	93%	*
	4,4' – DDT	ng/l	Total	ND	247	14	*	*	79%	*
	bis(2-ethylhexyl)phthalate)	ug/l	Total	ND	744	14	*	*	*	71%
	alpha-Chlordane	ug/l	Total	ND	13	14	*	*	*	50%
	gamma-Chlordane	ug/l	Total	ND	8.9	14	*	*	*	50%
	Benzo(a)pyrene	ug/l	Total	ND	23	14	*	*	*	57%
	Total Dissolved Solids	mg/l	Total	254	3490	14	*	*	*	43%
	Nitrate Nitrogen	mg/l	Total	2.4	214	14	*	*	*	21%
W3	Arsenic	ug/l	Total	8.8	188	17	0%	18%	*	0%
	Cadmium	ug/l	Total	ND	15.7	17	12%	6%	*	0%
	Copper	ug/l	Total	77	1750	17	88%	88%	*	0%
	Copper	ug/l	Dissolved	12	188	17	82%		*	0%
	Lead	ug/l	Total	ND	448	17	12%	0%	*	0%
	Nickel	ug/l	Total	16	570	17	0%	53%	*	0%
	Silver	ug/l	Total	ND	13	17	0%	6%	*	0%
	Zinc	ug/l	Total	68	2900	17	0%	59%	*	0%
	Fecal Coliform	MPN/100ml	Total	13000	500000	17	*	*	*	100%
	4,4' - DDD	ng/l	Total	ND	77.9	17	*	*	59%	*
	4,4' - DDE	ng/l	Total	ND	892	17	*	*	76%	*
	4,4' - DDT	ng/l	Total	ND	184	17	*	*	53%	*
	alpha-Chlordane	ug/l	Total	ND	17.4	17	*	*	*	29%
	gamma-Chlordane	ug/l	Total	ND	12.1	17	*	*	*	29%
	Benzo(a)pyrene	ug/l	Total	ND	64	17	*	*	*	29%
	bis(2-ethylhexyl)phthalate)	ug/l	Total	ND	2180	17	*	*	*	77%

* Have no applicable objectives
ND – Not Detected

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Table 42: Land Use Sites - Objective Exceedances

Site	Constituent	Units	Fraction	Min	Max	N	CTR Acute	OP Inst.	CTR Organisms Only	Basin Plan
A1	Cadmium	ug/l	Total	ND	12	23	0%	4%	*	0%
	Copper	ug/l	Total	ND	382	23	83%	87%	*	0%
	Lead	ug/l	Total	0.6	104.1	23	0%	57%	*	0%
	Nickel	ug/l	Total	4	152	23	0%	78%	*	0%
	Silver	ug/l	Total	ND	8.6	23	0%	4%	*	0%
	Zinc	ug/l	Total	ND	620	23	0%	70%	*	0%
	4,4-DDD	ng/l	Total	ND	872	23	*	*	52%	*
	4,4-DDE	ng/l	Total	ND	2940	23	*	*	74%	*
	4,4-DDT	ng/l	Total	ND	810	23	*	*	83%	*
	bis(2-ethylhexyl) phthalate	ug/l	Total	ND	602	23	*	*	*	50%
	Fecal Coliform	MPN/100ml	Total	120	110000	23	*	*	*	4%
	Total Dissolved Solids	mg/l	Total	241	1510	23	*	*	*	48%
I2	Copper	ug/l	Total	6	140	24	83%	46%	*	0%
	Copper	ug/l	Dissolved	6	48	24	58%		*	0%
	Lead	ug/l	Total	3	72	24	4%	4%	*	0%
	Nickel	ug/l	Total	ND	120	24	0%	17%	*	0%
	Silver	ug/l	Total	ND	4.1	24	13%	0%	*	0%
	Zinc	ug/l	Total	67	660	24	63%	38%	*	0%
	Zinc	ug/l	Dissolved	6	252	24	17%	*	*	0%
	Antimony	ug/l	Total	ND	36	24	*	*	*	13%
	Fecal Coliform	MPN/100ml	Total	300	160000	24	*	*	*	100%
	Thallium	ug/l	Total	ND	29	24	*	*	*	13%
R1	Copper	ug/l	Total	3.8	5	28	71%	32%	*	0%
	Copper	ug/l	Dissolved	67	38	28	54%	*	*	
	Lead	ug/l	Total	2	61	28	18%	36%	*	0%
	Lead	ug/l	Dissolved	ND	44	28	4%	*	*	
	Fecal Coliform	MPN/100ml	Total	500	160000	28	*	*	*	100%
	Nickel	ug/l	Total	ND	53	28	0%	4%	*	0%
	Silver	ug/l	Total	ND	18	28	14%	0%	*	0%
	Zinc	ug/l	Total	26	444	28	64%	25%	*	0%
	Zinc	ug/l	Dissolved	17	153	28	25%	*	*	

*Have no applicable objectives
ND – Not Detected

the work plan, the County conducted a March 2001 training session on bioassessment monitoring techniques. The actual bioassessment monitoring is scheduled to begin in the Fall of 2001.

In January, 2001, the Ventura County Flood Control District (VCFCD) began participating in the Ventura River volunteer monitoring effort. The VCFCD provides technical guidance and assistance for volunteer monitoring at thirteen sites on the Ventura River.

Summary of Monitoring Events

SAMPLE COLLECTION

Four wet weather monitoring events were monitored in 2000/2001. Samples were collected at the land use and receiving water monitoring sites during one wet weather event and the remaining three events were collected at the mass emission sites. One dry weather monitoring event was conducted on May 15, 2001 at the mass emission stations. However, the complete set of results for this event have not yet been received from the laboratories, and a discussion of this event is not included in this report. The wet weather monitoring events in 2000/2001 and the types of samples collected are summarized in Table 2.

Samples were collected as either flow-based composite samples or as grab samples. Automated equipment was used to collect composite samples at all locations except W-4, where a permanent monitoring station has not been installed. A permanent monitoring station is in the process of being installed at W-4 and will be operational by the start of the 2001/2002 wet weather monitoring. In addition, the permanent monitoring stations at the discharge characterization sites (A-1, I-2, and R-1) are being upgraded. The W-4 station and the upgraded units will be automated, refrigerated samplers with rain gauges and telemetry access similar to the equipment installed on at the two mass emission monitoring stations. The new equipment will be compatible with the new water quality YSI 6600 water sonde purchased by the monitoring program. The sonde will allow the measurement of fourteen parameters (including dissolved oxygen, pH, temperature, conductivity, nutrients, chloride and chlorophyll-a) at five minute intervals.

can be interpreted as the best available estimate of the event mean concentrations (EMC) for the given storm event. Table 6 through Table 10 contain the water quality monitoring and toxicity monitoring results from the discharge characterization sites and the receiving water monitoring stations. A complete set of results, as exported from the database, is included as Appendix 2. The data in the appendix includes appropriate qualifiers identified in the QA/QC analysis.

Table 6. Conventional and Nutrient Results from the Discharge Characterization and Receiving Water Stations

		1/10/01		
Constituent	***Units***	***A1-Wood Road***	***W3-La Vista***	***W4-Revolon Slough***
BOD5	mg/L	10	35	16
Conductivity	µmhos/cm	279	314	420
Hardness as CaCO3	mg/L	190	270	242
pH	STD UNITS	8	7	7.6
Solids, Total Dissolved	mg/L	366	236	254
Solids, Total Suspended	mg/L	2300	20000	4100
Bromide	mg/L	<0.5	<0.5	<0.5
Chloride	mg/L	17	16	20
Fecal Coliform	MPN/100 mL	5000	30000	13000
Fecal Streptococcus	MPN/100 mL	80000	300000	900000
Total Coliform	MPN/100 mL	500000	900000	1600000
Total Organic Carbon	mg/L	7	29	12
Oil and Grease	mg/L	<3	<3	<3
Ammonia as N	mg/L	0.9	0.4	0.5 *
Nitrate as N	mg/L	7.66	4.64	4.94 *
Orthophosphate-P	mg/L	0.95	0.51	0.55
Phosphorus, Dissolved	mg/L	0.99	0.57	0.64
Phosphorus, Total	mg/L	4.19	3.48	2.76 *
TKN	mg/L	9.8	14.8	10.9 *
TRPH	mg/L	<0.5	<0.5	0.7

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 7. Metals and MTBE Results from the Discharge Characterization and Receiving Water Stations

Constituent	Fraction	Units	1/10/01 A1-Wood Road	1/10/01 W3-La Vista	1/10/01 W4-Revolon Slough
Arsenic	Total	µg/L	27	188	35 *
Arsenic	Dissolved	µg/L	4	4	
Cadmium	Total	µg/L	9	15.7	6.5 *
Cadmium	Dissolved	µg/L	<0.2	<0.2	
Chromium	Total	µg/L	178	690	171 *
Chromium	Dissolved	µg/L	1	<1	
Copper	Total	µg/L	161	1750	187 *
Copper	Dissolved	µg/L	8	47	
Lead	Total	µg/L	54.3	448	69.8 *
Lead	Dissolved	µg/L	0.8	2.5	
Mercury	Total	ng/L	279	97.1	282 *
Mercury	Dissolved	ng/L	<0.83 *	<3.3 *	<1.54 *
Nickel	Total	µg/L	152	570	145 *
Nickel	Dissolved	µg/L	5	6	
Selenium	Total	µg/L	3	21	5 *
Selenium	Dissolved	µg/L	<2	<2	
Silver	Total	µg/L	<1	1 *	<1 *
Silver	Dissolved	µg/L	<1	<1 *	
Thallium	Total	µg/L	1.1	3.5	1.7 *
Thallium	Dissolved	µg/L	<0.2	<0.2	
Zinc	Total	µg/L	620	2900 *	540 *
Zinc	Dissolved	µg/L	<4	15 *	
Methyl Tertiary Butyl Ether		µg/L	<0.5	<0.5	<0.5

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 8. Pesticides and PCBs Results from the Discharge Characterization and Receiving Water Sites

Constituent	Units	1/10/01 A1-Wood Road	1/10/01 W3-La Vista	1/10/01 W4-Revolon Slough
EPA 8270				
2,4'-DDD	ng/L	110	<1	16.5 *
2,4'-DDE	ng/L	34.6	<1	12.3 *
2,4'-DDT	ng/L	451 *	247 *	92.9 *
4,4'-DDE	ng/L	1335 *	892 *	336 *
4,4'-DDT	ng/L	23 *	157 *	16 *
Chlordane, alpha	ng/L	7.4	17.4	10.9
Chlordane, gamma	ng/L	5.87	12.1	6.54
Methoxychlor	ng/L	<2 *	<2 *	<2 *
Mirex	ng/L	<2 *	<2 *	<2 *
Total Detectable DDTs	ng/L	1954	1296	474 *
Remaining 8270 non-detect at 1, 2,10, and 100 ng/L				
EPA 8270 (PCBs)				
PCB018	ng/L	112 *	<1 *	38.3 *
Total Detectable PCBs	ng/L	112	<1	38.3
Remaining 8270 PCBs non-detect at 1 ng/L.				
EPA 8151				
2,4-D	μg/L	<0.5	1.5 *	<0.5
Dinoseb	μg/L	<0.25	0.4 *	<0.25
Remaining 8151 non-detect at 0.1, 0.25, 0.5, and 1 μg/L				
EPA 8141				
Chlorpyrifos	μg/L	<0.05	0.46	0.9
Demeton	μg/L	<0.2 R*	<0.2 R*	<0.2 R*
Diazinon	μg/L	0.07	<0.05	0.22
EPTC	μg/L	0.16 *	<0.1	0.4 *
Malathion	μg/L	<0.1	<0.1	0.31
Simazine	μg/L	<0.1	100	13
Remaining 8141 non-detect at 0.1, 0.2, 0.5, 0.7, and 1 μg/L.				

"R" indicates a rejected organics result based on a laboratory control spike recovery below acceptable limits and the fact that the environmental sample result was not detected above the reporting limit.

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 9. Semi/Non-Volatile Results (EPA 8270) from the Discharge Characterization and Receiving Water Sites

Constituent	Units	1/10/01		
		A1-Wood Road	*W3-La Vista*	*W4-Revolon Slough*
1-Methylnaphthalene	ng/L	16	13	13
1-Methylphenanthrene	ng/L	<5	<5	<5 *
2,4-Dichlorophenol	ng/L	<50	65	<50
2,6-Dimethylnaphthalene	ng/L	15	<5	<5 *
2-Methylnaphthalene	ng/L	19	20	9 *
Acenaphthene	ng/L	13	<5	<5
Anthracene	ng/L	19	22	9 *
Benzo(a)anthracene	ng/L	25	46	<5 *
Benzo(a)pyrene	ng/L	27	64	23 *
Benzo(b)fluoranthene	ng/L	28	91	21 *
Benzo(e)pyrene	ng/L	20	61	28 *
Benzo(ghi)perylene	ng/L	19	66	22 *
Benzo(k)fluoranthene	ng/L	20	38	26 *
Biphenyl	ng/L	5	18	12 *
Bis(2-ethylhexyl)phthalate	ng/L	<240 *	<299 *	<213 *
Butyl benzyl phthalate	ng/L	<23 *	<10	<39 *
Chrysene	ng/L	66	98	37 *
Di-n-octyl Phthalate	ng/L	24	<10	23 *
Dibutyl Phthalate	ng/L	<50 *	<86 *	<54 *
Diethyl Phthalate	ng/L	<103 *	<112 *	<66 *
Dimethyl Phthalate	ng/L	57 *	49 *	<10 *
Fluoranthene	ng/L	86	114	56 *
Fluorene	ng/L	20	<5	<5 *
Indeno(1,2,3-cd)pyrene	ng/L	23	49	19 *
Naphthalene	ng/L	18	35	26 *
Perylene	ng/L	<5	<5	14 *
Phenanthrene	ng/L	87	75	59 *
Pyrene	ng/L	70	95	41 *
Total Detectable PAHs	ng/L	596	905	415 *
Remaining Semi/Non-Volatiles non-detect at 5, 50, 100, 200, and 500 ng/L.				

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 10. Acute Toxicity Results from the Discharge Characterization and Receiving Water Stations

Toxicity Result	Units	1/10/01				
		I2-Ortega St.	R1-Swan St.	A1-Wood Rd.	W3-La Vista	W4-Revolon
Acute Ceriodaphnia Survival	LC50	100%	100%	37.5%	18.8%	18.8%
Acute Ceriodaphnia Survival	TUa	0	0	2.67	5.33	5.33

At the agricultural discharge station (A1) and the two receiving water stations, which drain primarily agricultural areas, a number of commonly used pesticides (diazinon, chlorpyrifos, and simazine) were detected as well as a number of historically used pesticides (DDT and it's derivatives and chlordane). Additionally, a large number of semi-volatile and non-volatile compounds were detected in the runoff and receiving water. Discharges from the agricultural station exhibited toxicity, but significantly more toxicity was present in the receiving water. TIEs were requested by the VCFCD sampling crew on the chain-of-custody submitted to laboratory. However, the analyses were not conducted by the laboratory. In the future, the VCFCD will contact the laboratory to determine whether toxicity has been observed in the samples and ensure that TIEs are conducted if toxicity above 1 TUa is observed. Toxicity was not observed in the discharges from the industrial and residential monitoring locations.

Mass Emission Station Water Quality Results

Table 11 through Table 15 present the results from the wet weather monitoring events at the Calleguas Creek and Ventura River Mass Emission stations.

Table 11. Conventional and Nutrient Results from the Mass Emission Stations

Constituent	Units	ME-CC, Calleguas Creek			ME-VR, Ventura River		
		2/13/01	2/26/01	3/5/01	2/13/01	2/26/01	3/5/01
BOD5	mg/L	27	16 *	10	30	3	4
Conductivity	µmhos/cm	356	438	388	455	631	263
Hardness as CaCO3	mg/L	184	204	142	184	272	122
pH	STD UNITS	8	7.8	8	7.7	8	8.1
Solids, Total Dissolved	mg/L	216	224 *	242	328	420	172
Solids, Total Suspended	mg/L	1620	3900 *	2100	920	190	3500
Bromide	mg/L	<0.5	<0.5	<0.5	0.04 *	<0.5	<0.5
Chloride	mg/L	21	29	18	16	13	4
Fecal Coliform 400	MPN/100 mL	2200	30000	28000	5000	800	2300
Fecal Streptococcus	MPN/100 mL	2300	240000	140000	3000	17000	13000
Total Coliform	MPN/100 mL	30000	170000	500000	160000	13000	70000
Carbon, Total Organic	mg/L	5.2	12.9 *	7.3	5.9	6.9	5.7
Oil & Grease	mg/L	<3	<3	<3	<3	<3	<3
Ammonia as N	mg/L	0.1	0.3	0.3	0.1	<0.1	0.1
Nitrate as N	mg/L	2.35	2.26	2.23	2.22	1.32	2.19
Orthophosphate-P	mg/L	0.37	0.44	0.5	0.29	0.14	0.15
Phosphorus, Total	mg/L	2.42	3.07	4.12	1.73	0.17	3.72
Phosphorus, Dissolved	mg/L	0.45	0.47	0.6	0.35	0.17	0.35
TKN	mg/L	2.5	7.6	4.5	6.2	2.5	5.6
TRPH	mg/L	<0.5	<0.5	<1	0.17 *	<0.5	<1

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 12. Metals Results from the Mass Emission Stations

			ME-CC, Calleguas Creek			ME-VR, Ventura River		
Constituent	Fraction	Units	2/13/01	2/26/01	3/5/01	2/13/01	2/26/01	3/5/01
Arsenic	Total	µg/L	14.6	14	10	7.2	<2	21
Arsenic	Dissolved	µg/L	5	4	2	3.2	<2	<2
Cadmium	Total	µg/L	4.65	5.3	2.7	5.45	0.8	2.7
Cadmium	Dissolved	µg/L	<0.2	<0.2	0.2	<0.11 *	<0.2	<0.2
Chromium	Total	µg/L	140	129	80	53.8	16	151
Chromium	Dissolved	µg/L	<1 *	2	<1 *	<1.1 *	2	<1
Copper	Total	µg/L	79.5	93	<62 *	41.2	10	104
Copper	Dissolved	µg/L	<3.1 *	35	12	<4.2 *	84	<10 *
Lead	Total	µg/L	31.4	39.6	22.4	16.9	3.6	52.6
Lead	Dissolved	µg/L	<0.48 *	3.1	<2 *	<0.51 *	31.7	<4.3 *
Mercury	Total	ng/L	265	133	93.9	35.2	11	128
Mercury	Dissolved	ng/L	2.14	3.63	3.97	3.38	2.11	1.6
Nickel	Total	µg/L	105	112	58	53	17	137
Nickel	Dissolved	µg/L	<4.7 *	7	9	<4.7 *	9	5
Selenium	Total	µg/L	<4.4 *	4	3	<3.6 *	3	5
Selenium	Dissolved	µg/L	<2.3 *	<2	3	<2.8 *	2	2
Silver	Total	µg/L	0.6 *	2	<1	0.1 *	<1	<1
Silver	Dissolved	µg/L	0.1 *	<1	<1	<1 *	<1	<1
Thallium	Total	µg/L	0.53	0.6	0.4	0.27	<0.2	0.9
Thallium	Dissolved	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	Total	µg/L	273	290	101 *	<105 *	41	450
Zinc	Dissolved	µg/L	<16.8 *	42	<26 *	<40.1 *	103	<44 *

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

13µg/L

2.5 [illegible]

Table 13. Pesticide and PCB Results from the Mass Emission Stations

Constituent	Units	ME-CC, Calleguas Creek			ME-VR, Ventura River		
		2/13/01	2/26/01	3/5/01	2/13/01	2/26/01	3/5/01
EPA 8270							
2,4'-DDD	ng/L	<1	<1	5.2	<1	<1	<1
2,4'-DDT	ng/L	6.9	11.8	12.9	<1	<1	<1
4,4'-DDD	ng/L	4.4	15.3	9.1	<1	<1	<1
4,4'-DDE	ng/L	49.6	119	83.3	8.3	<1	8.1
4,4'-DDT	ng/L	4.1 *	<1 *	13.3 *	<1 *	<1 *	<1
Chlordane, alpha	ng/L	2.8	1.5	<2	<2	<2	<2
Chlordane, gamma	ng/L	3.6	3.1	<2	<2	<2	<2
Endosulfan Sulfate	ng/L	<2 *	<2	<2	<2 *	<2	<2
Heptachlor	ng/L	<2	<2 *	<2	<2	<2 *	<2
Methoxychlor	ng/L	<2 *	<2 *	<2 *	<2 *	<2 *	<2
Mirex	ng/L	<2 *	<2 *	<2 *	<2 *	<2 *	<2
Total Detectable DDTs	ng/L	65	146	124	8.3	<1	8.1
Remaining 8270 non-detect at 1, 2,10, and 100 ng/L.							
EPA 8270 (PCBs)							
PCB04	ng/L	9.2			<1		
PCB095	ng/L	4			<1		
Total Detectable PCBs	ng/L	13.2	<1	<1	<1	<1	<1
Remaining 8270 PCBs non-detect at 1 ng/L.							
EPA 8151							
2,4-D	μg/L	<0.5	<0.5	0.34 *	<0.5	<0.5	<0.5
Remaining 8151 non-detect at 0.1, 0.25, 0.5, and 1 μg/L.							
EPA 8141							
Chlorpyrifos	μg/L	<0.05	<0.05	0.04 *	<0.05	<0.05	<0.05
Diazinon	μg/L	0.07	0.07	0.13	<0.05	<0.05	<0.05
Ethoprop	μg/L	<0.1 *	<0.1	<0.1	<0.1 *	<0.1	<0.1
Simazine	μg/L	0.4 *			0.3 *		
Remaining 8141 non-detect at 0.1, 0.2, 0.5, 0.7, and 1 μg/L.							

* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 14. Semi/Non-Volatile Results (EPA 8270) from the Mass Emission Stations

Constituent	Units	*ME-CC, Calleguas Creek*			*ME-VR, Ventura River*		
		2/13/01	*2/26/01*	*3/5/01*	*2/13/01*	*2/26/01*	*3/5/01*
1,2,4-Trichlorobenzene	ng/L	<50	<50 *	<50 *	<50	<50 *	<50
1-Methylnaphthalene	ng/L	<5	<5	<5	15	<5	373
1-Methylphenanthrene	ng/L	<5	<5	<5	17	<5	202
2,3,5-Trimethylnaphthalene	ng/L	<5	<5	<5	<5	24	73
2,6-Dimethylnaphthalene	ng/L	<5	7	<5	25	6	370
2-Methylnaphthalene	ng/L	<5	5	<5	20	<5	428
Anthracene	ng/L	<5	6	<5	<5	<5	<5
Benzo(a)anthracene	ng/L	11	19	13	<5	<5	28
Benzo(a)pyrene	ng/L	8	26	11	7	<5	15
Benzo(b)fluoranthene	ng/L	18	36	22	20	<5	34
Benzo(e)pyrene	ng/L	10	24	15	15	<5	48
Benzo(ghi)perylene	ng/L	8 *	32	11	9 *	<5	8
Benzo(k)fluoranthene	ng/L	7	12	6	<5	<5	8
Biphenyl	ng/L	<5	6	<5	12	<5	102
bis(2-Chloroisopropyl)ether	ng/L	175	188	<100	195	<100	<100
Bis(2-ethylhexyl)phthalate	ng/L	<274 *	<402 *	<372 *	<331 *	<172 *	<222
Butyl benzyl phthalate	ng/L	<87 *	<122 *	<62 *	<43 *	<50 *	<39
Chrysene	ng/L	16	36	22	36	<5	114
Di-n-octyl Phthalate	ng/L	33 *	38 *	36	51 *	12 *	<10
Dibenzo(a,h)anthracene	ng/L	<5 *	<5	<5	<5 *	<5	9
Dibutyl Phthalate	ng/L	<93 *	<156 *	<102 *	<71 *	<97 *	<115
Diethyl Phthalate	ng/L	<111 *	<102 *	<49 *	<32 *	<77 *	<55
Dimethyl Phthalate	ng/L	<20 *	14 *	12	<10	<10	<10
Fluoranthene	ng/L	23	44	34	23	<5	49
Fluorene	ng/L	<5	<5	<5	6	<5	45
Indeno(1,2,3-cd)pyrene	ng/L	11	27	12	7	<5	10
Naphthalene	ng/L	<9 *	<5	7	<13 *	<5	155
Perylene	ng/L	<5	21	6 *	57	7	37
Phenanthrene	ng/L	20	25	23	65	11	582
Pyrene	ng/L	23	49	38	23	6	70
Total Detectable PAHs	ng/L	164	375	220	370	54	2760

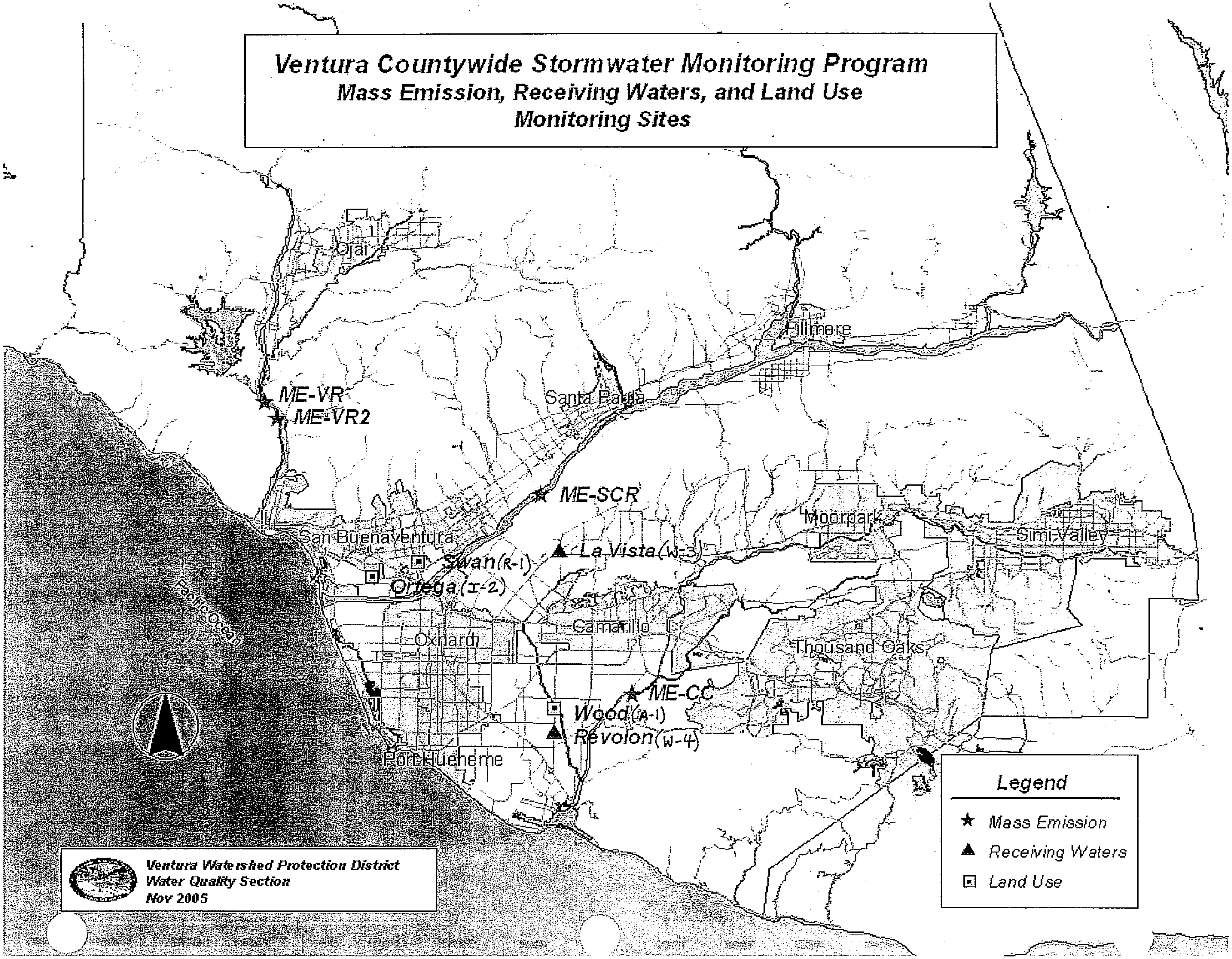
* See Appendix 2 for a description of the data qualifiers associated with this sample result.

Table 15. Chronic Toxicity Results from the Mass Emission Stations

Toxicity Result	*Units*	*ME-CC, Calleguas Creek* 02/13/01	*ME-CC, Calleguas Creek* 02/26/01	*ME-VR, Ventura River* 02/13/01	*ME-VR, Ventura River* 02/26/01
Chronic Silversides Larvae Survival	NOEC	50%	100%	100%	100%
	TUc	2	1	1	1
	IC25	92%	>100%	>100%	>100%
	IC50	>100%	>100%	>100%	>100%
Chronic Silversides Larvae Growth	NOEC	100%	100%	100%	100%
	TUc	1	1	1	1
	IC25	>100%	>100%	>100%	>100%
	IC50	>100%	>100%	>100%	>100%

The Calleguas Creek and Ventura River mass emission stations were monitored for the first time in 2000/01. Although this was the first year of stormwater mass emission monitoring, the VCFCD participated previously in a year long characterization of the Calleguas Creek watershed through a comprehensive monitoring program (CMP). The CMP involved monthly monitoring from July, 1998 through June, 1999. The results of this monitoring program can be found in *Results of the Coordinated Water Quality Monitoring Program, Surface Water Element* (LWA, 2000).

The results from the mass emission monitoring indicate that the conventional constituents and metals in the two watersheds are similar, with the exception that Calleguas Creek had higher total suspended solids concentrations than the Ventura River. In Calleguas Creek, many more pesticides were detected than in the Ventura River. In Calleguas Creek, eight historical pesticides (DDT and its derivatives and chlordane), diazinon, chlorpyrifos, and simazine were detected in at least one storm event. Only simazine and 4,4-DDE were detected in the Ventura River. Additionally, PCBs were detected in Calleguas Creek, but not in the Ventura River. On the other hand, the Ventura River appears to have higher PAH concentrations than Calleguas Creek and more semi volatiles and non-volatiles were detected in Ventura River than Calleguas Creek. Toxicity was only observed during one monitoring event in Calleguas Creek. Toxicity was not observed in the Ventura River.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Moorpark
Simi Valley
San Buenaventura
La Vista (W-3)
Swan (R-1)
Ortega (I-2)
Pacific Ocean
Camarillo
Oxnard
Thousand Oaks
ME-CC
Wood (A-1)
Revolon (W-4)
Port Hueneme
Legend
Mass Emission
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Water Quality Section
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Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
ME-CC	2003/04	Bacteriological	E. Coli	235	
ME-CC	2004/05	Bacteriological	E. Coli	235	
ME-CC	2005/06	Bacteriological	E. Coli	235	
ME-CC	2006/07	Bacteriological	E. Coli	235	
ME-CC	2003/04	Bacteriological	Fecal Coliform	400	
ME-CC	2004/05	Bacteriological	Fecal Coliform	400	
ME-CC	2005/06	Bacteriological	Fecal Coliform	400	
ME-CC	2006/07	Bacteriological	Fecal Coliform	400	
ME-CC	2003/04	Metal	Aluminum -Total	1000	
ME-CC	2004/05	Metal	Aluminum -Total	1000	
ME-CC	2005/06	Metal	Aluminum -Total	1000	
ME-CC	2006/07	Metal	Aluminum -Total	1000	
ME-CC	2003/04	Metal	Barium - Total	1000	
ME-CC	2003/04	Metal	Beryllium - Total	4	
ME-CC	2003/04	Metal	Cadmium - Total	5	
ME-CC	2004/05	Metal	Cadmium - Total	5	
ME-CC	2003/04	Metal	Chromium - Total	50	
ME-CC	2004/05	Metal	Chromium - Total	50	
ME-CC	2003/04	Metal	Mercury - Total		.051^
ME-CC	2004/05	Metal	Mercury - Total		.051^
ME-CC	2005/06	Metal	Mercury - Total		.051^
ME-CC	2006/07	Metal	Mercury - Total		.051^
ME-CC	2003/04	Metal	Nickel - Total	100	
ME-CC	2004/05	Metal	Nickel - Total	100	
ME-CC	2004/05	Nurtrient	Nitrate as N	10	
ME-CC	2004/05	Organic	Benzo(a)anthracene		.049^
ME-CC	2005/06	Organic	Benzo(a)anthracene		.049^
ME-CC	2004/05	Organic	Benzo(a)pyrene		.049^
ME-CC	2005/06	Organic	Benzo(a)pyrene		.049^
ME-CC	2004/05	Organic	Benzo(b)fluoranthene		.049^
ME-CC	2005/06	Organic	Benzo(b)fluoranthene		.049^
ME-CC	2006/07	Organic	Benzo(b)fluoranthene		.049^
ME-CC	2004/05	Organic	Benzo(k)fluoranthene		.049^
ME-CC	2005/06	Organic	Benzo(k)fluoranthene		.049^
ME-CC	2006/07	Organic	Benzo(k)fluoranthene		.049^
ME-CC	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-CC	2005/06	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-CC	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-CC	2003/04	Organic	Chrysene		.049^
ME-CC	2004/05	Organic	Chrysene		.049^
ME-CC	2005/06	Organic	Chrysene		.049^
ME-CC	2006/07	Organic	Chrysene		.049^
ME-CC	2006/07	Organic	Indeno(1,2,3-cd))pyrene		.049^
ME-CC	2004/05	Organic	Indeno(1,2,3-cd)pyrene		.049^
ME-CC	2004/05	Pesticide	4,4'-DDD		.00084^
ME-CC	2005/06	Pesticide	4,4'-DDD		.00084^
ME-CC	2006/07	Pesticide	4,4'-DDD		.00084^
ME-CC	2003/04	Pesticide	4,4'-DDE		.00059^
ME-CC	2004/05	Pesticide	4,4'-DDE		.00059^
ME-CC	2005/06	Pesticide	4,4'-DDE		.00059^
ME-CC	2006/07	Pesticide	4,4'-DDE		.00059^

A009491

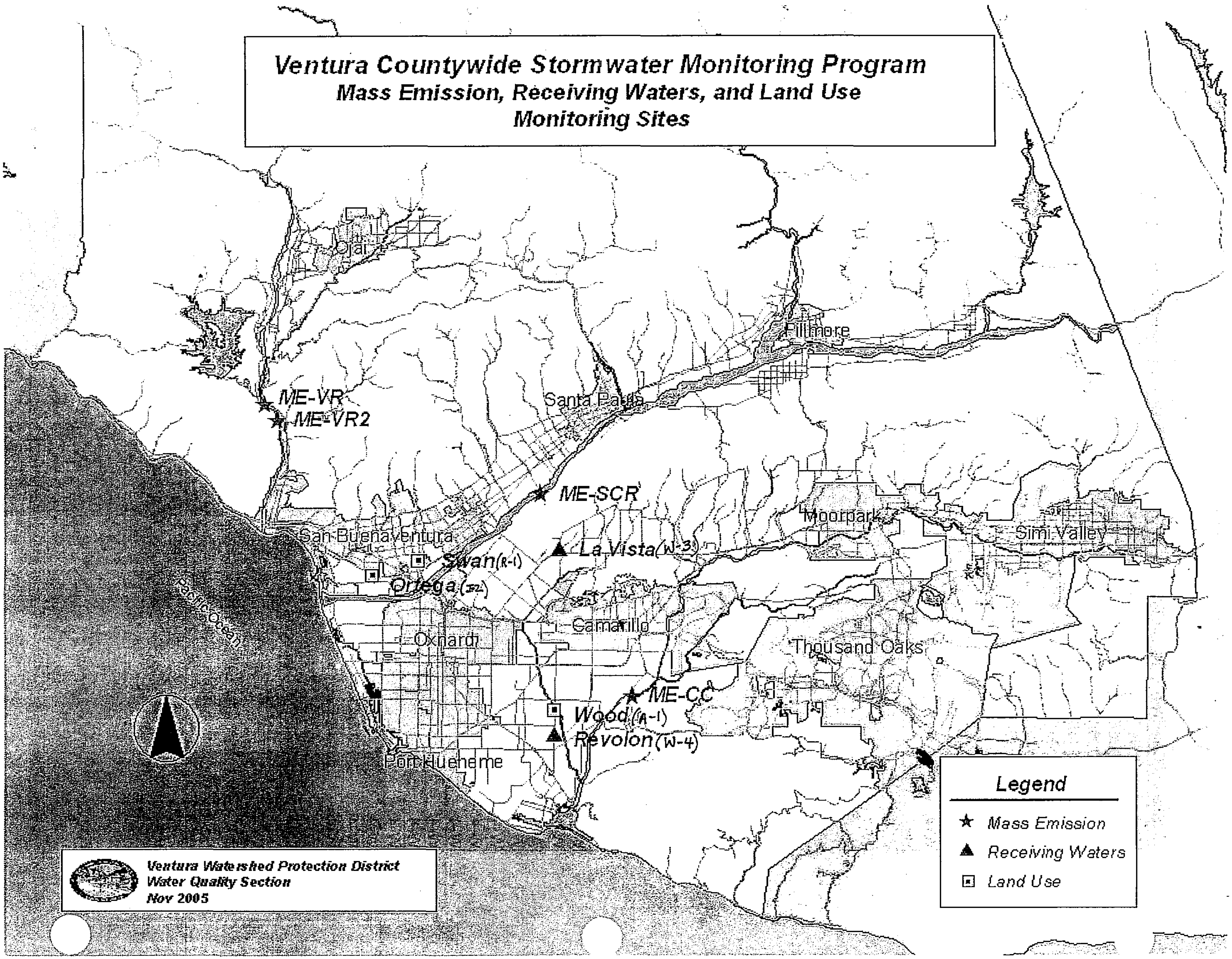
Site	Date/Year	Classification	Constituent	Basin Plan	CTR Chronic (Dry)
ME-CC	2003/04	Anion	Chloride	150	
ME-CC	2004/05	Anion	Chloride	150	
ME-CC	2005/06	Anion	Chloride	150	
ME-CC	2006/07	Anion	Chloride	150	
ME-CC	2003/04	Bacteriological	E. Coli	235	
ME-CC	2005/06	Bacteriological	E. Coli	235	
ME-CC	2003/04	Bacteriological	Fecal Coliform	400	
ME-CC	2005/06	Bacteriological	Fecal Coliform	400	
ME-CC	2003/04	Conventional	TDS	850	
ME-CC	2004/05	Conventional	TDS	1200	6.22
ME-CC	2005/06	Conventional	TDS	850	
ME-CC	2006/07	Conventional	TDS	850	
ME-CC	2005/06	Metal	Aluminum -Total	1000	
ME-CC	2004/05	Metal	Cadmium - Dissolved		6.22
ME-CC	2004/05	Metal	Cadmium - Total	5	
ME-CC	2004/05	Metal	Selenium - Total		5
ME-CC	2004/05	Nutrient	Nitrate as N	10	
ME-CC	2003/04	Organic	Bis(2-ethylhexyl)phthalate	4	
ME-CC	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	
ME-CC	2005/06	Pesticide	4,4'-DDD		.00084
ME-CC	2003/04	Pesticide	4,4'-DDE		.00059^
ME-CC	2005/06	Pesticide	4,4'-DDE		.00059
ME-CC	2006/07	Pesticide	4,4'-DDE		.00059
ME-CC	2005/06	Pesticide	4,4'-DDT		.001

A009492

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
A-1	2004/05	Bacteriological	E. Coli	235	
A-1	2005/06	Bacteriological	E. Coli	235	
A-1	2006/07	Bacteriological	E. Coli	235	
A-1	2004/05	Bacteriological	Fecal Coliform	400	
A-1	2005/06	Bacteriological	Fecal Coliform	400	
A-1	2004/05	Conventional	TDS	500	
A-1	2005/06	Conventional	TDS	500	
A-1	2006/07	Conventional	TDS	500	
A-1	2003/04	Metal	Aluminum -Total	1000	
A-1	2004/05	Metal	Aluminum -Total	1000	
A-1	2006/07	Metal	Aluminum -Total	1000	
A-1	2004/05	Metal	Mercury - Total		.051^
A-1	2003/04	Nutrient	Nitrate as N	10	
A-1	2004/05	Nutrient	Nitrate as N	10	
A-1	2005/06	Nutrient	Nitrate as N	10	
A-1	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
A-1	2003/04	Organic	Hexachlorobenzene		.00077^
A-1	2003/04	Organic	Pentachlorophenol	1	
A-1	2003/04	Pesticide	4,4'-DDD		.00084^
A-1	2004/05	Pesticide	4,4'-DDD		.00084^
A-1	2005/06	Pesticide	4,4'-DDD		.00084^
A-1	2003/04	Pesticide	4,4'-DDE		.00059^
A-1	2004/05	Pesticide	4,4'-DDE		.00059^
A-1	2005/06	Pesticide	4,4'-DDE		.00059^

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
W-3	2003/04	Bacteriological	E. Coli	235	
W-3	2004/05	Bacteriological	E. Coli	235	
W-3	2005/06	Bacteriological	E. Coli	235	
W-3	2006/07	Bacteriological	E. Coli	235	
W-3	2003/04	Bacteriological	Fecal Coliform	400	
W-3	2004/05	Bacteriological	Fecal Coliform	400	
W-3	2005/06	Bacteriological	Fecal Coliform	400	
W-3	2004/05	Conventional	TDS	500	
W-3	2005/06	Conventional	TDS	500	
W-3	2006/07	Conventional	TDS	500	
W-3	2004/05	Metal	Aluminum -Total	1000	
W-3	2005/06	Metal	Aluminum -Total	1000	
W-3	2006/07	Metal	Aluminum -Total	1000	
W-3	2006/07	Metal	Cadmium - Total	5	
W-3	2003/04	Metal	Chromium - Total	50	
W-3	2003/04	Metal	Cooper - Dissolved		14.96
W-3	2003/04	Metal	Mercury - Total		.051^
W-3	2004/05	Metal	Mercury - Total		.051^
W-3	2005/06	Metal	Mercury - Total		.051^
W-3	2006/07	Metal	Mercury - Total		.051^
W-3	2003/04	Nutrient	Nitrate as N	1	
W-3	2004/05	Nutrient	Nitrate as N	10	
W-3	2006/07	Nutrient	Nitrate as N	10	
W-3	2006/07	Organic	Benzo(a)pyrene		.049^
W-3	2006/07	Organic	Benzo(b)fluoranthene		.049^
W-3	2006/07	Organic	Benzo(k)fluoranthene		.049^
W-3	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
W-3	2006/07	Organic	Chrysene		.049^
W-3	2006/07	Organic	Hexachlorobenzene		.00077^
W-3	2006/07	Organic	Indeno(1,2,3-cd)pyrene		.049^
W-3	2003/04	Pesticide	4,4'-DDD		.00084^
W-3	2005/06	Pesticide	4,4'-DDD		.00084^
W-3	2006/07	Pesticide	4,4'-DDD		.00084^
W-3	2003/04	Pesticide	4,4'-DDE		.00059^
W-3	2004/05	Pesticide	4,4'-DDE		.00059^
W-3	2005/06	Pesticide	4,4'-DDE		.00059^
W-3	2006/07	Pesticide	4,4'-DDE		.00059^

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
W-4	2004/05	Bacteriological	E. Coli	235	
W-4	2005/06	Bacteriological	E. Coli	235	
W-4	2006/07	Bacteriological	E. Coli	235	
W-4	2004/05	Bacteriological	Fecal Coliform	400	
W-4	2005/06	Bacteriological	Fecal Coliform	400	
W-4	2006/07	Bacteriological	Fecal Coliform	400	
W-4	2003/04	Conventional	Residual Chlorine	100	
W-4	2004/05	Conventional	TDS	500	
W-4	2005/06	Conventional	TDS	500	
W-4	2006/07	Conventional	TDS	500	
W-4	2003/04	Metal	Aluminum -Total	1000	
W-4	2005/06	Metal	Aluminum -Total	1000	
W-4	2006/07	Metal	Aluminum -Total	1000	
W-4	2004/05	Metal	Mercury - Total		.051^
W-4	2006/07	Metal	Mercury - Total		.051^
W-4	2003/04	Nutrient	Nitrate as N	1	
W-4	2004/05	Nutrient	Nitrate as N	10	
W-4	2005/06	Nutrient	Nitrate as N	10	
W-4	2006/07	Nutrient	Nitrate as N	10	
W-4	2006/07	Organic	Benzo(a)anthracene		.049^
W-4	2005/06	Organic	Benzo(a)pyrene		.049^
W-4	2006/07	Organic	Benzo(a)pyrene		.049^
W-4	2005/06	Organic	Benzo(b)fluoranthene		.049^
W-4	2006/07	Organic	Benzo(b)fluoranthene		.049^
W-4	2005/06	Organic	Benzo(k)fluoranthene		.049^
W-4	2006/07	Organic	Benzo(k)fluoranthene		.049^
W-4	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	
W-4	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
W-4	2005/06	Organic	Chrysene		.049^
W-4	2006/07	Organic	Chrysene		.049^
W-4	2006/07	Organic	Dibenz(a,h)anthracene		.049^
W-4	2006/07	Organic	Hexachlorobenzene		.00077^
W-4	2005/06	Organic	Indeno(1,2,3-cd)pyrene		.049^
W-4	2006/07	Organic	Indeno(1,2,3-cd)pyrene		.049^
W-4	2003/04	Pesticide	4,4'-DDD		.00084^
W-4	2004/05	Pesticide	4,4'-DDD		.00084^
W-4	2005/06	Pesticide	4,4'-DDD		.00084^
W-4	2006/07	Pesticide	4,4'-DDD		.00084^
W-4	2003/04	Pesticide	4,4'-DDE		.00059^
W-4	2004/05	Pesticide	4,4'-DDE		.00059^
W-4	2005/06	Pesticide	4,4'-DDE		.00059^
W-4	2006/07	Pesticide	4,4'-DDE		.00059^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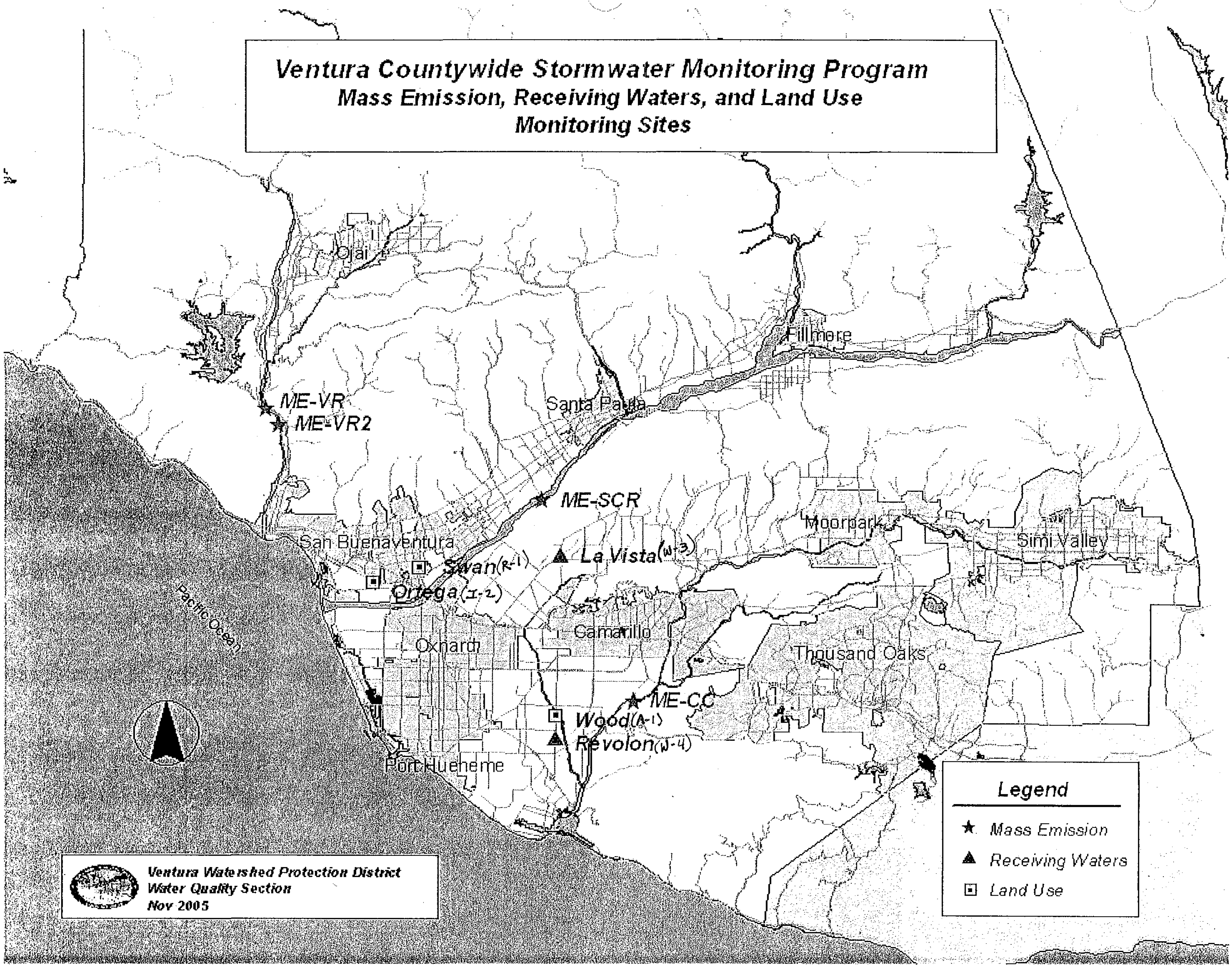
Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
ME-SCR	2006/07	Anion	Chloride	80	
ME-SCR	2003/04	Bacteriological	E. Coli	235	
ME-SCR	2004/05	Bacteriological	E. Coli	235	
ME-SCR	2005/06	Bacteriological	E. Coli	235	
ME-SCR	2006/07	Bacteriological	E. Coli	235	
ME-SCR	2003/04	Bacteriological	Fecal Coliform	400	
ME-SCR	2004/05	Bacteriological	Fecal Coliform	400	
ME-SCR	2005/06	Bacteriological	Fecal Coliform	400	
ME-SCR	2006/07	Bacteriological	Fecal Coliform	400	
ME-SCR	2004/05	Conventional	TDS	1200	
ME-SCR	2006/07	Conventional	TDS	1300	
ME-SCR	2003/04	Metal	Aluminum -Total	1000	
ME-SCR	2004/05	Metal	Aluminum -Total	1000	
ME-SCR	2005/06	Metal	Aluminum -Total	1000	
ME-SCR	2006/07	Metal	Aluminum-Total	1000	
ME-SCR	2003/04	Metal	Arsenic- Total	50	
ME-SCR	2003/04	Metal	Barium - Total	1000	
ME-SCR	2003/04	Metal	Cadmium - Total	5	
ME-SCR	2004/05	Metal	Cadmium - Total	5	
ME-SCR	2005/06	Metal	Cadmium - Total	5	
ME-SCR	2006/07	Metal	Cadmium - Total	5	
ME-SCR	2004/05	Metal	Chromium - Total	50	
ME-SCR	2003/04	Metal	Mercury - Total		.051^
ME-SCR	2005/06	Metal	Mercury - Total		.051^
ME-SCR	2003/04	Metal	Nickel - Total	100	
ME-SCR	2004/05	Metal	Nickel - Total	100	
ME-SCR	2005/06	Metal	Nickel - Total	100	
ME-SCR	2003/04	Metal	Selenium - Total	50	
ME-SCR	2003/04	Organic	Benzo(a)anthracene		.049^
ME-SCR	2004/05	Organic	Benzo(a)anthracene		.049^
ME-SCR	2006/07	Organic	Benzo(a)anthracene		.049^
ME-SCR	2003/04	Organic	Benzo(a)pyrene		.049^
ME-SCR	2003/04	Organic	Benzo(b)fluoranthene		.049^
ME-SCR	2004/05	Organic	Benzo(b)fluoranthene		.049^
ME-SCR	2006/07	Organic	Benzo(b)fluoranthene		.049^
ME-SCR	2003/04	Organic	Benzo(k)fluoranthene		.049^
ME-SCR	2003/04	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-SCR	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-SCR	2005/06	Organic	Bis(2-ethylhexyl)phthalate	4	
ME-SCR	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-SCR	2003/04	Organic	Chrysene		.049^
ME-SCR	2004/05	Organic	Chrysene		.049^
ME-SCR	2005/06	Organic	Chrysene		.049^
ME-SCR	2006/07	Organic	Chrysene		.049^
ME-SCR	2003/04	Organic	Indeno(1,2,3-cd)pyrene		.049^
ME-SCR	2003/04	Pesticide	4,4'-DDE		.00059^

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Chronic (Dry)
ME-SCR	2004/05	Anion	Chloride	150	
ME-SCR	2006/07	Anion	Chloride	80	
ME-SCR	2004/05	Bacteriological	E. Coli	235	
ME-SCR	2005/06	Bacteriological	Fecal Coliform	400	
ME-SCR	2003/04	Conventional	TDS	1200	
ME-SCR	2004/05	Metal	Aluminum -Total	1000	
ME-SCR	2005/06	Metal	Aluminum -Total	1000	
ME-SCR	2003/04	Metal	Selenium - Total		5
ME-SCR	2005/06	Metal	Selenium - Total		5
ME-SCR	2006/07	Metal	Selenium - Total		5^
ME-SCR	2003/04	Organic	Bis(2-ethylhexyl)phthalate	4	
ME-SCR	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
I-2	2003/04	Bacteriological	E. Coli	235	
I-2	2004/05	Bacteriological	E. Coli	235	
I-2	2003/04	Bacteriological	Fecal Coliform	400	
I-2	2004/05	Bacteriological	Fecal Coliform	400	
I-2	2003/04	Conventional	Ph	6.5	
I-2	2004/05	Conventional	TDS	500	
I-2	2003/04	Metal	Aluminum -Total	1000	
I-2	2004/05	Metal	Aluminum -Total	1000	
I-2	2003/04	Metal	Mercury - Total		.051^
I-2	2003/04	Metal	Selenium - Total	50	
I-2	2003/04	Organic	Benzo(a)anthracene		.049^
I-2	2003/04	Organic	Benzo(a)pyrene		.049^
I-2	2003/04	Organic	Benzo(b)fluoranthene		.049^
I-2	2004/05	Organic	Benzo(b)fluoranthene		.049^
I-2	2003/04	Organic	Benzo(k)fluoranthene		.049^
I-2	2004/05	Organic	Benzo(k)fluoranthene		.049^
I-2	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
I-2	2003/04	Organic	Chrysene		.049^
I-2	2004/05	Organic	Chrysene		.049^
I-2	2003/04	Organic	Dibenz(a,h)anthracene		.049^
I-2	2003/04	Organic	Indeno(1,2,3-cd)pyrene		.049^
I-2	2003/04	Pesticide	4,4'-DDE		.00059^
I-2	2004/05	Pesticide	4,4'-DDE		.00059^

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
R-1	2003/04	Bacteriological	E. Coli	235	
R-1	2004/05	Bacteriological	E. Coli	235	
R-1	2003/04	Bacteriological	Fecal Coliform	400	
R-1	2004/05	Bacteriological	Fecal Coliform	400	
R-1	2003/04	Conventional	Ph	6.5	
R-1	2003/04	Metal	Aluminum -Total	1000	
R-1	2004/05	Metal	Aluminum -Total	1000	
R-1	2003/04	Metal	Cooper - Dissolved		6.74^ & 5.21
R-1	2004/05	Metal	Cooper - Dissolved		8.67
R-1	2003/04	Metal	Zinc - Dissolved		49.99
R-1	2003/04	Organic	Benzo(a)anthracene		.049^
R-1	2003/04	Organic	Benzo(a)pyrene	.2	.049^
R-1	2003/04	Organic	Benzo(b)fluoranthene		.049^
R-1	2004/05	Organic	Benzo(b)fluoranthene		.049^
R-1	2003/04	Organic	Benzo(k)fluoranthene		.049^
R-1	2004/05	Organic	Benzo(k)fluoranthene		.049^
R-1	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	
R-1	2003/04	Organic	Chrysene		.049^
R-1	2004/05	Organic	Chrysene		.049^
R-1	2003/04	Organic	Dibenz(a,h)anthracene		.049^
R-1	2003/04	Organic	Indeno(1,2,3-cd)pyrene		.049^
R-1	2004/05	Organic	Indeno(1,2,3-cd)pyrene		.049^
R-1	2003/04	Pesticide	4,4'-DDE		.00059^
R-1	2004/05	Pesticide	4,4'-DDE		.00059^



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Nov 2005

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Acute (Wet)
ME-VR	2004/05	Anion	Chloride	60	
ME-VR2	2005/06	Anion	Chloride	60	
ME-VR2	2006/07	Anion	Chloride	60	
ME-VR	2003/04	Bacteriological	E. Coli	235	235
ME-VR	2004/05	Bacteriological	E. Coli	235	
ME-VR2	2005/06	Bacteriological	E. Coli	235	
ME-VR2	2006/07	Bacteriological	E. Coli	235	
ME-VR	2003/04	Bacteriological	Fecal Coliform	400	400
ME-VR	2004/05	Bacteriological	Fecal Coliform	400	
ME-VR2	2005/06	Bacteriological	Fecal Coliform	400	
ME-VR2	2006/07	Bacteriological	Fecal Coliform	400	
ME-VR2	2005/06	Conventional	TDS	1000	
ME-VR2	2006/07	Conventional	TDS	1000	
ME-VR	2003/04	Metal	Aluminum -Total	1000	
ME-VR	2004/05	Metal	Aluminum -Total	1000	
ME-VR2	2005/06	Metal	Aluminum -Total	1000	
ME-VR	2004/05	Metal	Cadmium - Total	5	
ME-VR	2004/05	Metal	Chromium - Total	50	
ME-VR	2004/05	Metal	Mercury - Total		.051^
ME-VR2	2005/06	Metal	Mercury - Total		.051^
ME-VR	2004/05	Metal	Nickel - Total	100	
ME-VR	2004/05	Metal	Zinc - Dissolved		316.32
ME-VR	2004/05	Organic	Benzo(a)pyrene		.049^
ME-VR	2004/05	Organic	Benzo(b)fluoranthene		.049^
ME-VR	2003/04	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-VR	2004/05	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-VR2	2005/06	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-VR2	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	
ME-VR	2004/05	Organic	Chrysene		.049^
ME-VR2	2006/07	Organic	Hexachlorobenzene		.00077^
ME-VR2	2006/07	Pesticide	4,4'-DDD		.00084^
ME-VR2	2006/07	Pesticide	4,4'-DDE		.00059^

Site	Date/Year	Classification	Constituent	Basin Plan	CTR Chronic (Dry)
ME-VR	2003/04	Anion	Chloride	60	
ME-VR	2003/04	Metal	Selenium - Total		5
ME-VR	2003/04	Organic	Bis(2-ethylhexyl)phthalate	4	5.9^
ME-VR2	2006/07	Organic	Bis(2-ethylhexyl)phthalate	4	

LARRY WALKER ASSOCIATES

Memorandum

DATE: August 26, 2005

TO: Darla Wise

CC: Mack Walker, LWA

SUBJECT: **Trend Analysis of POCs**

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I. INTRODUCTION

The Ventura Countywide stormwater monitoring program has collected data since 1993. The monitoring program is comprehensive and includes discharge characterization, and receiving water characterization and bioassessment. Periodically, these data should be reviewed to determine whether a discernible trend can be identified. In addition, the development of Total Maximum Daily Loads (TMDL) may impact the stormwater program and should be considered in identifying problematic constituents. Furthermore, for constituents that have been identified as problematic constituents, effort should be made to further identify the sources of these constituents and potential management control to reduce their contribution. The analysis described in this memorandum addresses the following pollutants of concern (POCs):

- Total nitrogen
- Total DDT
- Chlorpyrifos
- Copper (total and dissolved)
- Total coliform
- Ammonia
- Zinc (total and dissolved)
- Lead (total and dissolved)

The following trend analysis was conducted on stormwater runoff quality data collected between 1993 and 2004. The trend analysis was conducted to determine the following, to the extent allowed by the nature of the data:

- Trends in the runoff quality data over the period of data collection
- Influence of hydrological factors (event rainfall) on runoff quality
- Site-to-site differences in runoff quality from various land use types (industrial and residential) and different receiving waters.

This memo provides the following information:

I. Introduction

II. Description of monitoring sites and events.

III. Summary statistics for key pollutants of concern.

IV. Trend analysis using a simple linear regression analysis.

V. Review of upcoming TMDLs that may impact the Ventura County stormwater program.

VI. List of potential sources of the pollutants of concern as identified in items 1-3.

VII. List of current management practices to address pollutants of concern.

VIII. Summary and conclusions

II. MONITORING SITES AND EVENTS DESCRIPTION

The Ventura Countywide Stormwater Monitoring Program collects and analyzes stormwater samples throughout Ventura County. Monitoring efforts emphasize the characterization of stormwater runoff from monitoring sites that are representative of industrial and residential land uses. In addition, emphasis is placed on understanding the impact of stormwater runoff on receiving waters by conducting receiving water quality, mass emission, and bioassessment monitoring.

The trend analysis presented in this memo is based on four monitoring sites: two land use sites and two receiving water sites. Monitoring sites are described below and are summarized in table 1.

Land Use Sites

Land use monitoring is designed to capture and characterize stormwater runoff from specific types of land uses (industrial and residential). Monitoring sites are equipped with automated monitoring equipment. Sites were upgraded in 2003 with new, portable refrigerated samplers and ISCO 4250 area velocity flow meters prior to the first 2003/04 wet weather event.

Monitoring Site R-1: Site R-1 represents residential contributions. The site is located at Swan Street. The monitoring site receives runoff from a relatively new (15 to 20 year old) residential neighborhood that consists of single-family dwellings, churches, parks, and a recreation center.

Monitoring Site I-2: Site I-2 represents industrial contributions. The site is located at Ortega Street. The drainage basin for this monitoring site consists of diverse types of industrial facilities including older manufacturing facilities, newer industrial parks and a few undeveloped city lots.

Receiving Water Sites

Receiving water monitoring is designed to characterize the quality of receiving waters. Monitoring is focused on small tributaries to the main river systems. Monitoring small tributaries allows the Stormwater Monitoring Program to focus on smaller sub basins of the watershed that are impacted by nonpoint source runoff (as opposed to wastewater discharges) and subsequently allow more refined trend analysis. At monitoring sites, both water chemistry and toxicity samples are collected. Receiving water monitoring at these sites was first implemented during the 1997-98 season and captures stormwater runoff from the Revolon Slough sub basin. The land use surrounding both receiving water sites is dominated by agriculture. Samples at both sites are collected as time-paced composites.

Monitoring Site W-3: The La Vista station is located in the upper Revolon Slough watershed. Agricultural land makes up approximately 80% of the sub watershed. The most prevalent crops grown in the W3 watershed are lemon and avocado.

Monitoring Site W-4: The Revolon Slough station is located in the lower Revolon Slough Watershed at Wood Road. Agricultural land makes up approximately 63% of the watershed. Unlike the sub watershed represented by monitoring site W-3, approximately 20% of this sub watershed is developed. The most prevalent crops grown in the W-4 sub watershed are row crops, lemon and citrus, strawberry and avocados.

TABLE 1. MONITORING SITES INFORMATION

Station Code	*Year Installed*	*Location*	*Primary Land Use*	*Drainage Basin Area (Acres)*	*Rain Gauge Location*
R-1	*1992* *(2003 Upgrade)*	Swan Street and Macaw Avenue (City of San Buenaventura)	Residential	65	County Government Center
I-2	*1992* *(2003 Upgrade)*	Ortega Street (City of San Buenaventura)	Industrial	189	County Government Center
W-3	*1997* *(2003 Upgrade)*	La Vista Avenue south of Center Road	Agricultural/ Open Space	752	Somis- Bard
W-4	*2001* *(2003 Upgrade)*	Revolon Slough at Wood Road	Agricultural/ Mixed Use	28,800	Oxnard Airport

Monitoring Events

Land use monitoring and receiving water monitoring have been in place since 1993 and 1998, respectively. Wet weather monitoring occurs approximately once per year at each site. Most of the data was collected during wet weather events. Limited data is available for dry weather event for receiving water site W-4. Due to the limited information available for dry weather, no analysis was done to characterize dry weather data.

Precipitation data (1997-2004), collected by the Department of Water Resources, Division of Flood Control[1], was used to identify the timing of monitoring events in relation to the progression of the wet weather season and storm events. Majority of the sampling was done at the beginning of the wet weather season (see Table 2). Timing of monitoring events is shown in Figure 1 and Figure 2 for land use sites and receiving water sites, respectively. Given sufficient data, a statistical analysis can be performed to identify a relationship between hydrologic/meteorological factors and the water quality observed at the monitoring sites. Such an analysis might shed light on the effects of pollutant built-up (represented as dry days since last storm event), washoff (represented as stormwater event cumulative rainfall, in inches), cumulative seasonal rainfall (in inches), and annual variation (other factors such as implementation of management practices) on the observed water quality in the receiving waters and storm drain system. The analysis conducted as part of this study was limited to trend analysis for a single variable, time.

TABLE 2. NO. OF MONITORING SAMPLES BASED ON SEASONAL TIMING

SITE	FIRST FLUSH, CUMULATIVE PRECIPITATION <5"	MID SEASON, CUMULATIVE PRECIPITATION 5"-15"	LATE SEASON, CUMULATIVE PRECIPITATION >15"
Total	21 events (46 samples)	5 events (9 samples)	2 events (4 samples)
R1	10	1	1
I2	10	1	1
W3	14	4	1
W4	12	3	1

[1] Department of Water Resources, Division of Flood Control, California Data Exchange Center. http://cdec.water.ca.gov/ Station ID CHE, Ventura LA Coastal River Basin.

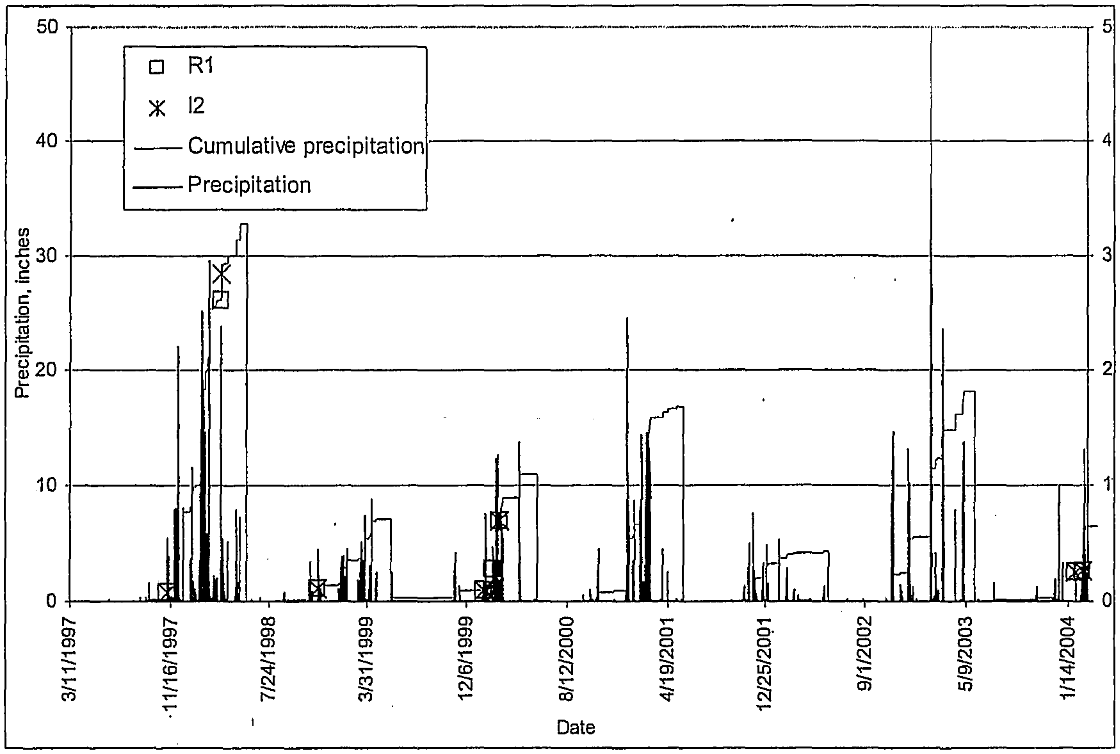

FIGURE 1. MONITORING EVENTS AT SITES R1 AND I2

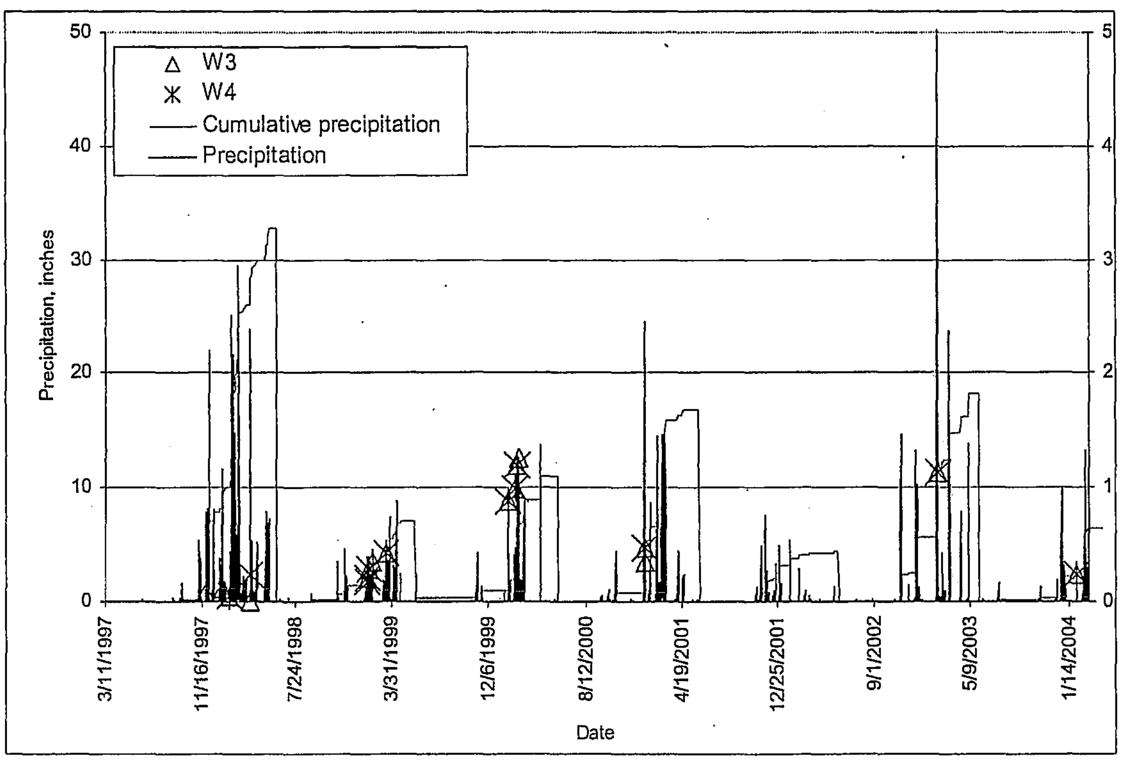

FIGURE 2. MONITORING EVENTS AT SITES W3 AND W4

III. SUMMARY STATISTICS FOR KEY POLLUTANTS OF CONCERN

A summary statistics for the constituents monitored at the four sites was completed and is provided in tables 3a-d. The summary includes the following statistical components:

n, percent detected, n detected: number of samples taken within the monitoring time period. The percent and n detected values represent samples with values higher than reporting limits. The reporting limits are dependent on sampling equipment and laboratory methodology.

Mean: arithmetic average of all sampling data at or above the detection limit.

Standard deviation: Standard deviation is a measure of the spread or dispersion of the data. The more widely the values are spread out, the larger the standard deviation.

Coefficient of variation (CV): The coefficient of variation measures the spread of a set of data as a proportion of its mean. It is the ratio of the sample standard deviation and the mean. The higher the CV, the more dispersed the data.

Confidence limit about the mean: Confidence limits are the lower and upper boundaries/values of a confidence interval, that is, the values which define the range of a confidence interval. The upper and lower bounds of a 95% confidence interval are the 95% confidence limits.

Table 3A. Summary Statistics for Constituents, R-1

Constituent	N	Percent Detected	N Detected	Mean[1]	Standard Deviation	Coefficient of Variation	Lower 95% Confidence Limit about Mean	Upper 95% Confidence Limit about Mean	Minimum Detected Value	Maximum Detected Value	Minimum Reporting Limit	Maximum Reporting Limit
2,4'-DDD (µg/L)	16	0.0%	0								0.001	20
2,4'-DDE (µg/L)	17	5.9%	1						0.003	0.003	0.001	20
2,4'-DDT (µg/L)	17	5.9%	1						0.006	0.006	0.001	20
4,4'-DDD (µg/L)	22	4.5%	1						0.007	0.007	0.001	20
4,4'-DDE (µg/L)	22	27.3%	6	0.016	0.016	0.991	0.010	0.023	0.012	0.0757	0.001	20
4,4'-DDT (µg/L)	22	4.5%	1						0.021	0.021	0.001	20
Ammonia as N (mg/L)	27	85.2%	23	0.63	0.69	1.10	0.37	0.89	0.1	3	0.05	0.1
Chlorpyrifos (µg/L)	10	0.0%	0								0.005	100
Copper, Dissolved (µg/L)	24	100.0%	24	18.07	17.98	1.00	10.87	25.26	3.80	91.90		
Copper, Total (µg/L)	27	100.0%	27	29.54	21.91	0.74	21.27	37.80	5.00	84.12		
Lead, Dissolved (µg/L)	24	87.5%	21	9.13	10.67	1.17	4.86	13.40	0.79	44.00	1	1
Lead, Total (µg/L)	27	100.0%	27	22.22	18.84	0.85	15.11	29.32	2.00	61.00		
Nitrate as N (mg/L)	27	100.0%	27	1.54	3.75	2.44	0.12	2.95	0.06	20.00		
Nitrite as N (mg/L)	7	71.4%	5	0.02	0.03	1.24	0.00	0.05	0.01	0.09	0.02	0.02
TKN (mg/L)	23	100.0%	23	4.84	4.60	0.95	2.96	6.72	1.20	23.40		
Total Coliform (MPN/100 ml)	18	100.0%	18	98,333	83,517	0.849	59,751	136,916	11,000	323,000		
Total Nitrogen(mg/L)	1	100.0%	1						4.3	4.3		
Zinc, Dissolved (µg/L)	24	95.8%	23	57.29	39.90	0.70	41.33	73.25	17.00	153.00	2	2
Zinc, Total (µg/L)	27	100.0%	27	163.48	105.66	0.65	123.63	203.34	26.00	444.00		
Total Detectable DDT (µg/L)	22			0.014					0	0.0757		

[1] Geometric mean

Table 3B. Summary Statistics for Constituents, I-2

Constituent	N	Percent Detected	N Detected	Mean[1]	Standard Deviation	Coefficient of Variation	Lower 95% Confidence Limit about Mean	Upper 95% Confidence Limit about Mean	Minimum Detected Value	Maximum Detected Value	Minimum Reporting Limit	Maximum Reporting Limit
2,4'-DDD (µg/L)	14	7.1%	1						0.004	0.004	0.001	20
2,4'-DDE (µg/L)	15	6.7%	1						0.003	0.003	0.001	20
2,4'-DDT (µg/L)	15	6.7%	1						0.007	0.007	0.001	20
4,4'-DDD (µg/L)	21	9.5%	2						0.013	0.023	0.001	20
4,4'-DDE (µg/L)	21	38.1%	8	0.109	0.205	1.880	0.021	0.197	0.0241	0.961	0.01	20
4,4'-DDT (µg/L)	21	4.8%	1						0.023	0.023	0.001	20
Ammonia as N (mg/L)	24	79.2%	19	0.61	0.55	0.90	0.39	0.83	0.20	2.3	0.05	0.1
Chlorpyrifos (µg/L)	9	11.1%	1						0.02	0.0168	0.005	100
Copper, Dissolved (µg/L)	22	100.0%	22	32.14	61.09	1.90	6.61	57.66	6.00	301.05		
Copper, Total (µg/L)	26	100.0%	26	52.25	54.51	1.04	31.30	73.20	6.00	254.45		
Lead, Dissolved (µg/L)	22	72.7%	16	8.34	13.39	1.61	2.74	13.93	0.34	58.58	0.1	10
Lead, Total (µg/L)	26	100.0%	26	17.43	17.59	1.01	10.67	24.19	3.00	72		
Nitrate as N (mg/L)	23	100.0%	23	1.14	0.76	0.67	0.83	1.45	0.19	3.22		
Nitrite as N (mg/L)	8	100.0%	8	0.06	0.04	0.73	0.03	0.09	0.01	0.13		
TKN (mg/L)	20	100.0%	20	3.61	2.21	0.61	2.64	4.58	1.10	8.1		
Total Coliform (MPN/100 ml)	17	100.0%	17	167,059	458,553	2.745	-50,924	385,041	8,000	1,935,000		
Total Nitrogen (mg/L)	1	100.0%	1						2.5	2.5		
Zinc, Dissolved (µg/L)	22	100.0%	22	69.86	55.65	0.80	46.61	93.11	6	252		
Zinc, Total (µg/L)	26	100.0%	26	210.88	156.68	0.74	150.66	271.11	67	660		
Total Detectable DDT (µg/L)	21			0.097					0	0.961		

[1]Geometric mean

A009511

Table 3c. Summary Statistics for Constituents, W-3

Constituent	N	Percent Detected	N Detected	Mean[1]	Standard Deviation	Coefficient of Variation	Lower 95% Confidence Limit about Mean	Upper 95% Confidence Limit about Mean	Minimum Detected Value	Maximum Detected Value	Minimum Reporting Limit	Maximum Reporting Limit
2,4'-DDD (µg/L)	10	30.0%	3	0.004	0.009	2.537	-0.002	0.009	0.001	0.0298	0.001	0.001
2,4'-DDE (µg/L)	12	50.0%	6	0.003	0.004	1.224	0.001	0.005	0.001	0.0114	0.001	0.001
2,4'-DDT (µg/L)	12	66.7%	8	0.025	0.070	2.790	-0.015	0.065	0.004	0.247	0.001	0.001
4,4'-DDD (µg/L)	13	69.2%	9	0.018	0.025	1.329	0.005	0.032	0.002	0.0779	0.001	0.05
4,4'-DDE (µg/L)	13	92.3%	12	0.266	0.285	1.069	0.112	0.421	0.0171	0.892	0.05	0.05
4,4'-DDT (µg/L)	13	76.9%	10	0.057	0.064	1.138	0.022	0.092	0.002	0.184	0.001	0.05
Ammonia as N (mg/L)	16	81.3%	13	0.58	0.64	1.09	0.27	0.90	0.2	2.3	0.1	0.1
Chlorpyrifos (µg/L)	15	66.7%	10	0.67	0.88	1.32	0.22	1.11	0.19	3.3	0.05	2
Copper, Dissolved (µg/L)	16	100.0%	16	49.92	39.16	0.78	30.74	69.11	12	188		
Copper, Total (µg/L)	16	100.0%	16	342.18	426.73	1.25	133.08	551.28	36.4	1750		
Lead, Dissolved (µg/L)	16	81.3%	13	10.87	12.98	1.19	4.51	17.23	0.12	45	0.1	2
Lead, Total (µg/L)	16	93.8%	15	81.02	107.02	1.32	28.57	133.46	12.6	448	2	2
Nitrate as N (mg/L)	1	100.0%	1						6.6	6.6		
Nitrite as N (mg/L)	16	100.0%	16	4.34	2.46	0.57	3.13	5.54	1.05	11.4		
TKN (mg/L)	3	100.0%	3	0.48	0.50	1.04	-0.09	1.05	0.13	1.06		
Total Coliform (MPN/100 ml)	16	100.0%	16	7.48	5.53	0.74	4.76	10.19	2.10	23.00		
Total Nitrogen (mg/L)	15	100.0%	15	751,928	668,508	0.889	413,616	1,090,240	110,000	2,382,000		
Zinc, Dissolved (µg/L)	16	93.8%	15	48.49	45.43	0.94	26.23	70.75	3.66	186.00	10	10
Zinc, Total (µg/L)	16	100.0%	16	483.66	703.57	1.45	138.91	828.41	65.60	2900.00		
Total Detectable DDT (µg/L)	13			0.28					0.00	1.30		

[1]Geometric mean

TABLE 3D. SUMMARY STATISTICS FOR CONSTITUENTS, W-4

CONSTITUENT	N	PERCENT DETECTED	N DETECTED	MEAN[1]	STANDARD DEVIATION	COEFFICIENT OF VARIATION	LOWER 95% CONFIDENCE LIMIT ABOUT MEAN	UPPER 95% CONFIDENCE LIMIT ABOUT MEAN	MINIMUM DETECTED VALUE	MAXIMUM DETECTED VALUE	MINIMUM REPORTING LIMIT	MAXIMUM REPORTING LIMIT
2,4'-DDD (µg/L)	11	81.8%	9	0.014	0.013	0.915	0.007	0.022	0.0024	0.045	0.001	0.001
2,4'-DDE (µg/L)	11	63.6%	7	0.006	0.006	1.101	0.002	0.009	0.001	0.0182	0.001	0.001
2,4'-DDT (µg/L)	11	90.9%	10	0.029	0.029	1.013	0.012	0.046	0.0063	0.0929	0.001	0.001
4,4'-DDD (µg/L)	12	83.3%	10	0.047	0.046	0.976	0.021	0.073	0.0082	0.148	0.001	0.05
4,4'-DDE (µg/L)	12	91.7%	11	0.255	0.223	0.875	0.129	0.382	0.0276	0.812	0.05	0.05
4,4'-DDT (µg/L)	12	83.3%	10	0.077	0.083	1.070	0.030	0.124	0.016	0.247	0.001	0.05
Ammonia as N (mg/L)	12	91.7%	11	0.53	0.30	0.56	0.36	0.69	0.08	1	0.1	0.1
Chlorpyrifos (µg/L)	12	75.0%	9	0.36	0.24	0.66	0.22	0.49	0.074	0.9	0.5	2
Copper, Dissolved (µg/L)	12	100.0%	12	14.56	11.99	0.82	7.77	21.35	3.16	44		
Copper, Total (µg/L)	12	100.0%	12	90.33	61.66	0.68	55.44	125.21	26.7	187		
Lead, Dissolved (µg/L)	12	66.7%	8	5.26	10.95	2.08	-0.94	11.45	0.2	38	0.1	2
Lead, Total (µg/L)	12	100.0%	12	27.59	21.72	0.79	15.30	39.88	6.8	69.8		
Nitrate as N (mg/L)	1	100.0%	1						22.3	22.3		
Nitrite as N (mg/L)	12	100.0%	12	10.67	6.93	0.65	6.74	14.59	2.40	23.4		
TKN (mg/L)	4	100.0%	4	1.60	3.03	1.90	-1.37	4.57	0.03	6.14		
Total Coliform (MPN/100 ml)	12	100.0%	12	7.48	5.80	0.78	4.19	10.76	1.60	18.2		
Total Nitrogen (mg/L)	12	100.0%	12	546,243	545,522	0.999	237,585	854,901	20,000	1,600,000		
Zinc, Dissolved (µg/L)	12	100.0%	12	63.48	118.55	1.87	-3.60	130.55	4.81	429		
Zinc, Total (µg/L)	12	100.0%	12	295.17	207.05	0.70	178.02	412.32	88.00	670		
Total Detectable DDT (µg/L)	12			0.265					0	1.1048		

[1]Geometric mean

Statistical summary results were used to identify POCs with sufficient data to ascertain potential trends in concentrations sampled in the receiving waters and land use sites. POCs were selected for the trend analysis based on two criteria:

- Pollutant was sampled at least 10 times (n value), and
- Pollutant concentration was detected at least 80% of the times (% detected value).

Based on these criteria, the following pollutants were selected:

- *Nutrients*: Ammonia as N, Nitrate as N, and TKN
- *Metals*: Copper, Lead, and Zinc
- *Pesticides*: 4,4'-DDE
- *Bacteria*: Total coliform

IV. TREND ANALYSIS USING A SIMPLE LINEAR REGRESSION ANALYSIS

The principal statistical method used to address the objectives of this analysis consisted of a simple linear regression (SLR). Unless specified, thresholds for statistical significance were set at a confidence level for 95% ($p < 0.05$) for all analyses.

Fitness Analysis

A fitness test, using a statistical program JMP 5.1, was completed to evaluate how well the data matches a lognormal or normal distributions. The normal distribution has a symmetric "bell shaped" probability density function. The lognormal distribution is defined with reference to the normal distribution of the data's natural logarithm. A reasonable fit to a distribution was assumed if its fit probability was calculated as 15 percent or higher. In cases where neither distribution resulted in a reasonable fit, the distribution with the highest probability was assumed to govern. Results are summarized in Table 4. A review of the table indicates that in most cases lognormal distribution provides a better distribution representation than normal distribution for the available data. The only exception is monitoring results for ammonia at receiving water station W-4, where normal distribution was a better fit. Some results are inconclusive for either distribution. Examples of inconclusive distribution (probability less than 15%) are total zinc at receiving water station R-1; dissolved zinc at monitoring station W-4; 4,4'-DDE data for monitoring stations R-1, I-2, and W-4; dissolved copper at monitoring station W-3; total lead at monitoring station W-4; and total coliform at monitoring station I-2. Based on these results, lognormal distribution was assumed for all POCs in the statistical analysis.

TABLE 4. FITNESS TEST RESULTS

	Goodness of Fit							
	R-1, Fit Prob.		I-2, Fit Prob.		W-3, Fit Prob.		W-4, Fit Prob.	
Constituent	LogNormal	Normal	LogNormal	Normal	LogNormal	Normal	LogNormal	Normal
4,4'-DDE	**0.01**	0.0001	**0.01**	0.0001	**0.15**	0.0076	**0.0625**	0.0233
Ammonia as N	**0.15**	0.0001	**0.15**	0.0017	**0.15**	0.0012	0.15	**0.742**
Copper, dissolved	**0.15**	0.0002	**0.15**	0.0001	**0.052**	0.0001	**0.15**	0.0096
Copper, total	**0.15**	0.0005	**0.15**	0.0001	**0.15**	0.0001	**0.15**	0.042
Lead, dissolved	**0.15**	0.0016	**0.15**	0.0001	**0.1411**	0.0021	**0.15**	0.0001
Lead, total	**0.15**	0.0003	**0.15**	0.0001	**0.15**	0.0001	**0.0829**	0.0388
Nitrate as N	**0.15**	0.0001	**0.15**	0.086	**0.15**	0.0431	**0.15**	0.0435
TKN	**0.15**	0.0001	**0.15**	0.0284	**0.15**	0.0072	**0.15**	0.0269
Total Coliform	**0.1494**	0.0185	**0.01**	0.0001	**0.1401**	0.0169	**0.15**	0.0081
Total detect. DDTs	**0.01**	0.0001	**0.01**	0.0001	**0.15**	0.0193	0.15	**0.205**
Zinc, dissolved	**0.15**	0.001	**0.15**	0.0013	**0.15**	0.0044	**0.0761**	0.0001
Zinc, total	**0.0784**	0.0216	**0.15**	0.0001	**0.15**	0.0001	**0.15**	0.077

Trend Analysis

A summary of trend analysis for POCs is provided in Table 5. The following factors were considered in identifying trends for the selected POCs.

No of Observations: number of observations used in estimating the fit (minimum of 10).

% Nondetect: Percent of samples that were detected at the limit (minimum of 80%).

Type of analysis: A lognormal analysis was assumed for all pollutants.

Rsquare (R^2): Coefficient of determination measures the proportion of the variation accounted for by fitting means to each factor level. The remaining variation is attributed to random error. The R^2 value is 1 if fitting the group means accounts for all the variation with no error. An R^2 of 0 indicates that the fit serves no better as a prediction model than the overall response mean.

Prob>F: Observed significance probabilities of 0.05 or less are considered evidence that the trend is statistically significant.

For pollutants with data that had a probability of 0.05 or less, a trend and a representative equation was identified. For other pollutants, it is assumed that a significant trend can not be established with the available data.

TABLE 5. TREND ANALYSIS FOR POCs

POC	SITE	NO. OF OBSERVATIONS	% NONDETECT	TYPE OF ANALYSIS	EQUATION	R^2	PROB > F	INTERCEPT	TREND
4,4'-DDE	I2	21	38.1	LogNormal		0.142	0.093		
	R1	22	27.3	LogNormal		0.155	0.070		
	W3	13	92.3	LogNormal		0.018	0.658		
	W4	12	91.7	LogNormal		0.003	0.875		
Ammonia as N	I2	24	79.2	LogNormal	Log(C) = -12.11354 + 3.811e-9T	0.172	**0.044**	-12.114	Increase
	R1	27	85.2	LogNormal		0.023	0.453		
	W3	16	81.3	LogNormal		0.064	0.346		
	W4	12	91.7	LogNormal		0.086	0.356		
Copper, Dissolved	I2	22	100	LogNormal		0.066	0.248		
	R1	24	100	LogNormal		0.064	0.231		
	W3	16	100	LogNormal		0.215	0.071		
	W4	12	100	LogNormal		0.155	0.205		
Copper, Total	I2	26	100	LogNormal	Log(C) = -5.620231 + 3.1457e-9 T	0.162	**0.041**	-5.620	Increase
	R1	27	100	LogNormal		0.055	0.240		
	W3	16	100	LogNormal		0.125	0.180		
	W4	12	100	LogNormal	Log(C) = 23.684695 - 6.3714e-9 T	0.372	**0.035**	23.685	Decrease
Lead, Dissolved	I2	22	72.7	LogNormal	Log(C) = 28.5693 - 9.2847e-9 T	0.386	**0.002**	28.569	Decrease
	R1	24	87.5	LogNormal		0.016	0.558		
	W3	16	81.3	LogNormal	Log(C) = 75.348187 - 2.4426e-8 T	0.851	**<.0001**	75.348	Decrease
	W4	12	66.7	LogNormal	Log(C) = 52.814871 - 1.7189e-8 T	0.497	**0.011**	52.815	Decrease
Lead, Total	I2	26	100	LogNormal		0.024	0.451		
	R1	27	100	LogNormal	Log(C) = 20.831703 - 6.442e-9 T	0.251	**0.008**	20.832	Decrease
	W3	16	93.8	LogNormal		0.045	0.431		
	W4	12	100	LogNormal		0.078	0.378		
Nitrate as N	I2	23	100	LogNormal		0.001	0.919		
	R1	27	100	LogNormal		0.002	0.816		
	W3	16	100	LogNormal		0.046	0.427		
	W4	12	100	LogNormal		0.206	0.138		
TKN	I2	20	100	LogNormal		0.065	0.277		
	R1	23	100	LogNormal		0.013	0.604		
	W3	16	100	LogNormal		0.224	0.064		
	W4	12	100	LogNormal	Log(C) = 23.858872 - 7.258e-9 T	0.433	**0.020**	23.859	Decrease
	I2	17	100	LogNormal	Log(C) = -	0.301	**0.023**	-9.794	Increase

TABLE 5. TREND ANALYSIS FOR POCS

POC	SITE	NO. OF OBSERVATIONS	% NONDETECT	TYPE OF ANALYSIS	EQUATION	R^2	PROB > F	INTERCEPT	TREND
					9.793606 + 6.9125e-9 T				
Total Coliform	R1	18	100	LogNormal		0.156	0.105		
	W3	15	100	LogNormal		0.180	0.115		
	W4	12	100	LogNormal		0.027	0.612		
Total Detectable DDTs[1]	I2	7	-	LogNormal		0.139	0.410		
	R1	22	-	LogNormal		0.210	0.361		
	W3	12	-	LogNormal		0.038	0.541		
	W4	11	-	LogNormal		0.000	0.953		
Zinc, Dissolved	I2	22	100	LogNormal		0.031	0.434		
	R1	24	95.8	LogNormal		0.003	0.810		
	W3	16	93.8	LogNormal	Log(C) = 42.327701 - 1.2835e-8 T	0.792	**<.0001**	42.328	Decrease
	W4	12	100	LogNormal		0.301	0.065		
Zinc, Total	I2	26	100	LogNormal		0.032	0.384		
	R1	27	100	LogNormal		0.001	0.880		
	W3	16	100	LogNormal		0.045	0.429		
	W4	12	100	LogNormal	Log(C) = 26.104093 - 6.7821e-9 T	0.392	**0.030**	26.104	Decrease

(1) Detection for DDTs is low and therefore trends cannot be established.

Results by POC

POCs with statistically significant trend at any of the four sites are summarized in Table 6. A review of the results reveals very small increase/decrease in the trends that were found statistically significant. Furthermore, the low R^2 values indicate that these trends are statistically weak and therefore should be regarded cautiously. Dissolved lead and zinc at monitoring site W3 show the most significant decreasing trend with R^2 values of 0.851 and 0.792, respectively. However, the observed decrease for these two metals is minor (see slope).

TABLE 6. TREND ANALYSIS FOR POCS

SITE	POC	NO. OF OBSERVATIONS	% NONDETECT	R^2	SLOPE	TREND
R1	Lead, Total	27	100	0.251	- 6.44 e-9	Decrease
I2	Ammonia as N	24	79.2	0.172	+ 3.81 e-9	**Increase**
I2	Copper, Total	26	100	0.162	+ 3.15 e-9	**Increase**
I2	Lead, Dissolved	22	72.7	0.386	- 9.28 e-9	Decrease
I2	Total Coliform	17	100	0.301	+ 6.91 e-9	**Increase**
W3	Lead, Dissolved	16	81.3	0.851	- 2.44 e-8	Decrease
W3	Zinc, Dissolved	16	93.8	0.792	- 1.28 e-8	Decrease
W4	Copper, Total	12	100	0.372	- 6.37 e-9	Decrease
W4	Lead, Dissolved	12	66.7	0.497	- 1.72 e-8	Decrease
W4	TKN	12	100	0.433	- 7.26 e-9	Decrease
W4	Zinc, Total	12	100	0.392	- 6.78 e-9	Decrease

DDT-pesticides: Analysis of DDT-pesticides sampling data did not reveal a significant trend in concentration increase or decrease in the four sites. Lack of discernable trend can be attributed to the limited data available for the analysis. DDT is a legacy pollutant, persistent in the environment, and very slow in degrading. Therefore, it is unlikely to observe a significant change in the sampling data.

Metals: The most consistent trend observed was the decrease in dissolved lead at sites I2, W3, and W4. Although no statistically significant trend has been observed at site R1 for dissolved lead, a decrease was observed at site R1 for total lead.

A statistically significant increase in total copper was found for site I2 data and a decrease in total copper was observed for site W4.

A statistically significant decrease in dissolved and total zinc was observed in the receiving water sites, W3 and W4.

Nutrients: A statistically significant increase in ammonia was observed at site I2 and a decrease in TKN in site W4. No trends were observed for nitrates on any of the sites.

Bacteria: The only statistically significant trend observed was an increase at site I2.

Results by Site

Site R1: The only statistically significant trend at site R1 is attributed to a decrease in total lead. Other POCs did not exhibit any discernable trend.

Site I2: The statistical analysis reveals an increase in ammonia, total copper, and total coliform concentrations and a decrease in dissolved lead at site I2.

Site W3: A statistically significant trend was identified for dissolved forms for lead and zinc. Concentrations for both metals appear to be decreasing for the monitoring period studied.

Site W4: A statistically significant trend was identified for dissolved lead, total copper and zinc, and TKN. All POCs concentrations appear to decrease over the monitoring period studied.

V. REVIEW OF RELEVANT TMDLS

A 1999 consent decree set by the US District court, in response to a lawsuit brought by Heal the Bay and Santa Monica Bay Keeper against USEPA, established a schedule for TMDLs for each and every pairing of water quality limit segments (WQLS) and associated pollutants listed in the 1998 303(d) list. The TMDL pollutant list includes nutrients, heavy metals, sediment, pathogens, and pesticides. The schedule spans 12 years to allow for the approval or establishment by EPA of TMDLs within the jurisdiction of the regional water quality control board, region 4 (Los Angeles)[2]. Although the list of WQLS and associated pollutants pairing is extensive, the schedule specifies completion dates only for selected TMDL units (a collection of related WQLS) as shown in Table 7. The status of selected TMDLs in the Los Angeles region is summarized in Table 8. In developing TMDLs, source assessments in most cases identify urban runoff and stormwater as significant sources of POCs (pathogens, trash, nitrogen compounds, sediments, metals, and pesticides) loading. The development and implementation of these and additional TMDLs in the Los Angeles regions are likely to further identify sources and trends of POCs and provide means for addressing POCs through implementation plans. Pollutants of concern identified in the Ventura Countywide monitoring program correlate well with listed TMDLs.

[2] Consent Decree in Heal the Bay, Inc.; Santa Monica BayKeeper, Inc. v. Browner, Case No. 98-5825 SBA on March 22, 1999

TABLE 7. SCHEDULE FOR TMDL ADOPTION BY EPA

REQUIRED COMPLETION DATE[1]	WATER BODY	POLLUTANT
1 year	San Gabriel River East Fork	Trash
2 years	Los Angeles River TMDL unit	Trash
	Ballona Wetland and Ballona Creek	Trash
	Calleguas Creek MDL unit	Chloride
3 years	Santa Monica Bay WMA TMDL unit	Eutrophication /nutrients
	Santa Monica Bay WMA TMDL unit	Beach closure/coliform
	Calleguas Creek MDL unit	Nitrogen compounds
4 years	Marina Del Rey Harbor Beach	Beach closure/coliform
	Los Angeles River TMDL unit	Ammonia, odor, nutrients, algae, pH
	San Gabriel River Watershed TMDL unit	Toxicity, ammonia, algae, pH
	Santa Clara River TMDL unit	Nitrogen compounds, org. enrichment/low DO
	McGrath Beach/Mandalay Beach, and Santa Clara Rive Estuary Beach/Surfers Knoll	Beach closure/coliform
5 years	Santa Monica Bay Near shore and offshore zone	Mercury, heavy metals
	Los Angeles River TMDL unit	metals
	Ballona Creek and estuary	Metals/toxicity
	Ballona Creek and estuary	Pesticides, sediment toxicity
	Los Angeles harbor/Cabrillo Beach	Beach closure
6 years	Marina Del Rey Harbor-back basins	Pesticides, metals
	Calleguas Creek MDL unit	Toxicity, chlorpyrifos
	Calleguas Creek MDL unit	Pesticides, sediment toxicity
7 years	Santa Monica Bay near shore and offshore zone	Chlordane
	Los Angeles River, Reach 5	Chlorpyrifos
	Ballona Creek and estuary	Coliform, enteric viruses
	San Gabriel River Watershed TMDL unit	Metals
	Calleguas Creek	metals

[1] Number of years from the adoption of the Consent Decree, March 1999.

TABLE 8. STATUS OF SELECTED TMDLS FOR WATER BODIES WITHIN THE JURISDICTION OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

WATER BODY NAME	POLLUTANT	SOURCES	SUMMARY
Ballona Creek	Ballona Creek (dissolved copper, dissolved lead, total selenium, and dissolved zinc) Sepulveda Canyon Channel (lead)	Dry weather (storm drain, groundwater discharge and flows from other permitted NPDES Discharges). Wet weather (storm water flows).	Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the Ballona Creek Metals TMDL was last revised in May 2005.
Ballona Creek Estuary	Cadmium, copper, lead, silver, zinc, chlordane, DDT, PCBs and PAHs	Urban storm water. Most prevalent metals in urban storm water are consistently associated with suspended solids.	Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the Ballona Creek Estuary Toxic Pollutants TMDL was last revised in May, 2005.
Ballona Creek and wetlands	Trash	Stormwater	Tentative resolution for the amendment to the Water Quality Control Plan for the Los Angeles Region to Amend the Total Maximum Daily Load for Trash in the

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TABLE 8. STATUS OF SELECTED TMDLS FOR WATER BODIES WITHIN THE JURISDICTION OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

WATER BODY NAME	POLLUTANT	SOURCES	SUMMARY
			Ballona Creek and Wetland was drafted May 2004.
Calleguas Creek, Its Tributaries, and Mugu Lagoon	Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation.	Agricultural runoff; residue of past use of PCBs as coolants and lubricants in transformers, capacitors, and other electrical equipment; atmospheric deposition.	A public hearing for Total Maximum Daily Load for Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation in Calleguas Creek, Its Tributaries, and Mugu Lagoon was held in July 2005.
Calleguas Creek, its tributaries and Mugu Lagoon	Chlorpyrifos, diazinon, other pesticides and/or other toxicants.	Agriculture and urban use, publicly owned treatment works (POTW), open space, groundwater accretion and atmospheric deposition.	A pubic hearing for the proposed Amendment to the Water Quality Control Plan – Los Angeles Region to Incorporate the Calleguas Creek Watershed Toxicity TMDL was held July 2005.
Calleguas Creek	salts	Public Owned Treatment Works.	Tentative resolution to find that the Calleguas Creek Watershed Salts TMDL Work Plan Does not provide an adequate approach to determining appropriate water quality standards and implementation with respect to Chloride in the Calleguas Creek Watershed was drafted April 2003
Calleguas Creek	Nitrogen compounds	Discharges from the POTWs in the watershed and runoff from agricultural activities in the watershed.	Amendment to the Water Quality Control Plan for the Los Angeles Region to include a TMDL for Nitrogen Compounds and Related Effects in Calleguas Creek became effective July 2003.
Los Angeles Harbor	Bacteria	Dry-weather urban runoff and storm water conveyed by storm drains. Potential nonpoint sources include marina activities such as waste disposal from boats, boat deck and slip washing, swimmer "wash-off", restaurant washouts and natural sources from birds, waterfowl and other wildlife.	Draft Los Angeles Harbor Bacteria Total Maximum Daily Load (Inner Cabrillo Beach and Main Ship Channel) - April 30, 2004. Response to comments posted on the regional board's website in June 2004.
Los Angeles River	Metals (copper, cadmium, lead, zinc, aluminum and selenium)	Dry weather (POTWs, storm drains) Wet weather (storm water flow) Direct atmospheric deposition	Proposed Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the Los Angeles River and Tributaries Metals TMDL drafted in May 2005.

TABLE 8. STATUS OF SELECTED TMDLS FOR WATER BODIES WITHIN THE JURISDICTION OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

WATER BODY NAME	POLLUTANT	SOURCES	SUMMARY
Los Angeles River	Ammonia and nitrogen compounds	Discharges from Water Reclamation Plants, urban runoff, stormwater, and groundwater discharge.	A resolution revising interim effluent limits for ammonia in the Amendment to the Water Quality Control Plan for the Los Angeles Region to include a TMDL for Nitrogen Compounds and Related Effects in the Los Angeles River was adopted July 2003.
Los Angeles River	Trash	Stormwater discharge	A resolution amending the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load for Trash in the Los Angeles River Watershed was adopted in September 2001.
Santa Clara River Estuary and beaches	Coliform		Public hearing for proposed TMDL for Santa Clara River Estuary beach/surfers' knoll, McGrath State Beach, and Mandalay Beach Coliform and beach closures was held October 2004.
Upper Santa Clara River	Chloride	Discharge from water reclamation plants	Tentative resolution for Chloride TMDL in the Upper Santa Clara River was drafted May 2004.
Santa Clara River	Nitrogen compounds	Discharges from the Saugus and Valencia Water Reclamation Plants (WRPs), the Fillmore and Santa Paula Publicly Owned Treatment Works (POTWs). Agricultural runoff, stormwater discharge, and groundwater discharge.	Amendment to the Water Quality Control Plan for the Los Angeles Region to include a TMDL for Nitrogen Compounds in the Santa Clara River was adopted August 2003.
Malibu Creek	Nutrients		Draft unavailable.
Malibu Creek	Bacteria	Stormwater and dry weather runoff, onsite wastewater treatment system, and animal waste.	Resolution amending the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load for Bacteria in the Malibu Creek Watershed was adopted December 2004.
Santa Monica bay and beaches	Bacteria		Tentative resolution amending the Water Quality Control Plan (Basin Plan) for the Los Angeles

TABLE 8. STATUS OF SELECTED TMDLS FOR WATER BODIES WITHIN THE JURISDICTION OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

WATER BODY NAME	POLLUTANT	SOURCES	SUMMARY
			Region to Incorporate a Wet-Weather Total Maximum Daily Load for Bacteria at Santa Monica Bay was drafted September 2002.
Channel Islands harbor	Bacteria		Public hearing to discuss the Channel Islands Harbor Bacteria TMDL was held October 2004.
Marina del rey Harbor Mother's beach and back basins	Bacteria	Dry-weather urban runoff and storm water marina activities such as waste disposal from boats, boat deck and slip washing, swimmer "wash-off", restaurant washouts and natural sources from birds, waterfowl and other wildlife.	Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the Marina del Rey Harbor Mothers' Beach and Back Basins Bacteria TMDL

VI. LIST OF POTENTIAL SOURCES OF POCS

Information on the make up and land uses that may contribute POC loading in the four sub-watersheds is limited. Rather, general observations are made in identifying and listing potential sources for the POCs that were detected at the four monitoring sites.

Nitrogen Compounds

Sources of nitrite, nitrate, and ammonia are generally agricultural activities (including nitrogenous-based fertilizers), animal and human fecal matter, natural environmental concentrations, and home use and disposal of fertilizers that are generally uncontrollable.

Nitrogen compounds in stormwater

- Agricultural activities
- Animal fecal matter
- Natural environmental concentrations
- Home use and disposal of fertilizers

Nitrogen compounds in wastewater

- Natural environmental concentrations
- Home use and disposal of fertilizers

DDT Pesticides

Prior to 1972 when its use was banned, DDT was a commonly used pesticide. Although it is no longer used or produced in the United States, DDT persists in the environment. DDT, and its break-down products DDE and DDD, are persistent, bioacculumative, and toxic. Sources of DDT include atmospheric deposition and soil and sediment runoff.

Total Coliform

Sources of total coliform are limited to human waste, agricultural areas, or wildlife. Typical sources of bacteria/pathogens are noted below:

- Soils
- Birds
- Animals
- Sewage from leaks, spills and illicit connections
- Outdoor defecation
- Pet and livestock waste
- Diaper cleaning and disposal
- Landfills containing animal and human waste
- Wastewater Treatment Plant

Metals (Copper, Lead, Zinc)

Sources for metals found in stormwater runoff include industries, commercial businesses, residential uses, ambient concentrations in soil, and water supply. Industries such as electroplating or metal finishing operations and commercial businesses such as vehicle services (fueling, auto repair and painting), machine shops, printers, or car washes are most likely to contribute metals into runoff without source control measures. In residential areas, painting activities are likely sources of metal contribution in drainage and runoff. Brake pad dust from roadways is a source of metals as well. Specific sources for metals are noted below:

Metals in stormwater

- Atmospheric (dust suspension)
- Natural (erosion)
- Residential related (illegal dumping, corrosion, root control, roof runoff, surface cleaners, paint, carpet cleaning)
- Vehicle related (vehicle washing, vehicle service/repair, tailpipe emissions, brake pad wear, auto recycling facilities)
- Agriculture (Copper is applied as pesticide and directly to the ground to compensate for local soils that contain concentrations which are less than optimal for growth of crops)

Metals in wastewater

- Natural (water supply)
- Human Activities (laundry gray water, carpet cleaning, paint, household products, food waste, pools/spas)
- Corrosion of copper piping and architectural copper (roofing, vents, etc).

Metals in commercial/industry

- Coil coaters, machine shops, metal fabricators/finishers
- Carpet cleaners, dry cleaners
- Dentists, laboratories, medical service
- Food service/ restaurants, food processors
- Plumbers, printers, radiator repair
- Wineries
- Textiles/ceramics
- Airports/Aircraft
- Cooling tower blowdown
- Electronics, machine shops, metal finishers

- Ammunition, batteries
- Arc lamps

VII. LIST OF CURRENT MANAGEMENT PRACTICES

In meeting its NPDES permit requirements, Ventura Countywide Stormwater Quality Management Program implements the following stormwater management plan programs to educate the community and reduce stormwater pollution[3].

Public outreach programs

- Media outlet
- Stencil program
- Oil recycling program
- Household hazardous material program
- Access point sign posting
- Pet waste program
- Reporting of clogged catch basin inlets and illicit discharges/dumping

POCs addressed include: metals, trash, pathogens

Industrial/Commercial Businesses programs

- Outreach effort and sharing educational materials to encourage implementation of best management practices.
- Target automotive service and food service facilities
- Onsite education visits

POCs addressed include: metals, pesticides, trash

Planning and Land Development Programs

- Placing Conditions on projects that require potential stormwater quality impacts to be mitigated through source and treatment controls.

POCs addressed include: nutrients, sediments, pesticides

Construction Sites Programs

- Implementation of an effective construction program
- Erosion control
- Sediment control
- Site management
- Material and waste management

POCs addressed include: sediments, metals, trash

Public Agency Activities Programs

- Drainage system operation and maintenance (catch basin cleaning)
- Roadways operation and maintenance (street sweeping)
- Pesticide, herbicide, and fertilizers application and use
- Training municipal staff

POCs addressed include: nutrients, sediments, pesticides, trash, metals

Illicit Discharges/Illegal Connections Programs

- Respond to illicit discharge reports and ensure discharges are terminated, cleaned up and/or perform follow-up education.
- Public outreach program (see above)

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[3] Ventura County Watershed Protection District (2004). Ventura Countywide Stormwater Quality Management Program Annual Report for Permit Year 4, Reporting Year 10.

POCs addressed include: pesticides, trash, metals

VIII. SUMMARY AND CONCLUSIONS

The trend analysis presented in this report is limited by available data. Monitoring at the sites was reported on average once a year and reflects one wet weather event per year. Of the eleven POCs considered in this analysis and are monitored at the sites, nine POCs had sufficient data to consider in a statistical analysis. Of these nine pollutants, data for seven POCs revealed trends that might be considered as statistically relevant and include DDT, copper, lead, zinc, ammonia, TKN, and total coliform. Generally, the receiving water sites exhibit a decrease in POCs. Data at site I2, representing an industrial land use, suggest an increase, albeit minor, in ammonia, copper, and total coliform. Data at site R1, representing residential land use, were generally inconclusive except for lead which appears to have a decreasing trend.

A review of the current BMP program above and the trend analysis supports in general that the Ventura Countywide Stormwater Quality Management Program is adequately addressing the current pollutants of concern and potential pollutants (e.g. trash and sediment) identified in regional TMDLs. The one caveat to this statement is in the industrial/commercial program. The trend analysis indicated that the one site that showed potential increase in pollutant concentrations was the industrial site (I-2) and the pollutants showing increases were metals and nutrients. These pollutants are prevalent at industrial sites, especially metals, and consequently the Program should consider an enhanced effort in this area. Currently the Program conducts educational inspections once every two years. This frequency should be increase to once every year. The inspection should be expanded to include more than just an educational visit. A more formal inspection program should be established and include:

- Inspection checklist
- BMP Fact Sheets (with appropriate references to the State Industrial General Permit and California BMP Handbooks)
- Progressive Enforcement and Referral Policy

Similarly the commercial/industrial inventory should be expanded and include business that have been identified as potential nutrient sources, e.g. kennels, nurseries.

Ventura County Beach Postings (1/5/2005-10/17/2006)

	Beach Name	ID Number
1	Rincon Beach (25 yds S. of creek mouth)	1000
2	Rincon Beach (at the flagpole)	1050
3	Rincon Beach (bottom of footpath)	1100
4	Hobson County Park Beach	5000
5	Rincon Parkway (near camp space 20)	6000
6	Faria County Park Beach	7000
7	Mandos Cove Beach	8000
8	Solimar Beach at Cypress Tree	9000
9	Solimar Beach at end of east gate	10000
10	Emma Wood State Beach	11000
11	Surfer's Point Beach (at Fairgrounds- stables)	13000
12	Promenade Park (Figueroa St.)	14000
13	Promenade Park (Redwood Apts)	15000
14	Promenade Park (S. of drain, end of Oak Street)	16000
15	Promenade Park (California St.)	17000
16	San Buenaventura Beach (Kalorama St.)	18000
17	San Buenaventura Beach (San Jon Rd.)	19000
18	San Buenaventura Beach (Dover Ln.)	20000
19	San Buenaventura Beach (Weymouth Ln.)	21000
20	Marina Park Beach (at cement boat)	22000
21	Peninsula Beach (aka Harbor Cove)	23000
22	South Jetty (Beach area S of Jetty, Ventura Harbor Marina)	24000
23	Surfer's Knoll (Beach next to parking lot, 1/4 mile up coast of Santa Clara River)	25000
24	McGrath State Beach (N. of Gonzales Rd.)	26000
25	McGrath State Beach (End of Gonzales Rd.)	27000
26	McGrath State Beach (S. end of McGrath Lake)	28000
27	Oxnard Beach (S. of Starfish Drive, End of Outrigger Way)	30000
28	Oxnard Beach Park (Falkirk St.)	32000
29	Hollywood Beach - La Crescenta Ave	34000
30	Hollywood Beach (Los Robles St.)	35000
31	Hobie Beach (S. end of Victoria Ave.)	36000
32	Channel Island Harbor Beach Park (Kiddie Beach)	37000
33	Silverstrand Beach (San Nicolas Ave.)	38000
34	Silverstrand Beach (Sawtelle Ave.)	40000
35	Port Hueneme Beach Park (50 yds N. of Pier)	41000
36	Ormond Beach (25 yds S. of "J" Street Drain)	42000
37	Ormond Beach (25 yds N. of Industrial Drain)	43000
38	Ormond Beach (End of Arnold Road)	44000
39	Point Mugu Beach	45000
40	Sycamore Cove Beach (25 yds S. of creek)	47000
41	Deer Creek Beach (25 yds S. of creek)	48000
42	County Line Beach	49000
43	Staircase Beach (bottom of staircase)	50000

Ventura County 2005 Beach Postings

Beach Name	ID Number
C.I. Harbor Beach Park (Kiddie Beach)	37000
County Line Beach	49000
Emma Wood State Beach	11000
Faria County Park Beach	7000
Hobie Beach	36000
Hobson County Park Beach	5000
Hollywood Beach (Los Robles St.)	35000
Mandos Cove Beach	8000
Marina Park Beach	22000
McGrath State Beach (End.of Gonzales Rd.)	27000
McGrath State Beach (N.of Gonzales Rd.)	26000
McGrath State Beach (S. end of McGrath Lake)	28000
Ormond Beach (Industrial Drain)	43000
Oxnard Beach (Outrigger Way)	30000
Oxnard Beach Park (Falkirk St.)	32000
Peninsula Beach/Harbor Cove	23000
Point Mugu Beach	45000
Port Hueneme Beach Park	41000
Promenade Park (California St.)	17000
Promenade Park (End of Oak St.)	16000
Promenade Park (Figueroa St.)	14000
Promenade Park (Redwood Apts)	15000
Rincon Beach (creek mouth)	1000
Rincon Beach (footpath)	1100
San Buenaventura Beach (Dover Ln.)	20000
San Buenaventura Beach (Kalorama St.)	18000
San Buenaventura Beach (San Jon Rd.)	19000
San Buenaventura Beach (Weymouth Ln.)	21000
Silverstrand Beach (San Nicolas Ave.)	38000
Silverstrand Beach (Sawtelle Ave.)	40000
Solimar Beach (cypress tree)	9000
South Jetty Beach	24000
Surfer's Knoll Beach	25000
Surfer's Point Beach (Stables)	13000
Sycamore Cove Beach	47000

Ventura County 2006 Beach Postings

Beach Name	ID Number
Channel Island Harbor Beach Park (Kiddie Beach)	37000
County Line Beach	49000
Deer Creek Beach (25 yds S. of creek)	48000
Emma Wood State Beach	11000
Hobie Beach (S. end of Victoria Ave.)	36000
Hollywood Beach - La Crescenta Ave	34000
Hollywood Beach (Los Robles St.)	35000
Marina Park at cement boat	22000
McGrath State Beach (End of Gonzales Rd.)	27000
McGrath State Beach (N. of Gonzales Rd.)	26000
McGrath State Beach (South end near McGrath Lake)	28000
Ormond Beach (25 yds N. of Industrial Drain)	43000
Ormond Beach (25 yds S. of "J" Street Drain)	42000
Ormond Beach (End of Arnold Road)	44000
Oxnard Beach (S. of Starfish Drive, End of Outrigger Way)	30000
Peninsula Beach (aka Harbor Cove)	23000
Point Mugu Beach	45000
Port Hueneme Beach Park (50 yds N. of Pier)	41000
Promenade Park - Figueroa Street	14000
Promenade Park (S. of drain, end of Oak Street)	16000
Promenade Park at California St.	17000
Promenade Park at Redwood Apartments.	15000
Rincon Beach (25 yds S. of creek mouth)	1000
Rincon Beach (at the flagpole)	1050
Rincon Beach (bottom of footpath)	1100
Rincon Parkway (near camp space 20)	6000
San Buenaventura Beach at Dover Lane	20000
San Buenaventura Beach at Kalorama St.	18000
San Buenaventura Beach at San Jon Road.	19000
San Buenaventura Beach at Weymouth Lane	21000
Silverstrand Beach - San Nicholas Ave	38000
Silverstrand Beach (Sawtelle Ave)	40000
Solimar Beach at Cypress Tree	9000
Solimar Beach at end of east gate	10000
South Jetty (Beach area S of Jetty, Ventura Harbor Marina)	24000
Staircase Beach (bottom of staircase)	50000
Surfer's Knoll (Beach next to parking lot, 1/4 mile up coast of Santa Clara River)	25000
Surfer's Point at Fairgrounds, stables	13000
Sycamore Cove Beach (25 yds S. of creek)	47000

County of Ventura

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OCEAN WATER QUALITY MONITORING PROGRAM

Log of Beach Postings: January 2005 - Present

Sign Posted	Sign Removed	No. of Days Posted	Beach Name	Indicator(s) Failed	ID Number
1/5/05	2/16/05	42	Mandos Cove Beach	TC & E	8000
1/5/05	1/19/05	14	Surfer's Point Beach (Stables)	TC, FC, & E	13000
1/5/05	1/26/05	21	Promenade Park Beach (Figueroa St.)	TC, FC, & E	14000
1/5/05	1/26/05	21	Promenade Park Beach (California St.)	TC	17000
1/5/05	2/2/05	28	Peninsula Beach/Harbor Cove	TC, FC, & E	23000
1/5/05	2/9/05	35	Oxnard Beach Park (Falkirk St.)	TC & E	32000
1/5/05	1/19/05	14	Hollywood Beach (Los Robles St.)	TC, FC, & E	35000
1/5/05	1/19/05	14	C.I. Harbor Beach Park (Kiddie Beach)	TC, FC, & E	37000
1/12/05	2/2/05	21	Marina Park Beach	TC & E	22000
1/12/05	1/19/05	7	Silverstrand Beach (Sawtelle Ave.)	TC & E	40000
1/12/05	1/19/05	7	Sycamore Cove Beach	TC	47000
1/12/05	1/26/05	14	County Line Beach	TC & E	49000
1/19/05	2/2/05	14	Hobson County Park Beach	TC	5000
1/19/05	2/2/05	14	San Buenaventura Beach (San Jon Rd.)	TC & E	19000
1/26/05	2/2/05	7	Rincon Beach	TC	1000
1/26/05	2/2/05	7	Surfer's Point Beach (stables)	TC	13000
1/26/05	2/2/05	7	Surfer's Knoll Beach	TC & E	25000
1/26/05	2/2/05	7	Hollywood Beach (Los Robles St.)	TC	35000
2/2/05	2/9/05	7	C.I. Harbor Beach Park (Kiddie Beach)	FC	37000
2/9/05	2/16/05	7	Hobson County Park Beach	TC & E	5000
2/9/05	2/16/05	7	Promenade Park Beach (Figueroa St.)	TC & E	14000

2/9/05	2/16/05	7	Promenade Park Beach (California St.)	TC & E	1[illegible]
2/9/05	2/16/05	7	Marina Park Beach	TC & E	22000
2/24/05	3/2/05	6	Rincon Beach	TC & E	1000
2/24/05	3/2/05	6	Hobson Co. Park Beach	TC & E	5000
2/24/05	3/16/05	20	Mandos Cove Beach	TC & E	8000
2/24/05	3/2/05	6	Surfer's Pt. (stables)	TC, FC, & E	13000
2/24/05	3/2/05	6	Promenade Pk. Beach (Figueroa St.)	TC, FC, & E	14000
2/24/05	3/2/05	6	Promenade Pk. Beach (California St.)	TC, FC & E	17000
2/24/05	3/16/05	20	San Buenaventura Beach (San Jon Rd.)	TC, FC, & E	19000
2/24/05	3/2/05	6	Marina Park Beach	TC & E	22000
2/24/05	3/2/05	6	Peninsula Beach/Harbor Cove	TC, FC, & E	23000
2/24/05	3/16/05	20	Surfer's Knoll Beach	TC & E	25000
2/24/05	3/16/05	20	Oxnard Beach (Falkirk Ave.)	TC & E	32000
2/24/05	3/2/05	6	Hollywood Beach (Los Robles St.)	TC & E	35000
2/24/05	3/2/05	6	C.I. Harbor Beach Park (Kiddie Beach)	TC, FC, & E	37000
2/24/05	3/2/05	6	Silverstrand Beach (Sawtelle Ave.)	TC & E	40[illegible]
2/24/05	3/2/05	6	Port Hueneme Beach Park	TC & E	41[illegible]
2/24/05	3/2/05	6	Point Mugu Beach	E	45000
3/9/05	3/16/05	7	Surfer's Point Beach (stables)	E	13000
3/9/05	3/16/05	7	Marina Park Beach	TC & E	22000
3/30/05	4/5/05	6	C. I. Harbor Beach Park (aka Kiddie Beach)	E	37000
3/30/05	4/5/05	6	Point Mugu Beach	TC	45000
4/4/05	4/5/05	1	McGrath State Beach (N.of Gonzales Rd.)	FC & E	26000
4/4/05	4/5/05	1	McGrath State Beach (End.of Gonzales Rd.)	E & Ratio	27000
4/6/05	4/7/05	1	Promenade Park (Redwood Apts)	E & Ratio	15000
4/6/05	4/7/05	1	Promenade Park (End of Oak St.)	E & Ratio	16000
4/13/05	4/14/05	1	Solimar Beach (cypress tree)	TC	9000
4/20/05	4/21/05	1	Faria County Park Beach	FC	7000
5/3/05	5/4/05	1	Ormond Beach (Industrial Drain)	TC	43000
5/10/05	5/11/05	1	Oxnard Beach (Outrigger Way)	E & Ratio	30000
5/10/05	5/11/05	1	Ormond Beach (Industrial Drain)	TC,FC,E,Ratio	43000

5/18/05	5/20/05	2	San Buenaventura Beach (San Jon Rd.)	TC& E	19000
5/24/05	5/27/05	3	C.I. Harbor Beach Park (Kiddie Beach)	E	37000
5/26/05	5/27/05	1	Rincon Beach (creek mouth)	E	1000
5/26/05	5/27/05	1	Rincon Beach (footpath)	FC	1100
5/26/05	5/27/05	1	Surfer's Point (stables)	TC	13000
5/26/05	5/27/05	1	Promenade Park (Figueroa St.)	TC	14000
5/26/05	5/27/05	1	Promenade Park (Redwood Apts)	TC	15000
5/26/05	5/27/05	1	Promenade Park (Oak St.)	TC	16000
5/26/05	5/27/05	1	Promenade Park (California St.)	TC	17000
5/26/05	5/27/05	1	San Buenaventura Beach (Kalorama St.)	TC	18000
5/26/05	5/27/05	1	San Bueanventura Beach (San Jon Rd.)	TC	19000
5/26/05	5/27/05	1	San Buenaventura Beach (Dover Ln.)	TC	20000
5/26/05	5/27/05	1	San Buenaventura Beach (Weymouth Ln.)	TC	21000
5/26/05	5/27/05	1	Marina Park Beach	TC	22000
6/1/05	6/2/05	1	San Buenaventura Beach (San Jon Rd.)	TC	19000
6/23/05	6/24/05	2	South Jetty Beach	TC	24000
6/23/05	6/24/05	2	Surfer's Knoll Beach	TC	25000
7/6/05	7/13/05	7	Rincon Beach (creek mouth)	FC	1000
7/6/05	7/12/05	6	San Buenaventura Beach (San Jon Rd.)	E	19000
7/19/05	7/26/05	7	Silverstrand Beach (San Nicolas Ave.)	TC & FC	38000
7/19/05	7/20/05	1	Ormond Beach (Industrial Drain)	TC	43000
7/26/05	7/27/05	1	McGrath State Beach (S. end of McGrath Lake)	E	28000
8/2/05	8/9/05	7	San Buenaventura Beach (San Jon Rd.)	Ratio	19000
8/2/05	8/3/05	1	San Buenaventura Beach (Weymouth Ln.)	Ratio & FC	21000
8/2/05	8/3/05	1	South Jetty Beach	E	24000
8/3/05	8/4/05	1	Hobie Beach	FC	36000
8/9/05	8/10/05	1	Rincon Beach (creek mouth)	E	1000
8/16/05	8/18/05	2	C.I. Harbor Beach Park (Kiddie Beach)	TC	37000
8/23/05	8/24/05	1	Marina Park Beach	E	22000
8/31/05	9/1/05	1	Rincon Beach (creek mouth)	TC & FC	1000
8/31/05	9/1/05	1	Rincon Beach (flagpole)	Ratio	1050

9/7/05	9/14/05	7	San Buenaventura Beach (San Jon Rd.)	E	1[illegible]
9/7/05	9/8/05	1	C.I. Harbor Beach Park (Kiddie Beach)	E	37000
9/14/05	9/15/05	1	Rincon Beach (creek mouth)	TC	1000
9/22/05	9/27/05	5	C.I. Harbor Beach Park (Kiddie Beach)	E	37000
9/28/05	10/4/05	6	San Buenaventura Beach (San Jon Rd.)	TC, FC, & E	19000
10/4/05	10/5/05	1	Rincon Beach (creek mouth)	E	1000
10/4/05	10/6/05	2	C.I. Harbor Beach Park (Kiddie Beach)	E	37000
10/5/05	10/6/05	1	Hobie Beach	Ratio	36000
10/17/05	10/20/05	3	C.I. Harbor Beach Park (Kiddie Beach)	E	37000
10/17/05	10/25/05	8	Silverstrand Beach (San Nicolas Ave.)	FC & Ratio	38000
10/17/05	10/25/05	8	Silverstrand Beach (Sawtelle Ave.)	E	40000
10/18/05	10/26/05	8	Promenade Park Beach (California St.)	Ratio	17000
10/18/05	10/26/05	8	Peninsula Beach/Harbor Cove	TC & E	23000
10/25/05	10/26/05	1	Ormond Beach (Industrial Drain)	TC	43000
10/26/05	11/1/05	6	San Buenaventura Beach (San Jon Rd.)	FC	19000
11/15/05	11/22/05	7	Emma Wood State Beach	E	11[illegible]
11/15/05	11/22/05	7	C.I. Harbor Beach Park (Kiddie Beach)	FC & E	370[illegible]

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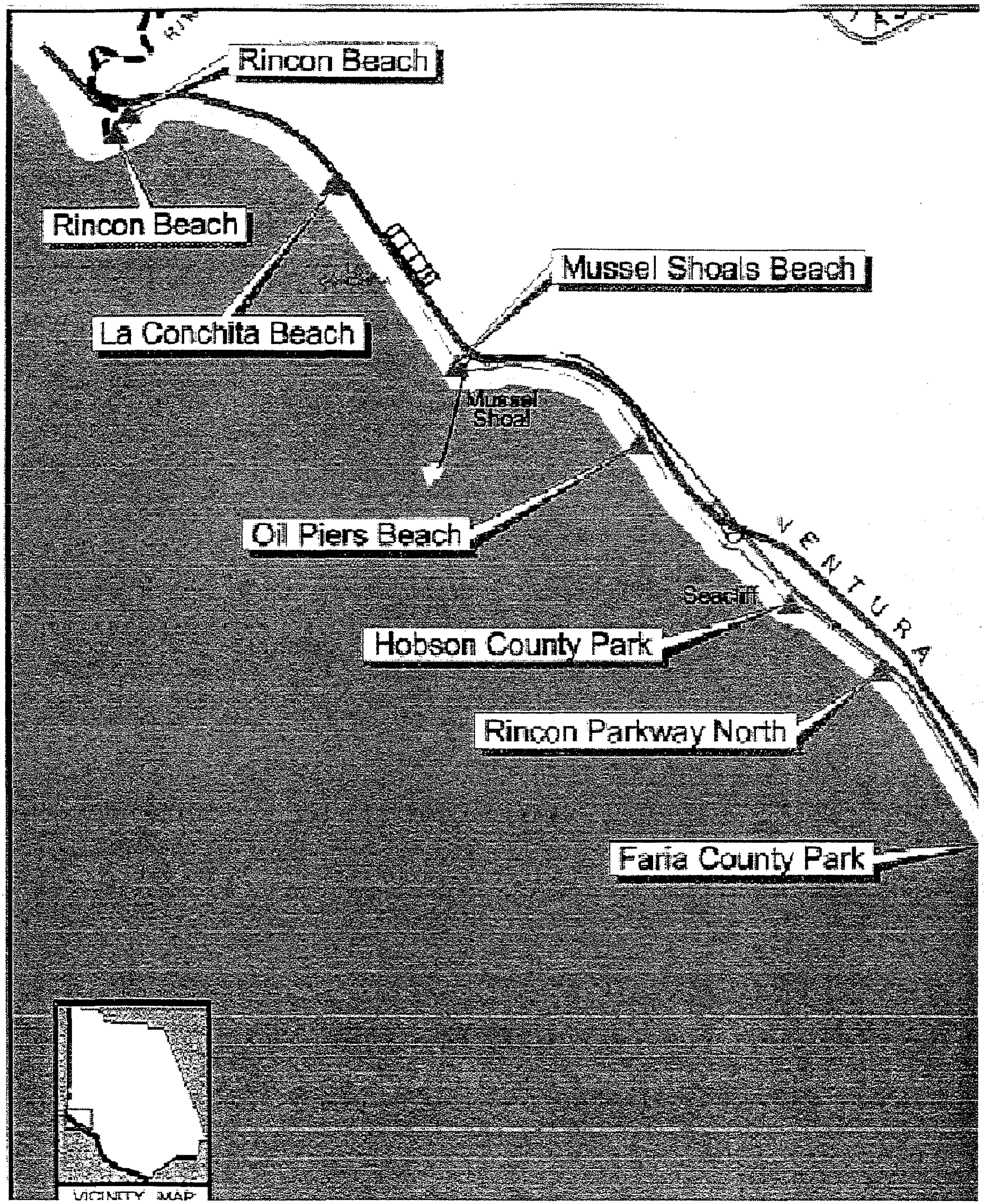
OCEAN WATER QUALITY MONITORING PROGRAM
Log of Beach Postings: January 2006 - Present

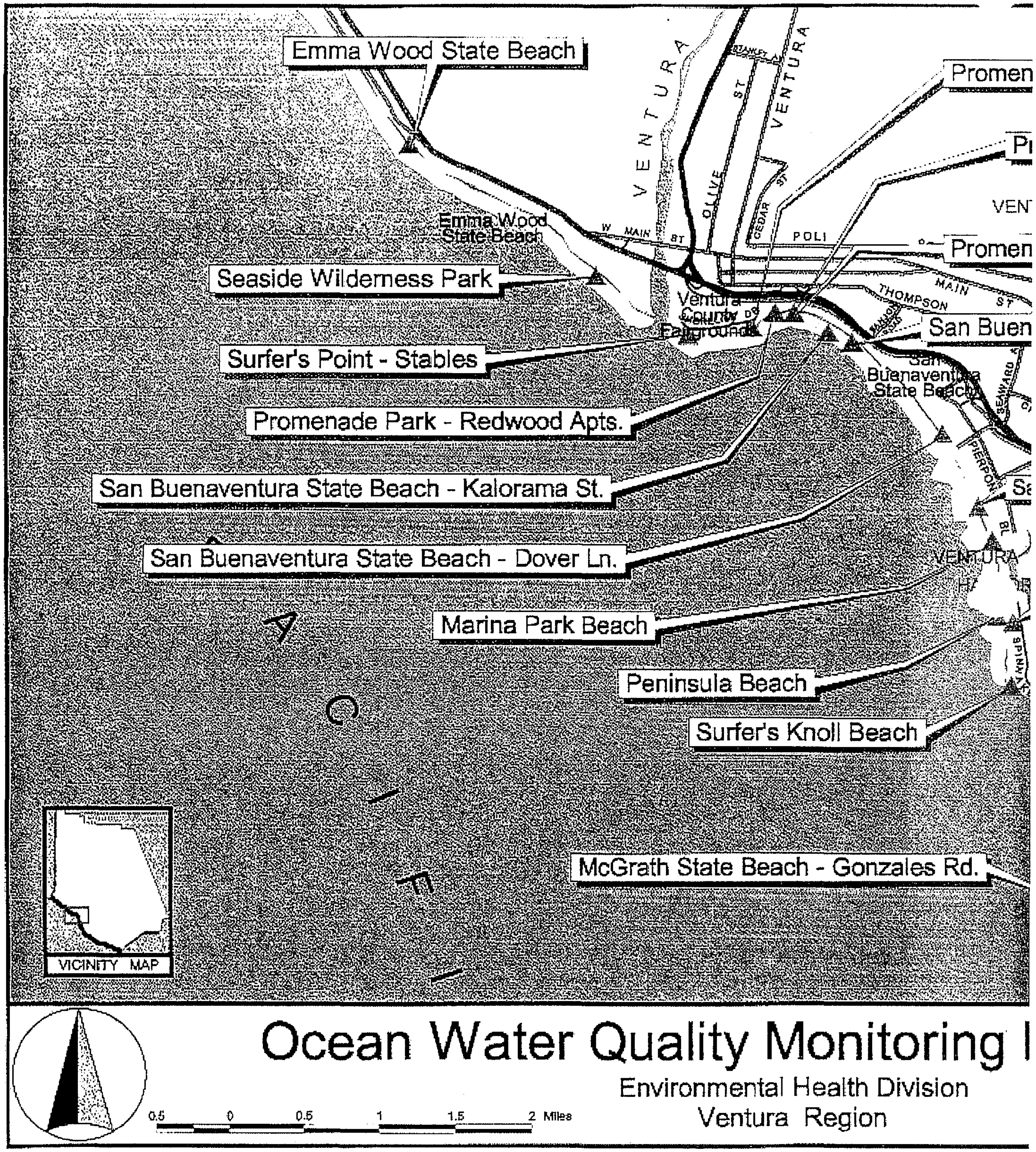
Sign Posted	Sign Removed	No. of Days Posted	Beach Name	Indicator(s) Failed	ID Number
01/4/06	01/10/06	7	Surfer's Point - Stables	TC & E	13000
01/4/06	01/10/06	7	Promenade Park - Figueroa Street	TC & E	14000
01/4/06	01/10/06	7	Peninsula Beach - Harbor Cove	TC & E	23000
01/4/06	01/10/06	7	Surfer's Knoll- nr Santa Clara River	E	25000
01/4/06	01/10/06	7	Hollywood Beach - La Crescenta Ave	E	34000
01/4/06	01/10/06	7	Channel Islands Harbor Beach Park - Kiddie Beach	E	37000
01/4/06	01/10/06	7	Silverstrand Beach - San Nicholas Ave	E	38000
02/14/06	02/22/06	8	Peninsula Beach - Harbor Cove	E	23000
02/28/06	03/07/06	7	Rincon Beach at Flagpole	E	1050
04/04/06	04/11/06	7	Rincon Beach 25 yds downcoast from creek	TC,E	1000
04/04/06	04/11/06	7	Solimar Beach at end of east gate access	TC	10,000
04/04/06	04/11/06	7	Promenade Park at Redwood Apartments	TC,E	15,000
04/04/06	04/11/06	7	Promenade Park at California St.	TC,E	17,000
04/04/06	04/11/06	7	San Buenaventura Beach at Kalorama St	E	18,000
04/04/06	04/11/06	7	Channel Islands Harbor Beach Park - Kiddie Beach	TC,FC,E	37000
04/05/06	04/12/06	7	McGrath State Beach (N. of Gonzales Rd.)	TC,FC,E	26000
04/05/06	04/12/06	7	McGrath State Beach (End of Gonzales Rd.)	TC,FC,E	27000
04/05/06	04/12/06	7	Hollywood Beach (Los Robles St.)	E	35000
04/05/06	04/12/06	7	Hobie Beach (S. end of Victoria Ave.)	TC, FC, E	36000
04/05/06	04/12/06	7	Silverstrand Beach (Sawtelle Ave)	E	40000

04/05/06	04/12/06	7	Hueneme Beach (50 yds N. of Pier)	TC	4
04/05/06	04/12/06	7	Ormond Beach (25 yds N. of Industrial Drain)	TC, E	43000
04/05/06	04/12/06	7	Staircase Beach (bottom of staircase)	E	50000
04/11/06	4/19/06	8	Surfer's Knoll (1/4 mile up coast of Santa Clara River)	TC, E	25000
04/13/06	4/18/06	5	Channel Islands Harbor Beach Park - Kiddie Beach	Ratio, FC,E	37000
04/18/06	4/19/06	1	Oxnard Beach (End of Outrigger Way)	Ratio,FC	30000
05/04/06	05/09/06	5	Channel Islands Harbor Beach Park - Kiddie Beach	E	37000
5/22/06	5/25/06	2	Rincon Beach (25 yds S. of creek mouth)	TC, FC,E, Ratio	1000
5/22/06	5/25/06	2	Rincon Beach (at the flagpole)	TC, FC,E, Ratio	1050
5/22/06	5/25/06	2	Rincon Beach (bottom of footpath)	TC, FC,E, Ratio	1100
5/22/06	5/25/06	2	Rincon Parkway, north end	E	6000
5/22/06	5/25/06	2	Solimar Beach at Cypress Tree	TC, E	9000
5/22/06	5/25/06	2	Solimar Beach at end of east gate	TC, FC,E	10000
5/22/06	5/25/06	2	Surfer's Point at Fairgrounds	TC, FC,E	1.
5/22/06	5/25/06	2	Promenade Park at Figueroa St.	TC, FC,E	14000
5/22/06	5/25/06	2	Promenade Park at Redwood Apartments.	E	15000
5/22/06	5/25/06	2	Promenade Park at Oak St.	E	16000
5/22/06	5/25/06	2	Promenade Park at California St.	E	17000
5/22/06	5/25/06	2	San Buenaventura Beach at Kalorama St.	TC, FC,E, Ratio	18000
5/22/06	5/25/06	2	San Buenaventura Beach at San Jon Road.	TC, FC,E, Ratio	19000
5/22/06	5/25/06	2	San Buenaventura Beach at Dover Lane	E	20000
5/22/06	5/25/06	2	San Buenaventura Beach at Weymouth Lane	E	21000
5/22/06	5/25/06	2	Marina Park at cement boat	TC,E	22000
5/22/06	5/25/06	2	Channel Island Harbor Beach Park (Kiddie Beach)	TC, FC,E	37000
5/24/06	5/25/06	1	Peninsula Beach (aka Harbor Cove)	TC, FC,E	23000
5/24/06	5/25/06	1	South Jetty (Beach area S of Jetty)	TC, FC,E	24000
5/24/06	5/25/06	1	Surfer's Knoll (Beach next to parking lot)	TC, FC,E	25000

5/24/06	5/25/06	1	Port Hueneme Beach Park	TC	41000
5/24/06	5/25/06	1	Ormond Beach (25 yds S. of "J" Street Drain)	TC	42000
5/24/06	5/25/06	1	Ormond Beach (50 yds N. of Industrial Drain)	TC	43000
5/24/06	5/25/06	1	Ormond Beach (End of Arnold Road)	TC	44000
5/31/06	6/1/06	1	San Buenaventura Beach at San Jon Road.	TC, FC,E	19000
6/6/06	6/7/06	1	Emma Wood State Beach	E	11000
6/7/06	6/8/06	1	Oxnard Beach Park S. of Starfish Drive	E	30000
6/14/06	6/15/06	1	Surfers' Knoll (Beach next to parking lot)	TC	25000
6/15/06	6/22/06	7	Channel Island Harbor Beach Park (Kiddie Beach)	E	37000
6/21/06	6/28/06	7	Surfers' Knoll (Beach next to parking lot)	TC	25000
7/5/06	7/11/06	5	Channel Island Harbor Beach Park (Kiddie Beach)	E	37000
7/6/06	7/11/06	5	County Line Beach	E	49000
7/12/06	7/13/06	1	Rincon Beach (25 yds S. of creek mouth)	E	1000
7/12/06	7/13/06	1	Surfers Point at stables	E	13000
7/19/06	7/26/06	7	Peninsula Beach (aka Harbor Cove)	Ratio, E	23000
7/19/06	7/26/06	7	McGrath State Beach (South end near McGrath Lake)	E	28000
7/25/06	7/27/06	2	Channel Island Harbor Beach Park (Kiddie Beach)	Ratio	37000
8/2/06	8/9/06	7	Rincon Beach (25 yds S. of creek mouth)	Ratio, E	1000
8/3/06	8/8/06	5	Channel Island Harbor Beach Park (Kiddie Beach)	E	37000
8/8/06	8/9/06	1	Hobie Beach	E	36000
8/9/06	8/10/06	1	Promenade Park (S. of drain, end of Oak Street)	FC	16000
8/10/06	8/15/06	5	Channel Island Harbor Beach Park (Kiddie Beach)	Ratio,TC,FC	37000
8/15/06	8/17/06	2	Sycamore Cove Beach (25 yds S. of creek)	Ratio	47000
8/16/06	8/17/06	1	Rincon Beach at the flagpole	Ratio	1050
8/22/06	8/23/06	1	Hobie Beach	TC,FC	36000
8/22/06	8/29/06	7	Channel Island Harbor Beach Park (Kiddie Beach)	TC,FC	37000
8/22/06	8/29/06	7	Point Mugu Beach	Ratio,FC	45000
8/23/06	8/24/06	1	Rincon Beach (25 yds S. of creek mouth)	TC	1000

8/29/06	8/30/06	1	Deer Creek Beach (25 yds S. of creek)	E	4[illegible]
8/30/06	8/31/06	1	Solimar Beach at the cypress tree	TC	9000
8/31/06	9/7/06	8	Channel Island Harbor Beach Park (Kiddie Beach)	TC,FC, E, Ratio	37000
9/6/06	9/7/06	1	Rincon Beach (25 yds S. of creek mouth)	TC,FC,E, Ratio	1000
9/12/06	9/26/06	14	Channel Island Harbor Beach Park (Kiddie Beach)	TC, FC,E, Ratio	37000
9/13/06	9/14/06	1	Rincon Beach (bottom of footpath)	Ratio	1100
9/13/06	9/14/06	1	Peninsula Beach (aka Harbor Cove)	E	23000
9/13/06	9/14/06	1	South Jetty (Ventura Harbor Marina)	E	24000
9/26/06	9/27/06	1	Rincon Beach (25 yds S. of creek mouth)	FC, Ratio	1000
9/27/06	9/28/06	1	Hobie Beach	Ratio	36000
9/28/06	10/05/06	7	Channel Island Harbor Beach Park (Kiddie Beach)	FC,E, Ratio	37000
10/03/06	10/04/06	1	Hobie Beach	TC	36000
10/10/06	10/12/06	2	Channel Island Harbor Beach Park (Kiddie Beach)	FC,E	37000
10/11/06	10/12/06	1	Rincon Beach (at the flagpole)	FC, Ratio	1050
10/11/06	10/12/06	1	Rincon Beach (bottom of footpath)	FC, Ratio	1[illegible]
10/11/06	10/12/06	1	Rincon Parkway (near camp space 20)	FC, Ratio	6000
10/17/06	--	--	Channel Island Harbor Beach Park (Kiddie Beach)	FC	37000


Rincon Beach
Rincon Beach
Mussel Shoals Beach
La Conchita Beach
Mussel Shoal
Oil Piers Beach
VENTURA
Seacliff
Hobson County Park
Rincon Parkway North
Faria County Park
VICINITY MAP


Emma Wood State Beach
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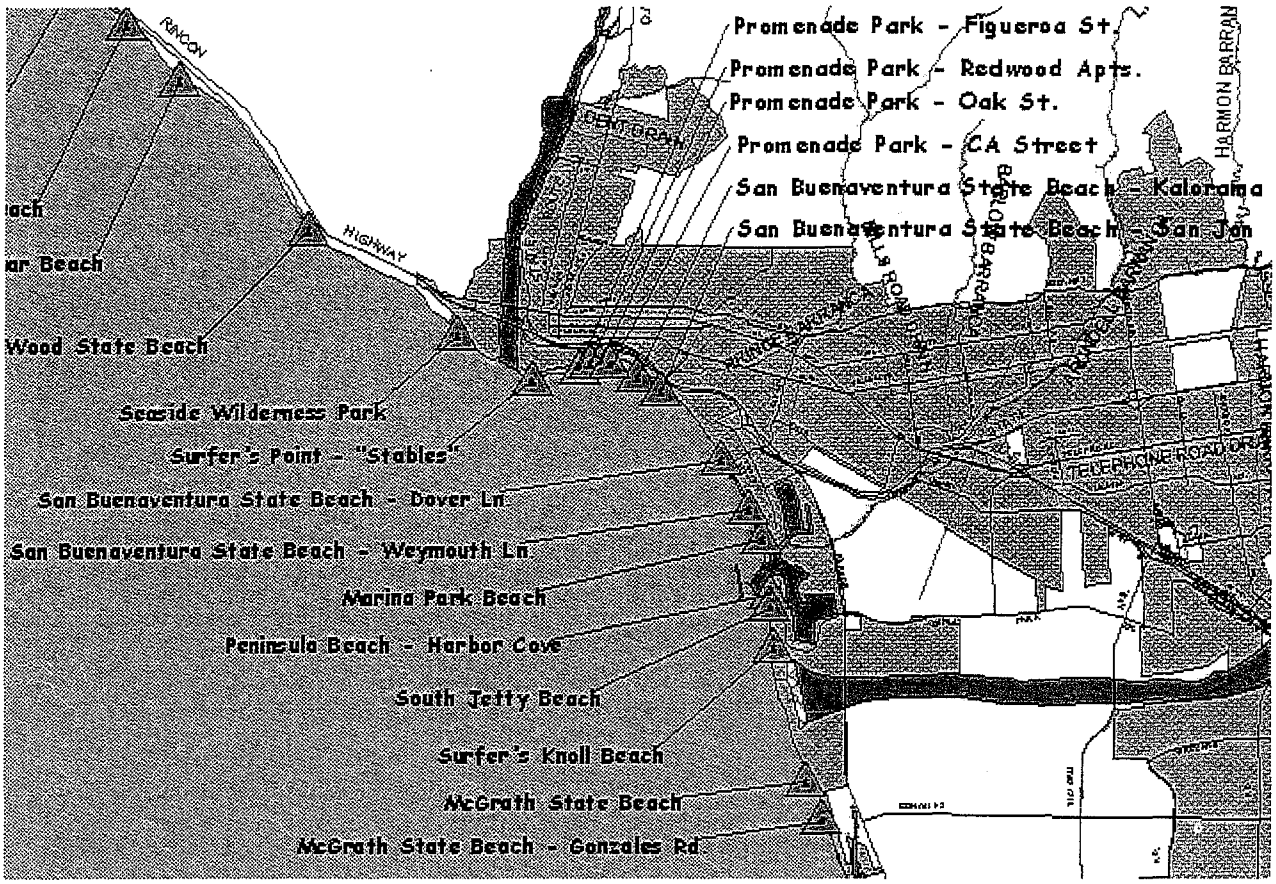
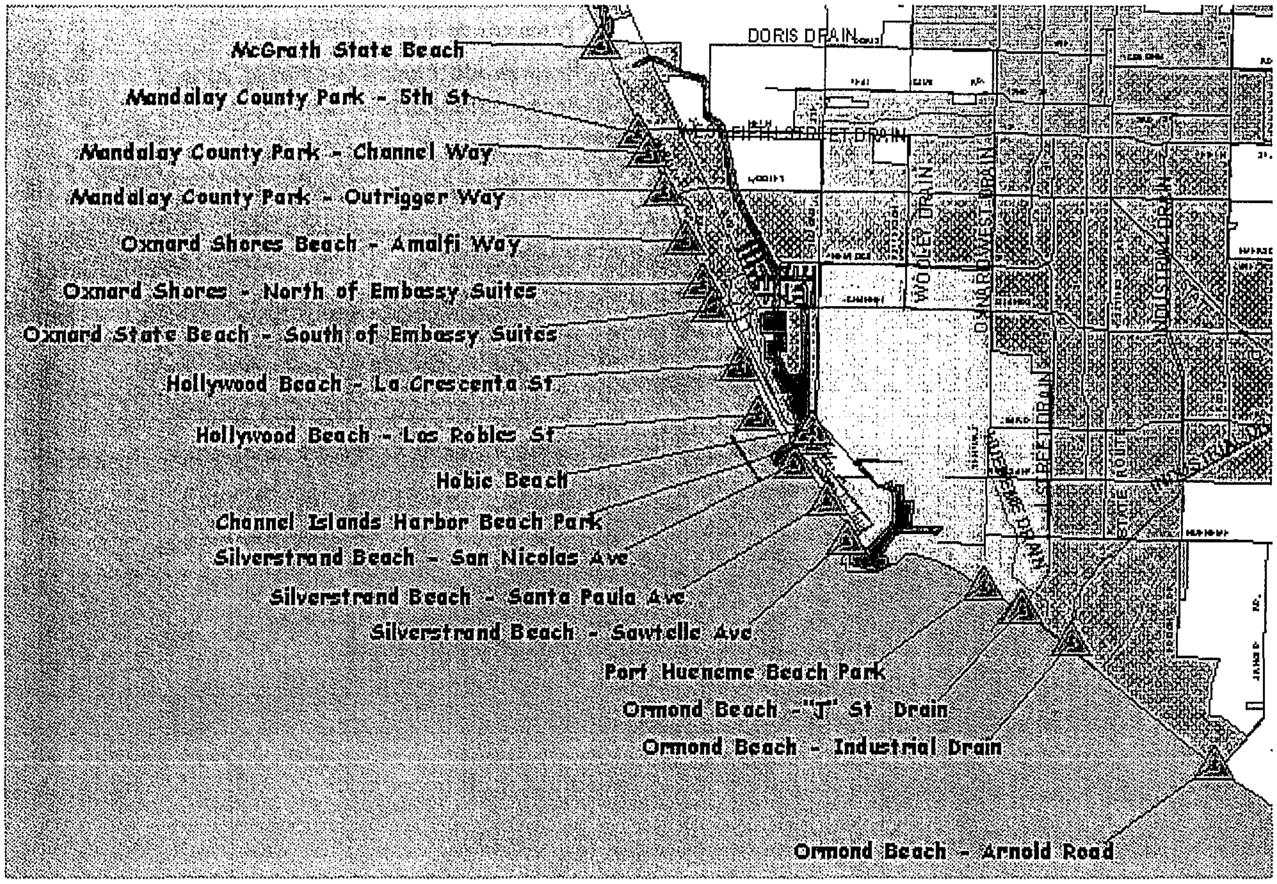
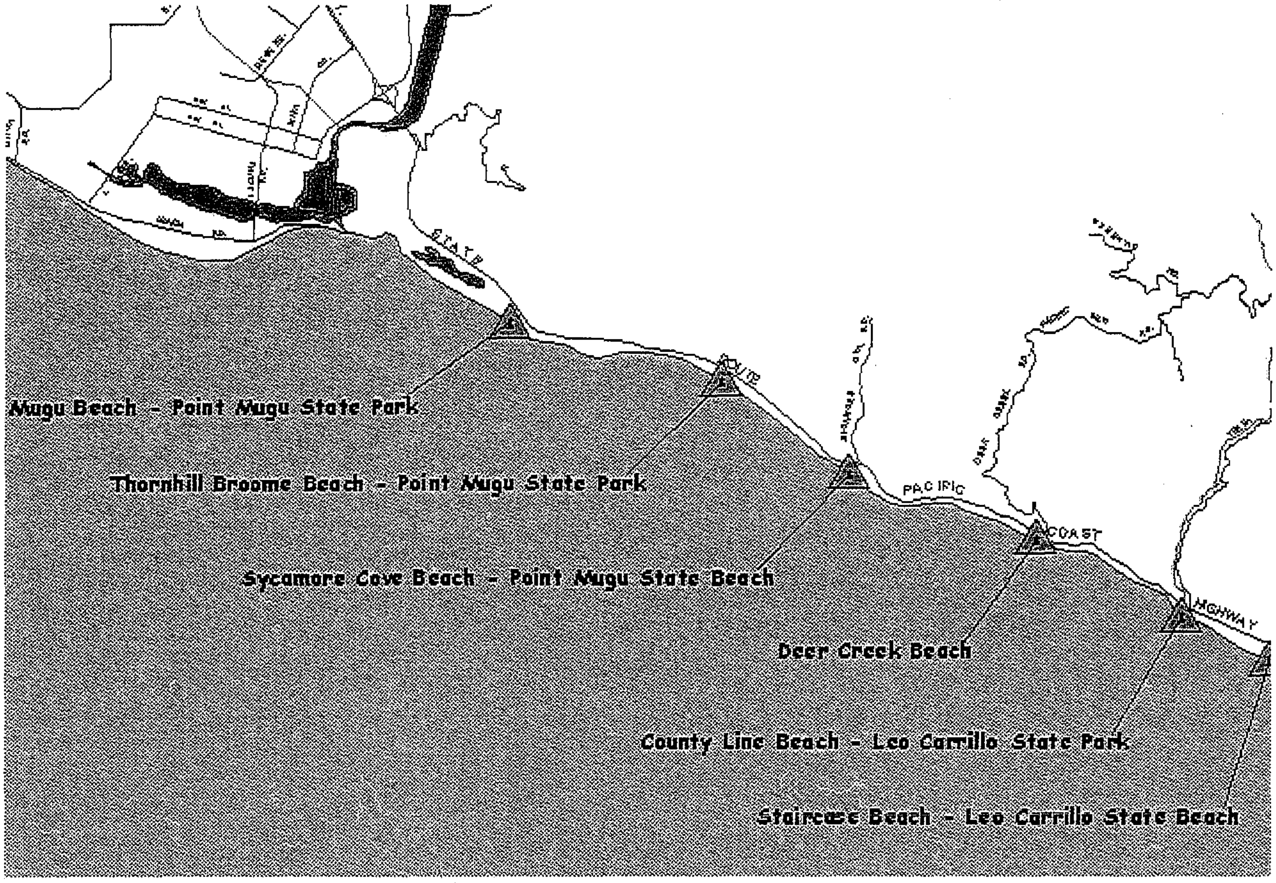
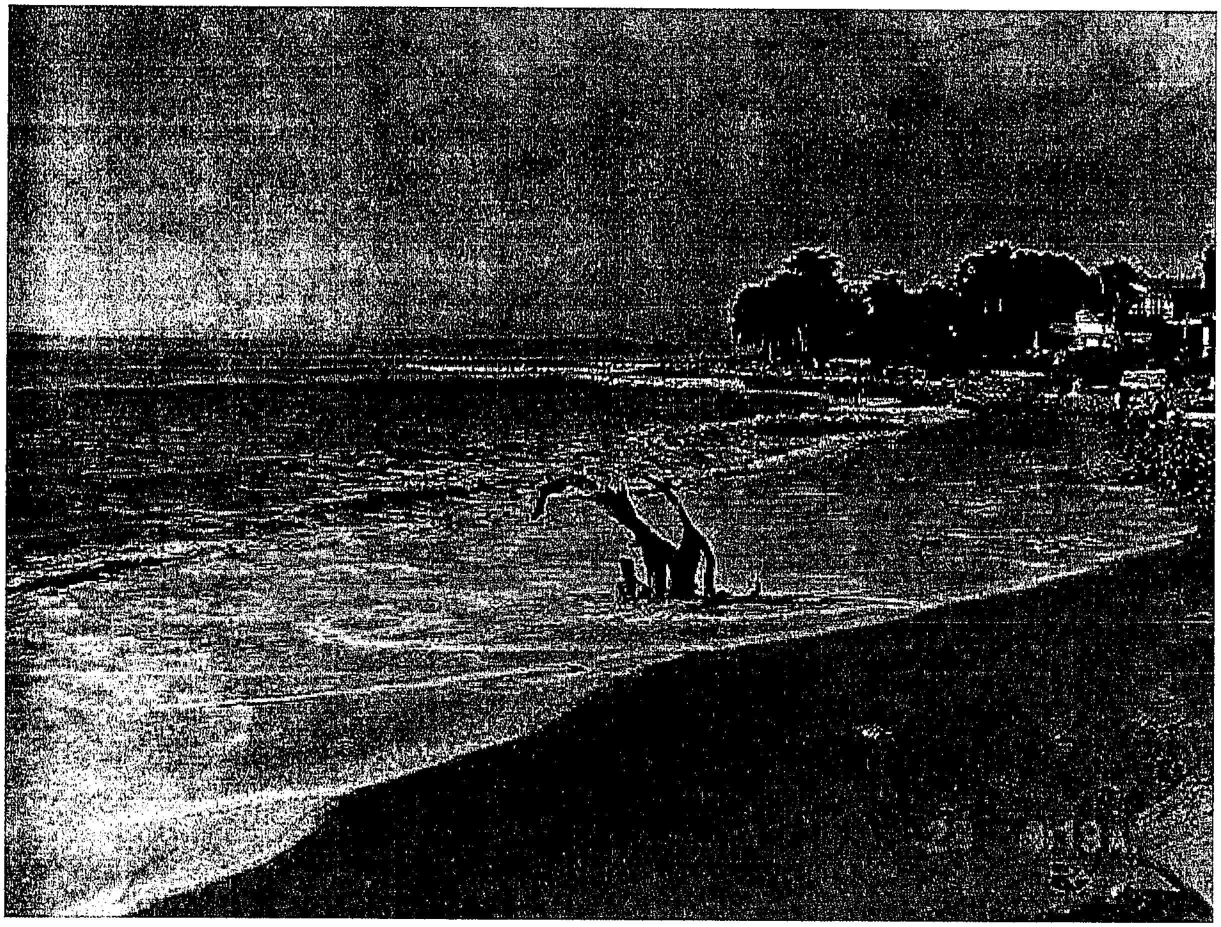
Emma Wood State Beach
Seaside Wilderness Park
Surfer's Point - Stables
San Buen
Ventura County Fairgrounds
San Buenaventura State Beach
Promenade Park - Redwood Apts.
San Buenaventura State Beach - Kalorama St.
San Buenaventura State Beach - Dover Ln.
Marina Park Beach
Peninsula Beach
Surfer's Knoll Beach
McGrath State Beach - Gonzales Rd.
VENTURA
OLIVE
CEDAR ST
W MAIN ST
POLI
THOMPSON
MAIN ST
PIERPONT
VICINITY MAP
Ocean Water Quality Monitoring
Environmental Health Division
Ventura Region
0.5 0 0.5 1 1.5 2 Miles


Promenade Park - Figueroa St.
Promenade Park - Redwood Apts.
Promenade Park - Oak St.
Promenade Park - CA Street
San Buenaventura State Beach - Kalorama
San Buenaventura State Beach - San Jon
Wood State Beach
Seaside Wilderness Park
Surfer's Point - "Stables"
San Buenaventura State Beach - Dover Ln
San Buenaventura State Beach - Weymouth Ln.
Marina Park Beach
Peninsula Beach - Harbor Cove
South Jetty Beach
Surfer's Knoll Beach
McGrath State Beach
McGrath State Beach - Gonzales Rd
HIGHWAY
HARMON BARRAN
TELEPHONE ROAD

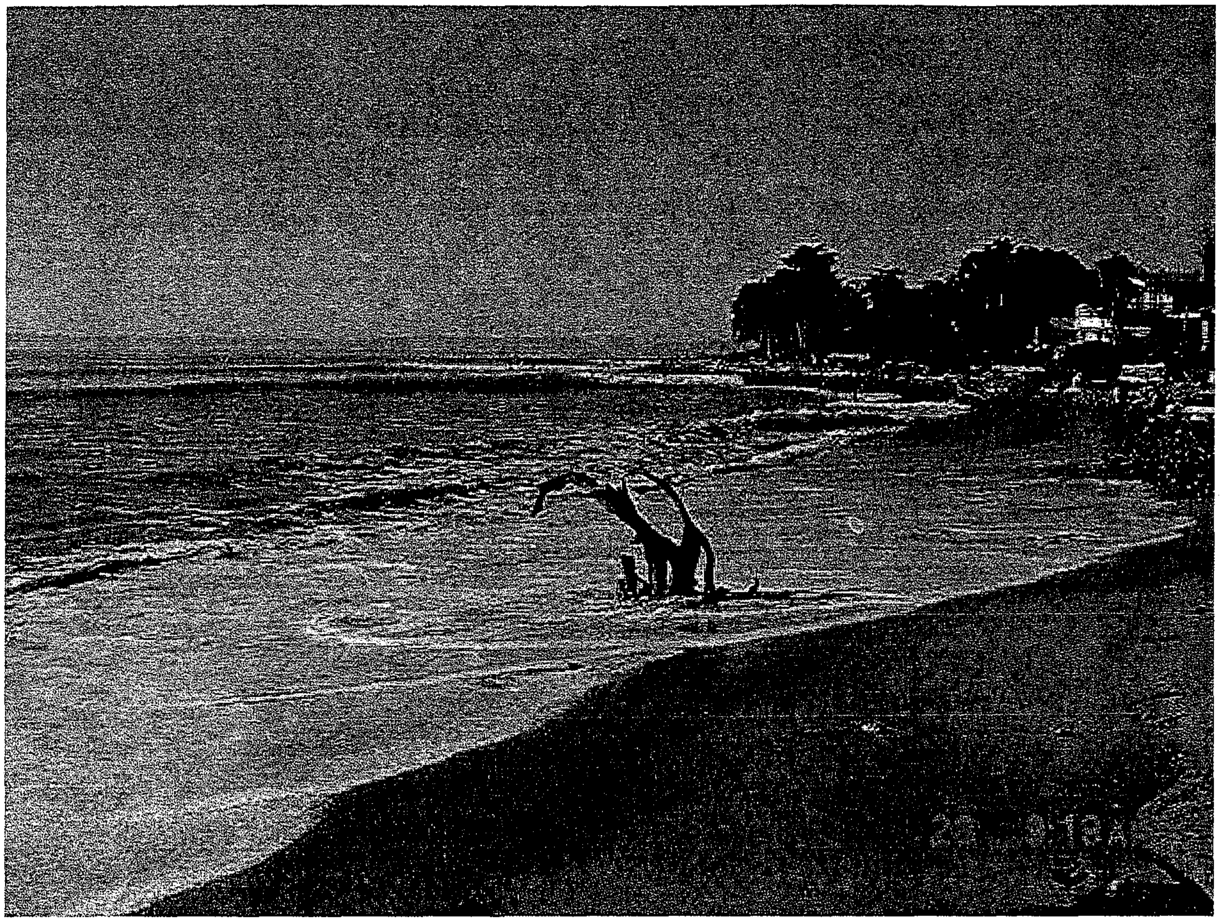

McGrath State Beach
Mandalay County Park - 5th St
Mandalay County Park - Channel Way
Mandalay County Park - Outrigger Way
Oxnard Shores Beach - Amalfi Way
Oxnard Shores - North of Embassy Suites
Oxnard State Beach - South of Embassy Suites
Hollywood Beach - La Crescenta St
Hollywood Beach - Los Robles St
Hobie Beach
Channel Islands Harbor Beach Park
Silverstrand Beach - San Nicolas Ave
Silverstrand Beach - Santa Paula Ave
Silverstrand Beach - Sawtelle Ave
Port Hueneme Beach Park
Ormond Beach - "J" St Drain
Ormond Beach - Industrial Drain
Ormond Beach - Arnold Road
DORIS DRAIN
WOOLEY DRAIN
OXNARD WEST DRAIN
J STREET DRAIN
INDUSTRIAL DRAIN
STATE ROUTE


STATE
PACIFIC
COAST
HIGHWAY
Mugu Beach - Point Mugu State Park
Thornhill Broome Beach - Point Mugu State Park
Sycamore Cove Beach - Point Mugu State Beach
Deer Creek Beach
County Line Beach - Leo Carrillo State Park
Staircase Beach - Leo Carrillo State Beach

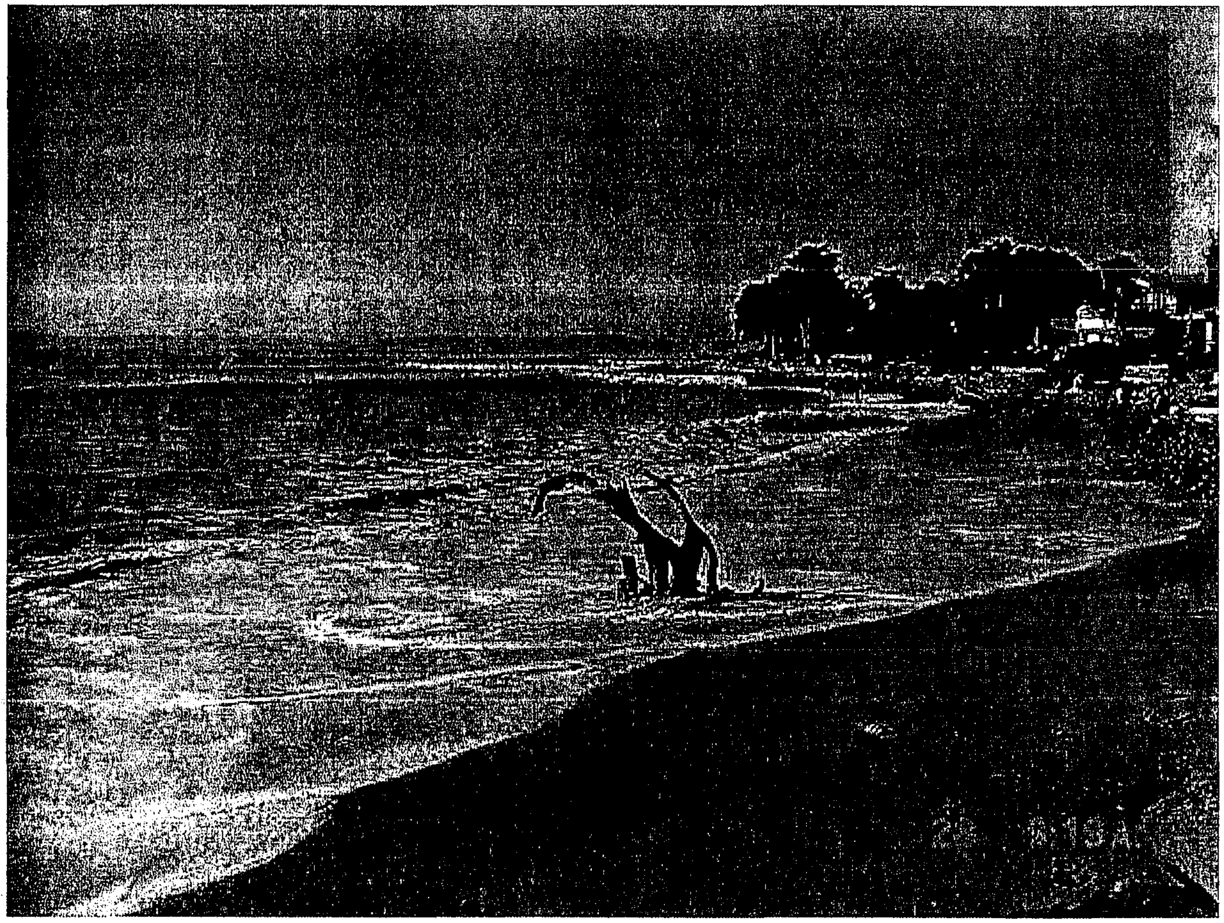
Rincon Beach (25 yards S. of creek mouth)



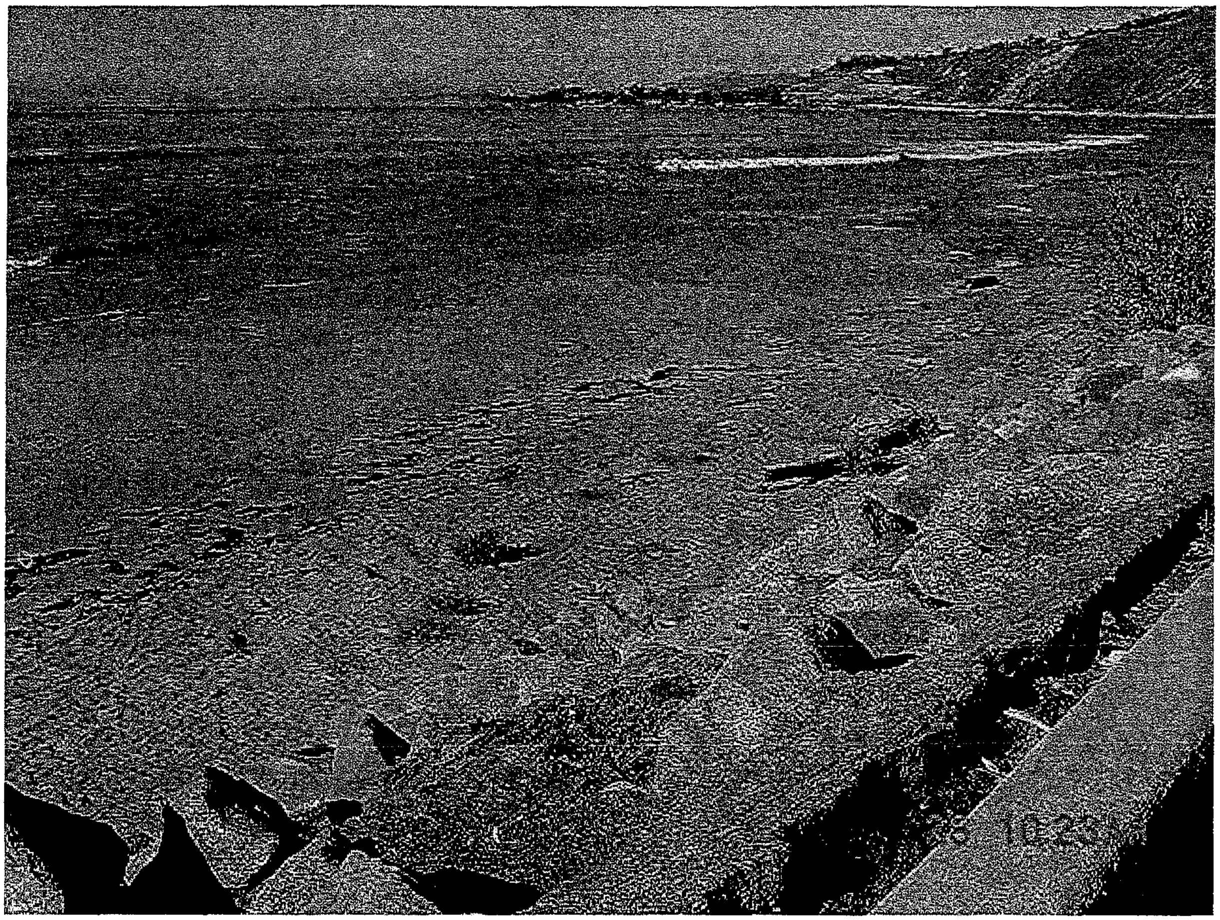
Rincon Beach (at the flagpole)



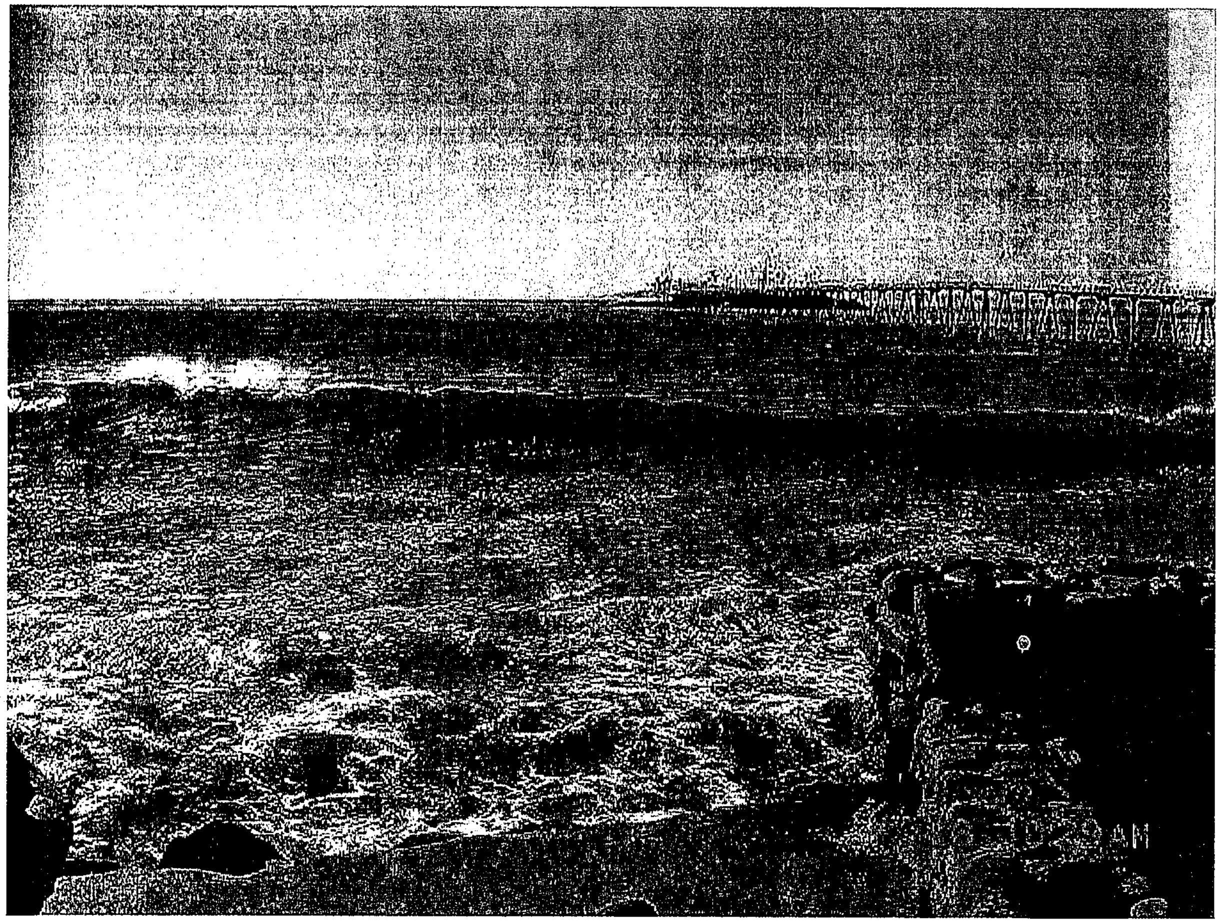
Rincon Beach (Bottom of footpath to beach)



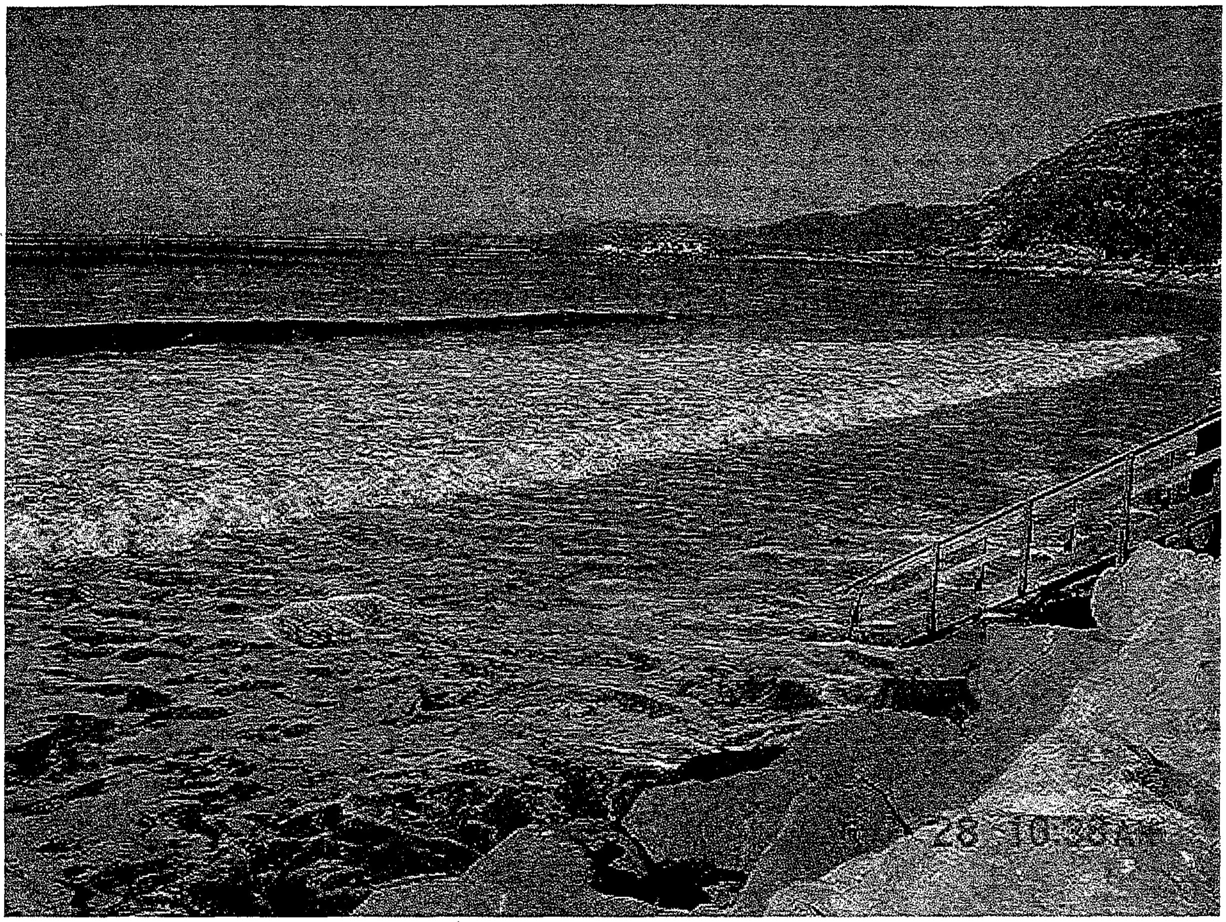
La Conchita Beach (25 yds. S. of drain, Ocean View Rd.)



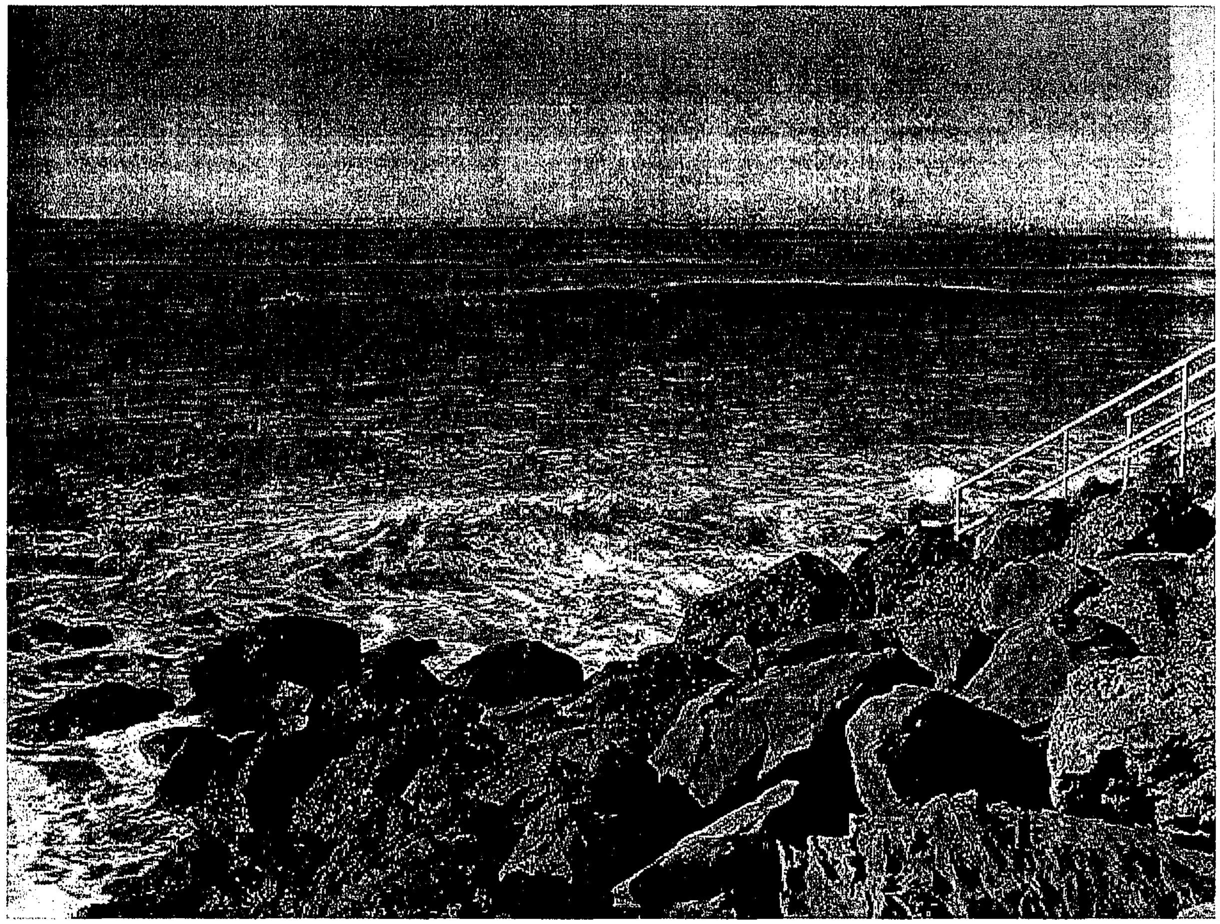
Mussel Shoals Beach (South of pier)



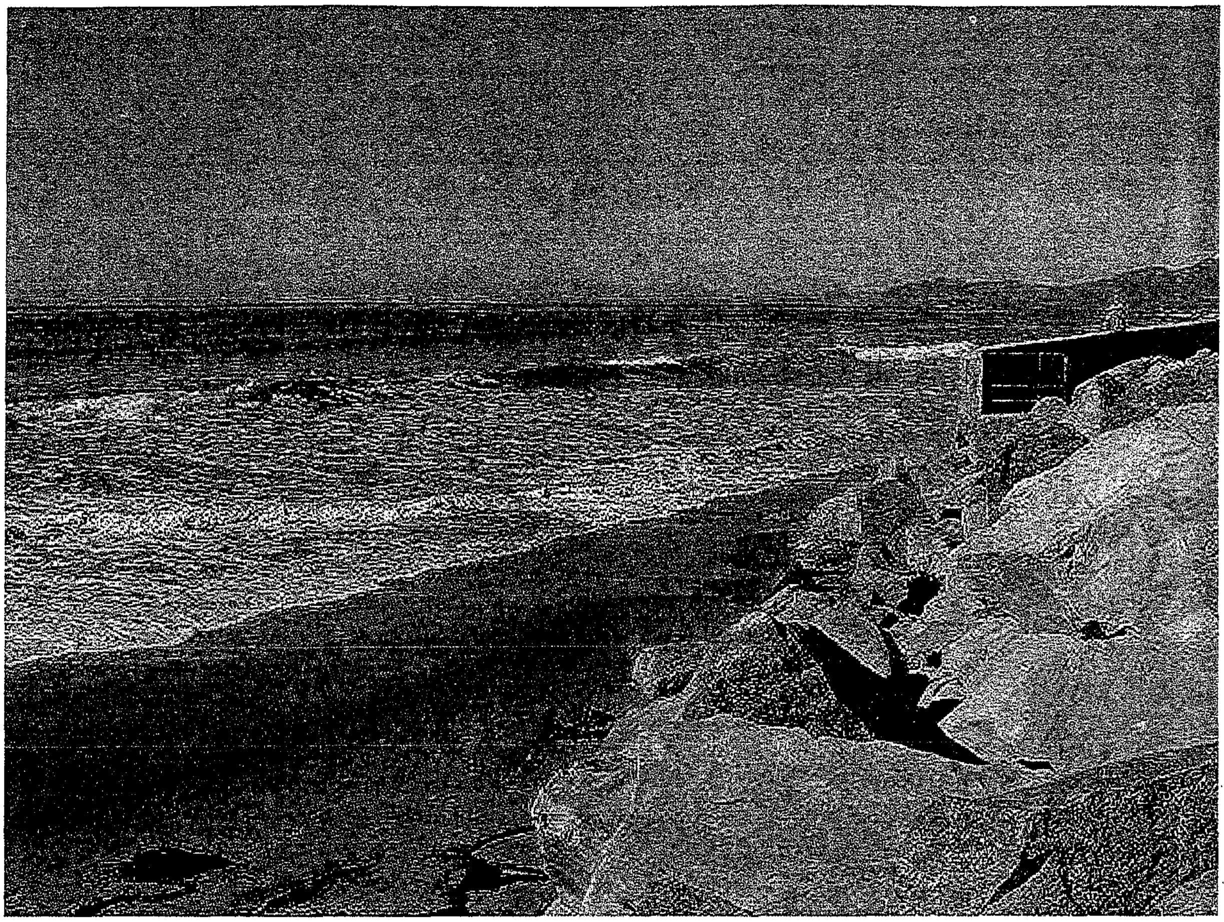
Oil Piers Beach (S. of drain, bottom of staircase)



Hobson County Park (Base of stairs to beach)

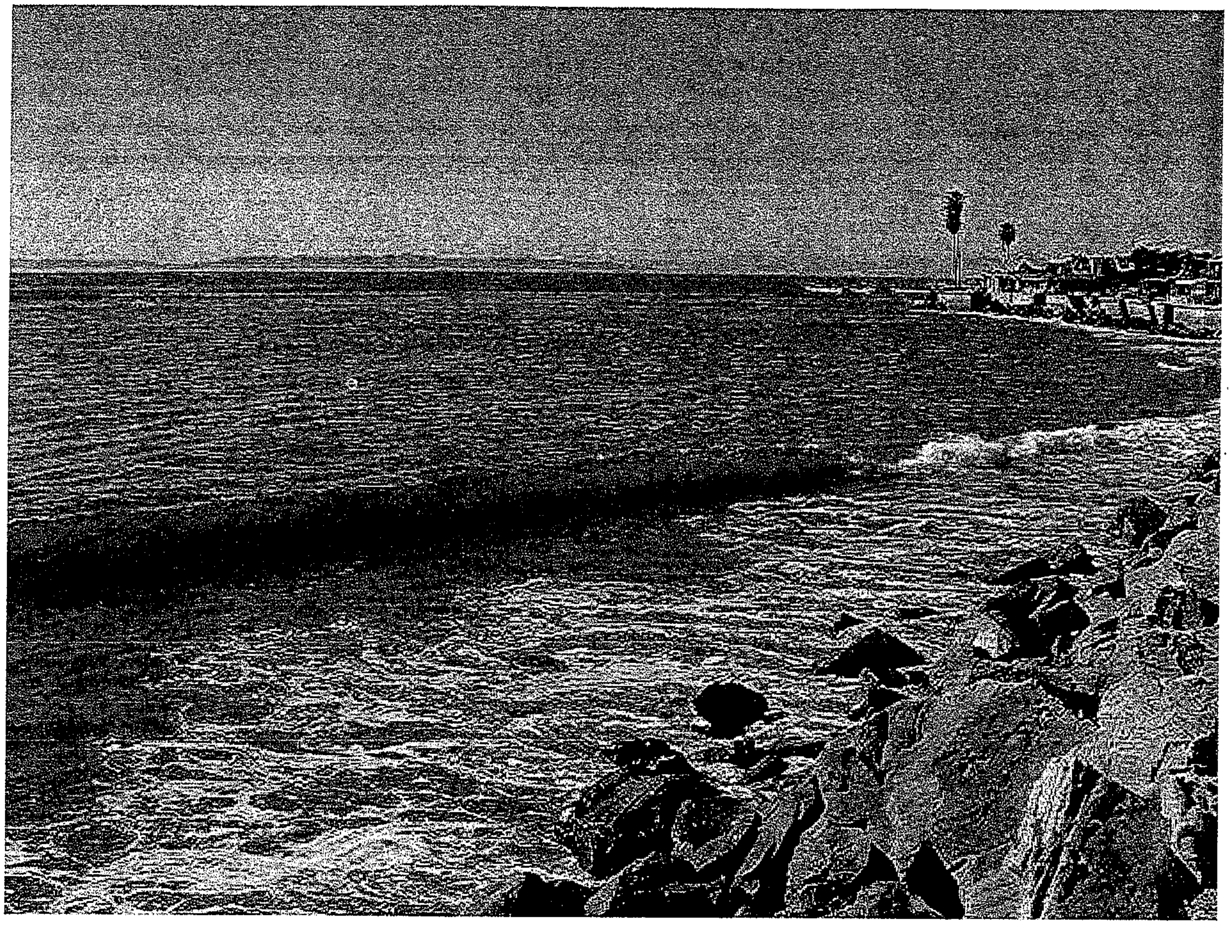


Rincon Parkway North (By camp space #20)



Faria County Park (S. of drain, N end of park)

Mandos Cove (South of drain)

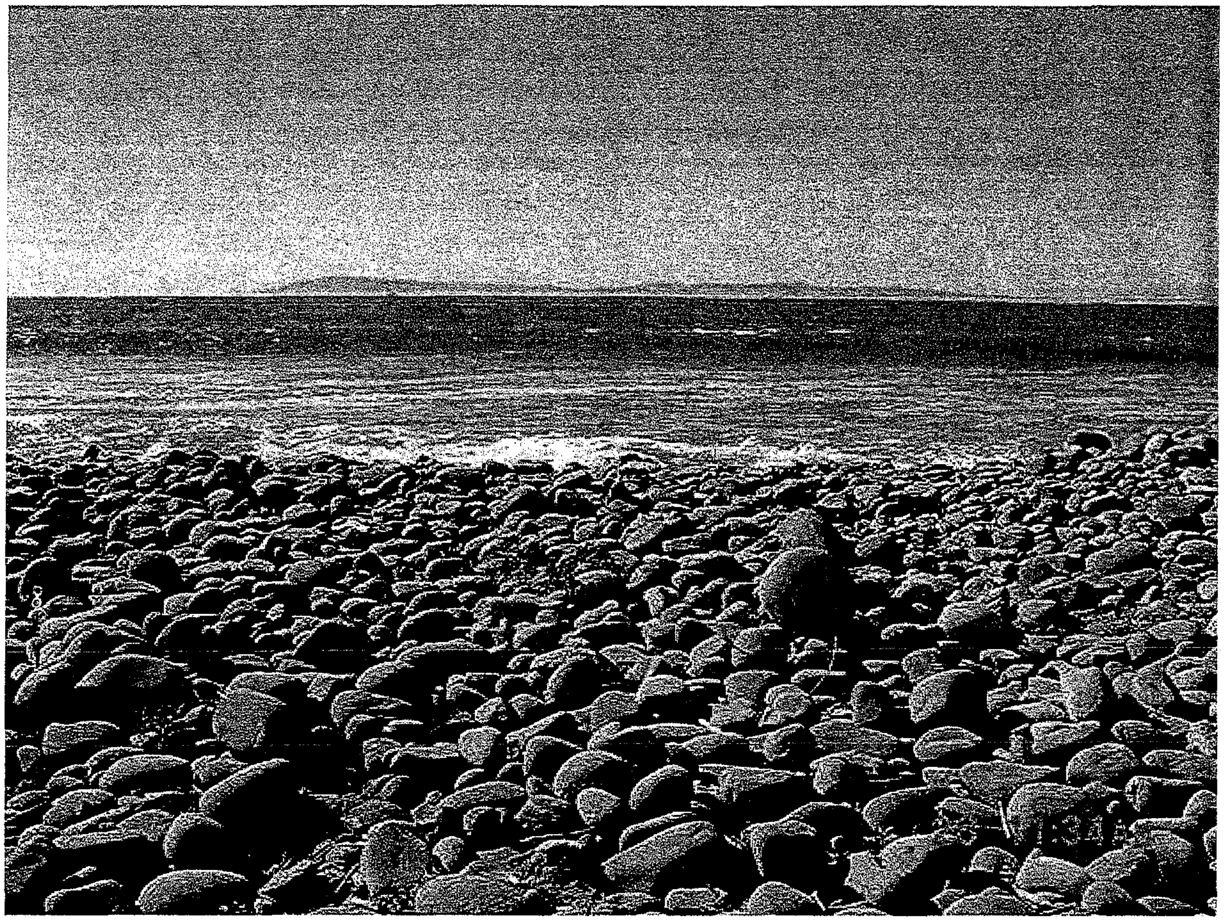


Solimar Beach (S. of drain, base of cypress tree)

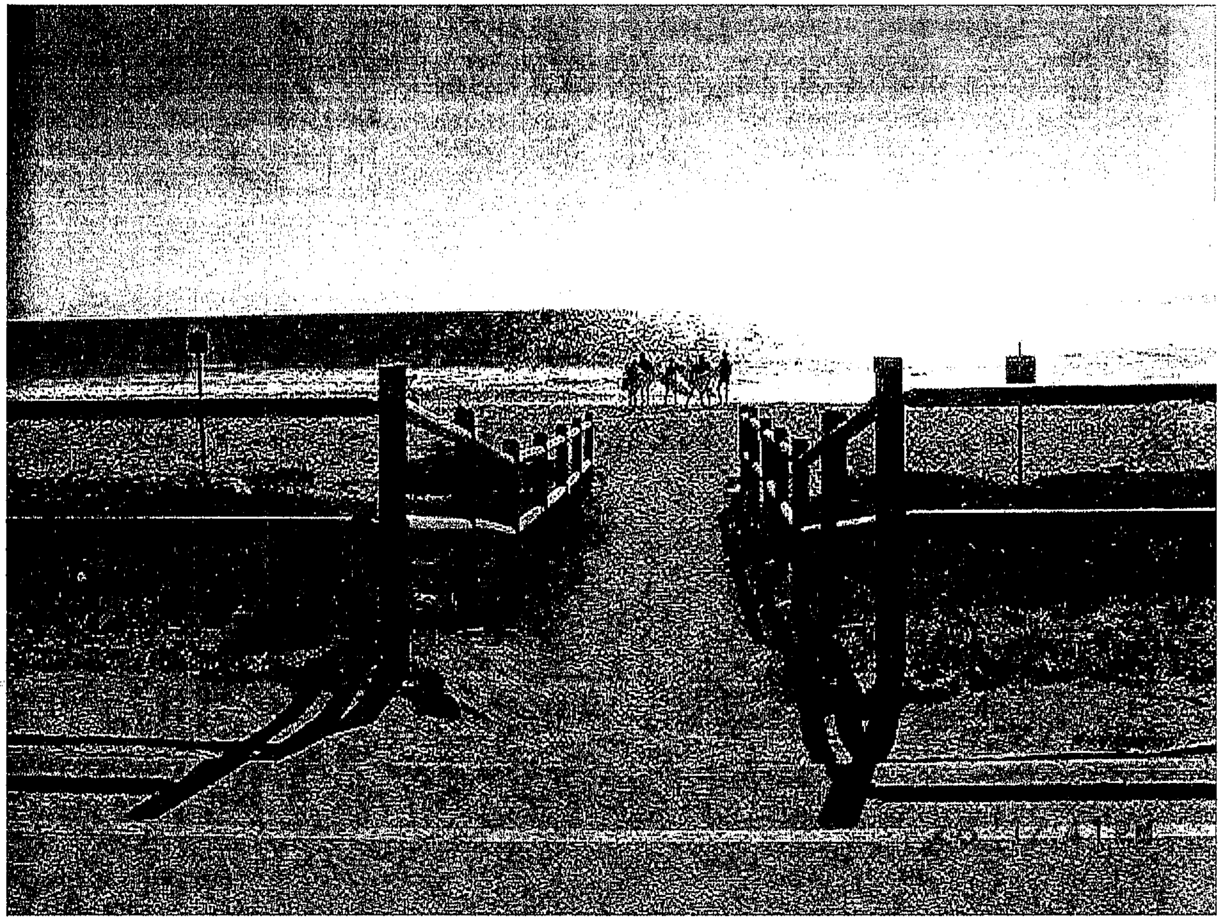
Solimar Beach (End of east gate access road)

Emma Wood State Beach (25 yards S. of first drain)

Seaside Wilderness Park (400yards N. of Ventura River)

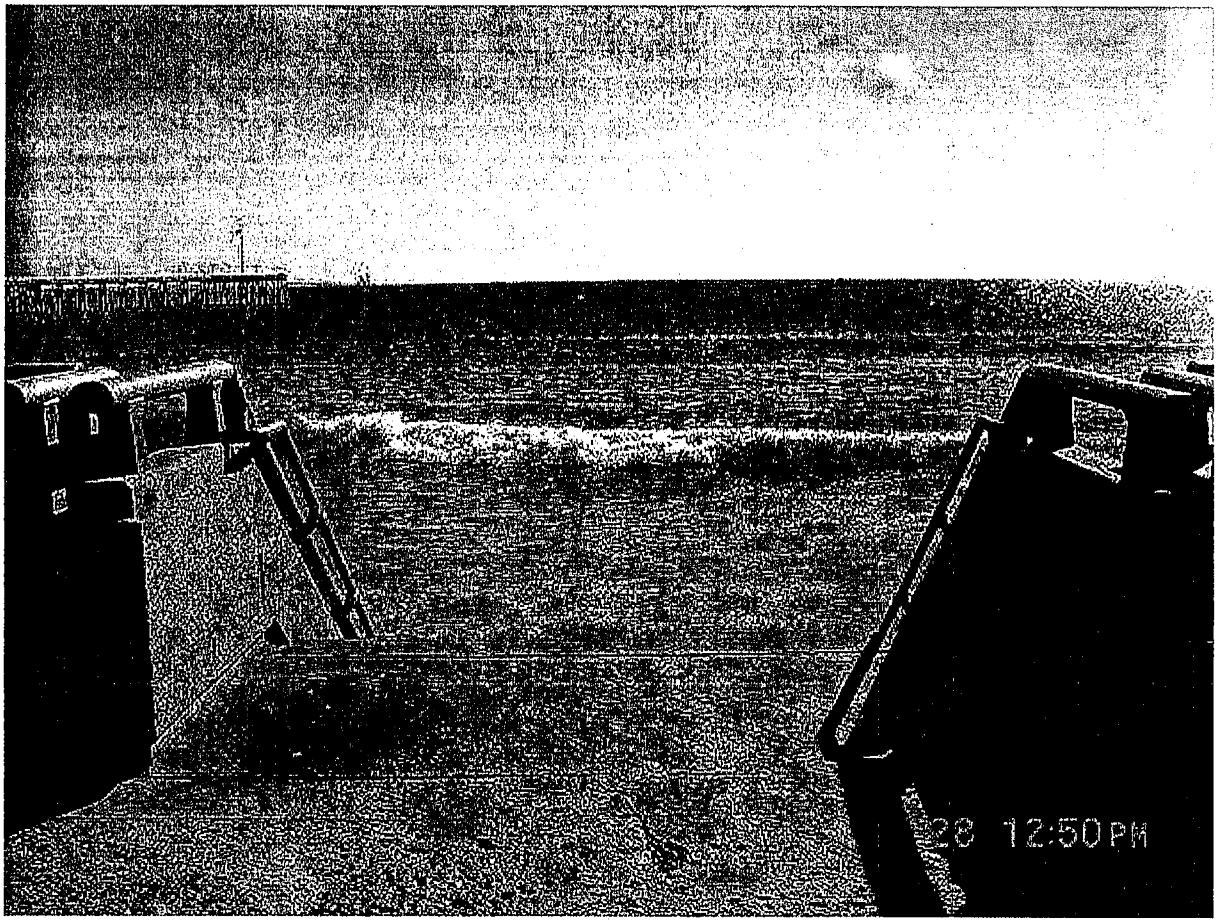


Surfers' Point at Seaside (End of access path through wooden gate)

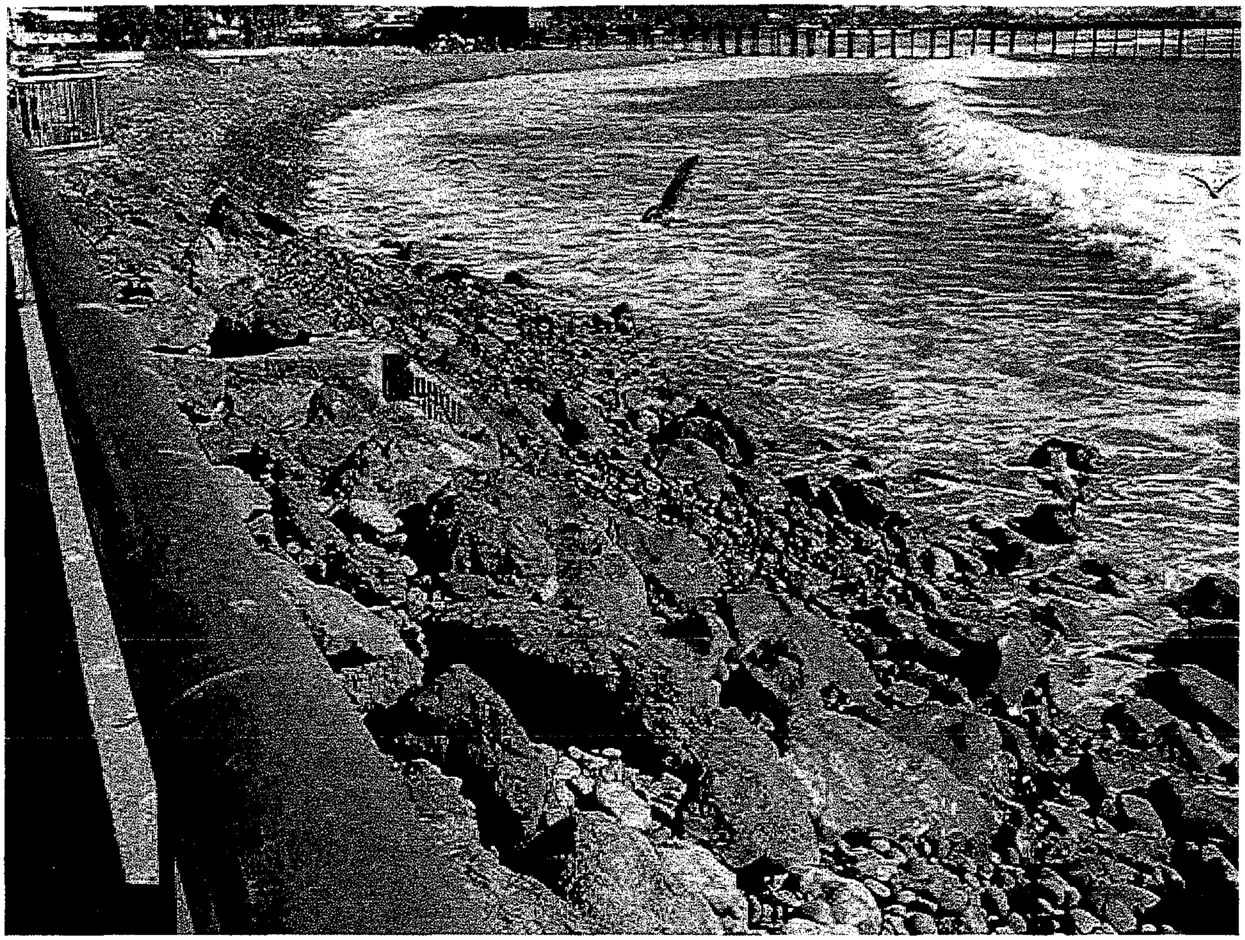


Promenade Park (S. of drain, at Figueroa Street)

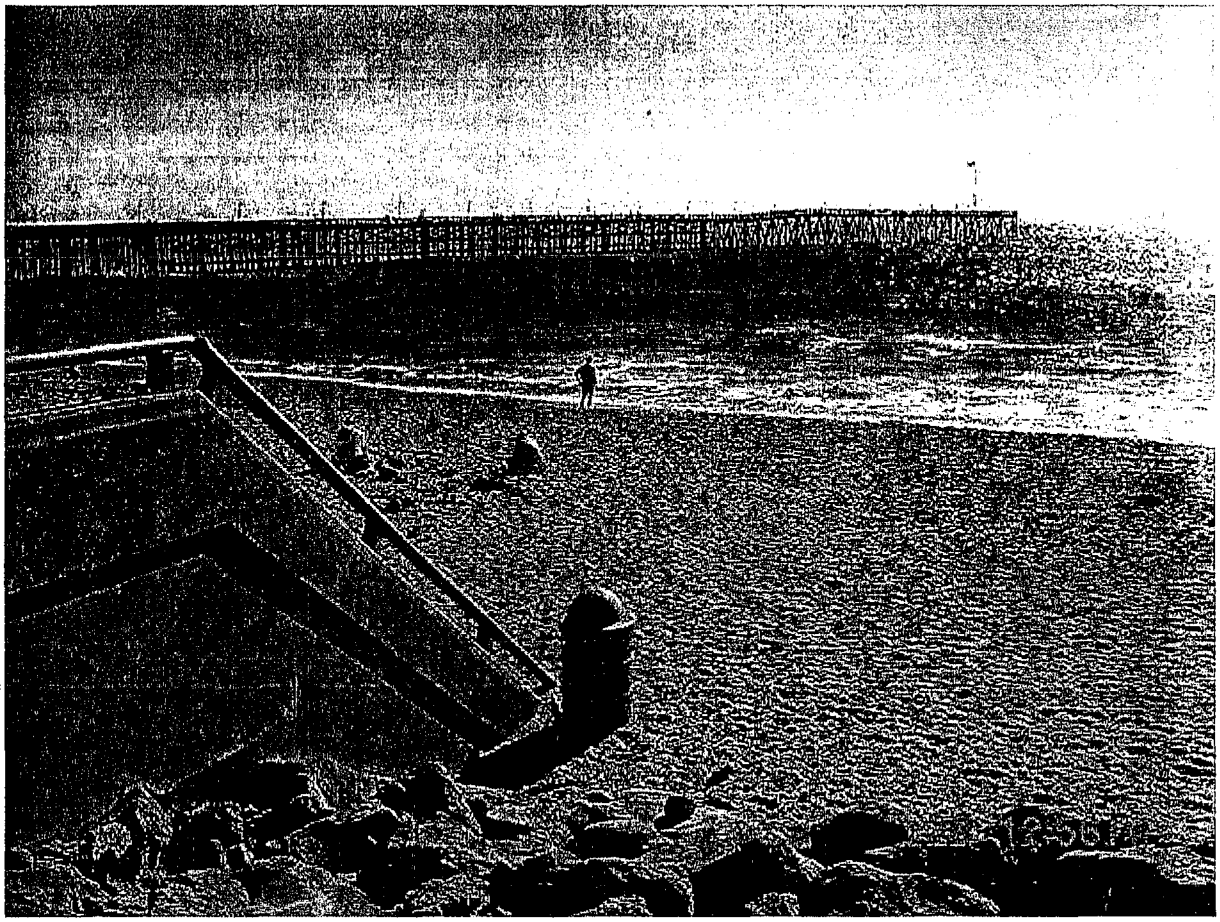
Promenade Park (S. of drain, at Redwood Apts.)



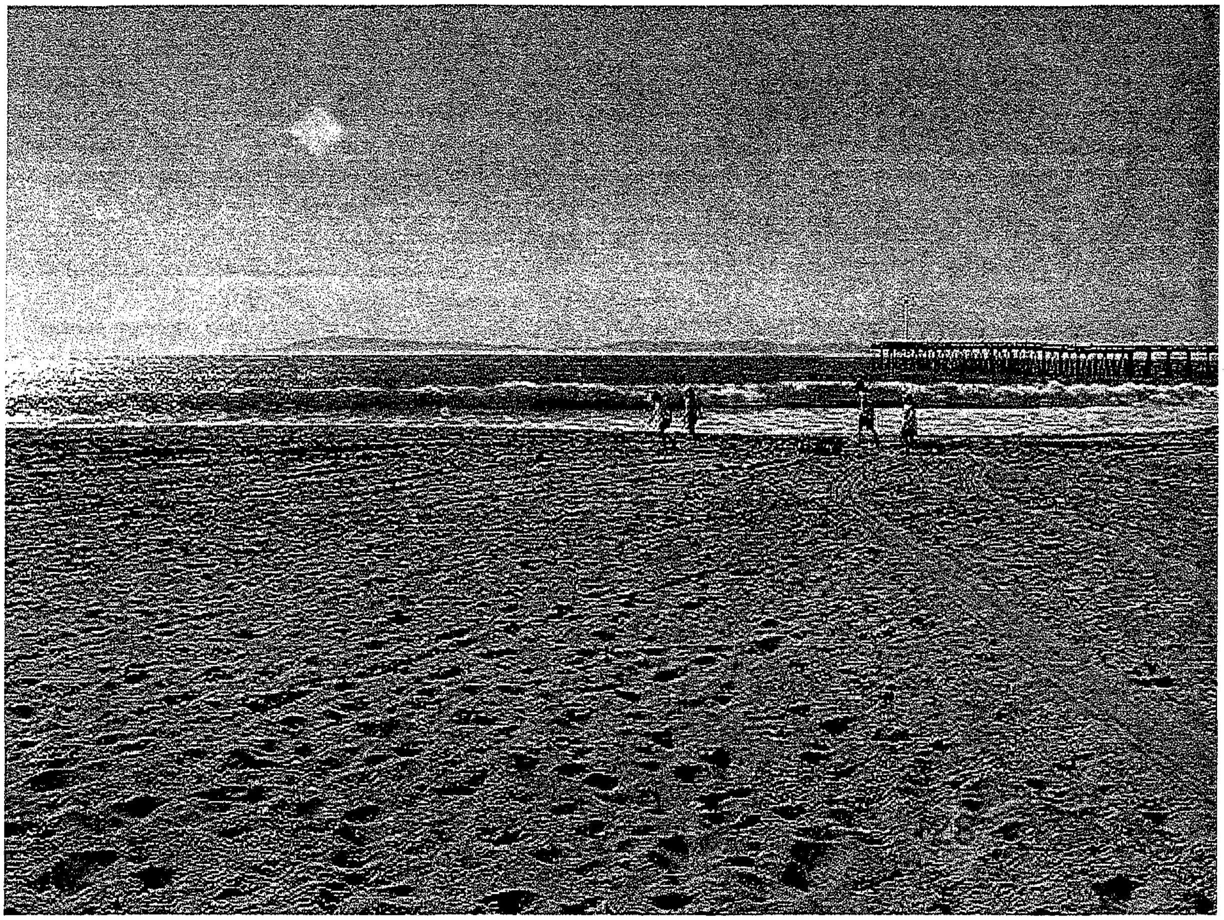
Promenade Park (S. of drain, end of Oak Street)



Promenade Park (S. of drain, at California Street)



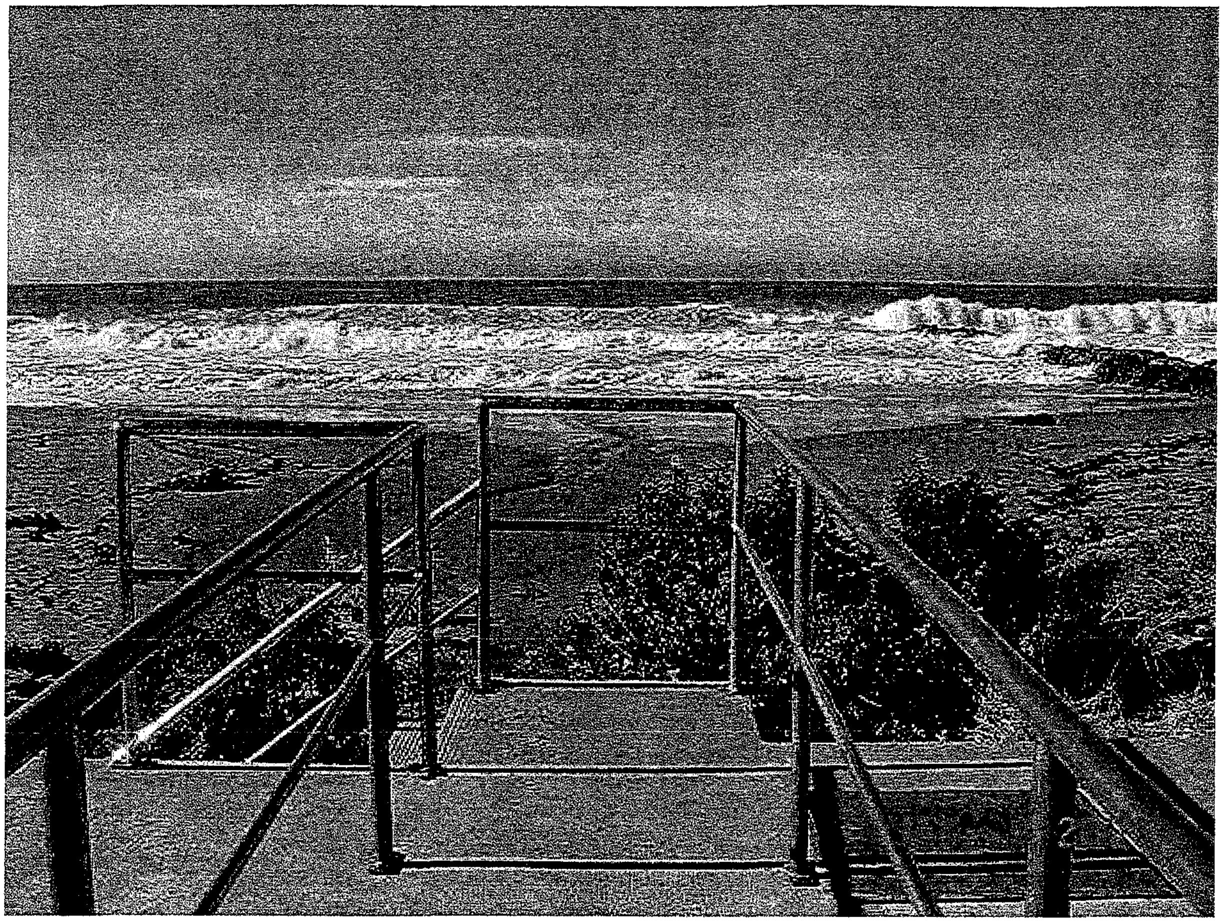
San Buenaventura Beach (S. of drain, end of Kalorama St.)



San Buenaventura Beach (S. of drain, end of Sanjon Road)

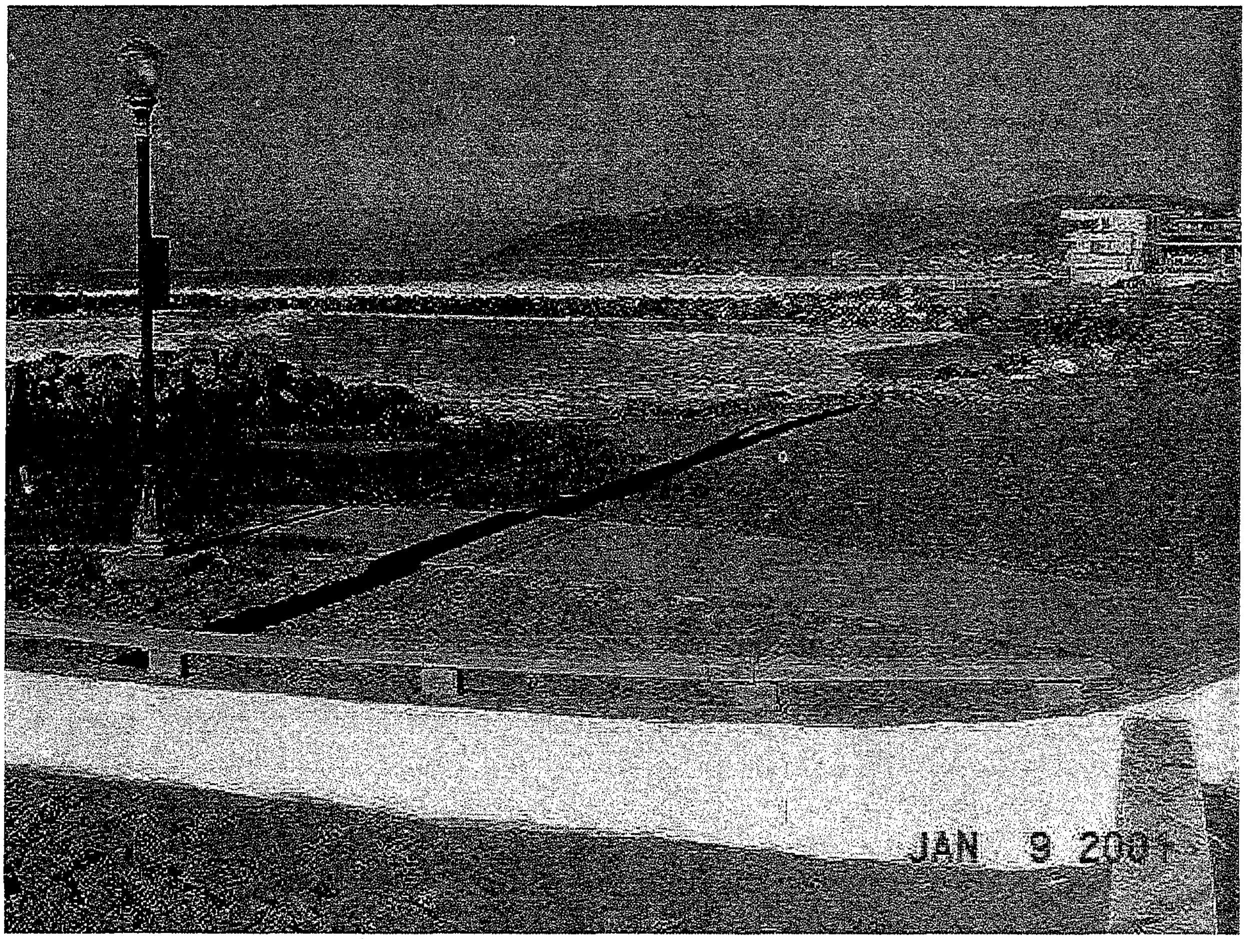
No Photo

San Buenaventura Beach (S. of drain, end of Dover Lane)

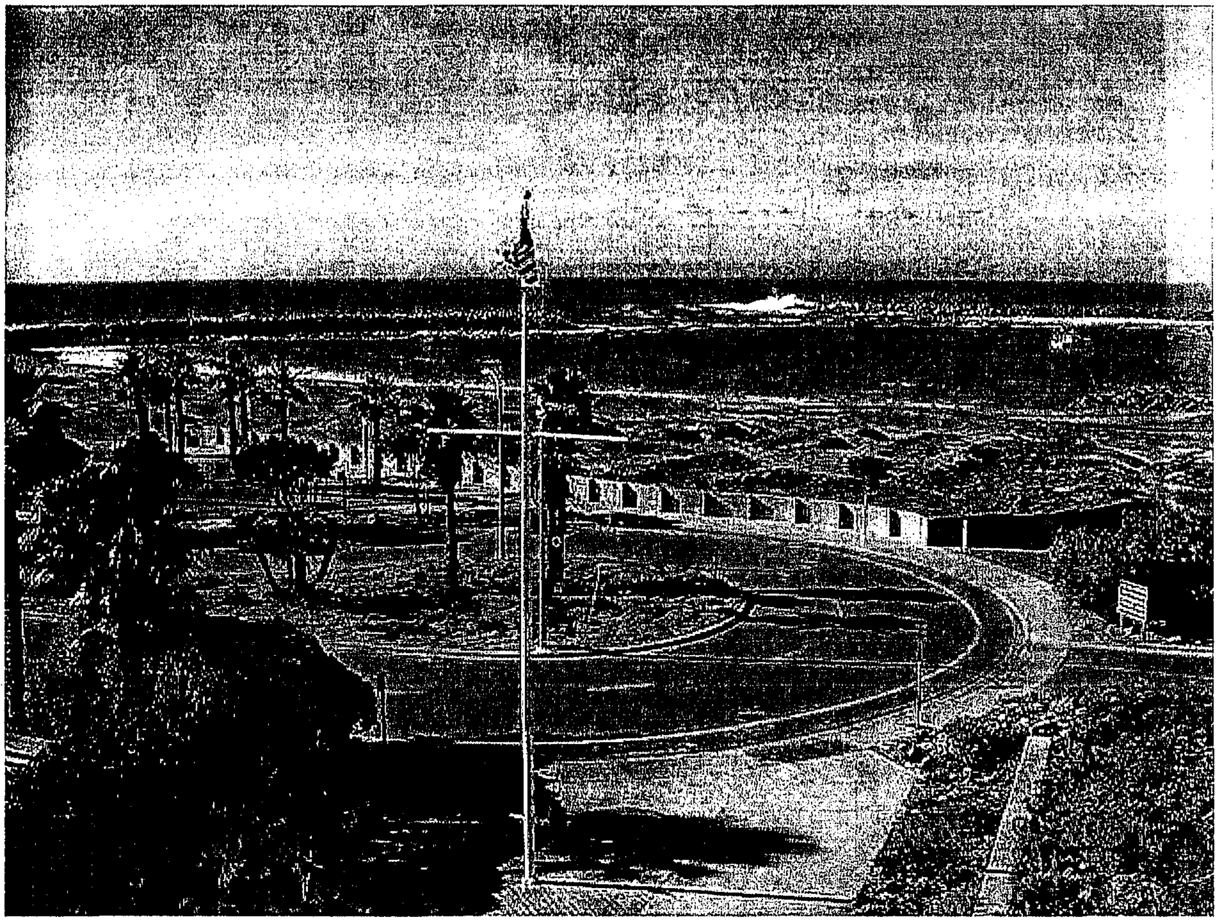


San Buenaventura Beach (S. of drain, end of Weymouth Ln.)

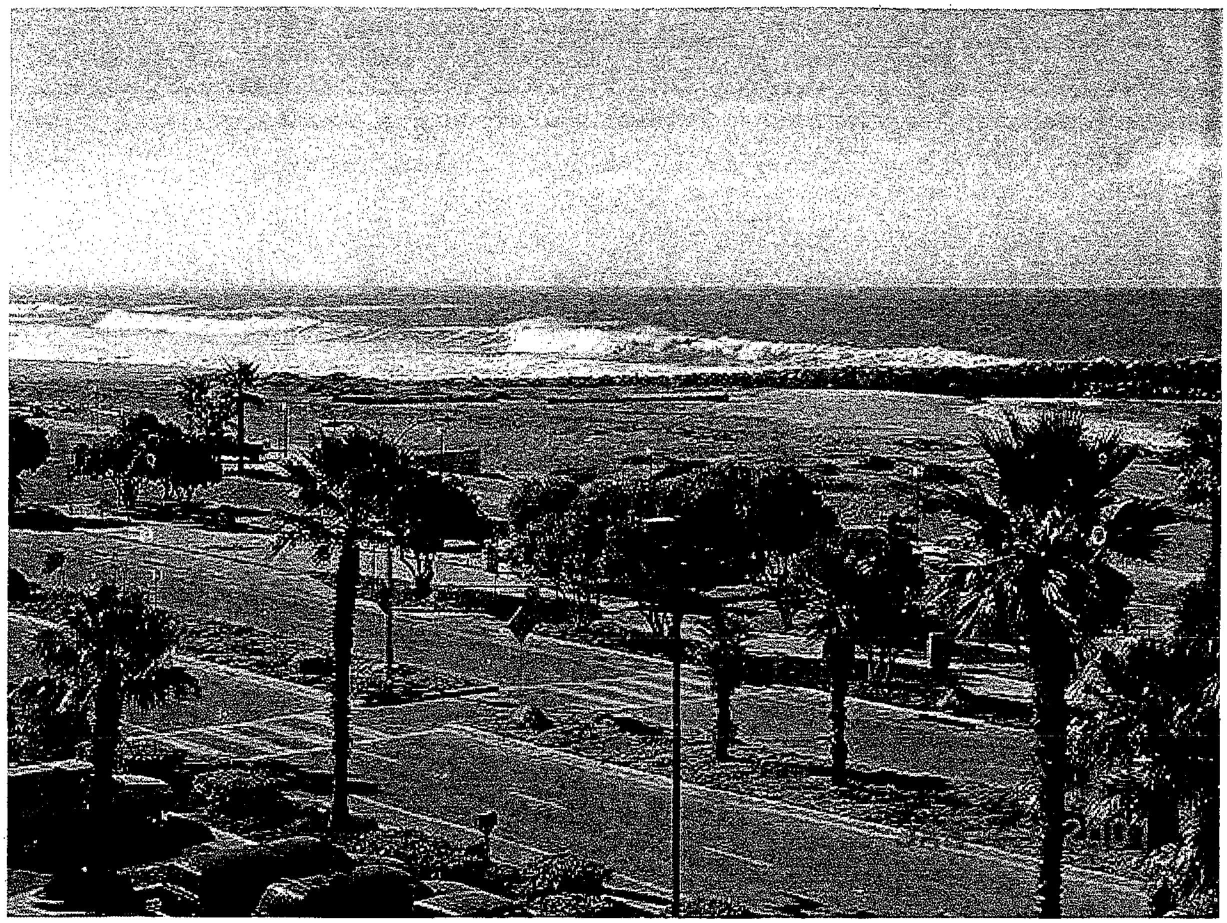
Marina Park (Beach at N. end of playground)



Peninsula Beach (aka Harbor Cove, N. of S. Jetty)

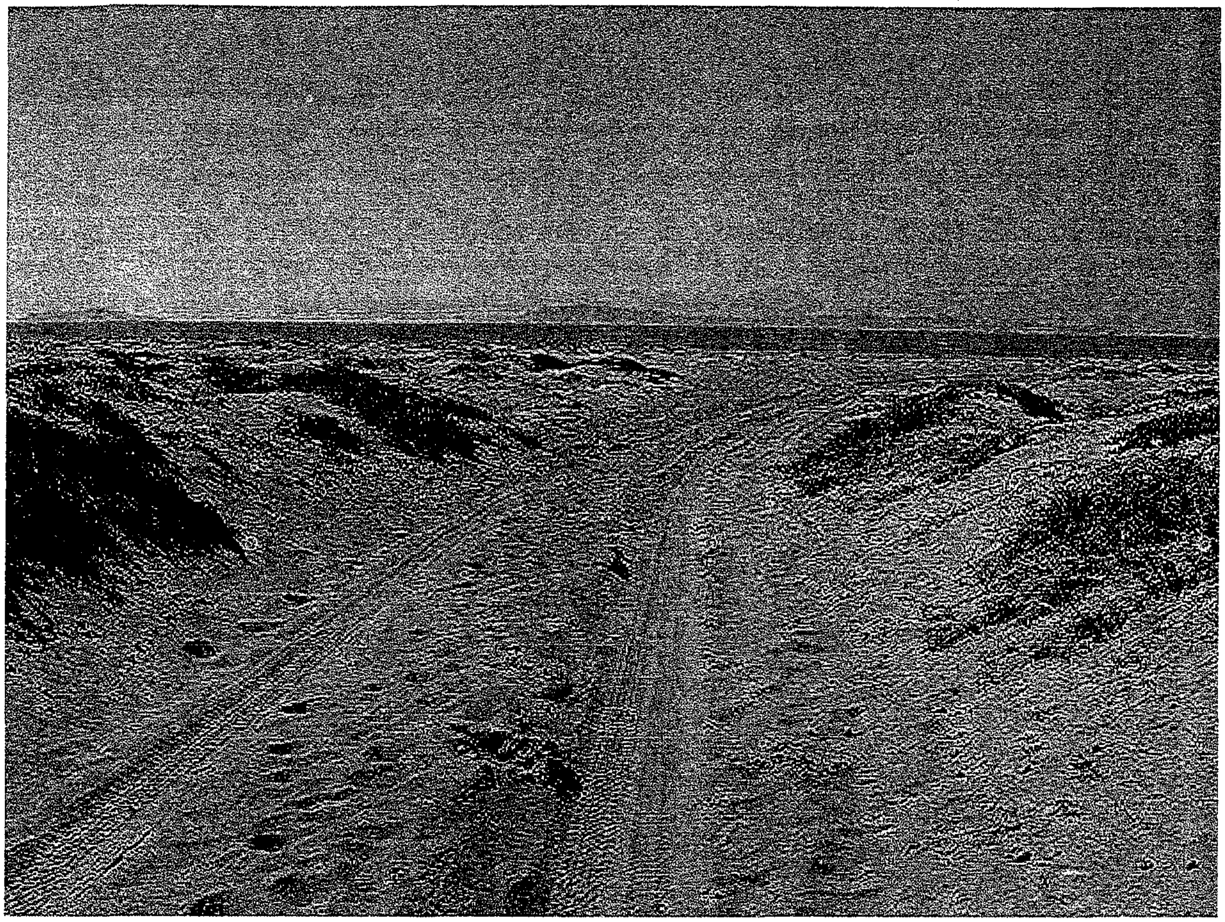


South Jetty (Beach area S. of the jetty)

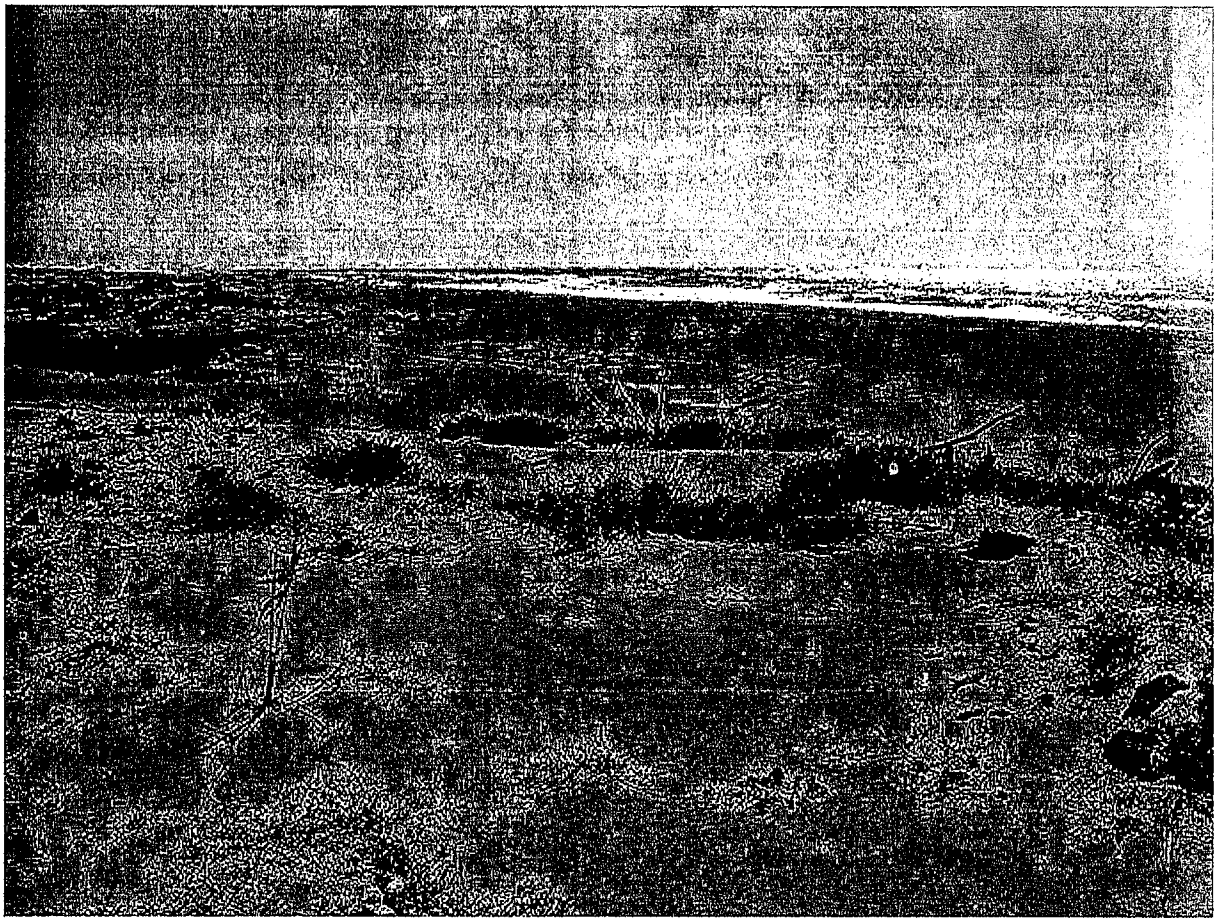


Surfers' Knoll (Beach next to parking lot, 1/4th mile upcoast from Santa Clara River)

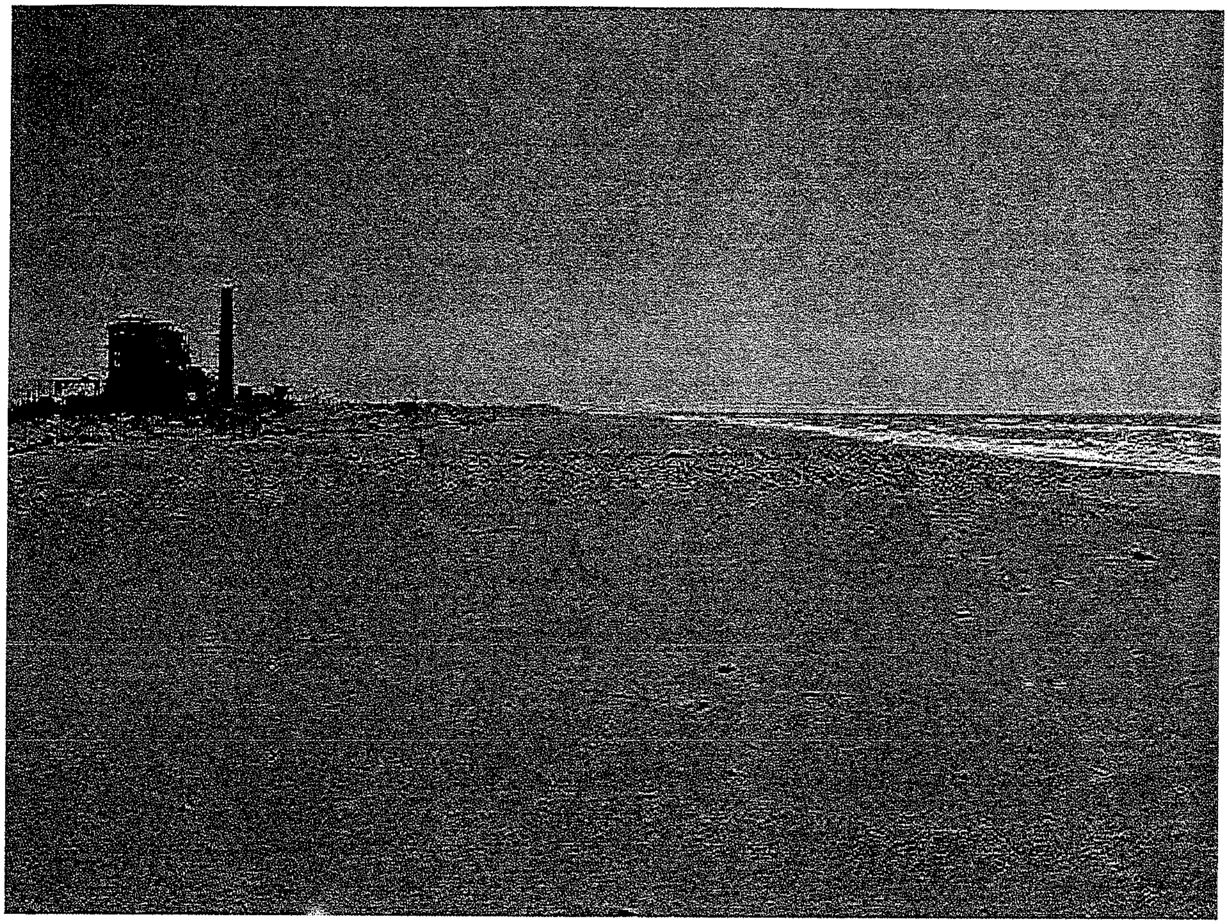
McGrath State Beach (N. of Gonzales Rd.)



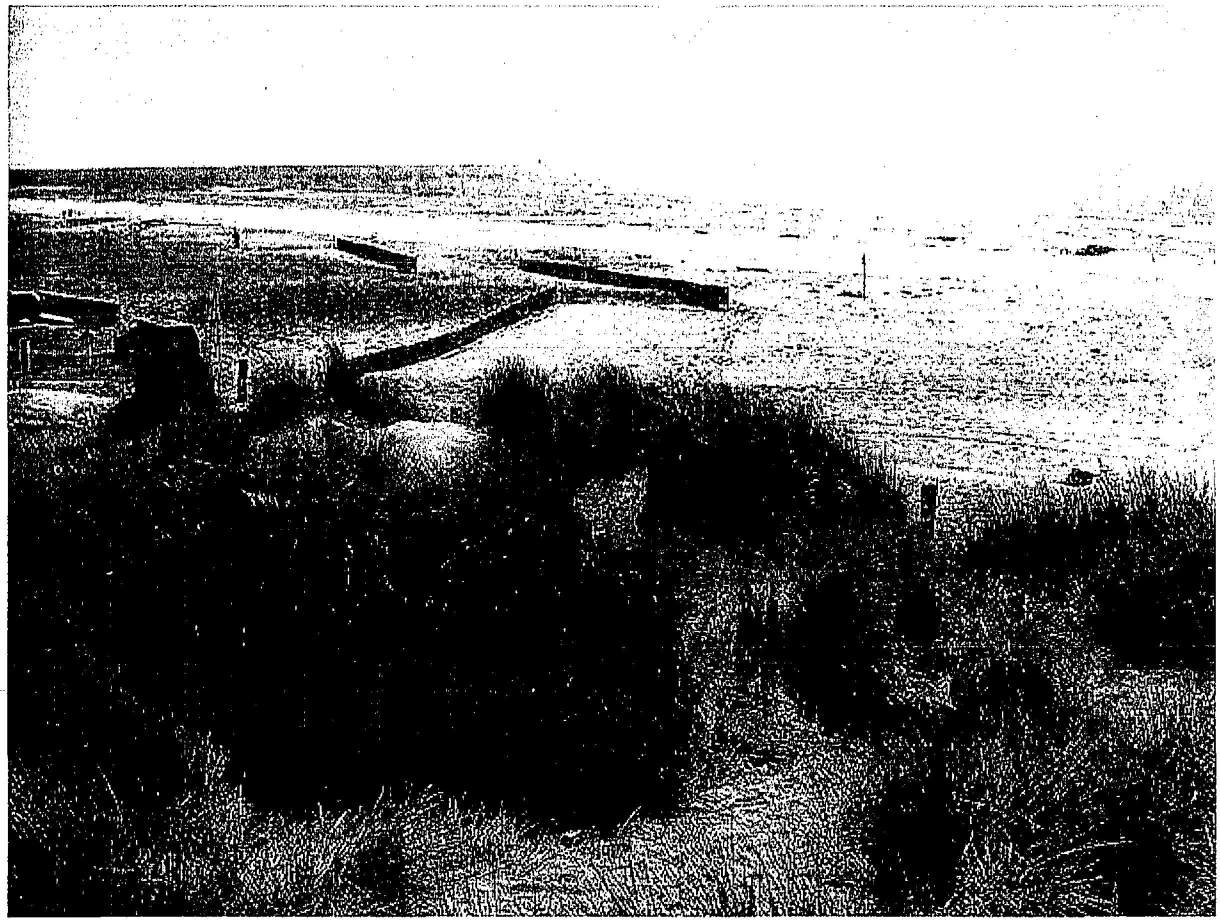
McGrath State Beach (end of Gonzales Road)



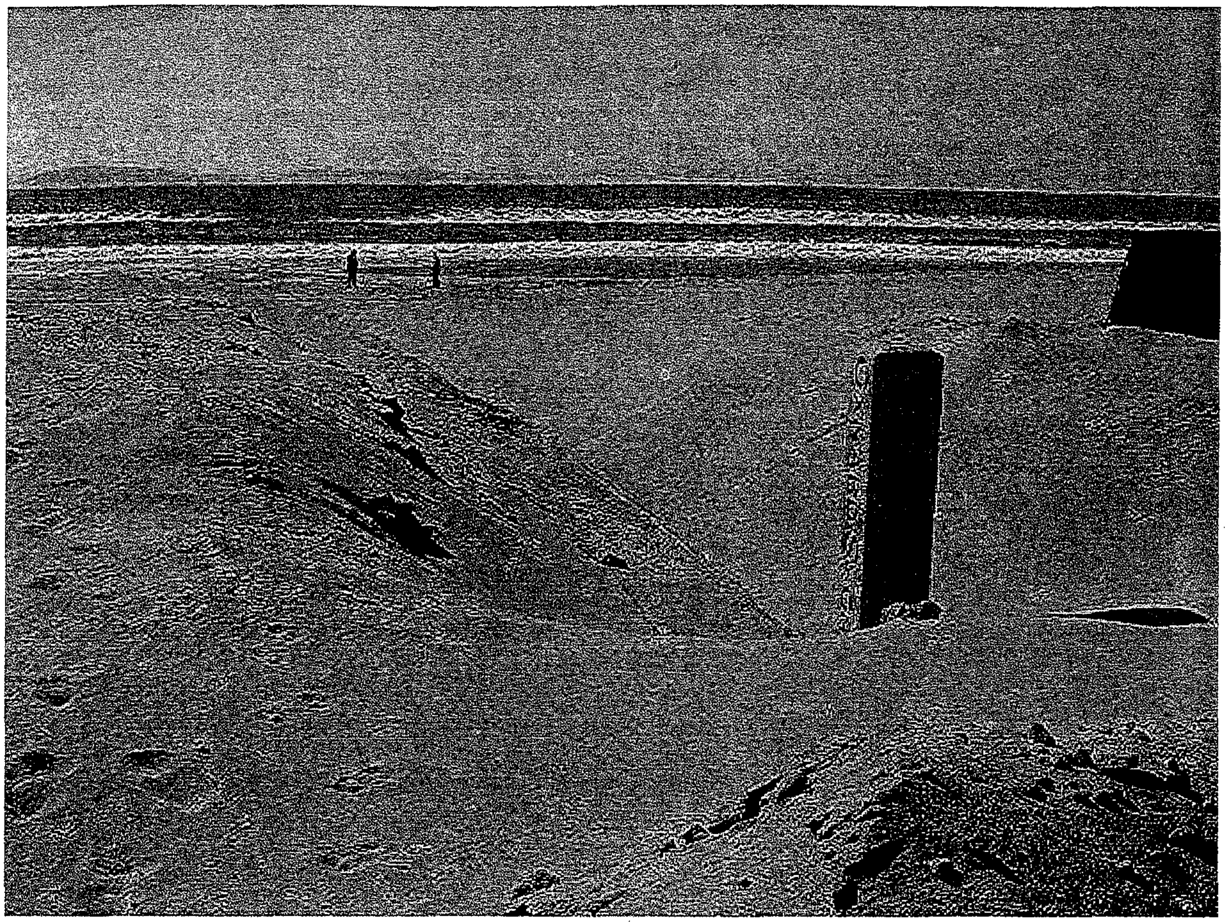
McGrath State Beach (S. end McGrath Lake)



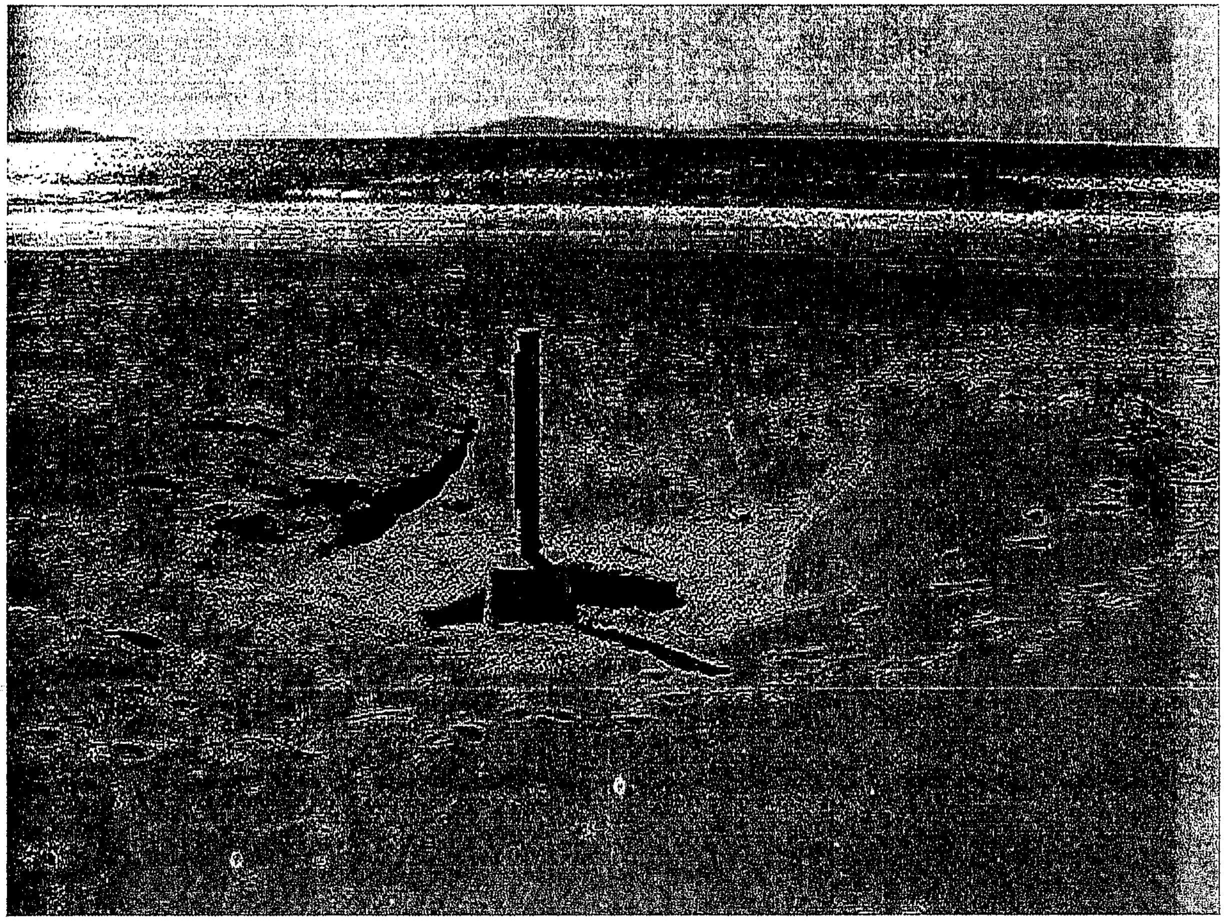
Oxnard Beach (S. of 5th Street drain)



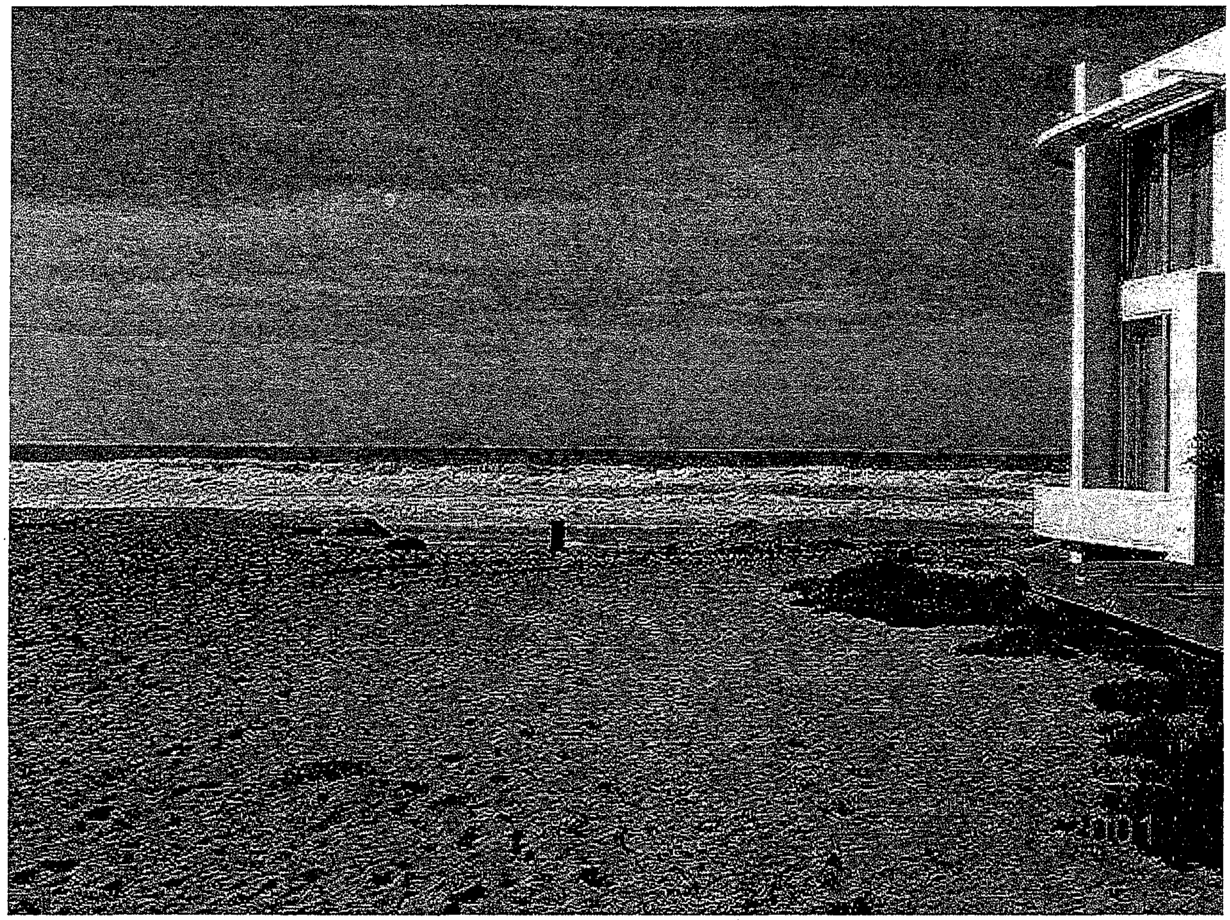
Oxnard Beach (S. of Channel Way drain)



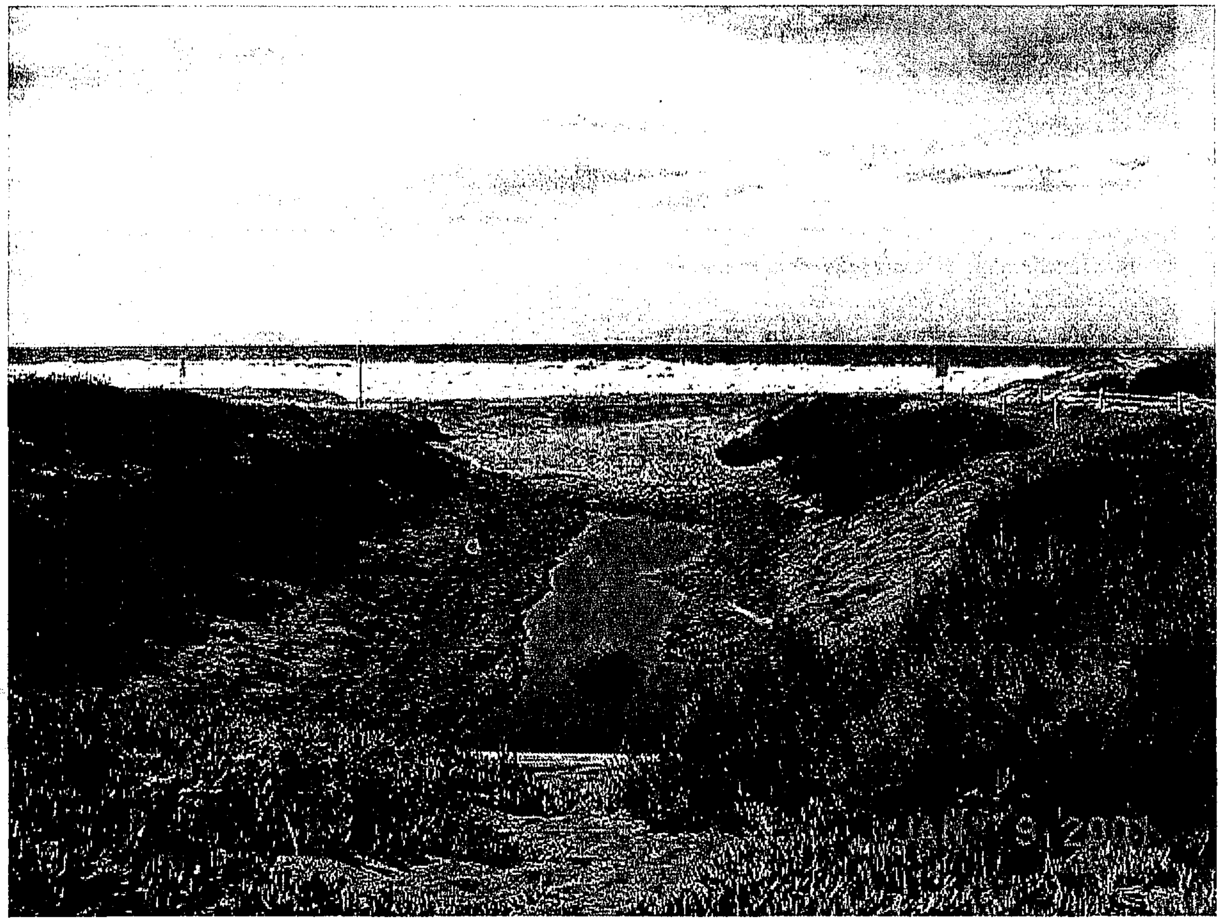
Oxnard Beach (S. of drain, end of Outrigger Way)



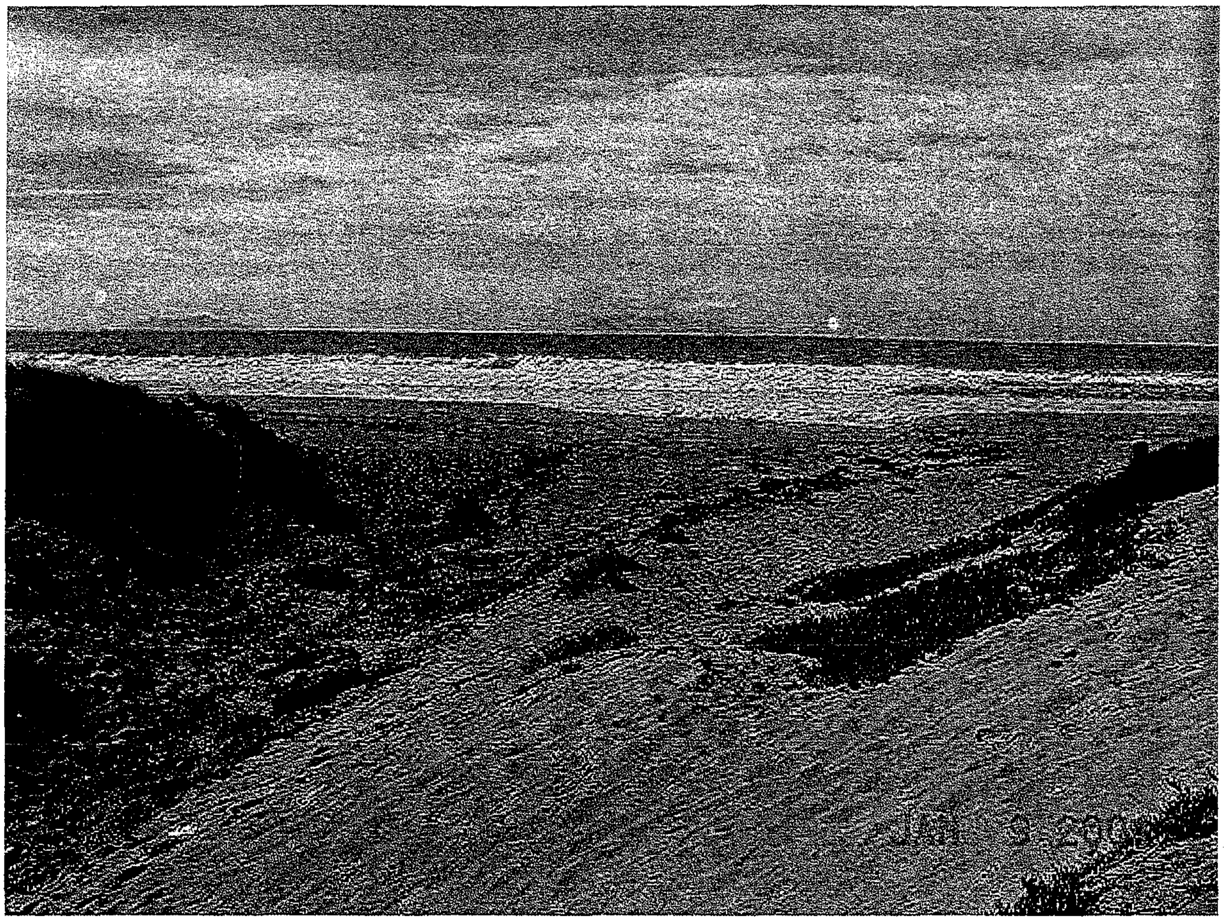
Oxnard Beach (S. of drain, end of Amalfi Way)



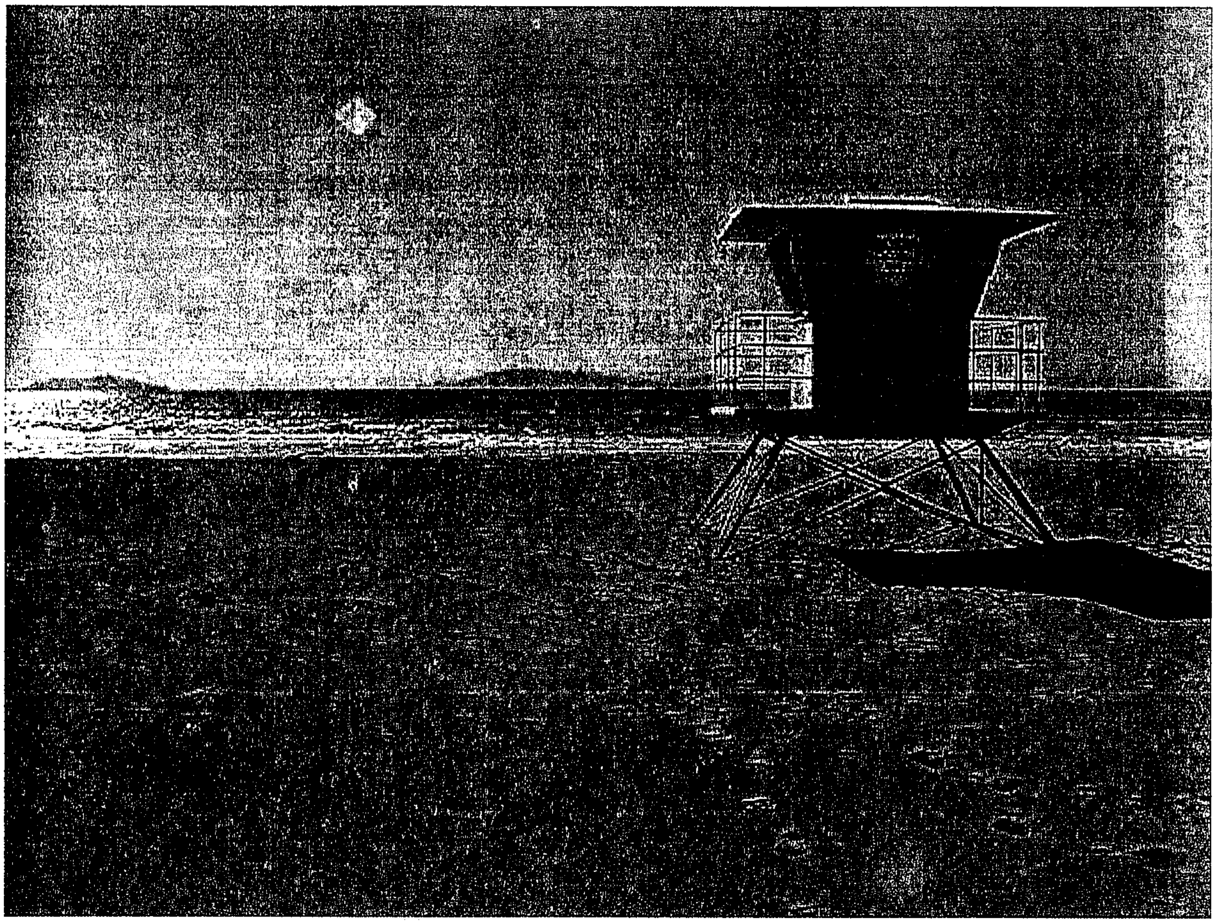
Oxnard Beach Park (S. of drain, Falkirk Ave.)



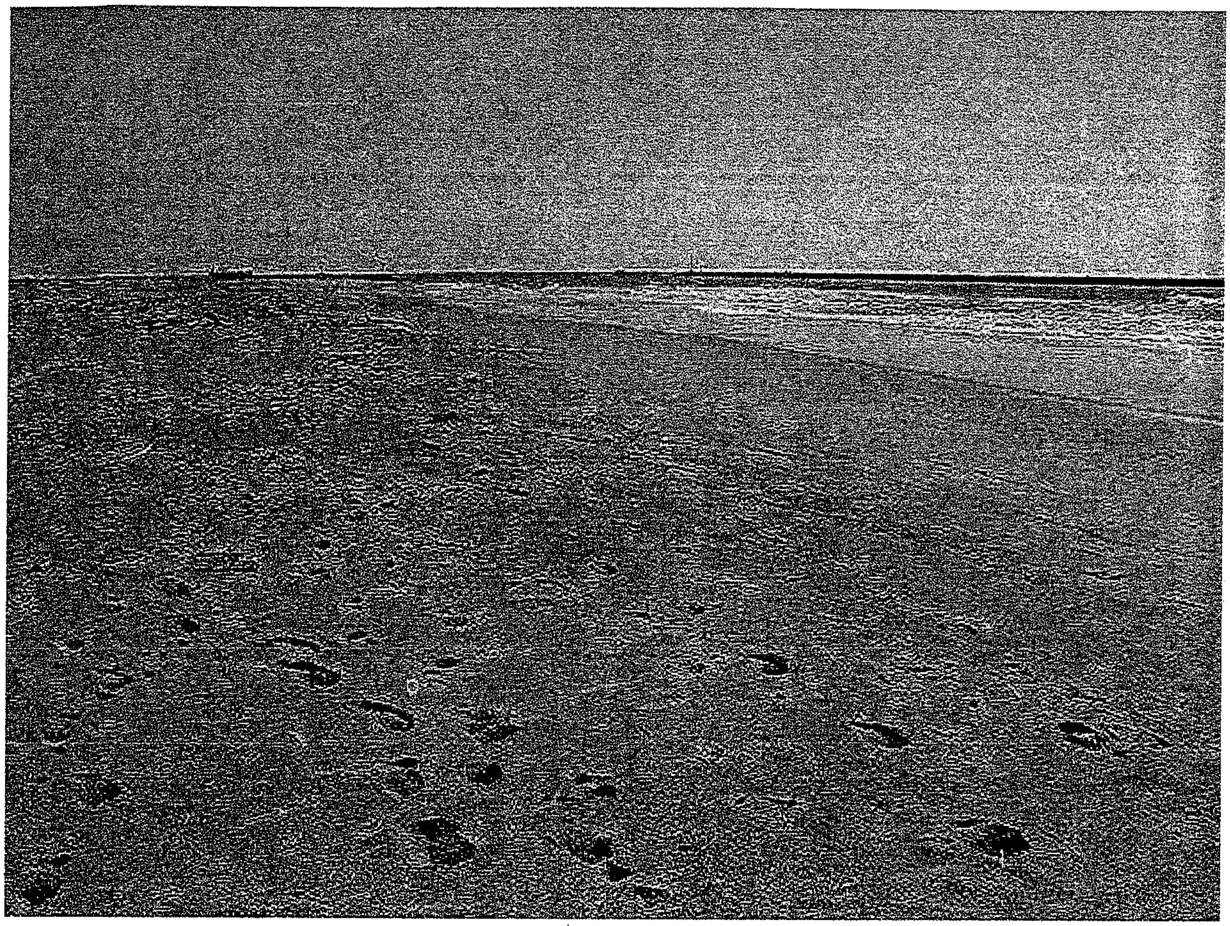
Oxnard Beach Park (S. of drain, Starfish Dr.)



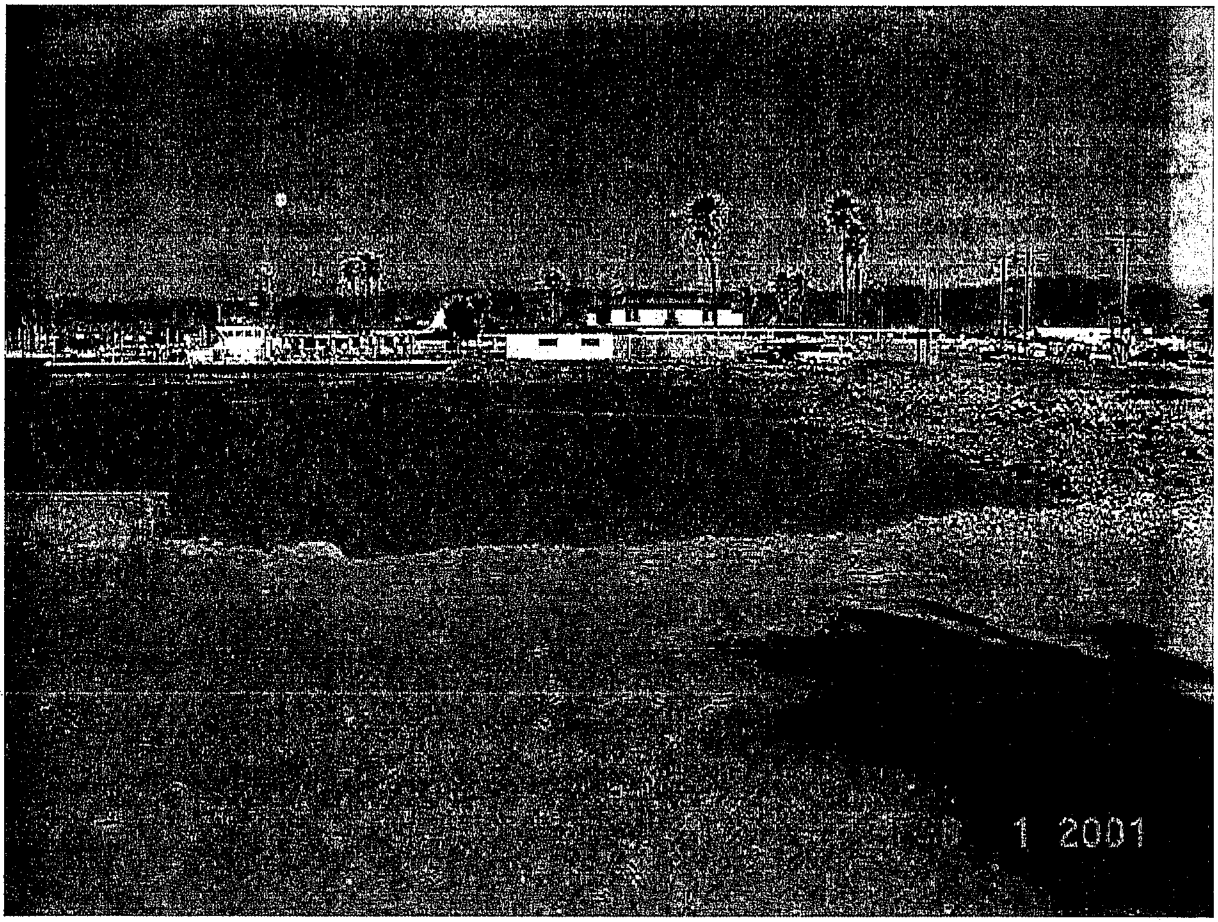
Hollywood Beach (La Crescenta St.)



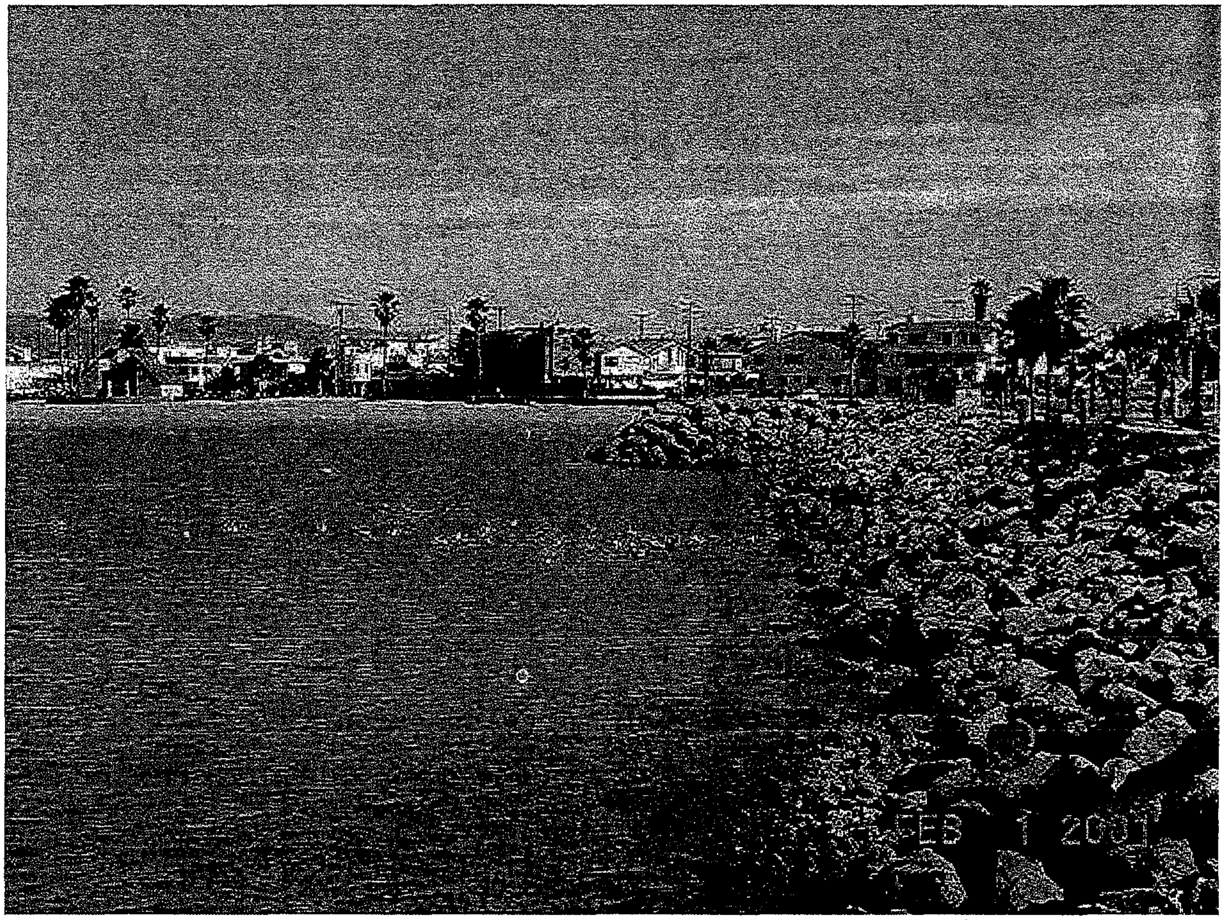
Hollywood Beach (Los Robles St.)



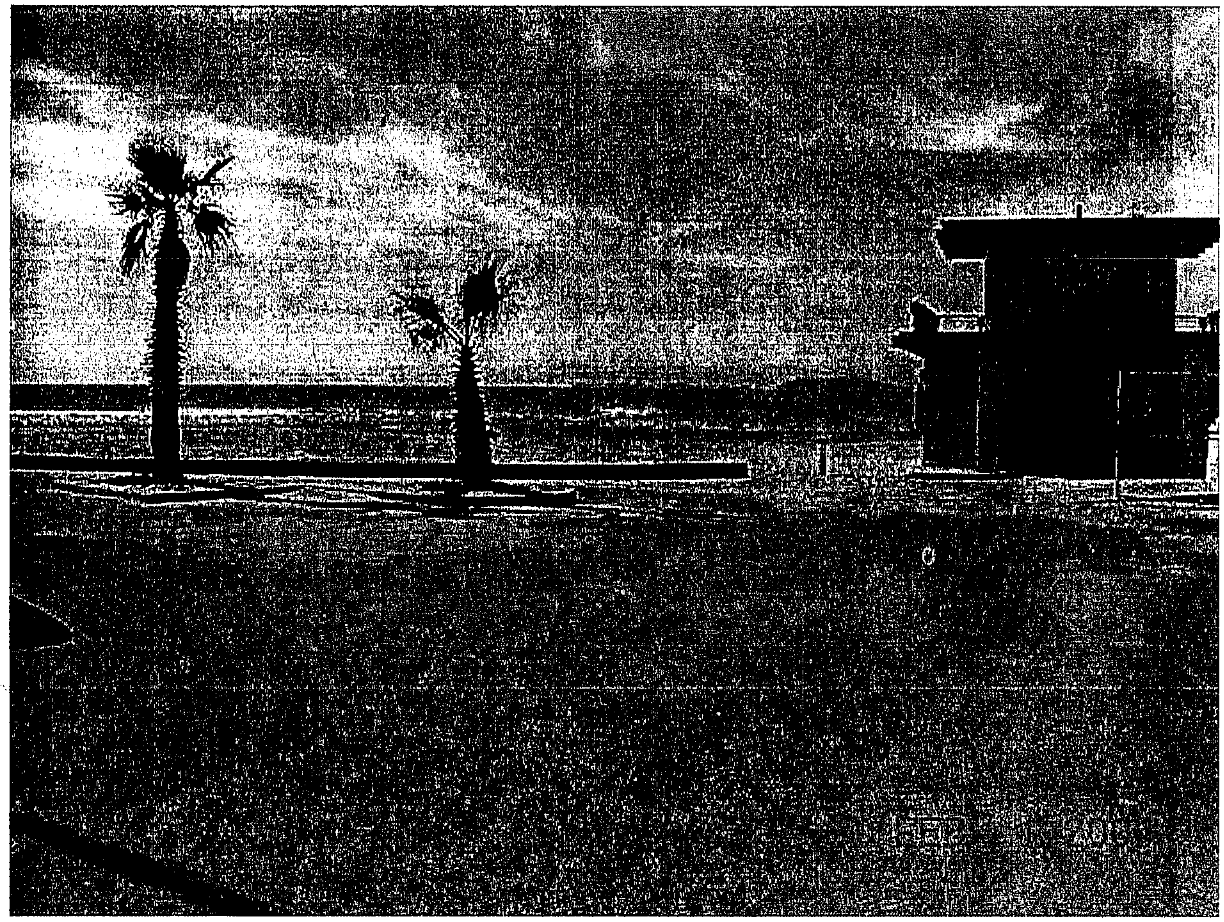
<u>Hobie Beach</u> (At the S. end of Victoria Ave.)



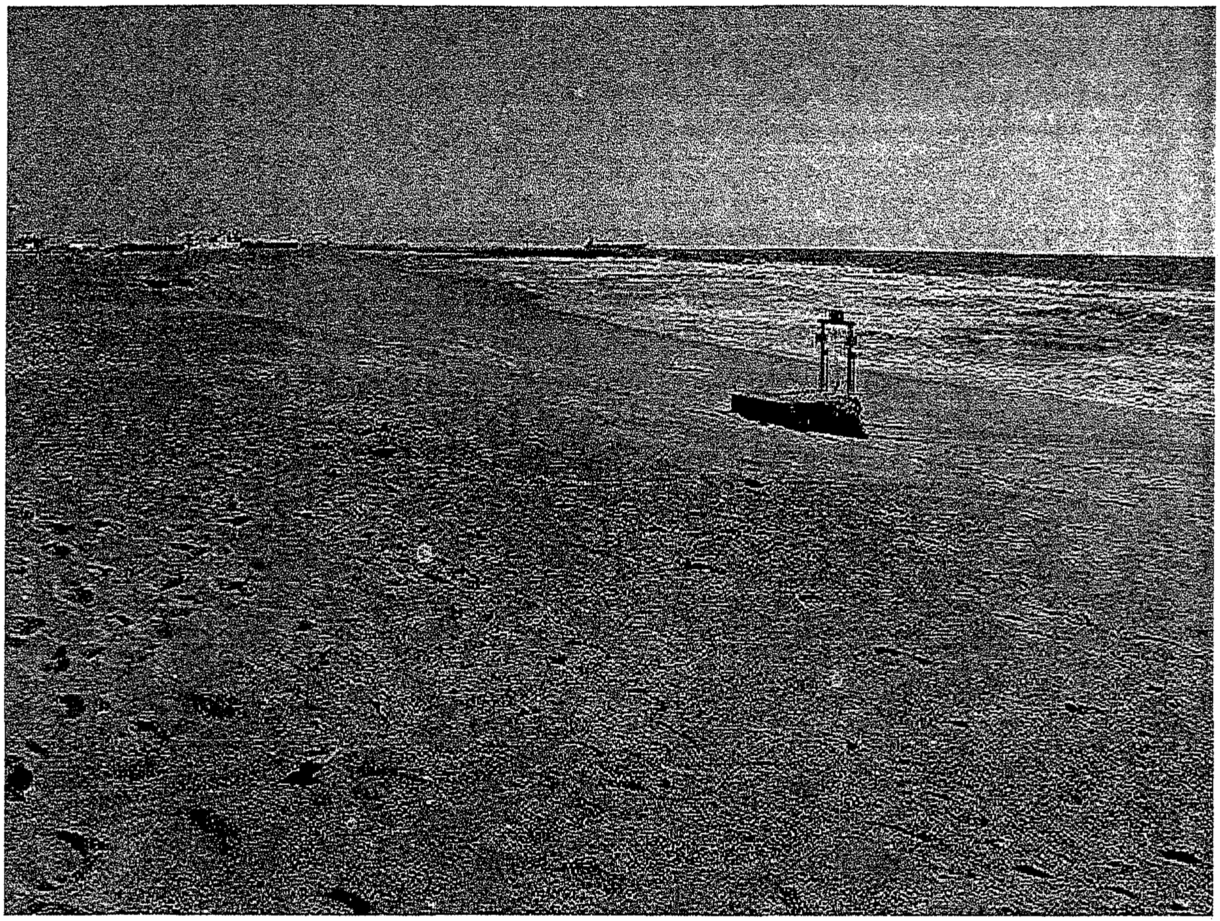
C. I. Harbor Beach Park (aka Kiddie Beach, at the S. end of Victoria Ave.)



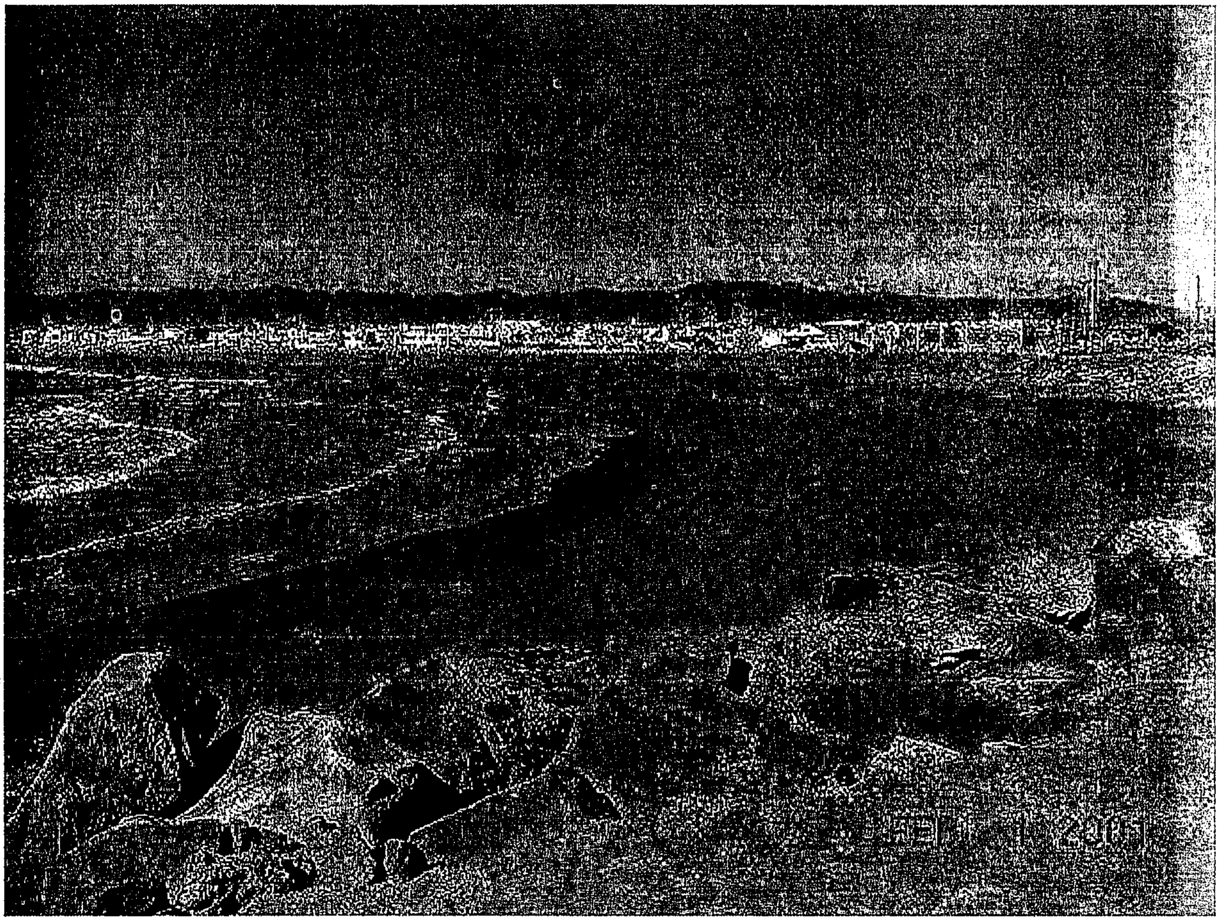
Silverstrand (S. of jetty, end of San Nicolas Ave.)



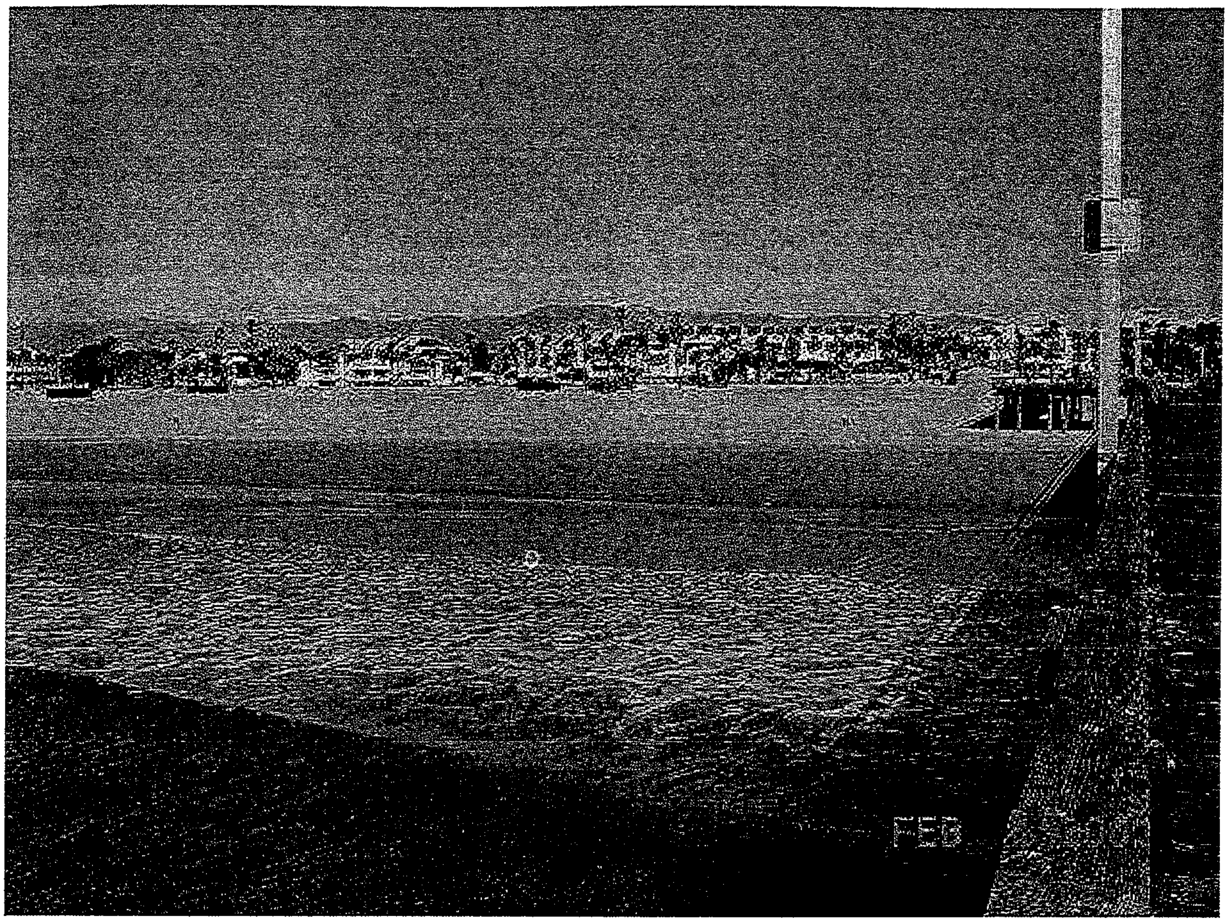
Silverstrand (S. of drain, end of Santa Paula Ave.)



Silverstrand (S. of drain, end of Sawtelle Ave.)

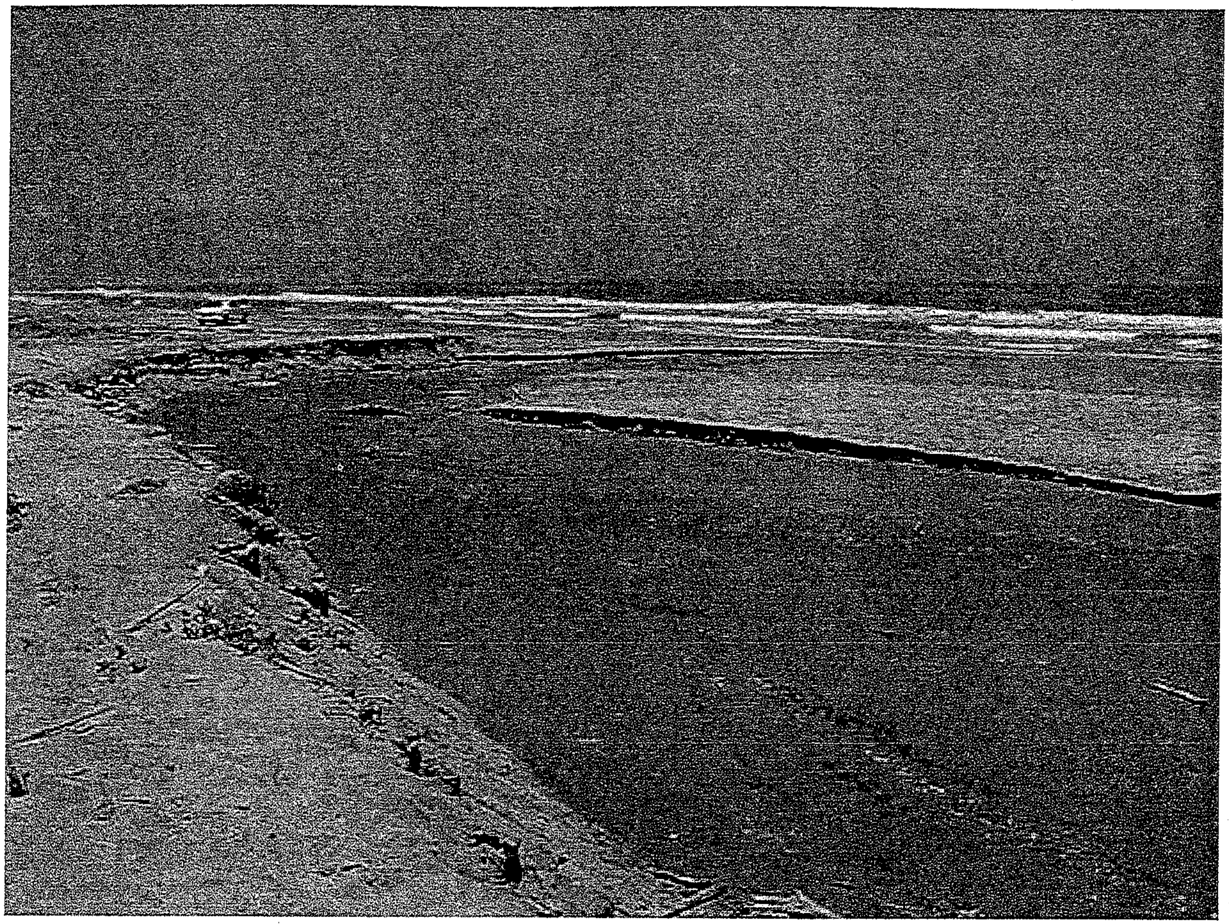


Port Hueneme Beach Park (50 yds N. of pier)

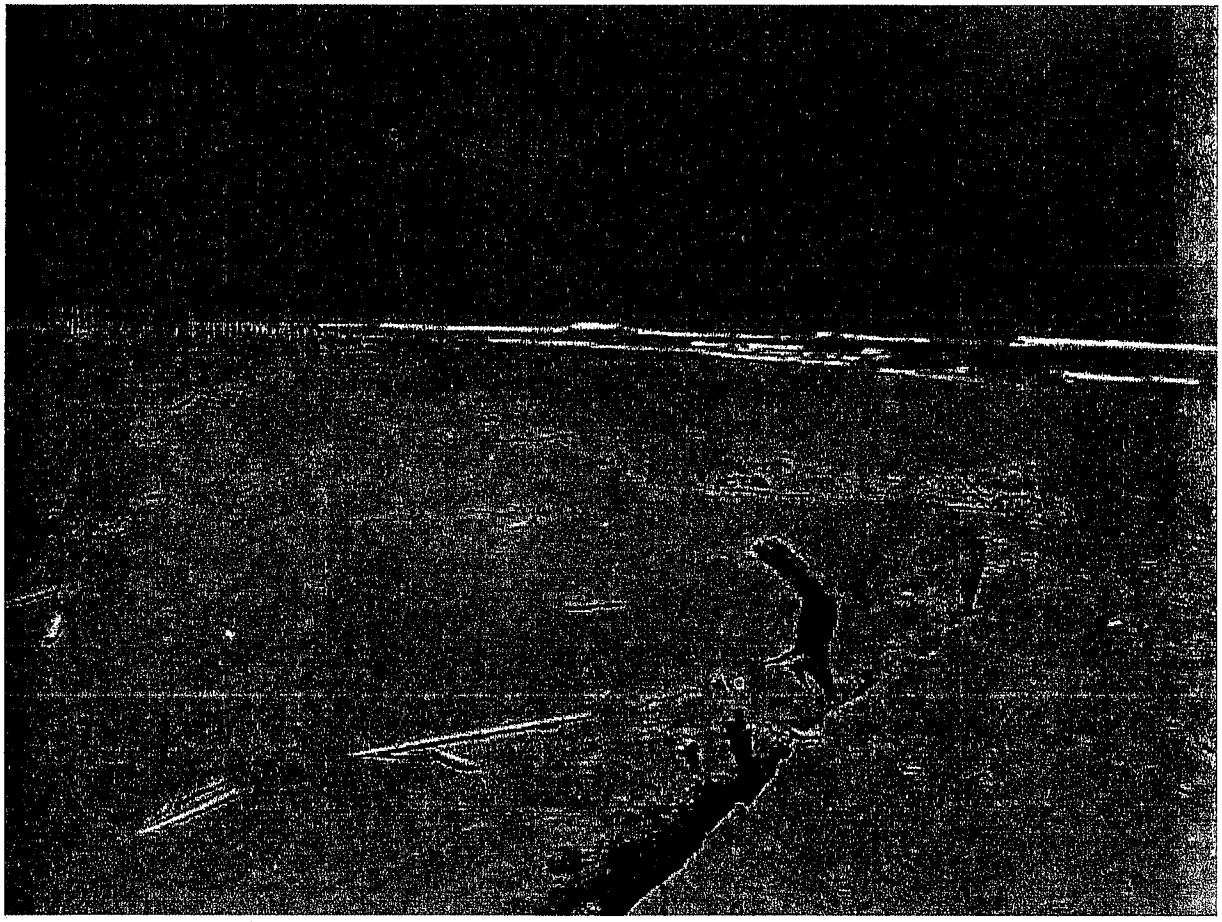


Ormond Beach (25 yards S. of "J" St. drain)

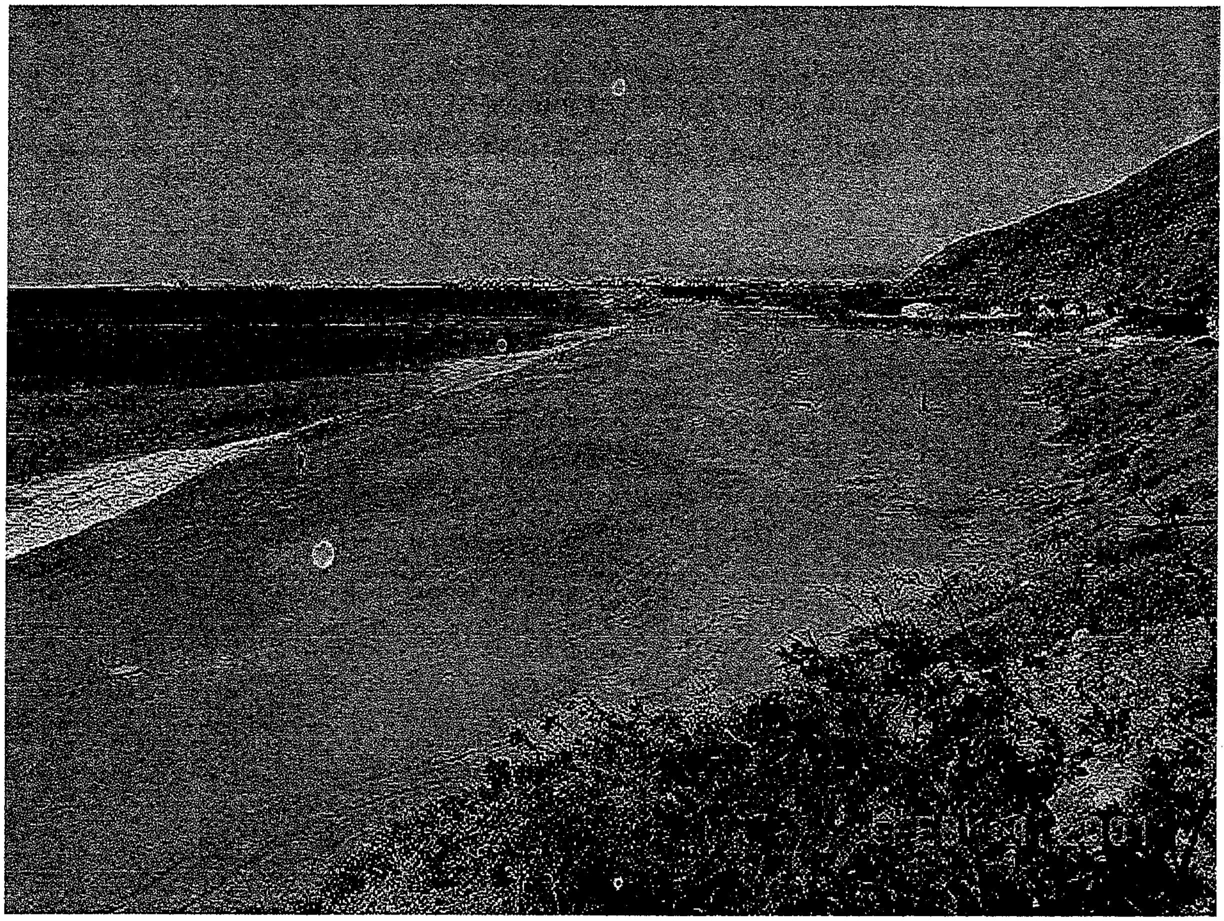
Ormond Beach (25 yards N. of Industrial Drain)



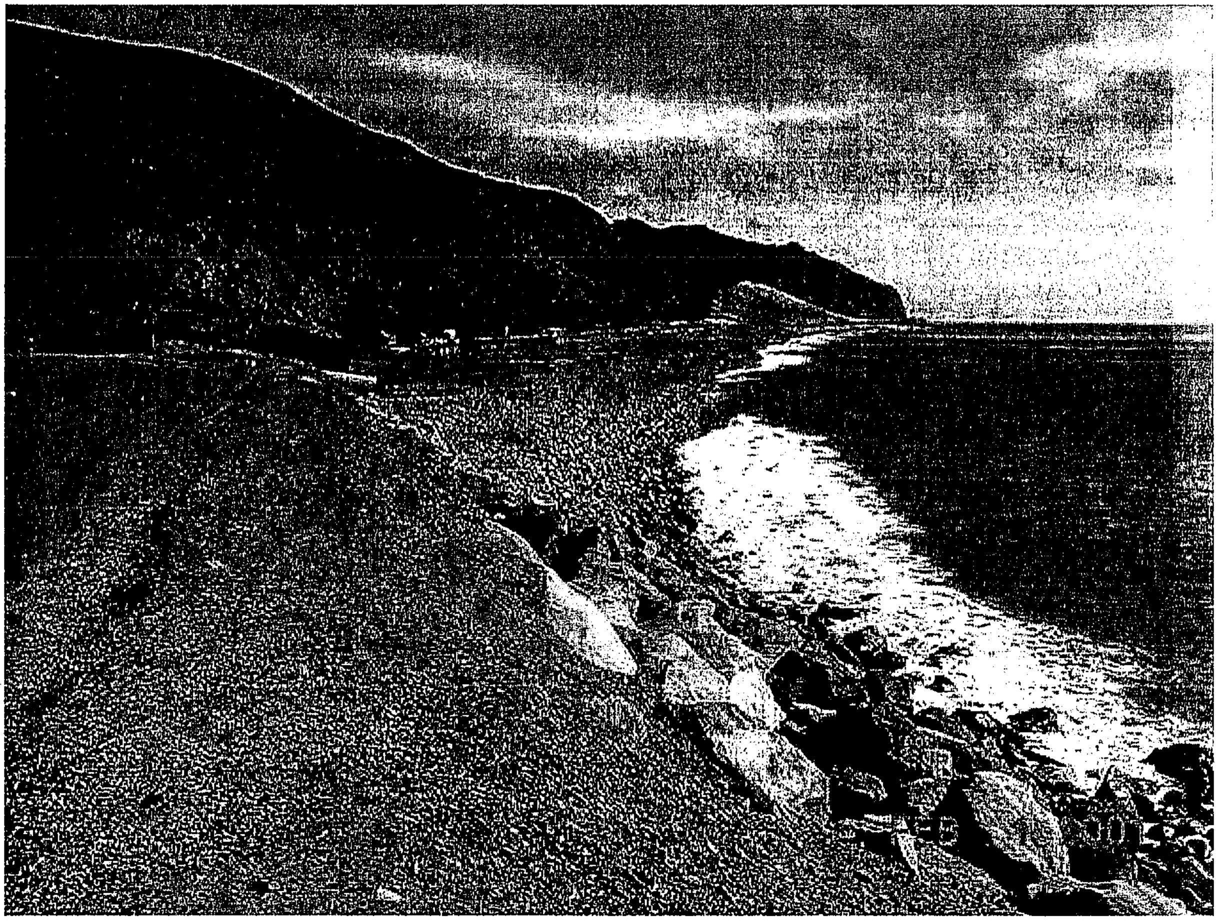
Ormond Beach (At end of Arnold Road)



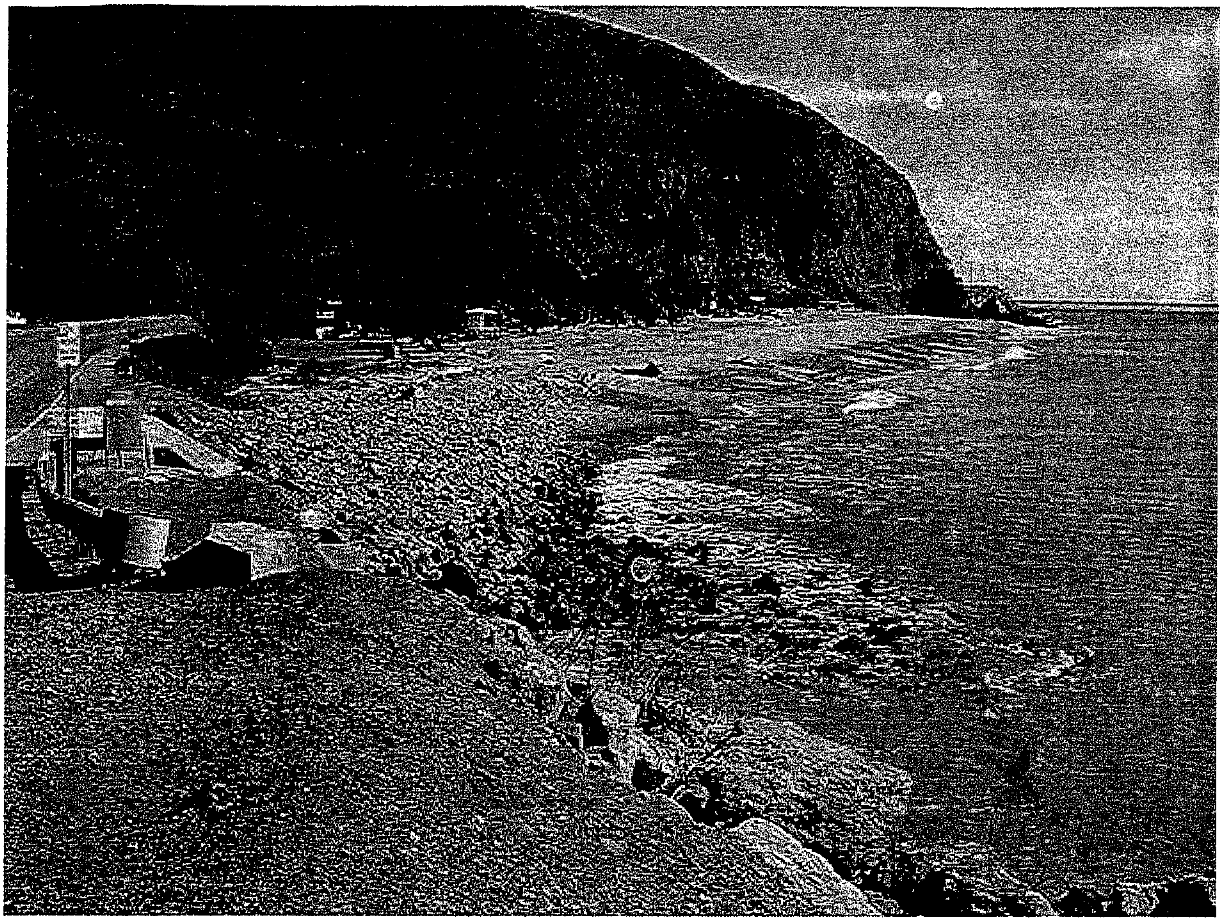
Point Mugu Beach (Adjacent to parking lot entry)



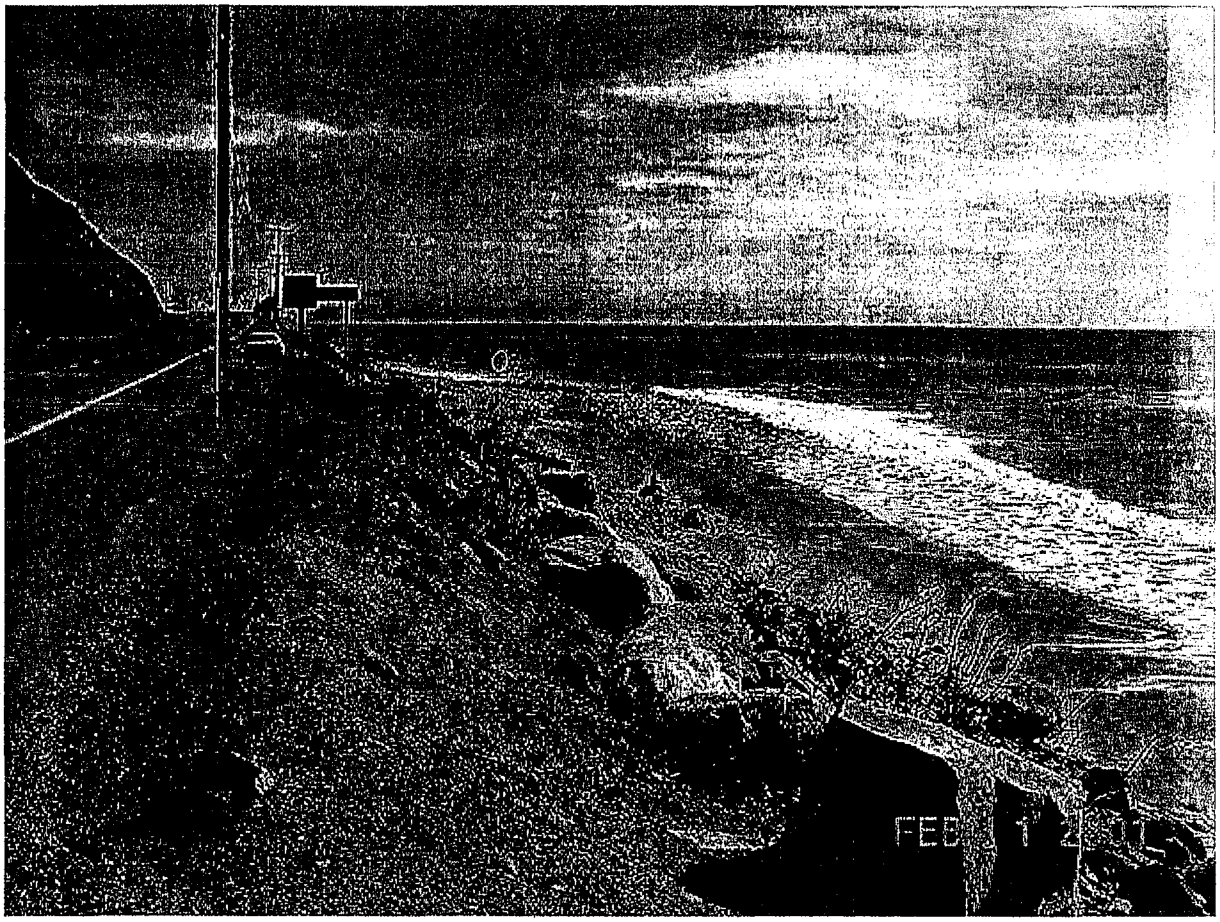
Thornhill Broome Beach (Adj. to park entry)



Sycamore Cove Beach (25 yds S. of creek)



Deer Creek (25 yards S. of creek)



County Line Beach (25 yards S. of creek)

Staircase Beach (At bottom of staircase)

No Photo

Heal The Bay does not have Weekly Report Card - Grade Maps for the following Ventura County Environmental Health Division sampling sites for bacteria:

1) Promenade Park (S. of drain, at Figueroa Street);

2) Promenade Park (S. of drain, at California Street); and

3) Promenade Park (S. of drain, end of Oak Street).

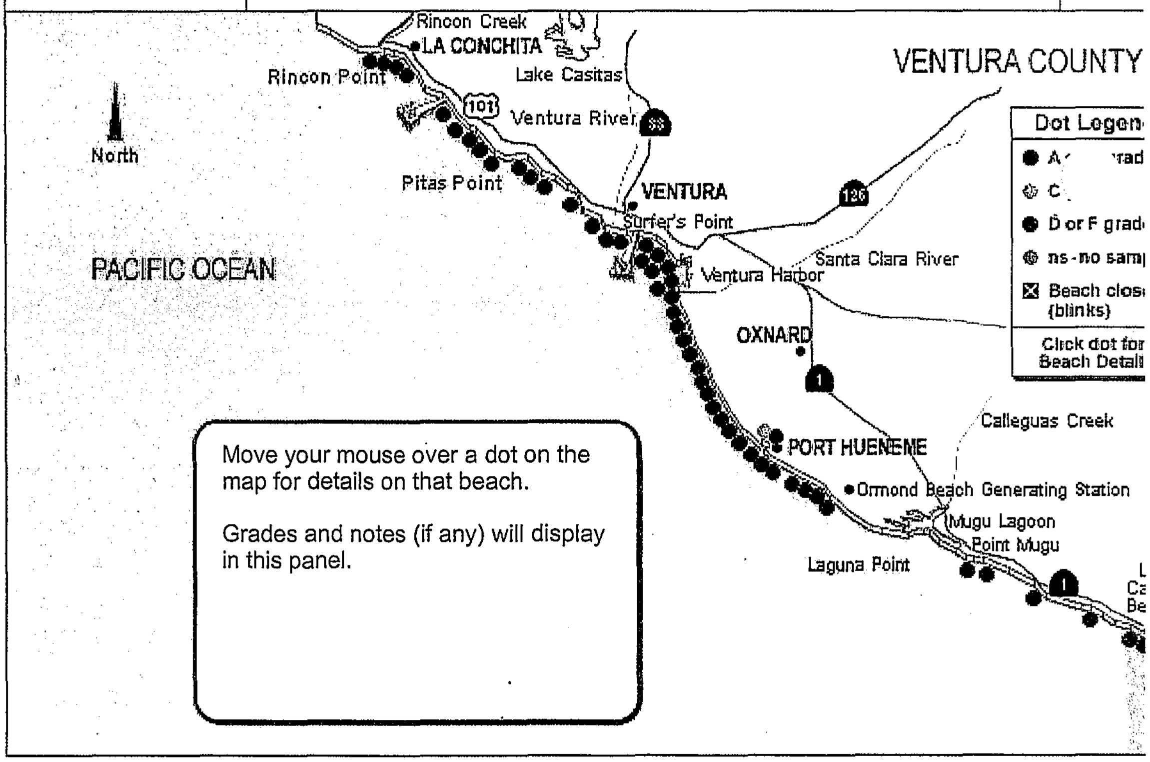
Beach Report Card[SM]

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 1, 2005	CA ma North South



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- Warning Signs
- Beach Details

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- Grading System
- About the BRC

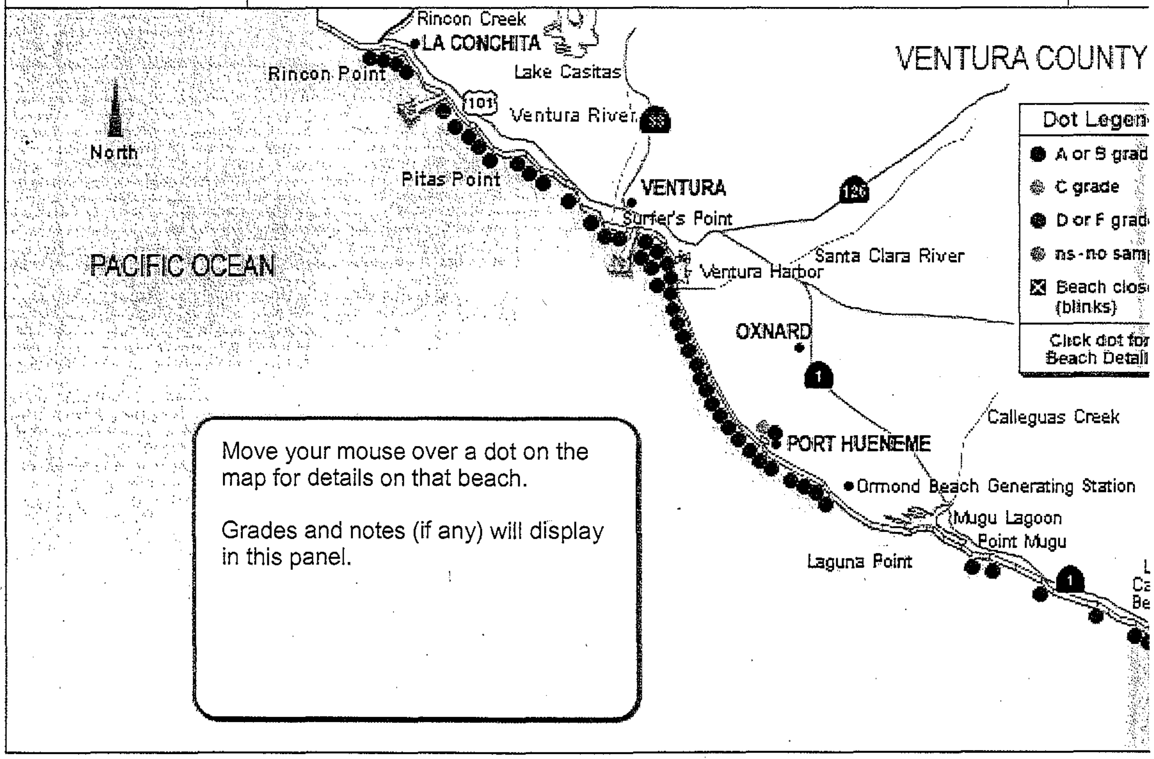
Beach Report Card℠

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	**Area:** Ventura County, CA **Weather:** Wet Show Dry Grades **Grade Period:** 4-week period ending June 8, 2005	CA ma North ▲ South ▼



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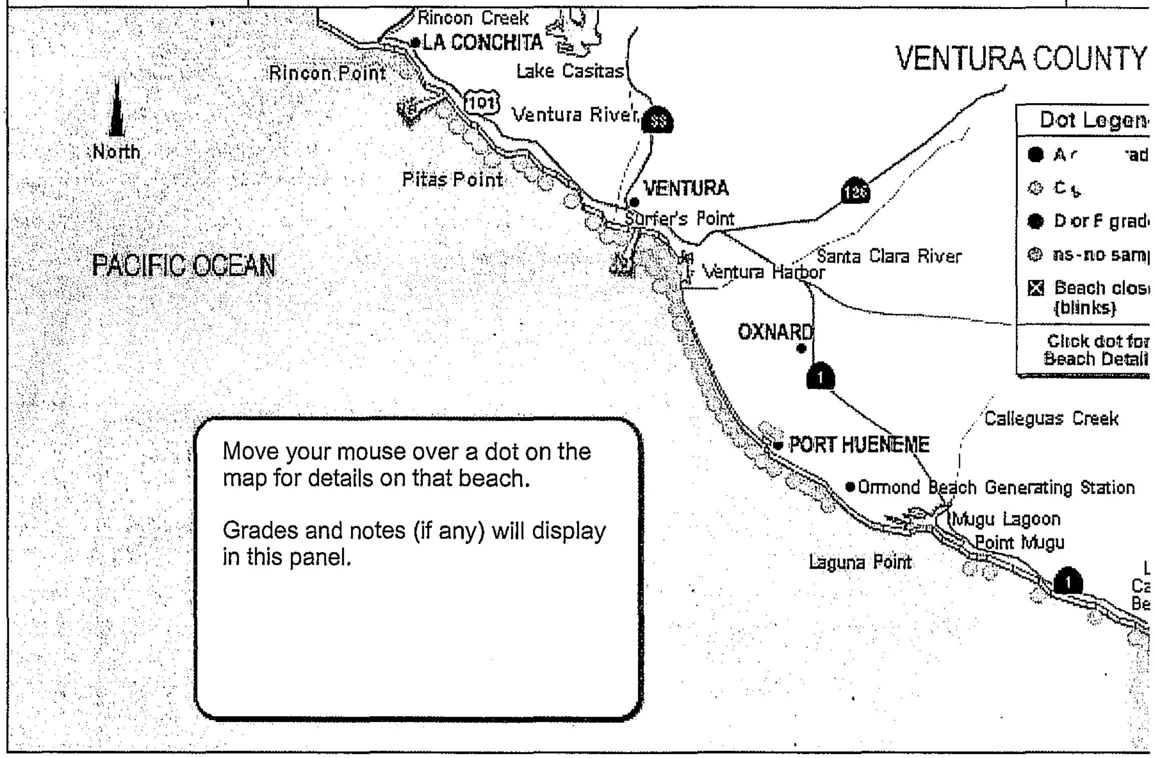
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 15, 2005	CA ma North South



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Beach Report Card℠

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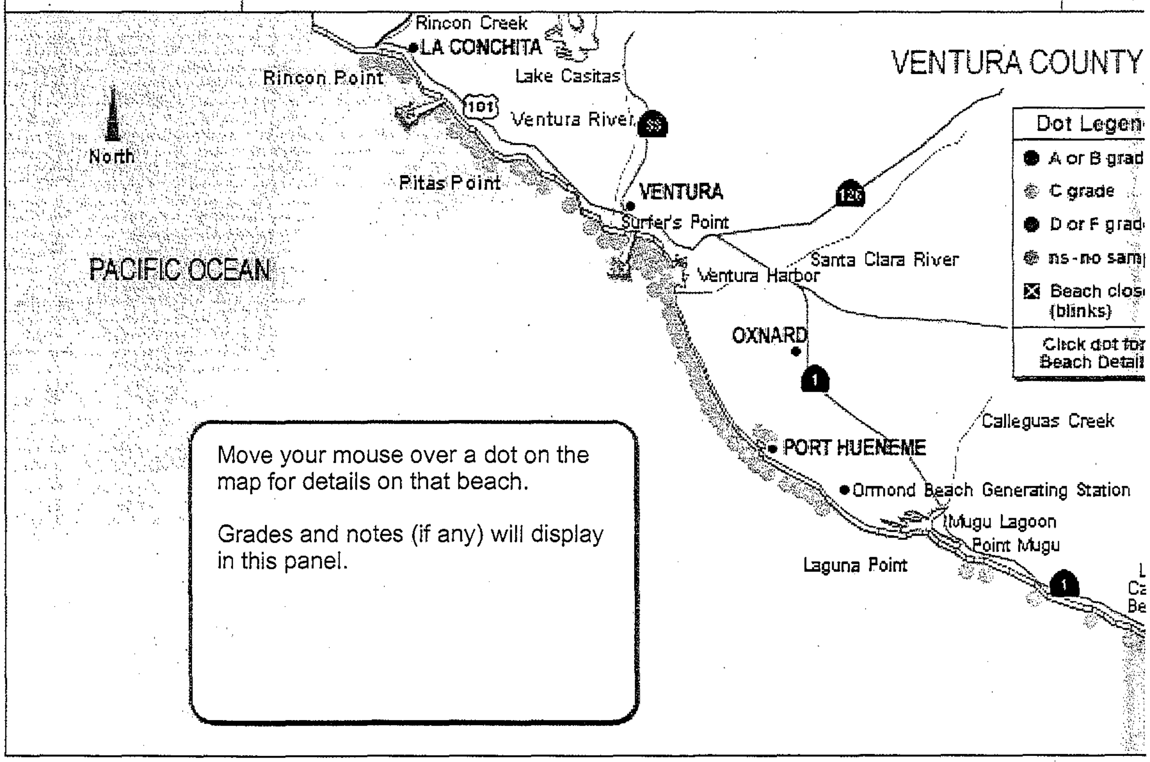
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 22, 2005	Navigat... North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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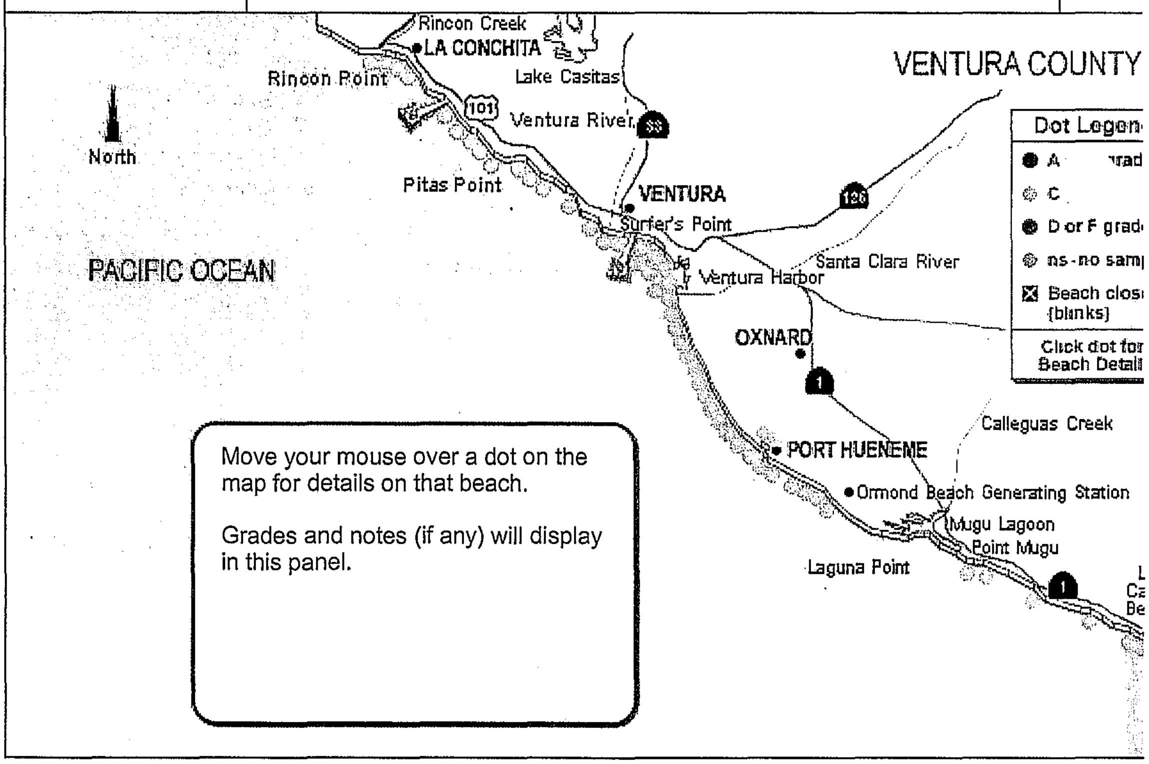
Beach Report Card[SM]

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 29, 2005	CA ma North South



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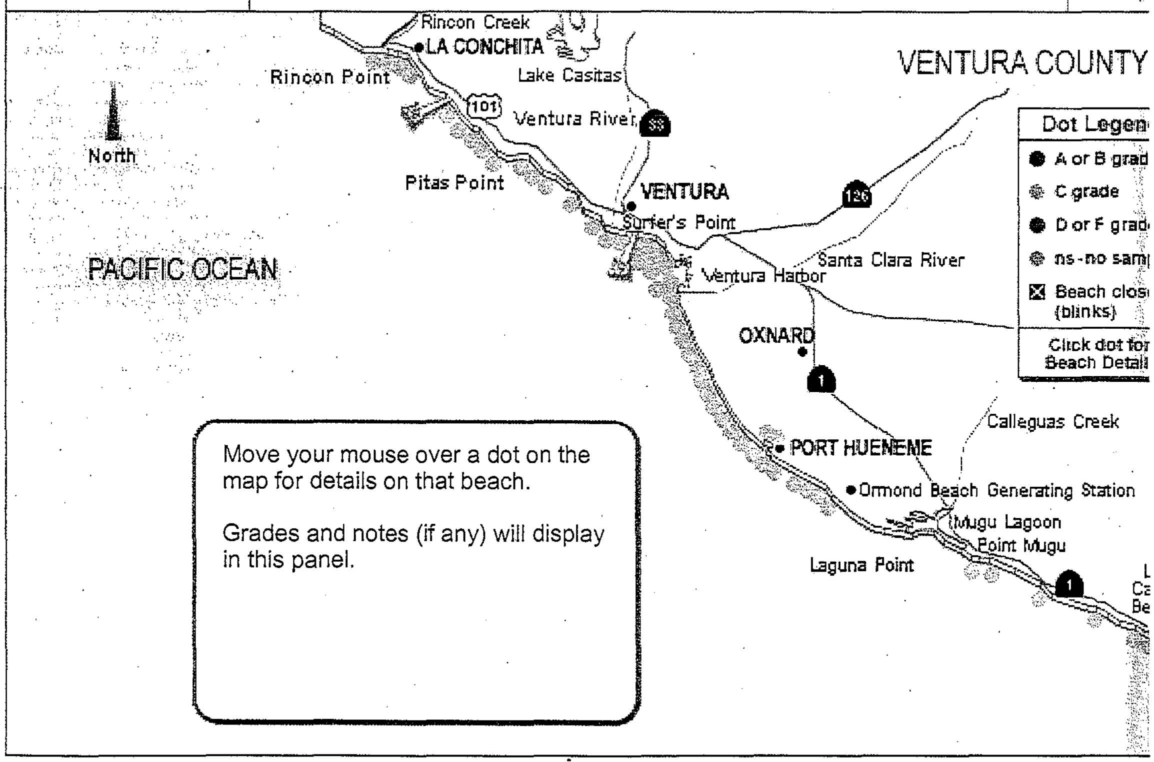
Beach Report Card℠

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending July 6, 2005	CA ma North ▲ South ▼



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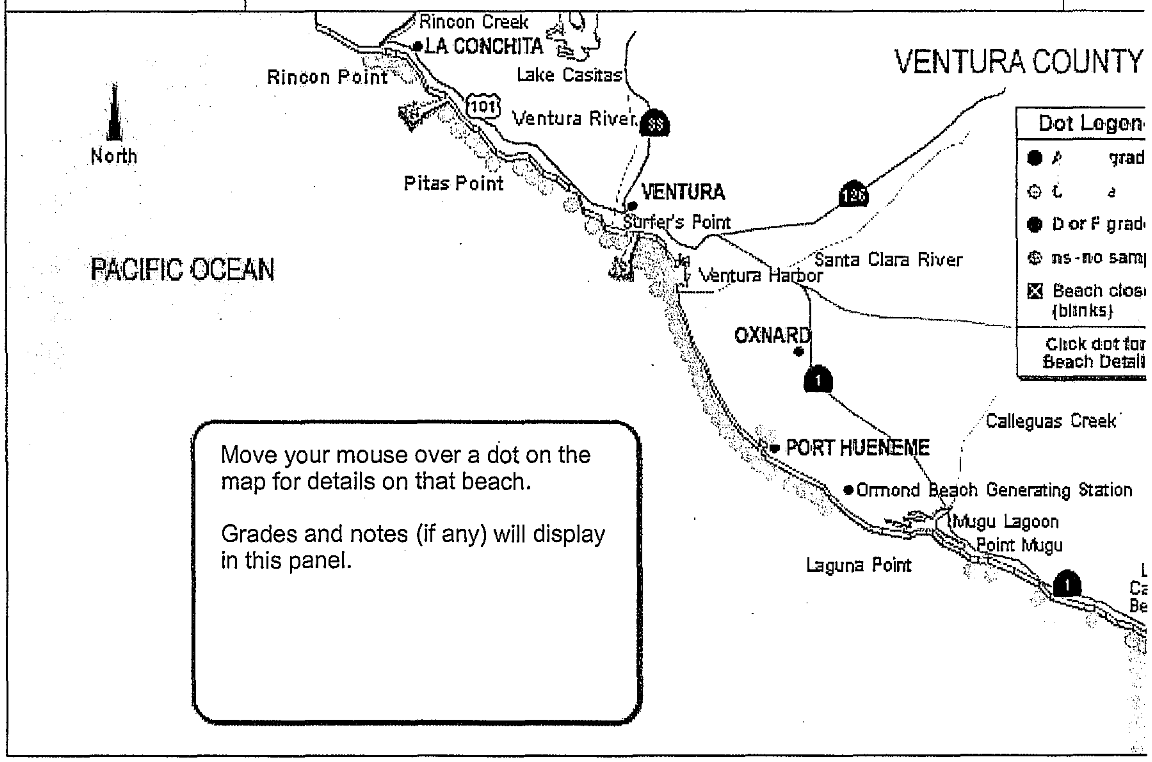
Beach Report Card[SM]

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending July 13, 2005	CA ma North South



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Beach Report Card[SM]

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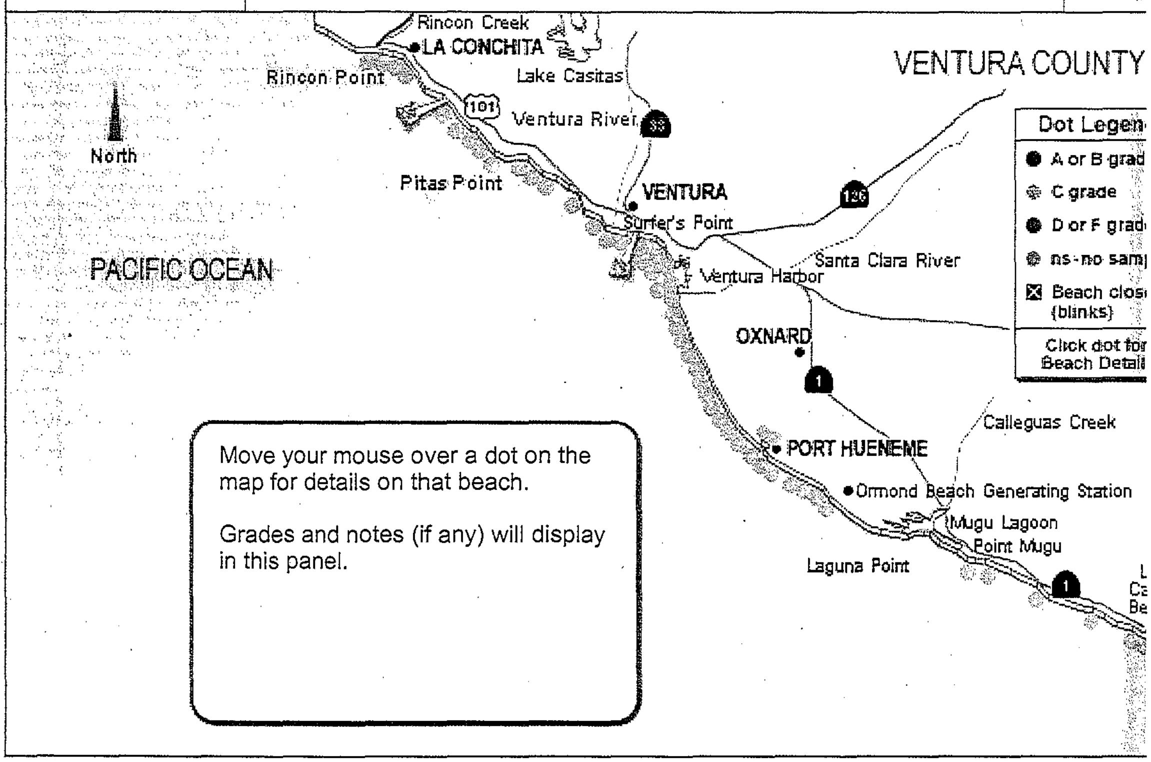
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending July 20, 2005	CA ma North South



Beach Report Card[SM]

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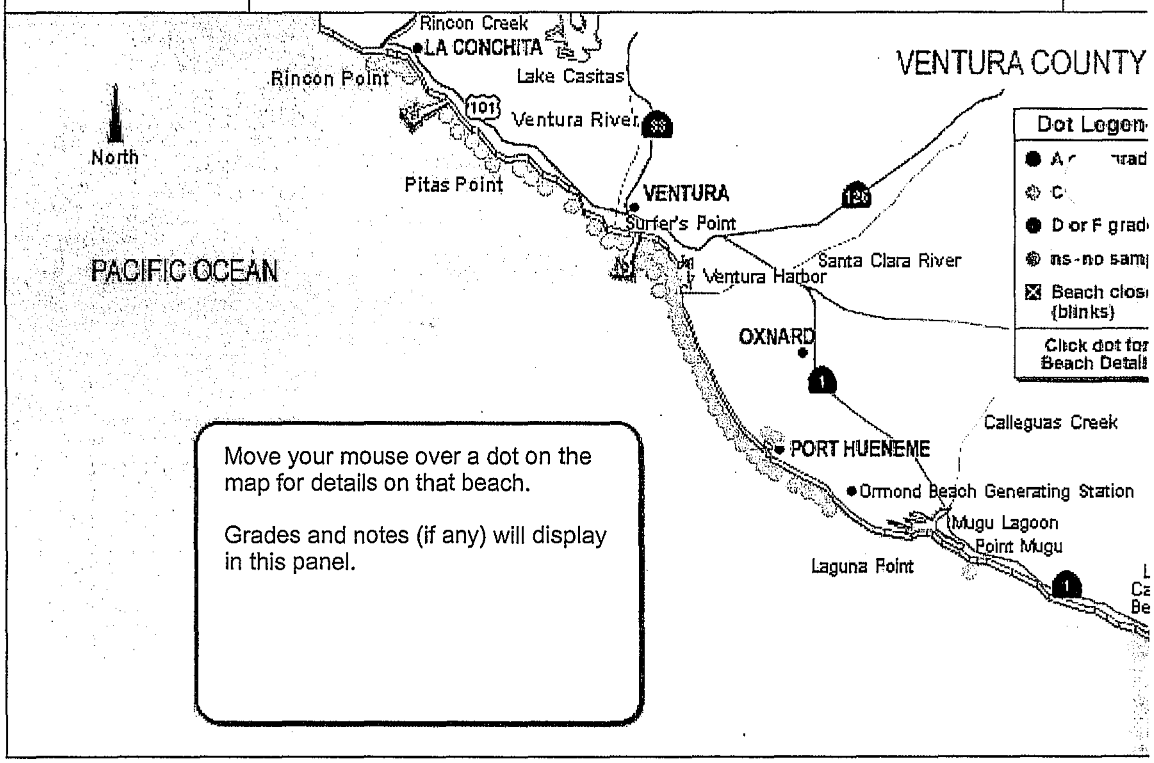
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet (Show Dry Grades) Grade Period: 4-week period ending July 27, 2005	CA ma North South



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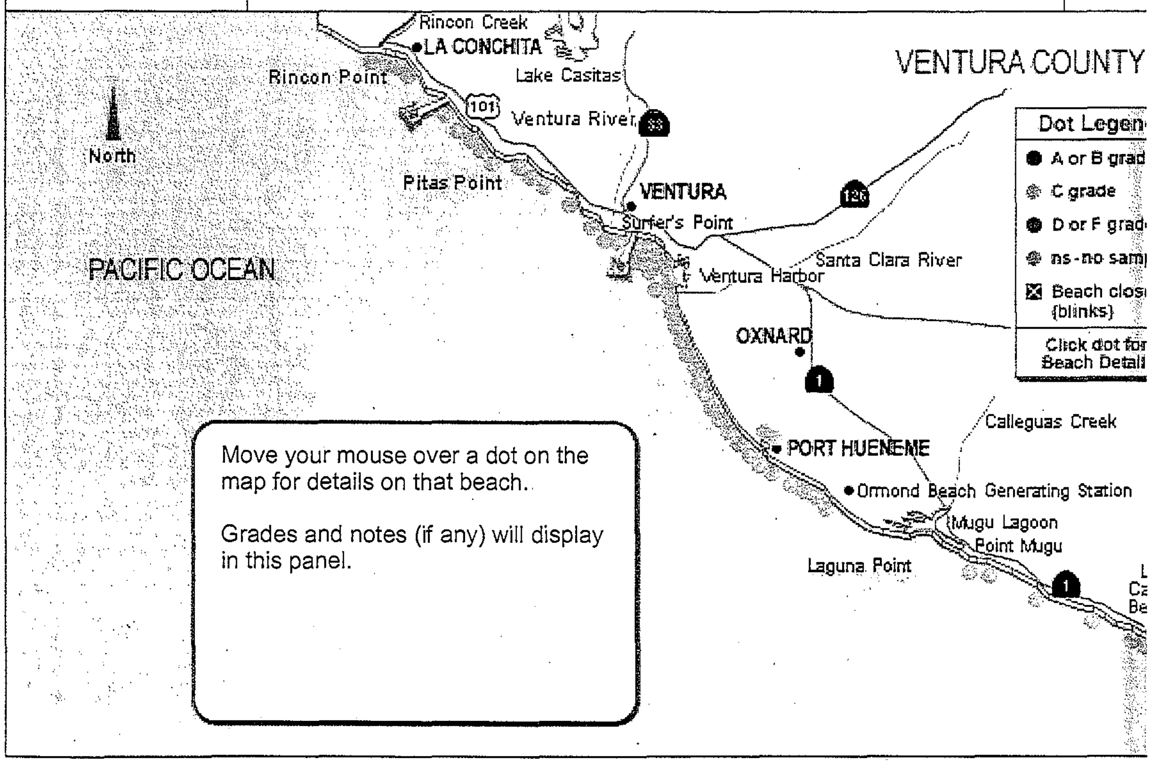
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending August 3, 2005	CA ma North ▲ South ▼



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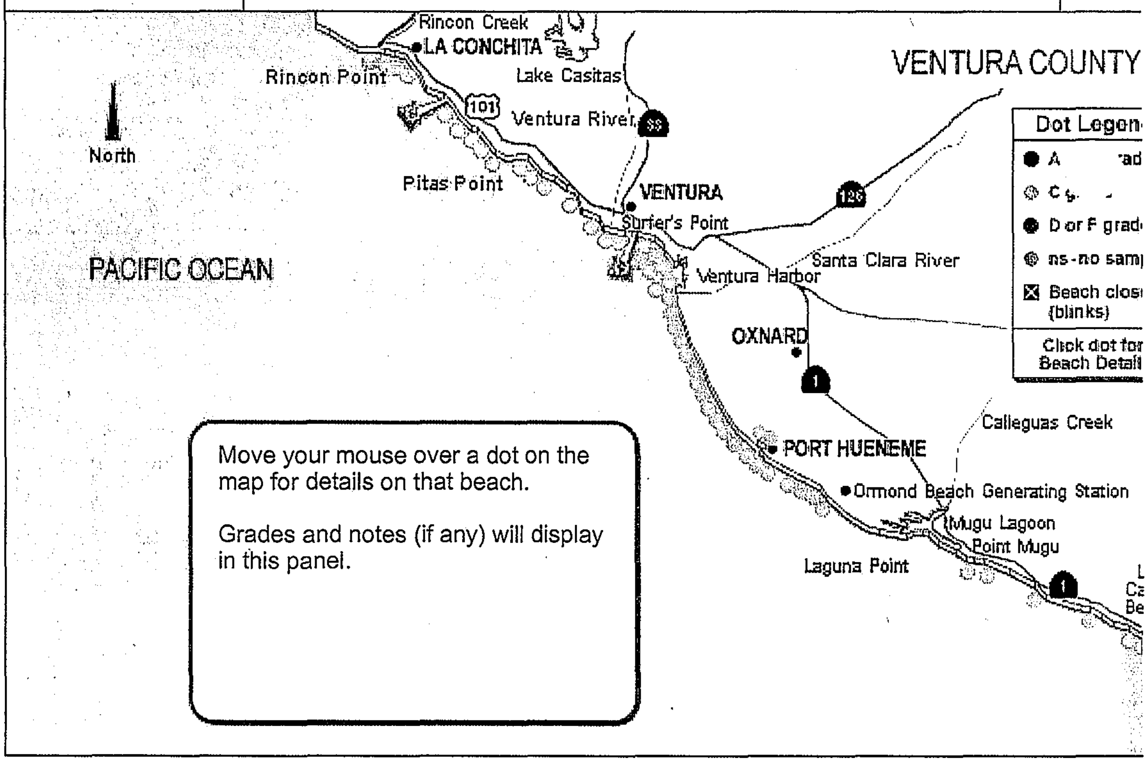
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending August 10, 2005	CA ma North South



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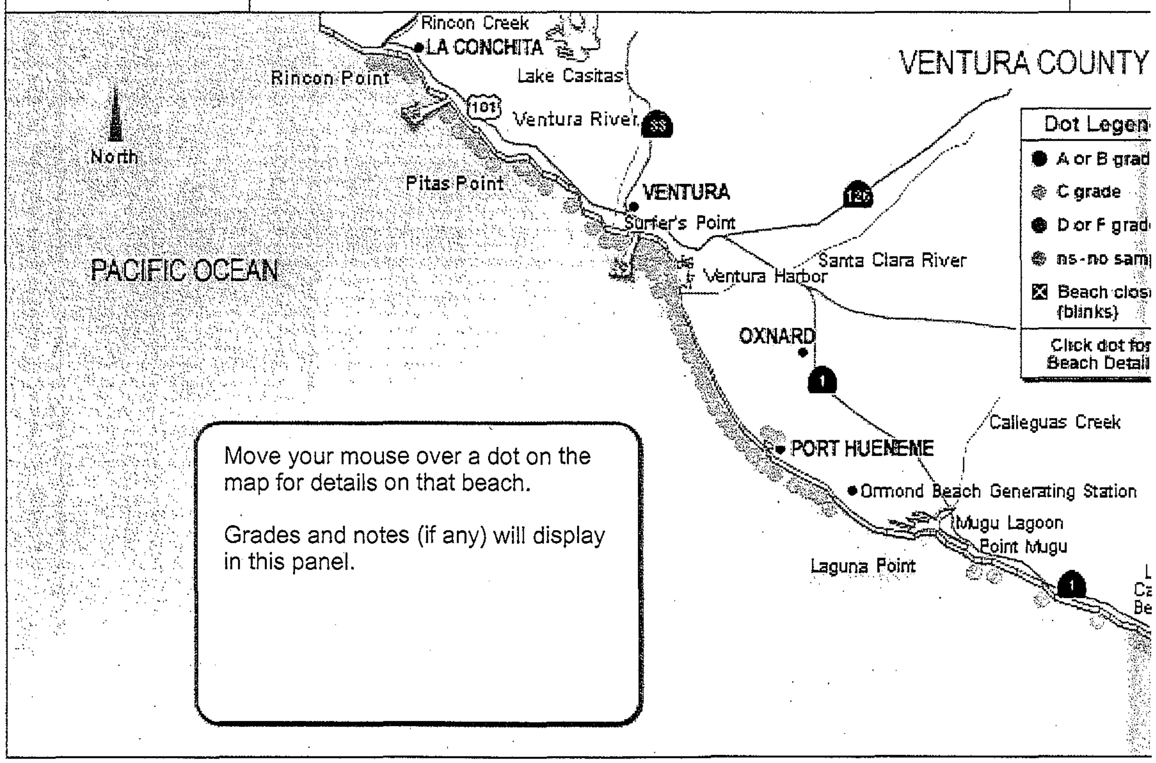
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending August 24, 2005	CA ma North ▲ South ▼



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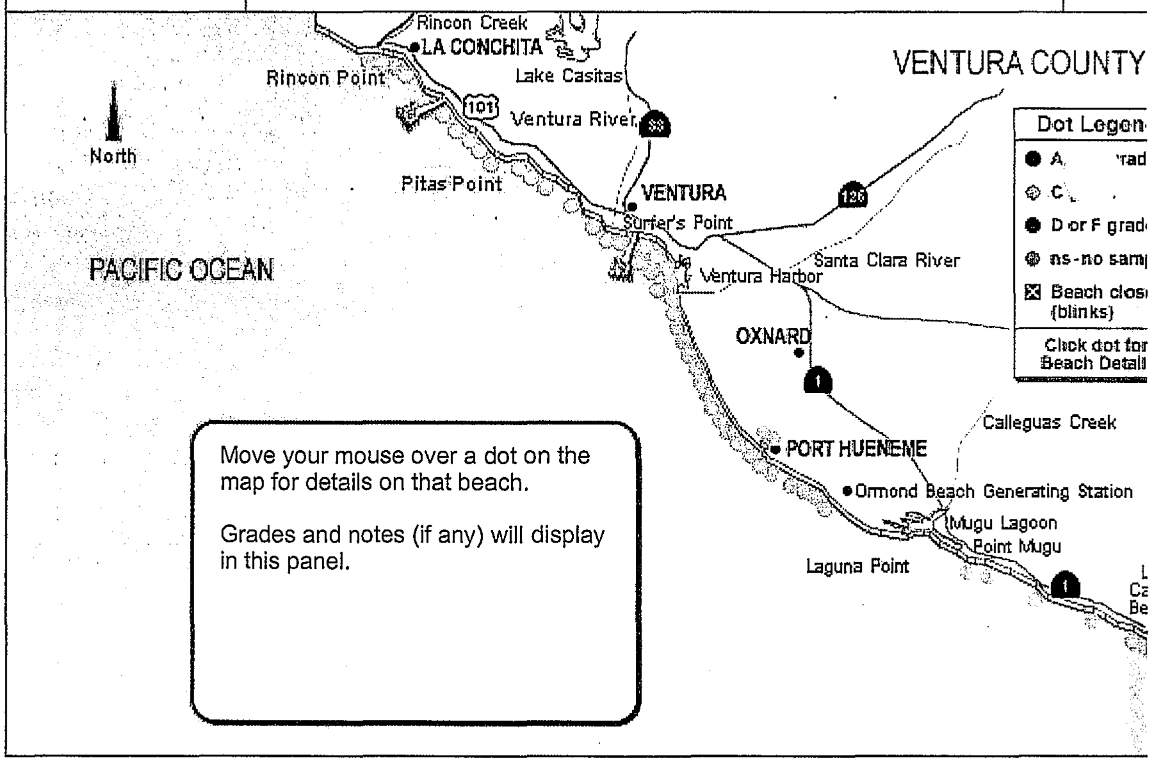
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	
Grade Map	Area:	Ventura County, CA
View Text List	Weather:	Wet [Show Dry Grades]
	Grade Period:	4-week period ending August 31, 2005



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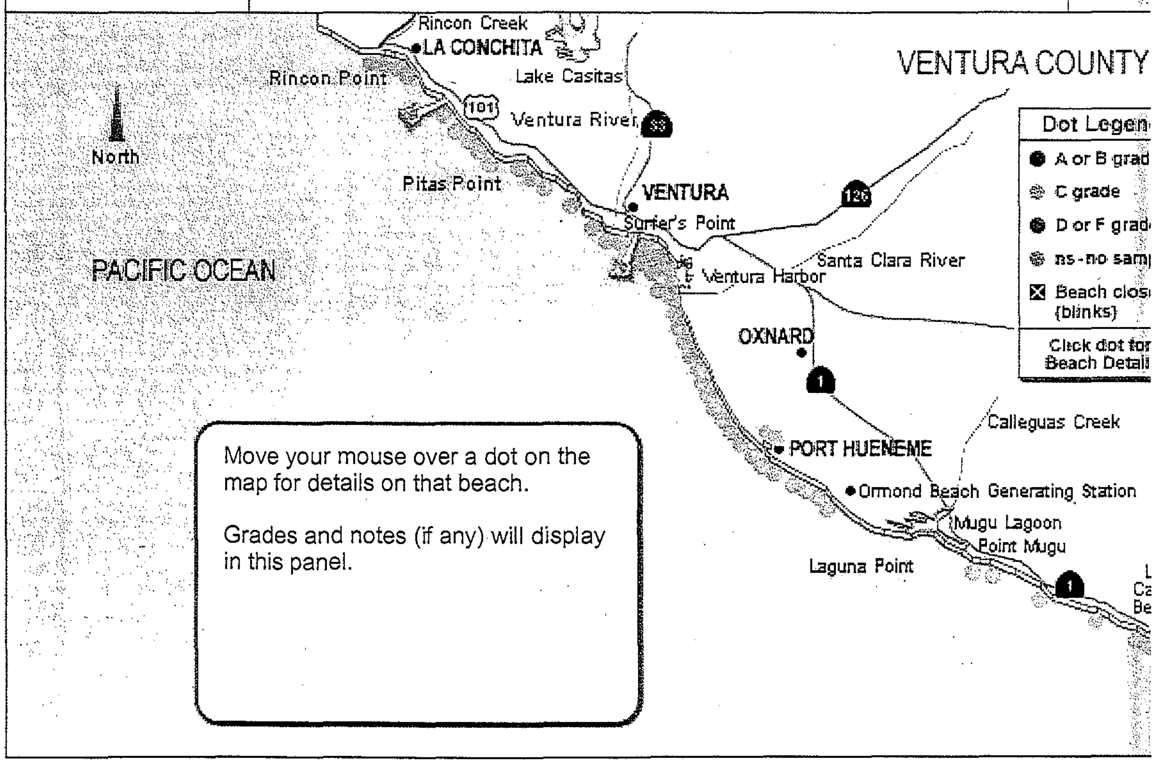
Weekly Report Card - Grade Map

◀ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending September 7, 2005	North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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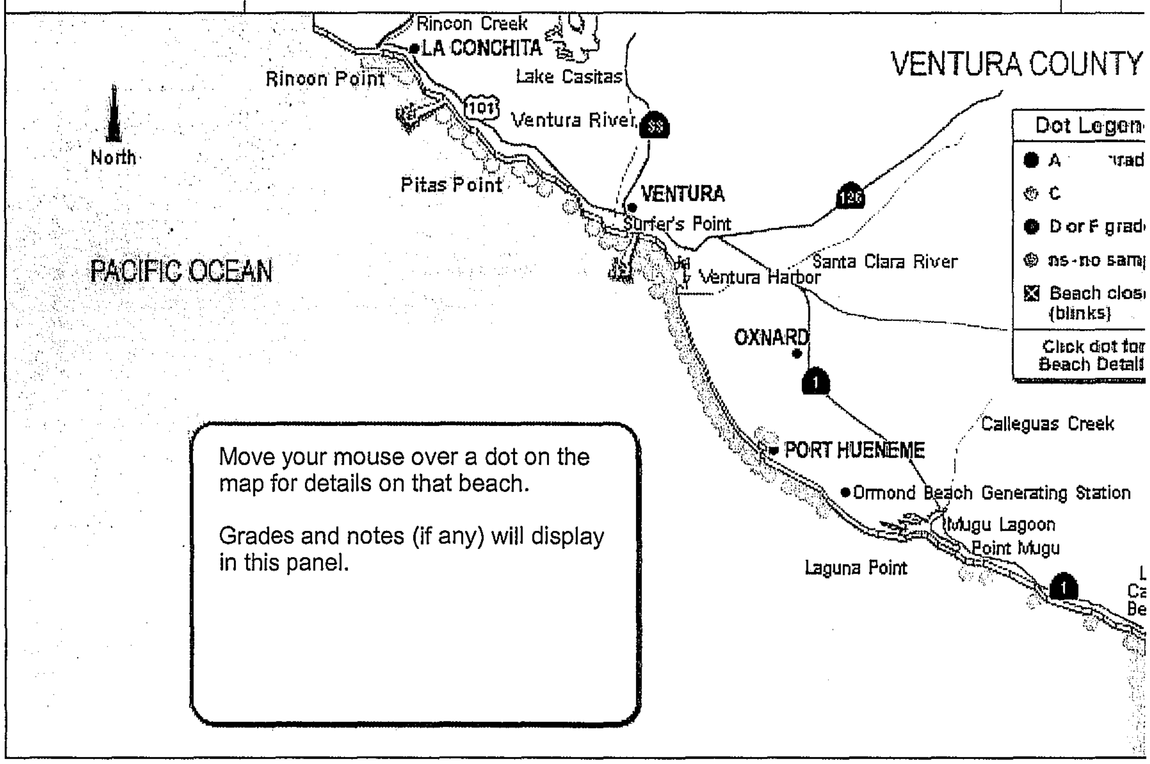
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending September 14, 2005	CA ma North South



Move your mouse over a dot on the map for details on that beach.

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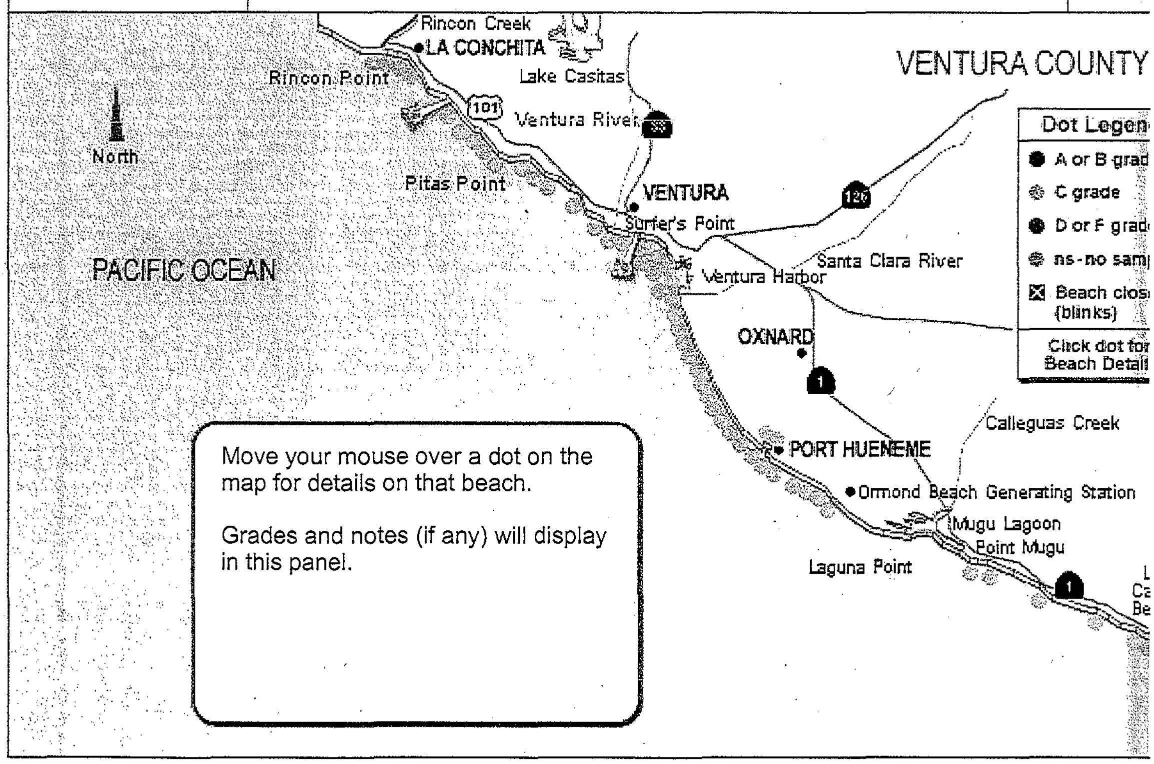
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending September 21, 2005	CA ma North South



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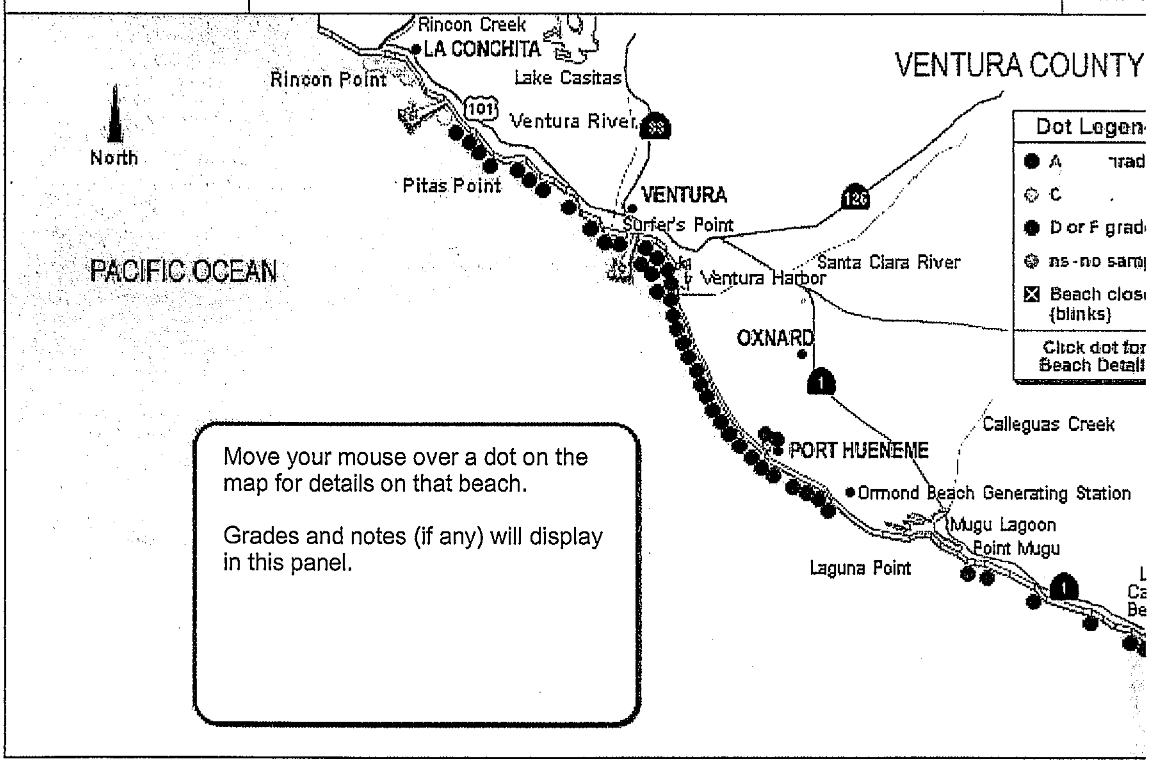
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet (Show Dry Grades) Grade Period: 4-week period ending September 28, 2005	CA ma North South



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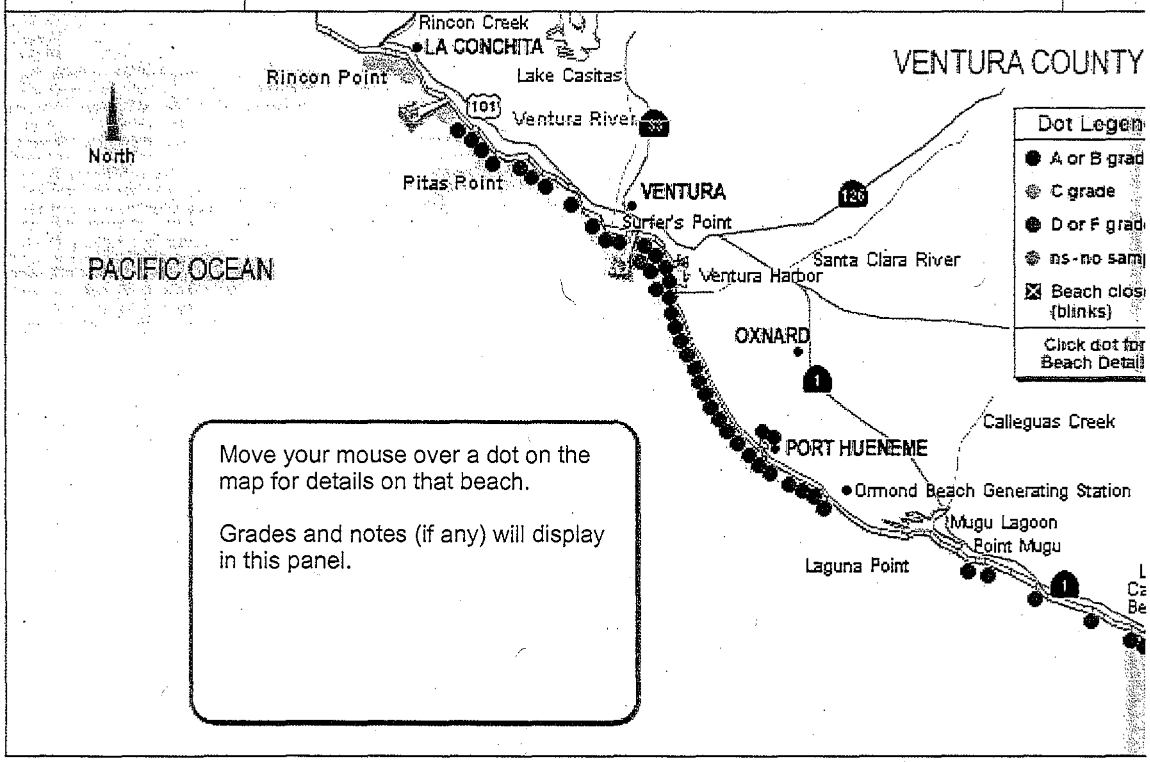
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	**Area:** **Ventura County, CA** **Weather:** **Wet** Show Dry Grades **Grade Period:** 4-week period ending October 5, 2005	CA ma North South



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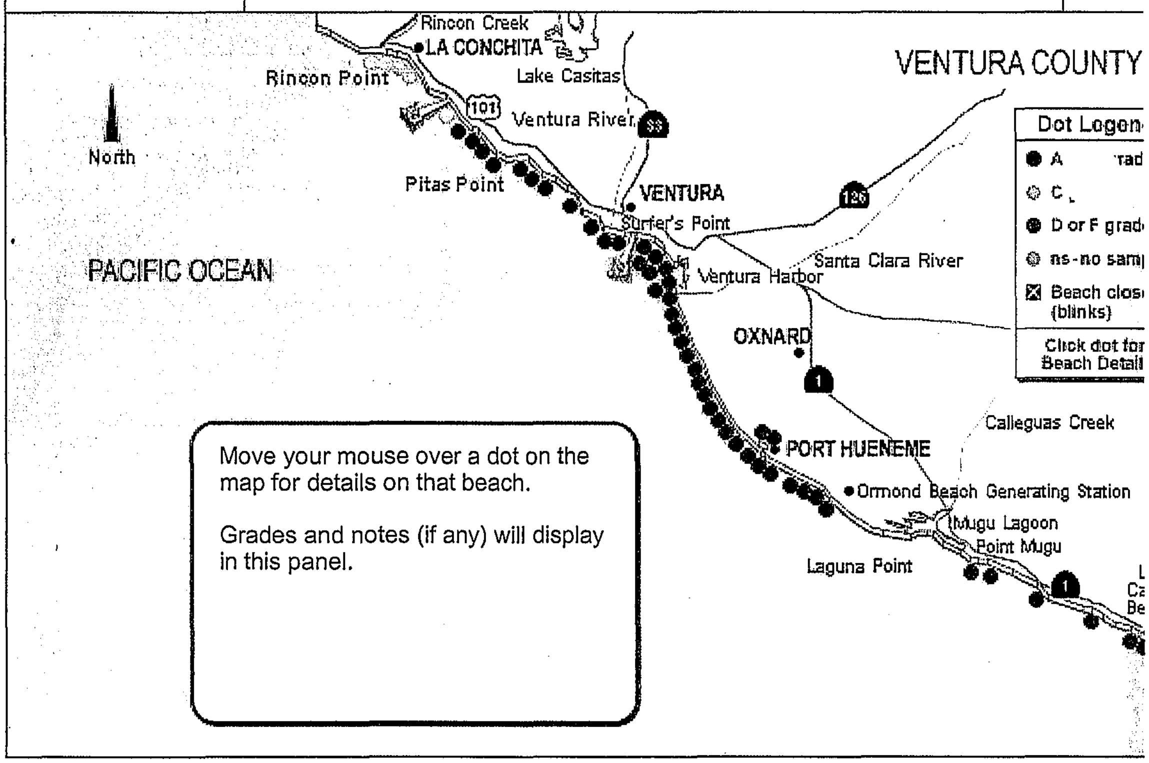
CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending October 12, 2005



Move your mouse over a dot on the map for details on that beach.

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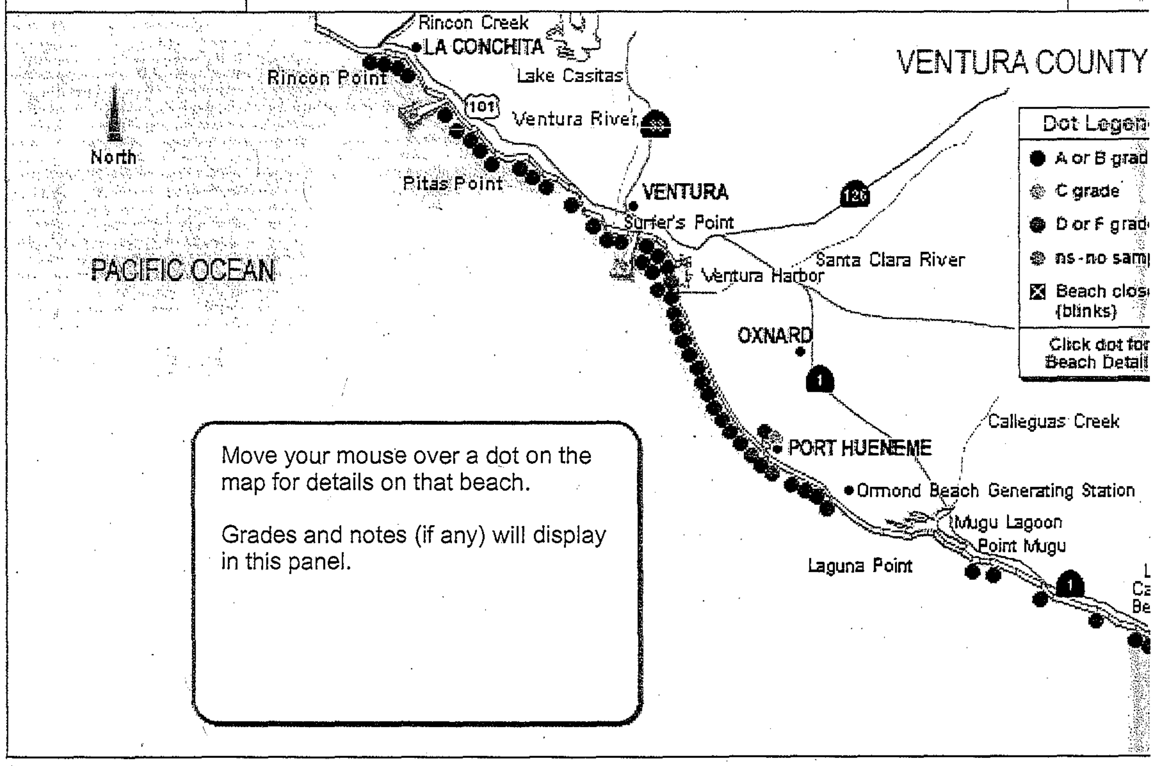
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending October 18, 2005	CA North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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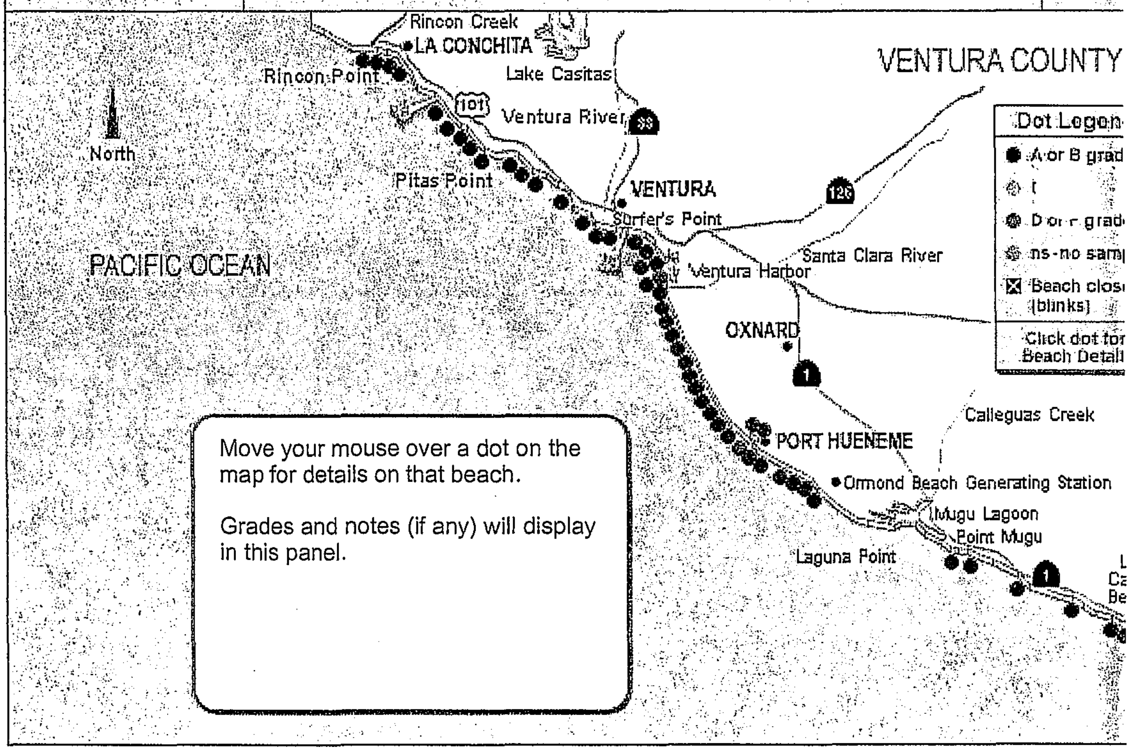
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending October 26, 2005	CA ma North South



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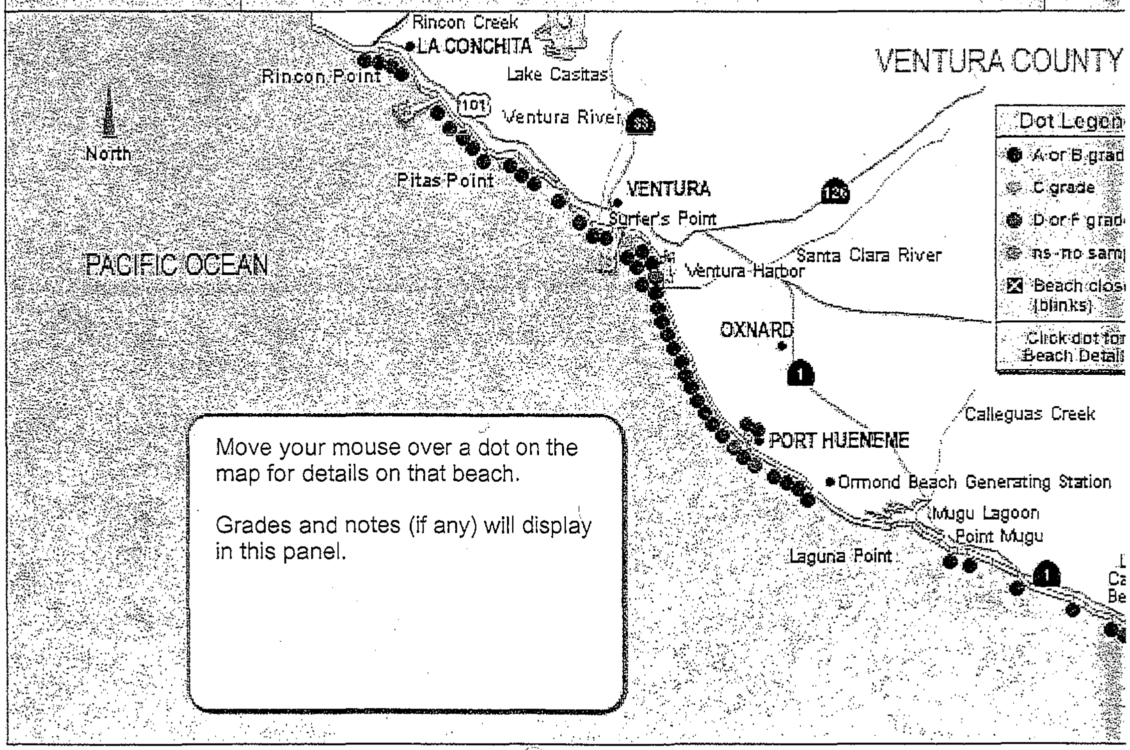
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending October 31, 2005	CA ma North South



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Weekly Report Card - Grade Map

◄ CA State Map

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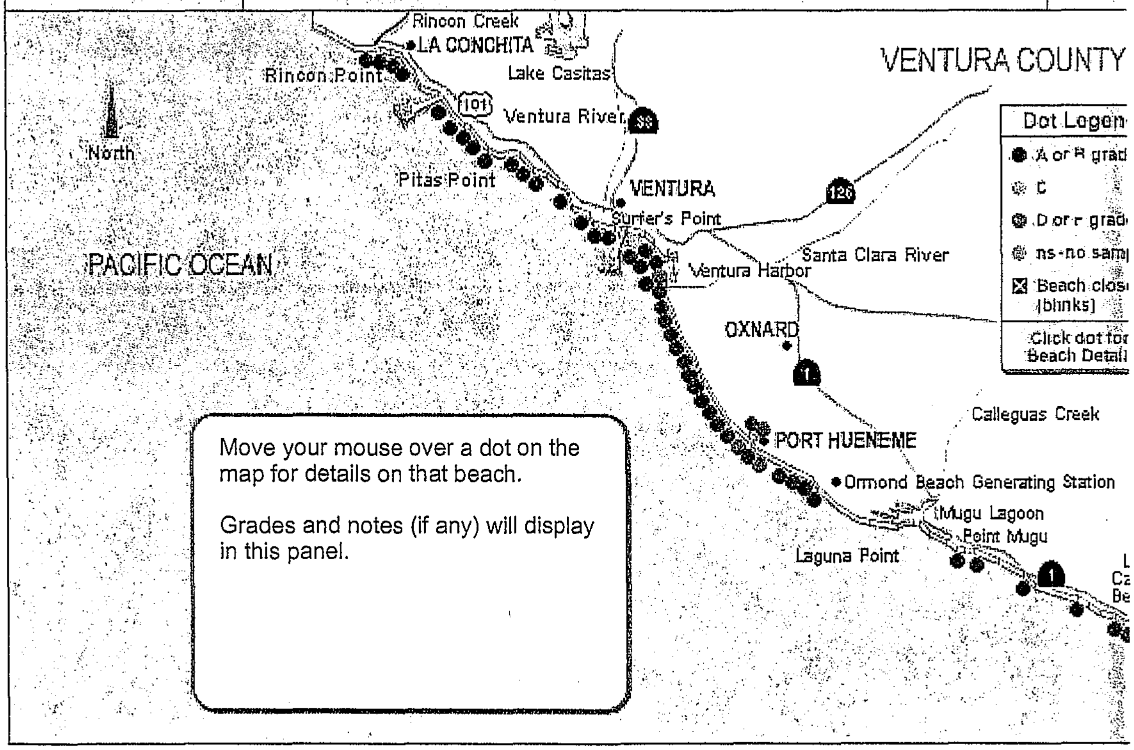
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending November 7, 2005	CA ma North South



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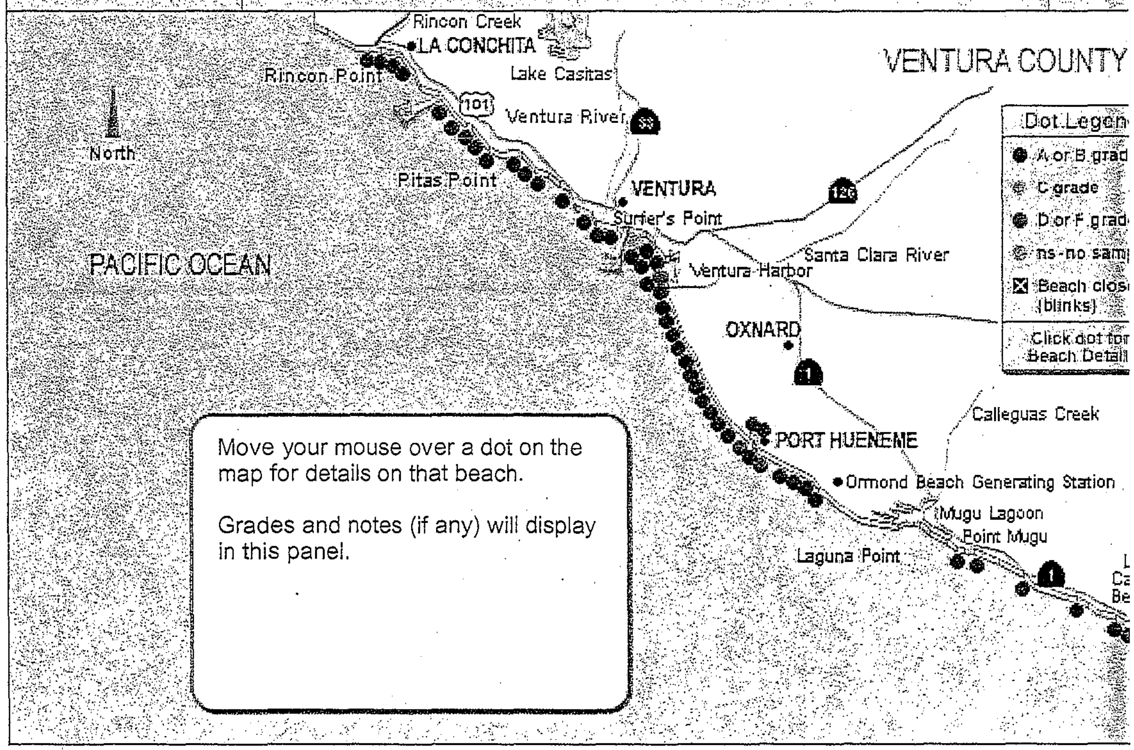
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending November 14, 2005	CA ma North South



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◄ CA State Map

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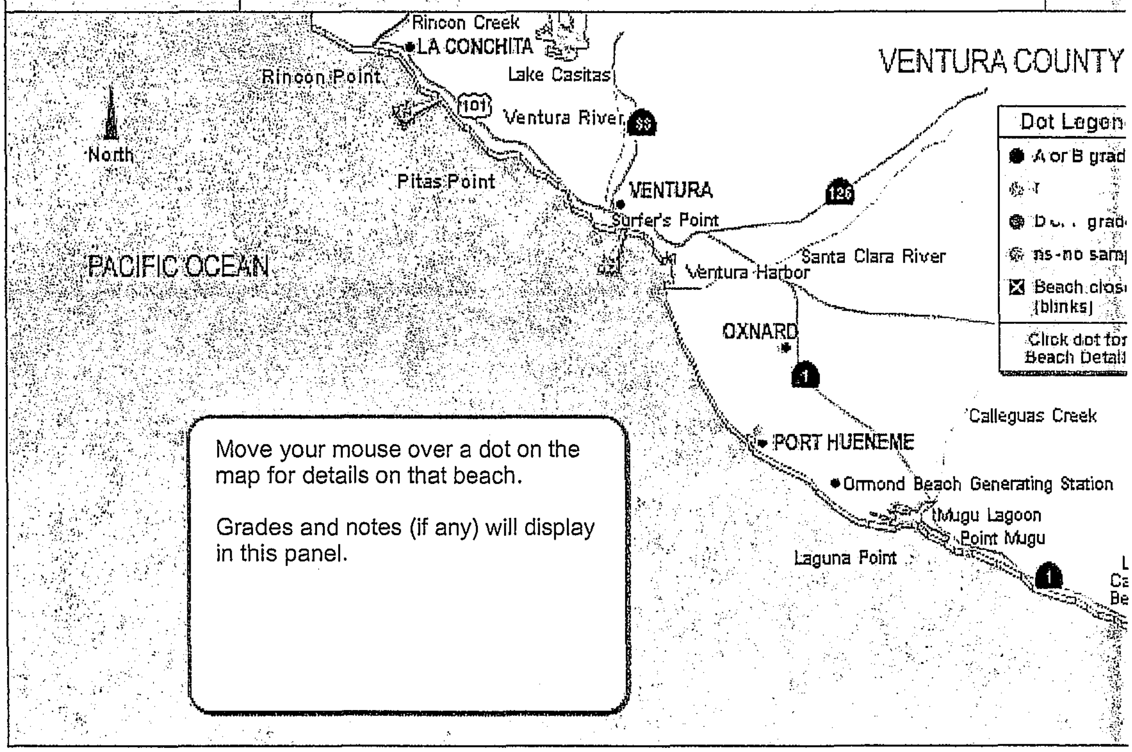
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending November 28, 2005	North South



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Beach Report Card[SM]

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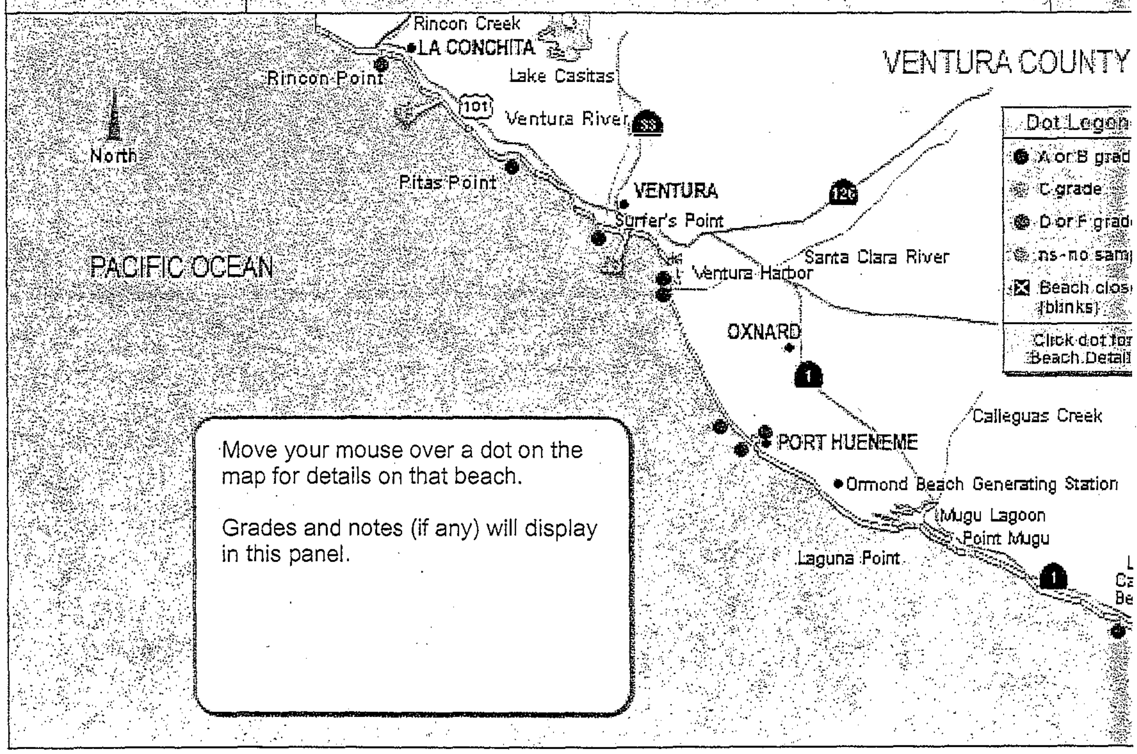
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending December 5, 2005	CA ma North South



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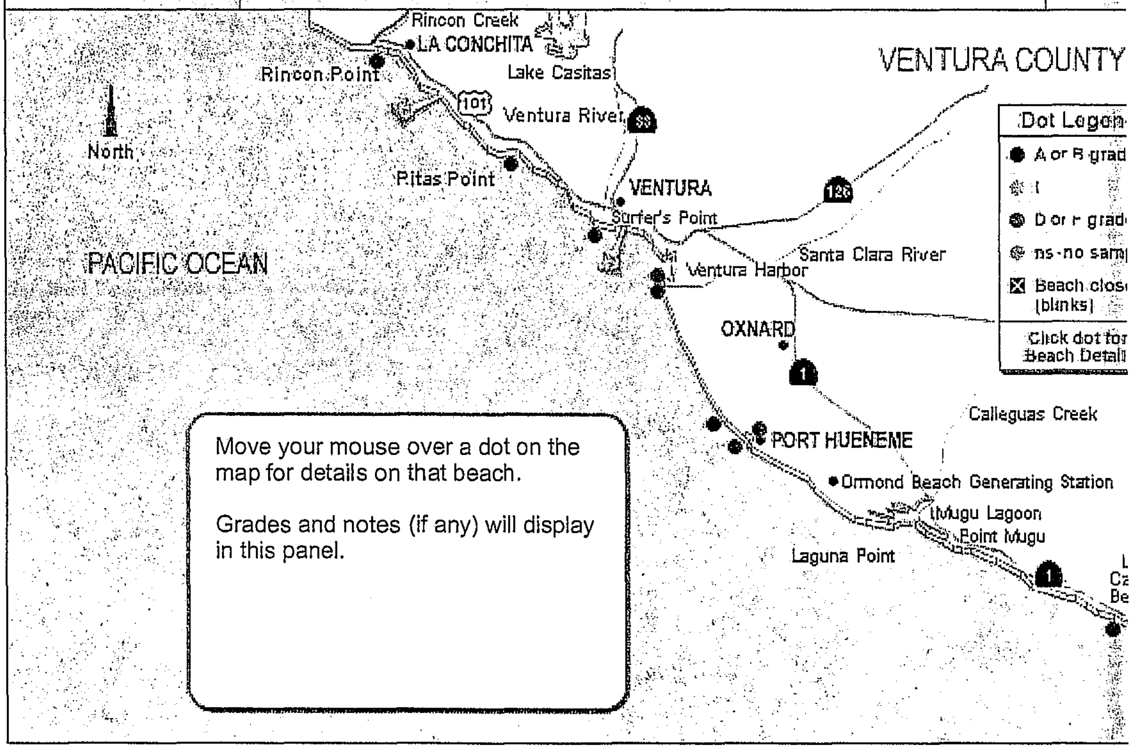
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending December 5, 2005	CA ma North South



A009622

Beach Report Card[SM]

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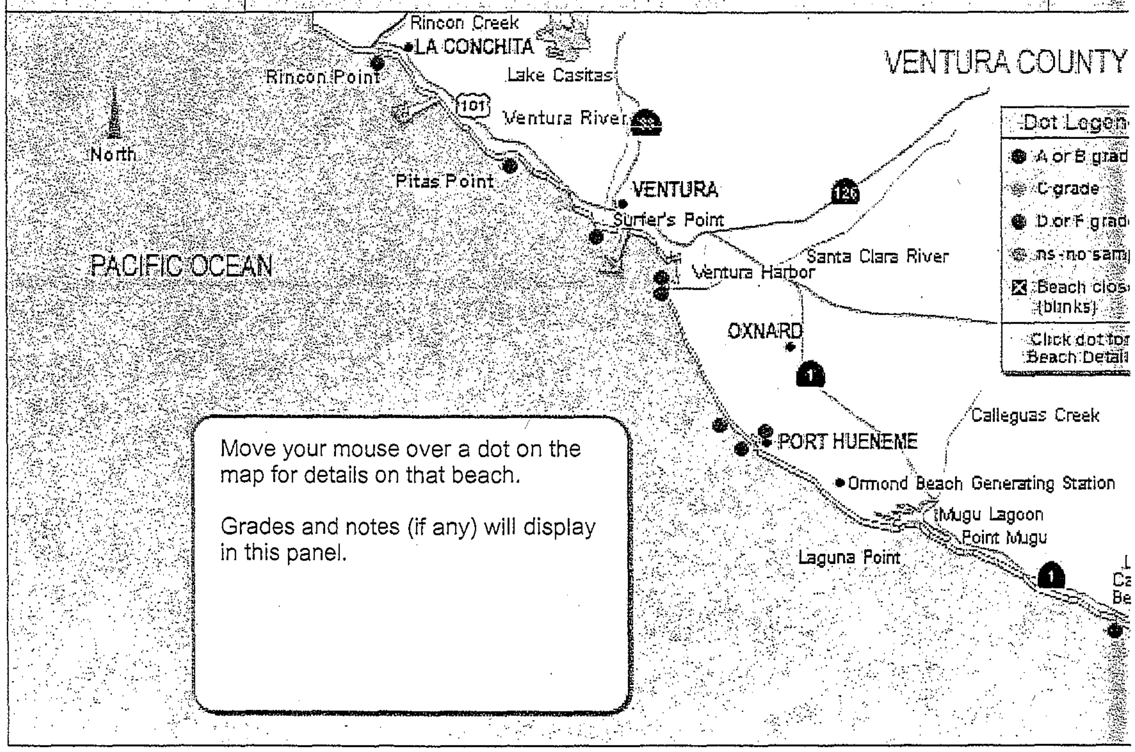
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending December 12, 2005	CA ma North South



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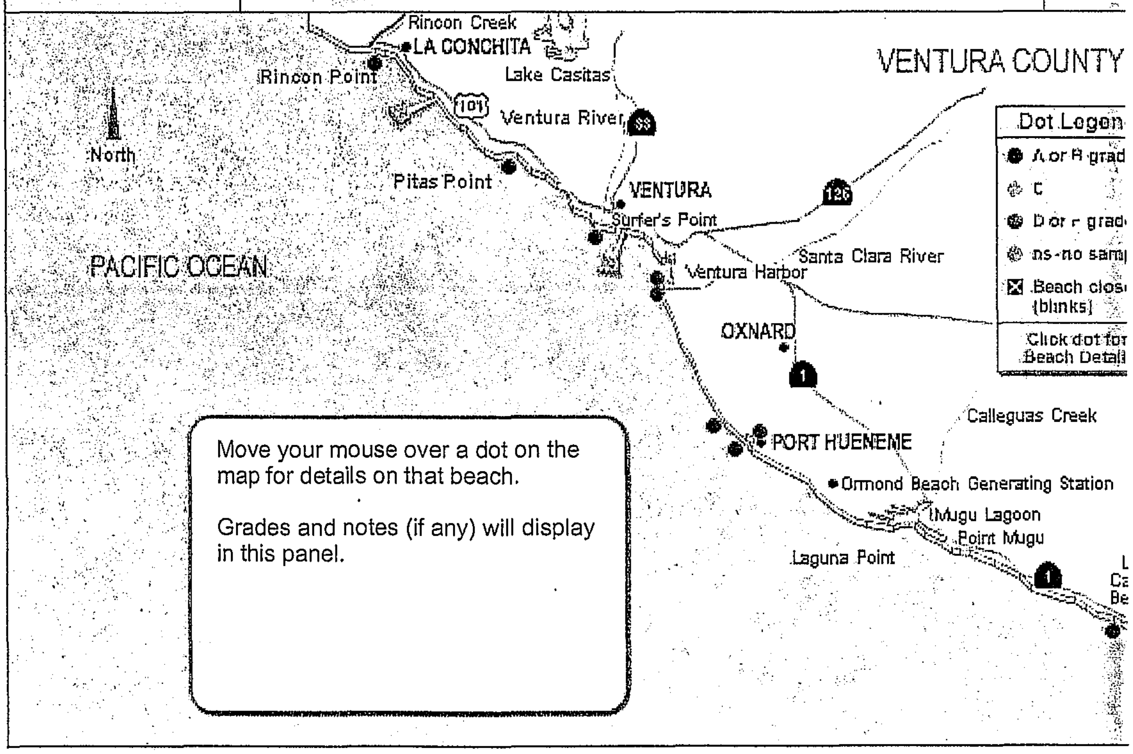
Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending December 20, 2005	CA North South



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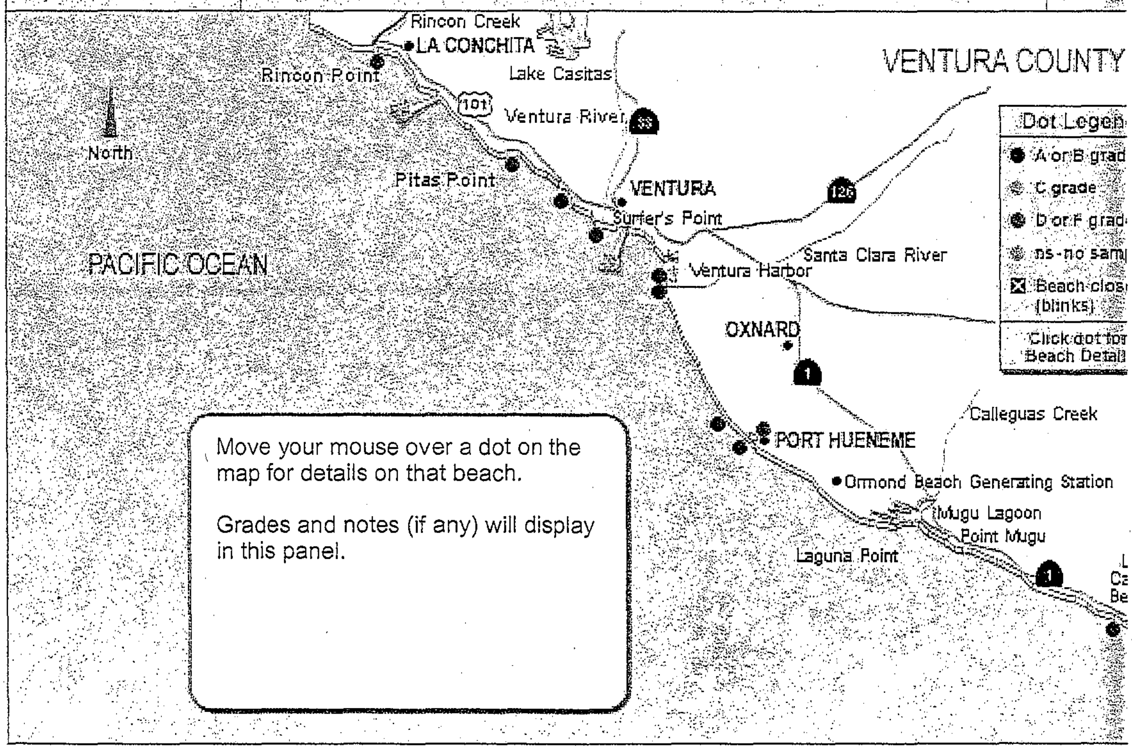
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending December 27, 2005	CA me North South



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Weekly Report Card - Grade Map

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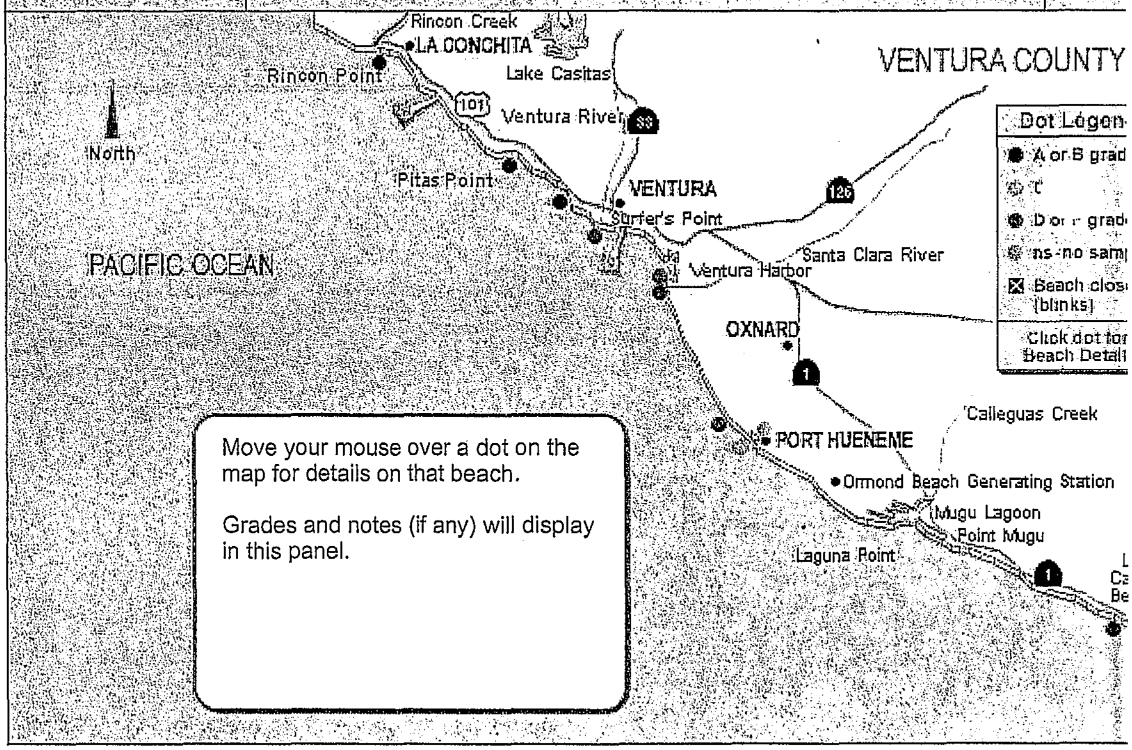
Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending January 3, 2006	CA ma North South



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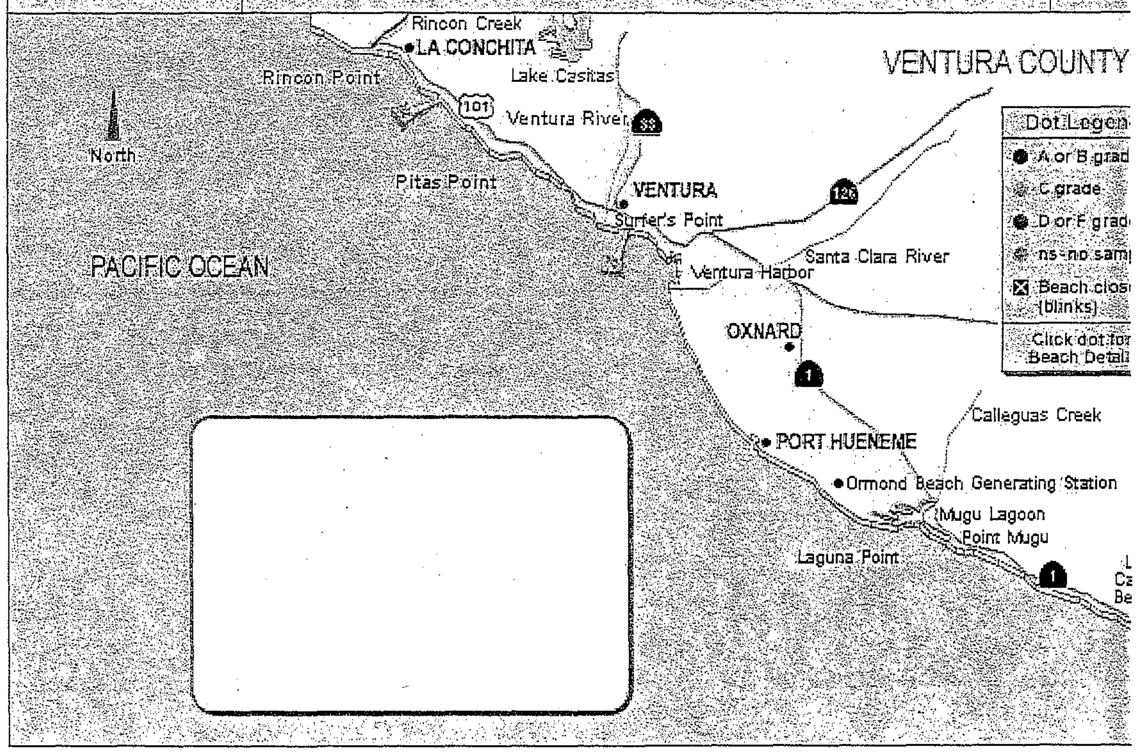
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending January 9, 2006	CA ma North South



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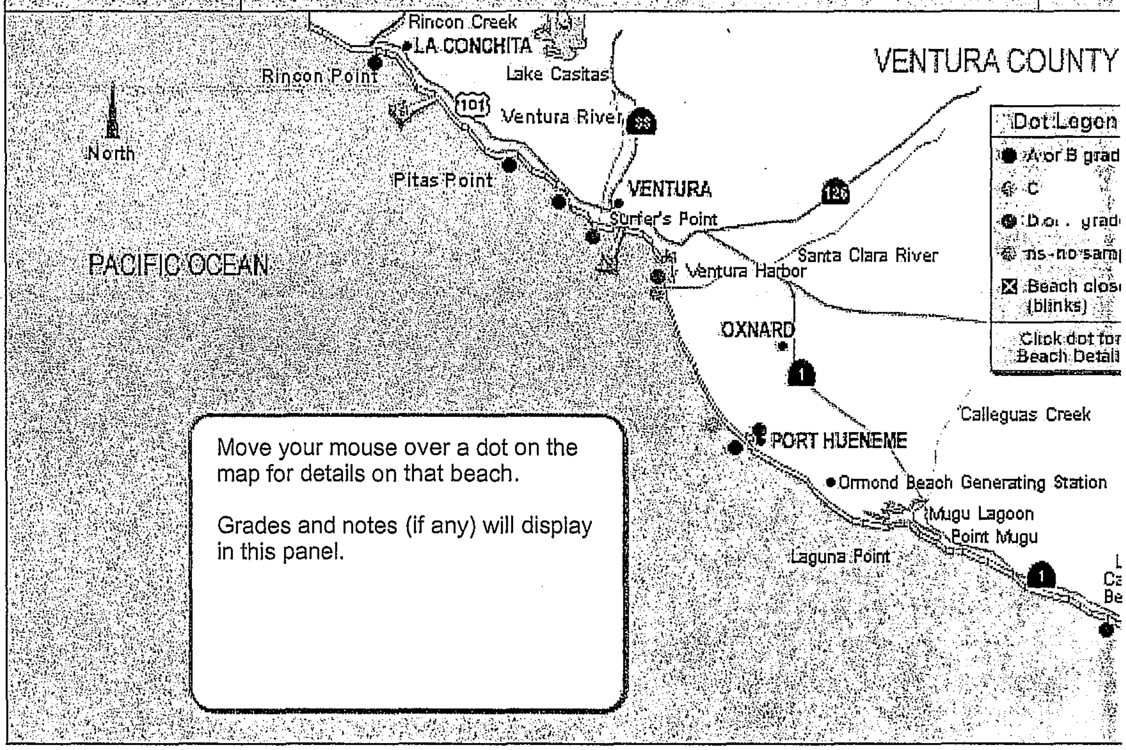
Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending January 17, 2006



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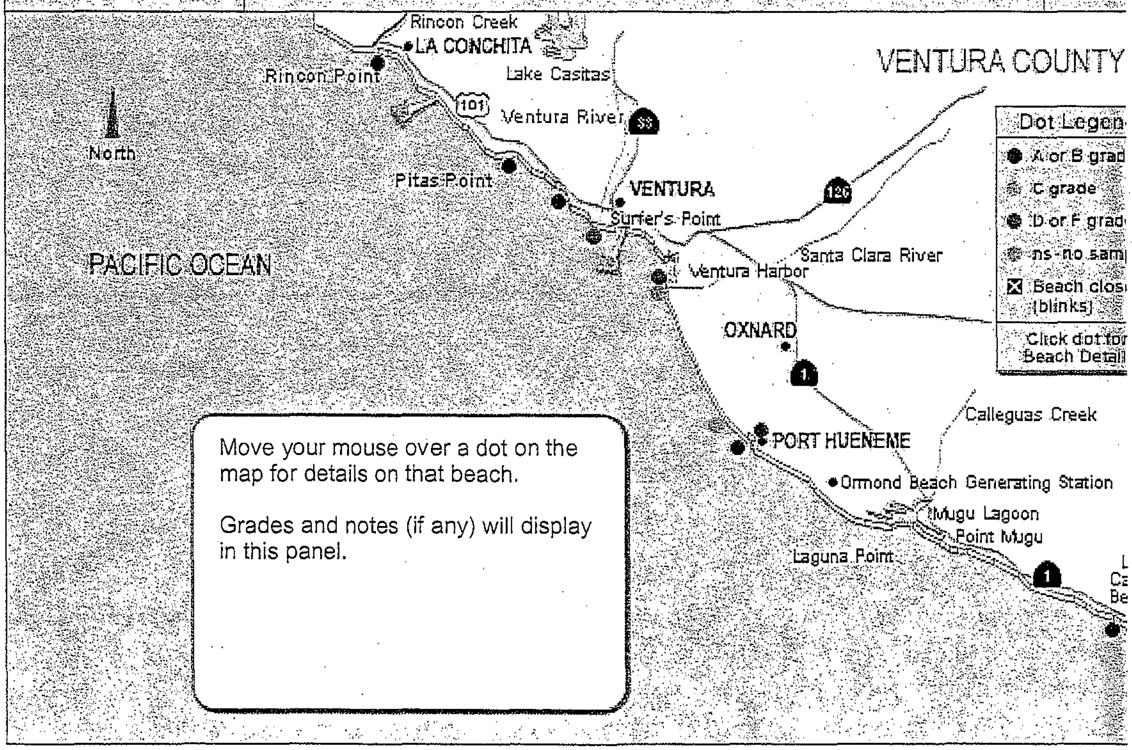
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending January 23, 2006	CA ma North South



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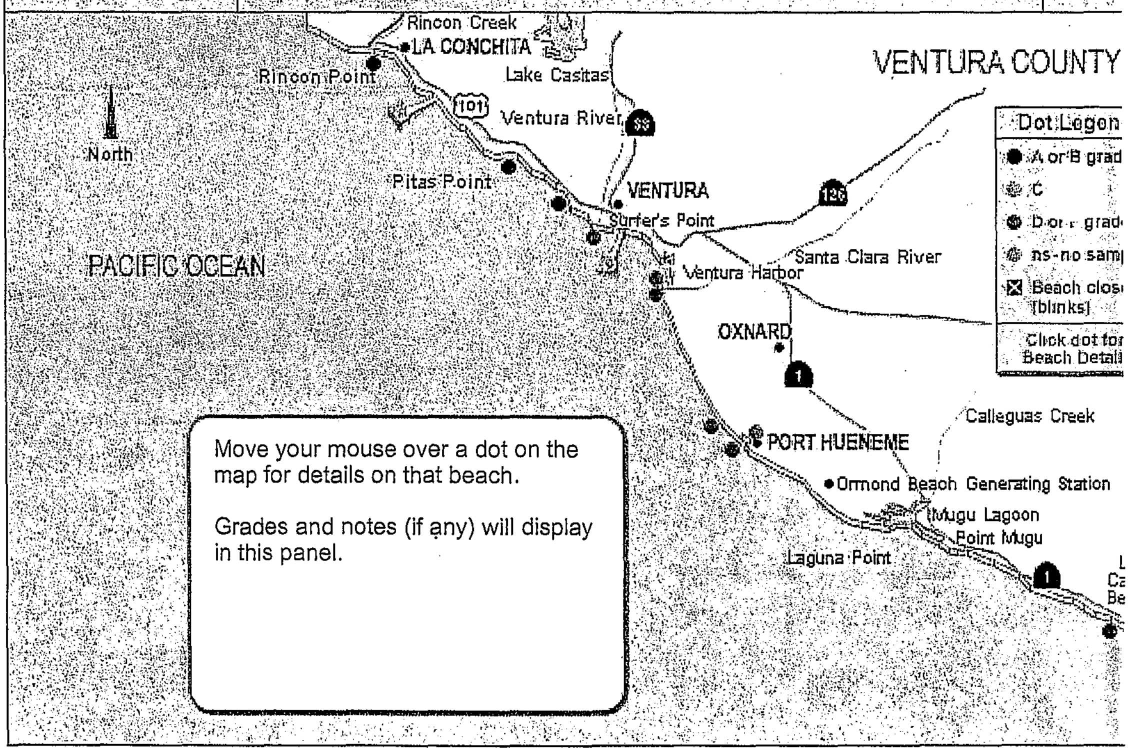
Display Format	Now Showing	Naviga
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending January 30, 2006	CA ma North South



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Beach Report Card[SM]

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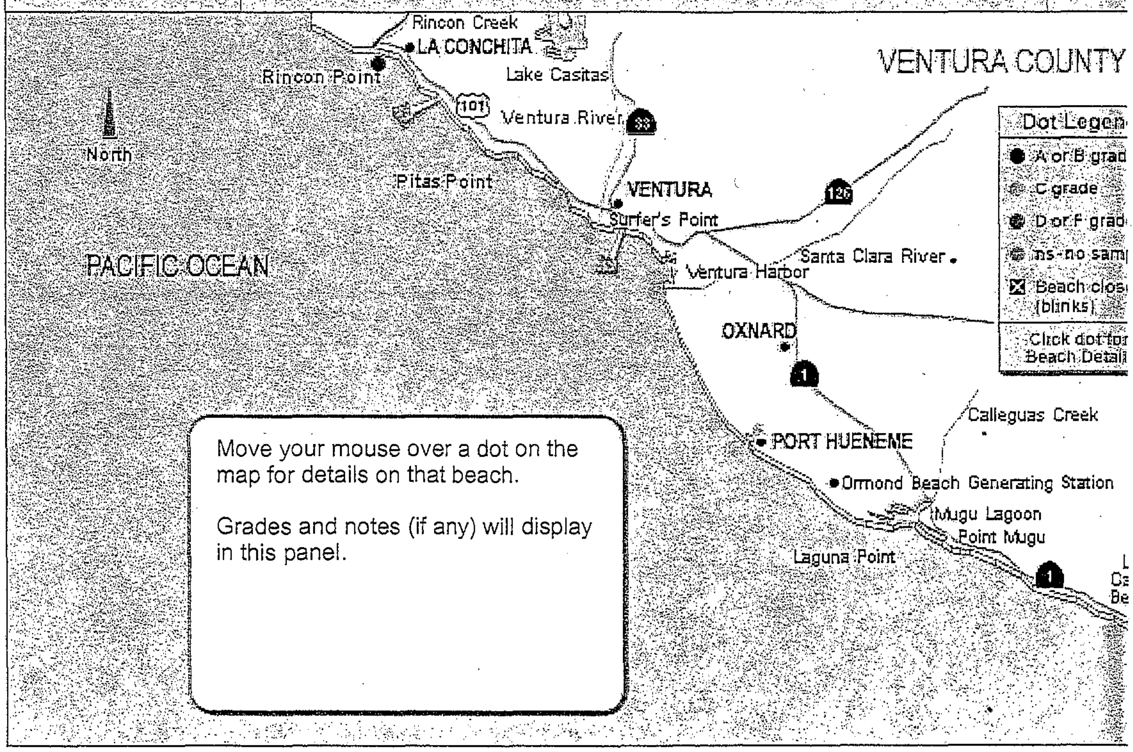
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending February 6, 2006	CA ma North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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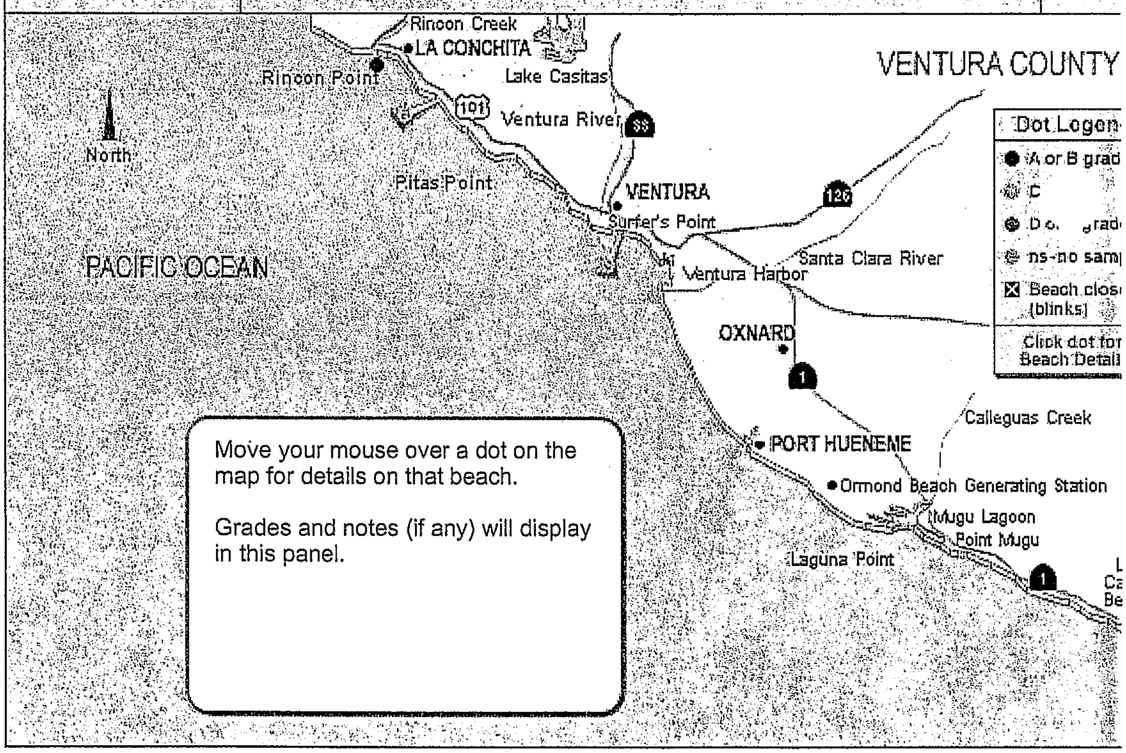
◄ CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending February 14, 2006



Move your mouse over a dot on the map for details on that beach.

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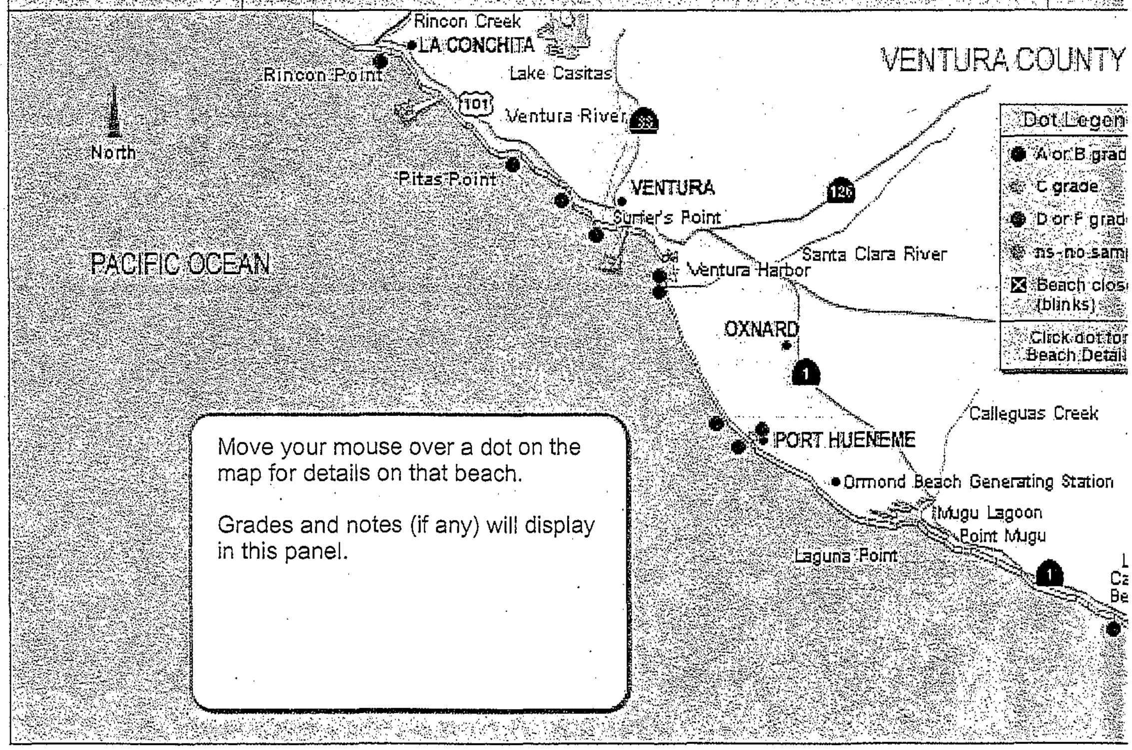
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending February 21, 2006	CA ma North South



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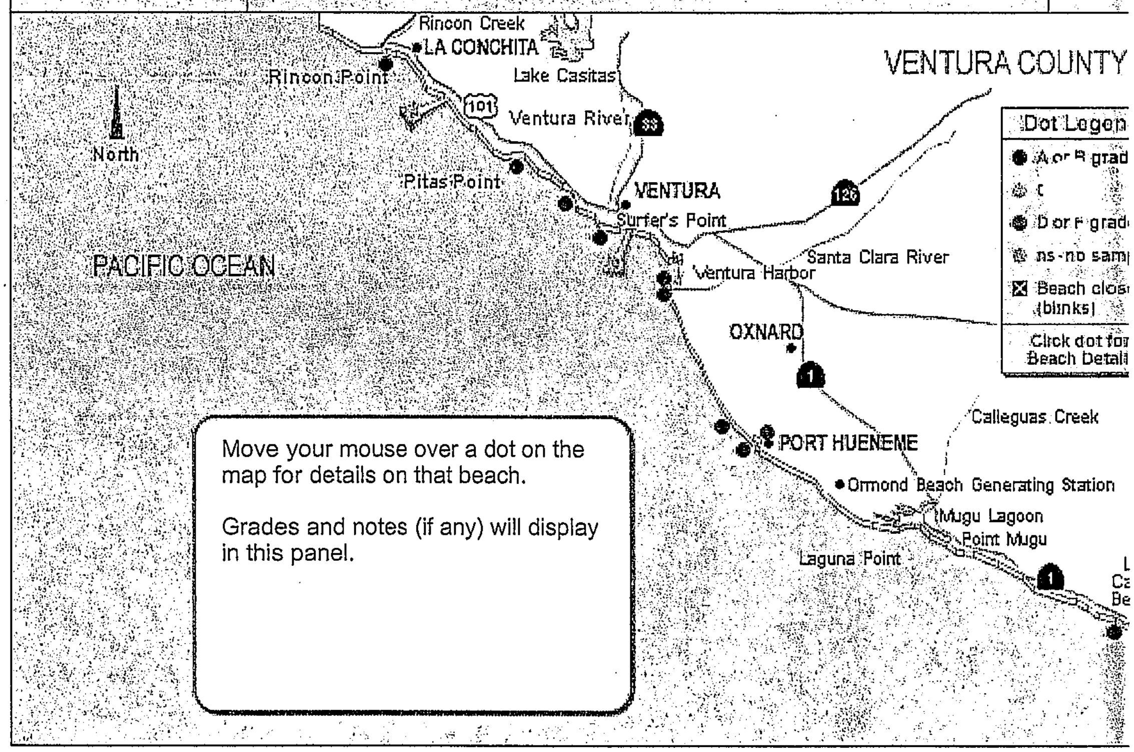
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending February 21, 2006	North South



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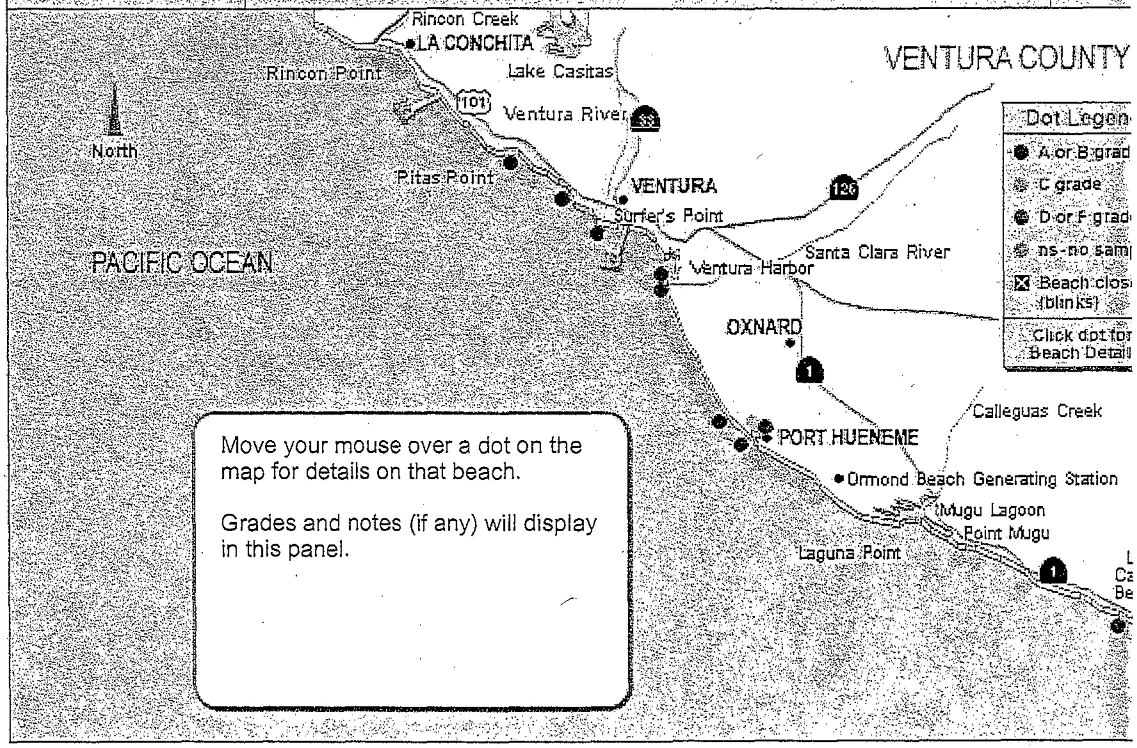
Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending February 27, 2006	CA ma North South



A009635

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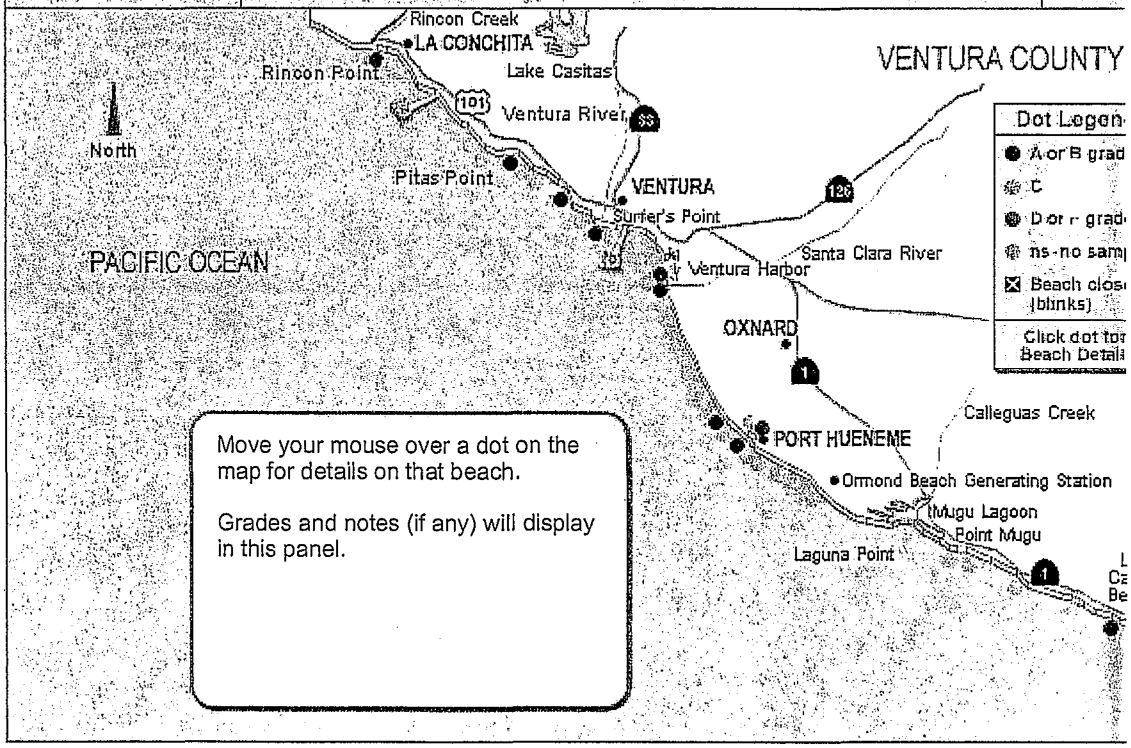
Weekly Report Card - Grade Map

◀ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending March 6, 2006	CA ma North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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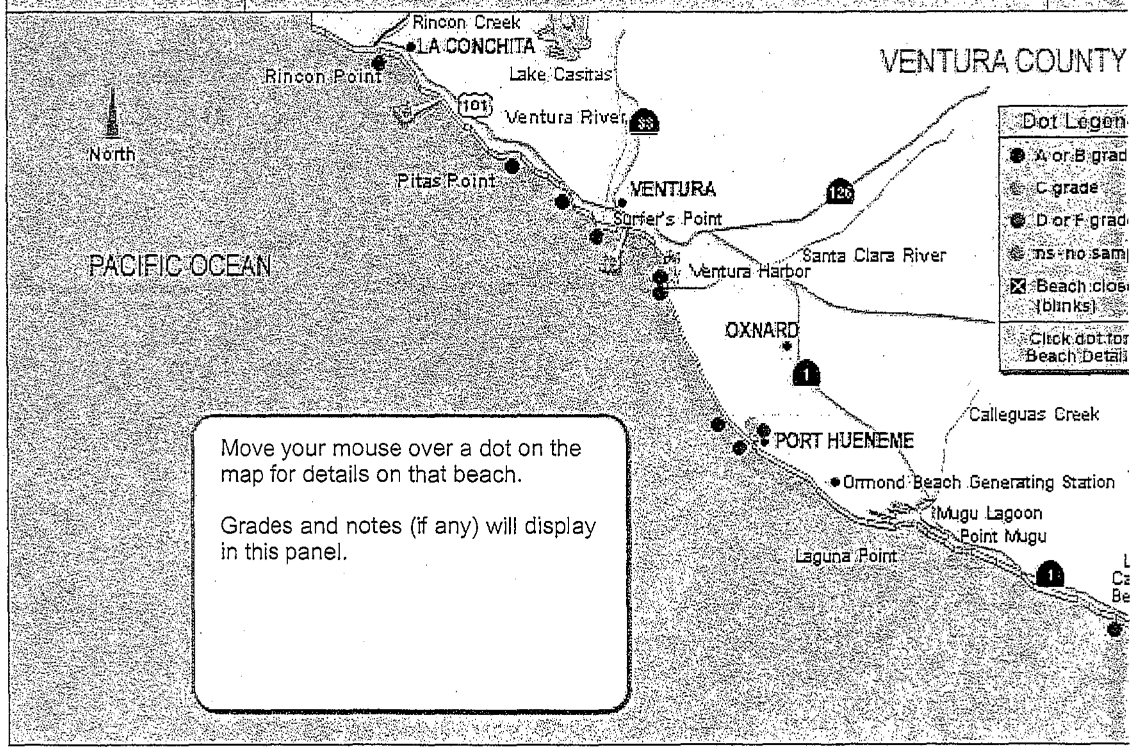
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending March 13, 2006	CA ma North South



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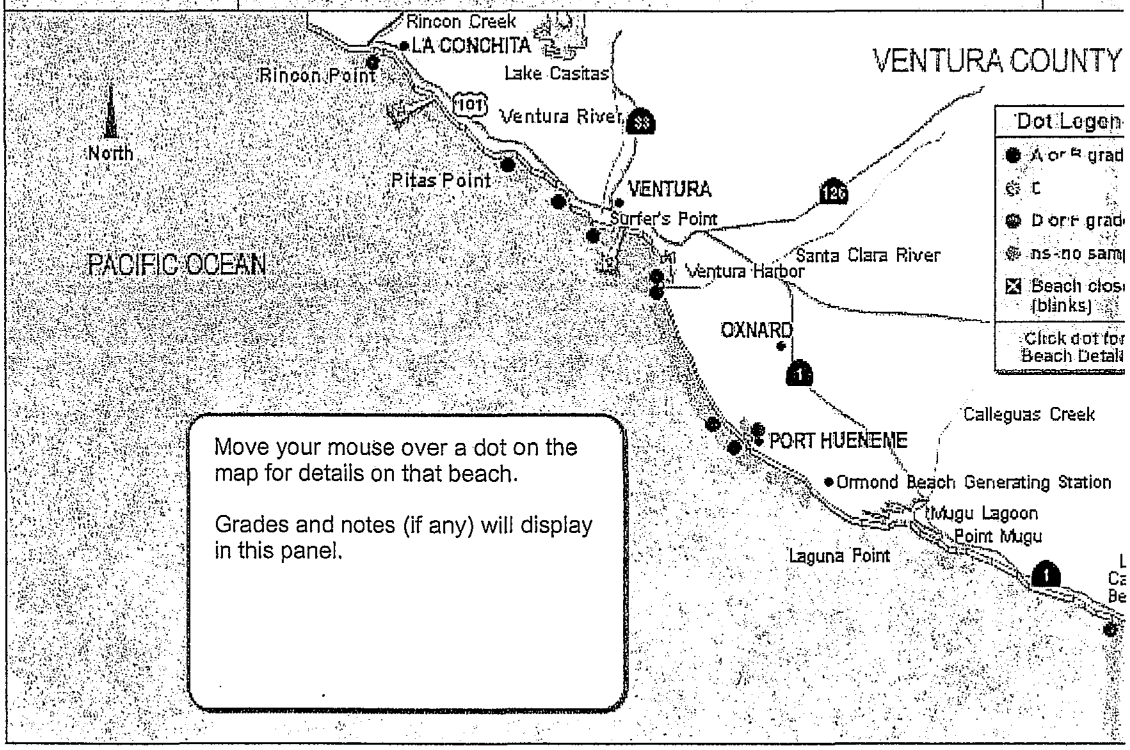
◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending March 20, 2006	CA North South



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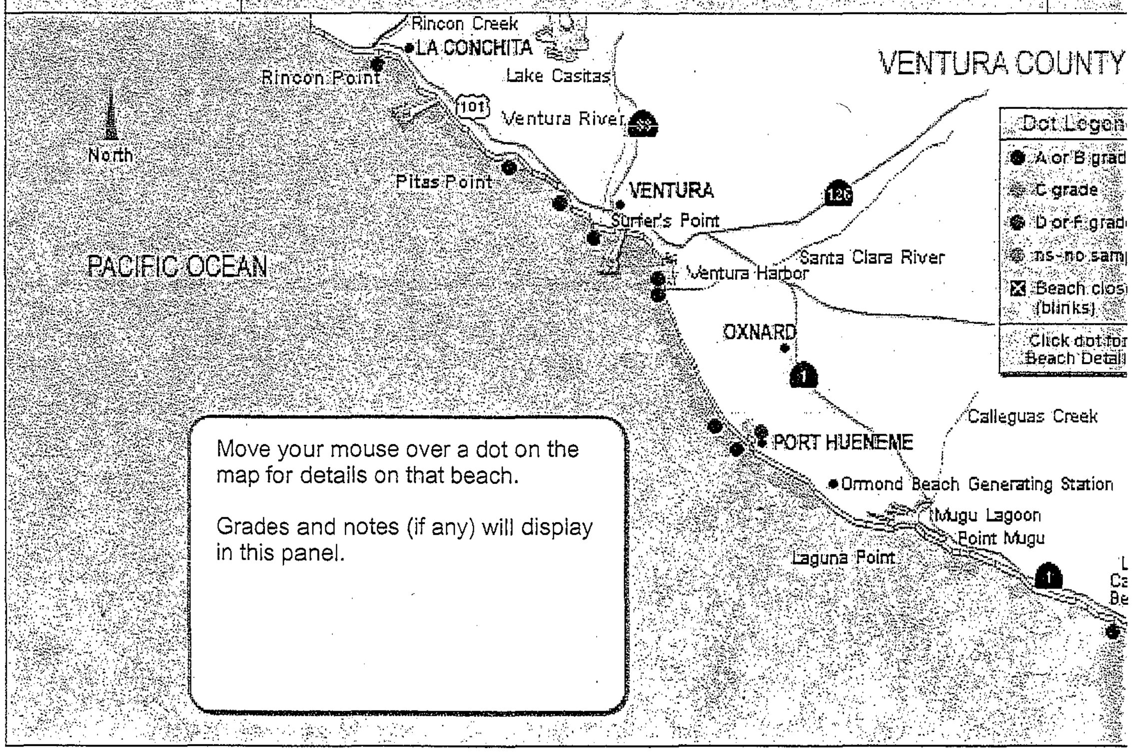
Weekly Report Card - Grade Map

◀ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending March 27, 2006	CA... North South



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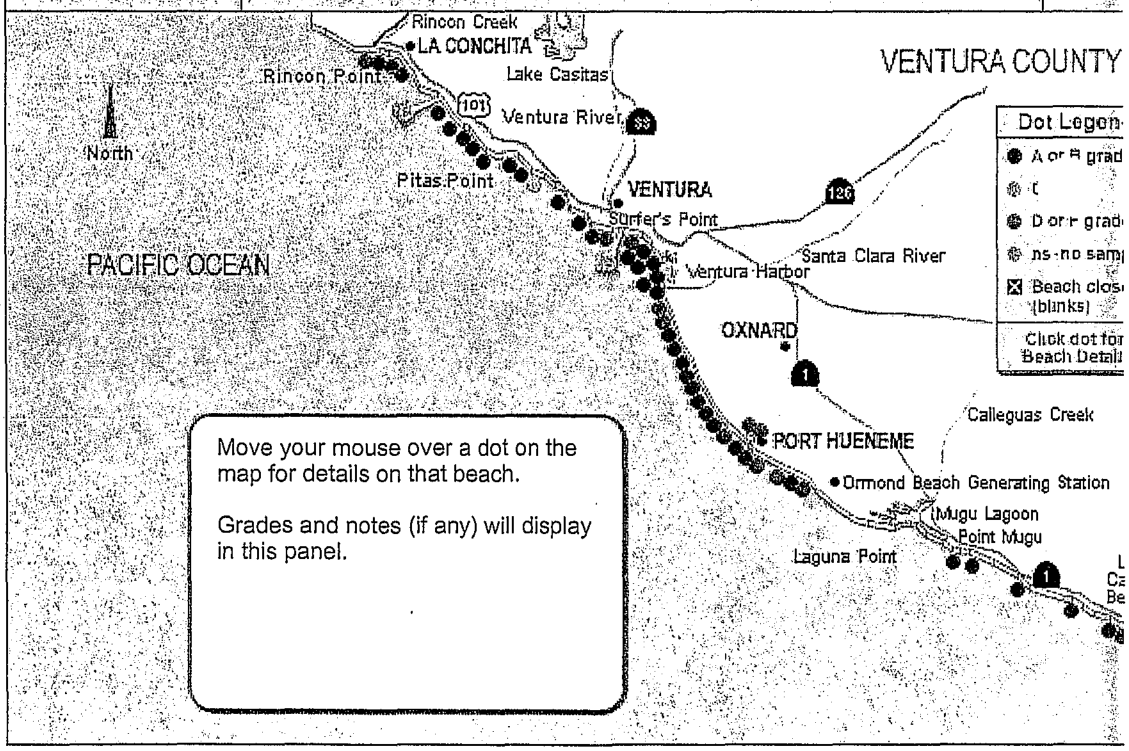
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending April 4, 2006	CA ma North South



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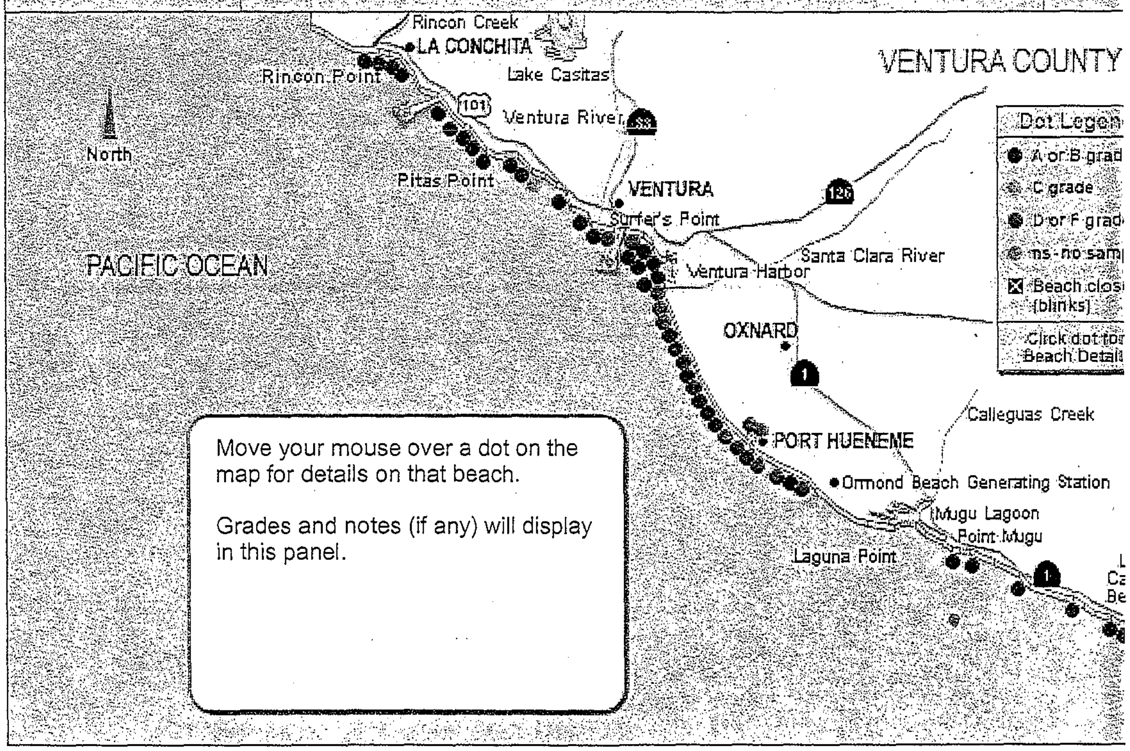
◄ CA State Map

Display Format: Grade Map — View Text List

Now Showing: Area: Ventura County, CA

Weather: Wet — Show Dry Grades

Grade Period: 4-week period ending April 12, 2006



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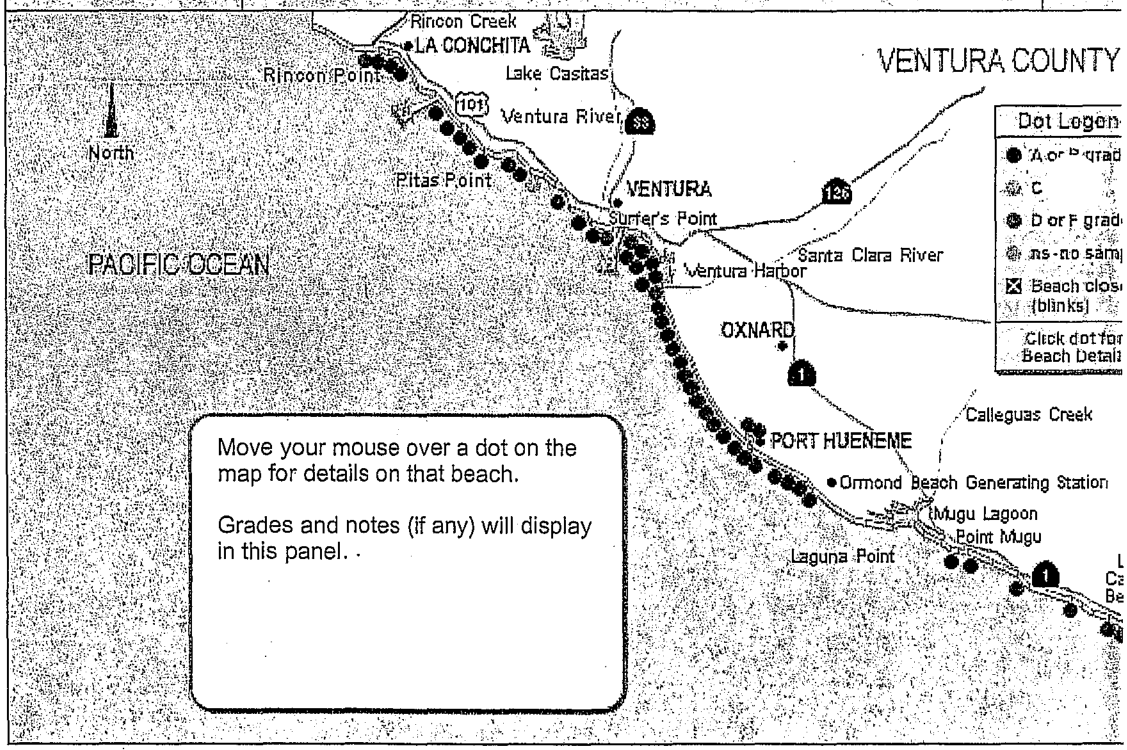
Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending April 18, 2006



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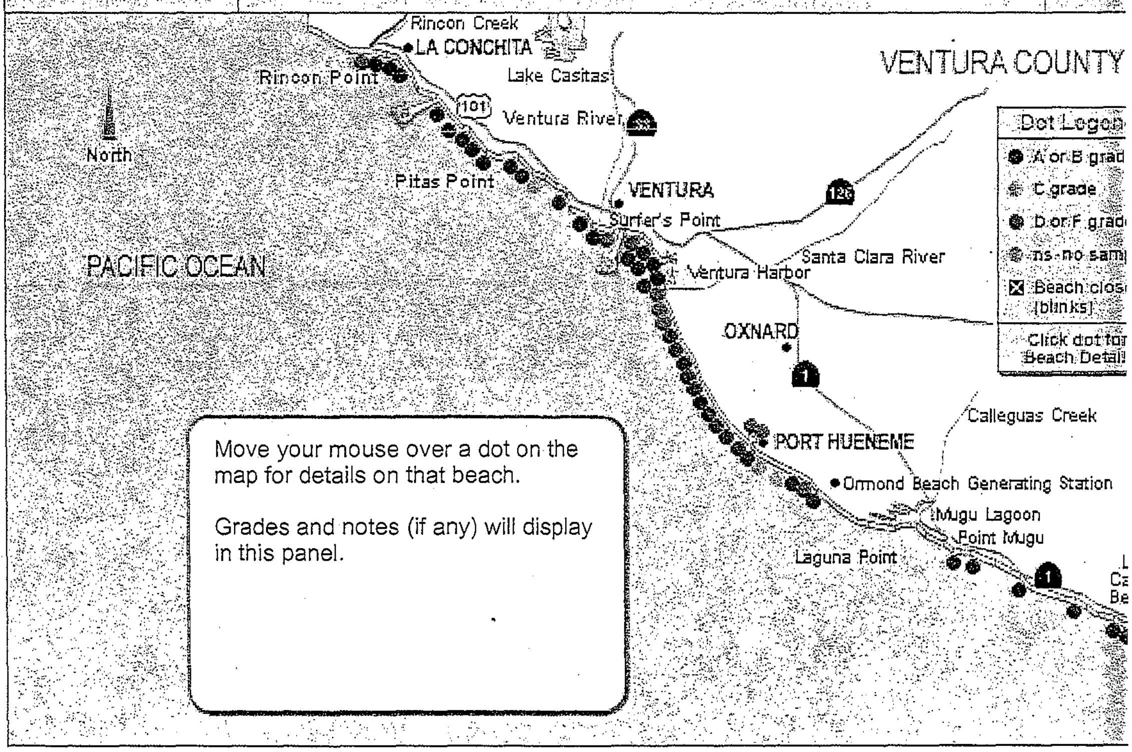
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending April 26, 2006	CA ma North South



Move your mouse over a dot on the map for details on that beach.

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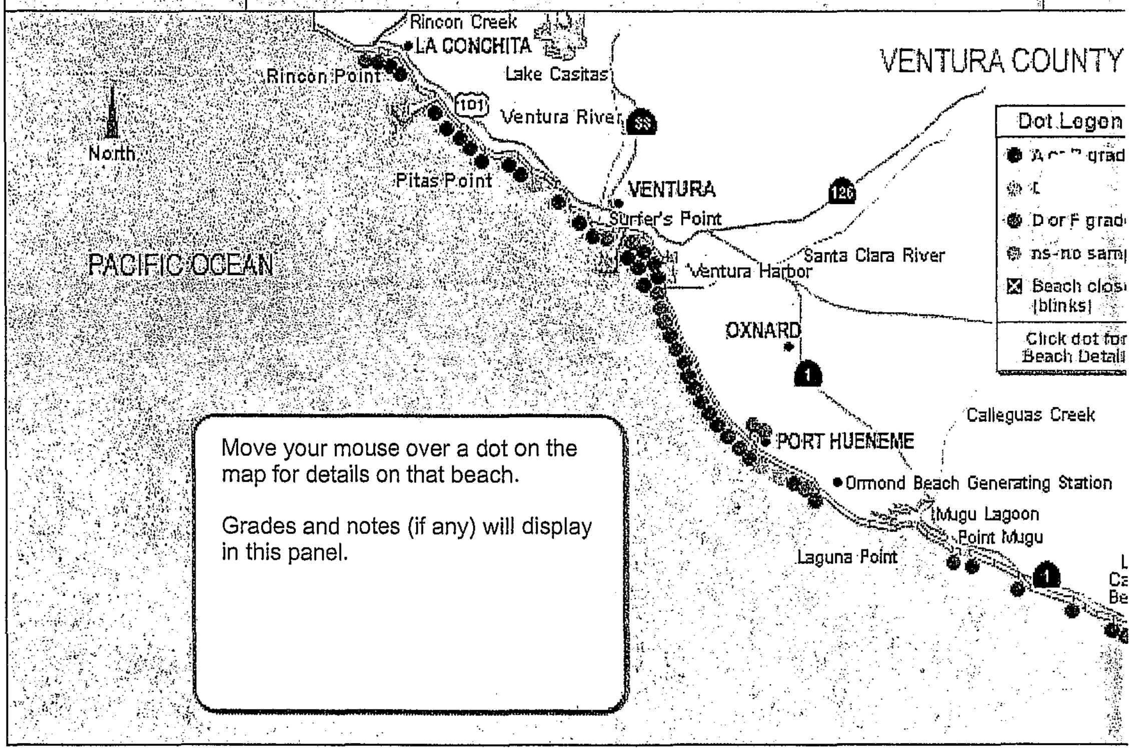
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending May 3, 2006	CA ma North South



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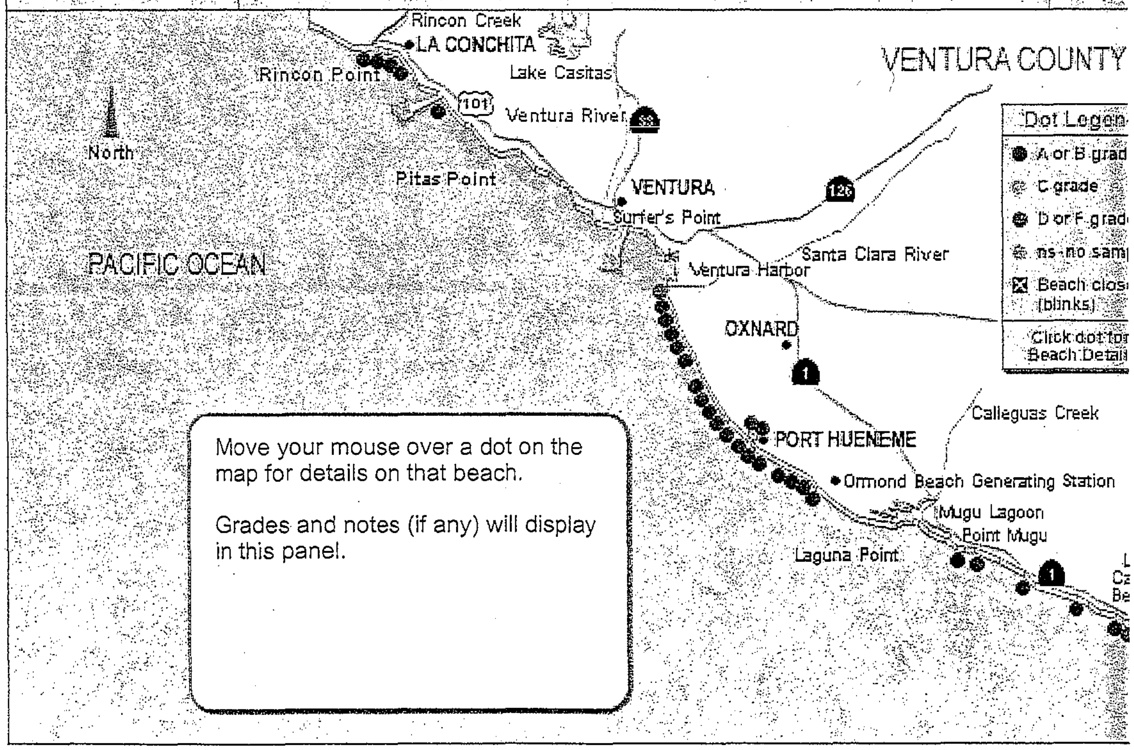
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending May 10, 2006	CA ma North South



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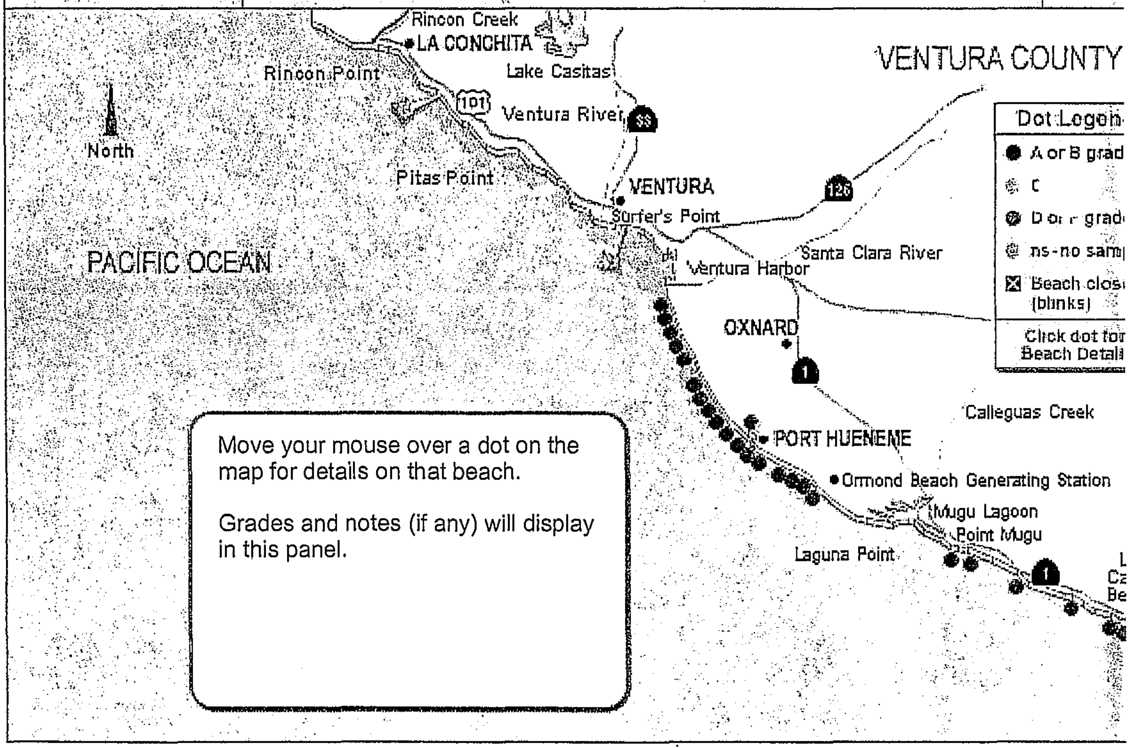
◀ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending May 17, 2006	CA ma North South



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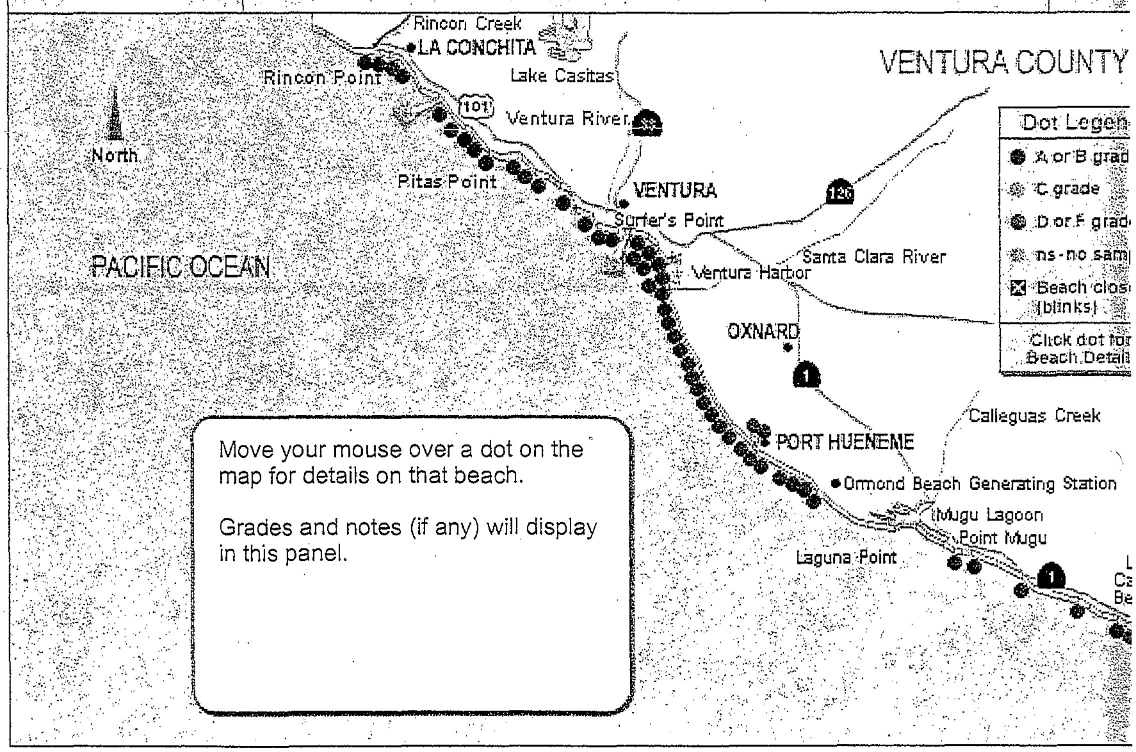
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending May 24, 2006	CA ma North South



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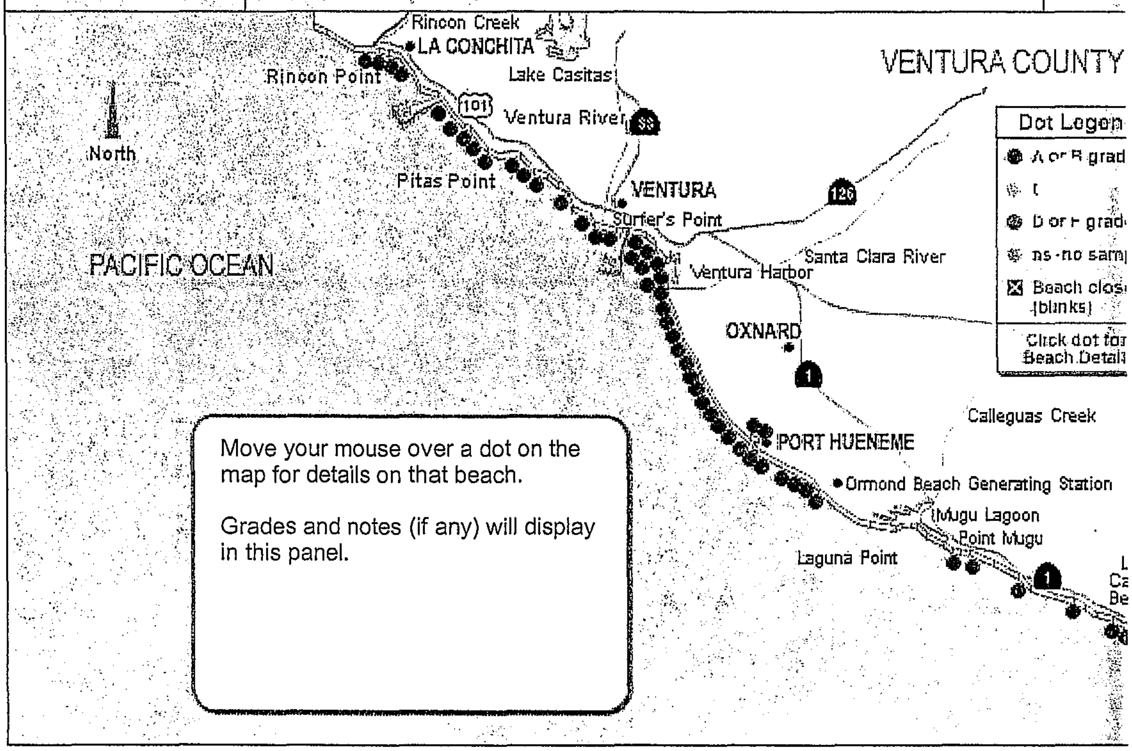
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending May 31, 2006	CA ma North South



A009648

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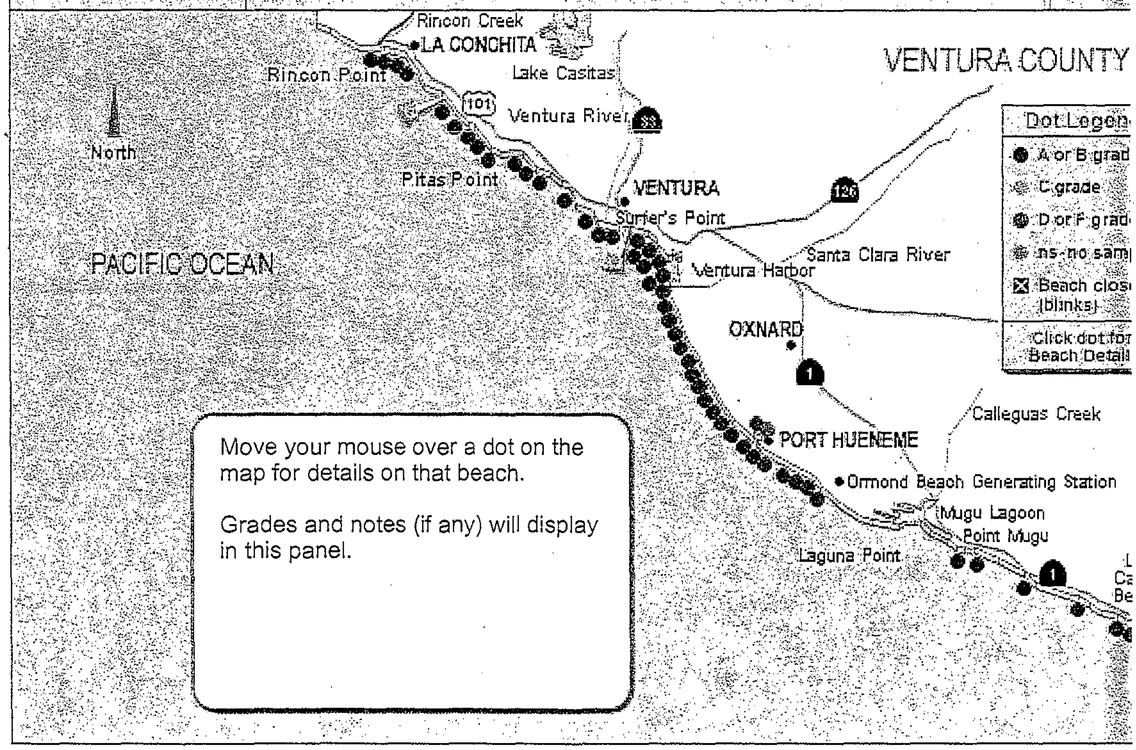
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet Show Dry Grades Grade Period: 4-week period ending June 7, 2006	CA ma North South



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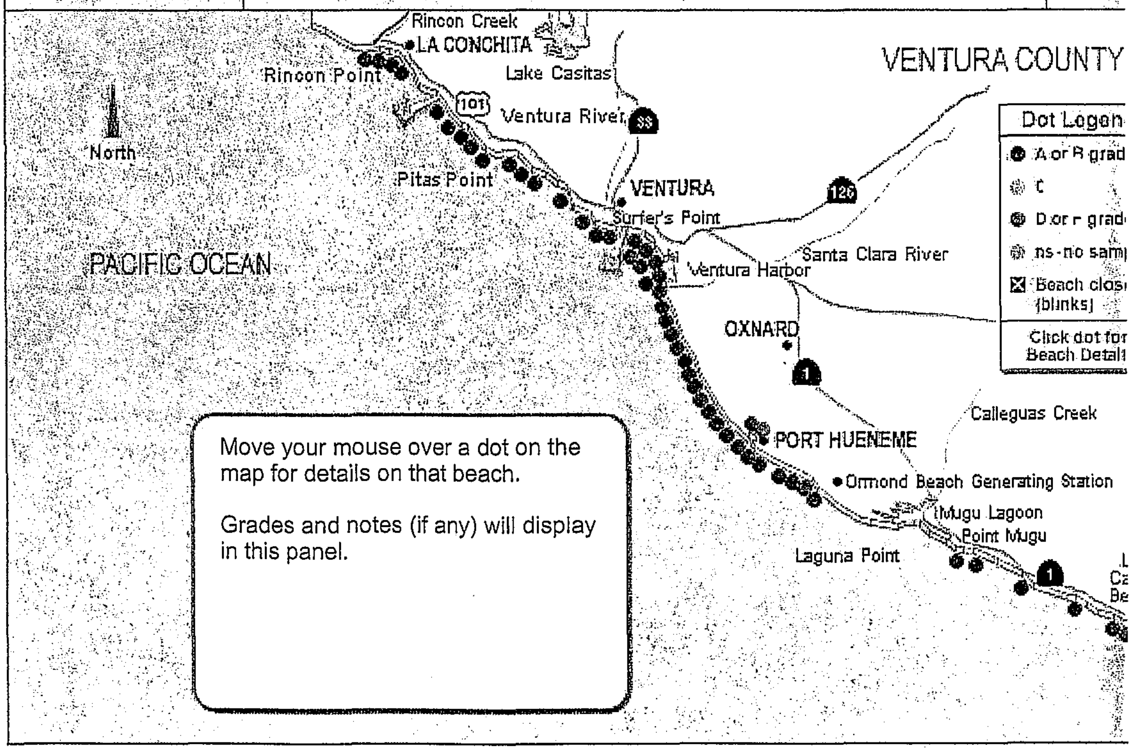
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 14, 2006	CA ma North South



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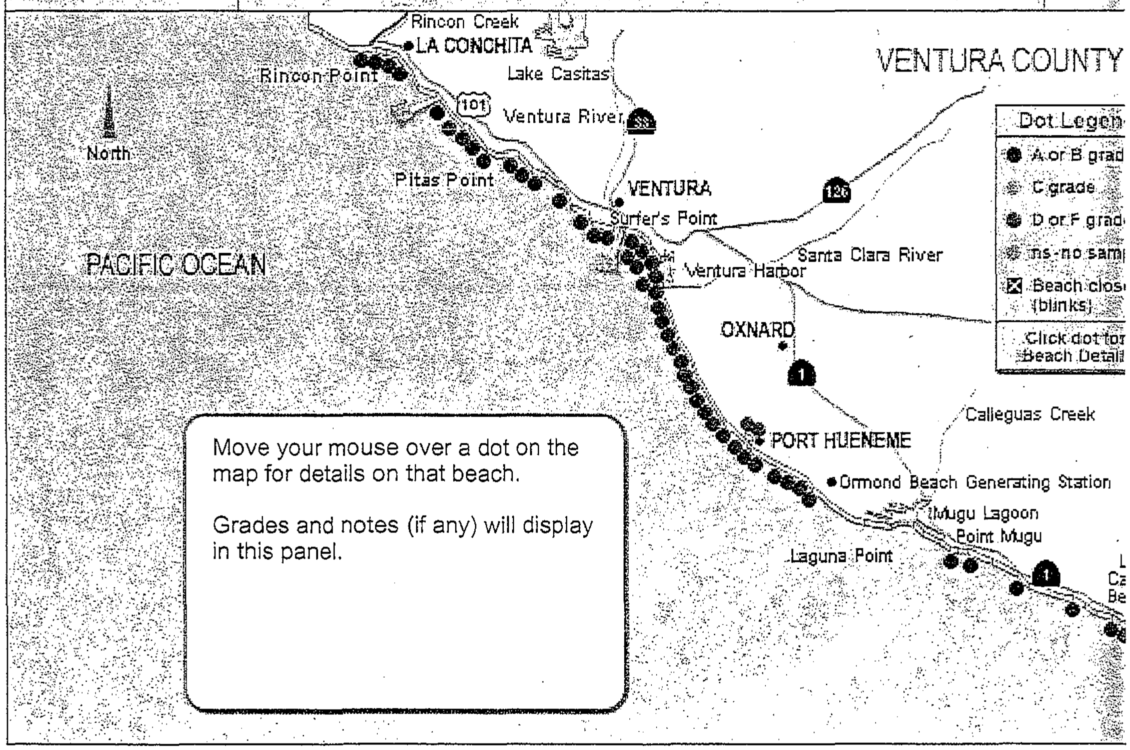
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 21, 2006	CA ma North South



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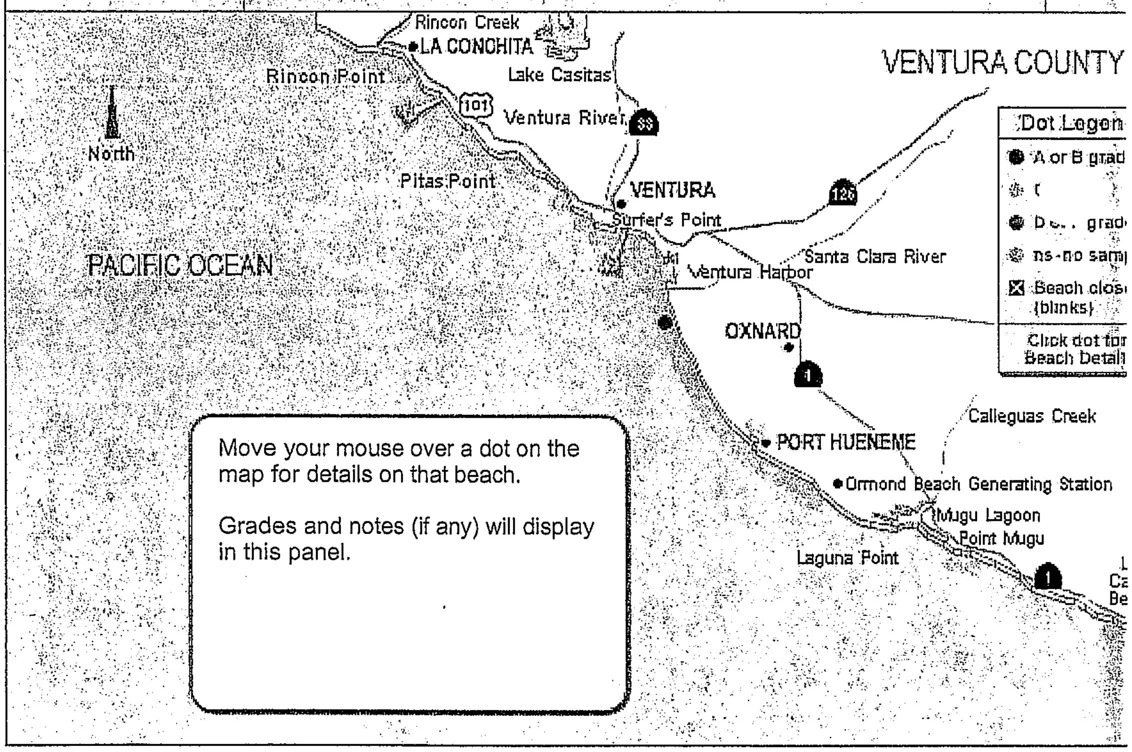
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Wet [Show Dry Grades] Grade Period: 4-week period ending June 28, 2006	CA ma North South



A009652

Heal The Bay does not have Weekly Report Card - Grade Maps for the following Ventura County Environmental Health Division sampling sites for bacteria:

1) Promenade Park (S. of drain, at Figueroa Street);

2) Promenade Park (S. of drain, at California Street); and

3) Promenade Park (S. of drain, end of Oak Street).

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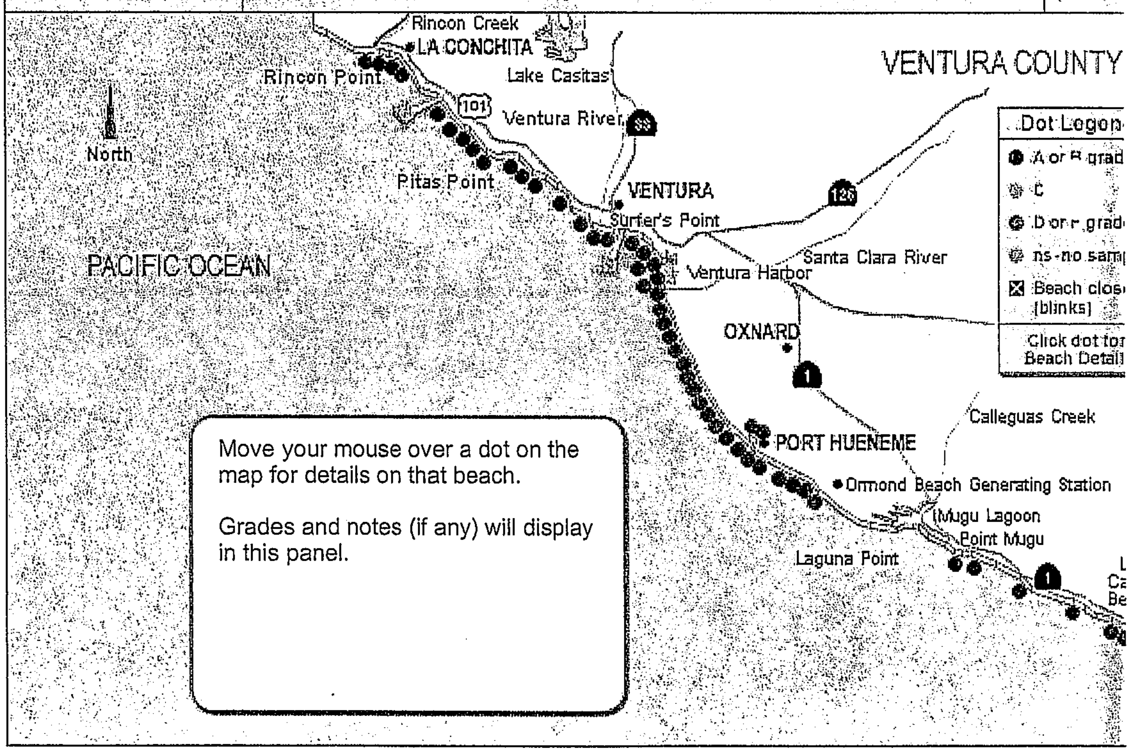
◄ CA State Map

Display Format: Grade Map — View Text List

Now Showing: Area: Ventura County, CA
Weather: Dry — Show Wet Grades
Grade Period: 4-week period ending June 1, 2005

Navigat... CA ma... North South



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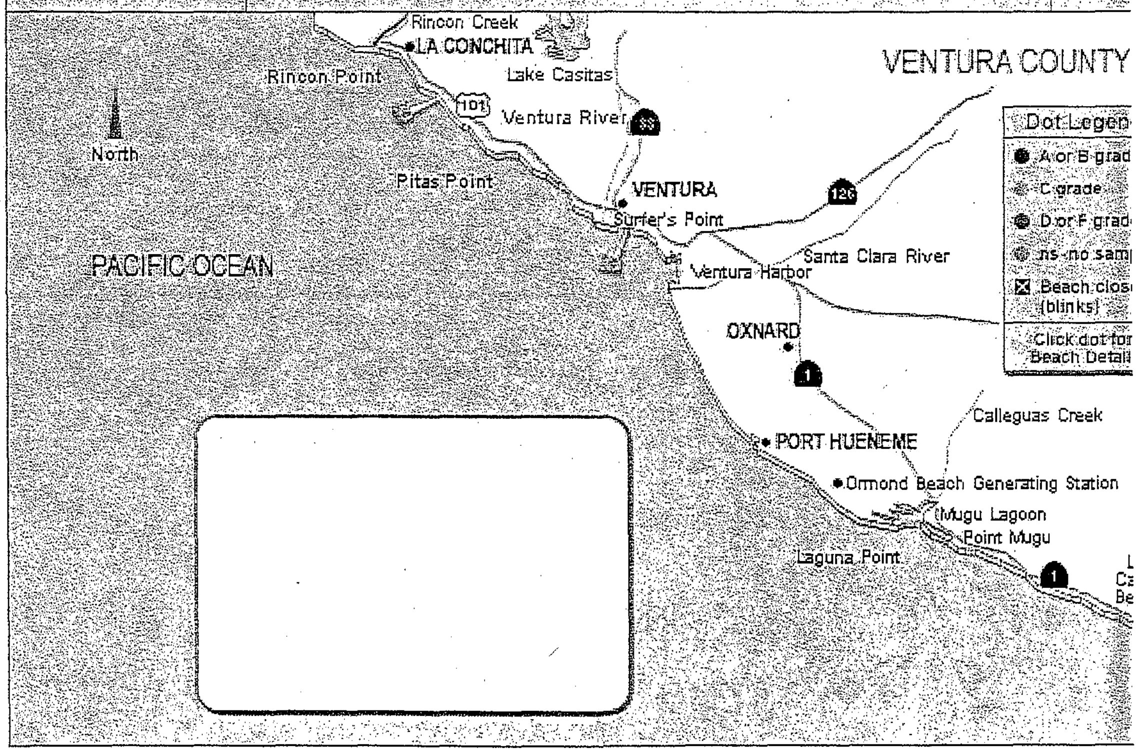
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending June 8, 2005	CA ma North South



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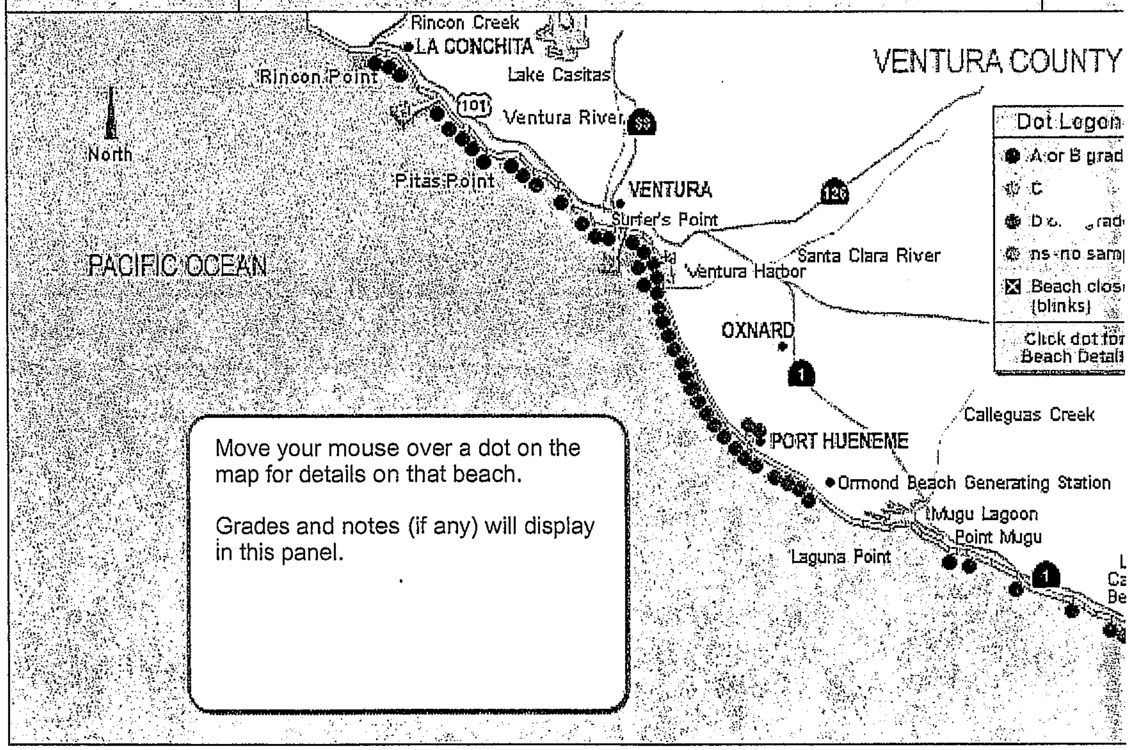
Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 15, 2005	CA ma North South



Move your mouse over a dot on the map for details on that beach.

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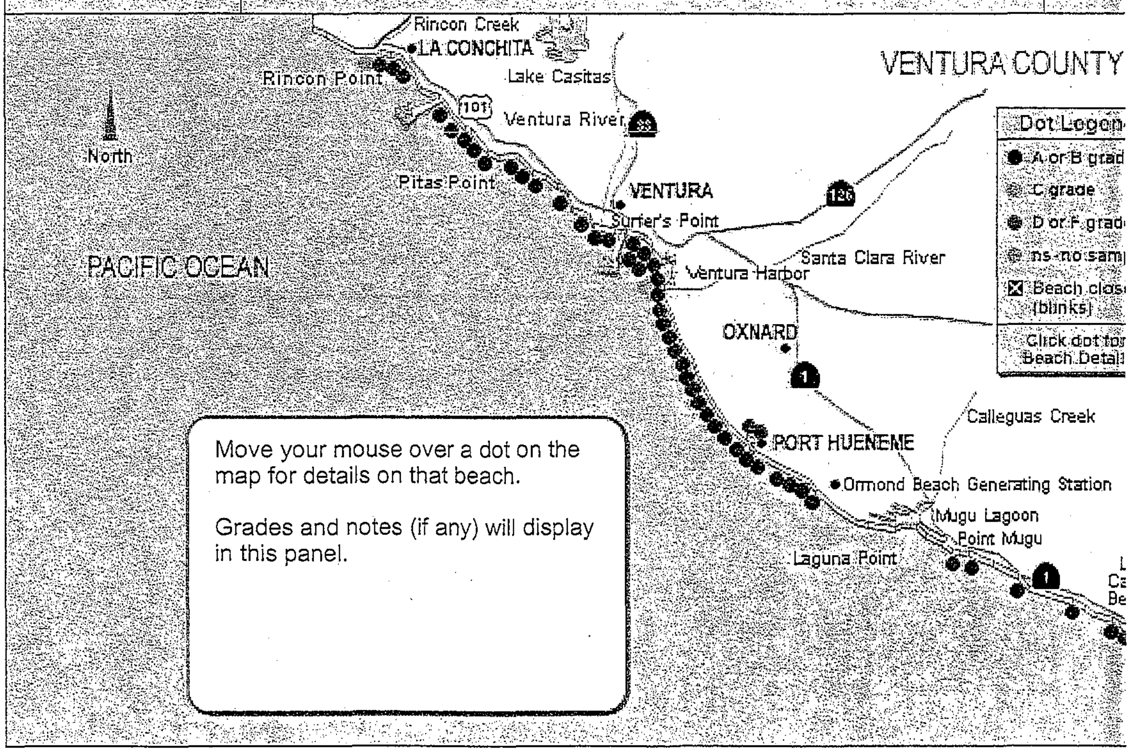
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending June 22, 2005	CA ma North South



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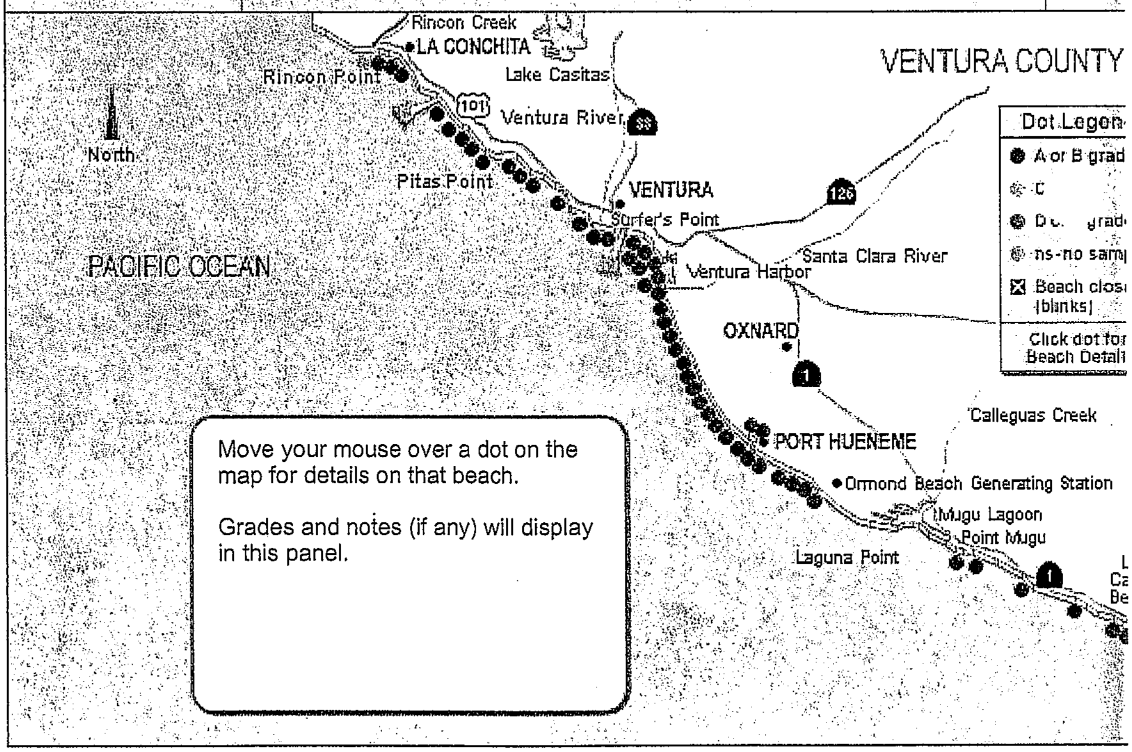
◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 29, 2005	CA ma North South



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CA State Map

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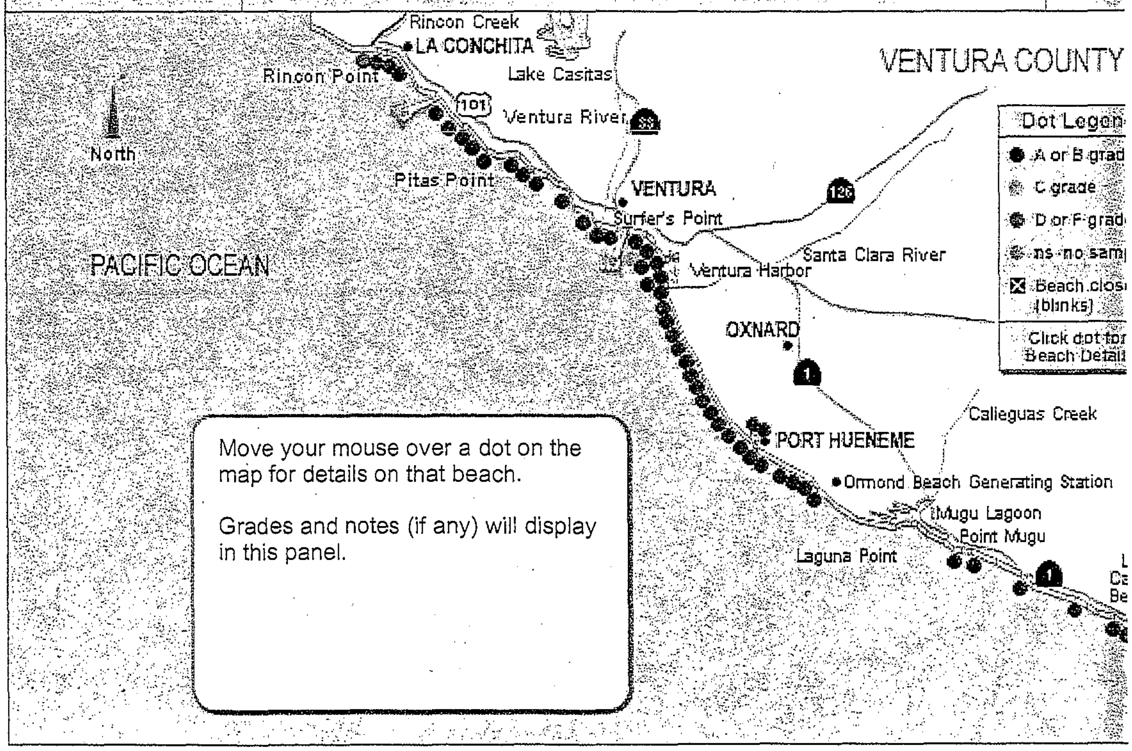
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending July 6, 2005



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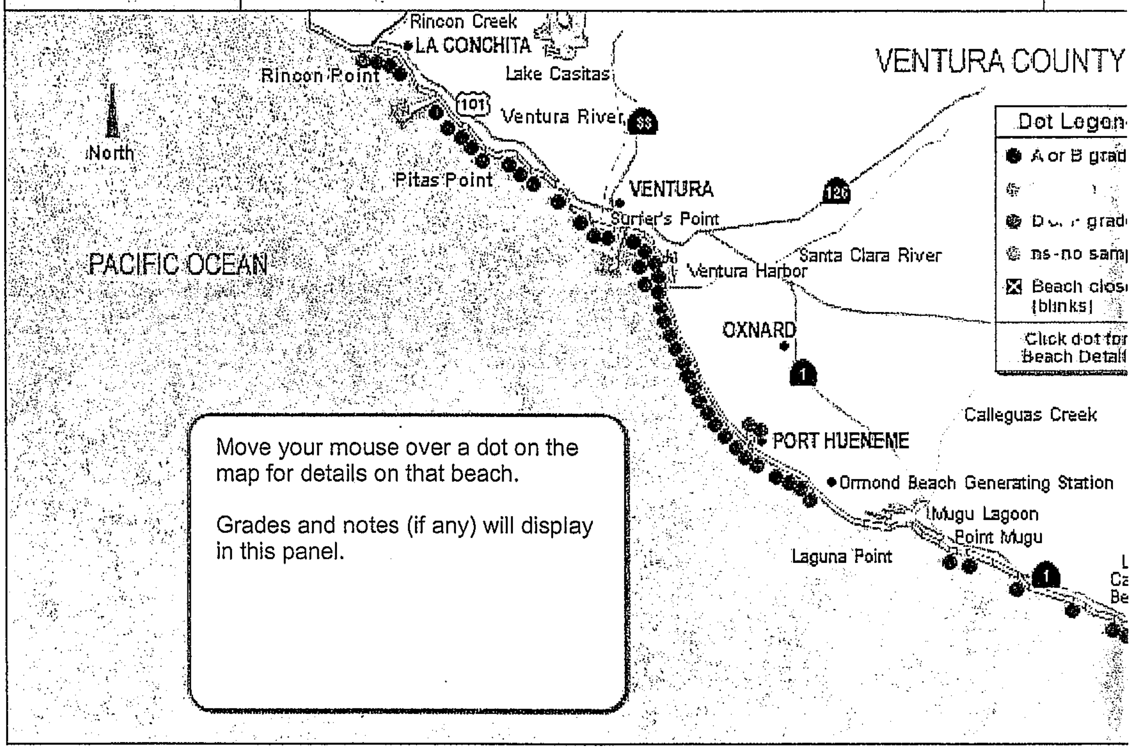
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending July 13, 2005	CA North South



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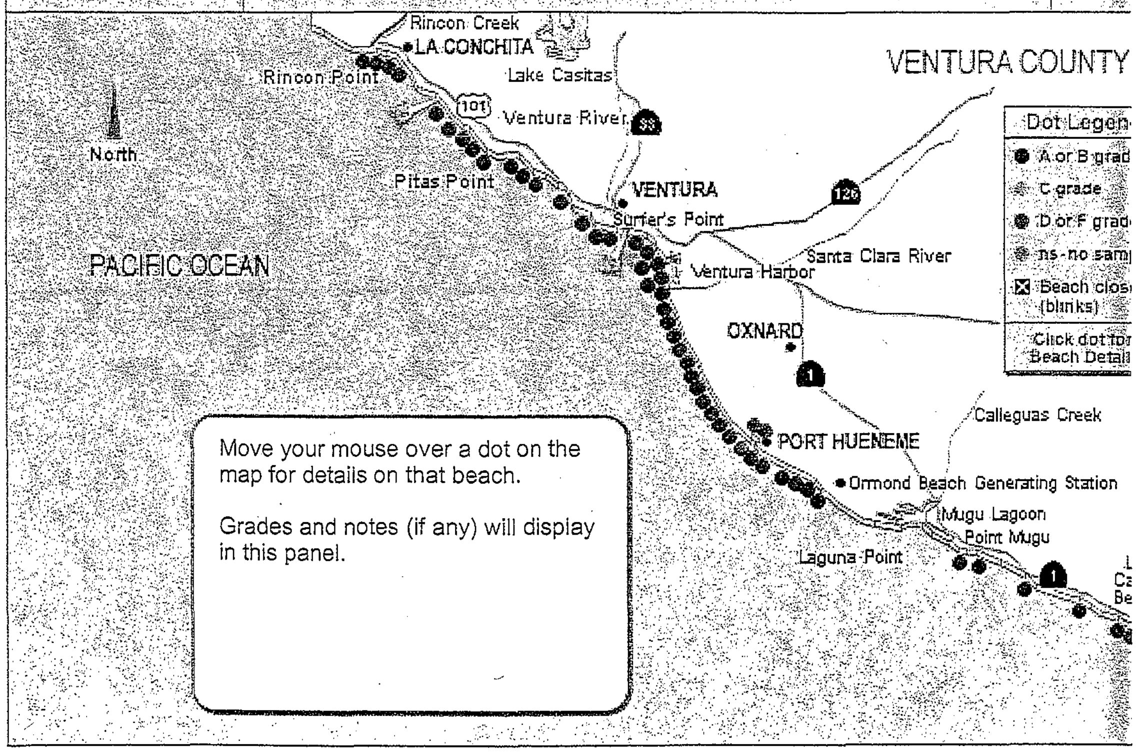
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending July 20, 2005	CA ma North South



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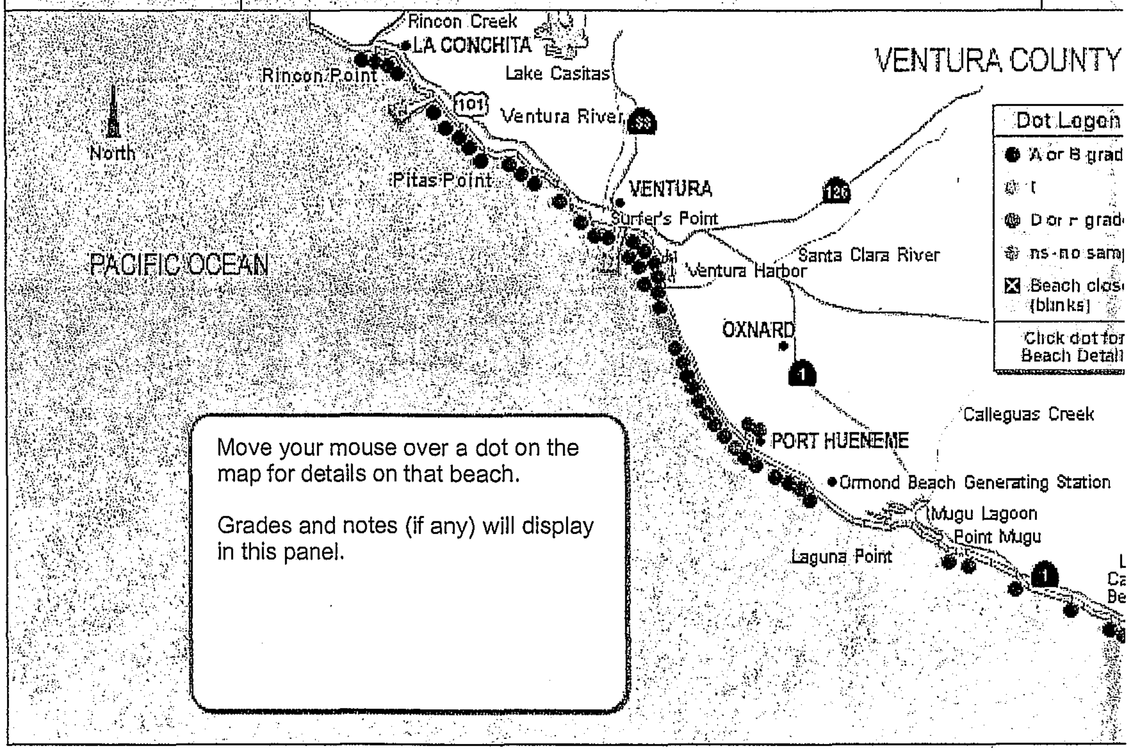

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◄ CA State Map

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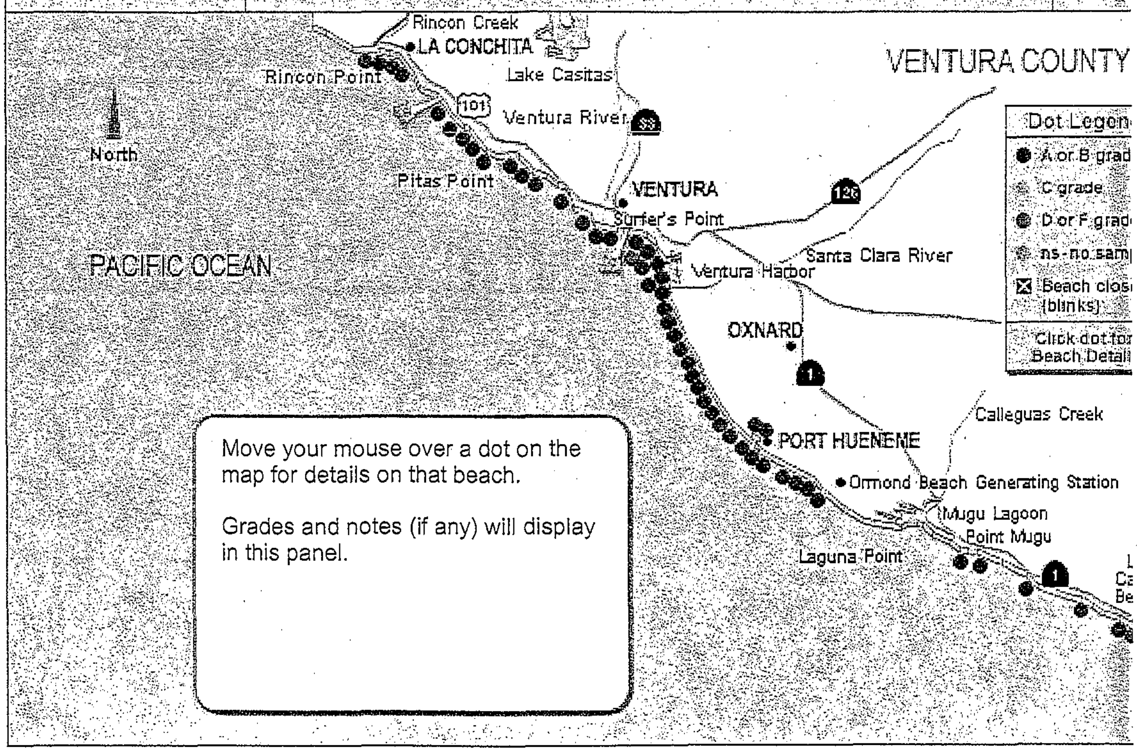
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending August 3, 2005	CA ma North South



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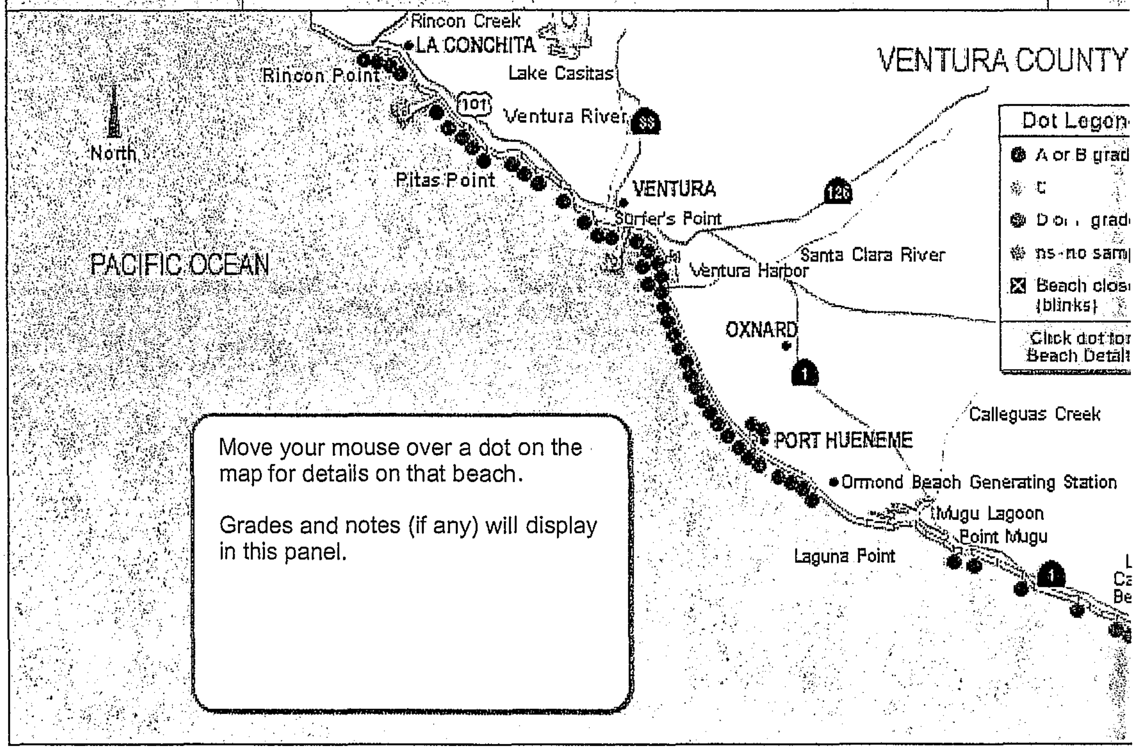
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending August 10, 2005	CA ma North South



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◄ CA State Map

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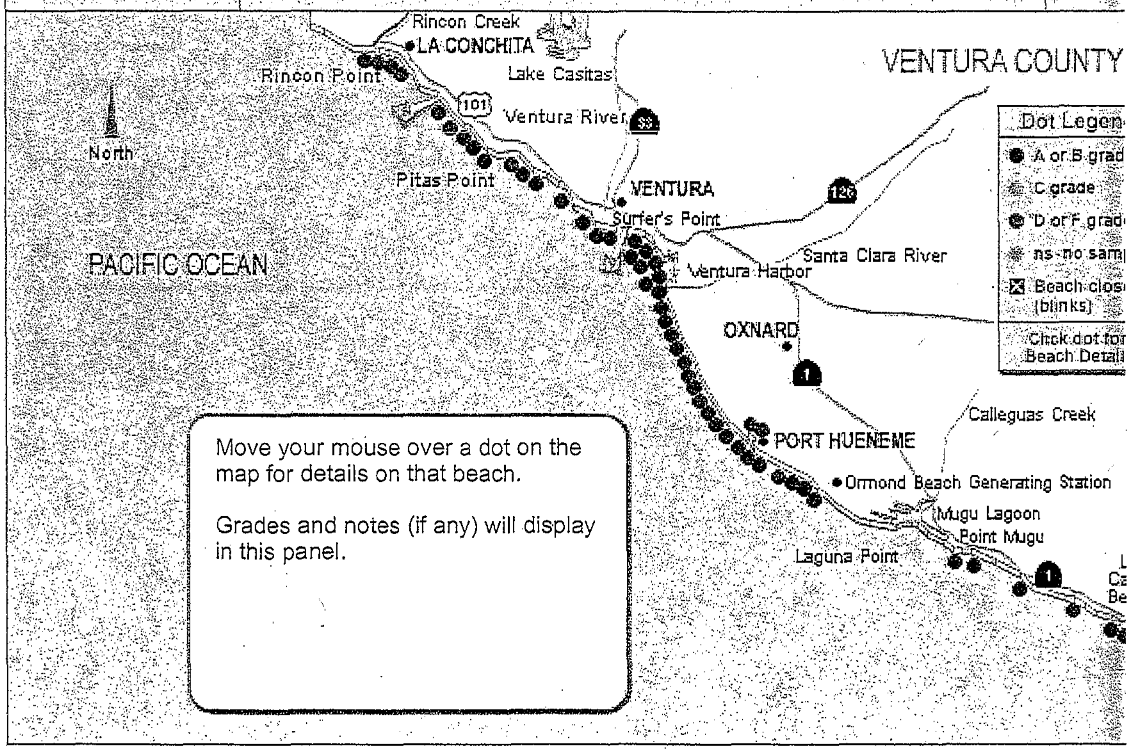
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending August 24, 2005	CA ma North South



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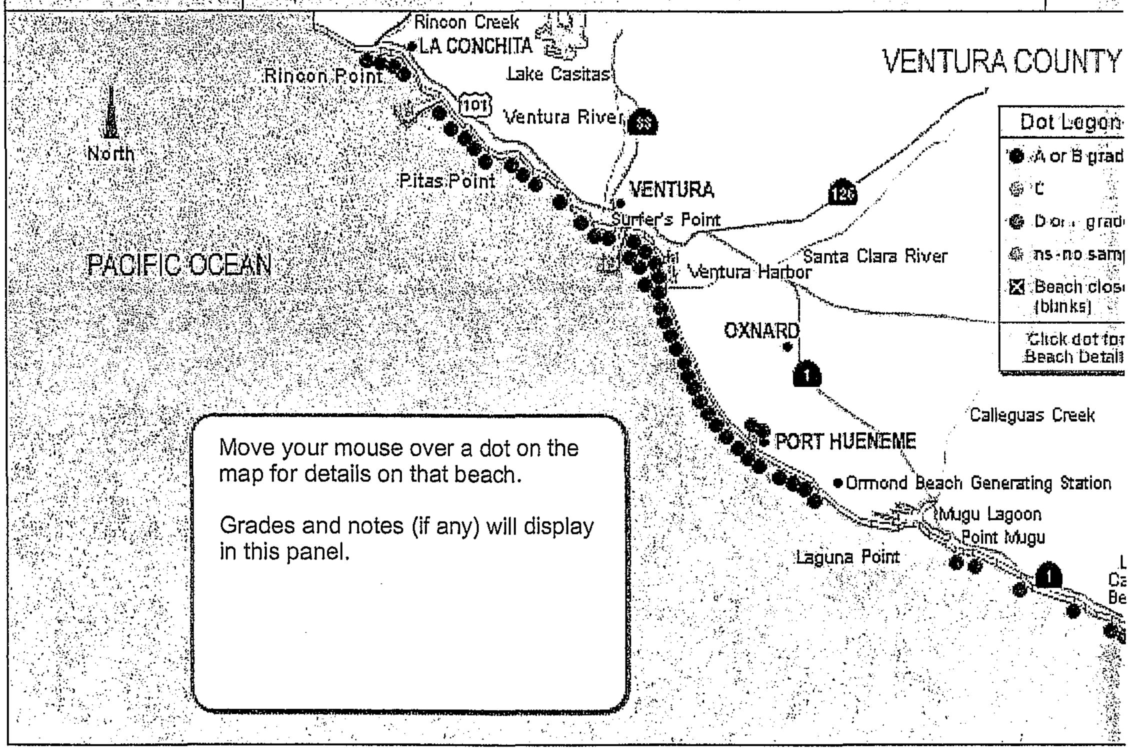
Beach Report Card[SM]

The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending August 31, 2005



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Beach Report Card[SM]

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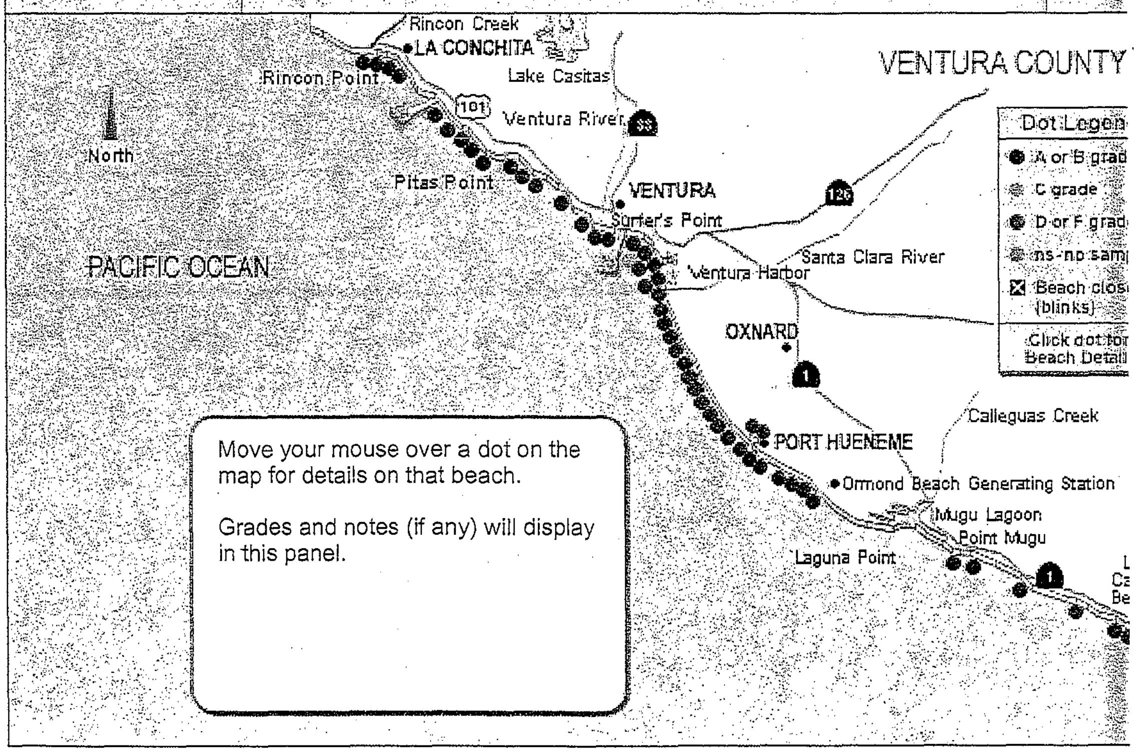
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending September 7, 2005	North South



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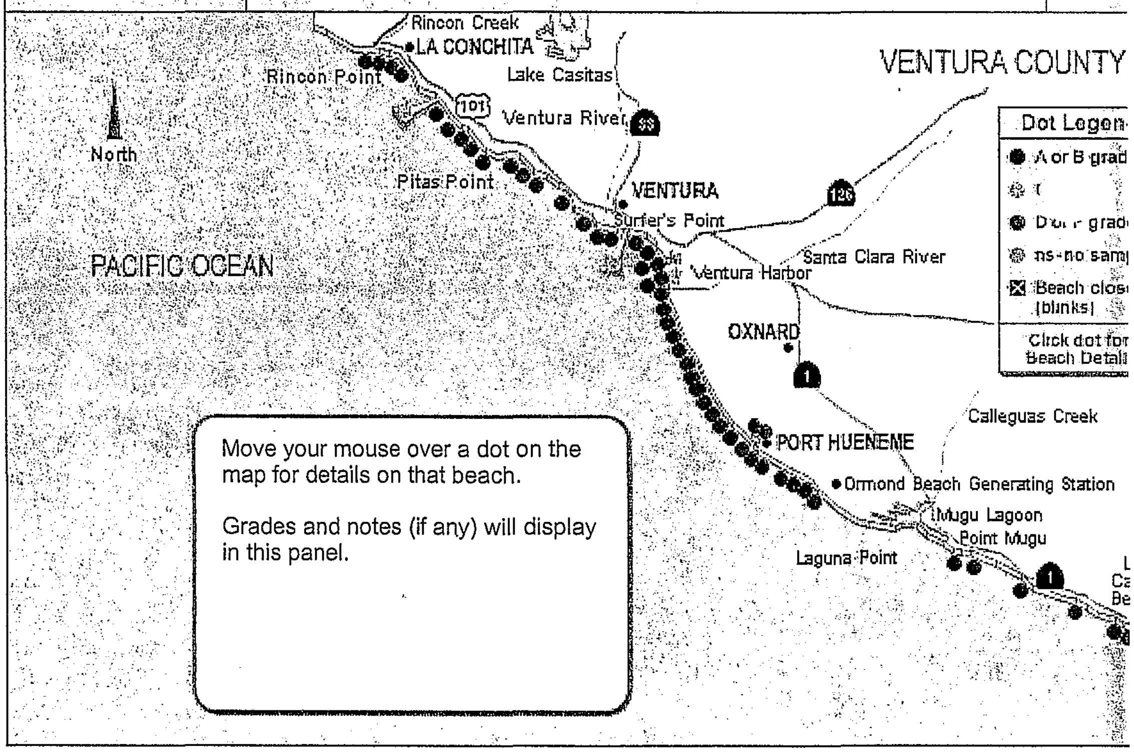
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending September 14, 2005	CA ma North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

Beach Report Card[SM]

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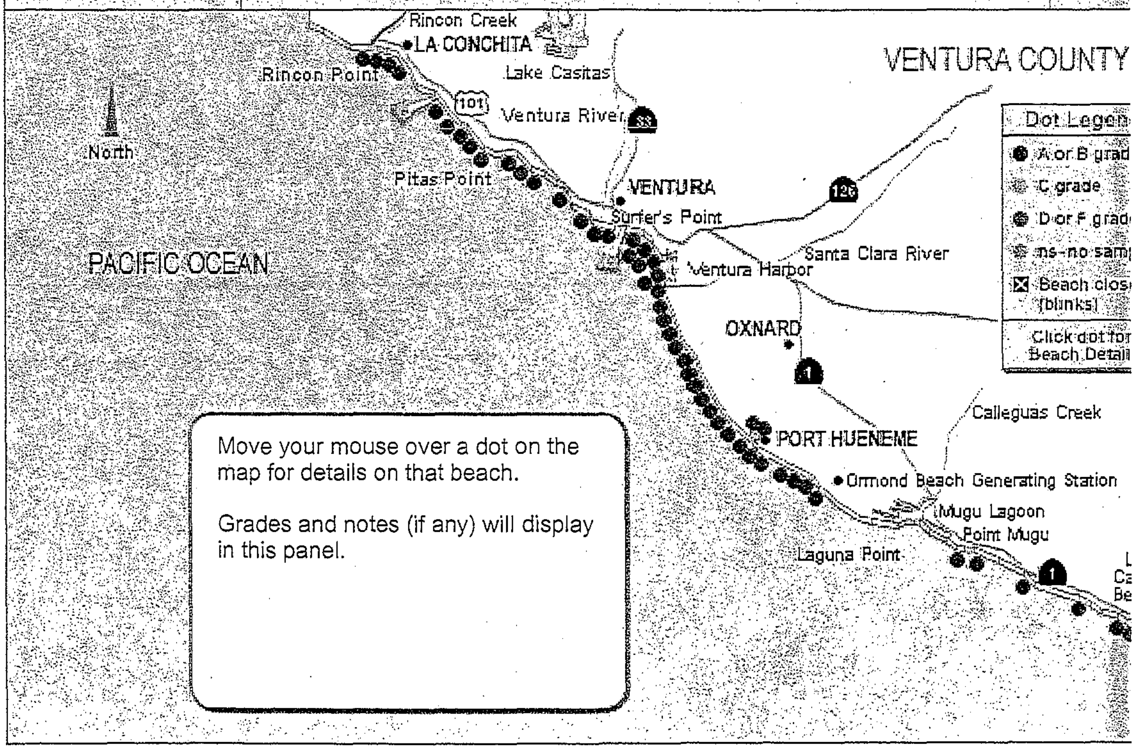
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending September 21, 2005	CA ma North South



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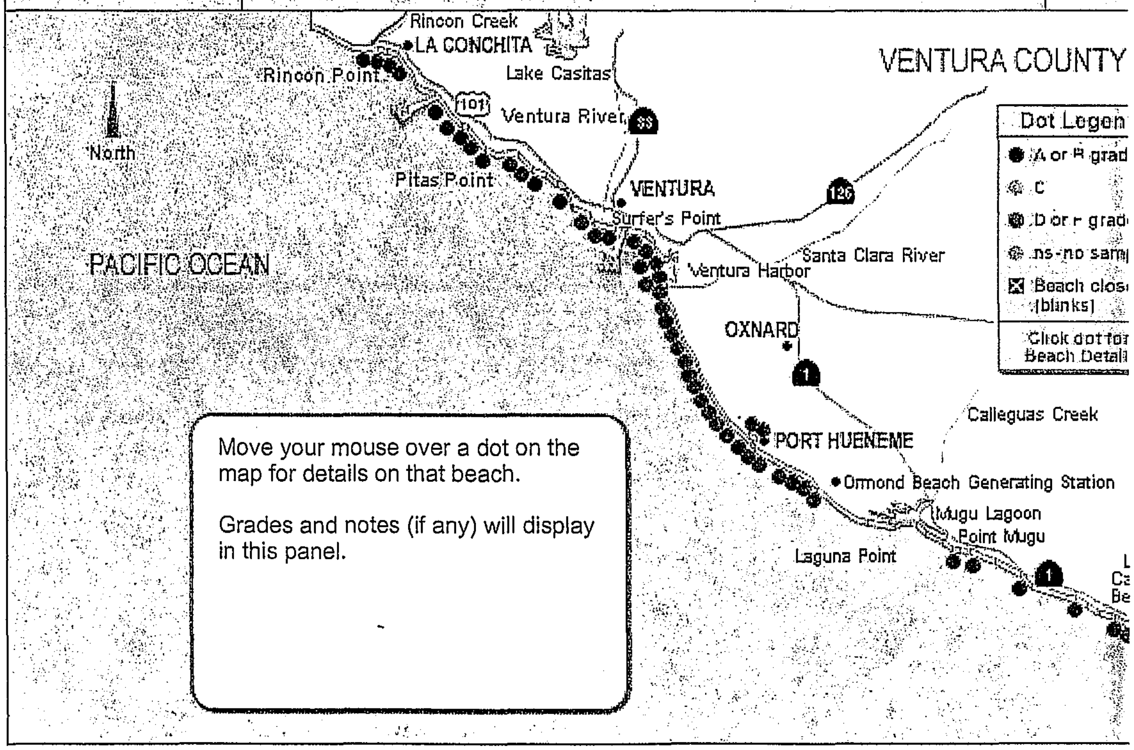
◂ CA State Map

Display Format	Now Showing	
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending September 28, 2005	



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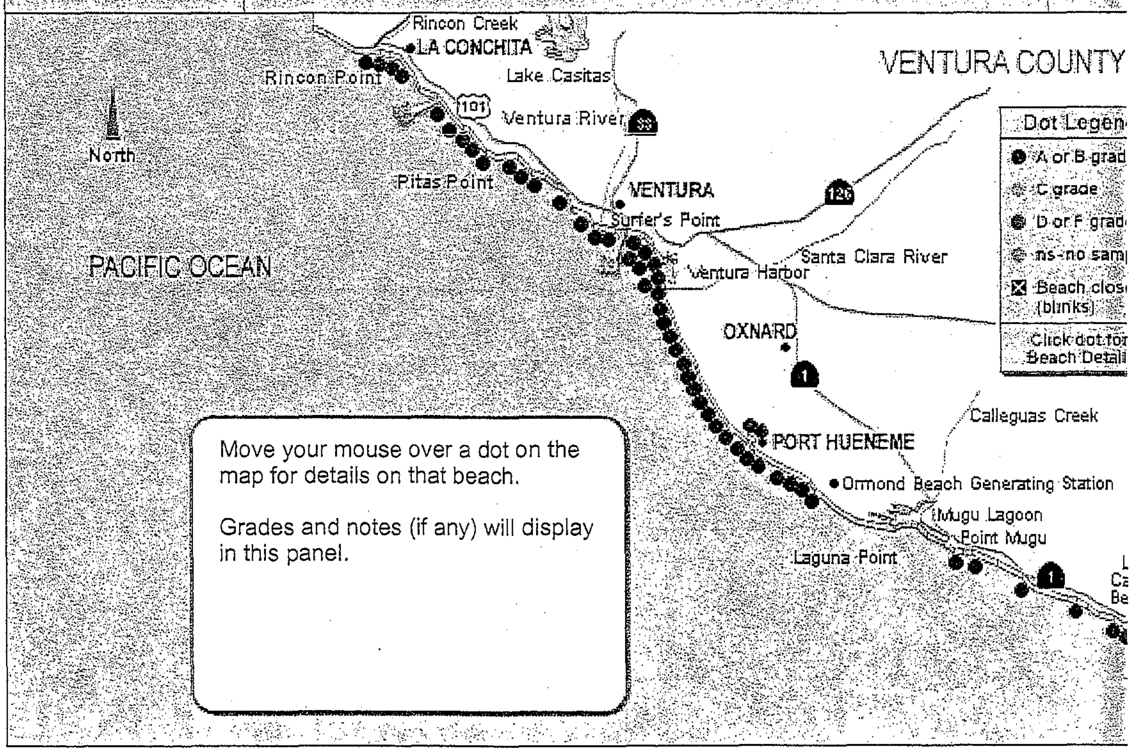
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending October 5, 2005	CA ma North South



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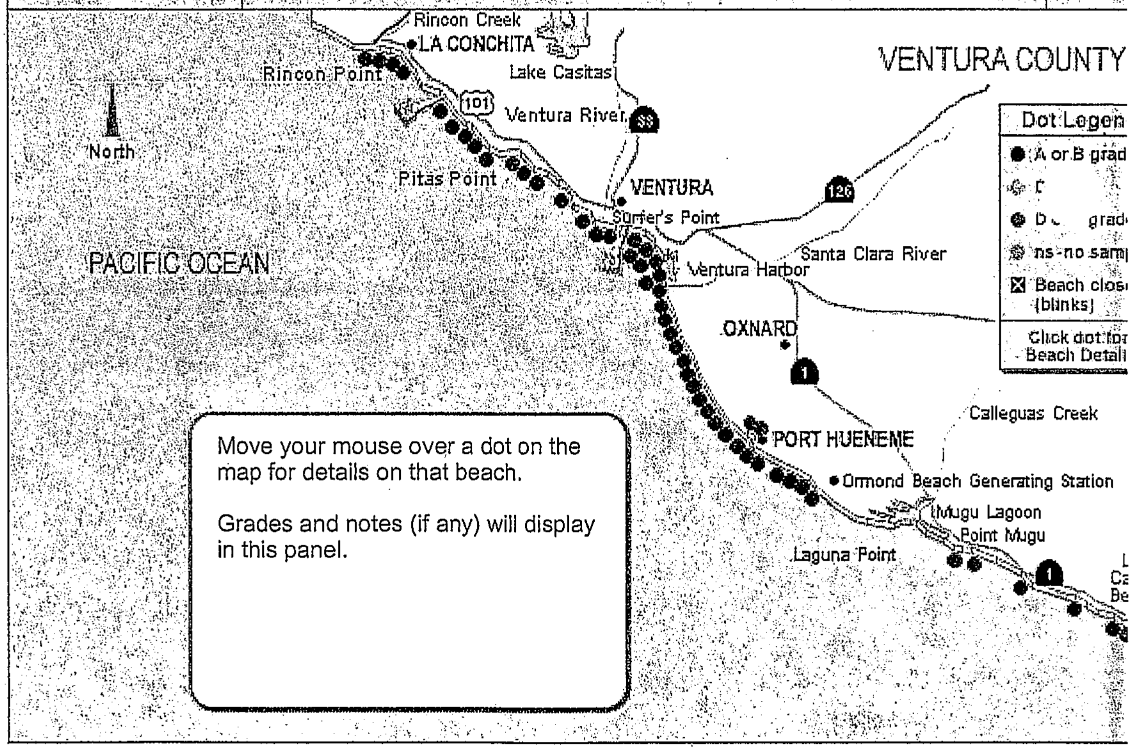
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending October 12, 2005	North South



Move your mouse over a dot on the map for details on that beach.

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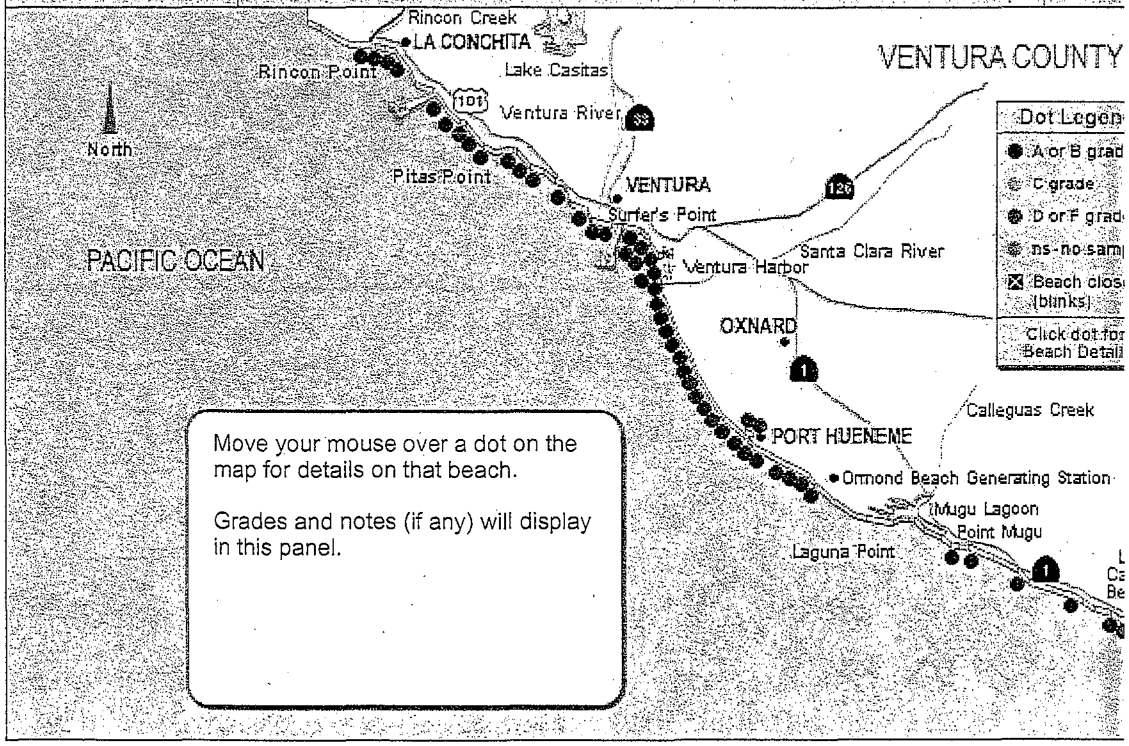
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending October 18, 2005	CA North South



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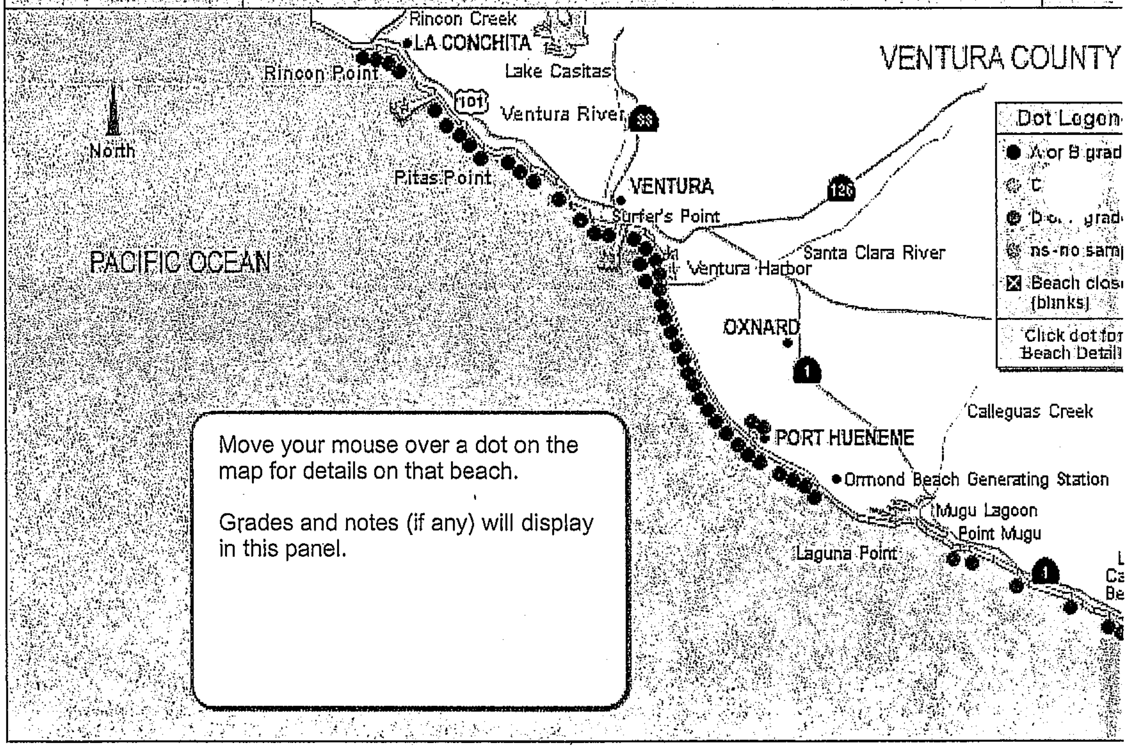
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry. Show Wet Grades Grade Period: 4-week period ending October 26, 2005	CA ma North South



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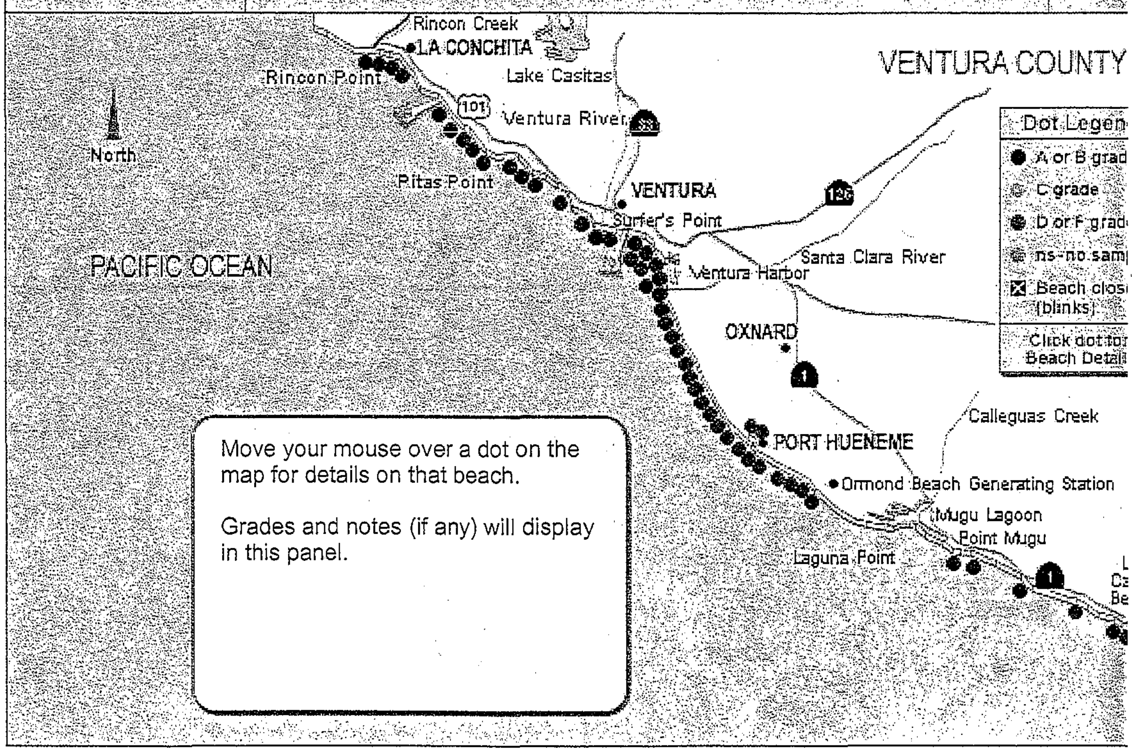
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending October 31, 2005	CA ma North South



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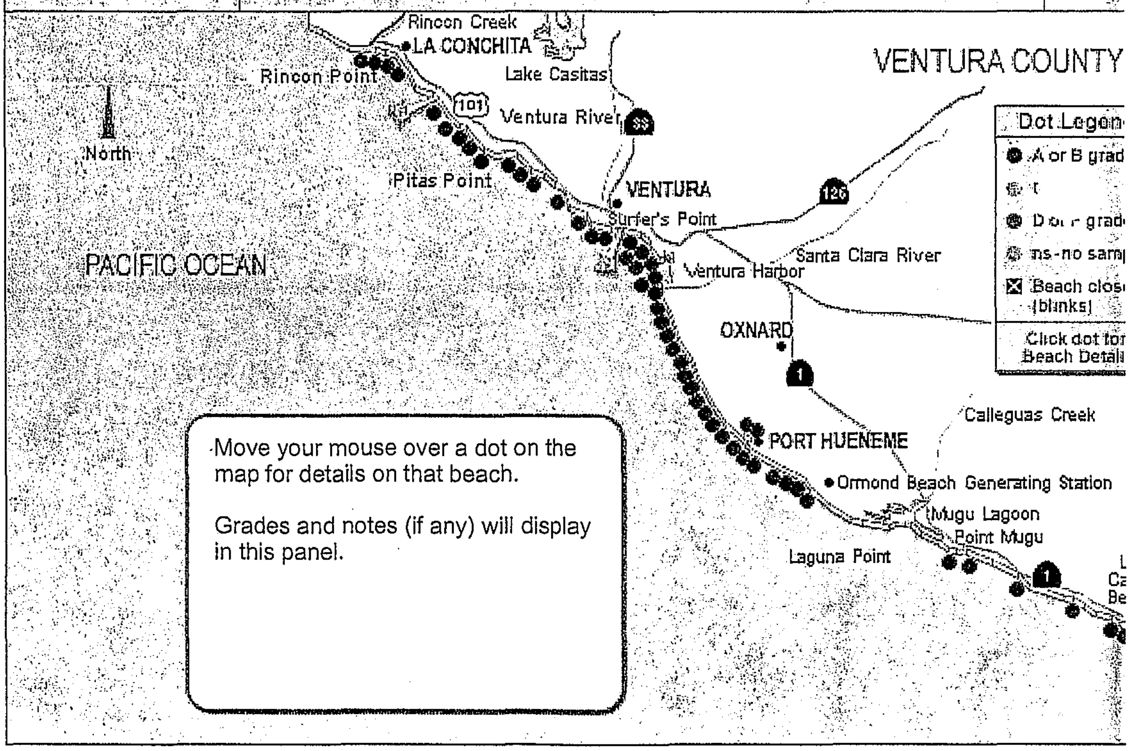
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending November 7, 2005	CA ma North South



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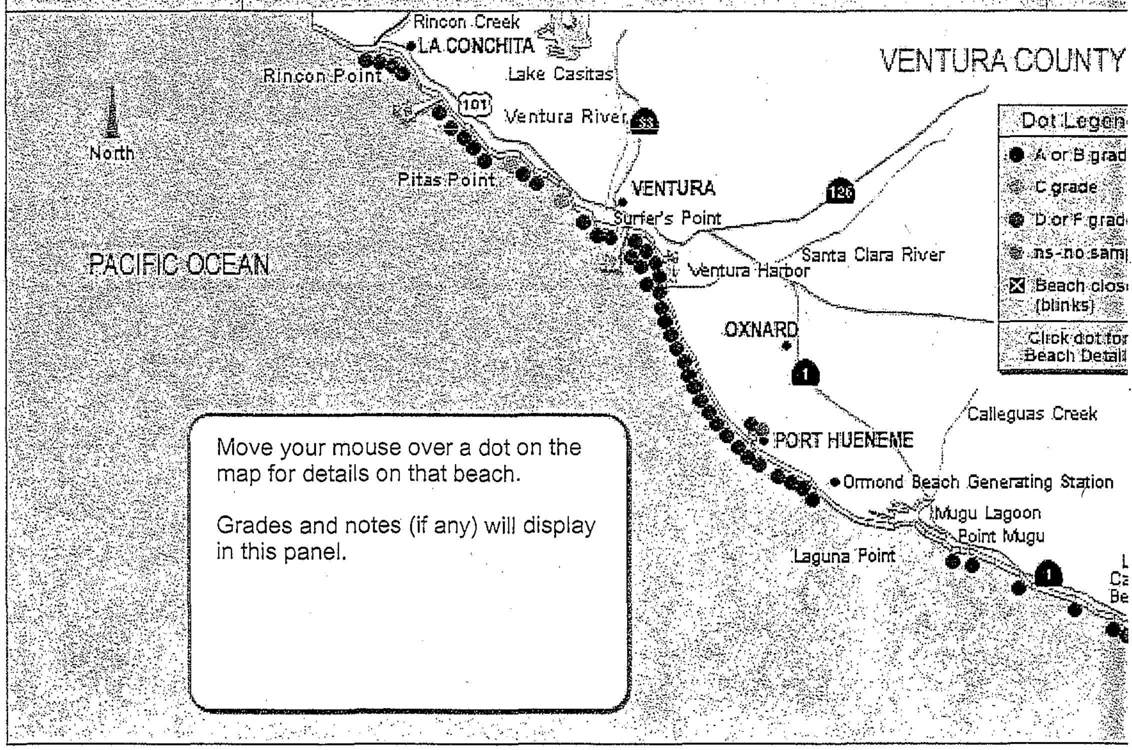
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending November 14, 2005	CA ma North South



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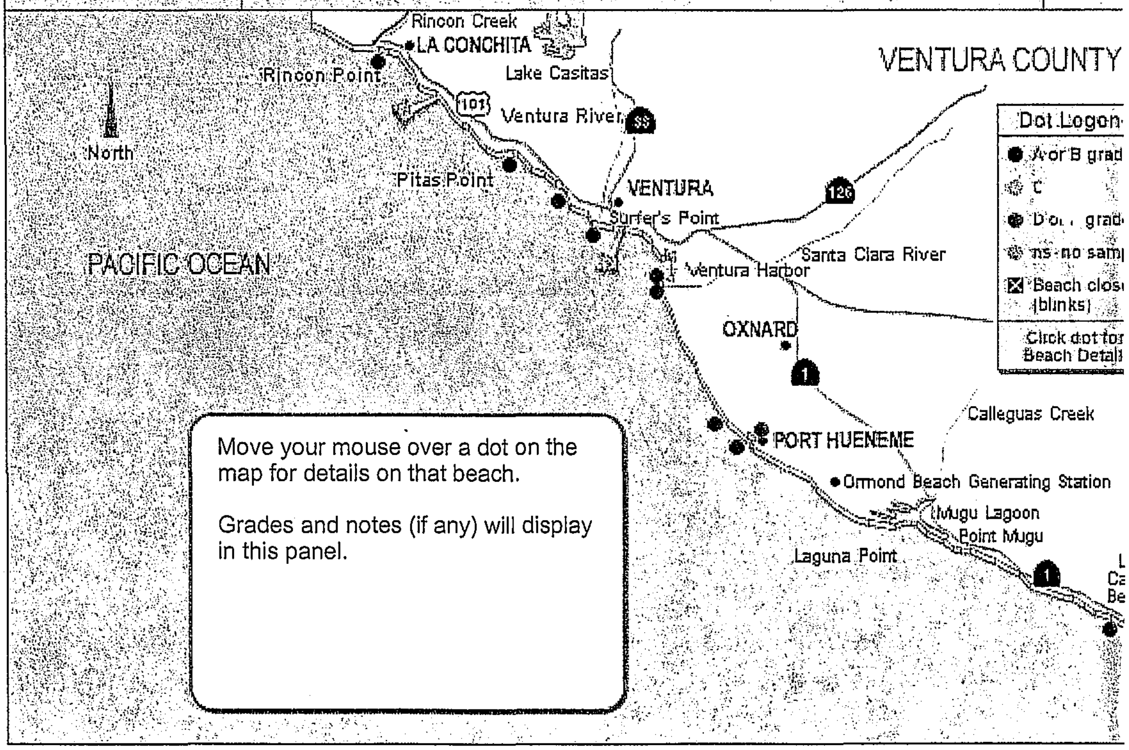
Weekly Report Card - Grade Map

CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending November 28, 2005



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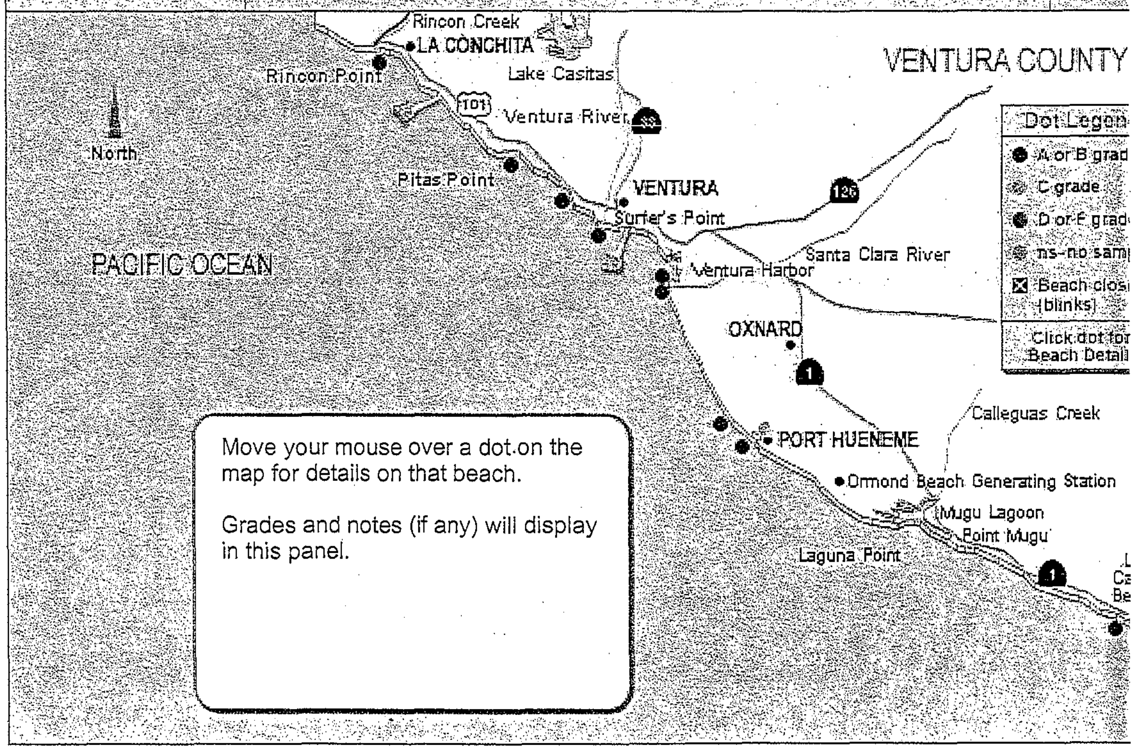
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending December 5, 2005	CA ma North South



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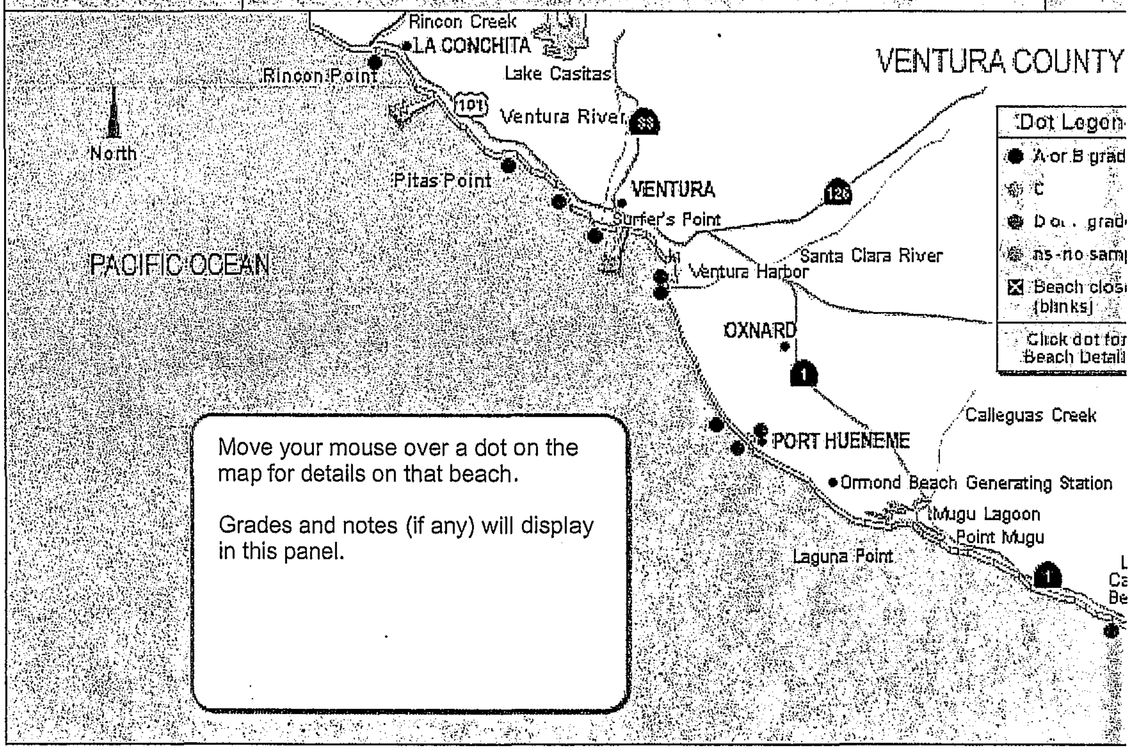
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending December 12, 2005	North South



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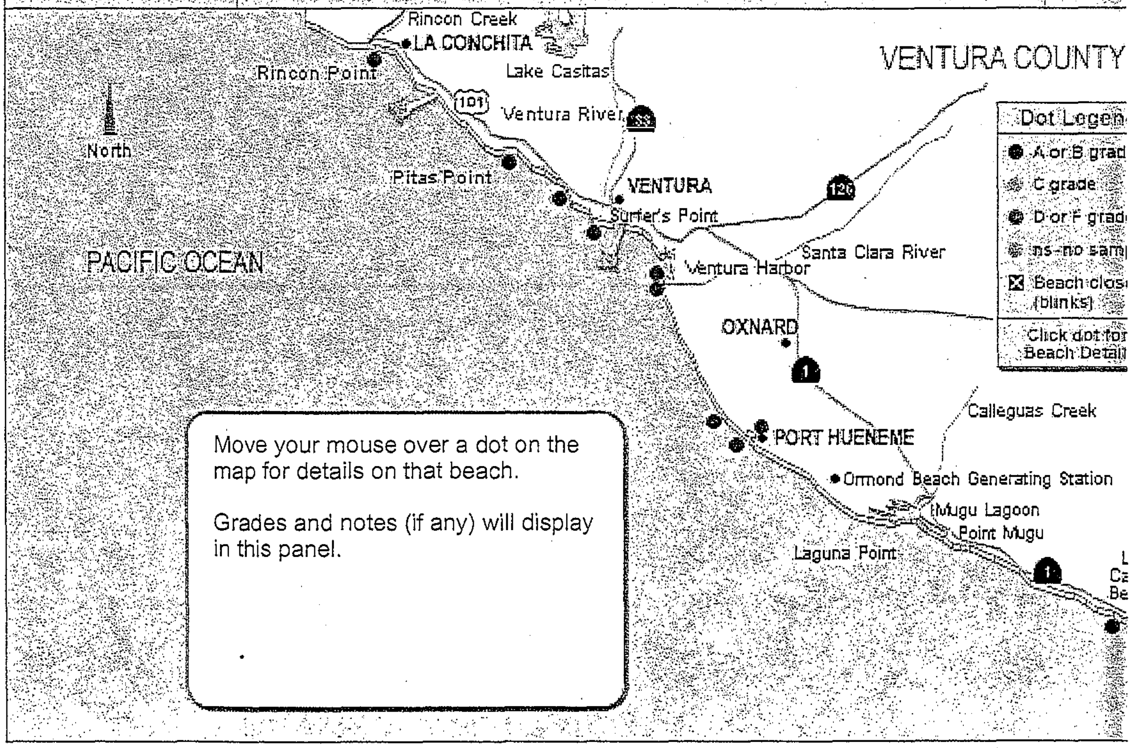
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending December 20, 2005	CA ma North South



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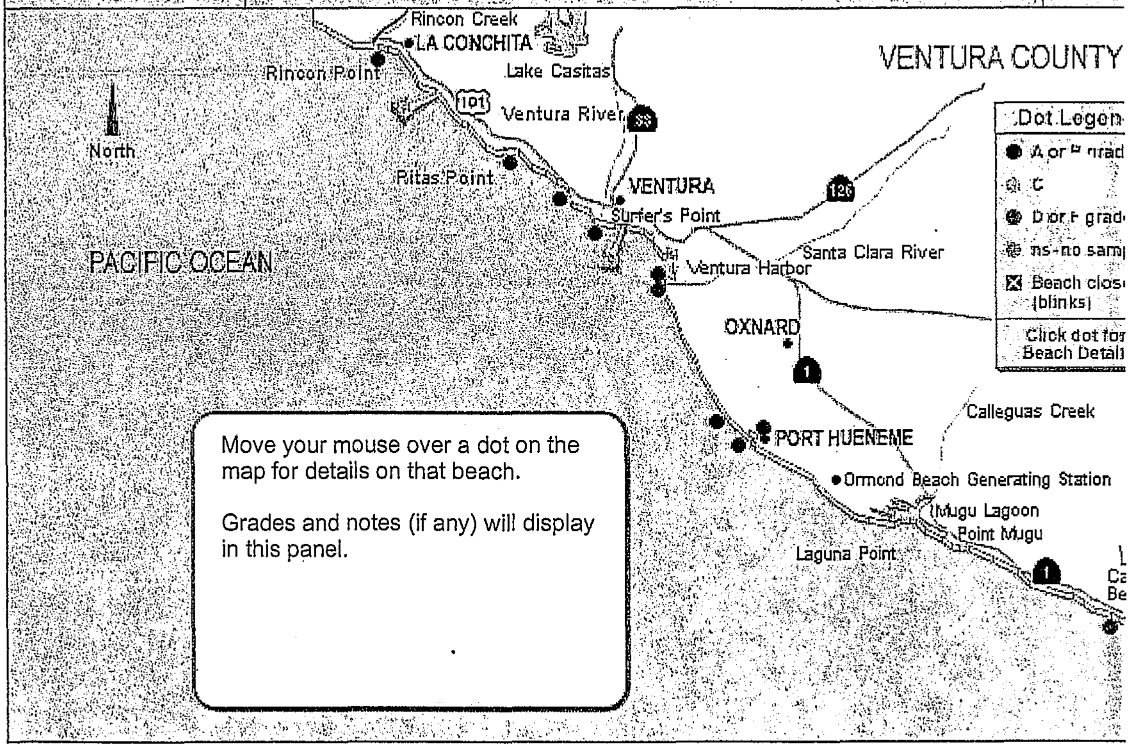
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending December 27, 2005	CA ma North South



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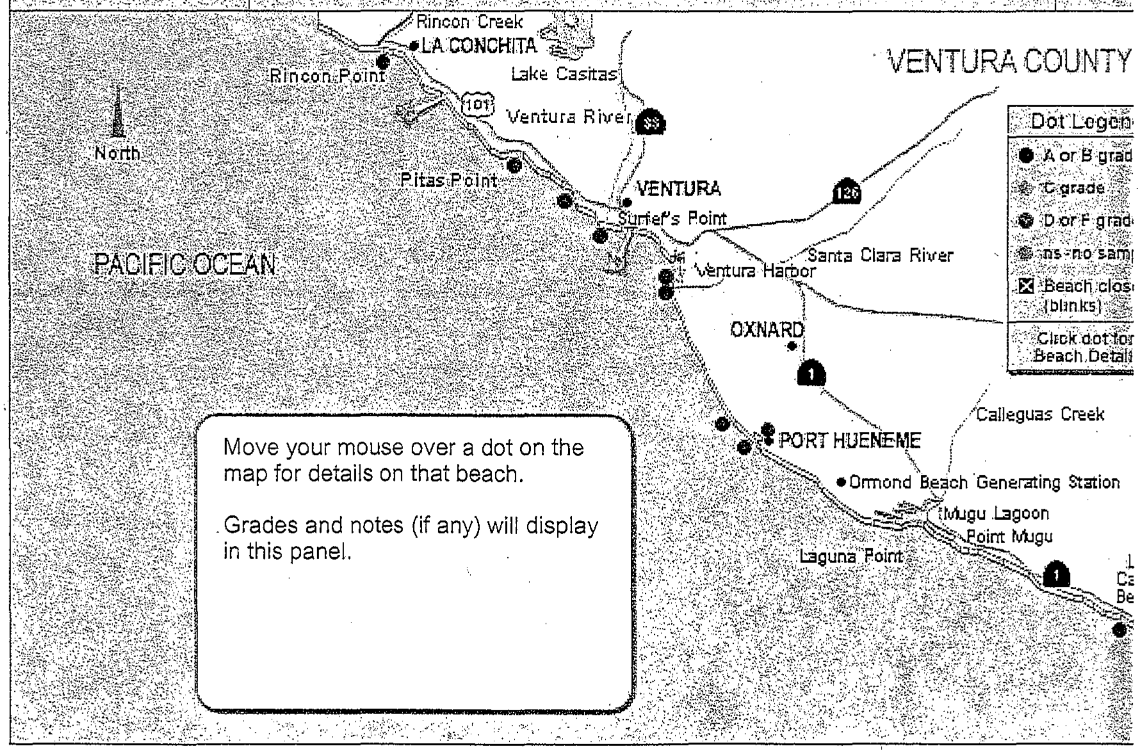
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending January 3, 2006	CA ma North South



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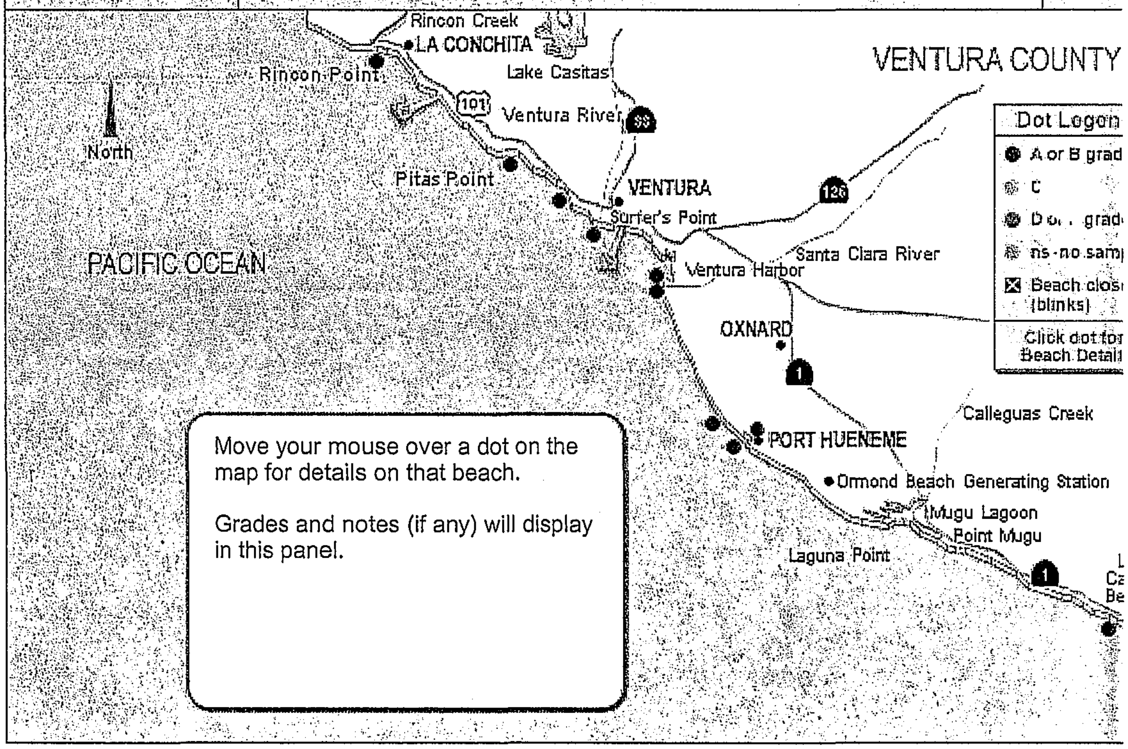
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending January 9, 2006	CA ... North South



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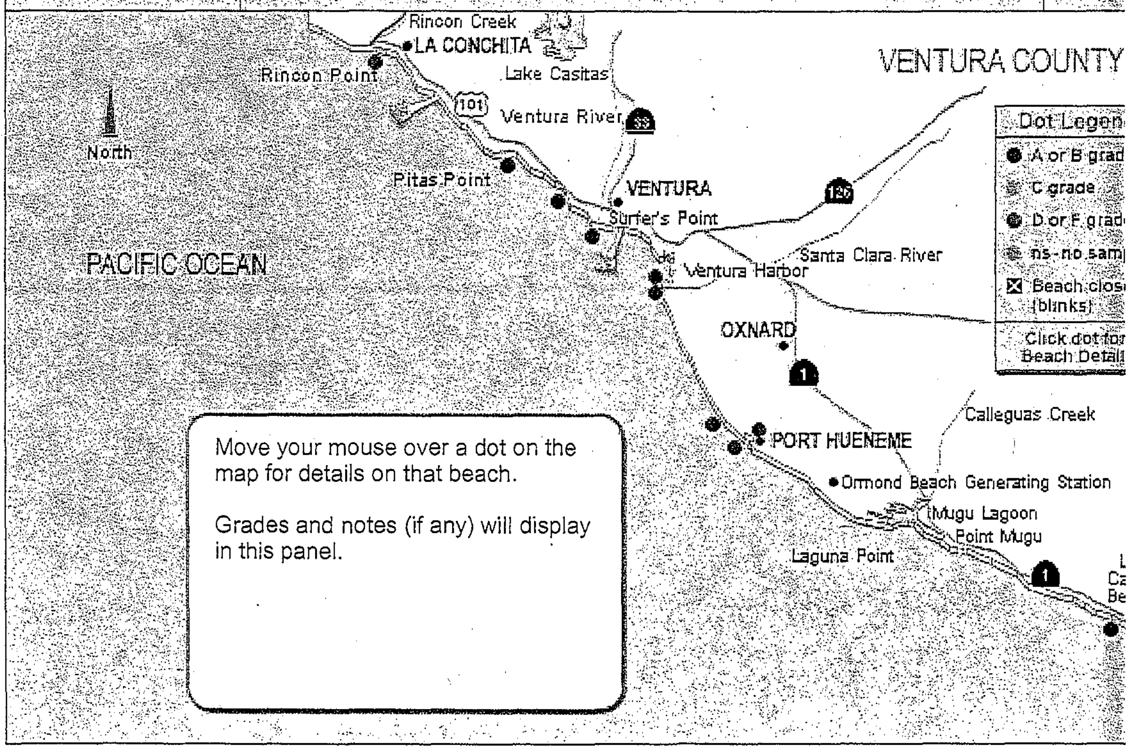
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending January 17, 2006	CA ma North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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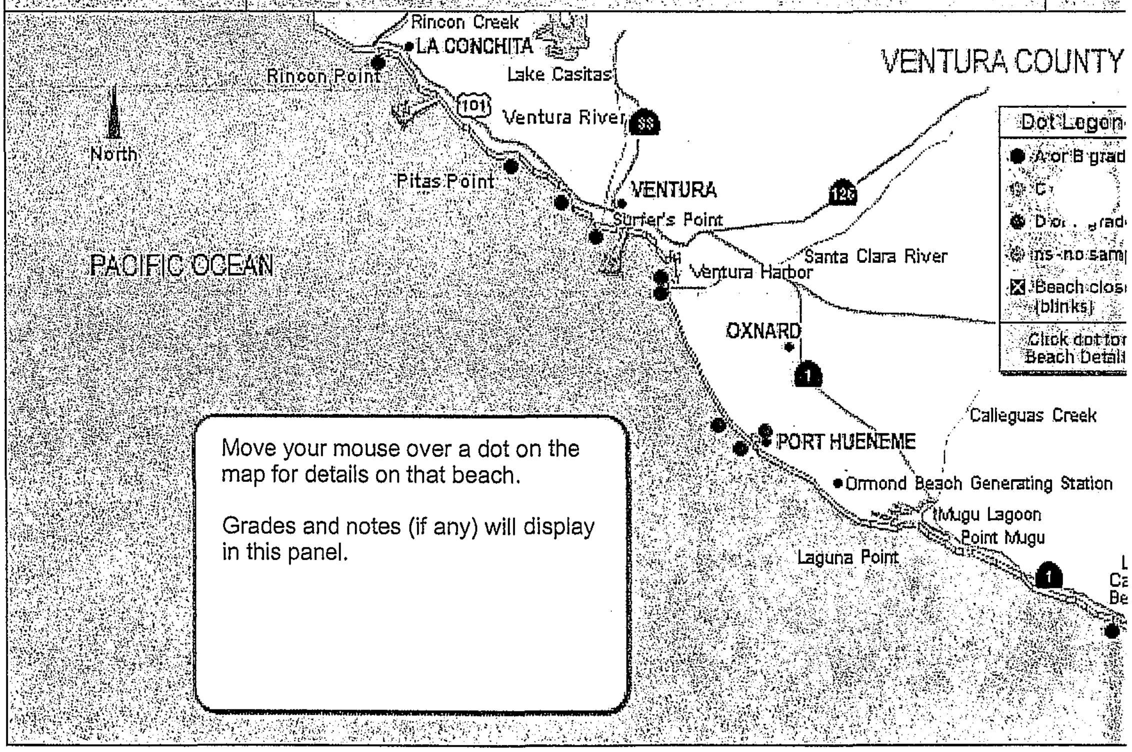
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending January 23, 2006	CA ma North South



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Beach Report Card[SM]

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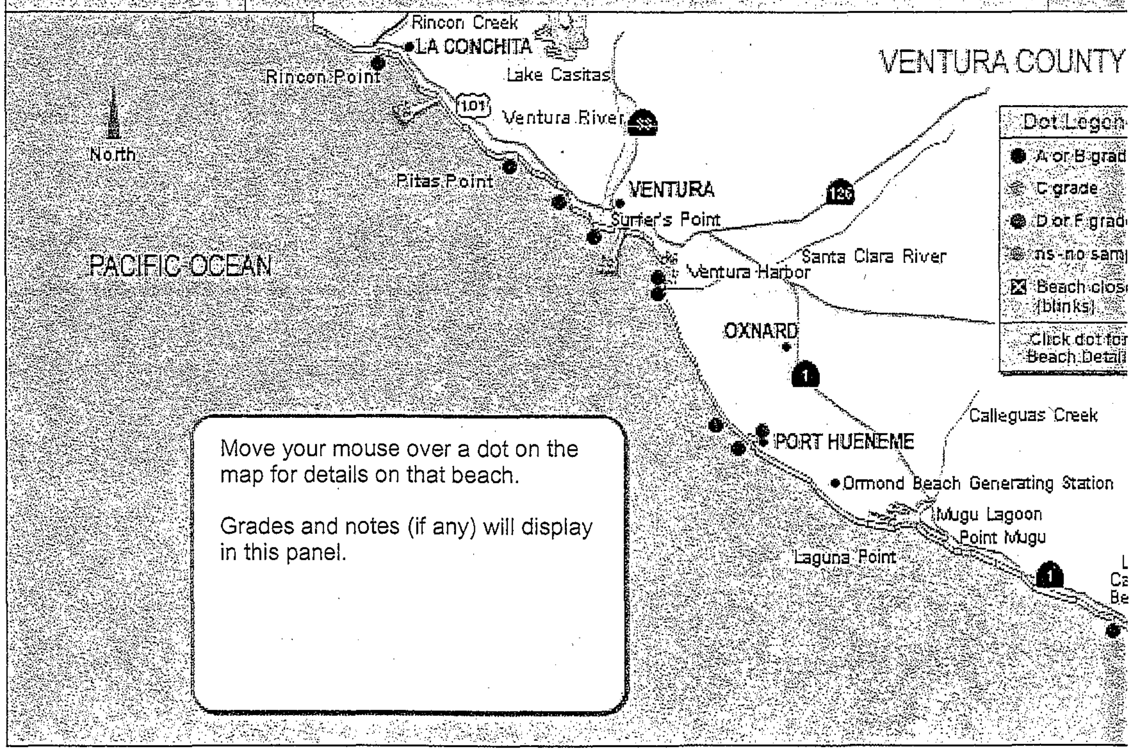
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending January 30, 2006	CA ma North South



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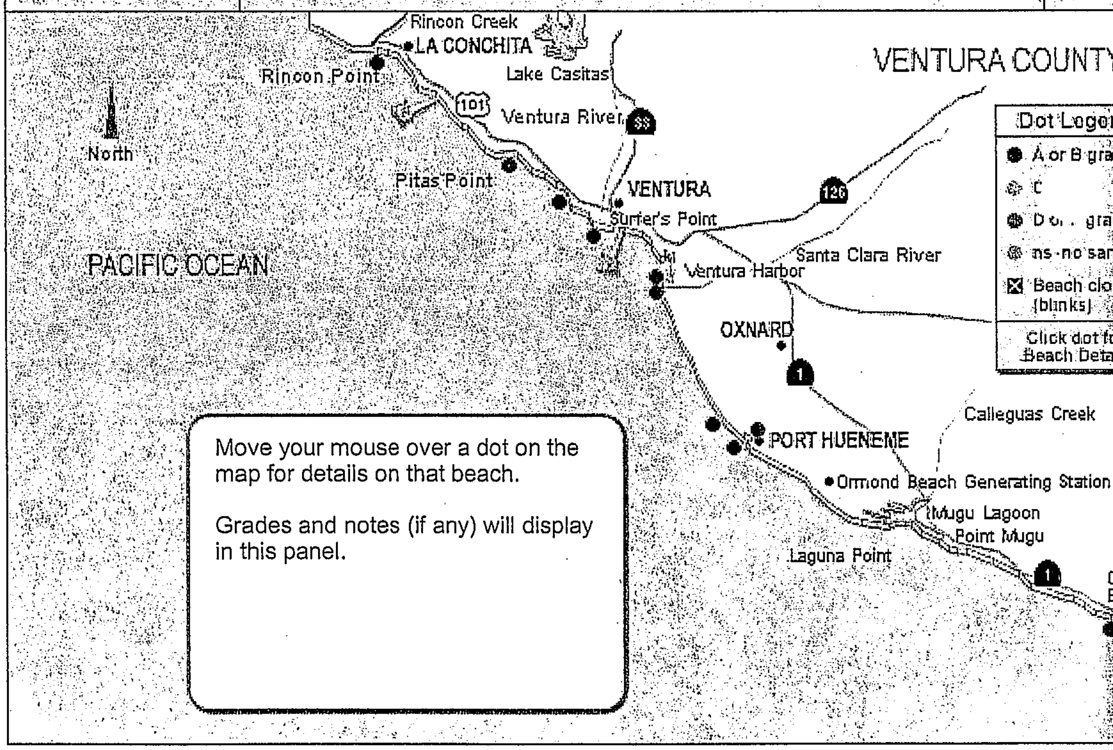
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending February 6, 2006	CA ma North South



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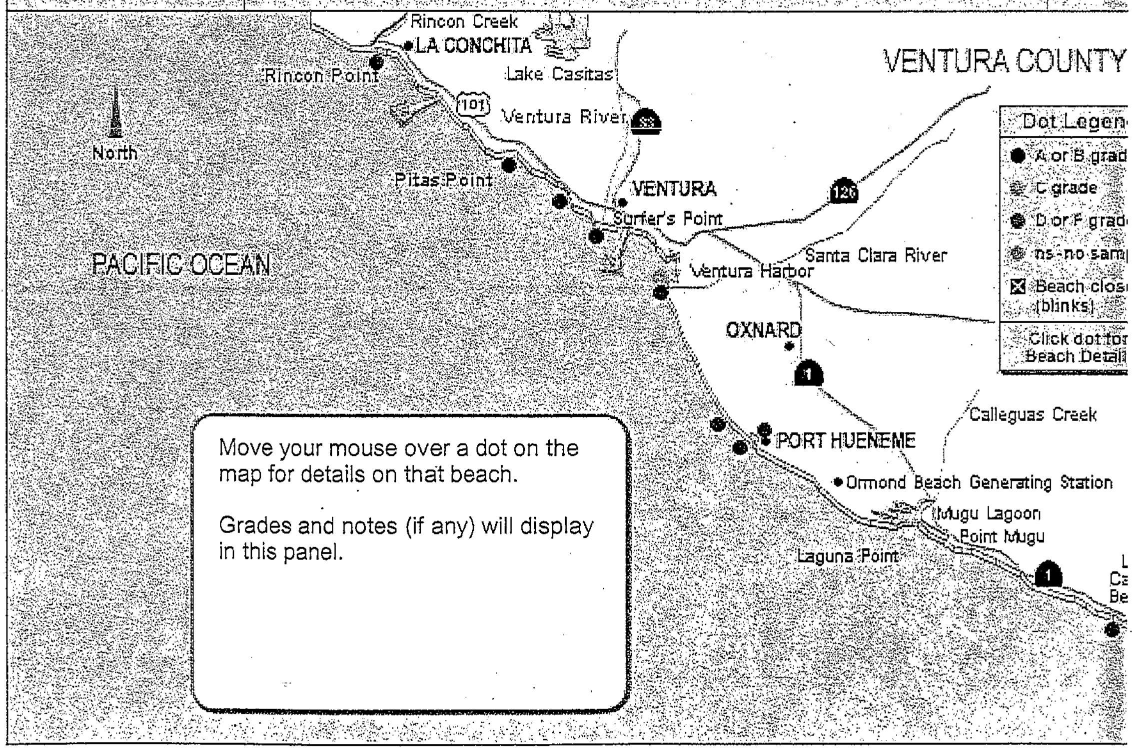
CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending February 14, 2006	CA ma North South



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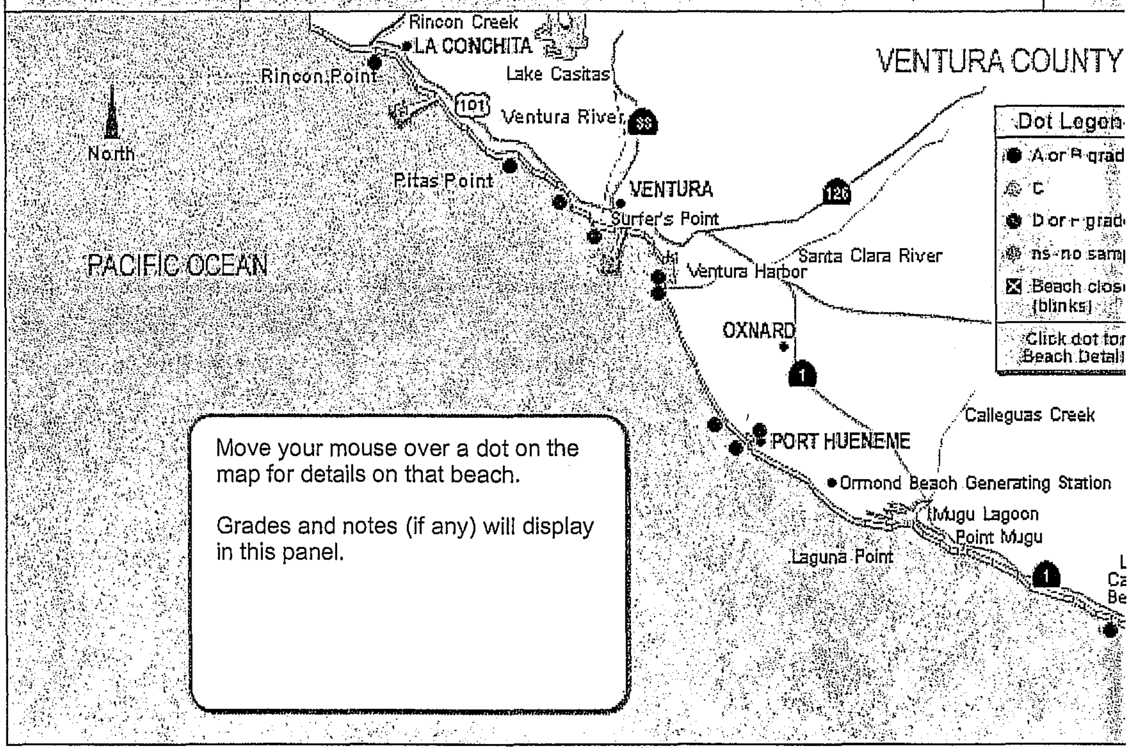
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending February 21, 2006	CA ma North South



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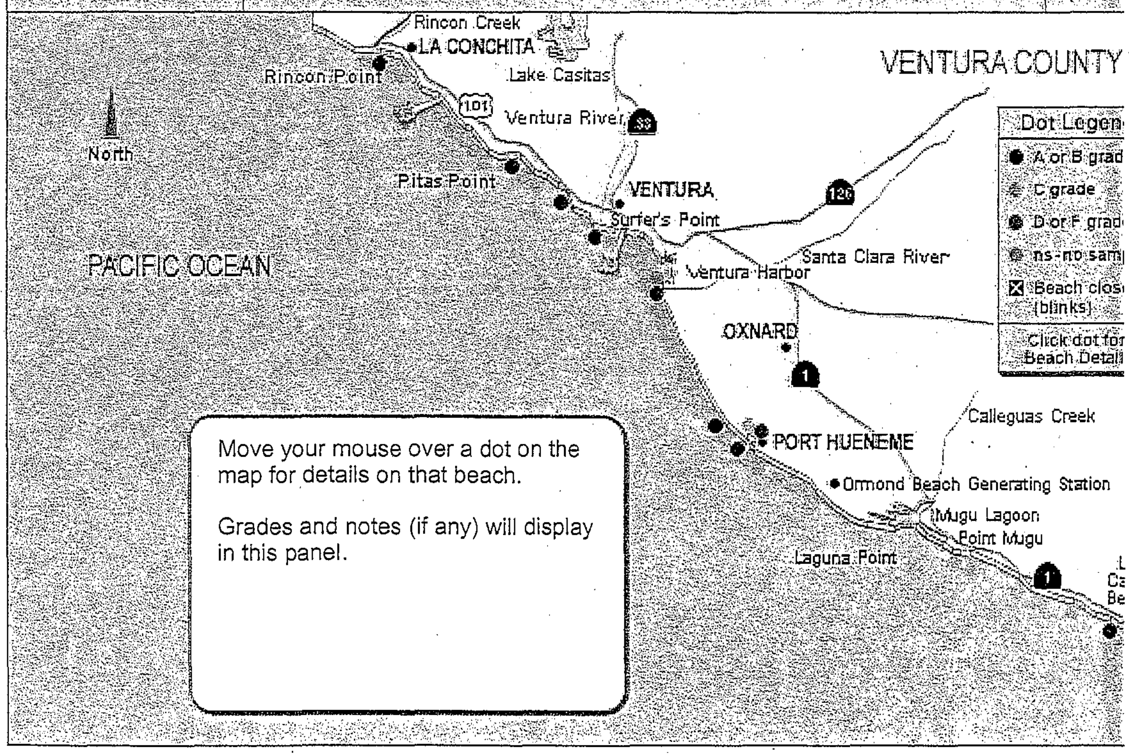
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending February 27, 2006



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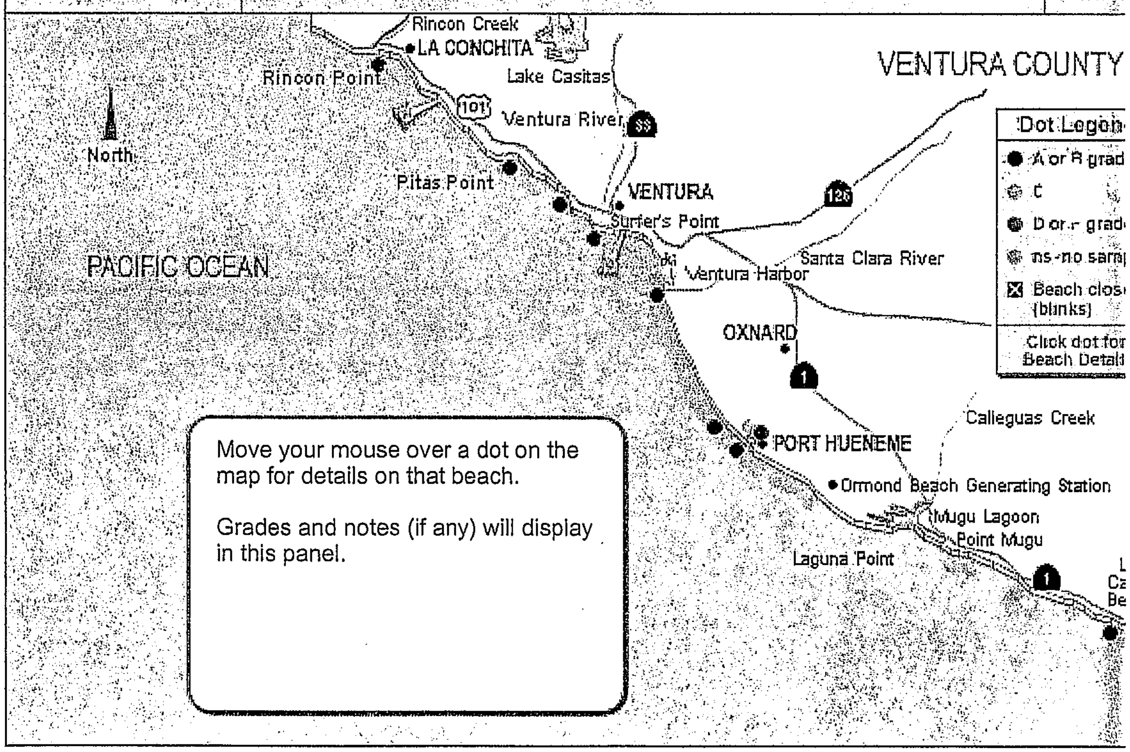
◄ CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending March 6, 2006



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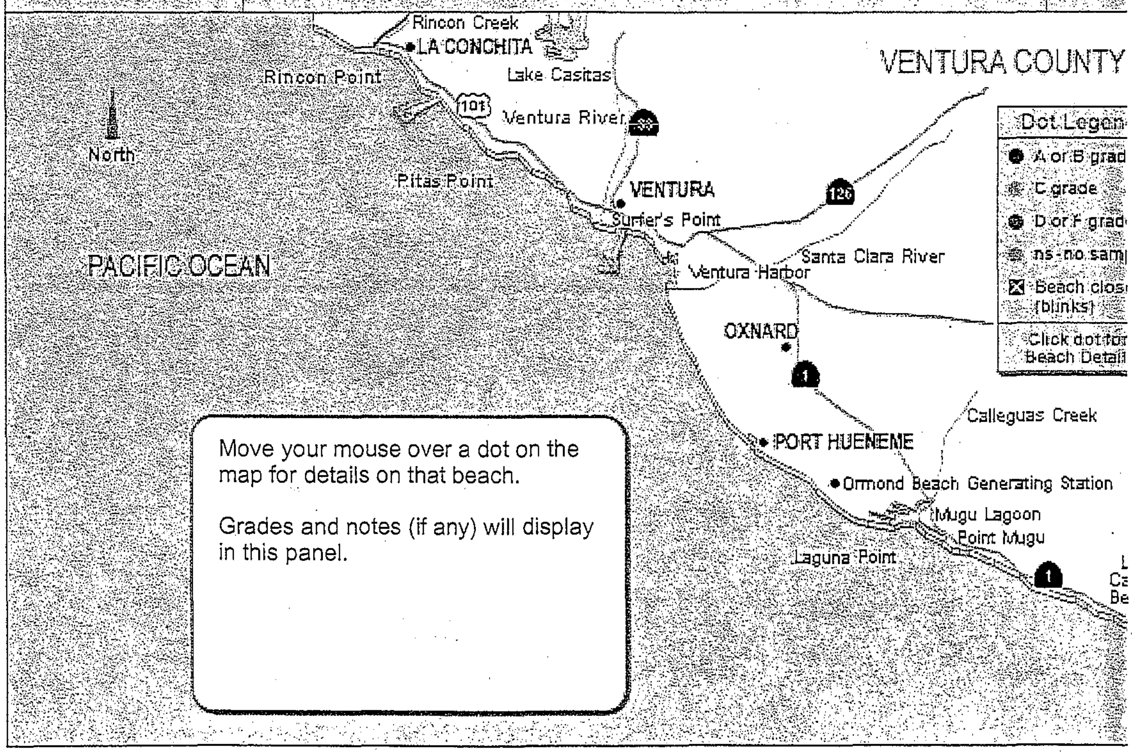
Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending March 13, 2006	CA ma North South



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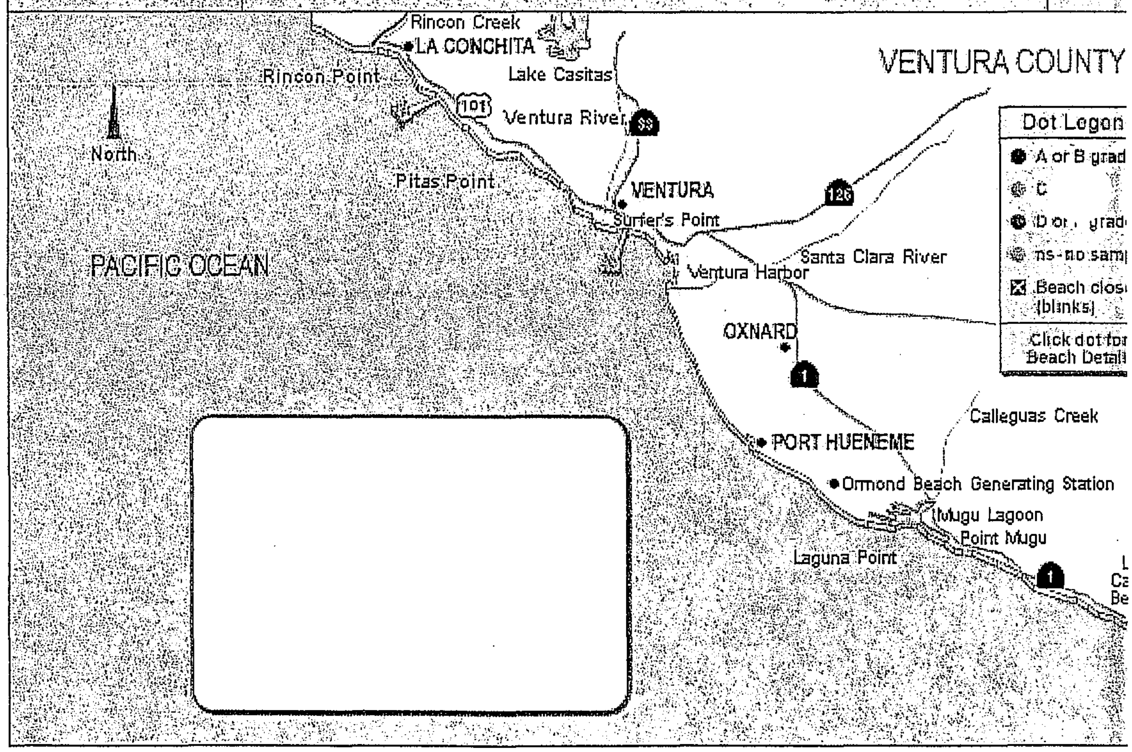
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending March 20, 2006	CA ma North South



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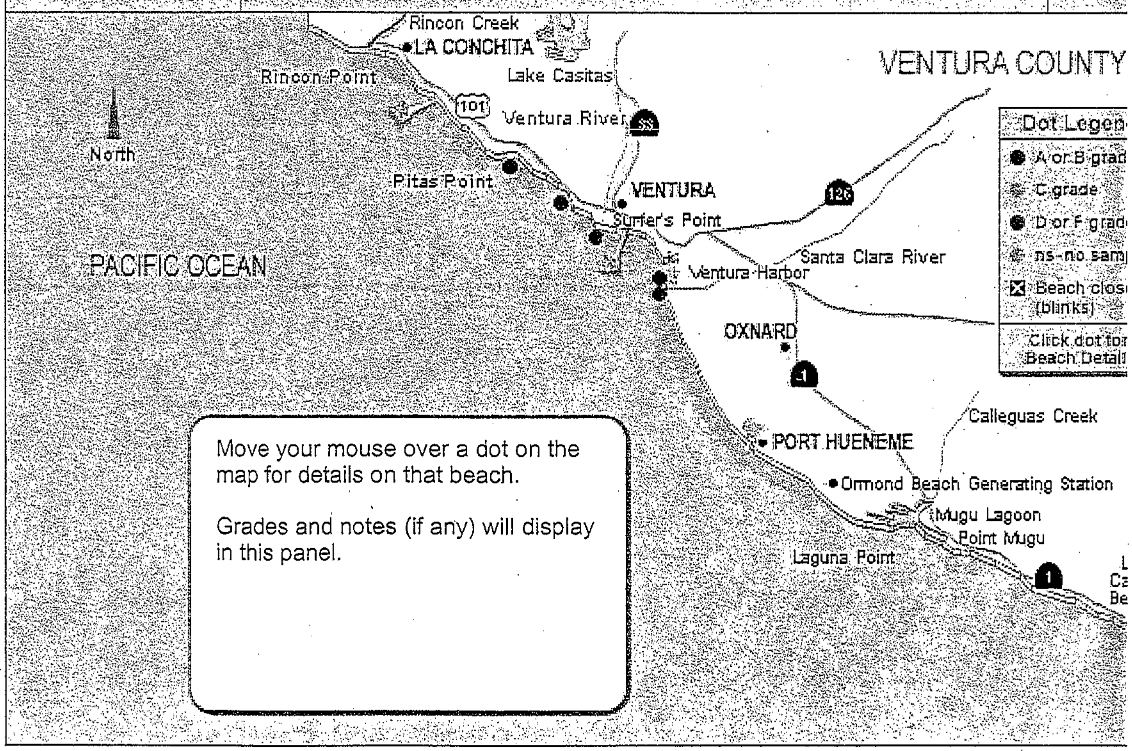
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending March 27, 2006	CA ma North South



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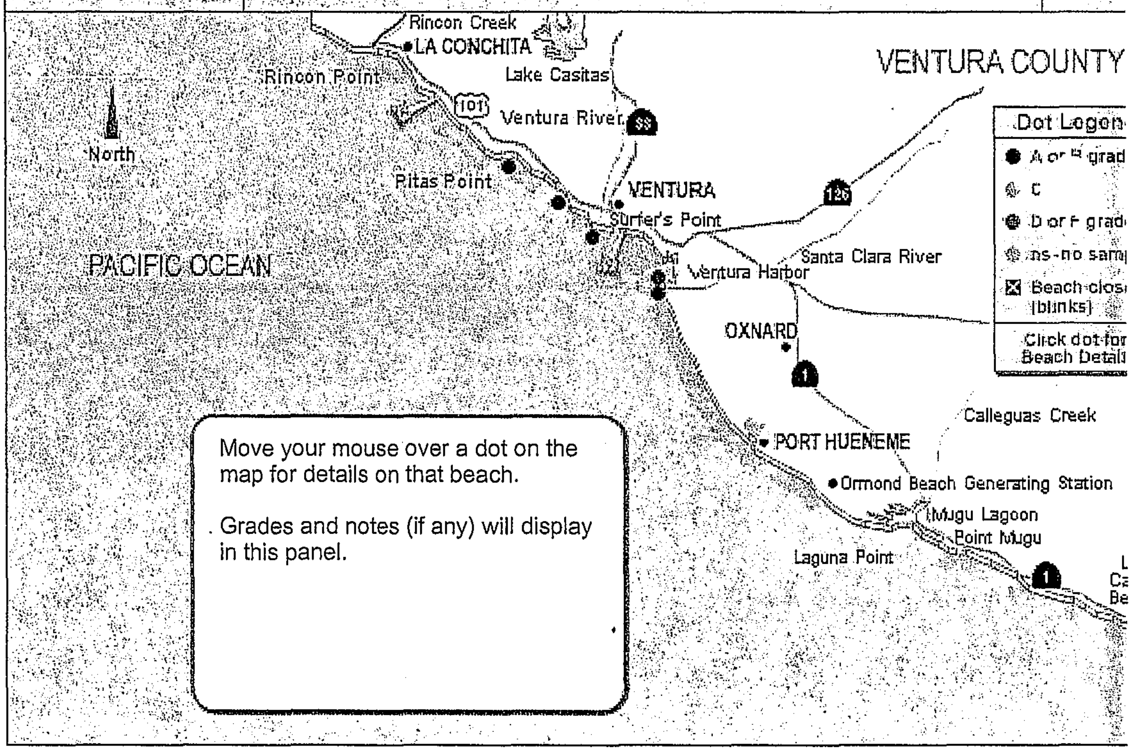
◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending April 4, 2006	CA ma North South



Move your mouse over a dot on the map for details on that beach.

Grades and notes (if any) will display in this panel.

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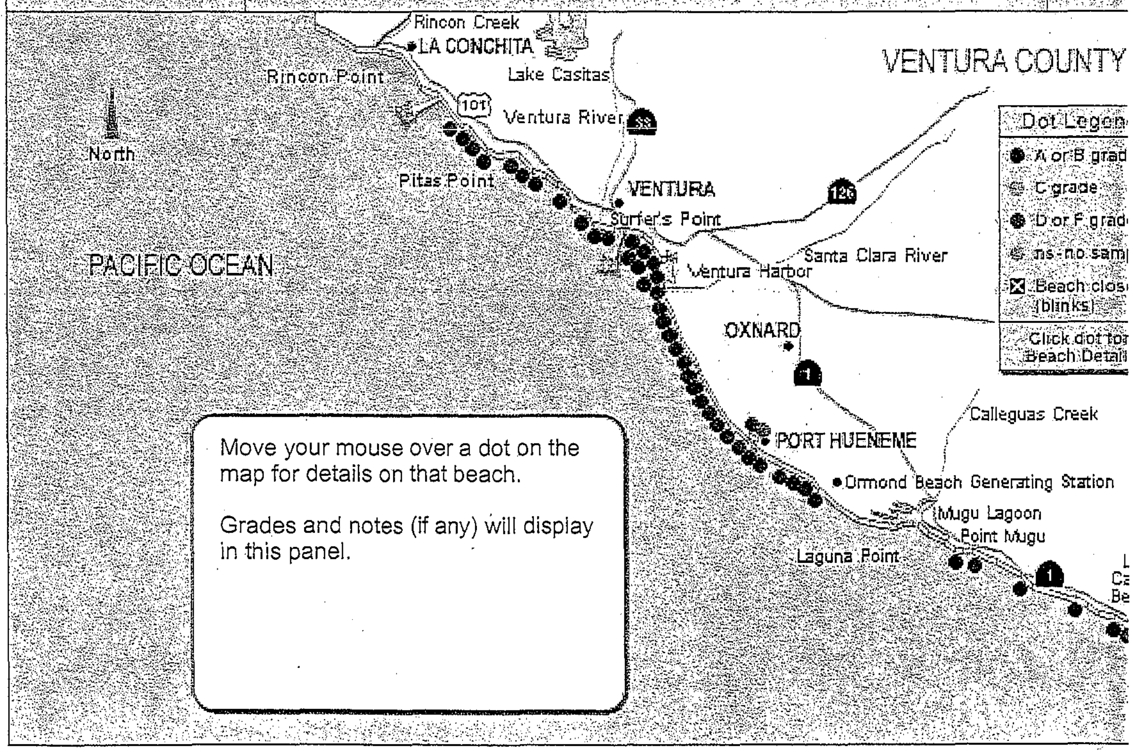

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◄ CA State Map

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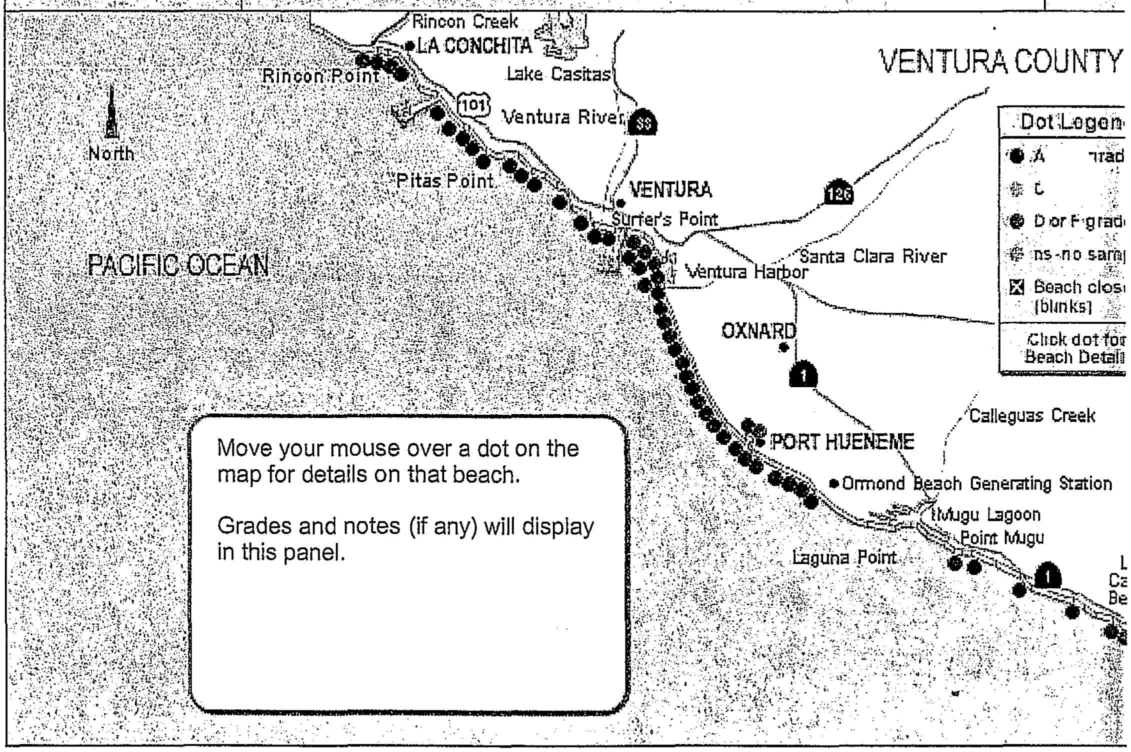

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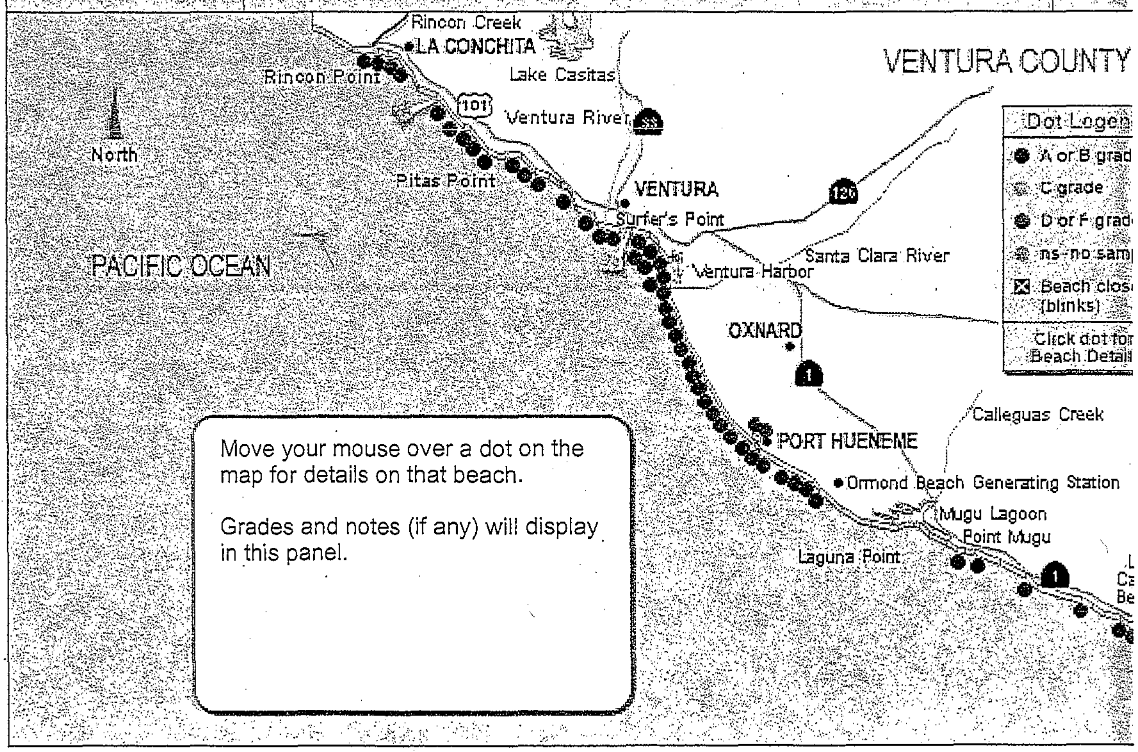

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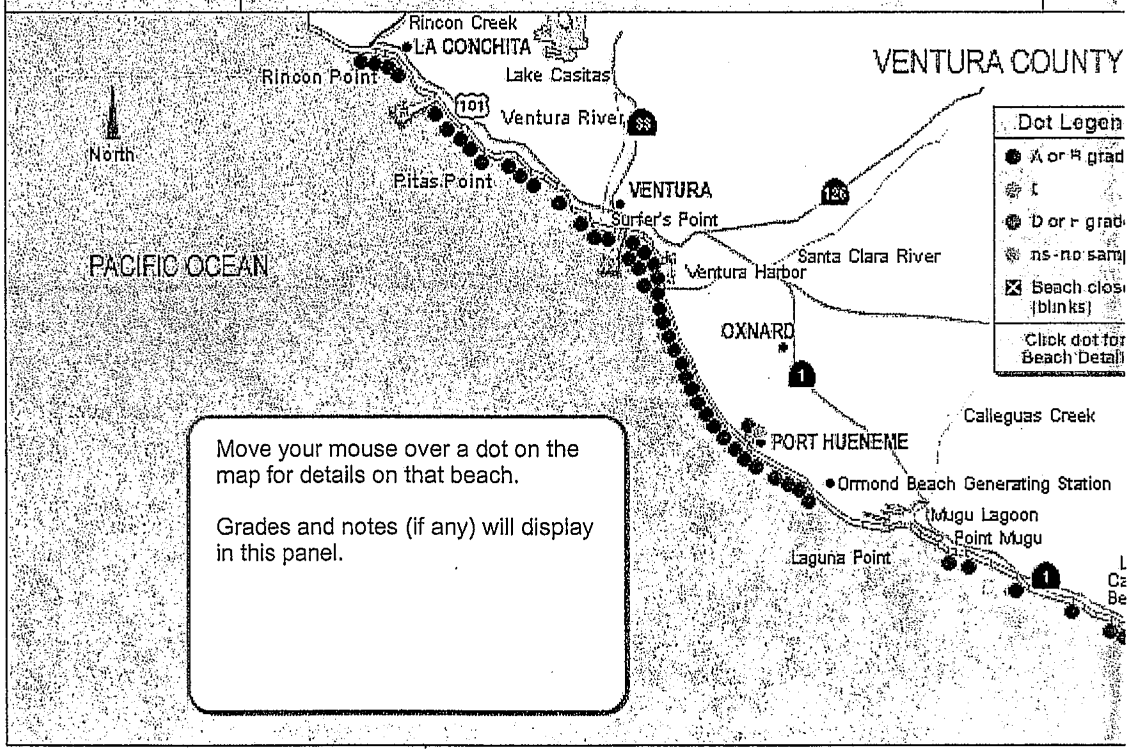
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending May 3, 2006



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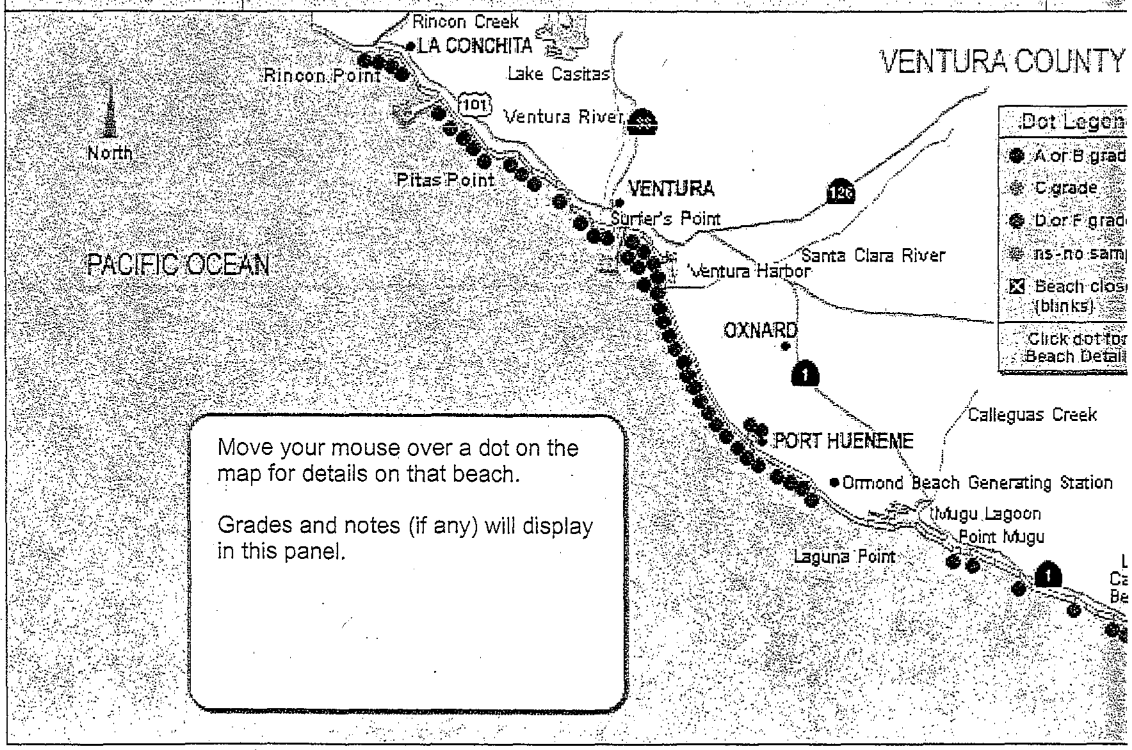
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending May 10, 2006	CA ma North South



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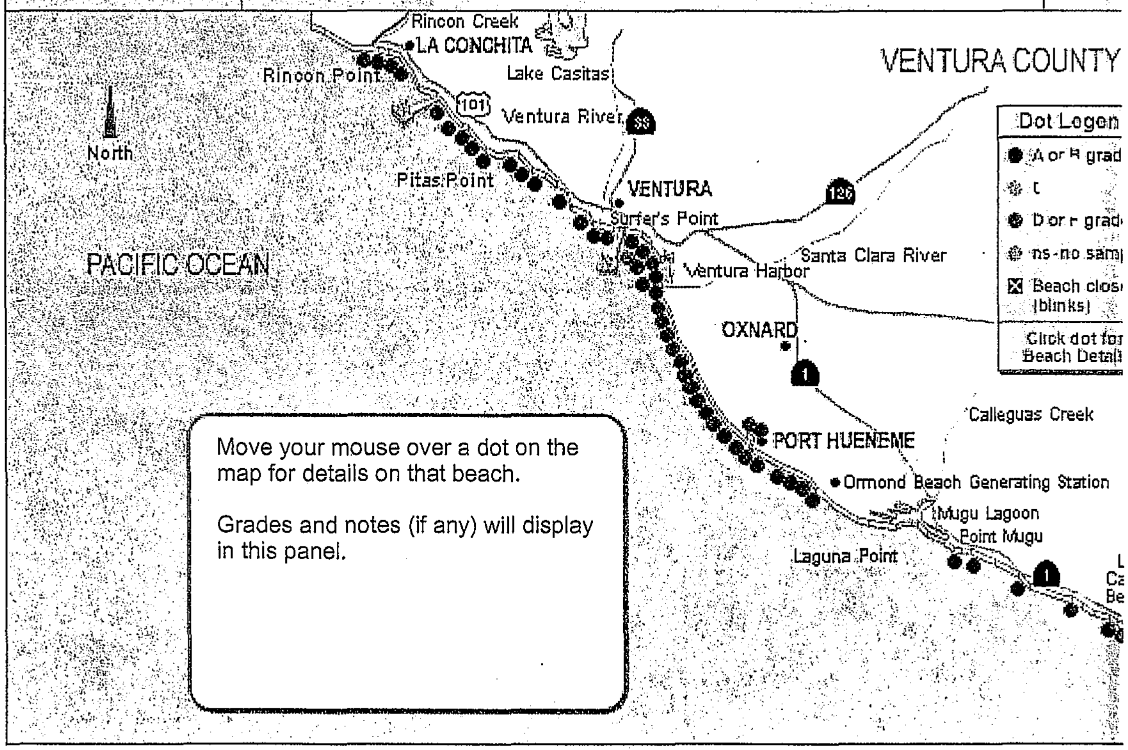
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending May 17, 2006	CA ma North South



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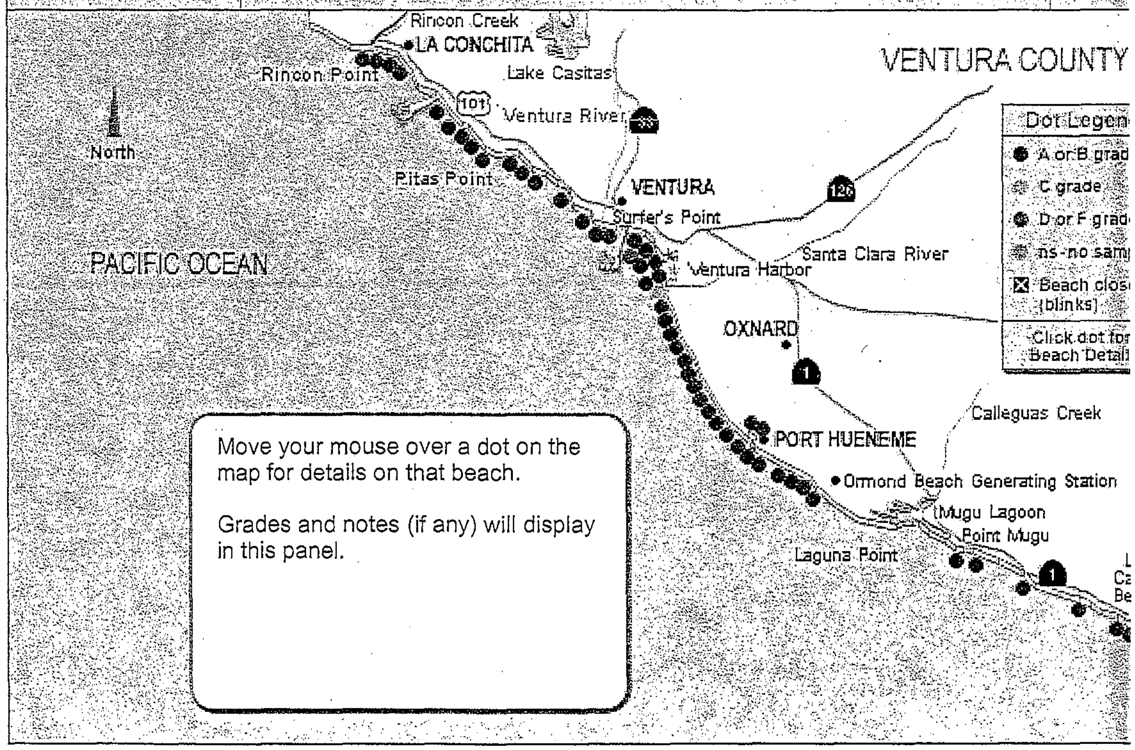
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending May 24, 2006	CA ma North South



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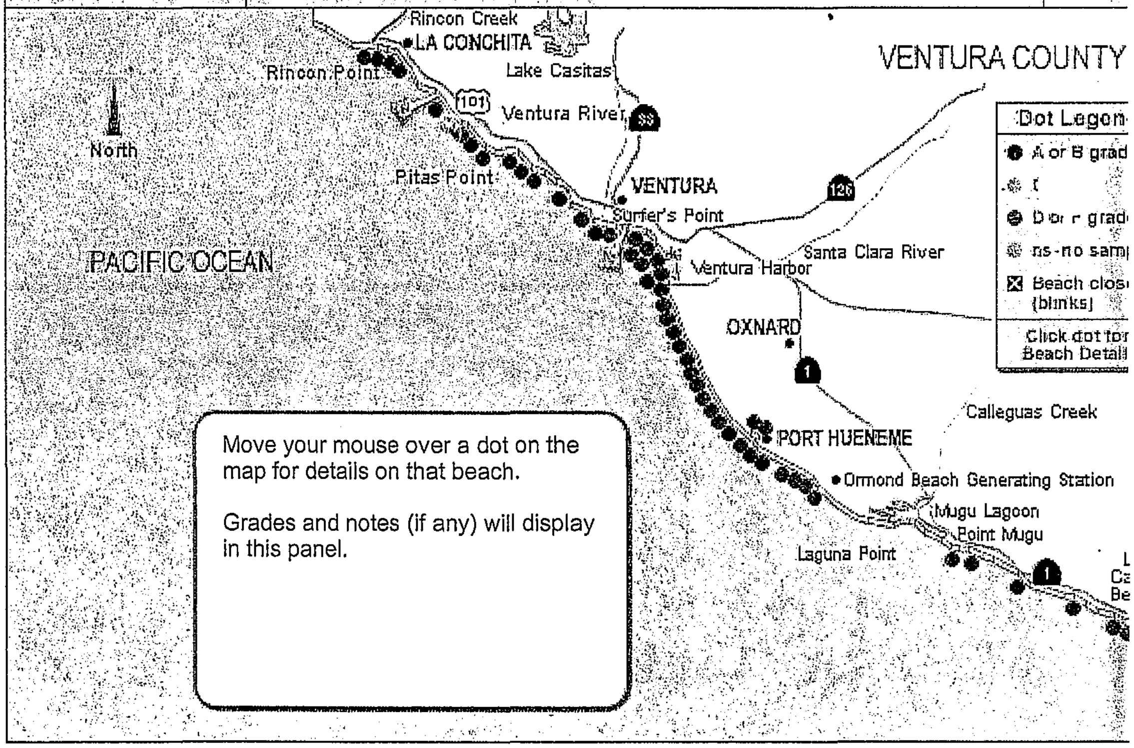
Grade Map View Text List	Area: Ventura County, CA Weather: Dry Show Wet Grades Grade Period: 4-week period ending May 31, 2006



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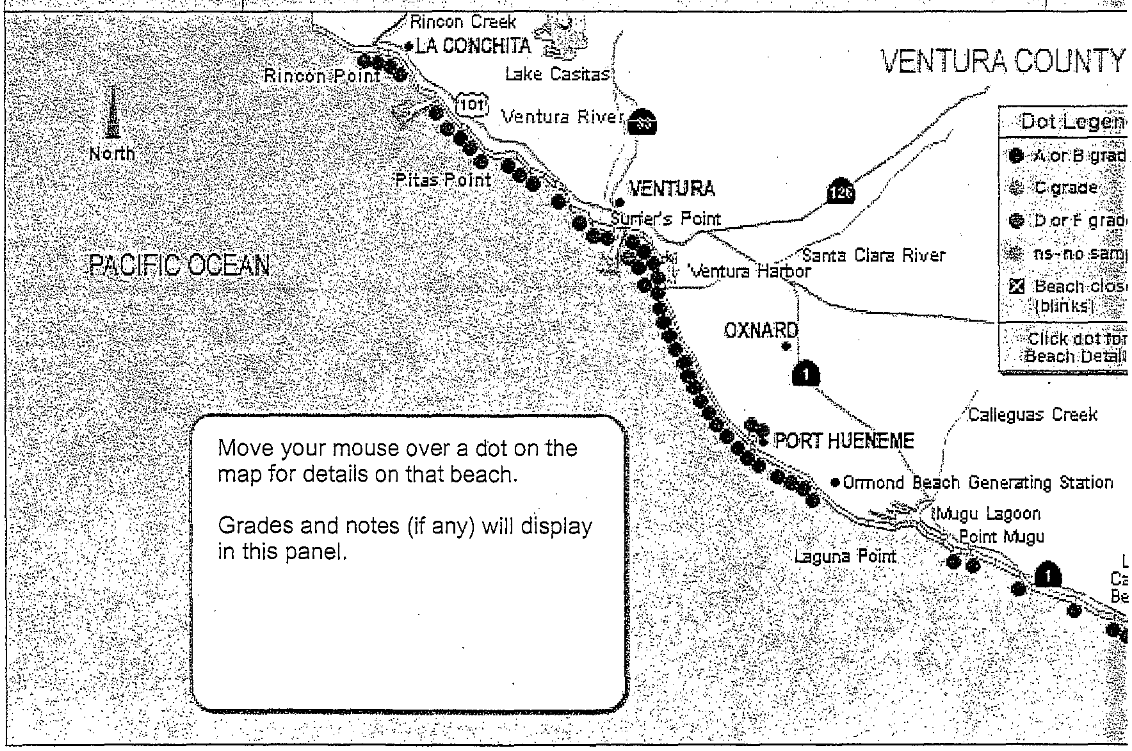
◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 7, 2006	CA ma North South



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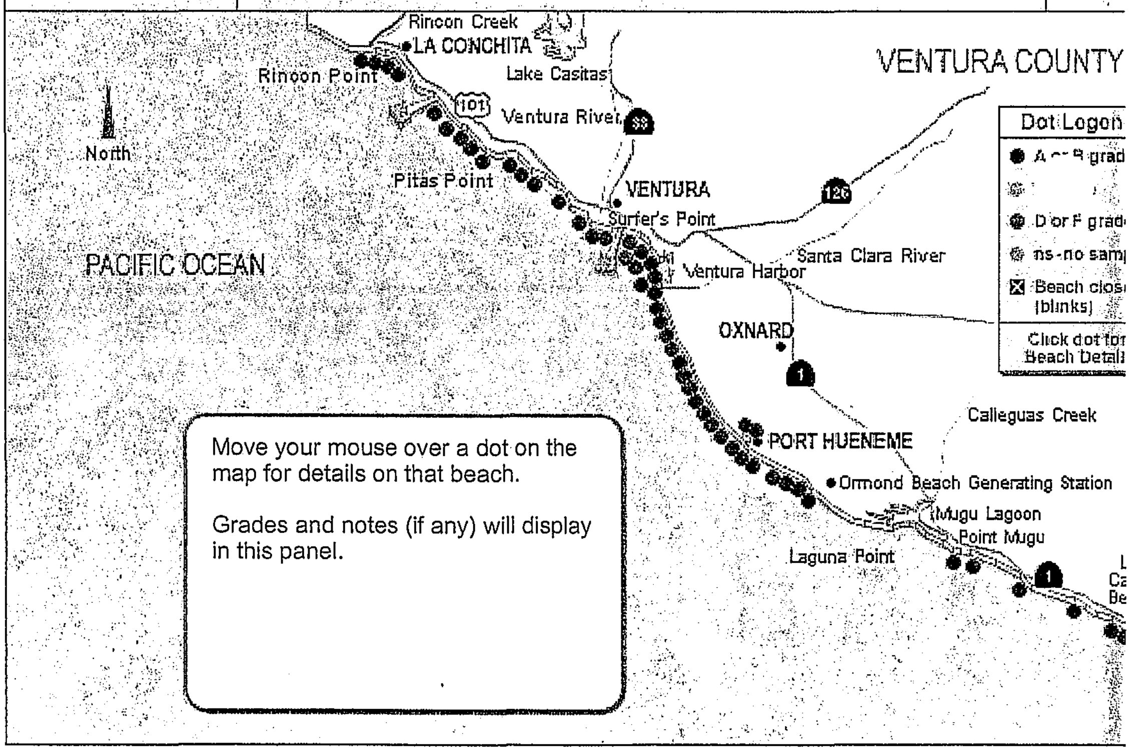
Weekly Report Card - Grade Map

◂ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 14, 2006	CA ma North South



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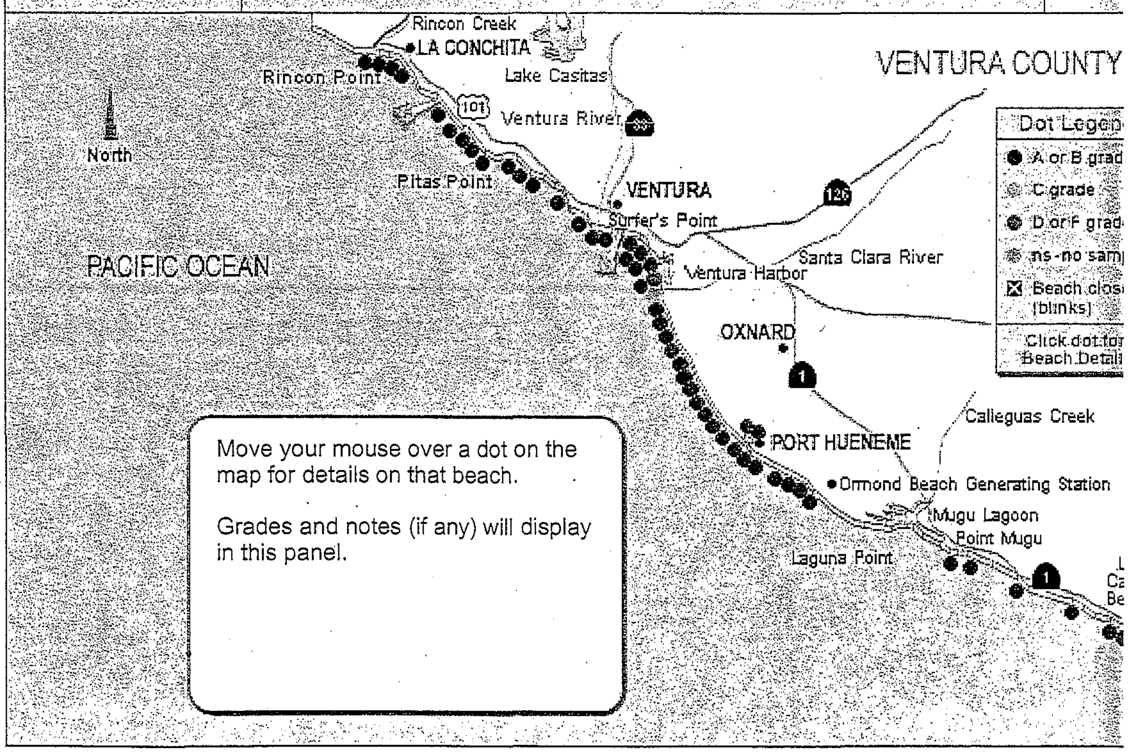
Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing	Navigat
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 21, 2006	CA ma North South



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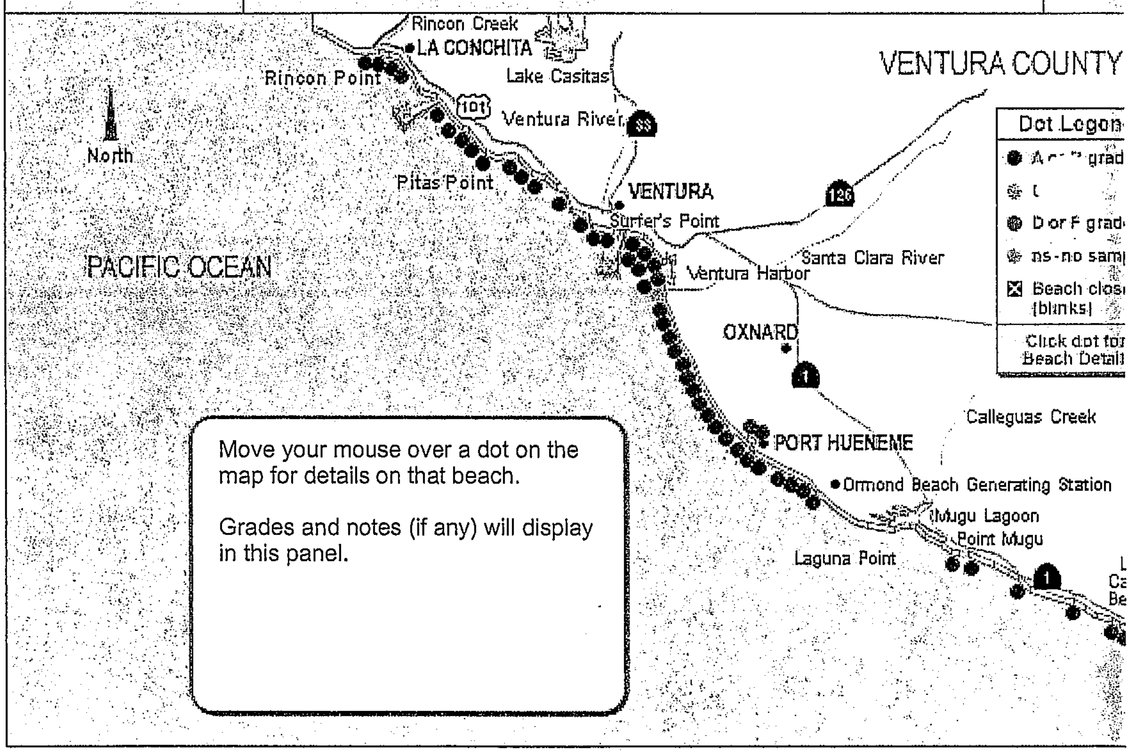
The Beach Report Card is made possible by a grant from Ford

Weekly Report Card - Grade Map

◄ CA State Map

Display Format	Now Showing
Grade Map View Text List	Area: Ventura County, CA Weather: Dry [Show Wet Grades] Grade Period: 4-week period ending June 28, 2006



REACH DOCUMENTATION Standard Reach Length (wetted width ≤10 m) = 150 m Distance between transects = 15 m
Alternate Reach Length (wetted width >10 m) = 250 m Distance between transects = 25 m

Project Name:	Date:	Time:
Stream Name:	Site Name/ Description:	
Site Code:	Crew Members:	
Latitude: °N	datum: NAD27 NAD83	
Longitude: °W		

AMBIENT WATER QUALITY MEASUREMENTS

Temperature (°C)		pH		Alkalinity (mg/L)		Turbidity (optional)	
Dissolved O_2 (mg/L)		Specific Cond. (µs)		Salinity (ppt)		Silica (optional)	

REACH LENGTH

150 m		Other	
Actual Length (m)			
Explanation:			

PHOTOGRAPHS:	A (up): ☐	F (up): ☐	F (down): ☐	K (down): ☐
Additional Photographs (optional):	A (down): ☐	K (up): ☐	Others:	

DISCHARGE MEASUREMENTS (first measurement = left bank) check if measurement not possible ☐

VELOCITY AREA METHOD (preferred) Transect Width:

	Distance from Bank (cm)	Depth (cm)	Velocity (m/sec)		Distance from Bank (cm)	Depth (cm)	Velocity (m/sec)
1				11			
2				12			
3				13			
4				14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			

BUOYANT OBJECT METHOD

	Float 1	Float 2	Float 3
Distance			
Float Time			

Float Reach Cross Section

width (m) depth (cm)	Upper Section	Middle Section	Lower Section
Width			
Depth 1			
Depth 2			
Depth 3			
Depth 4			
Depth 5			

NOTABLE FIELD CONDITIONS (check one box per topic)

Evidence of recent rainfall (enough to increase surface runoff)	NO		minimal		>10% flow increase	
Evidence of fires in reach or immediately upstream (<500 m)	NO		< 1 year		< 5 years	
Dominant land use/ land cover in area surrounding reach	Agriculture		Forest		Rangeland	
	Urban/ Indus		Suburb/Town		Other	

A009709

Site Code:	Date: __/__/____	[redacted]

SLOPE and BEARING FORM (transect based - for Full PHAB only)

CL=clionometer OT=other TR=autolevel HL=handlevel		MAIN SEGMENT					SUPPLEMENTAL SEGMENT				
Transect	**Method**	**Slope (%) or Elevation Difference (cm)**		**Segment Length (m)**	**Bearing (0°-359°)**	**Proportion (%)**	**Slope (%) or Elevation Difference (cm)**		**Segment Length (m)**	**Bearing (0°-359° C)**	**Proportion (%)**
K-J	CL TR HL OT		% cm					% cm			
J-I	CL TR HL OT		% cm					% cm			
I-H	CL TR HL OT		% cm					% cm			
H-G	CL TR HL OT		% cm					% cm			
G-F	CL TR HL OT		% cm					% cm			
F-E	CL TR HL OT		% cm					% cm			
E-D	CL TR HL OT		% cm					% cm			
D-C	CL TR HL OT		% cm					% cm			
C-B	CL TR HL OT		% cm					% cm			
B-A	CL TR HL OT		% cm					% cm			

REACH SLOPE (BASIC version only, use as many segments as needed)	**METHOD**	CL		HL		TR	HL	

SEGMENT 1		**SEGMENT 2**		**SEGMENT 3**		**SEGMENT 4**		**SEGMENT 5**		**SEGMENT 6**	
Slope (%) or Elevation Difference (cm)		Slope (%) or Elevation Difference (cm)		Slope (%) or Elevation Difference (cm)		Slope (%) or Elevation Difference (cm)		Slope (%) or Elevation Difference (cm)		Slope (%) or Elevation Difference (cm)	
	% cm		% cm		% cm		% cm		% cm		% cm

ADDITIONAL HABITAT CHARACTERIZATION

Parameter	Optimal	Suboptimal	Marginal	Poor
Epifaunal Substrate/ Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover (50% for low-gradient streams); mix of submerged logs, undercut banks, cobble or other stable habitat	40-70% mix of stable habitat (30-50% for low-gradient streams); well-suited for full colonization potential	20-40% mix of stable habitat (10-30% in low-gradient streams); substrate frequently disturbed or removed	Less than 20% stable habitat (10% in low-gradient streams); lack of habitat is obvious; substrate unstable or lacking
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition (>20% in low-gradient streams)	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% of the bottom affected (20-50% in low-gradient streams)	Moderate deposition of new gravel, sand, or fine sediment on bars; 30-50% of the bottom affected (50 - 80% in low-gradient streams)	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently (>80% in low-gradient streams)
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern	Some channelization present, (e.g., bridge abutments); evidence of past channelization (> 20yrs) may be present but recent channelization not present	Channelization may be extensive: embankments or shoring structures present on both banks; 40 to 80% of stream reach disrupted	Banks shored with gabion ' cement; Over 80% of the st reach channelized and disrup. Instream habitat greatly altered or removed entirely
Score:	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

SWAMP Stream Habitat Characterization Form   FULL VERSION   Original Issue Date: March 1, 2007

Site Code:	Site Name:	Date: __ __ / __ __ / __ __ __ __

Wetted Width (m):	Bankfull Width (m):	Bankfull Height:	**Transect:**

TRANSECT SUBSTRATES

Position	mm or Size Class	Depth (cm)	CPOM	Cobble Embed (%)
L Bank			P A	
LeftCtr			P A	
Center			P A	
RightCtr			P A	
R Bank			P A	

BANK STABILITY 5m up and 5m downstream of transect and from bankfull to wetted width

Left Bank	eroded	vulnerable	stable
Right Bank	eroded	vulnerable	stable

HUMAN INFLUENCE

0 = Not Present CH - Within Channel B = On Bank
C = Between Bank and 10 m from Channel P = >10 m and <50 m of Channel

	Left Bank				Channel	Right Bank			
Walls/ Rip-rap/ Dams	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P		0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P		0	B	C	P
Row Crops	0	B	C	P		0	B	C	P
Pasture/ Range	0	B	C	P		0	B	C	P
Logging Operations	0	B	C	P		0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P
Vegetation Management	0	B	C	P		0	B	C	P
Bridges/Abutments	0	B	C	P	CH	0	B	C	P
Orchards/ Vineyards	0	B	C	P		0	B	C	P

RIPARIAN VEGETATION (downstream)

0 = Absent (0%) 3 = Heavy (40-75%)
1 = Sparse (<10%) 4 = Very Heavy>75%)
2 = Moderate (10-40%) circle one

Vegetation Class	Left Bank					Right Bank				
Upper Canopy (>5 m high)										
Trees and saplings >5 m high	0	1	2	3	4	0	1	2	3	4
Lower Canopy (0.5 m-5 m high)										
Woody shrubs and saplings 0.5 m to 5 m	0	1	2	3	4	0	1	2	3	4
Ground Cover (<0.5 m high)										
Woody shrubs and saplings <0.5 m	0	1	2	3	4	0	1	2	3	4
Herbs/ grasses	0	1	2	3	4	0	1	2	3	4
Barren, bare soil/ duff	0	1	2	3	4	0	1	2	3	4

INSTREAM HABITAT COMPLEXITY

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)

Filamentous Algae	0	1	2	3	4
Aquatic Macrophytes/ Emergent Vegetation	0	1	2	3	4
Boulders	0	1	2	3	4
Woody Debris >0.3 m	0	1	2	3	4
Woody Debris <0.3 m	0	1	2	3	4
Undercut Banks	0	1	2	3	4
Overhang. Vegetation	0	1	2	3	4
Live Tree Roots	0	1	2	3	4
Artificial Structures	0	1	2	3	4

DENSIOMETER READINGS (0-17)
count covered dots

Center Left	
Center Upstream	
Center Downstream	
Center Right	

Inter-transect: not needed for last transect

indicate upper/ lower transects		Wetted Width (m):

FLOW HABITATS (% between transects, T=100%)

Channel Type	%
Cascade/ Fall	
Rapid	
Riffle	
Run	
Glide	
Pool	
Dry	

INTER-TRANSECT SUBSTRATES (measure in mm or use size classes)

Position (%)	mm or Size Class	Depth (cm)	CPOM
L Bank			P A
LeftCtr			P A
Center			P A
RightCtr			P A
R Bank			P A

Note: Substrate sizes can be recorded either as direct measures of the median axis of each particle or one of the size classes listed to right

SUBSTRATE SIZE CLASS CODES

RS = bedrock smooth (>car)
RR = bedrock rough (> car)
RC = concrete/asphalt
XB = large boulder (1-4 m)
SB = sml blder (.25 m-1 m)
CB = cobble (64-250 mm)
GC = coarse gravel (16-64 mm)
GF = fine gravel (2-16 mm)
SA = sand (0.06-2 mm)
FN = fines (<0.06 mm)
HP = hardpan (consol fines)
WD = wood
OT = other

CPOM/ COBBLE EMBEDDEDNESS

CPOM: Record presence (P)/ absence (A) of coarse particulate organic matter (>1.0 mm) within 1 cm of each particle.

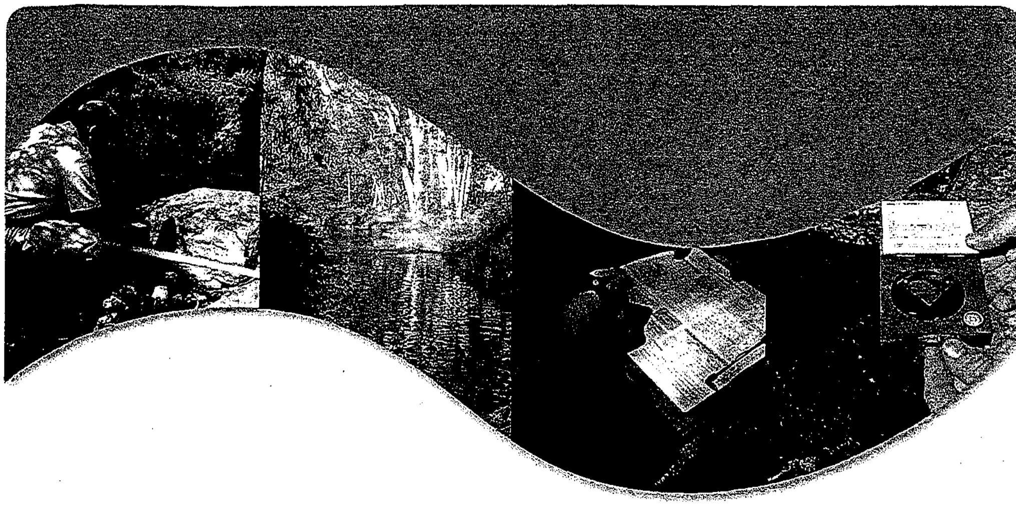
Cobble Embeddedness: visually estimate % embedded by fine particles (record to nearest 5%)

A005711

Site Code:	Date: __ / __ / ____	**FULL FORM**

Site Map:

Field Notes/ Comments:



SWAMP
Surface Water Ambient Monitoring Program

SWAMP Bioassessment Procedures 2007

Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California

February 2007

California Water Boards

www.waterboards.ca.gov/swamp

Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California

Prepared by: Peter R. Ode Peter Ode, SWAMP Bioassessment Coordinator, California Department of Fish and Game, Aquatic Bioassessment Laboratory

Preparation Date: January 23rd, 2007

Approved by: ____________ Beverly van Buuren, SWAMP QA Officer

Approval Date: 01/17/07

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ACKNOWLEDGEMENTS A

The protocols described here represent the contributions of a wide range of researchers and field crews. Most of the physical habitat methods are close modifications of those used in the U.S. Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP) and developed by EPA's Office of Research and Development (ORD, Peck et al. 2004). The benthic macroinvertebrate collection methods are based on EMAP methods (EPA's targeted riffle methods were derived in turn from methods developed at Utah State University; Hawkins et al. 2003).

The current version of these protocols was established by Peter Ode (Department of Fish and Game's (DFG's) Aquatic Bioassessment Laboratory (ABL)) and David Herbst (UC Santa Barbara's Sierra Nevada Aquatic Research Laboratory) with significant contributions from staff at the ABL (Jim Harrington, Shawn McBride, Doug Post, Andy Rehn, and Jennifer York), the Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance (QA) Team, Thomas Suk and other members of the SWAMP bioassessment committee (Mary Adams, Lilian Busse, Matt Cover, Robert Holmes, Sean Mundell, and Jay Rowan) and three external reviewers: Chuck Hawkins, Dave Peck, and Phil Kaufmann.

Ode, P.R.. 2007. Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

SWAMP GUIDANCE SG

SWAMP GUIDANCE FOR MACROINVERTEBRATE FIELD PROTOCOLS FOR WADEABLE STREAMS

Background: The SWAMP Bioassessment Committee met in December, 2004, and agreed that the SWAMP Quality Assurance Management Plan (QAMP) should be amended to provide greater consistency in bioassessment sampling protocols for wadeable streams. The Committee's recommendations were reviewed and accepted by the full SWAMP Roundtable[1] in February, 2005 (some of the key considerations are contained in Appendix A).

The current guidance for macroinvertebrate sampling under the SWAMP program is as follows:

1. For ambient bioassessment monitoring of wadeable streams in California, two methods are to be used at sites with riffle habitats (i.e., one "multihabitat" sample, and one sample that targets the "richest" habitat):
   - **For sites with sufficient riffle habitat,** the two samples shall be: (1) the reachwide benthos (RWB) method (also known as "multihabitat" sampling.); and (2) the targeted-riffle composite (TRC) method.
   - **For low-gradient sites that do not have sufficient riffle habitat,** the RWB method is the standard method, but we also recommend the option of collecting a sample with (2) the "Margin-Center-Margin" (MCM) method until ongoing methods comparisons are completed (see Appendix A).
   - **Notes:** (1) The protocols for each method are provided in this document; (2) Other appropriate method(s) will be allowed if the specific monitoring objectives require use of alternative method(s). (See Item #2, below.); (3) The protocol recommendations specified above will be reevaluated as results become available from ongoing methods comparison studies. (See Appendix A for more information.)

2. The SWAMP QAMP allows flexibility in sampling methods so that the most appropriate method(s) may be used to address hypothesis tests and project-specific objectives that differ from program objectives. Such situations may include, but are not necessarily limited to, special studies (e.g., evaluation of point source discharges, above/below comparisons where statistical replication is needed), stressor identification investigations, and long-term monitoring projects where consistent data comparability is desired and an alternative method is needed to achieve that comparability. In addition, in some rare cases where funding limitations would make it cost-prohibitive to complete a project in compliance with the protocols listed in #1, above, the project proponent may request to complete laboratory analysis of only one sample, and "archive" one of the macroinvertebrate samples (i.e., the RWB sample in streams with riffles) to reduce lab costs. Deviations from the protocols specified in #1 above may be granted by the SWAMP Bioassessment Coordinator or the full SWAMP Roundtable.

1. The SWAMP Roundtable is the coordinating entity for the program. Participants include staff from the State and Regional Water Boards, USEPA, the Department of Fish and Game, the Marine Pollution Studies Laboratory, Moss Landing Marine Laboratories, contractors, and other interested entities.

SECTION 1 INTRODUCTION

This document describes two standard procedures (TRC and RWB) for sampling benthic macroinvertebrate (BMI) assemblages for ambient bioassessments. This document also contains procedures for measuring instream and riparian habitats and ambient water chemistry associated with BMI samples. These sampling methods replace previous bioassessment protocols referred to as the California Stream Bioassessment Procedure (CSBP, Harrington 1995, 1999, 2002).

These procedures can produce quantitative and repeatable measures of a stream's physical/habitat condition and benthic invertebrate assemblages, but they require field training and implementation of QA measures throughout the field season.

The sampling layout described here provides a framework for systematically collecting a variety of physical, chemical, and biological data. The biological sampling methods are designed to nest within the overall framework for assessing the biotic, physical, and chemical condition of a reach. The layout used in these procedures and most of the physical habitat methods are close modifications of those used in EPA's EMAP and developed by EPA's ORD (Peck et al. 2004). Data collected using this methodology are generally directly comparable to equivalent EMAP data, except for the difference in reach length. Other exceptions are noted in the text.

The following steps are presented in an order suggested for efficient data collection. The specific order of collection for the physical parameters may be modified according to preferences of field crews, with the caveat that care must always be taken to not disturb the substrates within the streambed before BMI samples are collected.

PHYSICAL HABITAT METHODS

The physical habitat scoring methods described here can be used as a stand-alone evaluation or used in conjunction with a bioassessment sampling event. However, measurements of instream and riparian habitat and ambient water chemistry are essential to interpretation of bioassessment data and should always accompany bioassessment samples. This information can be used to classify stream reaches, associate physical and chemical condition with biotic condition, and explain patterns in the biological data.

Because bioassessment samples can be collected to answer a variety of questions, this document describes the component measures of instream and riparian habitat as independent modules. Although individual modules can be added or subtracted from the procedure to reflect specific project objectives, a standard set of modules will normally accompany bioassessment samples. This document describes two standard groupings of modules that represent two different levels of intensity for characterizing the chemical and physical habitat data (Table 1). The BASIC physical habitat characterization represents a minimum amount of physical and chemical data that should be taken along with any ambient BMI sample, the FULL physical habitat characterization represents the suite of data that should be collected with most professional level bioassessment samples (e.g., SWAMP regional monitoring programs). In addition to these data, we also briefly introduce additional data modules (e.g., excess sediment, periphyton) that can be collected as supplements to the full set (OPTIONAL). Table 1 lists the physical and chemical variables that should be measured under the different levels.

Note: *SWAMP intends to develop guidance for selecting appropriate physical habitat modules to the intended uses of data. Until this guidance is available, users of these protocols should consult with representatives of the Regional Water Quality Control Boards (Regional Boards) or the SWAMP Bioassessment Coordinator when selecting modules.*

FIELD CREW SIZE AND TIME ESTIMATES

These methods are designed to be completed by either two or three (or more) person field crews. A very experienced field crew can expect to complete the full suite of physical habitat measurements and the two BMI sampling protocols in approximately two hours. Less experienced crews will probably take closer to three or four hours to complete the work depending on the complexity of the reach. Note that this estimate includes only time at the site, not travel time between sites.

Equipment and Supplies

Recommended equipment and supplies are listed in Table 2.

Table 1. Summary of physical habitat and water chemistry and proposal for basic, full, and optional levels of effort.

Survey Task	Parameter(s)	Basic	Full	Option	Comments
REACH DELINEATION and WATER QUALITY [Conducted before entering stream to sample BMIs or conduct any habitat surveys]	Layout reach and mark transects, record GPS coordinates	X	X		Use 150-m reach length if wetted width ≤10 m; Use 250-m reach length if wetted width > 10 m
	Temperature, pH, specific conductance, DO, alkalinity	X	X		Multi-meter (e.g., YSI, Hydrolab, VWR Symphony)
	Turbidity, Silica			X	Use test kit or meter
	Notable field conditions	X	X		Recent rainfall, fire events, dominant local landuse
CROSS-SECTIONAL TRANSECTS BASIC Measurements at main 11 transects only FULL Measurements at 11 main transects (A, B, C, D, E, F, G, H, I, J, K) or 21 transects (11 main plus 10 inter-transects) for substrate size classes only	Wetted width	X	X		Stadia rod is useful here
	Flow habitat delineation	X	X		Record proportion of habitat classes in each inter-transect zone
	Depth and Pebble Count + CPOM		X		5 -point substrate size, depth and CPOM records at all 21 transects
	Cobble embeddedness		X		All cobble-sized particles in pebble count. Supplement with "random walk" if needed for 25
	Slope (%)	See reach scale	X		Average slope calculated from 10 transect to transect slope measurements. Use autolevel for slopes ≤ 1%; clinometer is OK for steeper gradients
	Sinuosity		X		Record compass readings between transect centers
	Canopy cover	X	X		Four densiometer readings at center of channel (facing L bank R bank, Upstream +Downstream)
	Riparian Vegetation		X		Record % or categories
	Instream Habitat		X		
	Human Influence		X		
	Bank Stability	X	X		Eroding / Vulnerable / Stable
	Bankfull Dimensions		X		
	Excess Sediment Transect Measures (optional)				
	Bankfull width and height bank angles			X	
	Large woody debris counts			X	Tallies of woody debris in several size classes
	Thalweg profile			X	100 equidistant points along thalweg

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Survey Task	Parameter(s)	Basic	Full	Option	Comments
DISCHARGE TRANSECT	Discharge measurements		X		Velocity-Area Method or Neutrally Buoyant Object Method
REACH SCALE MEASUREMENTS:	EPA-RBP visual scoring of habitat features	*		X	*Used for citizen monitoring and comparison with legacy data
	Selected RBP visuals:		X		Channel alteration, sediment deposition, epifaunal substrate (redundant if doing EPA-RBP scoring)
	Slope (%, not degrees)	X	See transect scale		Single measurement for entire reach only for BASIC. Use autolevel for slopes ≤ 1%, clinometer is OK for higher gradients
	Photo documentation	X	X		Upstream (A, F, K) Downstream (F)
OTHER OPTIONAL COMPONENTS					
FOOD RESOURCE QUANTIFICATION	Periphyton (3 replicates)			X	Qualitative characterization of diatom growth and filamentous algal growth, quantification of biomass (AFDM, chl-a)
	CPOM & FPOM (3 replicates)			X	CPOM field measure of wet mass >1 mm particles, FPOM as 0.25 – 1 mm fraction (AFDM in lab)

Table 2. Field equipment and supplies

Physical Habitat	BMI Collection	General/Ambient Chemistry
• GPS receiver • topographic maps • measuring tape (150-m) • small metric ruler or gravelometer for substrate measurements • digital watch, random number table or ten-sided die • stadia rod • clinometer • autolevel (for slopes < 1%) • handlevel (optional) • current velocity meter • stopwatch for velocity measurements • convex spherical densitometer • flags/ flagging tape • rangefinder	• D-frame kick net (fitted with 500-μ mesh bag) • standard # 35 sieve (500-μ mesh) • wide-mouth 500-mL or 1000 mL plastic jars • white sorting pan (enamel or plastic) • 95% EtOH • fine tipped forceps or soft forceps • waterproof paper and tape for attaching labels • 10-20-L plastic bucket for sample elutriation • preprinted waterproof labels (e.g., Rite-in-the-Rain™) • disposable gloves/ elbow length insulated gloves	• sampling SOP (this document) • hip or chest waders, or wading boots/shoes • field forms printed on waterproof paper (e.g., Rite-in-the-Rain™) • clip board and pencils • digital camera • centigrade thermometer • pH meter • DO meter • conductivity meter • field alkalinity meter • water chemistry containers • calibration standards • spare batteries for meters • first aid kit

SECTION 2 REACH DELINEATION AND WATER QUALITY

REACH LAYOUT AND GENERAL DOCUMENTATION

The systematic positioning of transects is essential to collecting representative samples and to the objective quantification of physical habitat measures. The standard sampling layout consists of a 150-m reach (length measured along the bank) divided into 11 equidistant transects that are arranged perpendicular to the direction of flow (Figure 1, Figure 2). Ten additional transects (designated "inter-transects") located between the main transects give a total of 21 transects per reach. Main transects are designated A through K while inter-transects are designated by their nearest upstream and downstream transects (e.g., AB, BC, etc.). In extreme circumstances, reach length can be shorter than 150 m (e.g., if upstream and downstream barriers preclude a 150-m reach), but this should be avoided whenever possible. If the actual reach length is other than 150 m or 250 m this should be noted and explained on the field forms.

Note 1: The standard reach length differs from that used in the EMAP design, in which reach length was defined as 40x stream width, with a minimum reach length of 150 m. The EMAP reach length approach is used to ensure that enough habitat is sampled to support accurate fish assemblage estimates and relatively precise characterization of channel characteristics (e.g., residual pool volumes and woody debris estimates, which that are critical for relative bed stability estimates). Programs wishing to sample fish assemblages or produce relative bed stability estimates should strongly consider adopting the EMAP guidance for setting reach length.

Note 2: Streams > 10 m wetted width should use a reach length of 250 m. Some very large streams (i.e., > 20-m wetted width) may not be adequately represented even by a 250-m reach. In these cases, field crews should define a reach length that is representative of the larger stream segment being studied (i.e., attempt to include two to three meander cycles, or four to six riffle-pool sequences when possible).

Note 3: When the exact reach location is not restricted by the sampling design, attempt to position reaches upstream of bridges to avoid this influence.

Step 1. Upon arrival at the sampling site, fill out the reach documentation section of the field forms (site and project identification, stream and watershed name, crew members, and date/time). If known at the time of sampling, record the Site Code following SWAMP site code formats. Determine the geographic coordinates of the downstream end of the reach (preferably in decimal degrees to at least four decimal places) with a GPS receiver and record the datum setting of the unit (preferably NAD83/ WGS84).

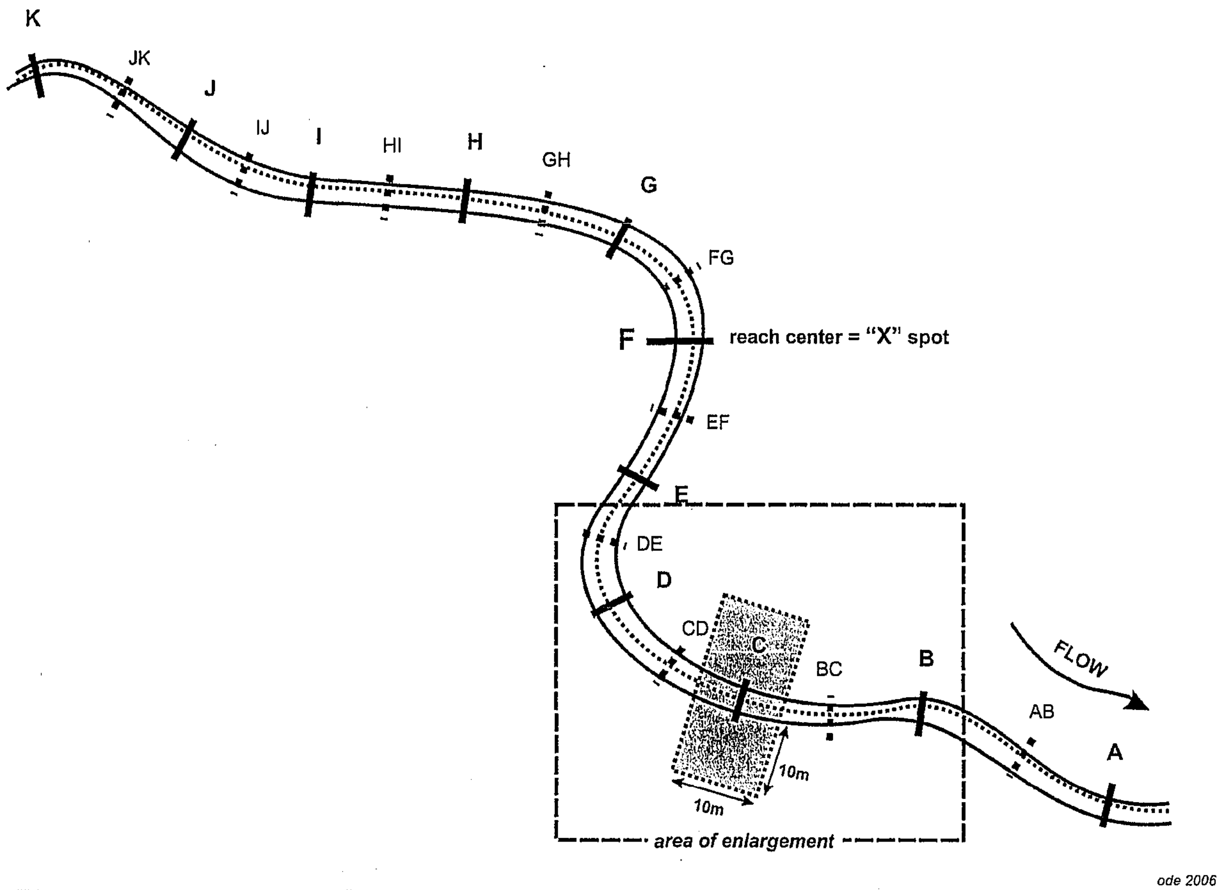

Figure 1. Reach layout geometry for physical habitat and biological sampling showing positions of 11 main transects (A – K) and the 10 supplemental inter-transects (AB- JK). The area highlighted in the figure is expanded in Figure 2. Note: reach length = 150 m for streams ≤ 10-m average wetted width, and reach length = 250 m for streams > 10-m average wetted width.

Step 2. Once a site has been identified, make an initial survey of the reach from the stream banks (being sure to not disturb the instream habitat). If TRC samples will be collected, identify all riffle habitats suitable for sampling (see Section IIIa for suitable habitat types) and note their positions so that a subset can be identified for sampling.

Step 3. Determine if the average wetted width is greater or less than 10 m. If the average wetted width ≤ 10 m, use a 150-m reach length. If the average wetted width > 10 m, use a 250-m reach length.

Step 4. Starting at one end of the reach, establish the position of the 11 main transects (labeled A-K from downstream to upstream) by measuring 15 m (25 m for streams > 10 m wetted width) along the bank from the previous transect. The 10 inter-transects should be established equidistant from the adjacent main transects (i.e., 7.5 m from main transects for 150-m reaches, 12.5 m for 250-m reaches). Since the data collection will start at the downstream end, is often easiest to establish transects starting from the upstream end. For easy setup and breakdown, mark the main transects with easily removable markers (e.g., large washers tied with strips of flagging, surveyor's flags).

Note 1: While it is usually easiest to establish transect positions from the banks (this also reduces disturbance to the stream channel), this can result in uneven spacing of transects in complex stream reaches. To avoid this, estimate transect positions by projecting from the mid-channel to the banks.

Note 2: Flagging of a single bank is recommended to reduce mistakes caused by missed markers.

Step 5. Measure and record common ambient water chemistry measurements (pH, DO, specific conductance, alkalinity, water temperature) at the downstream end of the reach (near same location as the GPS coordinates were taken). These are typically taken with a handheld water quality meter (e.g., YSI, Hydrolab), but field test kits (e.g., Hach) can provide acceptable information if they are properly calibrated. For appropriate calibration methods and calibration frequency, consult the current SWAMP QAMP (Appendix F), or follow manufacturer's guidelines.

Note 1: If characteristics of the site prohibit downstream entry, measurements may be taken at other points in the reach. In all cases, ambient chemistry measurements should be taken at the beginning of the reach survey.

Note 2: Alkalinity test kits may not perform well in low ionic strength waters. Programs should consider collecting lab samples for these sites (see SWAMP QAMP for guidance on collecting water chemistry samples).

Step 6. Take a minimum of four (4) photographs of the reach at the following locations: a) Transect A facing upstream, b) Transect F facing upstream, c) Transect F facing downstream, and d) Transect K facing downstream. It may also be desirable to take a photograph at Transect A facing downstream and Transect K facing upstream to document conditions immediately adjacent to the reach. Digital photographs should be used when possible. Record the image numbers on the front page of the field form.

Note 1: When possible, photograph names should follow SWAMP coding conventions ("StationCode_yyyy_mm_dd_uniquecode"). The unique code should include one of the following codes to indicate direction: RB (right bank), LB (left bank), BB (both banks), US (upstream), DS (downstream). SWAMP suggests using unique codes created by the camera to facilitate file organization. Example: 603WQLB02_2004_03_20_RBDS1253.

Step 7. Record the dominant land use and land cover in the area surrounding the reach (evaluate land cover within 50 m of either side of the stream reach).

Step 8. At the bottom of the form, record evidence of recent flooding, fire, or other disturbances that might influence bioassessment samples. Especially note if flow conditions have been affected by recent rainfall, which can cause significant under-sampling of BMI diversity (see note in the following section). If you are unaware of recent fire or rainfall events, select the "no" option on the forms.

SECTION 3 COLLECT BENTHIC MACROINVERTEBRATES

MULTIPLE HABITAT AND TARGETED RIFFLE PROTOCOLS

Note 1: BMI samples intended for ambient bioassessments are generally collected when streams are at or near base flow (i.e., not influenced by surface runoff) as sudden flow increases can dramatically alter local community composition.

Note 2: Guidance for choosing among TRC sampling, RWB sampling or both will be provided in a separate document (see Appendix A for current guidance for sampling under SWAMP).

Once the reach transects have been laid out, the biological samples (BMIs and algae if included) should be collected before any other physical habitat measures so that substrates are not disturbed prior to sampling. Both TRC and RWB methods use 500-µ mesh D-frame nets (see list of BMI sampling equipment in Table 2). The two samples can be collected at the same time by carrying two D-nets and compositing the material from the two samples in their respective nets. If a two person field crew is responsible for both the physical habitat data and benthic invertebrate samples, it is generally best to collect the benthos at each transect, then immediately record the physical habitat data before moving to the next transect. Obviously, this requires especially careful handling of the D-nets during the course of sampling to avoid loss or contamination of the samples. It can be helpful to clearly label the two D nets as RWB and TRC. Larger field crews may choose to split the sampling between biological team and a physical habitat team and have the biological team go through the reach first. The positions of the TRC and RWB subsampling locations are illustrated in Figure 2.

SECTION III A. TARGETED RIFFLE COMPOSITE PROCEDURE

The TRC method is designed for sampling BMIs in wadeable streams that contain fast-water (riffle/run) habitats and is not appropriate for waterbodies without fastwater habitats. The RWB protocol should be used in these situations. Riffles are often used for collecting biological samples (e.g., the old CSBP methods) because they often have the highest BMI diversity in wadeable streams. This method expands the definition to include other fast water habitats, however care should be taken when attempting to apply this method in low gradient streams.

Note: Since all streams (even low gradient streams) have variation in flow habitats within the channel, this guidance should not be interpreted as including areas within low gradient streams that are only marginally faster than the surrounding habitats. The RWB protocol should be applied in these situations.

The TRC was developed by the Western Center for Monitoring and Assessment of Freshwater Ecosystems (www.cnr.usu.edu/wmc) in Logan, Utah (Hawkins et al. 2003) and slightly modified by the EPA program (Peck et al. 2004). The TRC has been widely used in California (US Forest Service (USFS), the EMAP Western Pilot, and the California Monitoring and Assessment Program (CMAP)), and in the interest of methodological consistency between state and federal water resource agencies, has been adopted as the standard riffle protocol for bioassessment in California. The version described here is the EMAP modification, which distributes the sampling effort throughout the reach.

Sampling Locations – Acceptable Habitat Types

Riffles are the preferred habitat for TRC sampling, but other fast water habitats are acceptable for sampling if riffles are sparse. Common flow-defined habitat types are listed in Table 3 in decreasing order of energy. Most streams contain some or all of the following fast water habitat types: 1) cascades/falls, 2) rapids, 3) riffles, 4) runs. All of these are acceptable for TRC sampling if riffles are not available.

Note: Because the common habitat types are arranged on a continuum between high to low energy environments, the categories grade into each other continuously and are not discrete. Thus, determination of habitat types requires somewhat subjective decision-making.

Table 3. Common habitat types in stream channels, arranged in decreasing order of energy

Flow Habitat Type	Description
Cascades	Short, high gradient drop in stream bed elevation often accompanied by boulders and considerable turbulence
Falls	High gradient drop in elevation of the stream bed associated with an abrupt change in the bedrock
Rapids	Sections of stream with swiftly flowing water and considerable surface turbulence. Rapids tend to have larger substrate sizes than riffles
Riffles	Shallow sections where the water flows over coarse stream bed particles that create mild to moderate surface turbulence; (< 0.5 m deep, > 0.3 m/s)
Step-Runs	A series of runs that are separated by short riffles or flow obstructions that cause discontinuous breaks in slope
Runs	Long, relatively straight, low-gradient sections without flow obstructions. The stream bed is typically even and the water flows faster than it does in a pool; (> 0.5 m deep, > 0.3 m/s)
Glides	A section of stream with little or no turbulence, but faster velocity than pools; (< 0.5 m deep, < 0.3 m/s)
Pools	A reach of stream that is characterized by deep, low-velocity water and a smooth surface ; (> 0.5 m deep, < 0.3 m/s)

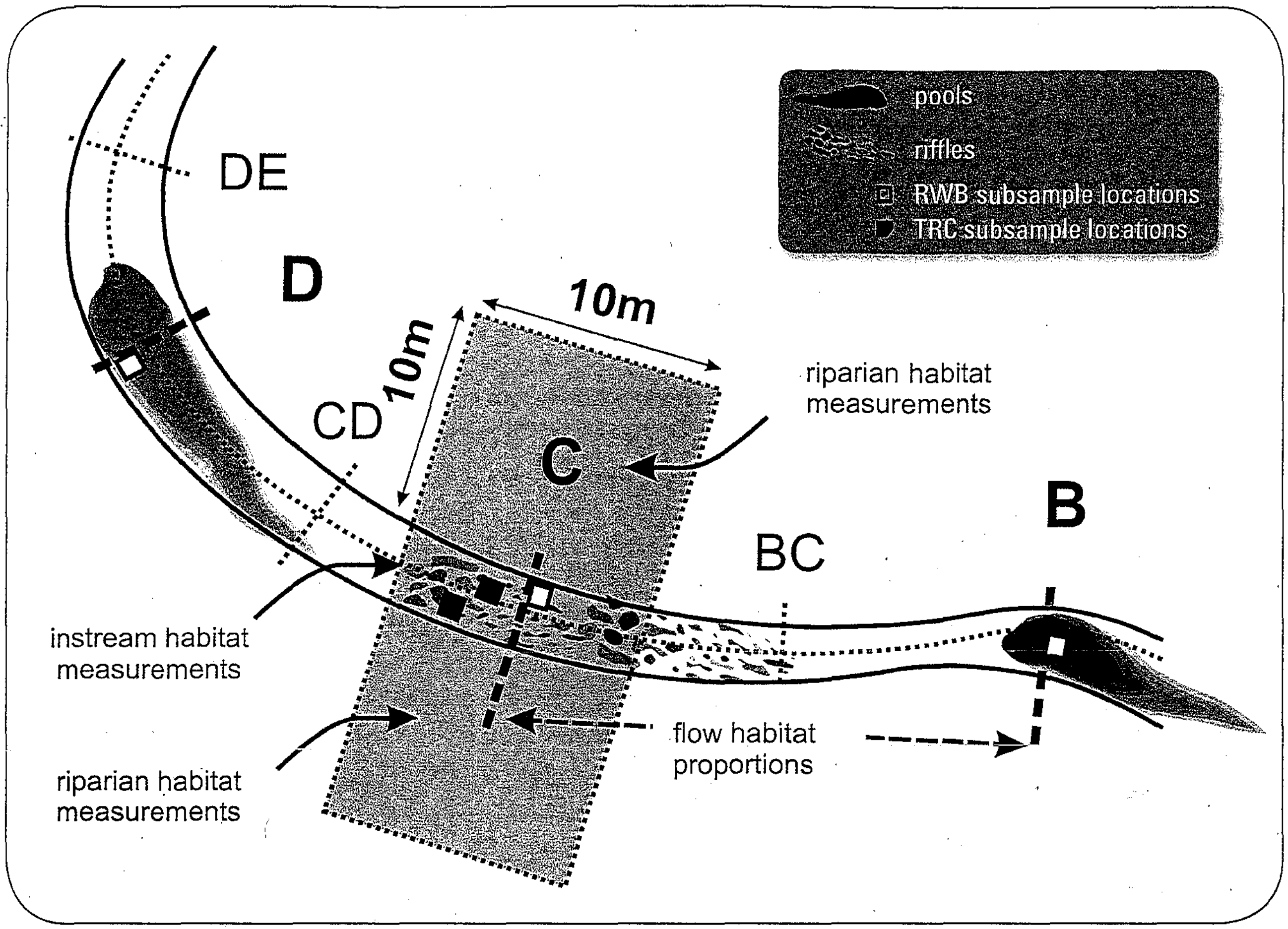

Figure 2. Section of the standard reach expanded from Figure 1 showing the appropriate positions for collecting benthic macroinvertebrate samples, instream and riparian habitat measurements and flow habitat proportion measurements.

Sampling Locations – Selecting Habitat Units

A TRC sample is a composite of eight individual kick samples of 1 ft² (0.09 m²) of substrate each. During your initial layout of the reach, take a mental note of the number and position of the main riffles in a reach (and other fast water habitats if needed). Randomly distribute the eight sub-samples among the fast water habitats in the reach, giving preference to riffles where possible. Unless you are sampling in small streams, try to avoid very small riffle units (i.e., < 5 ft²). If fewer than eight riffles are present in a reach, more than one sample may be taken from a single riffle, especially if the riffles are large.

Sampling Procedure

Begin sampling at the downstream end of the reach at the first randomly selected riffle and work your way upstream.

TRC-Step 1. Determine net placement within each habitat unit by generating a pair of random numbers between 0 and 9. Examples of convenient random number generators include the hundredths place on the stopwatch feature of a digital watch, a 10 sided die and a random number chart. The first number in each pair (multiplied by 10) represents the percent upstream along the habitat unit's length. The second number in each pair represents the percent of the riffle width from right bank. For example, if the two generated random numbers are 4 and 7, you will walk upstream 40% of the distance of the riffle and then go 70% of the distance across the riffle (see Figure 3). This position is the center of the 1 ft^2 (0.09 m^2) sampling quadrat for that riffle. If you are unable to sample this location because it is too deep or it is occupied by a large boulder, select a new pair of random numbers and pick a new spot.

TRC-Step 2. Position a 500-µ D-net (with the net opening perpendicular to the flow and facing upstream) quickly and securely on the stream bottom to eliminate gaps under the frame. Avoid, and if necessary remove, large rocks that prevent the sampler from seating properly on the stream bottom.

TRC-Step 3. Holding the net in position on the substrate, visually define a square quadrat that is one net width wide and one net width long upstream of the net opening. Since D-nets are 12 inches wide, the area within this quadrat is 1ft^2 (0.09 m^2). Restrict your sampling to within that area. If desired, a wire frame of the correct dimensions can be placed in front of the net to help delineate the quadrat to be sampled, but it is often sufficient to use the net dimensions to keep the sampling area consistent.

TRC-Step 4. Working backward from the upstream edge of the sampling plot, check the quadrat for heavy organisms such as mussels, snails, and stone-cased caddisflies. Remove these organisms from the substrat by hand and place them into the net. Carefully pick up and rub stones directly in front of the net to remove attached animals. Remove and clean all of the rocks larger than a golf ball (~3 cm) within your sampling quadrat such that all the organisms attached to them are washed downstream into your net. Set these rocks outside your sampling quadrat after you have cleaned them. If the substrate is consolidated or comprised of large, heavy rocks, use your feet to kick and dislodge the substrate to displace BMIs into the net. If you cannot remove a rock from the stream bottom, rub it (concentrating on cracks or indentations) thereby loosening any attached insects. As you are disturbing the plot, let the water current carry all loosened material into the net.

Note 1: *Brushes are sometimes used in other bioassessment protocols to help loosen organisms, but in the interest of standardizing collections, do not use a brush when following this protocol.*

Note 2: *In sandy-bottomed streams, kicking within run habitats can quickly fill the sampling net with sand. In these situations, follow the standard procedures but use care to disturb the substrate gently and avoid kicking.*

TRC-Step 5. Once the coarser substrates have been removed from the quadrat, dig your fingers through the remaining underlying material to a depth of about 10 cm (this material is often comprised of gravels and finer particles). Thoroughly manipulate the substrates in the quadrat.

Note: The sampler may spend as much time as necessary to inspect and clean larger substrates, but should take a standard time of 30 seconds to perform Step 5.

TRC-Step 6. Let the water run clear of any insects or organic material before carefully lifting the net. Immerse the net in the stream several times to remove fine sediments and to concentrate organisms at the end of the net, but be careful to avoid having any water or foreign material enter the mouth of the net during this operation.

TRC-Step 7. Move upstream to the next randomly selected habitat unit and repeat steps one through six, taking care to keep the net wet but uncontaminated by foreign material when moving the net from riffle to riffle. Sometimes, the net will become so full of material from the streambed that it is no longer effective at capturing BMIs. In these cases, the net should be emptied into sample jars as frequently as necessary, following guidelines described below in the "Preparation of BMI Sample Jars" section. Continue until you have sampled eight 1ft² (0.09 m²) of benthos.

TRC-Step 8. PROCEED to Section IIIc. Filling and Labeling BMI Sample Jars.

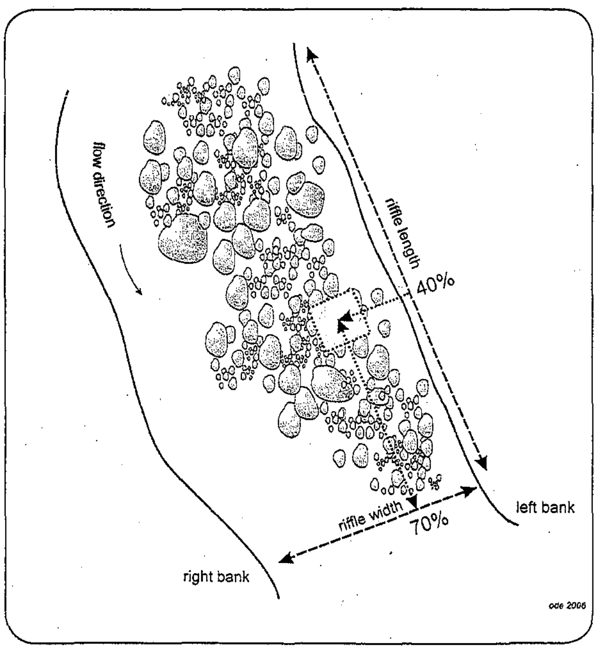

Figure 3. Example showing the method for selecting a subsampling position within a selected riffle under the TRC method. In this example, the random numbers 4 and 7 were selected

SECTION III B. REACHWIDE BENTHOS (MULTIHABITAT) PROCEDURE

The RWB procedure employs an objective method for selecting subsampling locations that is built upon the 11 transects used for physical habitat measurements. The RWB procedure can be used to sample any wadeable stream reach since it does not target specific habitats. Because sampling locations are defined by the transect layout, the position of individual sub-samples may fall in a variety of erosional or depositional habitats.

Note: Sampling locations should be displaced one meter downstream of the transects to avoid disturbing substrates for subsequent physical habitat assessments.

RWB -Step 1. The sampling position within each transect is alternated between the left, center and right positions along a transect (25%, 50% and 75% of wetted width, respectively) as you move upstream from transect to transect. Starting with the downstream transect (Transect

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A), identify a point that is 25% of the stream width from the right bank (note that the right bank will be on your left as you face upstream). If you cannot collect a sample at the designated point because of deep water obstacles or unsafe conditions, relocate the point as close as possible to the designated position.

Note: *A modification to this procedure is currently being investigated by SWAMP. This "margin-center-margin" (MCM) modification replaces the samples at 25% and 75% of wetted width with samples of the marginal habitats (including emergent and submergent vegetation).*

RWB -Step 2. Place a 500-µ D-net in the water so the mouth of the net is perpendicular to and facing into the flow of the water. If there is sufficient current in the area at the sampling point to fully extend the net, use the normal D-net collection technique to collect the sub-sample (TRC-Step 3 through TRC-Step 6 above). If flow volume and velocity is not sufficient to use the normal collection technique, use the sampling procedure for "slack water" habitats (RWB-Step 3 through RWB-Step 7 below).

RWB -Step 3. Visually define a 1 ft^2 (0.09 m^2) quadrat that is one net-width wide and one net-width long at the sampling point.

RWB -Step 4. Working backward from the upstream edge of the sampling plot, check the quadrat for heavy organisms such as mussels and snails. Remove these organisms from the substrate by hand and place them into the net. Carefully pick up and rub stones directly in front of the net to remove attached animals. Remove and clean all of the rocks larger than a golf ball within your sampling quadrat such that all the organisms attached to them are washed downstream into your net. Set these rocks outside your sampling quadrat after you have cleaned them. Large rocks that are less than halfway into the sampling area should be pushed aside. If the substrate is consolidated or comprised of large, heavy rocks, use your feet to kick and dislodge the substrate to displace BMIs into the net. If you cannot remove a rock from the stream bottom, rub it (concentrating on cracks or indentations) thereby loosening any attached insects.

RWB -Step 5. Vigorously kick the remaining finer substrate within the quadrat with your feet while dragging the net repeatedly through the disturbed area just above the bottom. Keep moving the net all the time so that the organisms trapped in the net will not escape. Continue kicking the substrate and moving the net for 30 seconds. For vegetation-choked sampling points, sweep the net through the vegetation within a 1ft^2 (0.09 m^2) quadrat for 30 seconds.

Note: *If flow volume is insufficient to use a D- net, spend 30 seconds hand picking a sample from 1ft^2 of substrate at the sampling point, then stir up the substrate with your gloved hands and use a sieve with 500-µ mesh size to collect the organisms from the water in the same way the net is used in larger pools.*

RWB -Step 6. After 30 seconds, remove the net from the water with a quick upstream motion to wash the organisms to the bottom of the net.

RWB -Step 7. PROCEED to Section IIIc: Filling and Labeling BMI Sample Jars

SECTION III C. FILLING AND LABELING BENTHIC MACROINVERTEBRATE SAMPLE JARS

Step 1. Once all sub-samples (eight for TRC, 11 for RWB) have been collected, transfer benthos to a 500-mL or 1000-mL wide-mouth plastic sample jar using one of the following methods.

Note: Field elutriation should only be used by well-trained field crews who are proficient at removing all benthic organisms from the discarded inorganic material. Training in the recognition of aquatic invertebrates is highly recommended.

Step 1a. Complete Transfer of all Sampled Material – Invert the contents of the kick net into the sample jar. Perform this operation over a white enameled tray to avoid loss of any sampled material and make recovery of spilled organisms easier. If possible, remove the larger twigs and rocks by hand after carefully inspecting for clinging organisms, but be sure not to lose any organisms. Use forceps to remove any organisms clinging to the net and place these in the sample jar.

Step 1b. Field Elutriation of Samples – Empty the contents of the net into a large plastic bucket (10-20 L is sufficient). Use forceps to remove any organisms clinging to the net and place these in the bucket. Add stream water to the bucket and gently swirl the contents of the bucket in order to suspend the organic material (being certain to not introduce entrained organisms from the source water). Pour the organic matter from the bucket through a 500-µ sieve (or use the 500-µ net). Repeat this process until no additional material can be elutriated (i.e., only inorganic material is left in the bucket). If possible, remove the larger twigs and rocks by hand after carefully inspecting for clinging organisms, but be sure not to lose any organisms. Transfer all of the material in the sieve (invertebrates and organic matter) into the sample jar. Carefully inspect the gravel and debris remaining in the bottom of the bucket for any cased caddisflies, clams, snails, or other dense animals that might remain. Remove any remaining animals by hand and place them in the sample jar.

		circle one:
Latitude: N	W	NAD27
Longitude: N	W	NAD83
Stream Name:		
Site Name/ Code:		
County:	Jar #:	of
Date:	Time:	
		circle one:
Collector:	BMI Method:	TRC RWB

Figure 4. Example date - locality label for all BMI samples.

Step 2. Place a completed date/locality label (see Figure 4) on the inside of the jar (use pencil only as most "permanent" inks dissolve in ethanol) and completely fill with 95% ethanol. Place a second label on the outside of the jar. Note that the target concentration of ethanol is 70%, but 95% ethanol is used in the field to account for dilution from water in the sample. If organic and inorganic material does not accumulate in the net quickly, it may be possible to transfer all the material in the net into one jar. Otherwise, divide the material evenly among several jars (being careful to clearly label them as part of a set). To ensure proper preservation of benthic macroinvertebrates it is critical that the ethanol is in contact with the BMIs in the sample jar. Never fill a jar more than 2/3 full with sampled material, and gently rotate jars that contain mostly mud or sand to ensure that the ethanol is well distributed. If jars will be stored for longer than a month prior to processing, jars should not contain more than 50% sample material.

SECTION 4
MAIN CROSS-SECTIONAL TRANSECT MEASURES

SECTION IVA. PHYSICAL MEASURES

The majority of physical habitat measurements in this protocol are made relative to the main cross-sectional transects (Figure 5). All the measures taken relative to each transect are recorded on forms specific to that transect. Start with the downstream transect (Transect A) and repeat steps 6-15 for all 11 main transects.

Module A. Transect Dimensions: Wetted Width and Bankfull Dimensions

Wetted Width – The wetted channel is the zone that is inundated with water and the wetted width is the distance between the sides of the channel at the point where substrates are no longer surrounded by surface water. Measure the wetted stream width and record this in the box at the top of the transect form.

Bankfull Width and Depth – The bankfull channel is the zone of maximum water inundation in a normal flow year (one to two year flood events). Since most channel formation processes are believed to act when flows are within this zone (Mount 1995), bankfull dimensions provide a valuable indication of relative size of the waterbody.

Note: *Bankfull dimensions are notoriously difficult to assess, even by experienced field crews (see Heil and Johnson 1995). It is often useful to discuss the interpretation of bankfull locations among the field crew members to reach a consensus. The USFS Stream Team provides a good set of instructional videos for improving consistency in accurate bankfull measurements (http://www.stream.fs.fed.us/publications/videos.html).*

Step 1. Scout along the stream margins to identify the location of the bankfull margins on either bank by looking for evidence of annual or semi-annual flood events. Examples of useful evidence includes topographic, vegetative, or geologic cues (changes in bank slope, changes from annual to perennial vegetation, changes in the size distribution of surface sediments). While the position of drift material caught in vegetation may be a helpful aid, this can lead to very misleading measurements.

Note: *The exact nature of this evidence varies widely across a range of stream types and geomorphic characteristics. It is helpful to investigate the entire reach when attempting to interpret this evidence because the true bankfull margin may be obscured at various points along the reach. Often the bankfull position is easier to interpret from one bank than the other; in these cases, it is easiest to infer the opposite bank position by projecting across the channel. Additionally, height can be verified by measuring the height from both edges of the wetted channel to the bankfull height (these heights should be equal).*

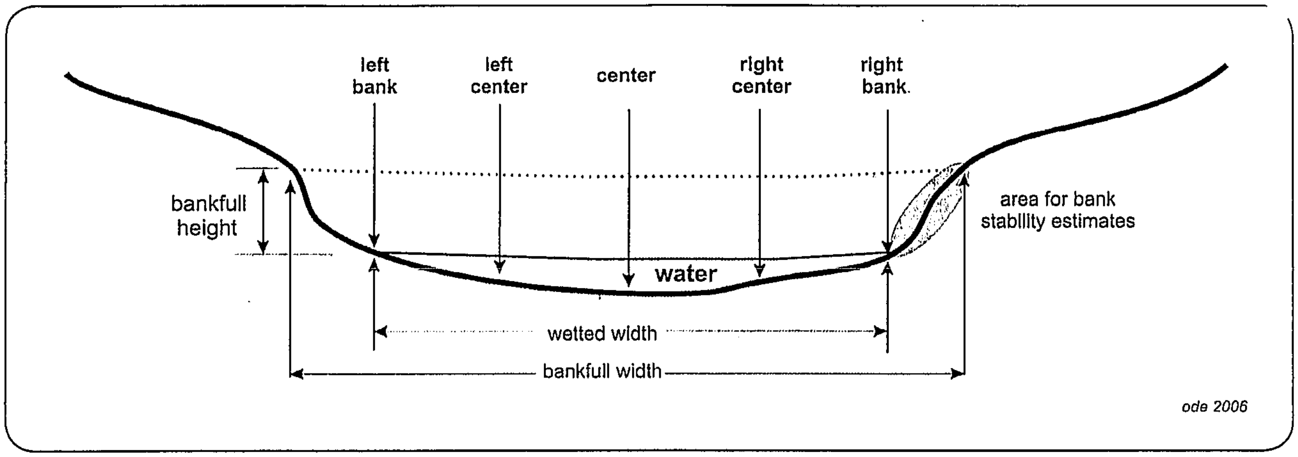

Figure 5. Cross sectional diagram of a typical stream channel showing locations of substrate measurements, wetted and bankfull width measurements, and bank stability visual estimates.

Step 2. Stretch a tape from bank to bank at the bankfull position. Measure the width of the bankfull channel from bank to bank at bankfull height and perpendicular to the direction of stream flow.

Step 3..Measure bankfull height (the vertical distance between the water height of the water and the height of the bank, Figure 5) and record.

Module B. Transect Substrate Measurements

Particle size frequency distributions often provide valuable information about instream habitat conditions that affect BMI distributions. The Wolman pebble count technique (Wolman 1954) is a widely used and cost-effective method for estimating the particle size distribution and produces data that correlates with costly, but more quantitative bulk sediment samples. The method described here follows the EMAP protocol, which records sizes of 105 particles in a reach (five particles from each of 11 main transects and 10 inter-transects).

Note: *The size cutoff for the finest particle sizes in the EMAP protocol (< 0.06 mm) differs from that used by the Sierra Nevada Aquatic Research Laboratory (SNARL) program (0.25 mm), although the narrative description for this cutoff is the same (the point at which fine particles rubbed between one's fingers no longer feel gritty).*

Coarse particulate organic matter (CPOM, particles of decaying organic material such as leaves that are greater than 1.0 mm in diameter) is a general indicator of the amount of allochthonous organic matter available at a site, and its measurement can provide valuable information about the basis of the food web in a stream reach. The presence of CPOM associated with each particle is quantified at the same time that particles are measured for the pebble counts.

Step 1. Transect substrate measurements are taken at five equidistant points along each transect (Figure 5). Divide the wetted stream width by four to get the distance between the five points (Left Bank, Left Center, Center, Right Center and Right Bank) and use a measuring device to locate the positions of these points (a stadia rod is especially helpful here). Once the positions are identified, lower a graduated rod (e.g., a marked ski pole) though the water column perpendicular to both the flow and the transect to objectively select the particle located at the tip of the rod.

Step 2. Measure the depth from the water surface to the top of the particle with the graduated rod and record to the nearest cm.

Step 3. Record the presence or absence of CPOM >1mm within 1 cm of the particle.

Step 4. If the particle is cobble-sized (64-250 mm), record the percent of the cobble that is embedded by fine particles (<2 mm) to the nearest 5% (see cobble embeddedness text below).

Step 5. Remove the particle from the streambed, then measure and record the length of its intermediate axis to the nearest mm (see Figure 6). Alternatively, assign the particle to one of the size classes listed in the bottom of the transect form. Particle sizes classes can be estimated visually or with a quantitative measuring device (e.g., pass/ no-pass template, "gravelometer"). Regardless of the method, all particles less than 0.06 mm should be recorded as fines, all particles between 0.06mm and 2.0 mm recorded as sand. Field crews may want to carry vials containing sediment particles with these size ranges until they are familiar with these particles.

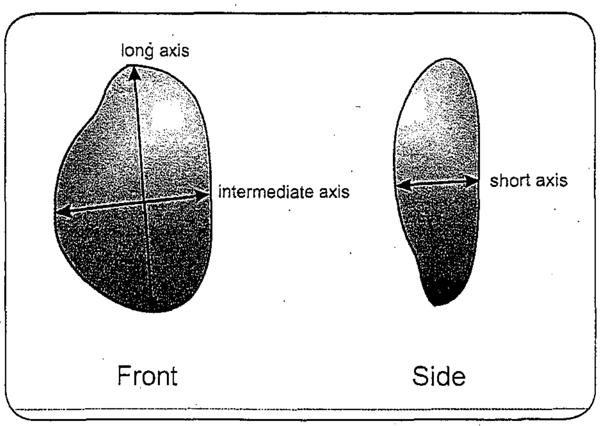

Figure 6. Diagram of three major perpendicular axes of substrate particles. The intermediate axis is recorded for pebble counts.

Module C. Cobble Embeddedness

The quantification of substrate embeddedness has long been a challenge to stream geomorphologists and ecologists (Klamt 1976, Kelley and Dettman 1980). It is generally agreed that the degree to which fine particles fill interstitial spaces has a significant impact on the ecology of benthic organisms and fish, but techniques for measuring this impact vary greatly (this is summarized well by Sylte and Fischenich 2002, http://stream.fs.fed.us/news/streamnt/pdf/StreamOCT4.pdf). Here we define embeddedness as the volume of cobble-sized particles (64-250 mm) that is buried by fine particles (<2.0 mm diameter).

Note: This method differs from the EMAP method for measuring embeddedness, which measures embeddedness of all particles larger than 2 mm.

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Table 4. Size class codes and definitions for particle size measurements

Size Class Code	Size Class Description	Common Size Reference	Size Class Range
RS	bedrock, smooth	larger than a car	>4 m
RR	bedrock, rough	larger than a car	>4 m
XB	boulder, large	meter stick to car	1 - 4 m
SB	boulder, small	basketball to meter stick	25 cm - 1.0 m
CB	cobble	tennis ball to basketball	64 - 250 mm
GC	gravel, coarse	marble to tennis ball	16 - 64 mm
GF	gravel, fine	ladybug to marble	2 – 16 mm
SA	sand	gritty to ladybug	0.06 – 2 mm
FN	fines	not gritty	< 0.06 mm
HP	hardpan (consolidated fines)		< 0.06 mm
WD	wood		
RC	concrete/ asphalt		
OT	other		

Step 1. Every time a cobble-sized particle is encountered during the pebble count, remove the cobble from the stream bed and visually estimate the percentage of the cobble's volume that has been buried by fine particles. Since visual estimates of volume and surface area are subject to large amounts of observer error, field crews should routinely calibrate their estimates with each other and with other field crews.

Step 2. In the spaces to the right of the pebble count data, record the embeddedness of all cobble-sized particles encountered during the pebble count.

Note: The cobble embeddedness scores do not correspond with the specific particles in the pebble count cells to the left, but are merely a convenient place to record the data.

Step 3. If 25 cobbles are not encountered during the pebble count, supplement the cobbles by conducting a "random walk" through the reach. Starting at a random point in the reach, follow a transect from one bank to the other at a randomly chosen angle. Once at the other bank reverse the process with a new randomly chosen angle. Record embeddedness of cobble-sized particles in the cobble embeddedness boxes on the transect forms until you reach 25 cobbles. If 25 cobble-sized particles are not present in the entire reach, then record the values for cobbles that are present.

Module D. Canopy Cover

This method uses the Strickler (1959) modification of a convex spherical densiometer to correct for over-estimation of canopy density that occurs with unmodified readings. Read the densiometer by counting the number of line intersections that are obscured by overhanging vegetation (see Figure 7). Taping off the lower left and right portions of the mirror emphasizes overhead vegetation over foreground vegetation (the main source of bias in canopy density measurements). All densiometer readings should be taken with the bubble leveled and 0.3 m (1 ft) above the water surface.

Step 1. Using a modified convex spherical densitometer, take and record four 17-point readings all taken from the center of each transect: a) facing upstream, b) facing downstream, c) facing the left bank, d) facing the right bank.

Note: This method deviates slightly from that of EMAP (in which two additional readings are taken at the left and right wetted edges to increase representation of bank vegetation).

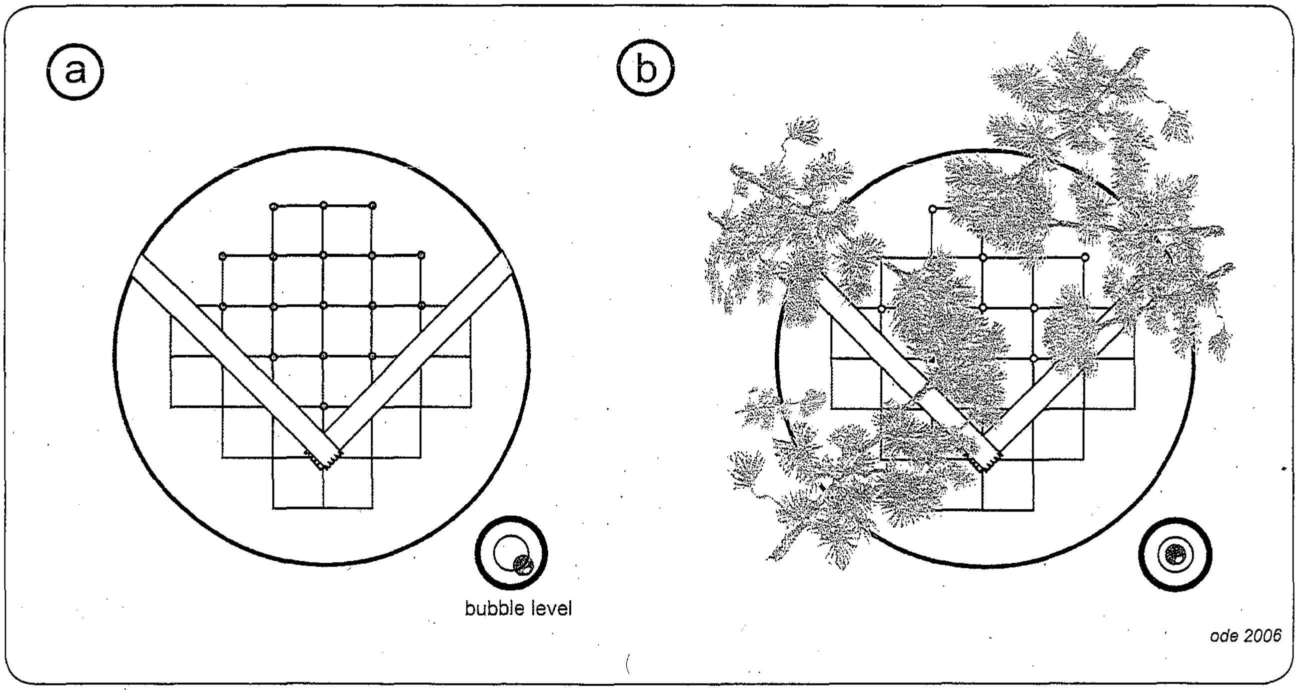

Figure 7. Representation of the mirrored surface of a convex spherical densiometer showing the position for taping the mirror and the intersection points used for the densiometer reading. The score for the hypothetical condition in (b) is 10 covered intersection points out of 17 possible. Note the position of the bubble level in (b) when the densiometer is leveled.

Module E. Gradient and Sinuosity

The gradient of a stream reach is one of the major stream classification variables, giving an indication of potential water velocities and stream power, which are in turn important controls on aquatic habitat and sediment transport within the reach. The gradient (slope) of a stream reach is often strongly correlated with many BMI metrics and other physical habitat measures and is therefore very useful when interpreting BMI data.

The "full" physical habitat method uses 10 transect to transect measurements to calculate the average slope through a reach. Although this is a little more time intensive than the reach-scale transect measures used in the "basic" protocol, it results in more precise slope determination and the ability to quantify slope variability within a reach. Sinuosity (calculated as the ratio of the length of the flow path between the ends of the reach and the straight line distance between the ends of the reach, Kaufmann et al. 1999) is measured at the same time as slope. These two measurements work best with two people, one taking the readings at the upstream transect ("backsighting") and the other holding a stadia rod at the downstream transect. If you cannot see the mid point of the next transect from the starting point, use the supplemental sections (indicating the proportion of the total length represented by each section). Otherwise, leave these blank.

Note 1: An auto level should be used for reaches with a percent slope of less than or equal to 1%. All methods (clinometer, hand level, or auto level) may be used for reaches with a percent slope of greater than 1%. The following description is for clinometer-based slope measurements, but the same principles apply to use of an auto or hand level.

Note 2: In reaches that are close to 1%, you will not know whether you are above or below the 1% slope cutoff before taking readings. In these cases, default to use of an autolevel.

Step 1. Beginning with the upper transect (Transect K), one person (the measurer) should stand at the water margin with a clinometer held at eye level. A second person should stand at the margin of the next downstream transect (Transect J) with a stadia rod flagged at the eye level of the person taking the clinometer readings. Be sure you mark your eye level while standing on level ground! Adjust for water depth by measuring from the same height above the water surface at both transects. This is most easily accomplished by holding the base of the pole at water level.

Note: An alternative technique is to use two stadia rods pre-flagged at the eye-height of the person taking the readings.

Step 2. Use a clinometer to measure the percent slope of the water surface (not the streambed) between the upstream transect and the downstream transect by sighting to the flagged position on the stadia rod. The clinometer reads both percent slope and degree of the slope. Be careful to read and record percent slope rather than degrees slope (these measurements differ by a factor of ~2.2). Percent slope is the scale on the right hand side as you look through most clinometers (e.g., Suunto models).

Note: If an auto level or hand level is used, record the elevation difference (rise) between transects and the segment length (run) instead of the percent slope.

Step 3. If the stream reach geometry makes it difficult to sight a line between transects, divide the distance into two or three sections and record the slope and the proportion of the total segment length between transects for each of these sections in the appropriate boxes on the slope form (supplemental segments).

Note: Never measure slope across dry land (e.g., across a meander bend).

Step 4. Take a compass reading from the center of each main transect to the center of the next main transect downstream and record this bearing to the nearest degree on the slope and bearing section of the form. Bearing measurements should always be taken from the upstream to downstream transect.

Step 5. Proceed downstream to the next transect pair (I-J) and continue to record slope and bearing between each pair of transects until measurements have been recorded for all transects.

SECTION IVB. VISUAL ESTIMATES OF HUMAN INFLUENCE, INSTREAM HABITAT, AND RIPARIAN VEGETATION

The transect-based approach used here permits semi-quantitative calculations from visual estimates even though most are categorical data (i.e., either presence/ absence or size classes) because we can calculate the percentage of transects that fall into different categories. These modules are adapted directly from EMAP protocols with some modifications as noted.

Module F. Human Influence

The influence of human activities on stream biota is of critical concern in bioassessment analyses. Quantification of human activities for these analyses is often performed with GIS techniques, which are very useful but are not capable of accounting for human activities occurring at the reach scale. Reach scale observations are often critical for explaining results that might seem anomalous on the basis of only remote mapping tools.

Step 1. For the left and right banks, estimate a 10 x 10 m riparian area centered on the edges of the transect (see Figure 2). Record the presence of 11 human influence categories in three spatial zones relative to this 10 x 10 m square (between the wetted edge and bankfull margin, between the bankfull margin and 10 m from the stream, and between 10 m and 50 m beyond the stream margins): 1) walls/rip-rap/dams, 2) buildings, 3) pavement/cleared lots, 4) roads/railroads, 5) pipes (inlets or outlets), 6) landfills or trash, 7) parks or lawns (e.g., golf courses), 8) row crops, 9) pasture/ rangelands, 10) logging/ timber harvest activities, 11) mining activities, 12) vegetative management (herbicides, brush removal, mowing), 13) bridges/ abutments, 14) orchards or vineyards. Circle all combinations of impacts and locations that apply, but be careful to not double-count any human influence observations.

Step 2. Record the presence of any of the 11 human influence categories in the stream channel within a zone 5 m upstream and 5 m downstream of the transect.

Module G. Riparian Vegetation

Riparian vegetation (vegetation in the region beyond the bankfull margins) has a strong influence on the composition of stream communities through its direct and indirect roles in controlling the food base, moderating sediment inputs and acting as a buffer between the stream channel and the surrounding environment. These methods provide a cursory survey of the condition of the riparian corridor. Observations are made in the same 10 x 10 m riparian area used for assessing human influence (see Figure 2).

Note: Riparian vegetation measurements should only include living or recently dead vegetation.

The riparian vegetation categories used here were condensed from the EMAP version, which further breaks the canopy classes into different components. However, because we have consolidated EMAP categories into fewer categories rather than creating new categories, existing EMAP data can be easily converted to this format simply by combining the appropriate categories.

Step 1. Divide the riparian zone into three elevation zones: 1) ground cover (<0.5 m), 2) lower canopy (0.5 m - 5 m), and 3) upper canopy (>5 m). Record the density of the following riparian classes: 1) Upper Canopy–Trees and Saplings, 2) Lower Canopy–Woody Shrubs and Saplings, 3) Woody Ground Cover–Shrubs, Saplings, 4) Herbaceous Ground Cover–Herbs and Grasses, and 5) Ground Cover–Barren, Bare Soil and Duff. Artificial banks (e.g., rip-rap, concrete, asphalt) should be recorded as barren.

Step 2. Indicate the areal cover (i.e., shading) by each riparian vegetative class as either: 1) absent, 2) sparse (<10%), 3) moderate (10-40%), 4) heavy (40-75%), or 5) very heavy (>75%).

Module H. Instream Habitat Complexity

Instream habitat complexity was developed by the EMAP program to quantify fish concealment features in the stream channel, but it also provides good information about the general condition and complexity of the stream channel. Estimates should include features within the banks and outside the wetted margins of the stream.

Step 1. Record the amount of nine different channel features within a zone 5m upstream and 5m downstream of the transect (see Figure 2): 1) filamentous algae (long-stranded algal forms that are large enough to see with the naked eye), 2) aquatic macrophytes (include mosses and vascular plants), 3) boulders (>25 cm), 4 and 5) woody debris (break into two classes- larger and smaller than 30 cm diameter), 6) undercut banks, 7) overhanging vegetation, 8) live tree roots and 9) artificial structures (includes any anthropogenic objects including large trash objects like tires and shopping carts). Indicate the areal cover of each feature as either: 1) absent, 2) sparse (<10%), 3) moderate (10-40%), 4) heavy (40-75%), or 5) very heavy (>75%).

SECTION 5
INTER-TRANSECT MEASURES

While most measures are taken at or relative to the main transects, a few measures are recorded at transects located at the midpoint between main transects. These are called "inter-transects".

Module B (Part 2) Pebble Counts (same as for transects, but no cobble embeddedness measures)

Step 1. Divide the wetted stream width by four to get the distance between the five points (Left Bank, Left Center, Center, Right Center and Right Bank) and use a measuring device to locate the positions of these points (a stadia rod is especially helpful here, see Figure 5). Once the positions are identified, lower a graduated rod through the water column perpendicular to both the flow and the transect to objectively select the particle located at its tip.

Step 2. With the graduated rod, measure the depth from the water surface to the top of the particle and record to the nearest cm.

Step 3. Remove the particle from the streambed, then measure and record the length of its intermediate axis to the nearest mm (see Figure 6). Alternatively, assign the particle to one of the size classes listed in the bottom of the transect form (see Table 3 for a list of size classes). Particle size classes may be estimated visually or with a quantitative measuring device (e.g., pass/ no-pass template, gravelometer). Regardless of the method, all particles less than 0.06 mm should be recorded as fines, while all particles between 0.06 mm and 2.0 mm should be recorded as sand. Field crews may want to carry vials containing sediment particles with these size ranges until they are familiar with these particle size classes.

Step 4. Record the presence (P) or absence (A) of any CPOM within 1 cm of each particle.

Module J. Flow Habitats

Because many benthic macroinvertebrates prefer specific flow and substrate microhabitats, the proportional representation of these habitats in a reach is often of interest in bioassessments. There are many different ways to quantify the proportions of different flow habitats (for example, see text on EMAP's "thalweg profile" below). Like the riparian and instream measures listed above, this procedure produces a semi-quantitative measure consisting of 10 transect-based visual estimates.

Note: The categories used here are based on those used in the EMAP protocol, with pools combined into one class and cascades and falls combined into another class.

Step 1. At each inter-transect, identify the proportion of six different habitat types in the region between the upstream transect and downstream transect: 1) cascades/falls, 2) rapids, 3) riffles, 4) runs, 5) glides, 6) pools, 7) dry areas. Record percentages to the nearest 5% — the total percentage of surface area for each section must total 100%.

SECTION 6 DISCHARGE

Stream discharge is the volume of water that moves past a point in a given amount of time and is generally reported as either cubic meters per second (cms) or cubic feet per second (cfs). Because discharge is directly related to water volume, discharge affects the concentration of nutrients, fine sediments and pollutants; and discharge measurements are critical for understanding impacts of disturbances such as impoundments, water withdrawals and water augmentation. Discharge is also closely related to many habitat characteristics including temperature regimes, physical habitat diversity, and habitat connectivity. As a direct result of these relationships, stream discharge is often also a strong predictor of biotic community composition. Since stream volume can vary significantly on many different temporal scales (diurnal, seasonal, inter-annually), it can also be very useful for understanding variation in stream condition.

This procedure (modified from the EMAP protocol) provides for two different methods for calculating discharge. It is preferable to take discharge measurements in sections where flow velocities are greater than 0.15 m/s and most depths are greater than 15 cm, but slower velocities and shallower depths can be used. If flow volume is sufficient for a transect-based "velocity-area" discharge calculation, this is by far the preferred method. If flow volume is too low to permit this procedure or if your flow meter fails, use the "neutrally buoyant object/ timed flow" method.

Note: Programs that sample fixed sites repeatedly may want to consider installing permanent discharge estimation structures (e.g., stage gauges, wiers).

Module K. Discharge: Velocity Area Method

The layout for discharge measurements under the velocity-area (VA) method is illustrated in Figure 8. Flow velocity should be measured with either a Swoffer Instruments propeller-type flow meter or a Marsh-McBirney inductive probe flow meter. Refer to the manufacturers' instrument manuals for calibration procedures.

VA-Step 1. Select the best location in the reach for measuring discharge. To maximize the repeatability of the discharge measurement, choose a transect with the most uniform flow (select hydraulically smooth flow whenever possible) and simplest cross-sectional geometry. It is acceptable to move substrates or other obstacles to create a more uniform cross-section before beginning the discharge measurements.

VA-Step 2. Measure the wetted width of the discharge transect and divide this into 10 to 20 equal segments. The use of more segments gives a better discharge calculation, but is impractical in small channels. A minimum of 10 intervals should be used when stream width permits, but interval width should not be less than 15 cm.

VA-Step 3. Record the distance from the bank to the end of the first interval. Using the top-setting rod that comes with the flow velocity meter, measure the median depth of the first interval.

VA-Step 4. Standing downstream of the transect to avoid interfering with the flow, use the top-setting rod to set the probe of the flow meter (either the propeller or the electromagnetic probe) at the midpoint of each interval, at 0.6 of the interval depth (this position generally approximates average velocity in the water column), and at right angles to the transect (facing upstream). See Figure 8 for positioning detail.

VA-Step 5. Allow the flow velocity meter to equilibrate for 10-20 seconds then record velocity to the nearest m/s. If the option is available, use the flow averaging setting on the flow meter.

Note: Under very low flow conditions, flow velocity meters may register readings of zero even when there is noticeable flow. In these situations, record a velocity of 0.5x the minimum flow detection capabilities of the instrument.

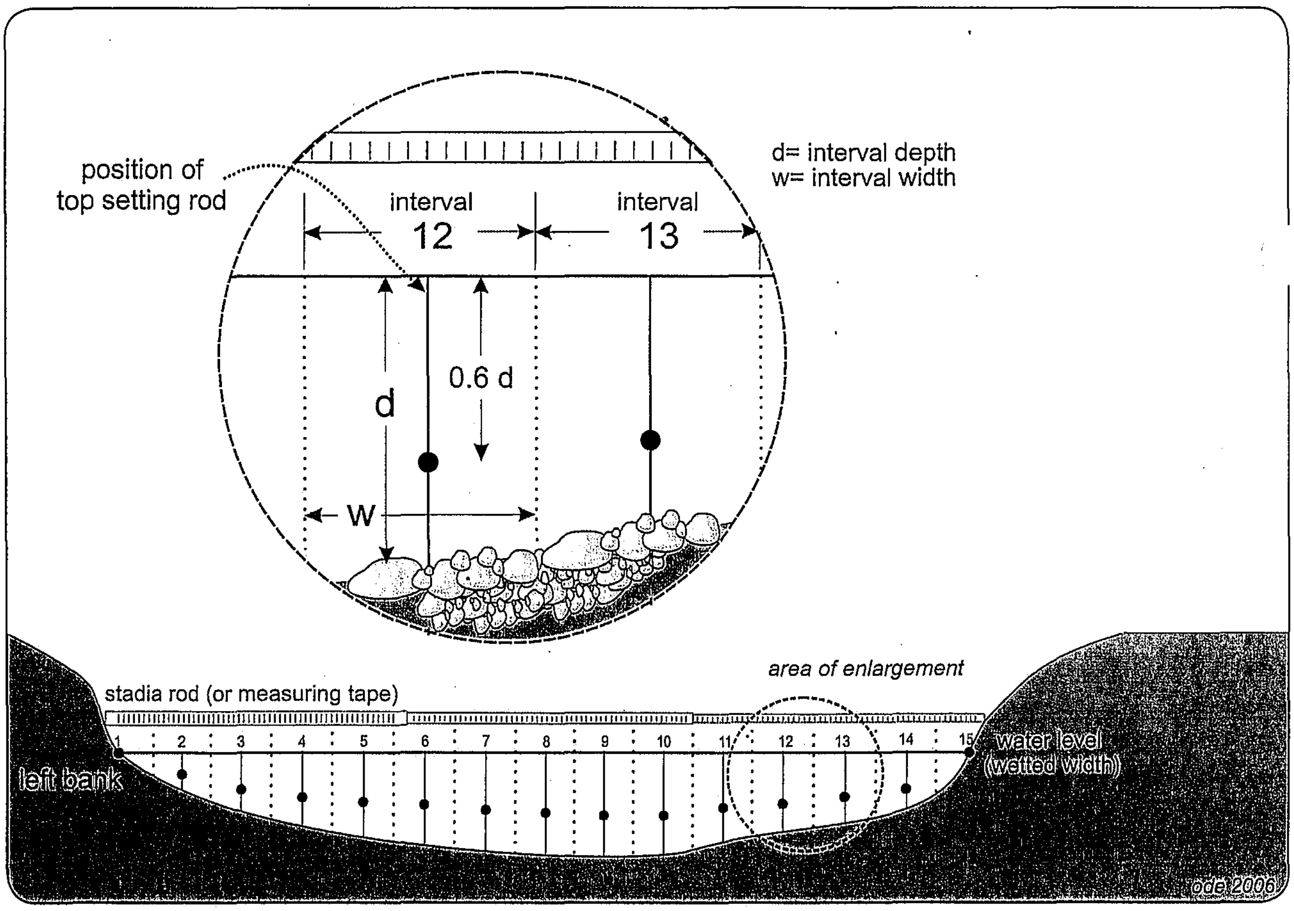

Figure 8. Diagram of layout for discharge measurements under the velocity-area method showing proper positions for velocity probe (black dots).

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VA-Step 6. Complete Steps 3 through 5 on the remaining intervals.

Note: The first and last intervals usually have depths and velocities of zero.

Module L. Discharge: Neutrally Buoyant Object Method

If streams are too shallow to use a flow velocity meter, the neutrally buoyant object (NBO) method should be used to measure flow velocity. However, since this method is less precise than the flow velocity meter it should only be used if absolutely necessary. A neutrally buoyant object (one whose density allows it to just balance between sinking and floating) will act as if it were nearly weightless, thus it's movement will approximate that of the water it floats in better than a light object. To estimate the flow velocity through a reach, three transects are used to measure the cross-sectional areas within the test section sub-reach and three flow velocity estimates are used to measure average velocity through the test reach. To improve precision in velocity measurements, the reach segment should be long enough for the float time to last at least 10-15 seconds.

NBO-Step 1. The position of the discharge sub-reach is not as critical as it is for the velocity-area method, but the same criteria for selection of a discharge reach apply to the neutrally buoyant object method. Identify a section that has relatively uniform flow and a uniform cross sectional shape.

NBO-Step 2. The cross sectional area is estimated in a manner that is similar but less precise than that used in the velocity area method. Measure the cross sectional area in one to three places in the section designated for the discharge measurement (three evenly-spaced cross sections are preferred, but one may be used if the cross section through the reach is very uniform). Record the width once for each cross section and measure depth at five equally-spaced positions along each transect.

NBO-Step 3. Record the length of the discharge reach.

NBO-Step 4. Place a neutrally buoyant object (e.g., orange, rubber ball, heavy piece of wood, etc.) in the water upstream of the discharge reach and record the length of time in seconds that it takes for the object to pass between the upstream and downstream boundaries of the reach. Repeat this timed float three times.

SECTION 7 POST-SAMPLING OBSERVATIONS

Module M. Rapid Bioassessment Procedures Visual Assessment Scores (for Basic Physical Habitat, or optional supplement)

EPA's Rapid Bioassessment Procedures (RBPs, Barbour et al. 1999) include a set of 10 visual criteria for assessing instream and riparian habitat. The RBP has been used in the CSBP since its first edition (1995) and thus, this information is often valuable for comparison to legacy datasets. The criteria also have a useful didactic role since they help force the user to quantify key features of the physical environment where bioassessment samples are collected.

Module N. Additional Habitat Characterization (Full Physical Habitat only)

The RBP stream habitat visual estimates described in Step 1 are not included in the Full Physical Habitat version because they are generally replaced by more quantitative measurements of similar variables. However, we have found that three of the RBP measures are reasonably repeatable and include them in the reachwide assessment portion of the Full Physical Habitat version.

Note: *This is the only case in which a measurement included in the basic procedure is not included in the full.*

Module O. Reach Slope (for Basic Physical Habitat only)

Reach slope should be recorded as percent slope as opposed to degrees slope to avoid confusion. Slope measurements work best with two people, one taking the readings at the upstream transect and the other holding a stadia rod at the downstream transect. If you cannot see the mid point of the next transect from the starting point, use the supplemental sections (indicating the proportion of the total length represented by each section).

An auto level (with a tripod) should be used for reaches with a percent slope of less than or equal to 1%. All methods (clinometer, hand level, or auto level) may be used for reaches with a percent slope of greater than 1%. In reaches that are close to 1%, you will not know whether you are above or below the 1% slope cutoff. In these cases, default to use of an autolevel.

Step 1. Divide the reach into multiple segments such that stadia rod markings can be easily read with the measuring device to be employed (this is especially a factor for clinometer and hand level readings).

Step 2. Use a clinometer, hand level, or auto level to measure the percent slope of the water surface (not the streambed) between the top and bottom of each segment. Be sure to adjust for water depth by measuring from the same height above the water surface at both transects. Also be sure to record percent slope, not degrees slope. Record the segment length for each of these sections in the appropriate boxes on the BASIC slope form.

SECTION 8
OPTIONAL EXCESS SEDIMENT MEASURES

Future editions of these protocols will include supplemental modules, including a full discussion of the measurements used for calculating the excess sediment index (sometimes referred to as log relative bed stability, LRBS). However, since several of the measurements in EMAP's physical habitat protocols are interwoven into the layout of this protocol, a brief overview of the additional measurements collected for the LRBS calculations is included here for information purposes only. For detailed explanations of these measurements, consult Peck et al. 2004.

Woody Debris Tallies

Large woody debris (logs, snags, branches, etc.) that is capable of obstructing flow when the channel is at bankfull condition (just short of flood stage) contributes to the "roughness" of a channel. The effect of this variable is to reduce water velocity and thereby reduce the stream's competence to move substrate particles. The EMAP protocol tallies all woody debris with a diameter greater than 10 cm (~4") into one of 12 size classes based on the length and width of each object. Tallies are conducted in the zone between the main transects.

Thalweg Measurements

A stream's thalweg is a longitudinal profile that connects the deepest points of successive cross-sections of the stream. The thalweg defines the primary path of water flow through the reach. Thalweg measurements perform many functions in the EMAP protocols, producing measurements for the excess sediment calculations (residual pool volume, stream size, channel complexity) and flow habitat variability.

SECTION 9 OPTIONAL PERIPHYTON QUANTIFICATION

Periphyton Quantification

Characterization of periphyton has a dual role in bioassessments, as periphyton is both a food and habitat resource for benthic macroinvertebrates and fish and an effective bioindicator on its own. Quantification of periphytic resources will be covered under a separate SWAMP bioassessment protocol, but will include procedures for qualitative characterization of diatom assemblages, documentation of filamentous algal growth, and biomass quantification (e.g., ash-free dry mass and chlorophyll a).

SECTION 10
QUALITY ASSURANCE & CONTROL PROCEDURES

The SWAMP bioassessment group is currently developing guidelines for quality assurance and quality control for bioassessment procedures. Future revisions to this document will include guidance covering personnel qualifications, training and field audit procedures, procedures for field calibration, procedures for chain of custody documentation, requirements for measurement precision, health and safety warnings, cautions (actions that would result in instrument damage or compromised samples), and interferences (consequences of not following the standard operating procedure, SOP).

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DEFINITIONS OF TERMS USED IN SOP D

Terms & Definitions

TERM	DEFINITION
ABL	California Department of Fish and Game's Aquatic Bioassessment Laboratory
Allocthonous	Derived from a source external to the stream channel (e.g., riparian vegetation) as opposed to autochthonous, which indicates a source inside the stream channel (e.g., periphyton).
Ambient Bioassessment	Biological monitoring that is intended to describe general biotic condition as opposed to a diagnosis of sources of impairment
Bankfull	The bankfull channel is the zone of maximum water inundation in a normal flow year (one to two year flood events)
BMI	Benthic macroinvertebrates: bottom-dwelling invertebrates large enough to be seen with the unaided eye
Cobble Embeddedness	The volume of cobble-sized particles (64-250 mm) that is buried by fine particles (<2.0 mm diameter)
CPOM	Coarse particulate organic matter (CPOM, particles of decaying organic material such as leaves that are greater than 1.0 mm in diameter)
CSBP	California State Bioassessment Procedures
DFG	California Department of Fish and Game
EMAP	The U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program
EPA	The U.S. Environmental Protection Agency
Fines	Substrate particles less than 0.06 mm diameter (not gritty to touch)
Inter-transects	Transects established at points equidistant between the main transects
MCM	Margin-Center-Margin alternative procedure for sampling low gradient habitats
ORD	EPA's Office of Research and Development
QAMP	Quality assurance management plan
RBP	EPA's Rapid Bioassessment Procedures
Reach	A segment of the stream channel
Riparian	An area of land and vegetation adjacent to a stream that has a direct effect on the stream.
RWB	Reach-wide benthos composite sampling method for benthic macroinvertebrates, also referred to as multi-habitat method
SCCWRP	Southern Coastal California Water Research Project
SNARL	Sierra Nevada Aquatic Research Laboratory
Substrate	The composition of a streambed, including both inorganic and organic particles
SWAMP	The State Water Resources Control Board's Surface Water Ambient Monitoring Program
Thalweg	A longitudinal profile that connects the deepest points at successive cross-sections of the stream. The thalweg defines the primary path of water flow through the reach

TERM	DEFINITION
Transects	Lines drawn perpendicular to the path of flow used for standardizing sampling locations
TRC	Targeted riffle composite sampling method for benthic macroinvertebrates
USFS	The United States Forest Service
Wadeable Streams	Streams that can be sampled by field crews wearing chest waders (generally less that 0.5 m - 1.0 meters deep)

APPENDIX A

FACTORS TO CONSIDER WHEN RECOMMENDING/ CHANGING BIOASSESSMENT METHODS

Beyond the primary considerations of precision and accuracy, there are at least five other key issues that SWAMP has considered and should consider in the future, when recommending or changing its official methods for bioassessment. These issues include:

1. **Costs of Collecting Samples via Multiple Protocols** – Collecting, processing, and interpreting samples using more than one method for each indicator (e.g., algae, macroinvertebrates, fish) per site adds significant costs to bioassessment monitoring programs. SWAMP should strive to identify the minimum set of protocols necessary for each indicator. However, this should not come at the expense of sound monitoring. If more than one method is needed to interpret the biological response, then this decision should be based on a cost-benefit assessment.

2. **Costs of Maintaining Multiple SWAMP Protocols** – While multiple methods for monitoring a given indicator may provide additional accuracy in specific habitats, there are significant costs to maintaining multiple protocols:

   a. Need to maintain method-specific infrastructure (e.g., separate reference samples, separate indices of biotic integrity (IBIs), separate O/E models, etc.).
   b. May lose or impair ability to compare across sites if different methods are used (see Issue 5 below).
   c. Guidance on when to use methods becomes more complex. For example, we need to define very specifically which methods to use at each water body type; and thus, which tools can be used to interpret them.

Recommendation: *SWAMP should maintain as few protocols as necessary. If we elect to add new or modified protocols it should be because we have determined that the added value is worth all of the costs listed above.*

3. **Separating Physical Impairment from Water Quality Impairment** – One of the original reasons for adding a multihabitat component to SWAMP bioassessment programs was the potential for distinguishing physical and water quality impairment sources (see recommendations in Barbour and Hill 2002). In regards to macroinvertebrate indicators, the conventional wisdom has been that reachwide (RW, sometimes referred to as multihabitat or MH) samples should be relatively more responsive to physical habitat alteration (i.e., fine sediment inputs) than targeted-riffle (TR) samples because it is believed that erosional habitats take longer

to respond to sediment stresses, and because pockets of riffle habitat are thought to act as refugia from habitat loss. To the extent that this is true, RW and TR samples may offer complementary information that allows us to separate these sources of impairment.

While very few studies have addressed this conventional wisdom directly, recent studies suggest that this may not be as much a factor as previously believed. In a recent comparison of TR and RW samples at nearly 200 sites statewide, the ABL found at most weak evidence to support this notion (Rehn et al. 2007). Gerth and Herlihy (2006) came to the same conclusion in their analysis of ~500 sites in the eastern and western United States. However, this issue is far from resolved and SWAMP scientists currently are not in agreement regarding this issue. Since the majority of bioassessment programs in California have emphasized targeted riffle sampling, SWAMP will undoubtedly want to evaluate this question further before making any policy decision to discontinue TR sampling.

Recommendation: *Until this issue can be evaluated further and resolved to SWAMP's satisfaction, ambient macroinvertebrate sampling should include collection of both RW samples and richest targeted habitat (TR or MCM) samples at every site. (The TR method should be used where sufficient riffles are present, and the MCM method should be used at low-gradient sites where sufficient riffle habitat is not available.)*

4. **Compatibility with Previous Data** – To address this issue, at least three sets of macroinvertebrate sampling method comparisons have been conducted in California.

a. **Targeted Riffle Methods** – Comparisons are complete. Samples collected under the current TR protocols are considered interchangeable with both CSBP and SNARL samples (Ode et al. 2005, Herbst and Silldorff 2006).
b. **Low Gradient Sand-Dominated Streams** – Collaborative studies are currently underway between Water Board Regions 3 and 5, the Southern California Coastal Water Research Project (SCCWRP), and ABL to compare the performance of: (1) the "low-gradient" CSBP; (2) RW samples; and (3) a modification of the RW method designed to emphasize habitats along stream margins (MCM). The results of these low-gradient methods comparisons are not yet available.
c. **Targeted Riffle vs. Reachwide Methods** – A recent comparison of RW and TR samples collected from nearly 200 EMAP/ CMAP sites is in peer review press (Rehn et al. 2007). Results demonstrate remarkably similar performance of the methods across a wide range of habitats. Gerth and Herlihy (2006) recently published a similar analysis with the same conclusions. However, the bioassessment committee has yet to carefully review and discuss these analyses and their implications for SWAMP biomonitoring.

5. **Comparability Among Sites** – The ability to compare biological condition across sites is a common requirement of most ambient bioassessment programs. This type of analysis is confounded if different methods are used at these sites. One of the big advantages of reachwide (i.e., multihabitat) methods is that they can be applied anywhere because they don't require a specific habitat for sampling. Statewide

bioassessments and most regional programs will require the ability to compare their bioassessment results among multiple sites (e.g., within a watershed, within a region, statewide).

INTERIM RECOMMENDATIONS FOR MACROINVERTEBRATE SAMPLING (UPDATED DECEMBER 2006):

1. Until we can reach consensus on the outstanding issues (i.e., whether a single method for macroinvertebrate sampling will meet our needs, and the outcome of RW vs. MCM comparison studies for low-gradient wadeable streams/rivers), SWAMP recommends collecting both a reachwide (i.e., multihabitat) and a targeted habitat sample at each site. In high gradient streams, this means using both the RW and TR methods. In low-gradient streams, we recommend collecting both RW and MCM samples until the results are available from the low-gradient ("non-riffle") comparison. In rare cases where monitoring objectives cannot be met following these recommendations, the SWAMP Bioassessment Coordinator may authorize deviations. For example, where project-specific objectives differ from ambient monitoring, the SWAMP Bioassessment Coordinator may authorize alternate methods. In rare cases where funding is extremely limited and the cost of following the above recommendations would be prohibitive, the SWAMP Bioassessment Coordinator may authorize cost-saving options such as collecting both samples, but archiving one of the samples for later lab analysis.

2. SWAMP should develop guidance specifying when and where different methods should be used. For example, at "low gradient" sites, what is the slope cut-off (or other channel feature criteria to use) when deciding whether to apply TR or MCM? In addition, while SWAMP may eventually choose to adopt a single method (such as RW) at most sites, some regions may determine that the value of targeted habitat sampling merits continued sampling with supplemental protocols. In the latter case, or if SWAMP determines that distinct methods are needed for different habitat types, the guidance should specify the types of waterbodies or classes of waterbodies that require different methods.

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A009760

J. N. Am. Benthol. Soc., 2007, 26(2):000–000

Comparisons of targeted-riffle and reach-wide benthic macroinvertebrate samples: implications for data sharing in stream-condition assessments

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Abstract. Recent comparisons of benthic macroinvertebrate (BMI) sampling protocols have shown that samples collected from different habitat types generally produce consistent stream classifications and assessments. However, these comparisons usually have not included biological endpoints used by monitoring agencies, such as multimetric indices (e.g., benthic index of biotic integrity [B-IBI]) or observed-to-expected (O/E) indices of taxonomic completeness, as target variables, and estimates of method precision are rarely provided. Targeted-riffle (TR) and reach-wide (RW) benthic samples have been collected at thousands of sites across the western USA, but little guidance is available for understanding 1) the extent to which raw data sets can be combined in regional or large-scale analyses, 2) the degree of precision afforded by each method, or 3) the efficacy of cross-application of biological indicators derived from one sample type to the other. To address these issues, we used data from 193 sites in California where the Environmental Monitoring and Assessment Program (EMAP) collected the 2 samples side by side. We also conducted a separate study wherein 3 replicates of each sample type were collected from 15 streams to estimate minimum detectable difference (MDD) as a measure of each method's precision. Metrics calculated from TR and RW samples showed similar dose–response relationships to stressors gradients and similar raw scoring ranges. Biological indices (B-IBI, O/E_0, and O/E_{50}) derived from RW samples were more precise than those derived from TR samples, but precision differences were not substantial. On average, pairwise differences in any index between TR and RW sample types were much less than the MDD associated with either sampling method. We observed a weak but consistent bias toward higher O/E_{50} scores from TR samples than from RW samples at the highest elevations and in the largest watersheds. Broad-scale condition assessments were nearly identical when B-IBI and O/E_0 were used as endpoints, and assessments based on O/E_{50} were only slightly less similar. Our analyses indicate that raw data sets and biological indicators derived from TR and RW samples may be generally interchangeable when used in ambient biomonitoring programs.

Key words: benthic macroinvertebrates, bioassessment, sample habitat, index of biotic integrity, predictive models, EMAP, California.

Benthic macroinvertebrates (BMIs) are the most commonly used organisms in freshwater biomonitoring programs (Bonada et al. 2006). Numerous multimetric indices (e.g., benthic index of biotic integrity [B-IBI]), observed-to-expected (O/E) indices of taxonomic completeness, and various other tools have been developed in many parts of the world, including North America (Klemm et al. 2003, Hawkins 2006), Australia (Simpson and Norris 2000), Europe (Moss et al. 1987, De Pauw et al. 1992), New Zealand (Stark 1993), South Africa (Chutter 1972), and Indonesia (Sudaryanti et al. 2001). These biological indicators aid in the interpretation of complex BMI assemblage data and help classify the ecological condition of test sites relative to regional reference conditions (Hughes 1994).

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Recently, B-IBI- and O/E-based assessments have been used in conjunction with probability survey designs to estimate the ecological condition of entire resource populations, such as all mapped wadeable stream lengths within large geographic regions (Herlihy et al. 2000, Stevens and Olsen 2004, Stoddard et al. 2005).

Despite their popular use in biomonitoring, there is no commonly agreed upon method for sampling BMIs or for processing samples (Carter and Resh 2001, Houston et al. 2002). Debates continue regarding which habitat is best to sample (Parsons and Norris 1996), what subsample size of organisms is best (Ostermiller and Hawkins 2004, Cao and Hawkins 2006), and what taxonomic resolution is sufficient to detect anthropogenic impairment (Lenat and Resh 2001, Waite et al. 2004). Decisions about where to sample frequently have been driven by the assumption that index values obtained at sites will be influenced by the types or mixture of habitats sampled rather than by water-quality differences among sites (Chessman 1995), or that certain disturbances (e.g., sedimentation) may have a more pronounced effect on biota in certain habitats and might go undetected if only a single habitat were sampled (Kerans et al. 1992, Parsons and Norris 1996). These assumptions seem to be supported by observations that like habitats can have more similar BMI assemblages among streams than different habitats within a stream (e.g., McCulloch 1986, Parsons and Norris 1996). Nonetheless, growing evidence suggests that BMI samples collected from different habitat types generally produce similar stream classifications and assessments (Hewlett 2000, Ostermiller and Hawkins 2004, Gerth and Herlihy 2006).

Thorough comparison of sampling methods requires evaluation of multiple performance characteristics, including precision, accuracy, bias, and sensitivity (Diamond et al. 1996). Quantitative performance characteristics aid in determinations of whether raw data sets derived from independent programs with different sampling techniques can be combined for larger analyses, and whether biological endpoints (i.e., B-IBI or O/E scores) derived from those programs can be compared directly. To date, comparisons of sampling methods that target different habitats usually have not included estimates of method precision (but see Stark 1993, Houston et al. 2002). Replicate samples are required to estimate the variance associated with sampling error in biological assessments (Barbour et al. 1996, Fore et al. 2001), and documentation of precision has been advocated as an essential component of any performance-based monitoring system (PBMS; Diamond et al. 1996).

We compared the 2 sampling methods (targeted-riffle [TR] and reach-wide [RW]) used by the US Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) survey of wadeable streams in the western USA. First, we evaluated whether the responses of several BMI metrics to gradients of anthropogenic stressors varied if the metrics were calculated from different sample types. Second, we determined whether within-site precision of B-IBI and O/E indices varied with sampling method, and we used within-method precision as a context for evaluating between-method differences in index scores. Third, we assessed whether systematic biases in B-IBI or O/E in relation to several natural gradients (elevation, watershed area, etc.) occurred between sampling methods. Last, we assessed whether sampling method affected site-specific and regional condition assessments based on B-IBI and O/E. If the 2 sampling methods produce comparable data and biological endpoints, raw TR and RW samples could be combined for large-scale analyses, and indicators developed from one sample type could be applied with reasonable confidence to data sets collected with the other.

Methods

Data sets

Data for pairwise comparisons of TR and RW sample types were obtained from 193 sites sampled in California (Fig. 1) during 2000 to 2003 by the western EMAP probability stream survey (Stoddard et al. 2005). Sampling sites were selected randomly from the digitized stream network depicted on 1:100,000-scale US Geological Survey topographic maps to ensure a spatially balanced, representative survey (Herlihy et al. 2000, Stevens and Olsen 2004). At each site, a sampling reach was defined as 40× the average stream width at the center of the reach, with a minimum reach length of 150 m and maximum length of 500 m. Eleven equidistant transects were established, and an RW sample was taken by sampling 0.09 m^2 of substrate with a kick net at each transect. Sampling points alternated among 25%, 50%, and 75% of stream width (thus, RW samples often contained at least some riffle components), and all 11 kick samples were composited into a single sample (Peck et al. 2004). A TR sample was taken from within the same reach by sampling 0.09 m^2 of substrate with a kick net from each of 8 randomly chosen riffle or fastest-water habitat units (Peck et al. 2004). All 8 kick samples were composited into a single sample.

Data for estimates of within-site precision, or sampling error, associated with each method were obtained from 29 streams in northern coastal Califor-

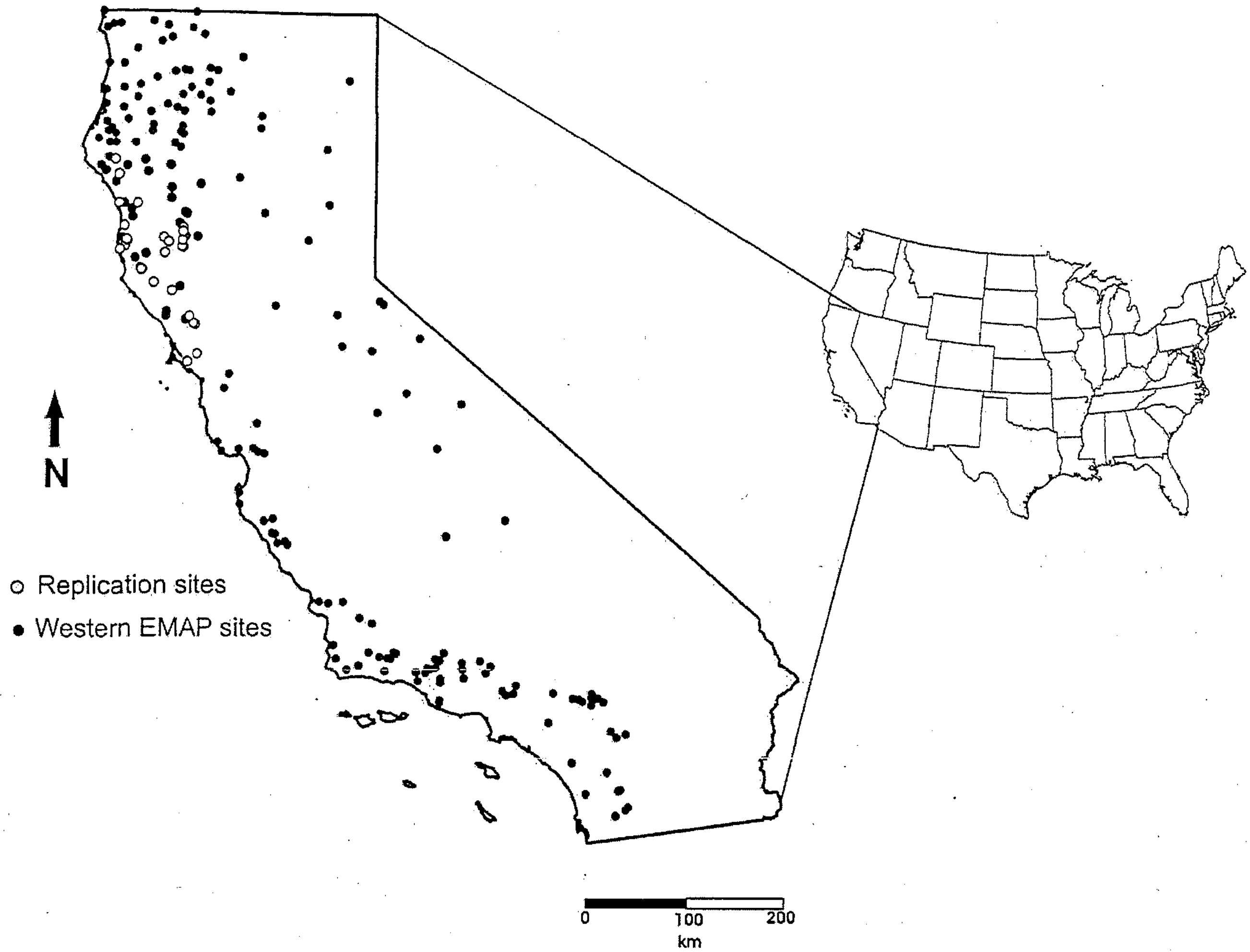


FIG. 1. Map of 193 sampling locations in California where targeted-riffle and reach-wide samples were collected for pairwise comparisons (Environmental Monitoring and Assessment Program [EMAP] sites) and 29 locations where replicate samples were collected for precision estimates.

nia (Fig. 1). Sites were sampled in September 2004 and were selected to represent the range of stream conditions found in the region. Four of the sites had been sampled in previous years by EMAP. At each site, a 150-m sampling reach was established. At 15 sites, 3 TR replicates were collected following the protocol described above after randomly assigning each fastest-water habitat unit in the reach to 1 of 3 bins (Rep 1, 2, or 3). At 15 other sites (except Mark West Creek, where the 2 methods were replicated in adjacent sampling reaches), 3 RW replicates were collected from within the sampling reach following the protocols described above by alternating the sampling position along each transect for each replicate.

In the laboratory, each BMI sample was rinsed carefully in a 0.5-mm-mesh sieve before being transferred to a 20 × 25-cm tray subdivided into a grid of 20 squares. Organisms were subsampled from randomly chosen squares until 500 individuals were picked from each sample. Insects were identified to genus with standards of taxonomic effort defined by the California Aquatic Macroinvertebrate Laboratory Network (www.dfg.ca.gov/cabw/camlnetste.pdf). Chironomid genera were lumped at the subfamily level for analyses described below.

Data analyses

Metrics comparisons.—Dose–response relationships of 11 biological metrics to 5 anthropogenic or human-influenced stressors (% sand and fines, conductivity, total N, qualitative channel alteration, and local road density) known to be associated with biological degradation were examined to determine whether the relationships differed for TR and RW sample types. The evaluated metrics were chosen because they are used currently in California B-IBIs that were developed from TR sample data (Ode et al. 2005, Rehn et al. 2005). Percent sand and fines, qualitative channel alteration, conductivity, and total N were measured at study reaches with EMAP protocols (Klemm and Lazorchak 1994, Peck et al. 2004). Local road densities were obtained through geographical information system (GIS) analyses. First, a polygon delineating the area drained within a 1-km radius upstream of each study reach was defined. Then the ArcView® (version 3.2; Environmental Systems Research Institute, Redlands, California) extension ATtILA (version 3.0; US Environmental Protection Agency, Washington, DC) was used to calculate road densities within polygons with a road network obtained from the US Forest Service Remote Sensing Lab (http://fsweb/gis/gis_data/calcovs/fs/nwctran03_2.html).

Linear regression was used to quantify the strength of each metric–stressor relationship for each sample type. In cases where relationships were clearly wedge shaped (i.e., had distinct ceilings or floors), upper-bound (or lower-bound) regression was used to quantify the limiting slope of the relationship (Blackburn et al. 1992). For this analysis, the stressor axis was divided into 10 equal-interval bins and either the 3 highest or 3 lowest metric values were selected from each bin. Ordinary least-squares regressions were then calculated for the subsets of data to estimate the upper- or lower-bound slopes of wedge-shaped polygons. As an approximate Bonferroni correction for a large number of correlations, only relationships with a p-value ≤ 0.0001 were considered significant. Box plots and Mann–Whitney U tests were used to evaluate whether raw metrics differed between TR and RW samples and might require different scaling in a B-IBI.

Minimum detectable difference (MDD).—Replicate samples allow estimation of the variance in metric or composite indicator values associated with sampling error. We were interested in the variance of actual endpoint indicators used by water-quality managers in California. Northern coastal California B-IBI scores (Rehn et al. 2005) were calculated for each TR and RW replicate from the 29 replication sites. The replicate samples also were assessed with a recently developed California O/E index (CPH, unpublished data). The index was based on TR samples and generates 2 O/E taxa ratios, one based on taxa with modeled site-specific probabilities of capture >0 (O/E_0) and another based on taxa with site-specific probabilities of capture ≥ 0.5 (O/E_{50}; see Ostermiller and Hawkins 2004 for further explanation). Nested analyses of variance (ANOVAs) with replicate samples nested within sites were used to estimate the average within-site variance (as mean squared error [MSE] with 30 df) for both B-IBI and O/E values. These estimates of MSE were then applied in 2-sample t-tests ($\alpha = 0.05$, $\beta = 0.10$) to calculate the MDD for each indicator (Zar 1999, Fore et al. 2001). The MDD provides a measure of how different B-IBI or O/E values must be before they are considered significantly different.

Pairwise comparisons of B-IBI and O/E scores.—Pairwise differences were evaluated between recently developed California B-IBI (Ode et al. 2005, Rehn et al. 2005) scores calculated from TR and RW sample types. Two sites were eliminated from B-IBI comparisons because of low sample counts (<450). Pairwise differences between O/E scores were evaluated for a subset of 187 statewide sites where sample counts were sufficiently large ($n \geq 300$) after taxon lists were reduced to those operational taxonomic units (OTUs) used in the index.

Average pairwise differences in B-IBI and O/E scores between TR and RW sample types and the number of cases where the pairwise differences in these 2 indicator values exceeded the MDD for each sampling method were calculated. The degree to which B-IBI and O/E discriminated between reference and test sites depending on whether they were calculated from TR or RW samples was also evaluated. A principal components analysis (PCA) of the 5 stressors used in metrics comparisons was done, and the responsiveness of B-IBI and O/E to the first PCA axis (PCA1) was plotted. Our purpose was not to compare responsiveness between indicators, but rather to evaluate whether each indicator showed different responses when calculated from TR and RW sample types. Last, to determine whether the effect of sampling method on indicator values was influenced by natural gradients or by the extent of human influence, pairwise differences in TR- and RW-derived indicator values were plotted against watershed area, elevation, mean channel slope, % fast-water habitat in the sample reach, and PCA1.

Condition assessments.—Use of a spatially balanced probability process for site selection in regional stream surveys is well documented (Herlihy et al. 2000, Stevens and Olsen 2004). In short, each EMAP site in California represented a portion of the total perennial wadeable stream length in the state, and the status of the total stream population was inferred from the sample data. Our purpose here was not to report on the condition of wadeable streams in California per se, but rather to present a comparison of condition assessments based on TR and RW sample types and

TABLE 1. r^2 values from mean and upper- (or lower-) bound regressions between metrics used in California benthic indices of biotic integrity (B-IBI) and example stressor gradients used in metric screening. TR = targeted-riffle samples, RW = reach-wide samples, TN = total N, EPT = Ephemeroptera, Plecoptera, and Trichoptera taxa. – indicates relationships that did not have ceilings or floors. Significant values ($p \leq 0.0001$) are shown in bold.

	EPT richness		Coleoptera richness		Diptera richness		Predator richness		% collector individuals		% intolerant individuals		% nongastropod scrapers		% noninsect taxa		% predator individuals		% shredder taxa		% tolerant taxa	
	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW	TR	RW
Mean																						
% sand and fines	**0.33**	**0.42**	**0.14**	**0.21**	0.04	0.06	**0.13**	**0.23**	**0.11**	**0.07**	**0.16**	**0.18**	**0.14**	**0.16**	**0.21**	**0.28**	0.006	0.005	**0.13**	**0.1**	**0.28**	**0.33**
Conductivity	**0.25**	**0.25**	0.05	0.05	0.02	0.03	**0.16**	**0.16**	0.06	0.05	**0.17**	**0.15**	**0.10**	**0.09**	**0.12**	**0.20**	0.005	0.001	**0.12**	**0.12**	**0.23**	**0.30**
Log_{10}(TN)	**0.34**	**0.31**	0.04	**0.08**	**0.09**	**0.09**	**0.23**	**0.25**	0.003	0.003	**0.13**	**0.10**	0.05	**0.04**	**0.33**	**0.39**	0.001	0.03	**0.18**	**0.15**	**0.27**	**0.31**
Channel alteration	**0.14**	**0.21**	0.07	**0.11**	**0.08**	**0.09**	**0.08**	**0.18**	0.001	0.005	0.03	0.06	0.03	**0.04**	**0.24**	**0.32**	**0.07**	0.01	0.04	0.04	**0.19**	**0.24**
Local road density	**0.11**	**0.14**	0.06	**0.10**	0.06	0.06	0.06	**0.12**	0.006	0.002	**0.08**	0.06	0.03	**0.04**	**0.18**	**0.23**	0.03	0.01	**0.07**	**0.09**	**0.18**	**0.14**
Upper (or lower) bound																						
% sand and fines	**0.79**	**0.84**	**0.77**	**0.80**	–	–	**0.41**	**0.76**	**0.48**	0.38	**0.69**	**0.61**	**0.65**	**0.65**	–	–	–	–	**0.51**	**0.58**	–	–
Conductivity	**0.76**	**0.77**	0.53	0.53	**0.76**	**0.71**	**0.60**	**0.61**	0.30	0.26	**0.61**	**0.55**	0.53	**0.55**	–	–	0.01	0.16	**0.55**	**0.63**	–	–
Log_{10}(TN)	**0.67**	**0.7**	–	–	**0.45**	**0.41**	**0.70**	**0.71**	–	–	**0.57**	**0.51**	–	–	–	–	–	–	**0.52**	**0.56**	–	–
Channel alteration	**0.77**	**0.82**	**0.8**	**0.84**	**0.73**	**0.73**	**0.69**	**0.82**	–	–	**0.64**	**0.69**	**0.76**	**0.76**	**0.73**	**0.81**	**0.55**	**0.38**	**0.50**	**0.53**	**0.57**	**0.74**
Local road density	**0.63**	**0.63**	**0.67**	**0.66**	**0.47**	**0.53**	**0.52**	**0.72**	0.28	0.33	**0.59**	**0.59**	–	–	–	–	–	–	**0.60**	**0.64**	**0.69**	**0.60**

to evaluate how robustly TR-derived indicators could be used to assess RW-derived samples. The R statistical program (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org) and an R contributed library (psurvey.analysis, www.epa.gov/nheerl/arm) were used to plot the cumulative distribution of B-IBI and O/E scores in the population of wadeable streams in California. Cumulative distribution functions (CDFs) and their 95% confidence intervals were used to evaluate whether assessments derived from different combinations of sample type and indicator produced similar stream-condition assessments in California.

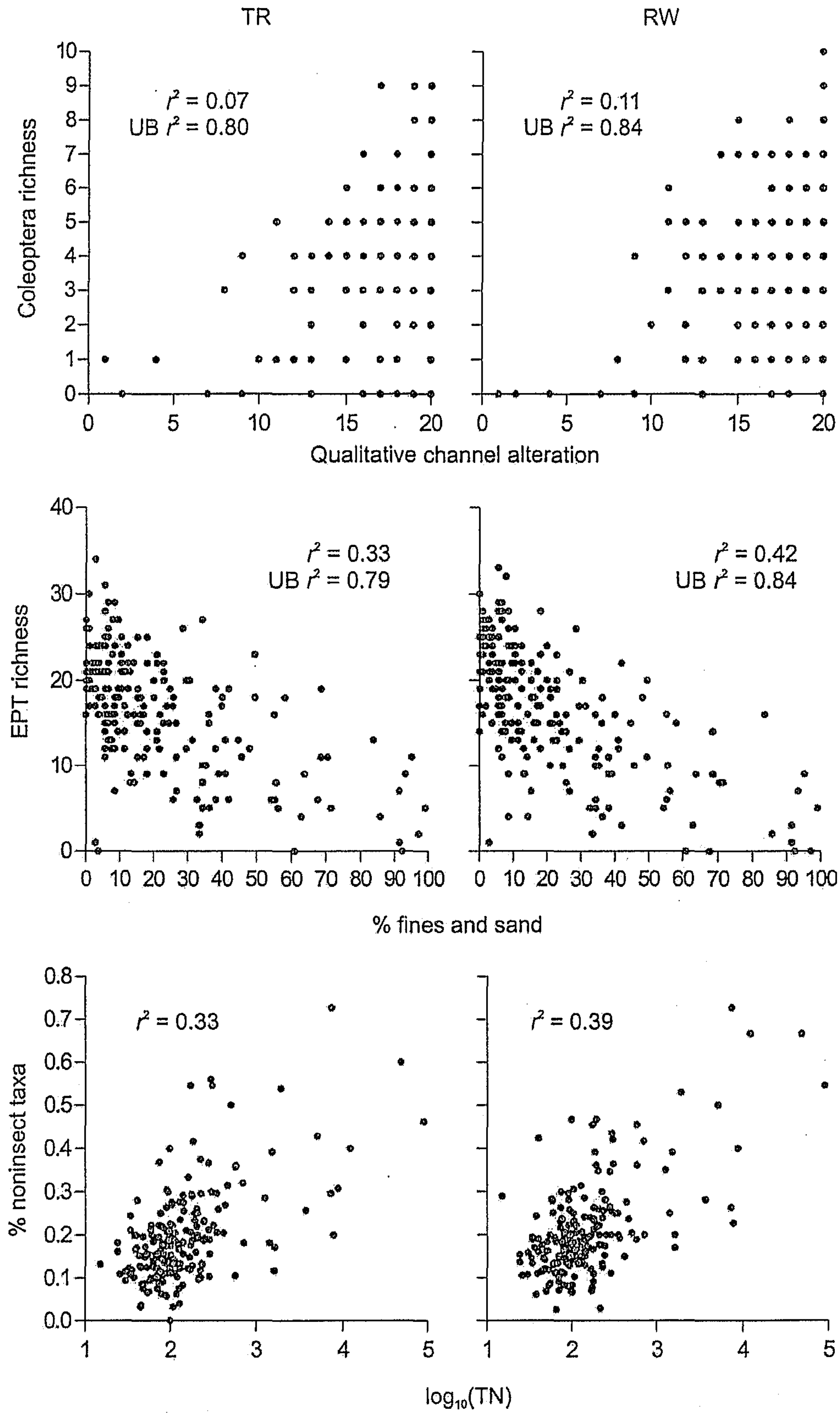
Results

Metrics comparisons

Metrics showed similar responses to stressor gradients regardless of whether they were calculated from TR or RW samples (Table 1, Fig. 2). In most cases, relationships were slightly tighter (r^2) when metrics were calculated from RW samples. Interquartile ranges of TR and RW samples were strongly overlapping (Fig. 3). Of the 4 metrics for which medians differed significantly different between sample types (Mann–Whitney U, $p < 0.05$), adjustments in scoring ranges to account for sample-type differences had little or no effect on resulting B-IBI scores. For example, predator richness was most different between TR and RW sample types ($p < 0.0001$; Fig. 3). This metric is used in the southern coastal California B-IBI where scoring ceilings were set as the 80^{th} percentile of the reference-site distribution (Ode et al. 2005). The 80^{th} percentile of reference-site predator richness was 13 for TR samples and 15 for RW samples. Therefore, consequent adjustments in overall metric and B-IBI scoring were minute. Current California B-IBIs were used as the biological endpoints in within-site precision comparisons even though the B-IBIs were developed with data from TR samples because of the similar responses of TR- and RW-derived metrics to stressors and similar ranges of raw metric values.

MDD

The MDD for B-IBI values adjusted to a 100-point scale was 15.5 for the RW sampling method and 19.7 for the TR sampling method (Figs 4A, B). Thus, we have a 90% chance of detecting a 15.5-point difference between RW-based B-IBI scores or a 19.7-point difference between TR-based B-IBI scores at a p-value <0.05. The RW method was slightly more precise than the TR method, but the difference in MDD between the 2 methods was small.



TR
RW
r^2 = 0.07
UB r^2 = 0.80
r^2 = 0.11
UB r^2 = 0.84
Coleoptera richness
Qualitative channel alteration
r^2 = 0.33
UB r^2 = 0.79
r^2 = 0.42
UB r^2 = 0.84
EPT richness
% fines and sand
r^2 = 0.33
r^2 = 0.39
% noninsect taxa
log10(TN)

Six sites were excluded from MDD estimates for O/E scores because of low sample counts in at least one of the replicates after reduction of taxon lists to OTUs used by the index, so our estimate of average within-site variance in O/E scores was slightly less robust than for B-IBI. The O/E MDD ranged from 0.19 to 0.31, depending on sample type and probability-of-capture threshold (O/E_0 vs O/E_{50}; Figs 5A–D).

Pairwise comparisons of B-IBI and O/E scores

B-IBI scores calculated from TR and RW sample types were highly correlated (Fig. 6A), as were O/E values (Figs 6B, C). Pairwise differences between TR and RW B-IBI and O/E scores were usually less than the corresponding within-method MDD (~83–92% agreement depending on the indicator and sampling method; Table 2). When pairwise differences exceeded MDD, values for TR samples were more often higher than those for RW samples when B-IBI and O/E_{50} were used as biological endpoints, but this pattern was not observed when O/E_0 was used as the endpoint (Table 2, Fig. 7).

TR- and RW-derived indices discriminated equally between reference and test sites (Fig. 8). Discrimination between reference and test sites was illustrated separately for northern and southern coastal California because the large number of high-quality EMAP test sites in the north coast obscured otherwise good discrimination observed in the south coast when all data were plotted together. TR- and RW-derived indices also showed similar responses (sensitivity) to a multivariate stressor axis (PCA1; Table 3, Fig. 9).

In general, little or no systematic bias was observed in pairwise differences between indicator scores in relation to watershed area, elevation, mean slope, % fast-water habitat in the sample reach, or PCA1 (Fig. 7). At the highest elevations, at sites with the largest watersheds, and where the sampling reach was predominantly slow water (>80%), O/E_{50} scores usually were higher if calculated from TR samples rather than RW samples (see ellipses in Fig. 7). However, many of these pairwise differences did not exceed the MDD for each combination of indicator and sampling method, and the trends were based on few data points. In no case was the pairwise difference in B-IBI or O/E_0 scores related to the natural or disturbance gradients we tested.

Condition assessments

Condition assessments for perennial streams in California based on TR and RW sample types collected at probability-survey sites were nearly identical for B-IBI and O/E_0 (Figs 10A, B). CDFs of indicator scores derived from each sample type were strongly overlapping, and each sampling method's CDF was within the 95% confidence interval of the other. Agreement in condition assessments based on TR and RW sample types was lower when O/E_{50} was used as the biological indicator, but the RW curve was still almost always within the 95% confidence interval of the TR curve (Fig. 10C). This greater difference implies that it may be less appropriate to apply a TR-derived O/E_{50} index than a B-IBI or an O/E_0 index to RW samples because only the most common riffle taxa (i.e., taxa with site-specific probabilities of capture ≥0.5) are included.

Discussion

As the popularity of BMI-based bioassessment has grown, interest also has grown in comparability between benthic data sets collected with different sampling protocols and in the precision associated with these protocols. Targeted-riffle and reach-wide BMI samples have been collected at thousands of sites across the western USA, but little guidance is available for understanding 1) the extent to which raw data sets can be combined in regional or large-scale analyses, 2) the degree of precision afforded by each method, or 3) the efficacy of cross-application of biological indicators derived from one sample type to the other. We used several approaches to address these issues and noted only minor systematic differences in indicator values between sample types across a range of stream types and levels of impairment. In addition, our documentation of performance characteristics for TR and RW sampling may help agencies establish assessment (condition) criteria that reflect true differences in assessment scores.

Sensitivity to stressor gradients

Few studies have compared the responses of metrics calculated from different sample types to stressor gradients. Klemm et al. (2003) found that riffle metrics were significantly correlated with more stressors than were pool metrics in the EMAP survey of Mid-Atlantic Highland streams. Even so, Klemm et al. (2003) were

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FIG. 2. Example dose–response relationships of benthic macroinvertebrate (BMI) metrics to stressor gradients. Metrics calculated from targeted-riffle (TR) samples are shown on the left, and the same metrics calculated from reach-wide (RW) samples are shown on the right. r^2 values are from ordinary linear and upper-bound (UB) regressions. TN = total N, EPT = Ephemeroptera, Plecoptera, and Trichoptera taxa.

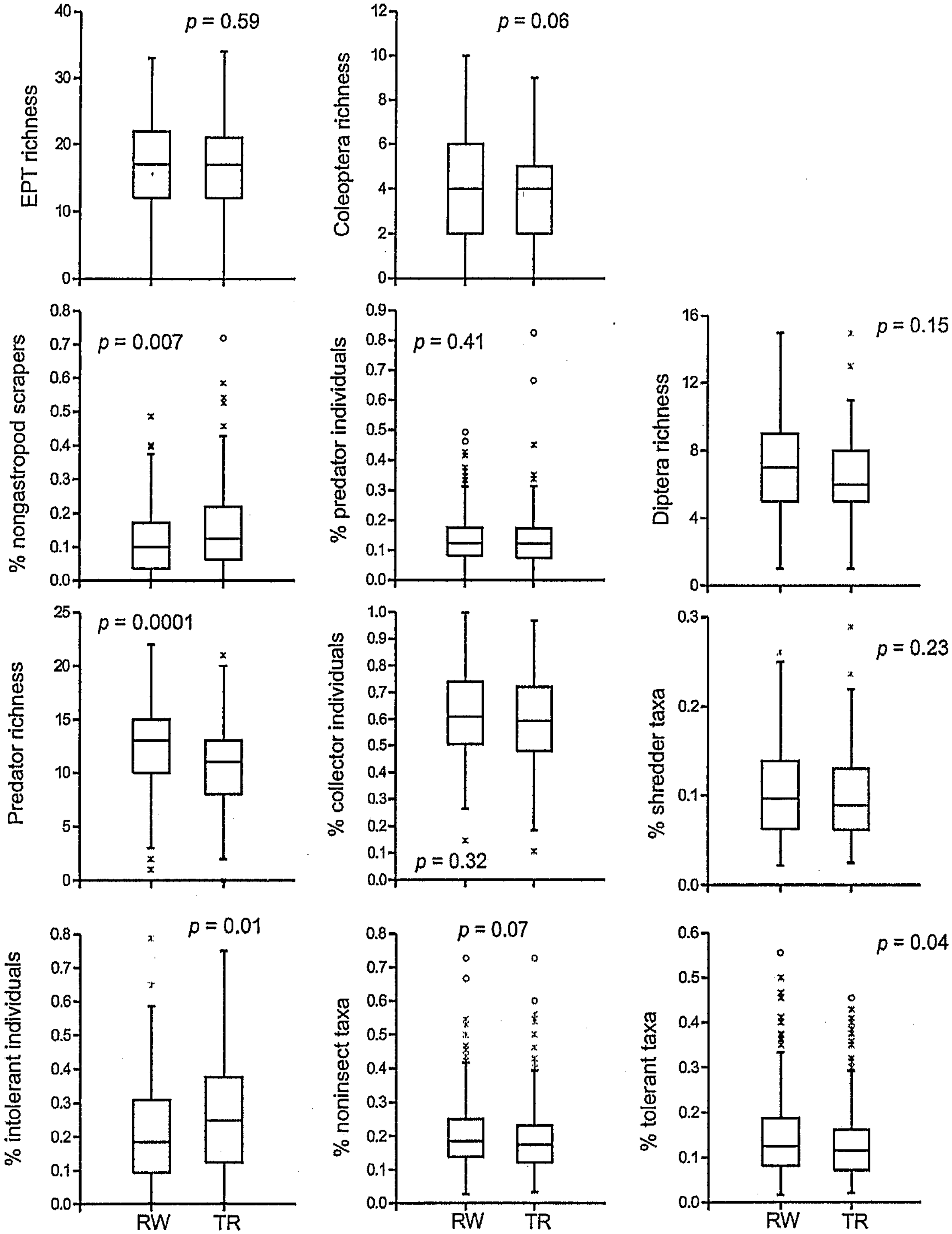


FIG. 3. Comparisons of raw benthic macroinvertebrate (BMI) metric values calculated from targeted-riffle (TR) and reach-wide (RW) samples. Boxes indicate median values and interquartile ranges, whiskers indicate 95th percentiles, outliers are indicated by an x or a circle. EPT = Ephemeroptera, Plecoptera, and Trichoptera taxa. $n = 201$, p-values from Mann–Whitney U tests are indicated.

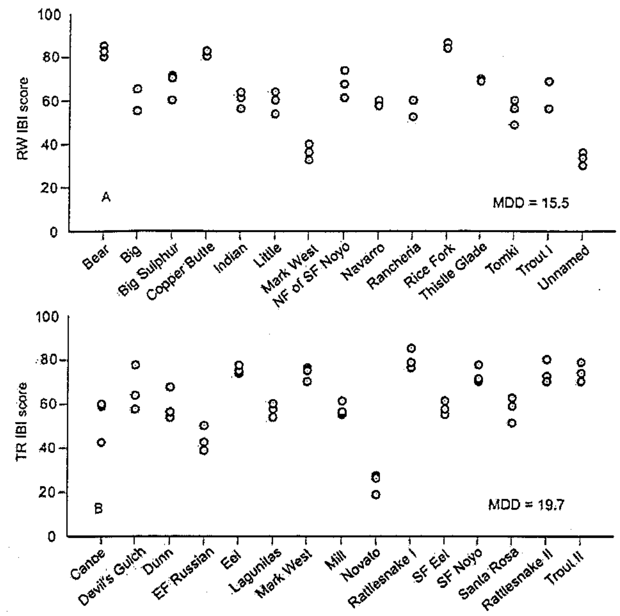


FIG. 4. Replicate benthic index of biotic integrity (B-IBI) scores calculated for 3 reach-wide (RW) samples collected at 15 sites (A) and 3 targeted-riffle (TR) samples collected at 15 sites (B). Replicates were used in estimation of minimum detectable difference (MDD) for each method.

able to use identical metrics for separate riffle and pool samples to develop a regional B-IBI, and had to adjust only the metric scoring scales to account for habitat differences. Using the same data set, Gerth and Herlihy (2006) found considerable differences between BMI assemblages in riffle and pool samples and found that Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness and taxon richness were higher in riffles than in pools. Despite these overall differences, assessments (i.e., percentages of sites in either good or poor biological condition based on EPT richness) were not substantially influenced by sample type.

In our study, metrics calculated from TR and RW showed similar responsiveness to various stressors and similar scoring ranges, indicating that raw data from these 2 sample types can be combined in development of regional B-IBIs. We presented only a few examples of individual metric responses to stressors, but we conducted similar comparisons for >70 BMI metrics and found no consistent differences in metric sensitivity to stressor gradients depending on whether they were derived from TR or RW samples. Parsons and Norris (1996) did not evaluate metric responsiveness, but found considerable data redundancy between riffle and edge samples collected in wadeable streams in the Australian Capital Territory, and that O/E indices based on either sample type (or

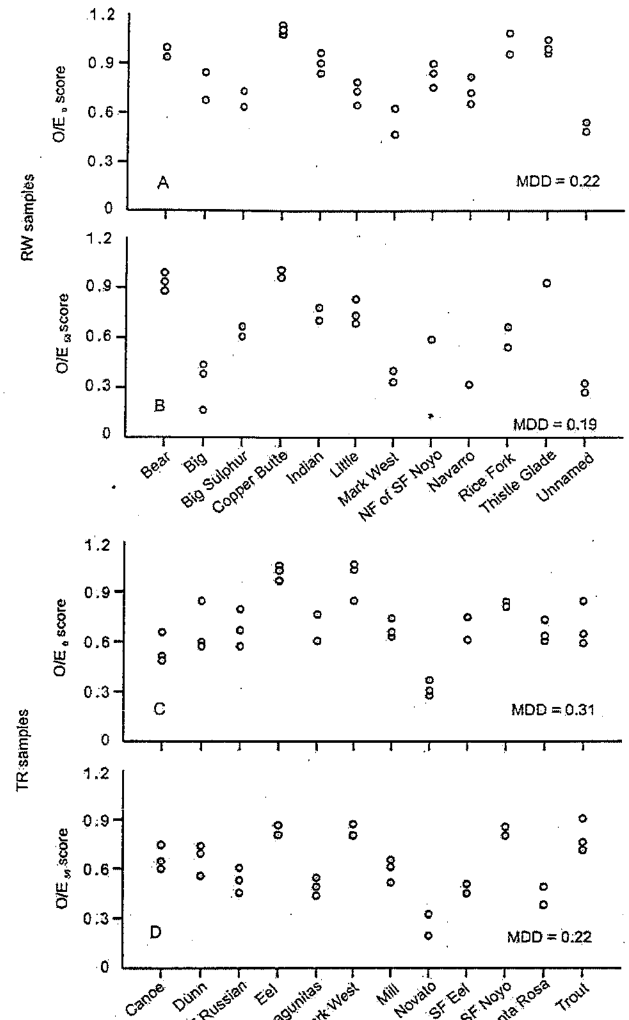
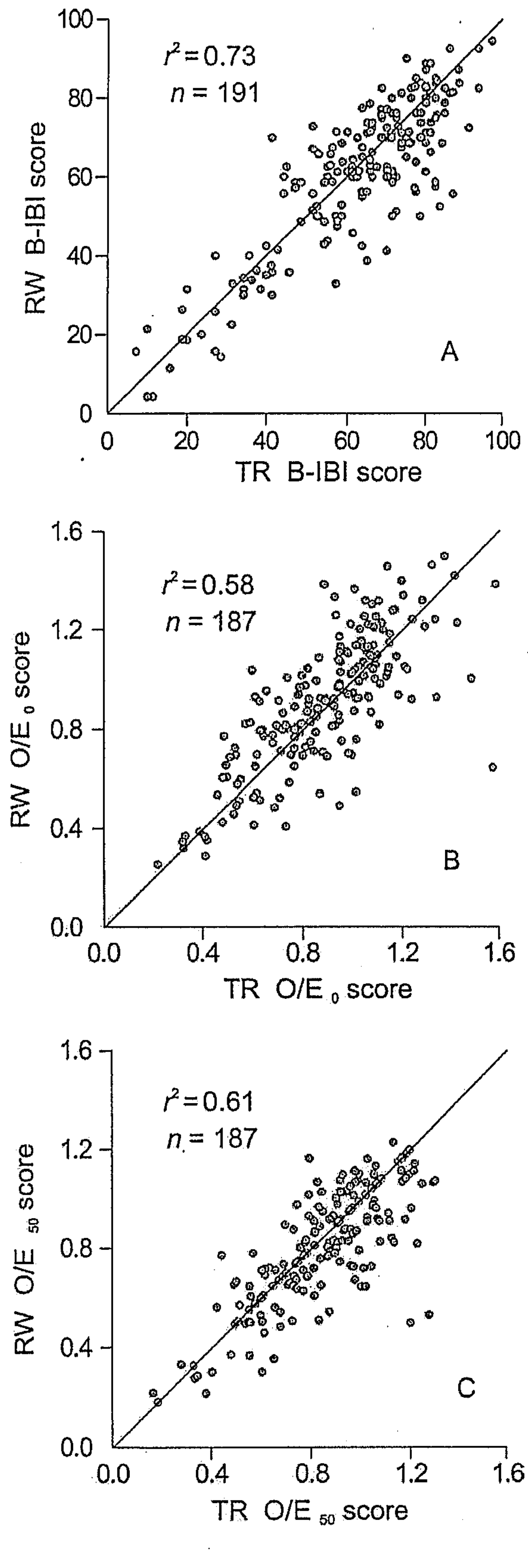


FIG. 5. Replicate observed-to-expected (O/E) index of taxonomic completeness scores calculated as O/E_0 (A, C) and O/E_{50} (B, D) for 3 reach-wide (RW) samples collected at 12 sites (A, B) and 3 targeted-riffle (TR) samples collected at 12 sites (C, D). Replicates were used in estimation of minimum detectable difference (MDD) for each method. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively).

combined samples) were equally capable of detecting biological impairment. Together, these results do not support the hypothesis that certain disturbances have a more pronounced effect on biota in certain habitats that might go undetected were only a single habitat sampled. However, these results might not extend beyond wadeable streams. For example, Blocksom and Flotemersch (2005) found that metrics significantly correlated with stressor gradients varied among 5 sampling methods for nonwadeable streams in Ken-



tucky and Ohio and concluded that raw data were not interchangeable.

Method precision

Indicators derived from different sampling methods may have equal precision, but may not necessarily produce identical site assessments (Cao and Hawkins 2006, Hawkins 2006). We chose MDD as the measure of method precision because it provided a statistical criterion to evaluate whether indicators calculated from TR and RW samples produced equivalent site assessments. Classification strength (Van Sickle 1997) or sampling-method comparability (Cao et al. 2005) can be used to quantify the comparability of raw taxa lists collected with different sampling methods, but similarity analyses provide no statistical criterion to determine whether assessment endpoints differ between sampling methods. Moreover, low taxonomic similarity does not necessarily result in disagreement between metric or B-IBI scores derived from different sample types. The coefficient of variation (CV) of indicator values among reference sites also has been used to estimate sampling-method precision, but has the disadvantage that it incorporates among-site variation in addition to sampling error.

Estimates of all indicator values (B-IBI, O/E_0, O/E_{50}) derived from RW samples were slightly more precise than those derived from TR samples (Figs 4, 5). Between-method differences in MDD were usually small, but RW-derived indicators (B-IBI, O/E_0, or O/E_{50}) were capable of detecting ~1 more condition category than TR-derived indicators (as determined by dividing the indicator scoring range by MDD). Contrary to bioassessment dogma, targeted-habitat sampling did not reduce within-site sampling error relative to multihabitat sampling, and thus, RW sampling may provide water-resource agencies with slightly more sensitive indicators. We suggest the following potential explanations for this observation: 1) the RW protocol sampled an additional 0.27 m^2 of substrate compared to the TR protocol, and the added sampling effort may have been sufficient to produce slightly more precise indicators; 2) the RW protocol, in which sampling was more systematic and spatially balanced, may have reduced sampling error compared

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FIG. 6. Correlations between benthic index of biotic integrity (B-IBI) scores (A), observed-to-expected (O/E) index of taxonomic completeness O/E_0 (B) and O/E_{50} (C) scores calculated from targeted-riffle (TR) and reach-wide (RW) sample types. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively). r^2 values are from ordinary linear regressions.

TABLE 2. Summary of pairwise differences in biological indicator scores calculated from targeted-riffle (TR) and reach-wide (RW) sample types, and the percentage (number) of sites where pairwise differences exceeded minimum detectable difference (MDD); $n =$ 191 for benthic index of biotic integrity (B-IBI) comparisons, $n = 187$ for observed-to-expected (O/E) index of taxonomic completeness comparisons. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively).

Summary of pairwise differences in indicator scores	B-IBI	O/E_0	O/E_{50}
Range in absolute differences	0–31.4	0–0.93	0–0.75
Mean absolute difference	7.8	0.13	0.1
% of sites exceeding TR MDD:			
RW scored higher	1.5% (3)	3.7% (7)	2.7% (5)
TR scored higher	6.8% (13)	4.3% (8)	11.2% (21)
% of sites exceeding RW MDD:			
RW scored higher	2.6% (5)	9.1% (17)	3.7% (7)
TR scored higher	8.9% (17)	6.9% (13)	13.4% (25)

to the TR protocol, in which eligible sample habitats were chosen by field crews; 3) riffle taxa may have had patchier distributions than taxa in other habitats in the streams, making TR-derived indicators more susceptible to sampling error and, therefore, less precise. In any case, TR and RW sample types may have sufficiently similar precision from a PBMS perspective (Diamond et al. 1996) for comparable assessment

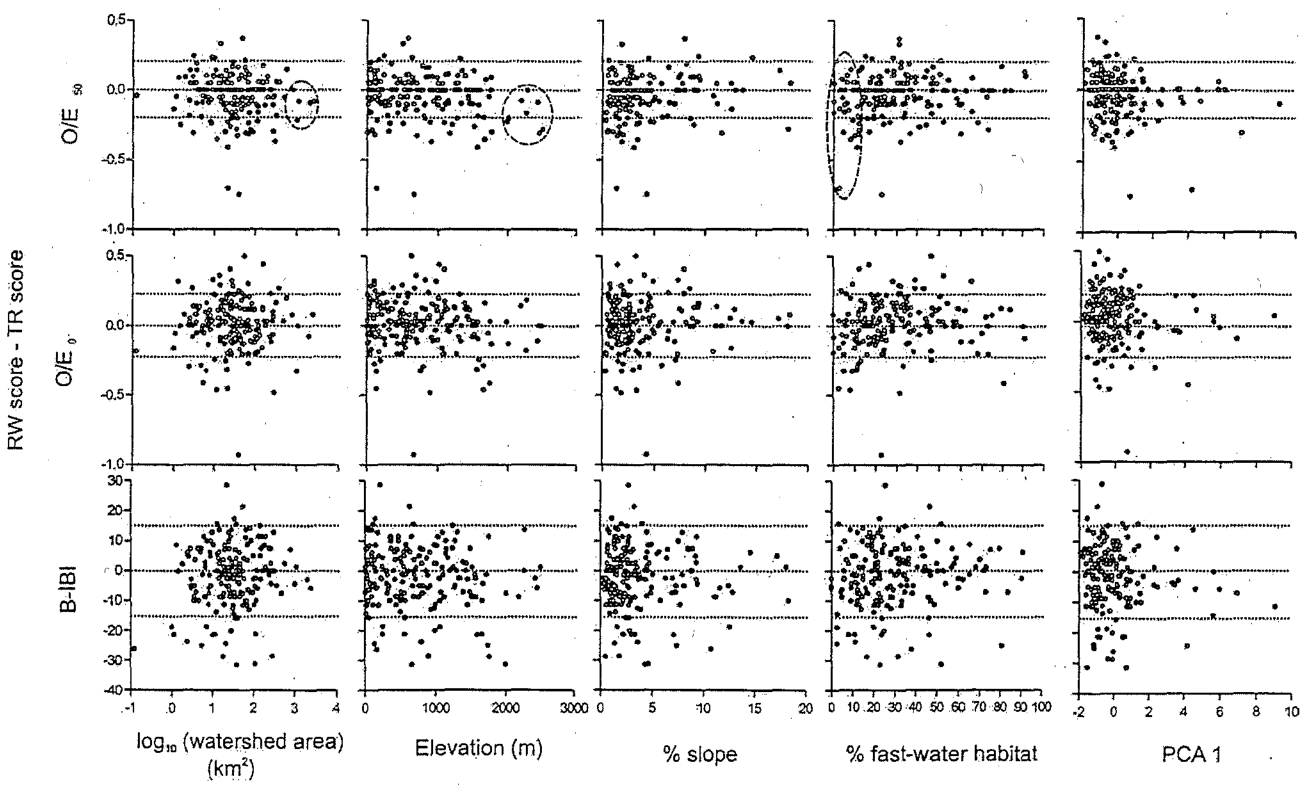


FIG. 7. Pairwise differences in benthic index of biotic integrity (B-IBI) and observed-to-expected (O/E) index of taxonomic completeness scores calculated from targeted-riffle (TR) and reach-wide (RW) sample types in relation to selected natural and disturbance gradients. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively). Horizontal dashed lines show the lowest minimum detectable difference (MDD) for each biological indicator. Pairwise differences between 0 and either the lower or upper MDD lines are not statistically significant. Ellipses were drawn subjectively and show potential conditions where indicator scores from TR samples are consistently higher than scores from RW samples, although many points in the ellipses do not represent statistically significant pairwise differences. PCA1 = principal components analysis axis 1.

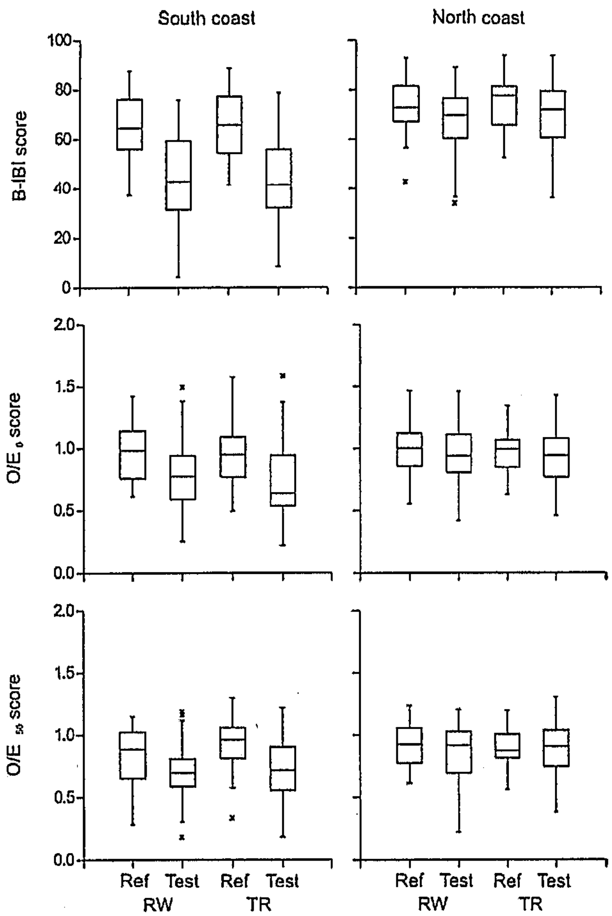


FIG. 8. Discrimination of benthic index of biotic integrity (B-IBI) and observed-to-expected (O/E) index of taxonomic completeness scores between reference (ref) and test sites based on reach-wide (RW) and targeted-riffle (TR) sample types. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively). Discrimination is illustrated by region because of the high frequency of good-quality test sites in northern coastal California. Symbols are as in Fig. 3.

results derived from either method (but see Cao and Hawkins 2006 for a fuller treatment of comparability issues).

Pairwise comparisons

On average, pairwise differences between TR and RW sample types for any indicator were much less than either method's MDD (Table 2). Our preliminary evaluations of raw metrics and the relatively high assemblage similarity between TR and RW sample types (Gerth and Herlihy 2006) indicated that riffle biases may not be present. The slight tendency for TR-derived indicators to overestimate impairment if applied to RW samples (Fig. 7) may be because riffles tend to have more taxa than other habitats. Given equal sampling effort, taxa should accrue more rapidly in TR samples than in RW samples. However, in the western EMAP survey, EPT richness did not differ between riffle and reach-wide samples and taxon richness was higher, on average, in reach-wide samples than in riffle samples (Gerth and Herlihy 2006). Therefore, the small riffle bias we observed may be partly because we used TR-derived indicators for comparisons.

TABLE 3. Loadings of stressor variables on the first principal components axis (PCA1; 55% of total variance explained).

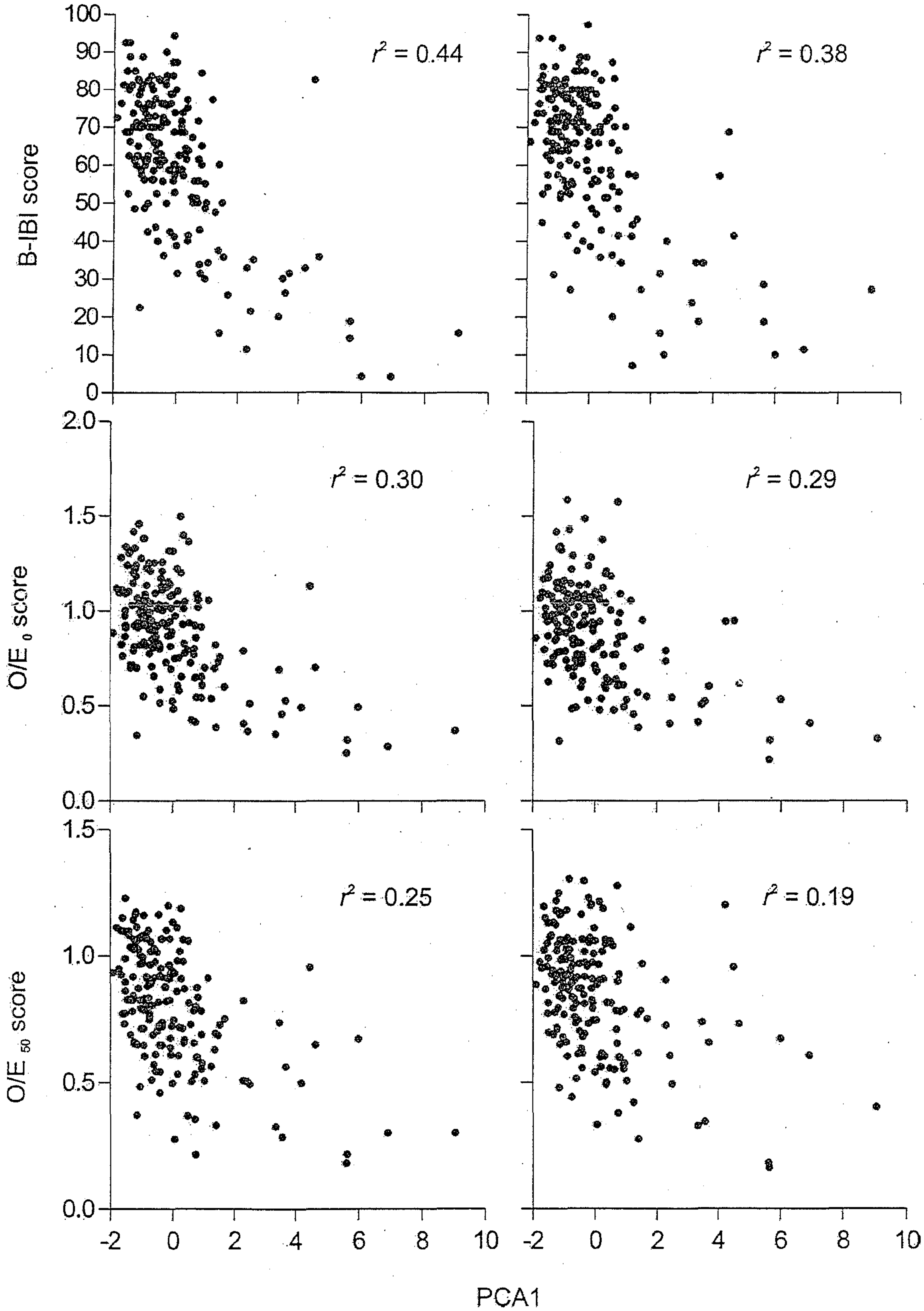
Variable	Axis 1
% sand and fines	0.45
Conductivity	0.46
Log_{10} total N	0.53
Qualitative channel alteration	−0.43
Local road density	0.36

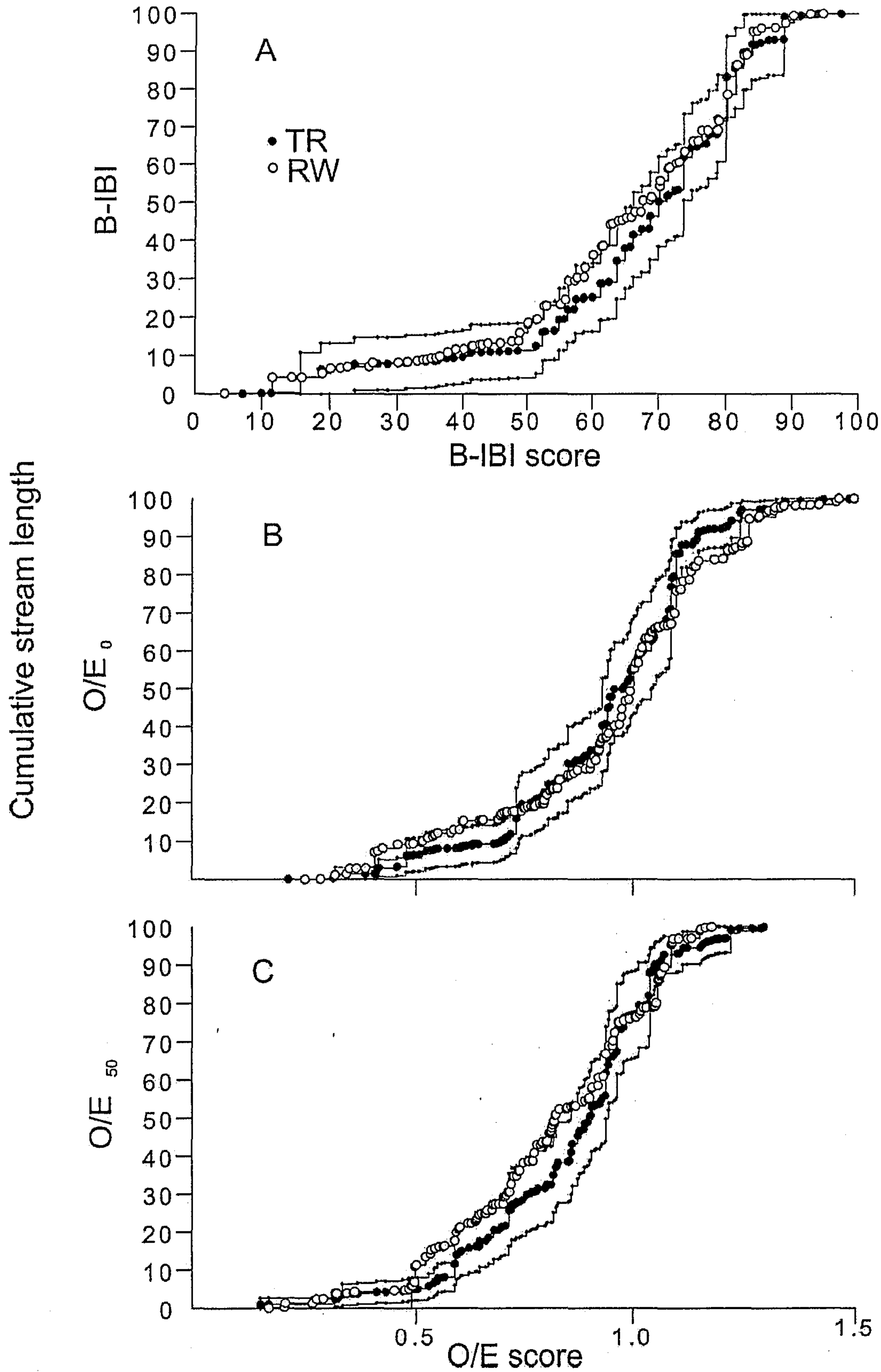
Gerth and Herlihy (2006) observed decreasing Bray–Curtis similarity between TR and RW sample types as % fast-water habitat in the sampling reach decreased. However, we did not observe substantial increases in pairwise differences in indicator scores as % fast-water habitat decreased, even for O/E (which is more akin to Bray–Curtis similarity than B-IBI). At the highest elevations, at sites with the largest upstream watersheds, and at sites with the most human influence, O/E_{50} scores were almost always higher when calculated from TR samples than from RW samples, but the pairwise differences usually did not exceed within-method sampling error (MDD). Therefore, evidence for systematic biases in relation to natural and disturbance gradients is not strong.

Condition assessments

Condition assessments were nearly identical when based on B-IBI and O/E_0 (Figs 10A, B), but were less similar when based on O/E_{50} (Fig. 10C). Therefore,

FIG. 9. Responsiveness of benthic index of biotic integrity (B-IBI) and observed-to-expected (O/E) index of taxonomic completeness based on targeted-riffle (TR) and reach-wide (RW) sample types to a composite stressor axis from principal components analysis (PCA1). Composite axis includes 5 stressor gradients: % sand and fines, conductivity, total N, qualitative channel alteration, and local road density. r^2 values are from ordinary linear regressions. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively).


100
90
80
70
60
50
40
30
20
10
0
B-IBI score
$r^2 = 0.44$
$r^2 = 0.38$
2.0
1.5
1.0
0.5
0.0
O/E $_0$ score
$r^2 = 0.30$
$r^2 = 0.29$
1.5
1.0
0.5
0.0
O/E $_{50}$ score
$r^2 = 0.25$
$r^2 = 0.19$
-2 0 2 4 6 8 10 -2 0 2 4 6 8 10
PCA1


A
B
C
TR
RW
B-IBI
O/E 0
O/E 50
Cumulative stream length
B-IBI score
O/E score
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
0.5 1.0 1.5

cross-application of indicators may be most appropriate when analyses are based on entire taxa lists. Winnowing taxonomic data sets to include only the most common taxa from a single habitat (riffles) may exaggerate differences between sample types, although it does produce more precise models. Therefore, a tradeoff may exist between greater accuracy and precision in models that exclude rare taxa and greater sample-type comparability in models that include rare taxa. Compromise models (e.g., models in which taxa with a predicted probability of occurrence ≥25% define expected conditions) may balance the tradeoff between model precision and cross-application of biological indicators.

Our results also are generally consistent with the results of other studies, including those of Hewlett (2000) who found that riffle, edge, and combined-habitat samples produced similar classifications of 165 sites in Victoria, Australia, and that taxonomic resolution was the most influential feature affecting patterns in reference-site data. Ostermiller and Hawkins (2004) found that O/E indices generated from targeted-riffle cf. timed multihabitat samples collected from wadeable streams in western Oregon and Washington were approximately equally precise. Ostermiller and Hawkins (2004) did show that assessments based on different habitat types sometimes resulted in different site-specific inferences of impairment, but that agreement improved as subsample size increased. For example, the percentage of test sites classified as impaired differed by only 1% when sample counts were ≥400 individuals.

In sum, broad-scale methods comparisons have consistently shown that analyses of BMI assemblages are robust to habitat differences and generally produce consistent stream-condition assessments and classifications. Therefore, the potential advantages of combining TR and RW samples for large-scale analyses, or of directly comparing assessment results based on either sample type, may greatly outweigh the apparently small problems associated with data compatibility. Development of accurate method-specific performance characteristics requires substantial data, but agencies may wish to conduct within-site repeatability analyses in ecoregions other than northern coastal California before they determine that combined data sets are appropriate for their program-specific needs.

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FIG. 10. Estimated cumulative distributions of benthic index of biotic integrity (B-IBI) scores (A), observed-to-expected (O/E) index of taxonomic completeness O/E_0 (B), and O/E_{50} (C) scores in perennial wadeable streams in California. Subscripts on O/E ratios indicate site-specific probabilities of capture >0 or ≥0.5 (O/E_0 and O/E_{50}, respectively). Biological indicators were calculated from both targeted-riffle (TR) and reach-wide (RW) sample types. 95% confidence intervals of the TR curves are shown for comparison.

Acknowledgements

The US EPA Environmental Monitoring and Assessment Program funded statewide data collection under Assistance Agreement CR82823801. The views expressed in this paper are those of the authors and do not represent the views of the US Environmental Protection Agency. The California Energy Commission funded our replication study under project #500-03-017. CPH's contributions to this study were supported, in part, by EPA Science to Achieve Results (STAR) grant R-82863701. Region 5 of the US Forest Service provided funding and conducted field work that supported most of the O/E index development. Thanks go to Tony Olsen (US EPA) for help with condition assessments. Alan Herlihy (Oregon State University) and 2 anonymous referees provided helpful reviews of earlier drafts of the manuscript. Thanks go to Jason May (US Geological Survey) for help with literature searches, and to our field crew and taxonomists (Mike Dawson, Shawn McBride, Dan Pickard, Doug Post, Brady Richards, Glenn Sibbald, Joe Slusark, and Jennifer York).

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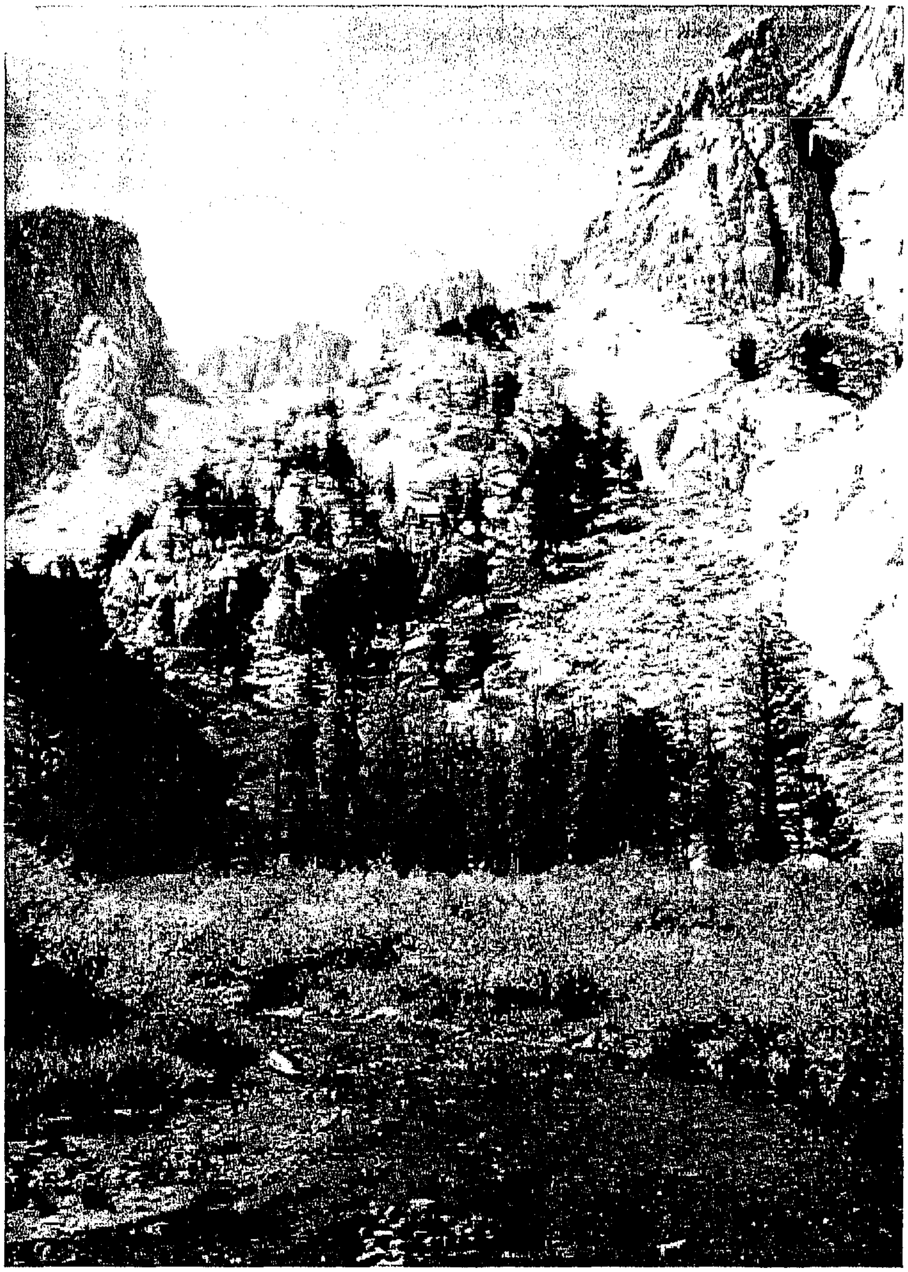
Received: 8 June 2006
Accepted: 19 October 2006

The Status and Future of Biological Assessment for California Streams



California State Water Resources Control Board
Division of Water Quality
January, 2003
Final Report

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Acronym List

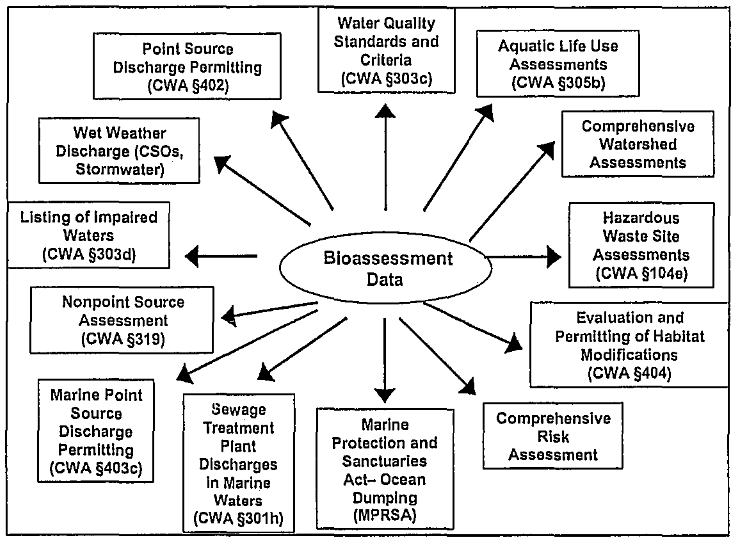
ABL	Aquatic Bioassessment Laboratory
ACCWP	Alameda Countywide Clean Water Program
ANOVA	Analysis of Variance
BLM	Bureau of Land Management
BMI	Benthic Macroinvertebrate
BMPs	Best Management Practices
BP	Basin Plan
BPJ	Best Professional Judgment
CABW	California Aquatic Bioassessment Workgroup
CAMLnet	California Aquatic Macroinvertebrate Laboratory Network
CCAMP	Central Coast Ambient Monitoring Program
CCMAP	Contra Costa Monitoring and Assessment Program
CDFG	California Department of Fish and Game
CSBP	California Stream Bioassessment Procedure
CV	Coefficient of Variability
CWA	Clean Water Act
DFG	California Department of Fish and Game
DWR	Department of Water Resources
EMAP	Environmental Monitoring and Assessment Program
FERC	Federal Energy Regulatory Commission
FRWMP	Feather River Watershed Monitoring Program

GIS	Geographic Information Systems
IBI	Index of Biological Integrity
IMAP	Inventory, Monitoring, and Assessment Program
LSTE	List of Standard Taxonomic Effort
MSE	Mean Squared Error
NAWQA	National Water Quality Assessment
NPDES	National Pollution Discharge Elimination System
NPS	Non-point Source
QA/QC	Quality Assurance/ Quality Control
RBP	Rapid Bioassessment Protocol
REMAP	Regional Environmental Monitoring and Assessment Program
RIVPACS	River Invertebrate Prediction and Classification System
RMAS	Regional Monitoring and Assessment Strategy
RMSE	Root Mean Squared Error
RWQCB	Regional Water Quality Control Boards
SNARL	Sierra Nevada Aquatic Research Laboratory
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resource Control Board
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPCL	Water Pollution Control Laboratory

Executive Summary

Biological communities integrate the effects of different pollutant stressors such as excess nutrients, toxic chemicals, increased temperature, and excessive sediment loading and thus provide an overall measure of the aggregate impact of the stressors. Biological communities respond to stresses of all degrees over time and, therefore, offer information on perturbations not always obtained with episodic water chemical measurements or discrete toxicity tests. The central purpose of assessing the biological condition of aquatic communities is to determine how well a water body supports aquatic life.

The diversity and condition of biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, bioassessment results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act (CWA). Biological assessments are crucial to evaluating ecosystem health and provide crucial water quality planning information for managing more complex water quality problems (see graphic listing uses in water quality programs).



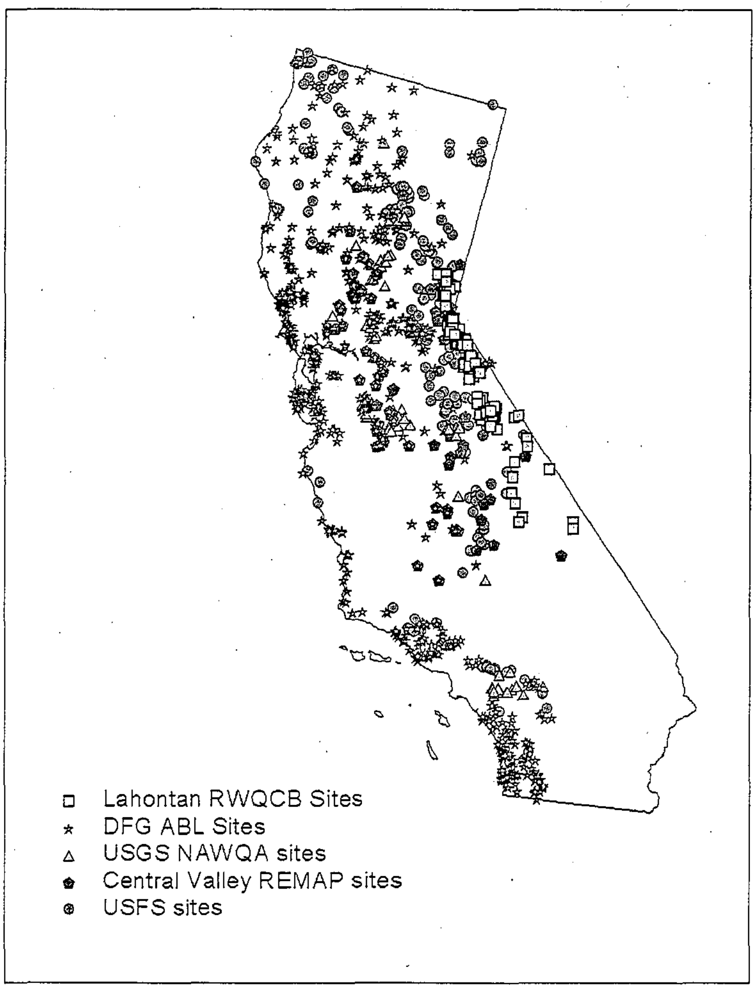
Use of Bioassessment in State Water Quality Programs

The purpose of this report is to document the salient information on the variety of bioassessment programs in California for streams, and to provide recommendations for a universal movement toward a standardized bioassessment program that will serve several entities, especially the SWRCB and RWQCBs. Key findings of this study and report are:

- California has over 200,000 miles of streams and rivers throughout its vast network of mountains and valleys.
- Ranked as the second state in number of stream/river miles (Alaska having the highest number), California is in its infancy in terms of viable biological assessment and monitoring to assess ecological condition.
- The State Water Resource Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB), who are responsible for implementing water quality standards for California=s surface waters, have only recently begun to apply biological assessment principles to their monitoring programs.
- To date, only a few selected instances in regulatory actions have occurred where biological information was used to support management decisions.
- The broader regulatory initiatives, such as measuring the attainment of Aquatic Life Use

designations as mandated by Section 305(b) of the CWA, has not relied on biological assessments in California.

- The last decade has been an important period of advancement and refinement of stream biological assessment for California.
- As a general data-gathering tool used for problem identification (i.e., not used for regulatory purposes), bioassessments have been conducted at over 3000 sites by a multitude of agencies, universities, and other entities.
- Dissimilarities in techniques and purposes for the bioassessments have precluded a universal comparability and data integration effort.
- Five candidate programs exist in California that have scientifically valid and robust methods, and have similar purposes and scope, which could provide the framework for the implementation of a statewide bioassessment approach.
- This reports documents 36 bioassessment programs, representing 22 government agencies (including tribes), 4 universities, 2 municipalities, and 8 environmental interest groups.
- The method developed by the California Department of Fish and Game (CDFG), known as the California Stream Bioassessment Procedure (CSBP) is the most widely used throughout the state, with more than 2500 sites sampled.



Stream Bioassessment Sites Sampled by Candidate Programs

Recommendations include:

- consideration of multihabitat methods to improve detection of non-chemical perturbations
- continuing to collect replicate bioassessment samples for the purpose of precision estimates, and possibly reducing the number of replicates to two or three as a compromise between statistical power and cost.
- closer interaction between the SWRCB and DFG-ABL and SNARL to consider evaluating its extensive ecological database for proceeding with characterizing reference conditions.
- creating a statewide database of bioassessment data that can accommodate the large quantity of data that will be produced in California.
- combining the resources of a statewide database and CAMLnet in order to provide California with a consistent and standard framework for calibrating biological indicators for use on a statewide basis.
- appointing a full-time SWRCB employee to manage the statewide database and provide technical support to database users throughout California.
- developing viable biological indicators and endpoints for assessing biological condition
- incorporating bioassessment into California's water quality regulatory programs
- making funding available for a concerted, statewide bioassessment program.

Chapter 1 Stream Bioassessment: A Framework For Monitoring

Biological assessments of aquatic communities, also referred to as bioassessments, are rapidly becoming a critical tool for water quality monitoring and are gaining popularity among scientists, resource managers, and decision makers alike. To fully understand the concept of bioassessments, it is important to know not only what they are, but also to understand the rationale for conducting them and how they can be used as a decision-making tool. The following text describes the rationale for conducting bioassessments including; 1) definitions of bioassessment and biocriteria, 2) utility of bioassessment as a decision-making tool, 3) success of bioassessment programs in other states, and 4) limitations. The application of bioassessment in California as well as the objectives of this report are described in this chapter.

1.1 The Role of Bioassessment in Water Quality Determination

State and tribal water resource agencies in the U.S. have developed bioassessment approaches that have added an important dimension of ecological understanding to their already over-burdened and under-funded monitoring programs (Barbour 1997). The central purpose of assessing the biological condition of aquatic communities is to determine how well a water body supports aquatic life (Barbour et al. 1996a). Biological communities integrate the effects of different pollutant stressors such as excess nutrients, toxic chemicals, increased temperature, and excessive sediment loading, and thus provide an overall measure of the aggregate impact of the stressors. Use of information about ambient biological communities, assemblages, and populations to protect, manage, and even exploit water resources has been developing and evolving for the past 150 years (Davis 1995). Despite this long history, it has only been in the last decade that a widely accepted technical framework has evolved for using biological assemblage data for assessment of the water resource (Barbour et al. 1996a).

1.1.1 Definition of Bioassessment and Biocriteria

Biocriteria are narrative descriptions or numerical values adopted into state or tribal water quality standards that can be used to factually and quantitatively describe a desired condition for the aquatic life in waters with a designated aquatic life use. The purpose of biocriteria is to establish standards based on biological characteristics that will protect the designated aquatic life use that can be used to direct water quality management. Biocriteria are developed by biologists and other natural resource scientists using accepted scientific principles to characterize the regional reference conditions for the different water bodies found within a state or tribal nation. Biocriteria depend on bioassessments as the scientific basis for making informed decisions regarding the aquatic resource. Bioassessment, on the other hand, is an evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota (i.e., fish, macroinvertebrates, periphyton). This report will focus primarily on bioassessments using benthic macroinvertebrates.

Bioassessments –

- directly measure the response of a biological community to disturbance and restoration actions.
- establish a benchmark of expected conditions.
- provide indication of impairment from multiple and cumulative stressors.

Biocriteria –

- assist in setting state water quality standards.
- help shift the emphasis of preservation and restoration goals from performance-based standards to impact-based standards.
- assist in setting restoration goals.

1.1.2 Utility of Bioassessment as a Decision-making Tool

Biological assessment provides crucial water quality planning information for managing complex water quality problems. Biological assessment serves four primary functions or uses:

1. Screening or initial assessment of conditions
2. Characterizing the magnitude of impairment
3. Assisting in the diagnosis of causes to impairment
4. Monitoring of temporal trends to evaluate improvements or further degradation

States and tribes are faced with the challenge of developing monitoring tools that are both appropriate and cost-effective, and that will provide comprehensive survey coverage of their water resources (Barbour 1997). The purpose for a water resource agency to establish an effective assessment and monitoring program is fourfold:

1. Assess attainment of water quality standards (per CWA §305[b]) and listing of impaired waters (per CWA §303[d]).
2. Identify causes and sources of impairments to support control strategy development including Total Maximum Daily Loads, or TMDLs, (e.g., use of biological response signatures – see Yoder and Rankin 1995, Simon 2002).
3. Evaluate changes in water quality in response to ongoing management actions to gauge level of success and guide strategy revisions.
4. Involve the public to increase their understanding of the environment, build working relationships and trust, and increase information available on water quality and stressors.

The advent of bioassessment in regulatory programs has provided a more comprehensive and effective monitoring and assessment strategy, which is described in detail in USEPA's Clean

Water Action Plan (USEPA 1998). In many instances of impairment, biological measures are better than chemical measures at reflecting the condition of the aquatic ecosystem (NRC 2001). Consequently, the use of bioassessments and biocriertia in state and tribal water quality standards programs has become a top priority of the U.S. Environmental Protection Agency (USEPA 2000). As such, one of the agency's objectives is to ensure that all states and tribes develop water quality standards and programs that use bioassessment information to evaluate the condition of aquatic life in all waterbodies (USEPA 2000). Furthermore, the development of biological criteria (biocriteria) within regulatory programs to serve as thresholds by which to judge the attainment of designated aquatic life conditions of surface waters is a major focus of states and tribes within the US (Barbour et al. 2000).

1.1.3 Success of Bioassessment Programs in other States

The last decade has been a period of progressive advancement in the development and implementation of bioassessment in the US. In 1989 when the Rapid Bioassessment Protocols were first introduced to state programs (Plafkin 1989), very few states and no tribes had viable bioassessment programs in place. In 1994, twenty states were beginning a biological monitoring program for streams and rivers, and fourteen states had biological programs in place (Davis et al. 1996). However, only eleven were developing or had developed biocriteria based on their monitoring programs. In contrast, by the year 2000, most states had established biological

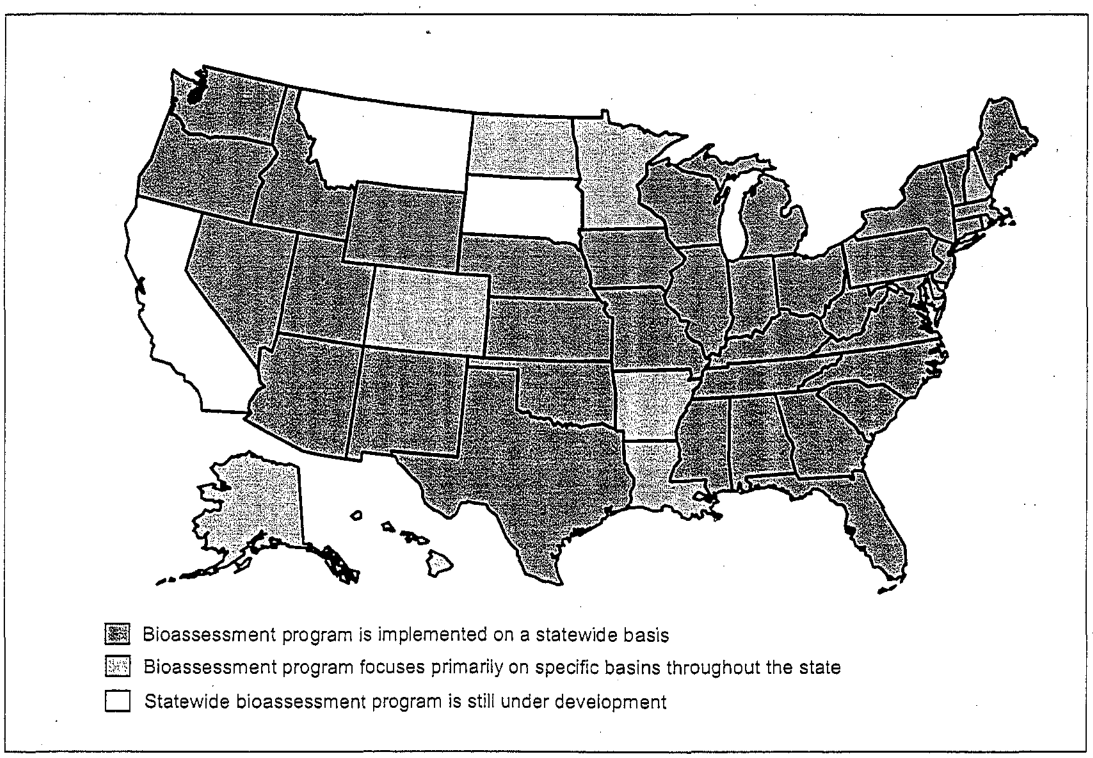


Figure 1. Current status of bioassessment programs (USEPA 2002, Draft).

monitoring programs for streams and rivers, and were developing or had developed quantitative biocriteria. As of 2001, only three states, including California, have yet to establish a concerted bioassessment program (Figure 1), and half of the states have at least 10 % of their streams/rivers assessed for biology (Figure 2). The states and tribes that have been the most progressive in developing biocriteria based on biological assessment include Idaho, Ft. Peck Affiliated Tribes, Maine, Vermont, Maryland, Ohio, Florida, Arizona, and Oregon. The development of bioassessment and biocriteria for bodies of water other than streams or rivers is a more recent phenomenon.

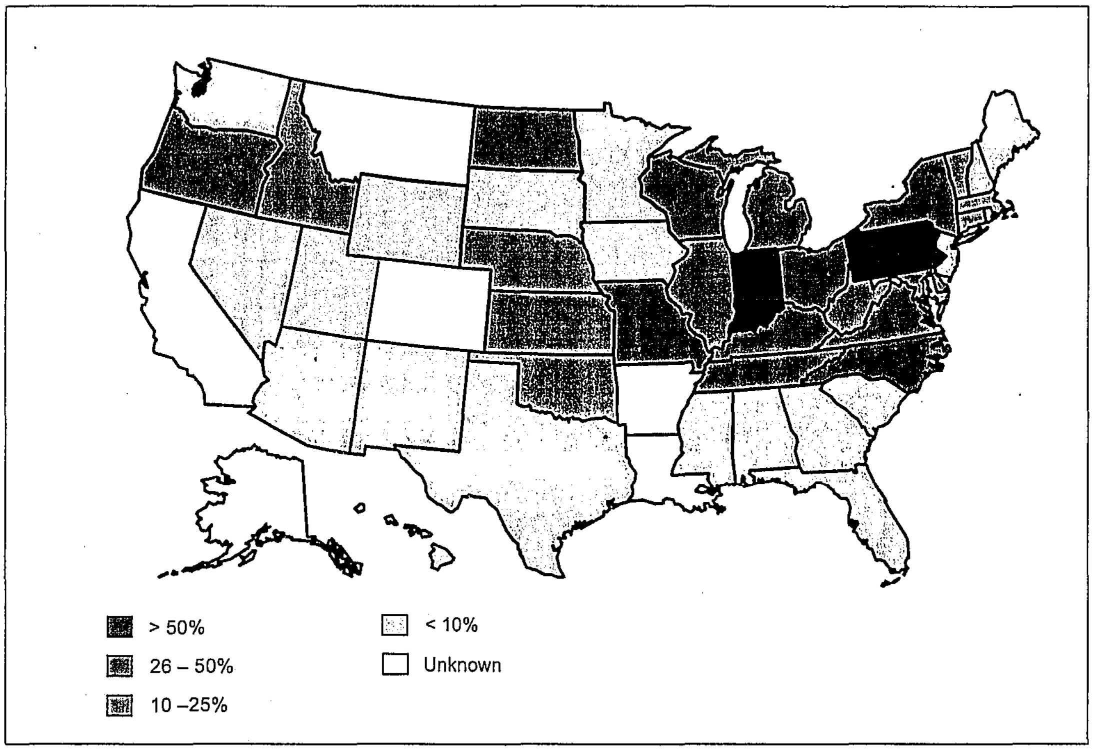


Figure 2. Percent of stream/river miles assessed using bioassessments (USEPA 2002, Draft).

Biocriteria programs begin with the development of a bioassessment framework. Expertise in ecological principles and resource investment by the agency is required to develop this framework and to implement biocriteria. State agencies vary in their investment of resources and effort in this process. In addition, the time frame for development, calibration of a biological indicator for assessment, and implementation is dependent upon resource investment and the ability to gather and compile data. Most states are able to develop the technical framework for bioassessment in less than five years (e.g., Arizona, Florida, Maryland, Wyoming).

1.2 Application of Bioassessment and Biocriteria in California

Historically, the use of bioassessment data in California water regulations and decision-making has not been a high priority. One of the first management actions was in 1993 when the Lahontan Regional Water Quality Control Board (RWQCB 6) required the use of EPA's Rapid Bioassessment Protocols in a fish hatchery permit. Furthermore, in 1993 the California Department of Fish and Game's Water Pollution Control Laboratory in Rancho Cordova began building the infrastructure necessary to develop biocriteria, including an Aquatic Bioassessment Laboratory (ABL) with field and laboratory capabilities large enough to support the bioassessment needs of the State and Regional Boards and other water resource management agencies. In addition, they developed and promoted standardized field and laboratory protocols (California Stream Bioassessment Procedure (CSBP)) for assessing biological integrity in wadeable streams and rivers. Since that time, bioassessment has steadily increased in use in water resource decision-making. Presently, bioassessment is used as an additional tool to NPDES and stormwater permitting to supplement the chemical and toxicological information obtained to address chemical standards. The recent organization of California's Surface Water Ambient Monitoring Program (SWAMP) is providing the impetus to implement a better organized and standardized biological assessment and monitoring program throughout the state. Current concerns over hydroaugmentation and use attainability analyses of targeted waterbodies will foster a greater dependence upon bioassessment information in making informed decisions regarding the protection and restoration of California's streams.

This project is an extension of the SWAMP program and is an attempt to identify and characterize viable bioassessment programs in California's streams. As such, five objectives were articulated for directing this project and resulting report. They are as follows:

1. *Summarize the historical significance of stream bioassessment in California (1992-2000).* Bioassessment development is historically varied and diverse in California. During this period, application of biological survey and assessment techniques was highly oriented toward watersheds and differed among regions of California.

2. *Provide an overview of current statewide bioassessment efforts (2000-present).* With the advent of improved technological advances in bioassessment, certain methods and procedures have come to the forefront as methods of choice for broad-scale assessments.

3. *Highlight candidate programs that can serve as foundations for bioassessment in California.* A few candidate programs encompass the concept and purposes of bioassessment, such that they are viable models for developing a statewide bioassessment approach.

4. *Discuss the future direction of stream bioassessment in California.* Ideally, a single bioassessment approach will emerge that best represents a method that can be used by various agencies and other entities to judge the biological condition, and thus ecological health, of California's streams.

5. *Assist in guidance for database development.* A uniform database to compile and house the multitude of bioassessment data provides a mechanism for integrating ecological data for statewide assessments. The database becomes a central repository where quality control of data integrity and taxonomic standardization can be conducted to ensure comparability.

Chapter 2 Status Of Stream Bioassessment Activities In California

The information presented herein does not constitute a comprehensive overview of all bioassessment activities conducted in California. The information required to complete this section was requested on a volunteer basis; however, only a small fraction of the entities and agencies conducting bioassessments in California responded with sufficient information. On the other hand, the information we collected is indeed representative of a wide range of rigor and interdisciplinary programs, and consequently, it provides a good overall picture of the nature of bioassessment programs throughout California. For more detailed information on specific programs summarized in this section, see Appendix A.

Prior to the 1990's, bioassessment programs were few and far between in California. The only well established long-term bioassessment program in California at this time was that designed and implemented by the California Department of Water Resources (DWR) Northern District. The DWR began collecting bioassessment data circa 1975 and has sampled approximately 100 sites per year. Other than the DWR program, there has been little or no documented information about broad-scale bioassessment programs in California prior to 1992. Historically, the use of bioassessment data in water quality program decisions and management actions has been virtually non-existent. California's State Water Resource Control Board (SWRCB) and RWQCBs have relied primarily on chemical and toxicological information to support management actions.

In the early- to mid-nineties, however, California saw a handful of new bioassessment programs develop across the state. In 1992, the United States Geologic Survey (USGS) began implementation of the first of a series of three broad-scale bioassessment programs in California as part of the National Water Quality Assessment (NAWQA) Program. Also in 1992, the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) began conducting projects covering many different applications of bioassessment throughout the state. Then in 1993, ABL distributed a set of standard protocols for assessing biological and physical conditions of wadeable streams, the California Stream Bioassessment Procedure (CSBP), which is a regional adaptation of the USEPA Rapid Bioassessment Protocols. In 1994, the United States Environmental Protection Agency (USEPA) initiated a broad-scale Regional Environmental Monitoring and Assessment Program (REMAP) bioassessment project in the Central Valley to test the applicability of the national Environmental Monitoring and Assessment Program (EMAP) approach to answer questions about ecological conditions at regional and local scales. In 1995, the Lahontan Regional Water Quality Control Board (RWQCB) began a bioassessment program to monitor the success of remediation efforts at the abandoned Leviathan Mine.

By the year 2000, many had discovered the benefits of conducting bioassessments, and bioassessment programs began sprouting up all over the state, ranging from state agencies to watershed organizations and even volunteer monitoring groups. Coordination among the various groups and agencies collecting bioassessment data began in earnest over the past two years. Consequently, a statewide approach to bioassessment has identified a need, so that differences in results reflect ecological differences, not just differences in methodologies.

2.1 The California Aquatic Bioassessment Workgroup (CABW)

In 1994, DFG, in cooperation with the State Water Resources Control Board and with funding from the U.S. EPA, established the California Aquatic Bioassessment Workgroup (CABW) as a forum for researchers, agency personnel and private consultants working in the field of freshwater biological assessment to communicate and exchange information regarding their work. The three-day meetings provided an opportunity for various state and federal agencies conducting bioassessments in California to update the group on their activities. The State and Regional Boards also discussed ways that they envisioned using bioassessment data in their regulation of water quality. At the first meeting, held in September of 1994, DFG set up a workgroup to review the 1993 edition of the California Stream Bioassessment Procedure (CSBP), assembled a steering committee to produce a Statement of Purpose for the CABW and established an on-going workgroup for defining reference stream criteria.

By the second meeting in 1995, the revisions to the CSBP for wadeable streams and the Statement of Purpose formulated by the steering committee were finalized. The Statement of Purpose outlined four specific objectives of the CABW:

1. Develop consistent, sound methodological approaches to aquatic bioassessment by (a) defining and testing sets of procedures for sampling aquatic communities; (b) establishing reference conditions; (c) developing quality assurance and quality control procedures; and (d) advancing analytical procedures, such as effective use of appropriate metrics and indices.

2. Provide a mentoring and support network concerning technical and professional issues for workgroup participants. The workgroup members envisioned frequent bioassessment workshop where techniques and issues could be presented and participants could network with each other.

3. Facilitate communication by (a) enhancing interagency cooperation; (b) providing an electronics communication platform; (c) disseminating pertinent technical literature; and (d) promoting discussion of findings and bioassessment issues.

4. Promote the incorporation of usable data gathered by volunteer monitoring groups into agency bioassessment programs.

The California Aquatic Macroinvertebrate Laboratory Network (CAMLnet) was formed in 1995 as a workgroup of the CABW with two missions: 1) to provide a forum for sharing technical expertise and experience among laboratories performing bioassessments in California and 2) to serve as a technical advisory body to the CABW and the California State Bioassessment Procedure (CSBP). Although CAMLnet was created as an advisory group to the CABW, its coverage includes all issues related to freshwater macroinvertebrate taxonomy and laboratory procedures. CAMLnet membership consists of private laboratories, tribal, state and federal agencies and university personnel.

One of CAMLnet's major roles is to standardize the levels of standard taxonomic effort used in bioassessments using the CSBP. CAMLnet produced the first edition of the CAMLnet List of Standard Taxonomic Effort (LSTE) in 1999. CAMLnet also sponsors taxonomic workshops to exchange taxonomic expertise, improve taxonomic precision and increase standardization for difficult taxonomic groups.

The objective of the 1996 meeting was to formulate the process for developing biocriteria in California. A workgroup was formed to address the regulatory need for California to have a biocriteria program and at the end of the meeting, an informal discussion concluded that implementation of biocriteria would probably be long in coming and that it most certainly would come after all the supporting science was in place. Also at that meeting, DFG distributed the 1996 version of CSBP, introduced, for review, the CSBP for Citizen Monitors and announced that the CABW web site was up and running.

The CABW continued its annual meetings from 1997 through 1999 providing a forum for updating the attendees on the status of bioassessment in California and presenting examples of bioassessment projects throughout the United States and even Australia. New workgroups were established and others were terminated. The reference stream criteria workgroup ended after three years because the work was dependent on volunteer efforts that were too difficult to support. Many other workgroups met for one or two years to review or gather input for the following issues:

- Identification of funding sources and programs which could promote biocriteria development;
- Review and finalization of revisions of Laboratory and QA/QC Procedures for the 1999 version of the CSBP;
- Formulation of an electronic data processing and storage platform;
- Technical support to citizen monitors and a bioassessment procedure for educational purposes;
- Use of bioassessment in water regulation and FERC re-licensing;
- Use of bioassessment in the California's Stormwater Management Program;
- Use of bioassessment in TMDL development and implementation;
- Assessment of the potential for applying the Rivers Invertebrate Prediction and Classification System (RIVPACS) model to California bioassessment data.

By the year 2000, many bioassessment programs supported by the State and Regional Boards and other water resource agencies needed a forum to present and gather input on their data and interpretation of the results. To accommodate this, DFG changed the seventh and eighth CABW meeting from a three-day workgroup session to two-day platform presentation and panel discussion format. This format was successful in bringing more state and national bioassessment programs to the attention of an expanding audience and providing examples of how bioassessment data was being used in various programs. For the 2002 CABW meeting, DFG returned to the three-day workgroup format consisting of the following sessions:

- The EPA's Environmental Monitoring Program (EMAP) in California and How Water Resource Managers Can Use the Information

- The Use of Bioassessment in Developing and Implementing Total Maximum Daily Loads (TMDLs)
- Developing Biocriteria and How Water Resource Managers Can Use an Index of Biological Integrity (IBI)
- Diagnosing Aquatic Resource Impairment Using Chemical, Toxicological, Physical and Biological Tools

Early in the history of the CABW, the Steering Committee identified the need for professional training in bioassessment. In response, the Sustainable Land Stewardship Institute International (SLSII) adapted a very successful training program for citizen monitors into two three-day workshops aimed at a professional audience. Since 1996, more than three hundred water resource professionals and monitoring coordinators have had extensive training on the concepts of bioassessment in California, use of the CSBP, how to contract public and private laboratories to process bioassessment samples, and how to interpret bioassessment data. The annual CABW meetings and the SLSII bioassessment trainings have been the core elements responsible for introducing the concepts of biocriteria and standardized bioassessment procedures in California.

2.2 Federal Programs

Several federal agencies are currently collecting bioassessment data throughout the State, most of which are large-scale programs. Federal agencies currently collecting bioassessment data are the US Geologic Survey (USGS), the US Environmental Protection Agency (USEPA), the US Forest Service (USFS), and the Bureau of Land Management (BLM). Since all of the agencies collect bioassessment data using candidate methods and are covered more thoroughly in Chapter 3, limited discussion will be afforded to those programs in this section.

Beginning in 1992, USGS has conducted two basin-scale bioassessment projects, and is in the process of conducting a third, as part of the National Water Quality (NAWQA) Program. The San Joaquin-Tulare Basin project was completed in 1995 and the Sacramento Basin Project was completed in 1998. The Santa Ana Basin Project began in 1998 and was not yet completed at the time this report was written (2002).

The US Environmental Protection Agency (USEPA) has conducted a broad-scale bioassessment project throughout the Central Valley as part of their Regional Environmental Monitoring and Assessment Program (REMAP). Biological data were collected for two years (1994-1995) at approximately 87 sites in the Sacramento-San Joaquin River Valley to test the applicability of the nationwide Environmental Monitoring and Assessment Program (EMAP) approach to answering questions about ecological conditions at regional and local scales. USEPA is also collecting bioassessment data in California as part of the EMAP Western Surface Water pilot study, which is a five-year research and monitoring project to assess the ecological condition of streams and rivers throughout the Western U.S. However, because this project has only recently begun and is still several years away from completion, more effort was focused on the completed REMAP study in this report.

The US Forest Service (USFS) has conducted numerous small-scale bioassessment studies throughout the State in the past; however, virtually all bioassessment monitoring has been for specific projects, with little regional perspective or application. Furthermore, different regional branches often conducted bioassessments using different sampling methods and were not coordinated with other branches. It was not until 2000 that they began a more consistent, standardized, scientifically credible, region-wide effort to address region-wide issues, such as watershed restoration.

2.3 State Agency Programs

Several state agencies have begun to utilize macroinvertebrate bioassessments for a variety of purposes. The California Department of Fish and Game's (CDFG) Aquatic Bioassessment Laboratory (ABL) utilizes bioassessment data in their Enforcement Case Program to measure deleterious effects to biological communities resulting from pollution events. Furthermore, ABL initiates bioassessments for numerous reasons when conducting special studies, such as the Consumnes River Watershed study and the Martinez Creek study. This program will be discussed in much greater detail in Chapter 3.

The State Water Resources Control Board utilizes bioassessment as part of their Federal Energy Regulatory Commission (FERC) Hydroelectric Relicensing and Repair Program to help determine compliance with the Clean Water Act and to assess water quality impacts. Under this program, licensees are requested to use rapid bioassessment to help determine impacts to water quality and beneficial uses. Furthermore, they use bioassessments in conjunction with water quality monitoring to determine the impacts of hydroelectric repair projects.

The California Department of Parks and Recreation has implemented bioassessment as part of their Natural Resources Inventory, Monitoring, and Assessment Program (IMAP) to assess water quality and the condition of aquatic ecosystems in state parks. Additionally, the project aims to assess the bioassessment findings in relation to steelhead and other aquatic organisms inhabiting these streams.

The Department of Water Resources (DWR) has been conducting bioassessments since 1975 as part of their responsibility per the California Water Code to determine the quality of the waters of the State. The primary objectives of their program are to provide long-term background information, to determine water quality based on types and abundance of individual species, and to monitor impact assessment and FERC relicensing of major DWR hydroelectric facilities.

2.4 State and Regional Water Quality Control Board Programs

Several Regional Water Quality Control Boards (RWQCB) have recently implemented bioassessment programs to assess the condition of streams within their jurisdiction. Only in its second year, the San Francisco Bay RWQCB (Region 2) has already collected bioassessment data from 72 sites throughout six watersheds. The primary purpose of this program is to establish screening-level ambient biological and physical monitoring in the region's streams along with chemical and toxicity monitoring, as well as establish reference conditions. Secondary purposes include impact characterization, pre- and post-project characterization, and support of regional efforts at habitat classification.

Since 1998, the Central Coast RWQCB (Region 3) has been using bioassessment as part of their Central Coast Ambient Monitoring Program (CCAMP). In this program, bioassessment is used in conjunction with other water quality monitoring approaches to characterize all watersheds throughout the region and to evaluate the effectiveness of best management practices (BMPs) in the Morro Bay Watershed.

The Los Angeles RWQCB (Region 4) is currently funding a bioassessment project to determine the biological health of streams relative to land use in three watersheds (Malibu, Calleguas, and Santa Clara). The University of California Los Angeles (UCLA) is conducting the project, which began in the Fall 2001 sampling season. Furthermore, Region 4 recently initiated a bioassessment program as part of the Surface Water Ambient Monitoring Program (SWAMP), whereby both site-specific monitoring goals and the regional monitoring goals have been integrated into one ambient monitoring program. The information gathered will be used to identify impaired beneficial uses, as well as potentially in the development of an index of biological integrity.

The Central Valley RWQCB - Sacramento (Region 5) began their stream bioassessment program in Fall 2000. The goal of this project is to provide a first step at identification of aquatic life stressors and associated development of ecological indicators in agriculturally dominated and effluent dominated waterbodies in the Central Valley.

Starting in 1995, the Lahontan RWQCB (Region 6) began collecting stream bioassessment data in order to monitor the success of the remediation efforts at the abandoned Leviathan Mine. In 1999, a more concerted, region-wide bioassessment program was implemented: 1) to establish regional reference conditions, 2) to assess the impacts of human activities on the biological integrity of streams and rivers, 3) to evaluate the effectiveness of restoration efforts, BMP implementation, and permit conditions, and 4) to develop narrative and numeric biocriteria. The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB. This program will be discussed in much further detail in Chapter 3.

The San Diego RWQCB (Region 9) initiated a bioassessment program in 1998 to support the ambient monitoring program and to provide baseline data on the benthic macroinvertebrate community in regional streams. The bioassessment program will evaluate the biological and physical integrity of targeted inland surface waters, and is designed to meet an obligation to assess the condition of the Region's waters relative to the attainment of water quality standards.

It should be noted that the North Coast RWQCB (Region 1) have also been conducting stream bioassessments throughout their region. However, since they chose not to participate in our report, we are unable to provide any details about their program.

2.5 Countywide Programs

Many counties have also begun utilizing bioassessments in their Clean Water Plans. The Alameda Countywide Clean Water Program (ACCWP) began using bioassessments in 1998 to support stormwater management activities in Alameda County creeks. The Alameda County

Flood Control and Water Conservation District sponsors the program, which focuses on providing watershed characterization, assessment, and trend monitoring data, and on ensuring compliance with NPDES permit requirements.

The Contra Costa Monitoring and Assessment Plan (CCMAP) began using bioassessment in 2001 as part of a long-term strategy that builds on previous special studies and data collection efforts. CCMAP is designed to assess the conditions of watersheds, water bodies, and water quality within Contra Costa County. CCMAP entails further characterization of watersheds and sub-watersheds, and the development of strategically placed monitoring stations where rapid bioassessment data can provide a valuable screening device to determine where water quality and watershed health are degraded or have the potential for degradation.

The Marin County Department of Public Works incorporated bioassessment in the form of a macroinvertebrate survey into the Marin County Stormwater Pollution Prevention Program in 1999. The primary focus of this survey is to provide data on watershed characterization, assessment, and trend monitoring.

The Ventura County Flood Control Department (VCFCD) began conducting bioassessment after the Regional Board inserted the requirement in the NPDES MS4 permit during the permit renewal. The County has created a program under consultation with CDFG and has conducted bioassessment at 12-14 stations throughout the Ventura River Watershed, which is much more extensive than the requirements placed in the MS4 permit. The main purpose of this program is to assess the biological condition of the Ventura County Watershed and to ensure compliance with NPDES permit requirements.

2.6 Municipal Programs

Both the City of San Jose and the City of San Diego began conducting stream bioassessments to assess water quality. The City of San Jose uses bioassessment data to establish a baseline condition of the benthic macroinvertebrate community prior to the release of recycled water into streams. The City of San Diego uses bioassessment data to assist the city's Metropolitan Wastewater and Storm Water Departments in assessing water quality. Furthermore, they also use bioassessment data to determine biological recovery after toxic events, such as sewage spills, and to assist other agencies with their bioassessment needs.

2.7 Watershed Organization Programs

There are over 100 watershed organizations located throughout the state of California, many of which incorporate bioassessments into their watershed protection/restoration strategies. While summarizing each individual program is not possible, we chose to include a few representative examples to indicate how and why bioassessments are being used by watershed organizations.

The Feather River Watershed Monitoring Program (FRWMP) began conducting bioassessments in 1999 with the purpose of obtaining and making available baseline and continuing data from which trends in watershed health can be measured. The FRWMP is a project of the Feather

River Coordinated Resource Management Group, which is a consortium of 21 public and private agencies and land management entities.

The Friends of Deer Creek began collecting bioassessment data in 2000 as part of the Deer Creek Watershed Bioassessment Program. The primary focus of this program is to assess the ambient condition of the watershed and to evaluate stream restoration efforts. Additionally, they provide data to community members and decision makers in order to support watershed protection and restoration.

The McCloud River Preserve began collecting bioassessment data in 1998 at the citizen level, and then in 1999 at the professional level. The primary focus of the program is to document and analyze the aquatic macroinvertebrate community in the McCloud River and to use the information in conjunction with on-going water quality research to provide a baseline review of the state of aquatic resources within the watershed.

The Reeds Creek/Red Bank Creek Watershed Program is a citizen-based bioassessment program overseen by the Tehama County Resource Conservation District. The program focuses on determining the long-tern trends in watershed conditions for Reeds and Red Bank Creeks through volunteer collected macroinvertebrate data. Both volunteers and students have been collecting bioassessment data since 2001.

The Upper Putah Creek Watershed Management Program began collecting bioassessment data in 2000, which is funded by a 319(h) grant administered by the Placer County Resource Conservation District. The program focuses on training and supervising citizen volunteers to monitor impacts to Upper Putah Creek and its tributaries and translate findings into restoration projects for the Stewardship to implement.

The South Yuba River Citizens' League began collecting bioassessment data in 2001 in order to assess ambient water quality throughout the Yuba River Watershed. The program trains volunteers to collect bioassessment data, which are used to educate community members and to provide data to decision makers for supporting watershed protection and restoration.

2.8 Tribal Programs

Several Native American Tribes across the State have recently begun conducting their own bioassessement programs to monitor water quality on Tribal lands. Both the Hoopa Tribe and the Yurok Tribe utilize rapid bioassessments as part of their ambient water quality monitoring programs. The Pit River Tribe, Smith River Rancheria, and several other tribes are still in the development phase of their water quality programs but plan to include bioassessment as part of their monitoring strategies in the near future.

2.9 Other Programs

There are various other programs/projects throughout California that utilize bioassessments, most of which are research oriented. For example, the Santa Clara Valley Project collected macroinvertebrate data from 14 streams in the Santa Clara Valley from May 1997 to October

1998. The primary focus of the project was to establish the relationships between benthic macroinvertebrate assemblage composition and physical and chemical factors associated with an urban environmental setting. Furthermore, the project aimed to develop a baseline data set representing the distribution of benthic macroinvertebrates in the Santa Clara Valley, which can also be used for evaluating the level of field and laboratory effort needed to conduct bioassessments.

Additionally, several universities (i.e., UC Davis, UC Berkeley, UC Santa Barbara, UC Los Angeles) have all been involved in conducting various bioassessment projects. The scope of these projects ranges from students' theses to private consulting projects for Regional Boards. For example, the Tahoe Research Group, which is a cooperative between UC Davis and The Tahoe Conservancy, is conducting a research project to quantify the effects of anthropogenic habitat degradation and restoration on stream insects in the Tahoe basin. The results of the study will provide necessary information for adaptive management land use decisions and for determining the feasibility of using benthic macroinvertebrates as biological indicators in sub-alpine streams.

Some industries, such timber harvesting, have also discovered the utility of bioassessments and began using them to monitor their impacts on the environment. For example, Scotia Pacific Company has been conducting extensive bioassessments over several years as part of their Habitat Conservation Plan requirements.

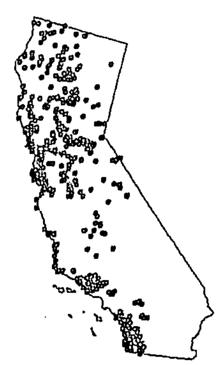
Chapter 3 Status Of Stream Bioassessment Activities In California

A few key programs in California encompass the concept and purposes of bioassessment, such that they are viable models for developing a statewide bioassessment approach. Five candidate stream bioassessment programs were identified in California based on the rigor of their scientific methods and the extent and relevancy of the data collected thus far. To qualify as a candidate program, each bioassessment program must: 1) utilize scientifically credible methods for data collection and processing, and 2) have collected a relatively large set of reliable data across a broad spatial and/or temporal scale. The following bioassessment programs in California meet these criteria: 1) California Department of Fish and Game (CDFG) Aquatic Bioassessment Laboratory (ABL) Program, 2) Lahontan Regional Water Quality Control Board Bioassessment Program, 3) U.S. Forest Service's Pacific Southwest Region Bioassessment Program, 4) U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program, and 5) U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP)/Regional Environmental Monitoring and Assessment Program (REMAP). However, it should be mentioned that the CDFG ABL provides a bioassessment support service to the state and regional boards, as well as other programs and agencies. The ABL provides sampling, taxonomic identification, and training support on a regular basis. The method developed by the ABL, the California Stream Bioassessment Procedure (CSBP) is currently the most widely used stream bioassessment method in California.

3.1 Summary of Candidate Programs

Each of the five candidate programs is summarized based on six major attributes: contact person, sampling method, timeline of sampling, data availability, purpose, and a brief description. More comprehensive summaries outlining key program elements such as habitat selection, sampling gear, sampling method, area sampled, replication, subsampling and enumeration, taxonomic identification, quality assurance procedures, data analysis/metrics, habitat assessment, and purpose for monitoring can be found in section 3.2 - Comparison of Key Elements of Candidate Programs.

3.1.1 California Department of Fish and Game (CDFG) Aquatic Bioassessment Laboratory - California Stream Bioassessment Procedure (CSBP)



The program of the California Department of Fish and Game, Aquatic Bioassessment Laboratory is designed to both investigate pollution events and to support other studies, particularly those of the RWQCBs. CDFG has been instrumental in developing technical resources and conducting numerous bioassessment studies, and in assisting with the design and collection of data for various other bioassessment programs throughout California since 1993.

Contact Person: James Harrington, State Water Quality Biologist, DFG Water Pollution Control Laboratory, 2005 Nimbus Road, Rancho Cordova, Ca 95670 (916) 358-2862 FAX (916) 985-4301 jharring@ospr.dfg.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1992 - present

Data Availability: Approximately 2500 sites statewide.

Purpose of Bioassessment:
- Enforcement and resource damage assessment
- Use attainability
- Ambient monitoring
- Special studies and research

Description: DFG was the first water resource agency to be asked to assess the condition of a freshwater stream using the U.S. EPA's Rapid Bioassessment Procedure (RBPs) (Plafkin *et al.* 1989). The Lahontan Board requested the assessment in 1993 as part of the NPDES requirement of the DFG Hot Creek Hatchery in Mono County. The request necessitated the need to adapt the RBPs to California and the resulting protocol became the California Stream Bioassessment Procedure (CSBP). Because the CSBP was developed for a point-source assessment, it incorporated the use of replicated sampling of a single, richest habitat. Although not consistent with the RBP, DFG decided on this procedure for the following reasons: a) the immediate need for bioassessment was for point-source assessments, enforcements and diagnosis of known, but undocumented water quality impairment; b) there was no interest, at that time, in using bioassessment as an ambient monitoring tool; and c) the ability to produce a measure of biological metric variability at every monitoring site was deemed necessary to convince water resource managers of the robustness of biological assessments.

The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour *et al.* 1999). The CSBP was reviewed and refined by a CABW workgroup in 1994 and 1995 resulting in an updated version in 1996. The CSBP for wadeable streams and rivers has remained consistent over the years and is recognized by the U.S. EPA as California's standardized bioassessment procedure (Davis et al. 1996). Since 1993, the ABL has processed nearly 9000 samples collected using the CSBP at more than 2500 sites throughout California. Thousands of additional CSBP samples have been collected and processed by other entities. In addition to the CSBP for wadeable streams and rivers, as of 2002, there are versions of the CSBP for non-wadeable streams (draft), citizen monitors, lentic environments (California Lentic Bioassessment Procedure), and there is a modification of the CSBP in which samples are composited for sites that are part of an ambient bioassessment program (this CSBP modification has been adopted by the Nevada DEQ).

In addition to the numerous special studies they conduct, CDFG investigates situations where reports of activities or pollution events in the surrounding watershed may have adversely impacted stream integrity and/or stability.

3.1.2 Lahontan Regional Water Quality Control Board Biological Assessment Program – Sierra Nevada Aquatic Research Laboratory (SNARL) Method

The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB.

Contact Person: Thomas J. Suk, Regional Monitoring Coordinator, California Regional Water Quality Control Board, Lahontan Region, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150. Phone: (530) 542-5419; Email: <tsuk@rb6s.swrcb.ca.gov>

Sampling Methods: Prior to 2000, all samples were collected following protocols developed by Dr. David Herbst at the University of California's Sierra Nevada Aquatic Research Laboratory (SNARL). Starting in 2000, the Lahontan RWQCB began using and evaluating three different bioassessment sampling methods: (1) benthic macroinvertebrates, periphyton, and physical habitat assessments following SNARL protocols; (2) California Stream Bioassessment Procedures (CSBP) developed by CDFG; and (3) RIVPACS protocols being used in the Sierra Nevada by the U.S. Forest Service

Timeline of Sampling: 1995 - present

Data Availability: Approximately 350 surveys have been conducted at 200 sites in the Lahontan Region using the SNARL method. At 40 of those 200 sites, sampling was conducted using three methods (e.g., SNARL, CSBP, RIVPACS) to facilitate quantitative comparison of the results provided by each of those three methods. At approximately 30 other sites (throughout the eastern Sierra Nevada) samples were collected using both the SNARL and RIVPACS methods, and at 20 other sites (all in the Walker River drainage) samples were collected using both the SNARL and USEPA-REMAP methods. Most of this data is not yet available, and lab identification and quality assurance procedures are still underway.

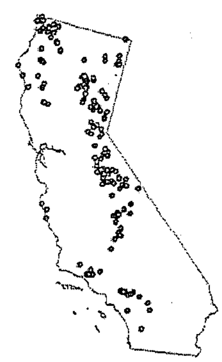
Purpose of Bioassessment:
- To establish regional "reference conditions" for benthic macroinvertebrates and periphyton in streams and rivers
- To assess the impacts of human activities on the biological integrity of streams and rivers
- To evaluate the effectiveness of stream & wetland restoration efforts, BMP implementation, and permit conditions
- To develop numeric targets for TMDLs
- To develop narrative and numeric biocriteria

Description: The Lahontan RWQCB began using bioassessment in 1995, in order to monitor the success of remediation efforts at the abandoned Leviathan Mine. A more concerted (i.e., region-wide) bioassessment program was begun in 1999, for the multiple purposes outlined above.

The current regional-scale effort is focused on developing reference conditions (based on benthic macroinvertebrates and periphyton) for the eastern Sierra "ecoregion," which covers six major watershed basins (e.g., Truckee River, Tahoe Basin, Carson River, Walker River, Mono Basin, Upper Owens River). Streams in this ecoregion were stratified based on stream order, and minimally impaired sites were selected from each class of streams. Sampling has been conducted during the summer reference period (i.e., late June to early September), using protocols developed by Dr. David Herbst of the University of California's Sierra Nevada Aquatic Research Laboratory. As of this writing (i.e., 2001), the effort has focused on data collection and lab identifications; analyses of the data for biocriteria are pending. Several project-specific reports have also been generated (Upper Truckee, Leviathan, Squaw sediment TMDL)(Herbst 2002a, Herbst 2002b, Herbst 2002c).

The Lahontan RWQCB, via contract with the University of California (SNARL), is also using bioassessment data to: (1) evaluate the effectiveness of several stream & wetland restoration projects (e.g., Upper Truckee River, Bagley Valley); (2) evaluate the effectiveness of BMP implementation (e.g., Upper West Walker River, Bridgeport Valley); (3) monitor the success of remediation efforts at Leviathan Mine; (4) verify and/or assess the effectiveness of regulatory permits (e.g., fish hatcheries, Grover Hot Springs State Park); and (5) develop targets based on benthic macroinvertebrates for sediment TMDLs (e.g., Squaw Creek, Heavenly Valley Creek).

3.1.3 U.S. Forest Service - Pacific Southwest Region (California) Bioassessment Program



The focus of this program is on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams throughout the entire state of CA, mainly on Forest Service lands. There are 18 national forests in the region (Angeles, Cleveland, Eldorado, Inyo, Klamath, Lassen, Lake Tahoe Basin Management Unit, Mendocino, Modoc, Plumas, San Bernardino, Sequoia, Shasta-Trinity, Sierra, Six Rivers, Stanislaus and Tahoe)

Contact Person: Joseph Furnish, Ecosystem Conservation Division, 1323 Club Drive, Vallejo, CA 94592

Sampling Method: Hawkins, Ostermiller, and Vinson (1998)

Timeline of Sampling: 2000 - present

Data Availability: Approximately 176 sites in 2000 and 85 sites in 2001 located in the following watersheds: Klamath- North Coastal; Sacramento; Tulare-Buena Vista; San Joaquin; Central Lahontan; Central California Coastal; South California Coastal; North Mojave- Mono Lake.

Purpose of Bioassessment:

- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation
- Reference site characterization

Description: The primary effort has been on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams, which can serve as the basis for monitoring biological condition and determining whether water quality has been degraded compared to reference conditions. Reference conditions will be based on development of a predictive RIVPACS (River InVertebrate Prediction And Classification System) model. Standard EPA metrics will also be considered for use if it is determined that they are sensitive to disturbances at the site and watershed (approximately 10,000-50,000 acre) scale.

3.1.4 U.S. Geological Survey: National Water Quality Assessment (NAWQA) Program

The U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status of and trends in the quality of the nation's surface water and ground water and to provide scientific understanding of the natural and human-induced factors that affect water quality.

Contact Person: Larry Brown, Placer Hall, 6000 J St, Sacramento, CA 95819-6129

Sampling Method: USGS NAWQA

Timeline of Sampling: San Joaquin-Tulare Basins 1992-95; Sacramento Basin 1995-98; Santa Ana Basin 1998-Present.

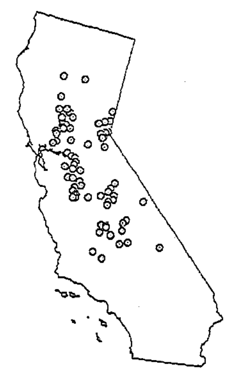
Data Availability: 17 sites in San Joaquin-Tulare Basins; 23 sites in Sacramento Basin; and 4 sites in Santa Ana Basin.

Purpose of Bioassessment:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams
- Describe how water quality is changing over time
- Improve our understanding of the primary natural and human factors affecting water quality

Description: Since 1991, the NAWQA program has been collecting and analyzing data and information in more than 50 major river basins and aquifers across the nation. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions. Three major river basins in California were assessed as part of this program: 1) Sacramento Basin, 2) San Joaquin-Tulare Basins, and 3) Santa Ana Basin.

3.1.5 U.S. Environmental Protection Agency Central Valley Regional Environmental Monitoring and Assessment Program (REMAP)



The Central Valley REMAP project focuses on assessing the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area of California.

Contact Person: Peter Husby, USEPA Region 9 Laboratory, 1337 S. 46th St.; Bldg. 201, Richmond, CA 94804

Sampling Method: USEPA EMAP, Lazorchak and Klemm (1994)

Timeline of Sampling: 1994-1995

Data Availability: Approximately 87 sites in the Sacramento-San Joaquin Valley, covering approximately 24,000 square miles.

Purpose of Bioassessment:
- Support State of CA bioassessment and monitoring
- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: REMAP was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program. EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and States.

3.2 Comparison of Key Elements of Candidate Programs

A series of key elements were identified and compared among the five candidate programs. More specifically, a comparison matrix was assembled and the following elements were listed and compared: habitat selection, sampling gear, sampling method, area sampled, replication, replication as quality assurance/quality control (QA/QC), subsampling and enumeration, taxonomic level of identification, QA procedures, data analysis/metrics, and habitat assessment (Table 1). Data availability/mode of storage, written protocol availability, purpose of monitoring, and additional comments were also included but not compared in any detail as they provide very little useful information for what we are trying to accomplish in this section. Furthermore, wherever possible, the precision of each method was calculated for comparison.

3.2.1 Major Similarities and Differences Among Methods

Although all of the programs collect benthic macroinvertebrate samples to measure water quality, each has a unique goal, or question, that they are trying to address. Therefore, these differences in program goals often translate into differences in program methods. Conversely, similarities in program goals often lead to similarities in the methods. The following section briefly describes the similarities and dissimilarities of eight bioassessment method elements: habitat selection, sampling gear, collection method, area sampled, replication, subsampling and enumeration, taxonomic identification, and habitat assessment.

Habitat Selection

Most of the candidate programs focus the majority, if not all, of their sampling effort on riffle or fast-water habitats. Both CSBP and SNARL methods focus all of their sampling effort on riffle habitat. In addition to the riffle (or richest-targeted) habitat sample, USGS NAWQA also takes a separate multi-habitat sample whereby all habitats present in the reach are sampled with a proportional amount of effort going to each habitat based on occurrence in the reach. The USFS takes a similar approach in that, in addition to fast-water habitat sampling, it also collects a 10-minute qualitative sample whereby the 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

The USEPA EMAP approach is slightly different from all other programs in that the amount of sampling effort is not subdivided based on habitat type, but rather the entire reach is subdivided by a number of cross-sectional transects and a sampling location is selected for each transect. Therefore, whatever habitat type is present at the selected point will be sampled. Samples collected from riffle and run habitats are composited into one sample and samples collected from pool and glide habitats are composited into another.

Table 1. Comparison of Key Elements for California Stream Bioassessment Programs

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Habitat Selection	• Reach determined as 40 times the wetted width with a minimum reach length of 150 meters and maximum length of 500 meters.	• Fast-water (Almost always riffles, runs may also be sampled), four consecutive areas within the sample reach. • Reach length may vary from about 200-500 meters	• Stream reach selected which contains at least 5 riffles within the same order and relative gradient. • If no riffles are present, or less than five within a reasonable distance, EMAP selection method is used as default.	Riffles within 150 m study reach.	• All habitats in selected reach (QMH sample) • "Richest-targeted sample" (RTH sample) with riffles being the priority habitat and woody debris sampled when riffles not available.
Sampling Gear	Rectangular net 50 cm wide, 500 µm mesh.	Surber sampler (0.09 m^2), 500 µm mesh, 1-meter long net to prevent backwashing	30 cm wide D-shaped kick net (500 µm mesh)	30 cm wide D-frame net (250 µm mesh)	• RTH: .5 m x .25 m net with 425 µm mesh. • QMH: standard d-frame net with 210 µm mesh.
Collection Method	• Samples collected at 9 evenly spaced transects within reach. • Composited as riffle/run or glide/pool, 0-9 samples per composite.	• Fixed area sample is composed of 8 Surber samples (4 riffles x 2 samples from each riffle) • 10-minute qualitative sample from all major habitats present.	One composite of 3 samples is collected from the upstream third of 3 randomly chosen riffles.	Each sample is a composite of 3 samples taken from each of 5 randomly selected riffles.	• RTH: composite of samples from 5 locations within riffles. • QMH: equal effort in all habitats present in entire reach. Time variable (usually 1 hr).
Area Sampled	• Area per sample is ~ 0.5 m^2 • Area per composite is variable depending on proportion of habitat type sampled.	• Total area sampled per fixed area composite = 0.72 m^2 • Total area sampled for fixed time samples variable.	Total area sampled per composite = 0.54 m^2 Total area sampled per site = 1.62 m^2	Total area sampled per composite = 0.27 m^2 Total area sampled per site = 1.28 m^2	• RTH: Total area sampled per composite = 1.25 m^2 • QMH: Total area sampled variable
Replication	• No site replicates.	• No site replication using the same methods.	3 randomly-selected samples taken at each site	5 randomly-selected riffles from each site	Limited replication.
Replication as QA/QC	• Same season, different team revisits (2 sites) • Next year revisits (10 sites).				• Replication limited to a subset of 4-6 sites • 3 samples are collected at each site

Table 1. Comparison of Key Elements for California Stream Bioassessment Programs (continued)

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Subsampling And Enumeration	• Random subsampling to 300 organism count/identification	• Composite samples are divided into equal-sized proportions and all organisms are removed from each sub-sample until a minimum of 500 specimens (early data was 300) have been obtained from a complete sort of 1 or more subsamples. • Big/rare specimens are also removed from the entire remaining sample during a 10-minute examination.	• 300 organisms for ID. • All organisms in grid are counted for abundance	• Subsampling using rotating drum splitter • Minimum count of entire split = 250 organisms, (actual range = 300-500) • Big/rare organisms are also removed	• Field splits conducted when sample volume is >0.75 L. • Field processing can result in 4 sample components: large-rare, main-body, elutriate, and split-sample. • Samples are split until composite volume is ≤ 0.75 L.
Taxonomic Level of ID	• Lowest taxon possible • Genus, species, or species group (including Chironomids and Mites).	• Insects are primarily identified to the genus level. • Chironomidae are identified to the sub-family level. • Non-insect invertebrates identified to various levels depending on available keys.	• Insects are primarily identified to the genus level. • Chironomidae are identified to the sub-family level. • Non-insect invertebrates identified to various levels depending on available keys.	• Lowest taxon possible • Genus, species, or species group (including Chironomids and Mites).	• Most insects to species or genus. • Other organisms variable.
QA Procedures	• Field: revisit by different team - same year (2 sites) and second year revisit on 10 sites • Vouchers and reference collection maintained • Lab: sorting checks 10%; ID checks 100%.	• Field: instrument calibration. • National Aquatic Monitoring Center (NAMC) procedures for sample processing. • Vouchers and reference collection maintained at NAMC.	• Field: crew members trained for sampling consistency, and audits • Lab: sorting checks 100%; ID checks 10-20%, bioassessment validation 10-20% • Internal and external QC, 10% each	• Field: instrument calibration, crew training. • Vouchers and reference collection maintained • Lab: sorting checks 20%; ID checks 100%. • Lab training and corrective actions.	• All identifications by qualified experts • 10 % internal QC • External vouchers
Data Analysis/ Metrics	Various including many alternatives for use in screening environmental correlation.	No standard procedure has been designated. RIVPACS will be utilized to develop a model to determine the level of impact to the biological assemblage at a site. Benthic-IBI may also be used depending on performance.	Developed own multimetric and multivariate approach.	Various including many alternatives for use in screening and environmental correlation.	No established metrics or endpoints used. Analysis emphasizes multivariate gradient analyses.
Habitat Assessment	Quantitative surveys of 11 transects (intensive) and full reach (water and sediment chemistry, thalweg, width, depth, velocity, substrate, etc.	1) Densiometer shade measurements, 2) wetted width, 3) mean depth (n=3 measures x 10 transects= 30), 4) substrate- Wolman pebble count, 5) conductivity, 6) alkalinity, 7) Gradient, 8) Habitat Types (Montgomery-Buffington channel classes)	EPA method and additional: • Canopy • Quantitative substrate • Pebble count • Substrate consolidation • Depth & width • Velocity	Quantitative surveys of 15 transects (intensive) and full reach (chemistry, width, depth, velocity, substrate, etc.)	Detailed habitat measurements at various scales (basin, segment, reach, transect). Protocols now call for 11 habitat transects within each reach.

Table 1. Comparison of Key Elements for California Stream Bioassessment Programs (continued)

	USEPA Central Valley R-EMAP	US Forest Service	Dept. Fish & Game (CSBP)	SNARL/Lahontan	USGS (NAWQA)
Data Availability and Mode of Storage	Obtained Excel spreadsheets for Central Valley 1994 & 1995 macroinvertebrate data (no habitat data)	Data are available from the NAMC and eventually will be deposited into the USFS corporate database system of the Natural Resource Information System (NRIS).	Access database (Cal EDAS). Much data still in Excel.	Obtained 4 Excel spreadsheets: Upper Truckee River 1998-2000, Leviathan Mine Watershed 1999, Leviathan Spring 1995/1997, Leviathan Fall 1998)	Obtained Excel spreadsheets for Sacramento River Basin 1996-1998 invertebrate data (no habitat data)
Written Protocols Availability	Lazorchak and Klemm, 1994.	Hawkins et al. 1998	Yes	http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm	http://water.usgs.gov/nawqa/protocols/doc_list.html
Comments		• Analysis tools not fixed, intend to use both multimetric and multivariate approaches. • Approximately 170 prospective reference sites sampled during FY2000 to develop a RIVPACS model.	• Calibration with RIVPACS and EMAP • More than 8000 samples to date	• Calibration with CSBP & RIVPACS underway. • Analysis tools not fixed, intend to use both multimetric and multivariate approaches. • Approximately 225-250 streams sampled to date (1996-2000). • About 25-50 of these are monitored annually or even seasonally.	Program is in support of the National Water Quality Assessment Program and does not include continuous (annual sampling). Intensive sampling typically only occurs for a year or two.
Purpose for Monitoring	• Support State of California bioassessment and monitoring. • Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem. • Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.	• Development of biocriteria & bioassessment protocol • Monitoring of impacts from timber harvest, grazing and mining activities • Ensure compliance with the Clean Water Act • TMDL implementation	• Enforcement and resource damage assessment • Use attainability • Ambient monitoring • Special studies and research • Develop and promote bioassessment methodologies • Test and troubleshoot methods	• Biocriteria development and assessment & monitoring. • Livestock grazing stream restoration • Acid Mine Drainage stream restoration monitoring. • TMDL development for sediments. • Reference condition sampling	In support of National Water Quality Assessment Program, a water quality program. Biological assessments are included as a measure of ecological health of streams.

Habitat Selection

Most of the candidate programs focus the majority, if not all, of their sampling effort on riffle or fast-water habitats. Both CSBP and SNARL methods focus all of their sampling effort on riffle habitat. In addition to the riffle (or richest-targeted) habitat sample, USGS NAWQA also takes a separate multi-habitat sample whereby all habitats present in the reach are sampled with a proportional amount of effort going to each habitat based on occurrence in the reach. The USFS takes a similar approach in that, in addition to fast-water habitat sampling, it also collects a 10-minute qualitative sample whereby the 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

The USEPA EMAP approach is slightly different from all other programs in that the amount of sampling effort is not subdivided based on habitat type, but rather the entire reach is subdivided by a number of cross-sectional transects and a sampling location is selected for each transect. Therefore, whatever habitat type is present at the selected point will be sampled. Samples collected from riffle and run habitats are composited into one sample and samples collected from pool and glide habitats are composited into another.

Sampling Gear

The majority of candidate programs prefer to use D-frame or rectangle frame kicknets to collect samples; however, net mesh size is variable among programs. Most of the methods prefer a net with a mesh size around 500 µm. For example, both CSBP and USFS methods use 500 µm mesh netting, while USEPA EMAP and USGS NAWQA (RTH sampling) use 595/600 µm and 425 µm, respectively. On the other hand, SNARL prefers 250 µm mesh netting, and USGS NAWQA (QMH sampling) uses 210 µm mesh netting.

The only obvious difference in sampling gear, other than mesh size, is USFS method's use of a Surber sampler. All other programs use either a D-frame net or rectangle frame kicknet to collect samples. CSBP, SNARL, and NAWQA (QMH) methods all use D-frame nets. Both EMAP and NAWQA (RTH) methods use rectangle frame kicknets.

Collection Method

Perhaps the largest difference between programs lies in the collection method used by each. All of the programs take one or more composite samples from each site, but the make up of and method of collecting each composite is quite variable. For a detailed description of each programs' sampling method see Appendix B.

Area Sampled

The area sampled per composite is quite variable ranging from 0.27 m^2 for the SNARL method to 1.25 m^2 for NAWQA (RTH) method. However, composites using the EMAP method may sample up to 4.5 m^2, but the area sampled varies based on habitat selection. The total area sampled per reach, not including fixed time or QMH sampling, ranges from 0.72 m^2 for the USFS method to 4.5 m^2 for the EMAP method.

Replication

Only three of the five methods collect valid site replicates as part of their sampling programs. Both the CSBP and SNARL methods routinely collect replicate samples at every site (i.e., three and five, respectively), whereas NAWQA collects replicate samples at a subset of 4-6 sites per study. USFS collects no replicates samples, and EMAP only collects QA/QC replicates using same season, different team revisits and same team, different year revisits.

Subsampling and Enumeration

Both the count and method of subsampling is highly variable among all programs. NAWQA uses both a qualitative visual sort method and a quantitative fixed-count method of subsampling; however, the organism count varies based on the data quality objectives of the study. Both the CSBP method and the EMAP method subsample to 300 organisms, but the remaining programs use subsampling methods based on composite sample splits and identifying the entire split to within a range of organisms. For example, USFS divides the composite into equal-sized portions and all organisms are removed until a minimum of 500 specimens have been obtained from a complete sort of one or more subsamples. The SNARL method uses a similar subsampling strategy whereby the composite sample is split until the minimum count of the entire split is 250 organisms.

Taxonomic Identification

Most of the programs identify insects to the lowest taxon possible, which is usually the genus and/or species level. However, USFS and CSBP identify Chironomid midges to the sub-family level. Non-insect invertebrate identification is variable, usually depending upon available taxonomic keys.

Habitat Assessment

Habitat assessment tends to be highly variable among programs in terms of rigor and detail of measurements. EMAP, NAWQA, and SNARL collect quantitative measurements at multiple (11-15) transects throughout the study reach, utilizing a relatively comprehensive habitat assessment approach. On the other hand, CSBP and USFS utilize more rapid habitat assessment techniques (visual-based for most measures) to characterize physical habitat semi-quantitatively.

3.2.2 Comparison of Performance Characteristics for Bioassessment Methods

Although water quality programs have distinct goals for conducting bioassessments and require different levels of effort in sample collection, taxonomic identification, and data analysis, discrete methods may yield comparable data for certain objectives despite these differences in effort. If discrete methods are similar with respect to the quality of data they produce, it is possible to use the results together. In other words, determining the performance characteristics of individual methods enables agencies to share the results of bioassessments by providing an estimate of the level of confidence in assessments from one method to the next (Barbour et al. 1999). The best way to determine the quality of data produced by a method is through the use of data quality objectives. Data quality objectives (DQOs) are qualitative and quantitative expressions that define requirements for data precision, bias, method sensitivity, and range of conditions over which a method yields satisfactory data (Klemm et al. 1990).

The documentation of performance characteristics for all methods is known as the performance-based method system (PBMS – see ITFM 1995), which is essentially a system that permits the use of any method of sampling and analysis that meets established requirements for DQOs (Diamond et al. 1996, NWQMC 2001). The basic elements of a PBMS approach include method precision (repeatability of measurements), bias (skewness of measurements), sensitivity (detection limit), and accuracy (proximity to the analytical truth).

For the PBMS approach to be useful, three basic assumptions must be met (ITFM 1995):

1. DQOs must be set that realistically define and measure the quality of the data needed; reference (validated) methods must be made available that meet those DQOs;
2. there must be proof that the method yields reproducible results that are sensitive enough for the program; and
3. the method must be effective over the prescribed range of conditions in which it is to be used.

Key Performance Characteristics
- Precision
- Sensitivity

For bioassessments, the above assumptions imply that a given method for sample collection and analysis produces data of known quality, including precision, the range of habitats over which the collection method yields a specified precision, and the magnitude of difference in data among sites with different levels or types of impairment (Diamond et al. 1996). Calculating the performance characteristics for a given bioassessment method is essential to understanding the robustness of the method for reliably determining the condition of the aquatic ecosystem. A method that is very labor intensive and requires a great deal of specialized expertise, and, in turn provides a substantial amount of information, is not necessarily the most appropriate if it is not very precise and repeatable. A less rigorous method may be less sensitive to detecting perturbation or have more uncertainty in its assessment. All of these attributes are important to minimizing Type I and II error in bioassessment. The ultimate question resides in a firm balance between cost and resolution, i.e., is more information better (more cost) or is a limited amount of the right information best (less cost). A knowledge of method precision, sensitivity, bias, and accuracy helps with this decision. For purposes of this discussion, the key performance characteristics are precision and sensitivity to establish a basis for understanding the CSBP and SNARL methods comparison presented later in his section.

Establishing DQOs for a bioassessment method helps to evaluate the adequacy and robustness of a method. For example, we may establish the following DQOs:

DQO 1. We want to be able to detect a 20% change, e.g., five categories of condition on a 100-pt scale for a calibrated biological index.

DQO 2. We want the method to have a discrimination efficiency of greater than 75%, i.e., the method is calibrated so that only 25% or less ($\beta = 25\%$) of the *a priori* determined sites of reference and degraded would be misclassified.

Using these two example DQOs, we establish the following hypothetical scenario.

Hypothetical Scenario

To conduct an analysis of the performance of a bioassessment method, or several methods, five steps can be identified: 1) compare the relative variability of the various methods from both reference and degraded sites – *DQO 1*, 2) evaluate sensitivity or discrimination efficiency – *DQO 2*), 3) evaluate precision, 4) evaluate bias and accuracy, and 5) evaluate ability to make a correct assessment – *DQO 2*. In this hypothetical example, we compare three methods used side-by-side to collect bioassessment data.

Step 1 (Characterization of sites). The first step toward evaluating a method's performance as a bioassessment tool, is to collect or assemble data from both reference and degraded sites. Having a population of reference sites as well as a population of data collected from known degraded sites is essential for determining both the relative performance using different levels of biological condition as well as determining sensitivity or discrimination efficiency. Box-and-whisker plots are used to plot data for a given biological indicator (e.g., a metric or index) from each of the three methods (Figure 1). These plots illustrate the amount of variability measured in a population of sites (in both reference and degraded categories). For this example, we will say that methods 1 and 2 have tight enough ranges in variability to allow us to meet the first DQO, i.e., an ability to detect a 20% change.

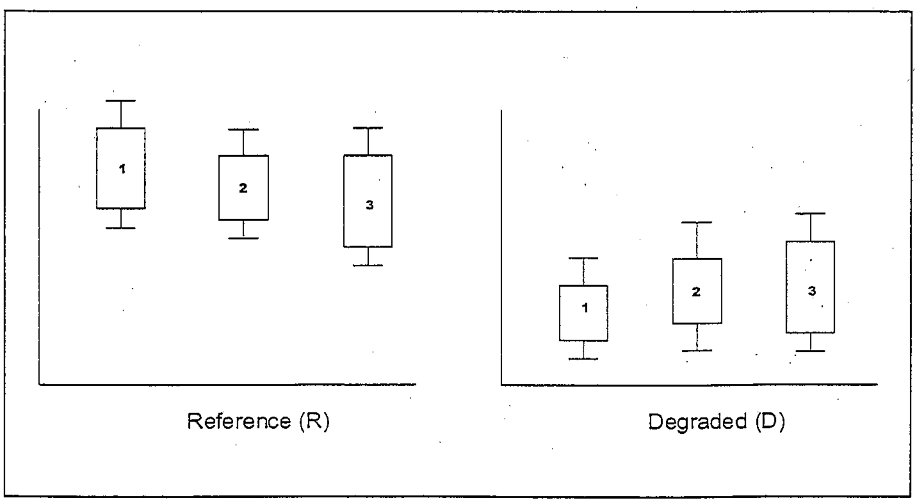


Figure 1. Box-and-whisker plots showing the distribution of data collected from reference and degraded sites using three separate methods (1, 2, and 3). Boxes illustrate population attributes (via percentile distribution, i.e., 25% - 75%) and whiskers provide a sense of variability.

Step 2 (Sensitivity). The second step is to evaluate the sensitivity of each method, or ability to discriminate between reference and degraded sites. By examining the reference and degraded box and whisker plots side-by-side, it is possible to determine the sensitivity of a given method. The reference and degraded plots are paired to show the amount of overlap, or lack thereof (Figure 2). The more overlap between plots the less sensitive the method, and vice versa. In this example, method one is the most sensitive because there is no overlap between plots, and method three is the least sensitive because it has the most overlap of the interquartile ranges. Method 1 meets the second DQO of having greater than 75% discrimination efficiency.

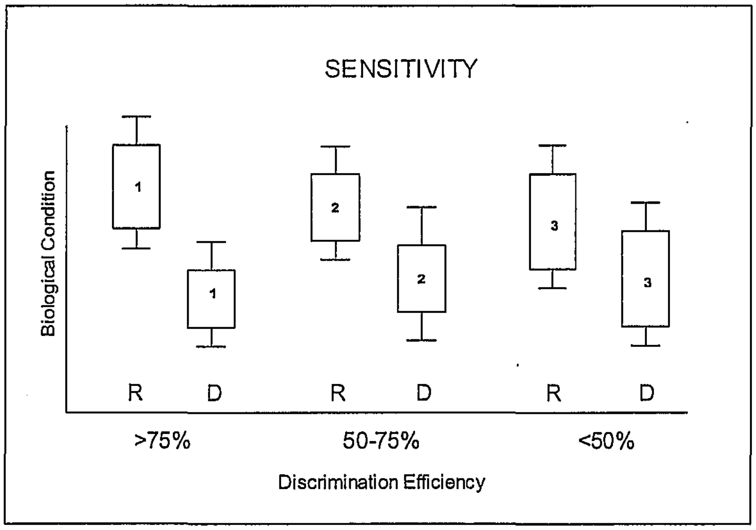


Figure 2. Box-and-whisker plots illustrating the ability of each method to discriminate between reference (R) and degraded (D) conditions. Method one discriminates greater than 75% of the sites correctly; method two can only discriminate between 50 and 75% of the sites correctly; and method three is least sensitive, discriminating less than 50% of the sites.

Step 3 (Precision). The third step is to evaluate the method precision, or repeatability of measurements, using all sites (i.e., reference and degraded) in the population. Repeated samples (replicates or duplicates) are required to calculate the standard deviation from the mean. This can be illustrated by graphing the mean value for a given metric or index and incorporating error bars to show the standard deviation (Figure 3). In this example, method two is the most precise because it has the smallest standard deviation around the central tendency (mean), and method three is the least precise because it has the largest deviation around the mean.

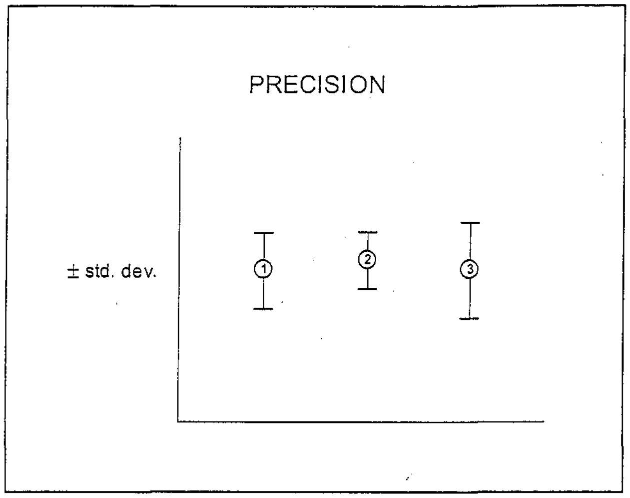


Figure 3. Graph illustrating the precision of each method for a given measure using means and standard deviations.

Step 4 (Bias and Accuracy). Although not treated here, bias and accuracy are often determined for various components of bioassessment, such as laboratory subsampling and taxonomic identification. In the laboratory setting, it is relatively easy to determine the accuracy of sorting as well as the bias of sorters and taxonomists through the implementation of simple QA/QC plans. For example, after organisms are identified, they can be sent to another independent taxonomist for confirmation of taxonomic identifications. Bias would be a consistent mis-identification that could be ascertained through QC checks. Additionally, after a sample is sorted, an assigned QC officer can resort the sample to determine the percentage of "missed" specimens. Bias might be in always missing midges, or very small specimens, for example. While both bias and accuracy can be determined at various stages in the bioassessment process, it is often unclear how these characteristics can be calculated for the overall assessment where "truth" is determined by an impairment threshold.

Step 5 (Site assessment). The fifth and final step is to evaluate the influence of the performance characteristics on making a correct assessment. By examining the performance characteristics of the three methods in relation to a fixed impairment threshold, we can determine a level of confidence in each index value (Figure 4.) In this example, we use the three methods at one site and their measurement precision and discriminatory efficiency to illustrate how a site assessed as impaired by all three might be evaluated. For Method 1, we have high discrimination efficiency and moderate precision. Because the value of the site and its error bars (precision) fall below the impairment threshold, we have a high level of confidence that this site is in fact impaired. Method 3 is the least precise and least discriminatory, and thus, our confidence that this site is impaired is low. For Method 2, which has the highest precision, the site would likely be assessed as impaired. However, the discrimination efficiency of Method 2 indicates that we only assess between 50 and 75% of our sites correctly. In this case, sites that are slightly impaired, i.e., near the threshold, would benefit from additional, supplemental data (e.g., complementary water or habitat quality data, a follow-up biosurvey, etc.).

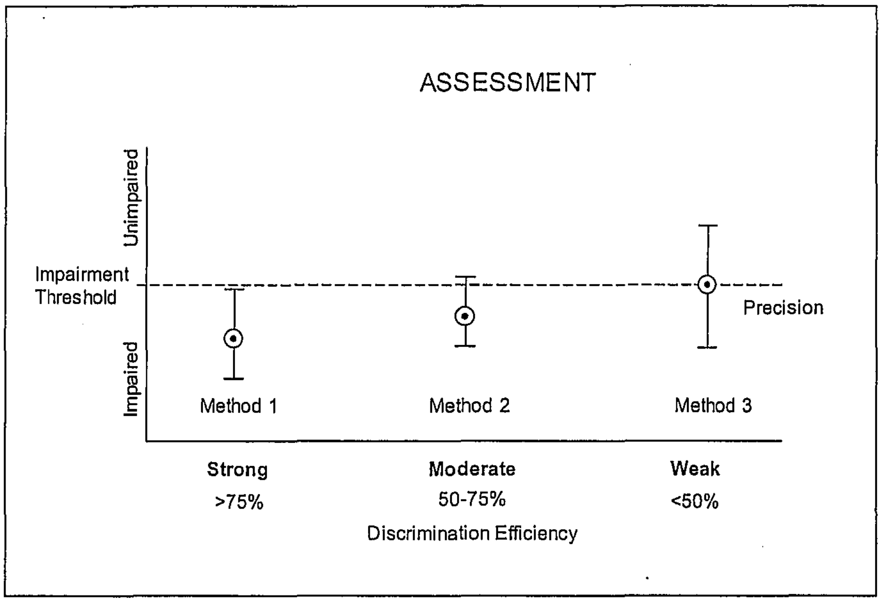


Figure 4. Graph illustrating the ability of a method to yield a correct assessment based on a combination of precision and sensitivity (or discriminatory efficiency) and the value of the assessed site in relation to the impairment threshold.

Comparison of CSBP and SNARL Methods

Due to the paucity of data provided to us at the time of this report, only one performance characteristic, method precision (i.e., measurement error within a site), could be evaluated for two candidate methods, CSBP and SNARL. It should be mentioned, however, that there are a few caveats with this precision comparison. First, the populations sampled using each method were quite different from each other. The SNARL method sampled primarily high elevation streams (5,000-7,500 feet) in the Sierra Nevada Mountain Range, whereas the CSBP collected samples across a wide variety of locations and across multiple ecoregions, primarily in lower elevation streams. Because variability is a combination of both natural variability and measurement error, greater variability does not necessarily imply greater measurement error when two distinct populations are sampled. Consequently, a side-by-side comparison would help to minimize the influence of natural variability and allow a more accurate comparison of measurement error between these two methods. Secondly, the net mesh size used in the SNARL method and CSBP is very different, 250 μm and 500 μm respectively. This difference can introduce a good deal of variability in the results because of organism selectivity (bias) associated with each method. However, it is uncertain as to whether this would significantly affect the comparison of precision estimates and requires further research. Thirdly, it is uncertain what types of sites (i.e., impacted, reference, etc.) and in what proportions these types of sites make up the datasets that were analyzed. Different types of sites may introduce more natural variability among replicates than others, and thus, could affect the precision estimate for that method. With this simple comparison, we provided estimates that the SNARL method may be more precise, except for the caveats cited previously. We do not know if the higher precision is either ecologically or statistically significant, and if so, whether cost implications justify the increased precision. However, this exercise demonstrates one of the steps necessary for adequately comparing methods.

As a focus of this methods comparison, sampling precision was evaluated using the root mean square error (RMSE) to measure variability. RMSE, also called the standard error of estimate, is an estimate of the standard deviation of a population of observations. The RMSE was calculated for eight common biological metrics used by both the CSBP and SNARL methods. RMSEs ranged from 0.72 to 11.78 for CSBP and from 1.03 to 7.78 for SNARL for the eight metrics (Table 2). The RMSE was lower for CSBP than for SNARL for the richness metrics (i.e., total number of taxa, EPT taxa, and components of the EPT – Ephemeroptera, Plecoptera, and Trichoptera). However, the reverse was true for the composition and tolerance metrics (i.e., %EPT, %Tolerant organisms, and %Dominance). The relative spread of the values for the two methods is illustrated when the mean and standard deviation for each metric are graphed (Figure 5). The SNARL method recorded a higher mean for each metric. However, the standard deviation was generally lower for the CSBP method.

Table 2. Comparison of ANOVA results between CSBP and SNARL methods.

Metric	CSBP			SNARL			RPD RMSE	Difference CV
	RMSE	*MEAN*	*CV*	*RMSE*	*MEAN*	*CV*		
Total Number of Taxa	3.21	16.72	19.23	3.76	27.09	13.9	15	5.4
EPT Taxa	1.59	6.45	24.71	1.85	11.1	16.67	15	8.04
Ephemeroptera Taxa	0.72	2.97	24.44	1.03	6.77	15.26	35	9.18
Plecoptera Taxa	1.09	2.83	38.54	1.26	4.33	28.99	10	9.55
Trichoptera Taxa	1	2.82	35.65	1.16	5.73	20.22	15	15.43
%EPT	11.29	42.21	26.76	9.5	63.32	15	17	11.76
% Tolerant Organisms	11.24	22.37	50.23	5.4	11.32	47.7	70	2.53
%Dominance	11.78	43.45	27.12	7.78	36.16	21.52	41	5.6

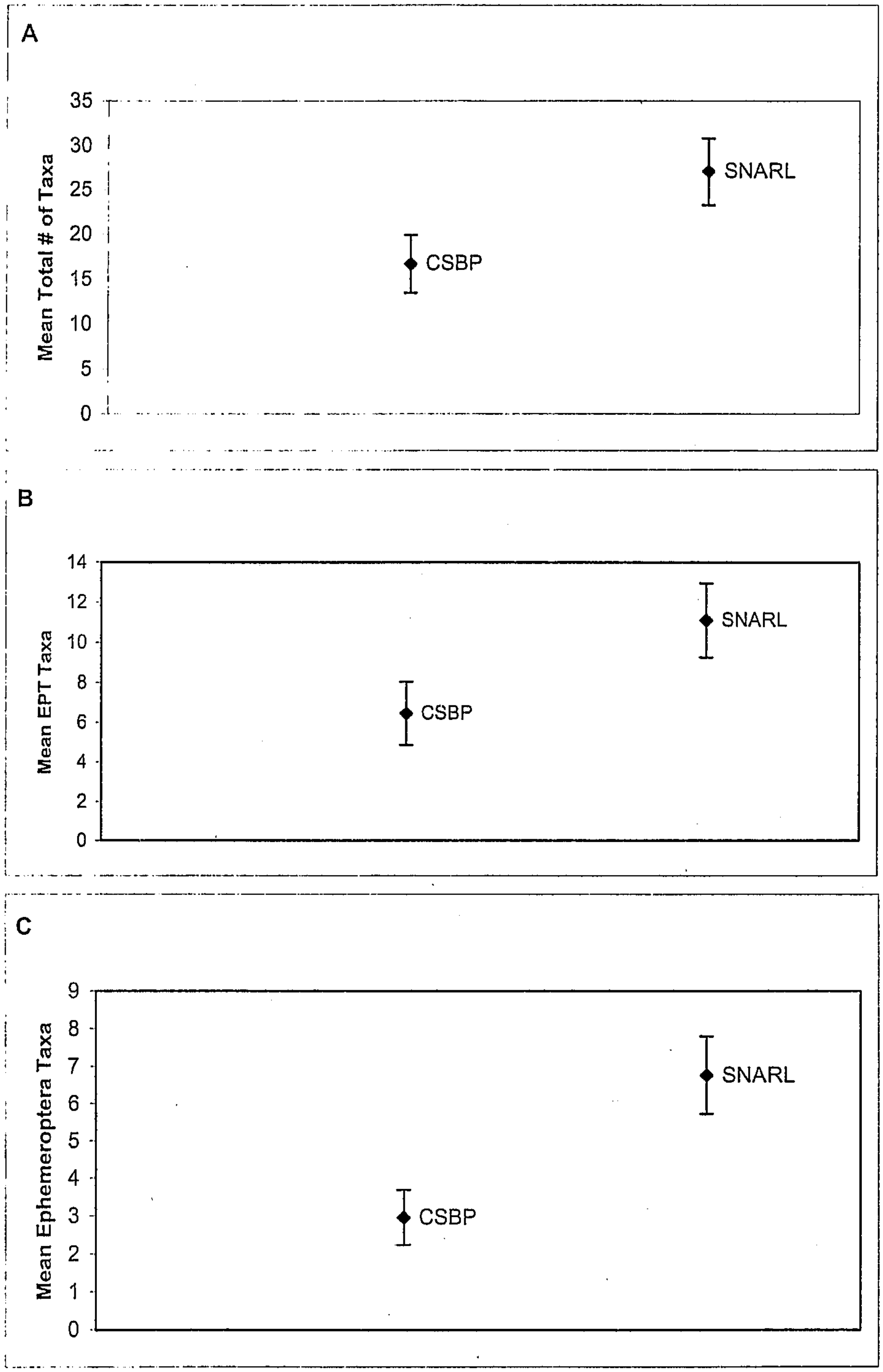


Figure 5. Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

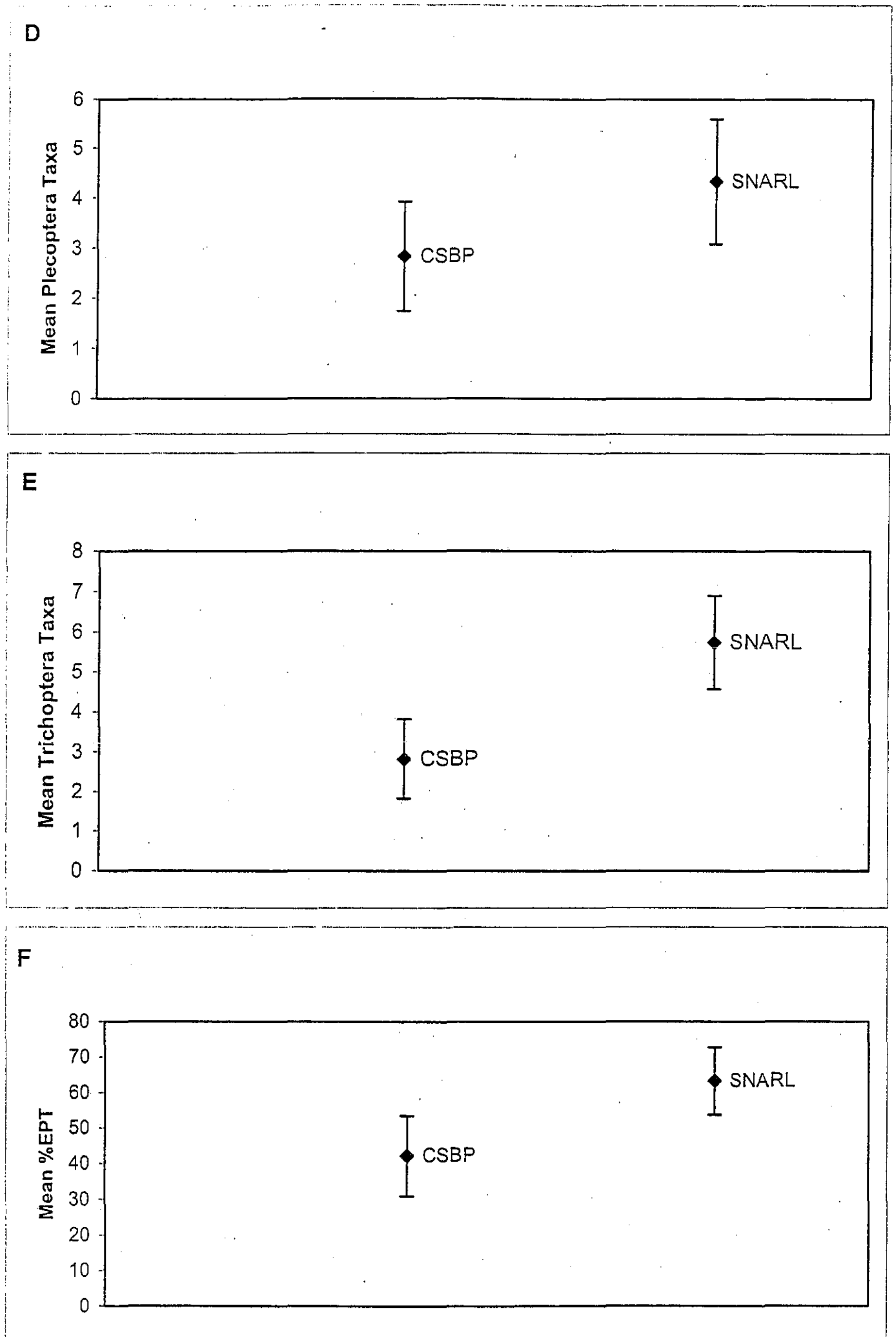


Figure 5 (continued). Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

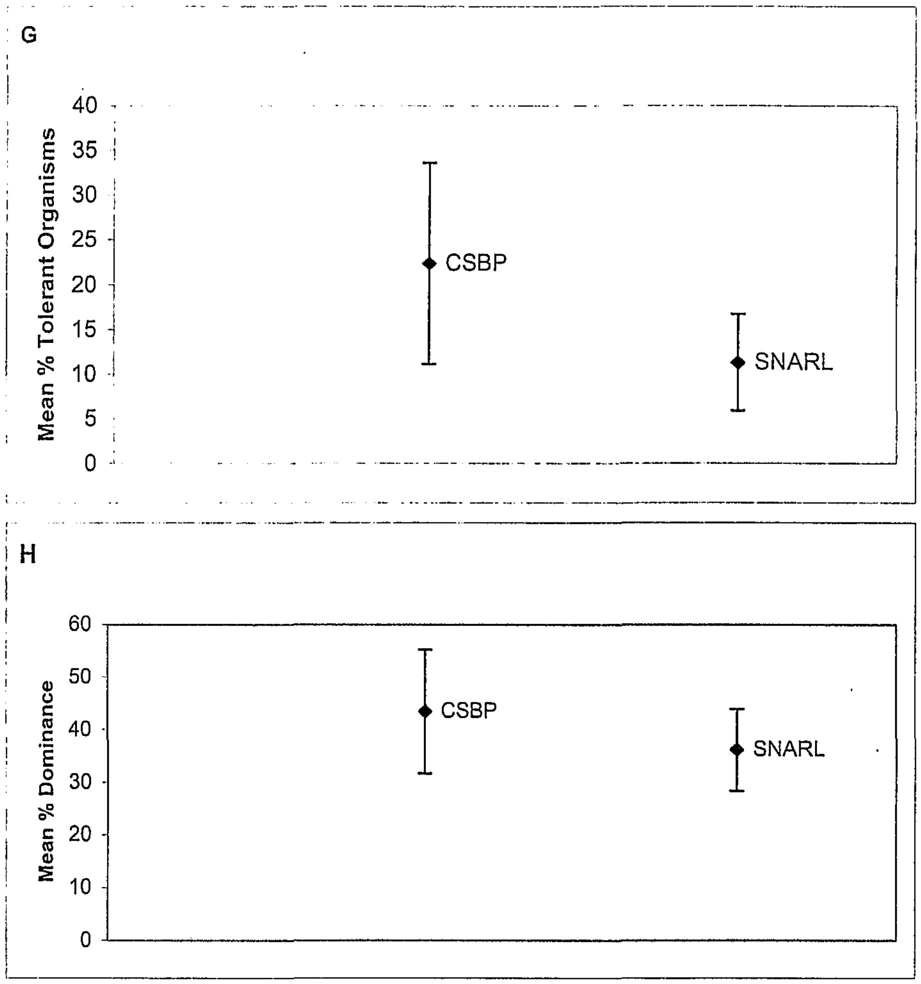


Figure 5. Comparison of precision (mean ± 1 s.d.) between the CSBP and SNARL methods for representative biological metrics for richness (graphs a-e), composition (f-g), and tolerance (g-h).

Because various components of these methods were vastly different, the coefficient of variation (CV) was calculated to evaluate the variation adjusted for the mean of each metric. The values of the CV were lower for the SNARL method for all eight metrics. However, because there are no calibrated indexes and impairment thresholds established for these methods, we do not know whether the lower CVs for the SNARL are ecologically significant. As a point of discussion, we can draw from our DQO 1 established as part of our hypothetical example. Although the difference in the CV values between the two methods never exceeded 20%, the majority of the individual metrics for each method did exceed 20% (our initial DQO from the hypothetical example). It should be noted that our DQO 1 is established for a calibrated index and not individual metrics. However, the precision for overall index scores are often more precise than for individual metrics (Stribling et al., in review). For example, Stribling et al. found that for three separate data sets (Maryland DNR, Prince George's County DER, Wyoming DEQ), the overall index score was consistently more precise than for any of the individual metrics, with one exception. Still, overall index precision cannot be easily speculated given the precision of only a few individual metrics. One critical step would be to develop a biological index for each method, and then compare the overall index precision to get a better understanding of which method is more precise. Depending on the outcome, another critical step would be to calculate a power cost efficiency (PCE) analysis (Barbour and Gerritsen 1996) to evaluate the cost implications of the added precision that might be realized from a more rigorous method.

Conclusions

From this simple comparison study with an incomplete data set, the results are inconclusive about the performance of the CSBP method vis-à-vis the SNARL method, and vice versa. However, Dr. David Herbst of the University of California Sierra Nevada Aquatic Research Laboratory has conducted a side-by-side comparison of these two methods along with a third method, USFS, also referred to as RIVPACS. Data analyses are ongoing and the results should be available near the beginning of 2003 (Herbst and Silldorff 2003). Furthermore, CDFG-ABL is currently conducting a side-by-side comparison of the CSBP, RIVPACS, and USEPA EMAP methods using a slightly larger dataset (approximately 240 sites from all over the state). This study is ongoing and the results are not yet available. We recommend that the results of these comparisons be sought and considered by anyone who is interested in the performance characteristics of these methods. In order to foster a valid scientific comparison of the performance and cost-effectiveness of a method, or multiple methods, several pieces of information must be made available:

- a data set of both known degraded and qualified reference conditions
- repeated samples (replicates or duplicates) to calculate the standard deviation from the mean (from both degraded and reference sites)
- DQOs from the QA/QC plan
- costs associated with the different levels of subsampling (for cost efficiency calculations)
- number of subsamples required to detect differences in the data
- discrimination (i.e., power) that is required to detect differences in the data.

A case example of how the Florida Department of Environmental Protection (DEP) examined the performance characteristics of their collection and assessment methods can be found in Appendix C.

3.3 Integrating Disparate Programs

The integration of discrete programs is primarily dependent on the results of the performance characteristic characterization. If it is evident that the quality of data is comparable among programs, then it is possible to integrate results of assessments among programs. Essentially, it is the quality and detail of data that defines the level of integration of disparate programs.

However, there are several elements that widely differ among the programs and may hinder the integration of actual biological data:

- Mesh size that retains/excludes certain organisms
- Level of subsampling & enumeration
- Sampling area and method
- Taxonomic resolution

Although there is a certain amount of disparity among all the candidate programs in each of these elements, most will likely allow a certain level of integration provided that the DQOs yield comparable data. This could ultimately lead to an integrated set of reference sites, which could be used to characterize reference conditions all throughout California. The features or attributes proffered by these candidate programs for integrating ecological information include:

- Candidate reference sites
- Identification of impaired sites or sites at risk
- Characterization of watersheds and stream reaches
- Quality ratings for water resource management
- Taxonomic distribution list and statewide records

3.4 Recent Initiatives in Bioassessment

A few recent and notable bioassessment initiatives in California include the development of 1) an Inter-laboratory Quality Assurance/Quality Control (QA/QC) Program, 2) the CalEDAS Database, 3) an Index of Biological Integrity (IBI), and 4) a standardized methodology of reference site selection for wadeable streams.

3.4.1 Inter-laboratory Quality Assurance/ Quality Control Program

Bioassessment data are being collected in California at a rapidly increasing rate. Since there will be much more taxonomic identification work than can be managed by a single laboratory, the standardization of laboratory techniques and taxonomic data is critical to sharing data analyzed by different laboratories.

In 1999, DFG-ABL instituted an inter-laboratory quality assurance/quality control (QA/QC) program for taxonomic identification. There are two main goals of an external QA/QC program, 1) to assess the quality of taxonomic data and its impacts on bioassessment metrics and 2) to assure that taxonomic data from different sources can be included in a common database. The QA/QC procedures are designed to help ensure compatibility of data among different macroinvertebrate laboratories and to ensure taxonomic consistency and high quality of taxonomy for all laboratories involved.

The DFG QA/QC procedure compares each taxonomic identification and groups of all discrepancies into two categories, 1) identification discrepancies, and 2) relative taxonomic effort discrepancies. Identification discrepancies are instances in which the two laboratories do not agree on the identification of a particular taxon. Relative taxonomic effort discrepancies are cases in which the original taxonomic determination is less or more precise than that of the QC laboratory. Although these differences in taxonomic effort are not as obvious as disagreements over identification, they can have a very strong impact on metrics calculations and often make up the majority of differences in the taxa lists of different laboratories. In addition to taxonomic discrepancies, the procedure evaluates differences in enumeration by the two laboratories. Small differences are a common occurrence in QC analysis and should not be a cause for concern unless the discrepancies are large.

The current external QA/QC program only involves assessment of taxonomy and enumeration; it does not include checks of subsampling procedures. A QA/QC protocol for sub-samples may be included in future programs, but at this point, it is considered the internal responsibility of each laboratory.

3.4.2 CalEDAS Database Development

As bioassessment has become increasingly more included in California's water quality management programs, the amount of biological community data and associated physical and chemical data collected around the state has grown at a rapid pace. The benefits of being able to manage and manipulate this data in a consistent way are immense; these data will ultimately provide the basis for fully exploiting bioassessment's potential as a water quality management tool.

Since 1998, DFG-ABL has been developing a Microsoft Access® database for managing its own bioassessment datasets. CalEDAS is a modification of the EDAS® (Environmental Data Analysis System), which was developed by Tetra Tech, Inc. for the USEPA. The main taxonomic table in CalEDAS (the Benthic Master Taxa List) is based on the CAMLnet List of Standard Taxonomic Effort. DFG-ABL uses CalEDAS in all laboratory aspects of its bioassessment program (from sample log tracking to data analysis) and is currently updating the database with older datasets produced in MS Excel spreadsheets. Although the DFG does not provide technical support for this database, the ABL is willing to share working copies of the database in its current form with other laboratories.

3.4.3 Standardization of Reference Site Selection for Wadeable Streams

Variation is fundamental to biological communities and measures of biotic integrity based on these communities vary accordingly. Most bioassessment techniques account for variation through the use of reference sites. Since practical considerations limit our ability to find "undisturbed" or even "minimally disturbed" sites, most reference condition approaches seek to identify a compromise, the "least disturbed condition". Once candidate reference reaches have been identified, these can be used to characterize the range of biotic conditions expected for minimally disturbed sites.

For both the Russian River and San Diego IBI, the relatively subjective technique of "best professional judgment" (BPJ) and some semi-quantitative selection criteria were used for selecting reference sites. These early studies have demonstrated the need for a framework for interpreting community data that can be applied in a standardized manner throughout the state.

At the February 2001 Western EMAP Reference Condition workshop in Phoenix, AZ, the workgroup drafted an approach to identifying reference sites that provides a strong framework for standardizing reference site methodologies. In May 2000, the DFG and Dr. David Herbst of SNARL collaborated to develop a quantitative approach to selecting reference sites in California. The basic approach uses landscape analysis tools (i.e., Geographic Information Systems, GIS) to identify areas within the region of interest that have minimal impacts (target areas). Field reconnaissance is then used to identify suitable stream reaches within these target areas, resulting in a pool of reference sites for the region of interest. The procedure consists of the following five steps:

1. Preliminary Organization and Prioritization
   a. Identify the region of interest and classes of streams to be evaluated
   b. Develop a list of land use disturbances of interest

2. Use GIS to Select Areas with Minimal Impact
   a. Divide the region of interest into areas that will serve as the basic reporting units of GIS analysis
   b. Summarize potential land use impacts for each area
   c. Determine impact scores using statistical properties of their distributions
   d. Use impact scores to identify regions with minimal disturbance: target areas

3. Ground Truthing
   a. Stage I– rapid reconnaissance.
   b. Stage II–identify ownership and obtain access permission.
   c. Stage III–intensive habitat scoring and selection of reference sites for sampling.

4. Sampling of Biotic Communities
   a. Sample a subset of the pool of reference sites for benthic invertebrates and analyze the data to define the range of biological metric values in the pool of reference sites.
   b. Reference sites may be sampled for other measures of stream or riparian health (e.g. fish/algal communities, water column chemistry, toxicity, etc.)

5. Iterative Refinement of the Reference Pool
   a. Refine the reference site pool based on biological, chemical and physical habitat data collected at each site.
   b. Eliminate or add candidate reference sites as land use changes occur.

This quantitative approach to selecting reference sites will be used by SNARL for developing an IBI in the eastern Sierras for the Lahontan Regional Board and by ABL for all other regions of California. For all past projects, where BPJ was used to select reference sites, this approach will be applied to assess the accuracy of BPJ selections. Currently, the ABL is using this quantitative approach for selecting reference sites in the Sierra Nevada Foothills Ecoregion and Central

Valley streams for the Central Valley Regional Board and the Sacramento River Watershed Program.

3.4.4 Development of an Index of Biological Integrity (IBI) for California

While there are many potential methods for evaluating biotic condition from community data, most approaches in the United States use a combination of multimetric and multivariate techniques. In multimetric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kearns and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (Harrington 1999). The Russian River watershed drains the third largest area in California, sustains an important anadromous salmonid population and is subject to a wide range of land uses including a variety of agricultural, timbering and urban development land uses. This demonstration IBI was based on a conceptual model described by the U.S. Environmental Protection Agency for development of numeric biocriteria. Benthic macroinvertebrates (BMI) were collected from 35 reaches within 21 tributary streams and the main stem of the Russian River during the fall 1995 and spring 1996 and 1997 using the CSBP. Although there was no indication of strong seasonal variability in the BMI communities, it was recommended that the index period for the Russian River tributary streams be in the spring. Since the original IBI was developed, samples have been collected annually (1998-2001) from the original sites and some additional locations.

As the Russian River IBI was being developed, DFG began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. The initial sampling strategy was designed to gather a baseline of information to support several project goals:

- To include biological information in the San Diego RWQCB's ongoing water quality monitoring programs
- To create a species list of BMIs known from the region
- To establish a biological classification of different stream types in the region
- To identify potential reference sites for the San Diego regional bioassessments
- To determine the best index period for sampling BMI communities
- To select appropriate metrics for southern California stream bioassessments

During 1997 through 2000, data was collected from 93 locations distributed throughout the San Diego region. Most of the initial sampling sites were chosen to supplement chemical data collected from long-term sampling locations, but some were established as reference sites based on "best professional judgment". In 2001, a new set of sites were chosen and sampled to further establish reference conditions in the San Diego region. The results of this sampling event were combined with the results of earlier sampling events to establish a preliminary IBI for the San Diego region. In July 2002, a final report was presented as a working IBI for the San Diego region.

Data from several sites sampled for the Los Angeles Regional Board were applied to the San Diego IBI with promising results. With additional refinement, the IBI developed for the San Diego region might be appropriately applied to all Southern California and perhaps Central Coastal wadeable streams and rivers. In 2002 and 2003, testing of impaired and potential reference steams will be conducted on data sets developed throughout this region using the CSBP.

The framework for developing an IBI for the Sierra Nevada Foothills Ecoregion and Central Valley streams will be available in 2004 and 2005, respectively. An IBI for wadeable coastal streams in northern California is being developed for the North Coast Regional Board. This IBI should be available in 2004 and will incorporate sites from the Russian River IBI that comply with the new quantitative approach to selecting reference sites, in addition to new sites throughout the region. Since this region extends from the Oregon border to south of San Francisco Bay, sites chosen by the San Francisco Regional Board will be tested and perhaps incorporated into Northern California Coastal IBI.

Chapter 4 INSTITUTIONAL/POLICY CONSIDERATIONS

In order for any state to effectively implement a bioassessment program, it is important to consider not only the technical issues, but the state's legal and policy framework as well. For example, some states rely on "technical addenda" to their water quality control plans that contain sampling protocols and/or numeric biocriteria that can be updated with relative efficiency as new information becomes available, but unfortunately, this may not be an option for California at the present time.

4.1 California's Regulatory Framework

Pursuant to its Porter-Cologne Water Quality Control Act (California Water Code Section 13000 et seq.), the State of California relies on a State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs) to implement water quality regulatory programs. In general, the SWRCB adopts statewide plans and policies, and the RWQCBs adopt and enforce region-specific standards. The RWQCBs may adopt standards for regional or localized areas that are more protective of water quality than required by the SWRCB's plans and policies, but the RWQCBs may not adopt standards that are less protective than those adopted by the SWRCB.

Given the large size and diversity of California, and the de-centralized framework for adoption of region-specific standards, it is anticipated that the implementation of bioassessment will need to be appropriately tailored to the regional setting, and biocriteria will need to be developed and, over time, adopted by the RWQCBs.

4.2 California's Standard-Setting Process

The water quality standards setting process in California appears to be more rigorous and time-consuming than in many other states, and once standards are incorporated into a water quality control plan, or "basin plan" (BP), those standards cannot be modified in any way without repeating the entire standard-setting process.

California law also requires that the specific sampling protocols, supporting data, and methods for calculating compliance with standards be specified at the time that standards are adopted. This makes it impossible to modify the sampling methods (for example, if more cost-effective methods become available), or to modify biocriteria (for example, as more data becomes available regarding natural variability) without going through the entire standard-setting process. The rigidity of the standard-setting process will create some key hurdles to implementing biocriteria in California.

Given the difficulty of amending water quality standards in California, the state needs to be relatively certain that any biocriteria, whether narrative or numeric, are both protective of water quality and beneficial uses of water, and also accurate enough so that "false positives" will not occur to any great extent. For example, once biocriteria are adopted, streams found to violate those criteria could be listed as "impaired," triggering requirements for mandatory development of Total Maximum Daily Loads (TMDLs).

Options for California include the following:

1. Wait many years before incorporating any numeric or narrative biocriteria into the BPs.
   This would be the most conservative approach to avoiding "false positives," but would abdicate the state's responsibility under the Clean Water Act to protect and restore the biological integrity of the state's waters. While the USEPA currently does not require that biocriteria be included in state water quality control plans, this may become a requirement in the not distant future, and the state would be wise to diligently proceed with developing a bioassessment program even if this option is relied upon in the short-term.

2. Focus on narrative biocriteria.
   The USEPA has prepared guidance to assist the states in developing narrative biocriteria (USEPA 1992). California could potentially proceed with refining aquatic life uses and developing narrative biocriteria, without specifying mandatory methods or numeric criteria. The numeric information to support decisions based on the narrative criteria could be developed, specified, and refined over time, outside of the water quality control plans. While this may be the best approach available to the SWRCB and RWQCBs at this time, refining the aquatic life uses and developing narrative biocriteria would require significant resources, which the agency does not appear to have available at this time.

3. Revise state law(s) to allow technical addenda outside of the BPs.
   Biological systems are more variable than the chemical and physical properties that were the basis of California's water quality regulatory scheme. In recognizing this fact, California could consider revisions to state law(s) to allow numeric biocriteria to be developed and continually updated, outside of the normal water quality standard-setting process, in order to reflect new biological information. Such an approach would apparently require legislation at the state level.

4.3 Budgetary and Other Considerations

At this time, there appears to be little statewide, programmatic funding for a concerted bioassessment program in California. The SWRCB has no staff positions dedicated to bioassessment. Efforts to implement bioassessment in California have primarily been led by the RWQCBs, using a variety of ephemeral funding sources.

In order to effectively implement a bioassessment program in California, it should be recognized that there are common resource needs throughout the state. Some of the key resource needs are summarized below:

Statewide Coordination
The SWRCB should strive to establish an institutional infrastructure to facilitate on-going coordination of the many different bioassessment efforts throughout California. This would ideally include at least one full-time staff position at the SWRCB dedicated to coordinating

bioassessment programs at the SWRCB and RWQCBs, as well as funding for bringing together relevant experts, on a regular basis, to address issues related to taxonomy, tolerance values, reference site selection, standard-setting, etc.

Reference Site Selection

In order for the state's bioassessment program to be most meaningful and defensible, the state should strive toward objective procedures for selecting reference sites, where possible. This would include the use of Geographic Information Systems (GIS) to allow identification and selection of "minimally-impaired" reference sites based on objective criteria. Staff experienced with the use of GIS are needed, as well as funding for the computer hardware and software needed to perform GIS analyses. Where minimally impaired reference sites are lacking, funding would be needed to review historic literature and convene panels of experts to develop reference conditions based on best professional judgment.

Refinement of Tolerance Values

A fundamental tenet of bioassessment is that some organisms are tolerant to certain types of stress or pollution, while others are very sensitive to stress or pollution. For bioassessment to be most powerful, the tolerance values assigned to each class of organisms (whether species, genus, family, etc.) need to be meaningful and should be based on objective evidence. There is a need for research to refine tolerance values for some classes of organisms found in California.

Determination of Index Period

The "index period" refers to the time of year or "season" that bioassessment samples are collected. In order for data to be comparable between years, it is important that samples be collected in the same index period. However, in a state as large and diverse as California, it is probable that the most appropriate index period will vary from region to region. A degree-day model could be developed to assist in the selection and refinement of the most appropriate index period for the various regions of California.

Chapter 5 Recommendations

It is beneficial to the State of California and its affiliated agencies and environmental interest groups to consider standardization and methods consistency of bioassessment and biomonitoring throughout its vast watershed network. The benefits include data sharing, conformity in evaluating ecological status, implementation of scientifically based management decisions, maximizing limited technical resources, statewide calibration of biological indicators, and broadscale application and linkage to regulatory activities. From a technical standpoint, the endorsement of consistent methods will provide development of a statewide reference condition and indicator calibration that will, in turn, provide cost efficiencies and enhance program effectiveness for watershed protection and restoration goal-setting.

Our recommendations are structured into areas such as (1) candidate methods, (2) replication, (3) reference condition, (4) calibration of biological indicators, (5) physical habitat assessment, (6) database management, and (7) institutional/policy issues.

5.1 Candidate Methods

Of the five candidate methods, the CSBP is the most widely used throughout the state. Data from multiple collections at more than 2500 sites are available from streams throughout California. A method similar in performance to the CSBP is that developed by SNARL. While the sampling precision of the SNARL method is somewhat more robust than that of the CSBP, both methods are similar enough in results to be considered equally effective in assessing biological condition. Both methods, and those of most of the other candidate programs, focus on cobble substrate (i.e., riffle habitat) as the primary habitat type for collection. It is generally thought by stream ecologists that the riffle habitat is the most productive habitat, where present, and that the macroinvertebrate assemblage of the riffle or other cobble substrate contains the most diverse and sensitive fauna with respect to water quality. Both EMAP and NAWQA methods have endorsed a more multihabitat approach that accounts for techniques that are more representative of stream reach characteristics, and not just site-specific conditions relevant to a single riffle. We recommend that a multihabitat feature be added to the methods to enable a more pertinent evaluation of multiple stressors, such as both chemical (water quality) and non-chemical (habitat-induced) perturbations. Adding a multihabitat component may be in the form of the EMAP method or the NAWQA Qualitative Multihabitat method, or even a variation of the CSBP method to enable advancement to current methodologies rather than radical modifications. Current collaborative efforts between CSBP and EMAP lend themselves to adopting an EMAP sampling methodology. The important aspect of method development is to maintain continuity and data integrity of existing ecological data as methods refinement is adopted into a water resource program. This can be done, in the simplest of techniques, by documenting the biological condition of sites and prioritizing along a disturbance gradient. Changes in condition from one method to another are evaluated for influential factors related to methods changes. Specific considerations for adopting a multihabitat approach are to provide a framework for characterizing regional reference conditions that are parceled out from a statewide network of candidate reference sites, and to enable a characterization of natural variability associated with a composite of habitat types expected to be present in California streams.

5.2 Replication

For bioassessment purposes, replication is important to identify the performance characteristics, namely sampling precision, of a method, and to strengthen a judgment of the biological condition of a site where uncertainty exists from the results. Most state water resource agencies follow a sequential decision process whereby a composited sample (i.e., composited from a variety of habitats or microhabitats within a habitat) from a method with known precision is used to assess the biological condition. If the results indicate that the judgment of biological condition may be in error because the precision of the method is insufficient, then additional data or other information is needed to confirm the assessment. Therefore, replication, albeit considered pseudoreplication by most biostatisticians, is needed at sites where judgment of biological condition is contentious or uncertain and also to establish precision estimates of the method and investigators. The collection of replicates as a routine procedure is a good practice, but cost considerations may prevent a wide scale implementation of such a procedure. At a minimum, 10% of collections should be replicated. Furthermore, sites that are likely to be in the intermediate portion of the biological condition gradient (i.e., neither considered of reference caliber nor severely impaired status) would benefit from replication, depending on the precision of the method. The exact number of replicates should be decided by a technical workgroup. Factors to be considered are overall objectives and cost implications. Most states take duplicates (Barbour et al. 1999) because the objective is method precision, and two replicates are all that are needed. A precedent has been established in California for three and five replicates (CSBP and SNARL, respectively) to be taken. Our analyses indicate that the two techniques are relatively similar and that cost implications may be a factor. We recommend that replication be continued in California bioassessments for the purpose of precision estimates. We also support a reduction in replicates to two or three as a compromise between statistical power and cost.

5.3 Reference Condition

Regardless of methods, either the identification of candidate reference sites or the elimination of degraded stream reaches from consideration as reference should be possible from the volume of data acquired from around the state in the various monitoring programs. Compilation of the locations and watersheds that contain candidate reference sites can be used as a basis to conduct a land use characterization that will detail the extent of potential disturbance from human activities. Once these candidate sites are delineated on maps and land use overlays, data gaps should be identified and addressed. Data gaps would also include an identification of the kind of methods and collecting techniques. For this subsequent step, only biological data from consistent methods can be used to avoid introducing sampling bias in the results. It may be necessary to schedule some targeted sampling to procure the comparable data. The reference condition is the expected or best idea of the structure and function of the aquatic community, and it also reflects a partitioning of the natural variability into homogeneous classes or groups. This analysis is usually done via multivariate analyses. The DFG-ABL and SNARL are collaborating in an effort to identify and characterize reference sites in California. This effort is extremely important for establishing a benchmark for bioassessments. We recommend that the SWRCB interact closely with DFG-ABL and SNARL and consider evaluating its extensive ecological database to proceed with characterizing reference conditions.

5.4 Calibration of Biological Indicators

Through the endorsement of a statewide database (i.e., CCAMP), SWRCB is compiling all available and viable biological data. The centralization of biological data through this process will provide a means to reconcile differences in certain technical issues, such as sampling and sample processing documentation practices, taxonomic discrepancies, and metric or biological attributes used in different indices. Of particular interest to calibrating a statewide indicator is the CSBP data, which comprise over 8000 data points. The refinement of existing biological indicators can be done using this comprehensive data source. Using a standard of lowest common denominator for methods and level of taxonomy, and following upon the reference condition development, a benthic macroinvertebrate indicator could be developed for use in assessing biological condition and in producing restoration goals for impaired streams. The creation of the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet) was formed in 1995 as a technical advisory body to facilitate the standardization of freshwater macroinvertebrate taxonomy and laboratory procedures. We recommend that the combination of the central database and CAMLnet be used to provide California with a consistent and standard framework for calibrating biological indicators for use on a statewide basis.

5.5 Physical Habitat Assessment

While conducting physical habitat assessments in conjunction with biological assessments is an important feature to any bioassessment program, it is not within the scope of this document to develop any recommendations in regards to physical habitat assessment methods currently used by the candidate programs. It should be noted, however, that further refinements to current physical habitat assessment methods are being explored.

5.6 Database Management

While the CalEDAS database model currently used by DFG works well at the laboratory scale, it will not able to store all the bioassessment data for California. There is, therefore, a strong need for a statewide database of bioassessment data that can accommodate the large quantity of data that will be produced in California. Ongoing statewide efforts of SWAMP, the SWIM II database and the U.S. EPA's STORET database may eventually meet this need, but neither of these is currently ready to handle the bioassessment data. There are currently no provisions for creating a repository for all California bioassessment data. Once a common database is agreed upon (i.e., SWIM II, SWAMP), it is our recommendation that the SWRCB consider appointing a full-time employee to manage the database and provide technical support to database users throughout the State.

5.7 Institutional/Policy Issues

The State of California should decide among the available options for effectively incorporating bioassessment into its water quality regulatory programs (see Section 4.2). Furthermore, the State of California should strive to make funding available for a concerted, statewide bioassessment program. Funding is needed for: (1) establishing a full-time bioassessment coordinator at the SWRCB; (2) ensuring on-going bioassessment sampling and analysis at the RWQCBs; (3) organizing and facilitating workshops where relevant experts can address issues related to taxonomy, tolerance values, reference site selection, standard-setting, etc.; (4) developing and maintaining the capability to conduct GIS exercises to select reference sites; and (5) meeting other common needs such as contracts for refinement of tolerance values and specification of appropriate index periods (see Section 4.3).

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Appendix A

Program/Project Summaries

Appendix A PROGRAM/PROJECT SUMMARIES

This section includes all program/project summary survey responses received from numerous water quality agencies, entities, etc. in California. The survey was sent to dozens of groups across the state; however, only a small proportion responded with complete information while several more groups responded with incomplete information.

Alameda Countywide Clean Water Program - Bioassessment in Alameda County Creeks

The primary focus of this program is to provide watershed characterization, assessment, and trend monitoring using rapid bioassessments. The Alameda Co. Flood Control and Water Conservation District sponsor this program.

Contact Person: Arleen Feng Alameda County PWA, 951 Turner Court, Room 300, Hayward, CA 94545 (510) 670-5575 arleen@acpwa.mail.co.alameda.ca.us

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1998 - Present

Data Availability: 3-4 sites in 1998-2000, 10 in 2001. Watersheds: San Lorenzo Creek (1998-2001); Sausal Creek, Mission Creek, Sabrecat Creek (2001)

Purpose of Bioassessment:

- watershed characterization, assessment, trend monitoring
- NPDES permitting
- ambient water quality monitoring
- establishing reference conditions
- supporting habitat classification
- stream restoration

Description: ACCWP's stormwater management activities include this project to provide understanding of relatively small, highly urbanized watersheds, and develop macroinvertebrate community indicators as tools to assist local municipal watershed managers. Selection of sampling watersheds and sites was based on a) representation of different portions of urbanized Alameda County; b) availability of publicly owned reaches that could be accessed; c) relatively strong opportunities for / interest in restoration activities. Related volunteer monitoring with "streamside" educational protocol is ongoing in Sausal Creek.

California Department of Fish and Game (CDFG) Enforcement Case Program

CDFG investigates situations where reports of activities or pollution events in the surrounding watershed may have adversely impacted stream integrity and/or stability. The California Stream Bioassessment Procedure (CSBP) is used to measure deleterious effects to the biological community resulting from the pollution event.

Contact Person: Angie L. Montalvo (916) 358-4398, CDFG Aquatic Bioassessment Laboratory 2005 Nimbus Road, Rancho Cordova, CA 95670

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: Wine Creek (May 2000 – Present), East Walker River (Oct 1999-Present), Slug Canyon Creek (Sept 2000), Weber Creek (Mar 2001- Present), Cherokee Creek (Aug 2001), Goose Creek (Apr 2001) Hangtown Creek (Sept 1998), F-1 Line Zone Flood Control Channel (Oct 2001)

Data Availability: Wine Creek (6 sites), East Walker River (39 sites), Slug Canyon Creek (6 sites), Weber Creek (15 sites), Cherokee Creek (3 sites), Goose Creek (3 sites) Hangtown Creek (5 sites), F-1 Line Zone Flood Control Channel (3 sites)

Purpose of Bioassessment: Investigation of pollution spills can be enhanced by measuring the biological and physical/ habitat condition of the receiving waters. Bioassessment can contribute to an enforcement case by documenting injury resulting from a spill of a known pollutant or can stand alone as evidence of a pollution event when chemical analysis is unavailable. Bioassessments are particularly helpful when a pollution event is reported some time after it occurs (thus preventing the collection of timely chemical samples) and when dealing with chemical spills where the substance rapidly dissipates, become diluted or flows as a pulse downstream. Bioassessments may be the only enforcement tool available for physical/habitat destruction, and for spills of substances with low or no toxicity values (sediment, nutrients and elemental metals), but which cause eutrophication or smother benthic communities in the water body.

Description: Under the CDFG 5650 Code Enforcement Case Program, each case is treated as an individual project, which addresses a specific problem of concern. Each project or case is categorized into a classification system based on pollution type: sediment, petroleum, chemical, and other. Benthic macroinvertebrate (BMI) sampling (as well as standard physical habitat, flow, gradient, and ambient chemistry) is conducted in a similar manner for each case (one or more control sites, one site at or near the spill/impacted area, and one or more sites downstream from the spill/impacted area). Often, additional follow-up/ recovery sampling will occur up to 3 years following a pollution event. The results of the bioassessments are used in a court of law to prosecute responsible parties for damages and to recovery departmental costs associated to the case.

California Department of Water Resources (Northern District) Bioassessment Program

The primary objectives of this program are to provide long-term background information, to determine water quality based on types and abundance of individual species, and to monitor impact assessment and FERC relicensing of major DWR hydroelectric facility.

Contact Person: Jerry Boles, Department of Water Resources, 2440 Main Street, Red Bluff, CA 96080 (530) 529-7326 bolesj@water.ca.gov

Sampling Method: DWR professional classic method – multiple sites (three riffles/three cross sections/three samples per cross-section); sort entire sample; identify to genus/species – rely on mathematical metrics as well as biology of insects to determine impacts/water quality.

Timeline of Sampling: 1975-Present

Data Availability: Over 100 sites per year throughout Northern California

Purpose of Bioassessment:

- Support State of CA bioassessment and monitoring
- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: DWR's long time bioassessment program has historically used classic, professional methods employing a frame to delineate sampling area and collecting downstream from frame in a kick net. Entire sample is sorted and identified. Purposes of program are to provide long-term background information, determine water quality based on types and abundance of individual species, impact assessment, and FERC relicensing of major DWR hydroelectric facility. CSBP sometimes used when we only want cursory assessment of organisms and actual species population information is not that important.

Central Coast Ambient Monitoring Program

The Central Coast Ambient Monitoring Program is conducting watershed characterization monitoring for the Central Coast Regional Water Quality Control Board, using a 5-year rotational strategy. It has been in place since 1998 and covers Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara, and portions of San Mateo, Santa Clara, and Ventura counties in central California.

Contact Person: Karen Worcester, 81 Higuera Suite 200 San Luis Obispo, CA 93401

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996); some sites with protocols modified for low gradient streams

Timeline of Sampling: Ambient monitoring 1998 – Present, 5-year watershed rotational strategy (April – May sampling period); Morro Bay 1993-Present (although they missed a few years); Coastal confluence monitoring 1999-Present.

Data Availability: Morro Bay, 10-15 sites; Pajaro Watershed, 8 sites; Salinas Watershed, 13 sites; Santa Maria Watershed,10 sites; Santa Barbara Coast,12 sites; 28 coastal confluence sites.

Purpose of Bioassessment:

- Conducted as part of ambient assessment along with conventional water quality, sediment chemistry, and tissue bioaccumulation data
- Also evaluation of the effectiveness of BMPs in the Morro Bay watershed

Description: Bioassessment is used in conjunction with other water quality monitoring approaches to characterize condition. Approximately thirty sites are selected along the main stem at the primary discharge point of the watershed, above major tributary inputs, and at the lower ends of major tributaries. For the purposes of site selection a "major tributary" is defined as a watercourse which drains a minimum percentage of the rotation area or which is the major watercourse that drains a Hydrological Area, Hydrological Subarea, or watershed of special concern. Some sites are also located above and below areas of significant human activity, including urban development, agriculture, and point source discharges. Site selection is constrained by site accessibility, since conventional monitoring is done on a monthly basis. Benthic invertebrate sites are located upstream of conventional water quality sites, but out of the immediate influence of bridges. Other sampling activities are conducted at a subset of conventional water quality sites.

Another program component includes monitoring of coastal confluences, where rivers meet the ocean. This monitoring is conducted continuously, rather than in 5-year rotation. Benthic invertebrate samples have been collected at these sites for three years in a row, at approximately thirty sites. Data from this program will be assessed in the near future for its effectiveness at detecting water quality impairment.

The Morro Bay National Monitoring Program has approximately 10 sites, which have been monitored for six years in order to detect changes from implementation of Best Management Practices. Sites are primarily upstream and downstream of cattle exclusion areas.

Central Valley Regional Water Quality Control Board (Sacramento) - Surface Water Ambient Monitoring Program (SWAMP)

The primary focus of this project is to provide insight into the condition of the aquatic community beneficial uses in agriculturally dominated and effluent dominated waterbodies of the Central Valley.

Contact Person: Robert Holmes, 3443 Routier Rd., Ste. A, Sacramento CA 95827-3003 (916) 255-0749 holmesr@rb5s.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: Fall 2000 – Present. Spring & Fall index periods

Data Availability: Approximately 36 sites in the Sacramento River Watershed.

Purpose of Bioassessment:
- Watershed characterization, assessment, trend monitoring
- Research
- Ambient water quality monitoring

Description: The goal of this project is to provide a first step at identification of aquatic life stressors and associated development of ecological indicators in agriculturally dominated and effluent dominated waterbodies in the Central Valley.

Chicarita Creek Bioassessment Study for the Friends of Los Penasquitos Canyon Preserve, Inc.

The purpose of the Chicarita Creek Bioassessment Study is to assess impacts on the Chicarita Creek due to point-source discharge violations.

Contact Person: Andre Macedo, City of San Diego, Environmental Monitoring & Technical Services Division, 14103 Highland Valley Road, Escondido, CA. 92025 (858) 538-8193, amacedo@sandiego.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: May 2001-Present

Data Availability: 4 sites in the Los Penasquitos Watershed

Purpose of Bioassessment:
- Point-source/incident

Description: The study of this creek is funded by a fine assessed against a discharge violator. There had been no pre-event samples available of this site.

Contra Costa Monitoring and Assessment Plan (CCMAP)

The Contra Costa Monitoring and Assessment Plan (CCMAP) focuses on assessing the biological integrity of watersheds in Contra Costa County (Northern California) to reduce pollutants from entering the municipal separate storm sewer system (MS4) and protect beneficial uses of its water bodies.

Contact Person: Chris Sommers, Contra Costa Clean Water Program, 255 Glacier Dr., Martinez, CA, 94553

Sampling Method: California Stream Bioassessment Protocol (CSBP) (Harrington 1999)

Timeline of Sampling: 2001-Present

Data Availability: Currently 10 sites in Alhambra Creek watershed (16 sq. miles)

Purpose of Bioassessment:
- To comply with the Program's Joint Municipal NPDES Permits;
- To collect baseline information necessary to identify and reduce and/or eliminate stormwater pollutants in the County;
- To prioritize sub-basins within individual watersheds, allowing direction for future studies to determine types and sources of stormwater pollutants adversely affecting beneficial uses;
- To begin identifying specific land uses that may be contributing to decreases in biological integrity;
- To contribute valid data to a Bay/State-wide data set intended to characterize watersheds and possibly create an Index of Biological Integrity (IBI) for the region.

Description: The Contra Costa Monitoring and Assessment Plan (CCMAP) is a long-term strategy, which builds on previous special studies and data collection efforts. CCMAP is designed to assess the conditions of watersheds, water bodies, and water quality within Contra Costa County. CCMAP entails further characterization of watersheds and sub-watersheds, and the development of strategically placed monitoring stations where rapid bioassessment data can provide a valuable screening device to determine where water quality and watershed health are degraded or have the potential for degradation. The Program intends to conduct bioassessments in approximately 6-8 watersheds in the next four years.

California Department of Parks and Recreation Natural Resources Inventory, Monitoring, and Assessment Program (IMAP)

A pilot project began in 2001 for Wilder Ranch State Park near Santa Cruz, where four streams were sampled to assess water quality and the condition of aquatic ecosystems, with an intent that this data would serve as baseline measures for future monitoring.

Contact Person: Roy Woodward, Inventory, Monitoring & Assessment Program, P.O. 942896 Sacramento, CA 94296-0001 (916) 651-6940, rwoodw@parks.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: Spring (May-June) and Fall (Sept. – Nov.) 2001. Future sampling of the streams may take place depending on available funding.

Data Availability: Currently 11 sites have been sampled. Spring 2001 data is now available. Fall 2001 data will become available by February 2002.

Purpose of Bioassessment:
- Assess water quality and the condition of aquatic ecosystems
- Establish baseline measures for future monitoring

Description: A small full-time staff at Sacramento HQ supports field staff in all 266 state park units with collection and compilation of data for wildlife, vegetation, and physical resources (e.g. water quality, soils, caves, air quality). A pilot project began in 2001 for Wilder Ranch State Park near Santa Cruz, where four streams, Wilder Creek, Peasley Creek, Majors Creek, and Baldwin Creek have been sampled for water chemistry and macroinvertebrates. These are small, short perennial coastal streams that are mostly contained within Wilder Ranch State Park.

State park ecologists collected the macroinvertebrate samples. Richard Bottoroff, a contractor, performed the macroinvertebrate identifications. Water chemistry was taken with a portable sampling device, and habitat was characterized using the CDFG technique. Under a separate contract, steelhead were counted, red-legged frogs were counted, and fish and aquatic organism habitat was assessed. The final report for the project will assess the findings in relation to steelhead and other aquatic organisms in these streams and will be prepared by June 30, 2002.

Dry Creek Conservancy Watershed Monitoring Program

Physical, chemical, and biological assessment and monitoring of the aquatic resources of the watershed.

Contact Person: Gregg Bates

Sampling Method: Grab samples, benthic macroinvertebrate collection, fish surveys

Timeline of Sampling: Seasonal, and periodic

Data Availability: Data is currently being organized and put into data bases

Purpose of Bioassessment:
- Assess condition of streams
- Identify negative impacts
- Suggest management solutions

Description: None provided.

Feather River Watershed Monitoring Program

The purpose of the program is to obtain and make available baseline and continuing data from which trends in watershed health could be measured. The Feather River Watershed Monitoring Program is project of the Feather River Coordinated Resource Management Group.

Contact Person: Leslie Mink, Watershed Coordinator, or Jim Wilcox, Project Manager, Feather River Coordinated Resource Management Group, c/o Plumas Corporation P.O. Box 3880 Quincy, CA 95971 phone: 530-283-3739; fax: 530-283-5465; email: leslie@plumascounty.org Or plumasco@psln.com

Sampling Method:
Three riffles suitable for sampling are identified, beginning at the downstream extent of the survey segment. Identified riffles are composed of large gravel to cobble size substrate where the water surface is turbulent. Care is taken to not disturb the sample sites prior to sampling. This is the first measurement taken at each survey segment.

Once the three riffles are identified, measurements are taken from bottom to top (downstream to upstream) beginning at the farthest downstream riffle. A tape is placed parallel to the longest upstream-downstream axis and the length of the riffle is measured. The riffle is divided into equal segments of length. Three segments are randomly selected for sampling using a random numbers sheet. One of three lateral sampling locations (1/4, 1/2, 2/3 width from the right edge of suitable habitat) is randomly selected at each of the three selected segments.

Once the sampling locations have been selected, a D-net with a one-foot wide opening and a mesh size of 0.5mm is placed perpendicular to the flow, and adjusted as necessary to prevent flow under the net frame. An area upstream of the net that is one foot wide by two feet long is chosen for sampling.

Samples are sent to: The Buglab, Dept. Fish and Wildlife, Utah State University, Logan,UT 84322-5210.

Timeline of Sampling: Samples are usually collected once every two years; samples have been collected during the Summer 1999 and 2001.

Data Availability: Biological samples are collected at 19 of the 21 sites, which are strategically located at low-gradient "response" reaches near mouths of the major sub-watersheds; samples are still being processed and are not expected to be completed until summer 2002, however, data will be available on our website at feather-river-crm.org

Purpose of Bioassessment:
- To evaluate the effectiveness of stream restoration efforts
- To assess trends in watershed health
- To accompany other watershed data such as geomorphic data including permanent cross-sections, longitudinal profiles, bedload, bank stability, water temperatures, and flows, water quality, fish populations, etc.

Description:
The Feather River Coordinated Resource Management group has been in existence since 1985, and is a consortium of 21 public and private agencies and land management entities. Our primary mission is watershed restoration, which we successfully implement across jurisdictional boundaries. Since 1985, we have implemented over 40 restoration projects. Project monitoring has been an integral part of our program. In the late 1990's we realized the need for monitoring on a watershed scale. This type of monitoring will help us evaluate the impact of our projects on a larger scale, and allow an observation of trends in the health of the Feather River watershed.

Federal Energy Regulatory Commission Hydroelectric Relicensing and Repair

The SWRCB has authority to issue Clean Water Act (CWA) section 401 water quality certifications for hydroelectric facilities undergoing relicensing. To help us determine compliance with the CWA and Basin Plan we have been requesting that rapid bioassessment be completed to help assess water quality impacts.

Contact Persons: Russ Kanz (916) 341-5341, Sharon Stohrer (916) 341-5397; State Water Resources Control Board, P.O. Box 2000, Sacramento, CA 95812-2000

Sampling Method: California Stream Bioassessment Procedure

Timeline of Sampling: Completed during the relicensing process. Usually a single sampling program with limited follow-up. We are also requiring bioassessement to determine impacts of repair projects. A number of rivers have been completed with more planned.

Data Availability: PG&E –Stanislaus River (44 sites), Pit River (16 sites), Mokelumne River (26 sites), Feather River (?? sites), Fordyce Creek (?? sites): El Dorado Irrigation District – SF American River (?? sites)

Purpose of Bioassessment:

- Assess impacts to water quality

Description: Hydroelectric projects licensed by the FERC undergo relicensing every 30-50 years. Currently in California there are a large number of facilities either being relicensed, or will be relicensed soon. The State Water Resources Control Board has the authority to issue Clean Water Act (CWA) section 401 certifications for these facilities. The CWA 401 certification requires an assessment of the impacts to beneficial uses. We have been requesting that the licensees use rapid bioassessment to help determine impacts to water quality/beneficial uses. We also use bioassessment in addition to water quality monitoring to determine the impacts of hydroelectric repair projects. Upcoming projects include Southern California Edison relicensing – Upper San Joaquin River sampling (planned for 2001-2002) and PacifiCorp relicensing – Klamath River sampling (planned for 2002).

Hoopa Valley Environmental Protection Agency Water Quality Monitoring Program

Our primary goals are to use rapid bioassessment as a tool to sample all streams that have been damaged by fires and logging and to protect domestic water sources.

Contact Person: Forrest Blake, 1348 Hoopa, California 95546

Sampling Method: California Stream Bioassessment Procedure (CSBP) citizen monitoring method

Timeline of Sampling: Continuous monitoring of annual events

Data Availability: Available on the EDAS program

Purpose of Bioassessment:

- To make sure our streams are safe for our people

Description: We have continuous data recorders on our creeks as well as high flow stations. We feel that bioassessments are just one more component to our Water Quality Monitoring Program.

Los Angeles Regional Water Quality Control Board – Surface Water Ambient Monitoring Program (SWAMP)

Primary purpose is to design a distinctive monitoring program for each watershed based on its unique characteristics and based on what data exists and what data gaps are present. Because each watershed is treated individually, the approach to each watershed is different. For example, in the Santa Clara River watershed, a random design based on EMAP was employed because the watershed covers an extensive area and little is known about the watershed. The goal was to obtain an overall picture of the health of the watershed. On the contrary, Calleguas Creek watershed encompasses a much smaller area and a multitude of data exists. Therefore staff chose a directed sampling program to address each major tributary and stream within the watershed and chemical analyses where chosen based on the data that already existed. Further information can be obtained in the SWAMP Workplan document for fiscal years 2000/01, 2001/02, and 2002/03, edition date June 30, 2002.

Contact Person: Tracy Vergets, 320 W. 4th Street, Suite 200, Los Angeles, California, 90013; (213) 576-6661; tvergets@rb4.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001-Present

Data Availability: currently 17 sties in the Santa Clara River sampled in 2001; 30 more to be sampled in 2002; 13 sites sampled in Calleguas Creek in 2001; 45 sites to be sampled in Santa Monica Bay WMA in 2003 with repeat sampling at 6 of the best stations in 2004 & 2005; 12 stations to be sampled in the Dominguez Channel and LA/LB Harbor Watershed in 2003.

Purpose of Bioassessment:
- Ambient water quality monitoring
- Establish reference conditions
- Watershed characterization, assessment, trend monitoring
- Determine attainment of beneficial uses
- Assess biological integrity of surface waters
- Detect biological responses to pollution
- Identify probable causes of impairment not detected by chemical or physical water quality analysis

Description:
The overall goal of the Site-Specific Monitoring portion of SWAMP is to develop site-specific information on representative sites or water bodies that are (1) known or suspected to have water quality problems and (2) known or suspected to be clean. This portion of SWAMP is focused on collecting information from sites in water bodies of the State that could be potentially listed or delisted under Clean Water Act Section 303(d). This workplan has been developed to implement the Site-Specific Monitoring Requirements of SWAMP per State Board directive. However, in Region 4, both the Site-Specific Monitoring goals and the Regional Monitoring goals have been integrated into one ambient

monitoring program. The scope encompasses the regional goals, while still obtaining site-specific information.

Per AB 982, monitoring is required in each hydrologic unit of the State at least once every five years. Region 4 proposes to visit each hydrologic unit one year ahead of the WMI schedule for targeted watersheds, which rotate on a five-year cycle. In this strategy, data will be gathered, analyzed, and interpreted in time to use the following year during NPDES permit renewals and other ongoing activities within the targeted watershed. Ultimately, the information from these analyses will be used in the water quality assessment for the targeted watershed. Other uses of this data include, but are not limited to, development of the 305(b) report and 303(d) List of Water Quality-Limited segments, TMDL development, and NPDES permit renewals.

The sampling and analysis will be used to assess the ambient conditions of the watersheds in Los Angeles and Ventura counties, and will further delineate the nature, extent, and sources of toxic pollutants, which have been detected or are suspected to be problematic for this region and its individual watersheds. Where applicable, a triad approach (benthic community analysis, water chemistry, and toxicity testing) is being used. In addition, bioaccumulation tests, historically funded through the statewide Mussel Watch and Coastal Fish Contamination Programs, are being conducted in order to address possible human health concerns (contaminants in edible fish tissue) and ecological concerns (benthic community impacts), which may result if the contaminants at a site are bioavailable for uptake by organisms. These bioaccumulation tests will help to demonstrate the bioavailability of contaminants at these stations and may identify impaired beneficial uses. There is also a large focus on bioassessment, which historically has been overlooked. The bioassessment performed will follow the California Stream Bioassessment Protocol developed by CDFG, which focuses on the benthic macroinvertebrate assemblage and a physical habitat assessment. The information gathered will be used in trend analysis, identifying impaired beneficial uses, as well as potentially in the development of an index of biological integrity.

Lahontan Regional Water Quality Control Board: Biological Assessment Program

The primary objective of this program is to incorporate consideration of biological integrity into the many regulatory and watershed management functions of the Lahontan RWQCB.

Contact Person: Thomas J. Suk, Regional Monitoring Coordinator, California Regional Water Quality Control Board, Lahontan Region, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150. Phone: (530) 542-5419; Email: <tsuk@rb6s.swrcb.ca.gov>

Sampling Methods: The Lahontan RWQCB is using and evaluating three different bioassessment sampling methods: (1) benthic macroinvertebrates, periphyton, and physical habitat assessments following protocols developed by Dr. David Herbst at the University of California's Sierra Nevada Aquatic Research Laboratory (SNARL); (2)

California Stream Bioassessment Procedures (CSBPs) developed by the California Dept. of Fish and Game; and (3) RIVPACS protocols being used in the Sierra Nevada by the U.S. Forest Service

Timeline of Sampling: 1995 - present

Data Availability: Approximately 350 surveys have been conducted at 200 sites in the Lahontan Region using the UC-SNARL method. At 40 of those 200 sites, sampling was conducted using three methods (e.g., UC-SNARL, CSBPs, RIVPACS) to facilitate quantitative comparison of the results provided by each of those three methods. At approx. 30 other sites (throughout the eastern Sierra Nevada) samples were collected using both the UC-SNARL and RIVPACS methods, and at 20 other sites (all in the Walker River drainage) samples were collected using both the UC-SNARL and USEPA-REMAP methods. Most of this data is not yet available, and lab identification and quality assurance procedures are still underway.

Purpose of Bioassessment:

- To establish regional "reference conditions" for benthic macroinvertebrates and periphyton in streams and rivers
- To assess the impacts of human activities on the biological integrity of streams and rivers
- To evaluate the effectiveness of stream & wetland restoration efforts, BMP implementation, and permit conditions
- To develop numeric targets for TMDLs
- To develop narrative and numeric biocriteria

Description: The Lahontan RWQCB began using bioassessment in 1995, in order to monitor the success of remediation efforts at the abandoned Leviathan Mine. A more concerted (i.e., region-wide) bioassessment program was begun in 1999, for the multiple purposes outlined above.

The current regional-scale effort is focused on developing reference conditions (based on benthic macroinvertebrates and periphyton) for the eastern Sierra "ecoregion," which covers six major watershed basins (e.g., Truckee River, Tahoe Basin, Carson River, Walker River, Mono Basin, Upper Owens River). Streams in this ecoregion were stratified based on stream order, and minimally-impaired sites were selected from each class of streams. Sampling has been conducted during the summer reference period (i.e., late June to early September), using protocols developed by Dr. David Herbst of the University of California's Sierra Nevada Aquatic Research Laboratory. As of this writing (i.e., 2001), the effort has focused on data collection and lab identifications; analyses of the data are pending.

The Lahontan RWQCB, via contract with the University of California (SNARL), is also using bioassessment data to: (1) evaluate the effectiveness of several stream & wetland restoration projects (e.g., Upper Truckee River, Bagley Valley); (2) evaluate the effectiveness of BMP implementation (e.g., Upper West Walker River, Bridgeport

Valley); (3) monitor the success of remediation efforts at Leviathan Mine; (4) verify and/or assess the effectiveness of regulatory permits (e.g., fish hatcheries, Grover Hot Springs State Park); and (5) develop targets based on benthic macroinvertebrates for sediment TMDLs (e.g., Squaw Creek, Heavenly Valley Creek).

The Lahontan RWQCB, via contract with the University of California (SNARL), is also conducting a comparison of three common bioassessment methods (e.g., UC-SNARL, CSBP, RIVPACS). Sampling was conducted using all three methods at forty (40) sites during the summer of 2000. The objective of this study is to evaluate the potential strengths and weaknesses of the various methods for use by the RWQCB.

Development of narrative and numeric biocriteria is a long-term goal of this project, and will be subject to available funding.

McCloud River Preserve Aquatic Macroinvertebrate Monitoring Program

The primary focus of this program is to document and analyze the aquatic macroinvertebrate community in the McCloud River and to use this information in conjunction with on-going water quality research to provide a baseline view of the state of the aquatic resources within the watershed.

Contact Person: John Crandall, McCloud River Preserve, P.O. Box 409, McCloud, CA 96057 (530) 926-4386

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: started in 1998 at citizen's level, 1999-2001 at professional level

Data Availability: All years data available (taxa and metrics) plus brief write-up for each year.

Purpose of Bioassessment:
- Assess water quality and the condition of aquatic ecosystems
- Establish baseline measures for future monitoring

Description: None provided.

San Diego Regional Water Quality Control Board: Biological Assessment Program

The primary objectives of this project are to introduce biological information to the San Diego Regional Water Quality Control Board's ambient monitoring program and to provide baseline data on the benthic macroinvertebrate BMI community in regional streams.

Contact Person: Linda Pardy, 9174 Sky Park Court, Suite 100 San Diego, CA 92123

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: May 1999 – Present

Data Availability: Approximately 48 sites

Purpose of Bioassessment:
- To include biological information in the San Diego RWQCB's ongoing water quality programs
- To create a species list of BMIs known from the region
- To establish a biological classification of different stream types in the region
- To identify potential reference sites for the San Diego regional bioassessments
- To determine the best index period for sampling BMI communities
- To select appropriate metrics for southern California stream bioassessments
- To assist with 305(b) assessments, 303(d) listings, development of TMDLs, assessments of nonpoint sources (NPS), and assessments of effectiveness of NPS management measures.
- To develop biocriteria

Description:
The bioassessment program will evaluate the biological and physical integrity of targeted inland surface waters in the San Diego Region and is designed to meet an obligation to assess the condition of the Region's waters relative to attainment of water quality standards. Information developed will be used for the Section 305(b) Water Quality Assessment, the Section 303(d) list of impaired water bodies, development of Total Maximum Daily Loads (TMDLs), assessments of nonpoint sources, and assessments of effectiveness of nonpoint source management measures. Information will also be used to define issues, set priorities, and evaluate effectiveness of actions under the Watershed Management Initiative.

This ambient bioassessment program will put initial emphasis on biological community structure monitoring. Only after the biological information indicates impairment will samples be chemically analyzed. It is assumed that municipal storm water co-permittees, the Regional Water Board, and citizen volunteer monitoring groups will be responsible for biological monitoring. The program will be in concert with the San Diego Region's *Watershed Management Plan.*

The Regional Water Board will use the information gained from these bioassessments to identify areas of stream impairment and most likely causes. For the coastal lagoons identified as impaired, the bioassessments will help to identify those areas of the influent streams, which are most significant contributors of pollutants. With the accompanying data on water column and sediment chemistry provided by various sources, the Regional Water Board can initiate a scientifically based TMDL development for each of the impaired streams and coastal water bodies.

In addition, the program will produce a workable IBI using a modified approach outlined by the USEPA. Ultimately, the results of this bioassessment program will be used to develop biocriteria, which will serve as the standard against which future assessment results are compared.

San Francisco Bay Regional Water Quality Control Board - Surface Water Ambient Monitoring Program (SWAMP)

Primary purpose is to establish screening-level ambient biological and physical monitoring in the region's streams along with chemical and toxicity monitoring, as well as establish reference conditions. Secondary purposes include impact characterization, pre- and post-project characterization, and support of regional efforts at habitat classification.

Contact Person: Steve Moore and Karen Taberski, 1515 Clay St., #1400, Oakland, CA 94612 (510) 622-2439; (510) 622-2424; smm@rb2.swrcb.ca.gov; kmt@rb2.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001-Present; Spring Index Period (Mar- May)

Data Availability: 72 sites in 2001; 49 sites in 2002 3rd year: estimated 45 sites in 2003. Watersheds sampled: 2001 - Lagunitas Cr., Walker Cr., Suisun Cr., San Pablo Cr., Wildcat Cr., Arroyo Las Positas, San Leandro Cr.; 2002 - San Gregorio Cr., Pescadero Cr., Butano Cr., Stevens Cr., Permanente Cr.; 2003 - Petaluma R., San Antonio Cr. (Marin), San Mateo Cr., Mt Diablo Cr., Kirker Cr.

Purpose of Bioassessment:

- Ambient water quality monitoring
- Establish reference conditions
- NPDES permitting
- Point-source/incident monitoring
- Watershed characterization, assessment, trend monitoring
- Support habitat classification
- Stream restoration monitoring

Description: The three components that make up the Board's Regional Monitoring and Assessment Strategy (RMAS) include: 1) SWAMP funding from the State Water Resources Control Board for Regional Board-lead activities (these activities will concentrate on monitoring watersheds, lakes/reservoirs and bays and estuaries other than San Francisco Bay and will include other Regional Board programs such as State Mussel Watch, the Toxic Substances Monitoring Program and the Coastal Fish Contamination Program), 2) partner-lead watershed monitoring programs that are being conducted by local agencies/groups and are of similar goals, structure and scope as the Regional Board-lead activities and 3) the San Francisco Estuary Regional Monitoring Program (RMP), funded by dischargers. Specific objectives of the Regional Board-lead SWAMP-funded monitoring program are to: 1) identify reference sites, 2) identify impacted sites or waterbodies in order to determine if beneficial uses are being protected, 3) identify the cause of impacts (i.e., sediment, specific chemical contaminants, temperature), 4) determine if these impacts are associated with specific land uses and 5) evaluate monitoring tools in watersheds in order to develop a program that uses the best environmental indicators to achieve the purposes of the program. Data developed in this program will be used for evaluating waterbodies for the Clean Water Act Section 305b report and the 303d list. Data will include physical, chemical, and biological information.

Santa Clara Valley Project

The primary focus of this project is to examine the factors influencing the development of bioindicators based on lotic macroinvertebrate assemblages in urban environmental settings. Little is known of the specific factors found in urban environmental settings that affect macroinvertebrate distributions. Determining the natural and anthropogenic factors that most influence the distribution of macroinvertebrates is a necessary step prior to developing bioindicators based on resident macroinvertebrate assemblages found in urban streams.

Contact Person: Dr. James L. Carter, US Geological Survey, 345 Middlefield Road Mail Stop 465, Menlo Park, CA, 94025

Sampling Method: Two macroinvertebrate collection methods were used. First, a semi-quantitative method that consisted of compositing 5 - 0.1 m^2 collections made from riffle habitats. Each of the 5 collections per sample was systematically located. Second, a multi-habitat collection made by collecting macroinvertebrates from all habitats in a reach (=1 pool/riffle sequence). Collecting effort was partitioned based on the percentage composition of various invertebrate habitat types found in the sampled reach. All collections were made using a D-frame kicknet fitted with a 500 μm mesh.

Timeline of Sampling: Samples were collected in May 1997 and September/October 1998.

Data Availability: 85 sites from 14 streams in the Santa Clara Valley area. These include:

San Francisquito Ck	Ross Ck.	Saratoga Ck.	Arroyo Calero
Guadelupe River	Coyote Ck.	Corte Madera Ck.	Guadelupe Ck.
Los Gatos Ck.	Penitencia Ck.	Los Trancos Ck.	Alamitos Ck.
Stevens Ck.	Barret Ck.		

Purpose of Bioassessment:
- Develop a baseline data set representing the distribution of benthic macroinvertebrates in the Santa Clara Valley area.

- Development of a macroinvertebrate dataset for evaluating the level of field and laboratory effort needed to conduct bioassessments.
- Establish the relationships between benthic macroinvertebrate assemblage composition and physical and chemical factors associated with an urban environmental setting.

Description:
Fourteen streams were Sampling locations were +/- equidistant, with sites set at approximately 2 km intervals. Eighty-five sites were sampled in total. The downstream limit of sampling was either the point of assumed or observed intermittent flow or where there appeared to be a tidal influence. The upstream limit was approximately 300 m. Sampling at all sites for both types of invertebrate collections occurred during May 1997 and for riffle collections only during September/October 1998.

Depth and velocity were measured at each riffle subsample location (5 locations per riffle). At each riffle DO, temperature, conductivity, and pH were measured at the time of invertebrate sampling. Qualitative estimates of riparian vegetation, instream algal and macrophyte cover also were made. Quantitative measures of channel morphology and pebble counts were made at each site. Lastly, dissolved nutrients and trace metals were measured at each site.

For more information see:
Carter, J. L., and S. V. Fend. 2000. The Distribution and Abundance of Lotic Macroinvertebrates during Spring 1997 in Seven Streams of the Western Santa Clara Valley area, California. U.S. Geological Survey, Open-File Report 00-346.

Carter, J. L., and S. V. Fend. 2000. The Distribution and Abundance of Lotic Macroinvertebrates during Spring 1997 in Seven Streams of the Santa Clara Valley area, California. U.S. Geological Survey, Open-File Report 00-68.

Tecolote Creek and Alvarado Creek Bioassessment Studies

The purpose of the Tecolote Creek and Alvarado Creek Bioassessment Studies is to assess impacts due to a sewage spill.

Contact Person: Andre Macedo, City of San Diego, Environmental Monitoring & Technical Services Division, 14103 Highland Valley Road, Escondido, CA. 92025 (858) 538-8193, amacedo@sandiego.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: May 2000-Present

Data Availability: 3 sites in 2000, 4 sites in 2001, and 5 sites in 2002 located in the San Diego Watershed.

Purpose of Bioassessment:
- Point-source/incident

Description: None provided.

Truckee River Aquatic Monitors Bioassessment Program

The primary purpose of this program is to obtain data for watershed characterization, assessment, and trend monitoring in addition to educating the public and decision makers. Secondary purposes include ambient water quality monitoring, pre- and post-project monitoring, and establishing reference conditions in the watershed.

Contact Person: Jill Wilson, 2501 Lake Tahoe Blvd., South Lake Tahoe, CA 96150 (530) 542-5449 jwilson@rb6s.swrcb.ca.gov

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 1999-Present

Data Availability: Approximately 3-5 per year throughout the Truckee River Watershed

Purpose of Bioassessment:
- Ambient water quality monitoring
- Establish reference conditions
- Watershed characterization, assessment, trend monitoring
- Support habitat classification
- Stream restoration monitoring
- Education

Description: TRAM is an all-volunteer group that follows the CSBP protocol to collect samples. Sampling occurs within the Truckee River Watershed from the Lake Tahoe outlet to the California state line. Most samples are sent out for professional identification. However, during the winter the group does do some of its own identification at the CSBP citizen's level.

UCLA/Los Angeles Regional Water Quality Control Board Biological Assessment Project

The purpose of this project is to determine the biological health of streams relative to land use in three southern California watersheds (Malibu, Calleguas, and Santa Clara) using modifications to existing protocols. This work was conducted by University of California Los Angeles and funded by Los Angeles Regional Water Quality Control Board with the goal of collecting data that would be used in the generation of nutrient TMDL's for southern California watersheds, but in so doing, new methods were explored for determining the relationship between human influences and the biological health of streams.

Contact Person: Steven F. Lee M.S. and Rich Ambrose, Ph.D. UCLA.
Department of Environmental Health Sciences, 46-059 CHS Building, Los Angeles, CA 90095-1772

Sampling Method: Combination of CSBP (Harrington and Born, 2000) and modified USEPA REMAP, Lazorchak and Klemm (1994) methods.

Timeline of Sampling: Fall, 2001 season

Data Availability: ~40 sites throughout three Southern California watersheds (Malibu, Calleguas, and Santa Clara). Data are public and will be available through LARWQCB sometime in the middle of 2002.

Purpose of Bioassessment:

- Determine the health of biological communities relative to human land use, incorporating new methodologies and metrics
- Collect data for use by Los Angeles RWQCB in the generation of nutrient TMDL's.

Description: Benthic invertebrates were collected according to CSBP methods to keep data comparable to other state agency bioassessment work, but then a modified EMAP-type protocol was superimposed over the riffle/reach to collect data on stream morphology, physical habitat, riparian vegetation, fish and fish habitat etc. Site selection involved targeted reaches rather than a probabilistic approach. The reach length and the number of transects were reduced, but with expanded data taken at each transect. We feel this was appropriate because 1. we targeted more homogeneous sites and 2. these southern California stream reaches tend to be more homogeneous in general. In addition, data for percent cover of macroalgae, vascular macrophytes, and diatoms, macroalgae biomass, and light meter measurements were added to the protocol. Streamside riparian vegetation data were enhanced with focus on cover of native and introduced species. More extensive data were taken alongside the benthic invertebrates including light meter readings, macroalgae, macrophyte, and diatom data, and substrate type including percent composition, embeddedness, and consolidation.

Upper Putah Creek Citizen Based Watershed Management Program

The Stewardship will organize, train and supervise citizen volunteers to monitor impacts to Upper Putah Creek and its tributaries from sediment and other non-point pollution sources and translate findings into restoration projects for the Stewardship to implement.
Funded by a 319(h) grant administered by Placer County Resource Conservation District.

Contact Person: Dwight Holford, Project Coordinator, Box 27 Middletown, CA 95461-0027 707-987-2600 showmums@jps.net

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington and Born 2000

Timeline of Sampling: 2000-2002

Data Availability: March 2002

Purpose of Bioassessment:
- Support CA State bioassessment program
- Train citizen monitors
- Establish bioassessment program in the Upper Putah Creek Watershed
- Produce restoration projects
- Establish base for biocriteria in watershed

Description:
A team of citizen monitors has been established, led by a Ph.D. scientific advisor. By the end of this 319(h) project they will have surveyed the upper third of the watershed. A restoration project for St. Helena Creek will be proposed. They are helping other watershed groups establish bioassessment programs. They are also involved in education/outreach programs.

U.S. Environmental Protection Agency Central Valley Regional Environmental Monitoring and Assessment Program (REMAP)

The Central Valley REMAP project focused on assessing the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area of California and is one of the nation's most productive agricultural areas.

Contact Person: Peter Husby, USEPA Region 9 Laboratory, 1337 S. 46th St.; Bldg. 201, Richmond, CA 94804

Sampling Method: USEPA EMAP, Lazorchak and Klemm (1994)

Timeline of Sampling: 1994-1995

Data Availability: Approximately 87 sites in the Sacramento-San Joaquin Valley, covering approximately 24,000 square miles.

Purpose of Bioassessment:
- Support State of CA bioassessment and monitoring

- Assess the biotic condition of surface waters in a highly modified agriculturally influenced ecosystem.
- Determine variability of aquatic organisms in natural and man-made conveyances within the Central Valley.

Description: REMAP was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program. EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

U.S. Forest Service - Pacific Southwest Region (California) Bioassessment Program

The primary focus is on establishing reference conditions by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams throughout the entire state of CA, mainly on Forest Service lands. There are 18 national forests in the region (Angeles, Cleveland, Eldorado, Inyo, Klamath, Lassen, Lake Tahoe Basin Management Unit, Mendocino, Modoc, Plumas, San Bernardino, Sequoia, Shasta-Trinity, Sierra, Six Rivers, Stanislaus and Tahoe)

Contact Person: Joseph Furnish, Ecosystem Conservation Division, 1323 Club Drive, Vallejo, CA 94592

Sampling Method: Hawkins, Ostermiller, and Vinson (1998)

Timeline of Sampling: 2000 - present

Data Availability: Approximately 176 sites in 2000 and 85 sites in 2001 located in the following watersheds: Klamath- North Coastal; Sacramento; Tulare-Buena Vista; San Joaquin; Central Lahontan; Central California Coastal; South California Coastal; North Mojave- Mono Lake.

Purpose of Bioassessment:

- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation
- Reference site characterization

Description: The primary effort has been on establishing reference condition by collecting macroinvertebrates from a network of both perennial and intermittent wadeable streams, that can serve as the basis for monitoring biological integrity and determining whether water quality has been degraded compared to reference condition. Reference condition will be based on development of a predictive RIVPACS (River InVertebrate Prediction And Classification System) model. Standard EPA Metrics will also be considered for use if it is determined that they are sensitive to disturbances at the site and watershed (approximately 10,000-50,000 acre) scale.

U.S. Geological Survey: National Water Quality Assessment (NAWQA) Program

The U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status of and trends in the quality of the nation's surface water and ground water and to provide scientific understanding of the natural and human-induced factors that affect water quality.

Contact Person: Larry Brown, Placer Hall, 6000 J St, Sacramento, CA 95819-6129

Sampling Method: USGS NAWQA

Timeline of Sampling: San Joaquin-Tulare Basins 1992-95; Sacramento Basin 1995-98; Santa Ana Basin 1998-Present.

Data Availability: 17 sites in San Joaquin-Tulare Basins; 23 sites in Sacramento Basin; and 4 sites in Santa Ana Basin.

Purpose of Bioassessment:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams.
- Describe how water quality is changing over time, and
- Improve our understanding of the primary natural and human factors affecting water quality.

Description: Since 1991, the NAWQA program has been collecting and analyzing data and information in more than 50 major river basins and aquifers across the Nation. The goal is to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions. Three major river basins in California were assessed as part of this program: 1) Sacramento Basin, 2) San Joaquin-Tulare Basins, and 3) Santa Ana Basin.

Studies in the San Joaquin-Tulare Basins NAWQA Study Unit focus on the status of and the processes influencing the quality of surface water, ground water, and aquatic ecology. The Study Unit is located in central California and includes the San Joaquin Valley, the eastern slope of the Coast Ranges and the western slope of the Sierra Nevada.

In 1994, the Sacramento River Basin study unit team began planning assessment activities. The basin was subdivided into six physiographic subunits and nine ecological subunits that were determined to be the most influential natural factors affecting water quality. Stream sampling began in 1995 and lasted until April 1998. Much of the data collection focused on the Sacramento Valley and Klamath Mountain subunits, but ecological sampling also included the Cascade Mountains and Sierra Nevada subunits. Hundreds of water-quality characteristics were measured in different media during this time, including ground water, stream water, streambed sediments, and aquatic biological tissues. Fish, invertebrate, and algal communities and stream habitat also were sampled or assessed. In addition, spatial data such as geology, land use, hydrography, and other watershed characteristics were compiled into a geographic information system (GIS) to support the assessment. After April 1998, the project entered a period of less frequent sampling called the low-intensity phase.

The Santa Ana Basin study began in 1997. Study planning and analysis of existing data was done during the first 2 years of the study. After that 2-year planning period, surface- and ground-water and biological data were collected intensively for 3 years (termed the high-intensity phase). A low-intensity phase will follow for 6 years, during which water quality is monitored at a limited number of sites and areas that were sampled during the high-intensity phase. This combination of high- and low-intensity monitoring phases allows the NAWQA Program to examine long-term trends in water quality and aquatic ecology.

Ventura River Bioassessment Monitoring Program

The main purpose of this program is to assess the biological condition of the Ventura County Watershed and to ensure compliance with NPDES permit requirements.

Contact Person: Darla Wise, County of Ventura Flood Control Department, (805) 645-3942

Sampling Method: California Stream Bioassessment Procedure (CSBP), Harrington (1996)

Timeline of Sampling: Annual sampling Fall 2001- Present,

Data Availability: 15 sites

Purpose of Bioassessment:

- Assess biological health in the watershed
- Ensure compliance with NPDES permit requirements

Description: Bioassessments are conducted as part of an overall program to assess water quality for stormwater monitoring throughout the Ventura County Watershed. In addition to collecting biological samples, they also look at conventional

water quality
parameters. They also have a group of volunteers who collect water quality samples on a monthly basis at the bioassessment sites. Recently acquired a Water Sonde and anticipate monitoring nutrients (nitrate, nitrite and ammonia) chlorophyll a in addition to basic water quality parameters. Also plan to monitor fecal coliform and streptrococcus bacteria in future monitoring efforts.

Yurok Tribe Water Quality Program

The primary focus of this program is to provide ambient water quality data for the Klamath River watershed.

Contact Person: Kevin McKernan, PO Box 355 Orick, CA 95555
(707) 834-2536 / kevinmck@reninet.com

Sampling Method: California Stream Bioassessment Procedure (CSBP) Rapid Bioassessment Protocol (RBP)

Timeline of Sampling: 2001– Present. Spring & Fall index periods

Data Availability: 30 sites in the Klamath River Watershed.

Purpose of Bioassessment:
- ambient water quality monitoring
- research
- point-source/incident
- watershed characterization, assessment, trend monitoring
- establish reference conditions
- stream restoration
- education

Description: Sites include mainstem Klamath River during low flow conditions, bio-metrics used to support ambient physical and chemical monitoring. Sites in Lower Klamath tributaries support ambient physical and chemical monitoring, watershed trends, presence/absence of forest herbicide impacts.

Appendix B

Candidate Methods

Appendix B CANDIDATE METHODS

This section includes the complete information on the key program elements (i.e., habitat selection, sampling gear, sampling method, area sampled, replication, subsampling and enumeration, taxonomic identification, quality assurance procedures, data analysis/metrics, habitat assessment, and purpose for monitoring), which is summarized in Chapter 3.

California Department of Fish and Game - Aquatic Bioassessment Laboratory

DFG was the first water resource agency to be asked to assess the condition of a freshwater stream using the U.S. EPA's Rapid Bioassessment Procedure (RBPs) (Plafkin *et al.* 1989). The Lahontan Board requested the assessment in 1993 as part of the NPDES requirement of the DFG Hot Creek Hatchery in Mono County. The request necessitated the need to adapt the RBPs to California and the resulting protocol became the California Stream Bioassessment Procedure (CSBP). Because the CSBP was developed for a point-source assessment, it incorporated the use of replicated sampling of a single, richest habitat. Although not consistent with the RBP, DFG decided on this procedure for the following reasons: a) the immediate need for bioassessment was for point-source assessments, enforcements and diagnosis of known, but undocumented water quality impairment; b) there was no interest, at that time, in using bioassessment as an ambient monitoring tool; and c) the ability to produce a measure of biological metric variability at every monitoring site was deemed necessary to convince water resource managers of the robustness of biological assessments.

The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour *et al.* 1999). The CSBP was reviewed and refined by a CABW workgroup in 1994 and 1995 resulting in an updated version in 1996. The CSBP for wadeable streams and rivers has remained consistent over the years and is recognized by the U.S. EPA as California's standardized bioassessment procedure (Davis et al. 1996). Since 1993, the ABL has processed nearly 9000 samples collected using the CSBP at more than 2500 sites throughout California. Thousands of additional CSBP samples have been collected and processed by other entities. In addition to the CSBP for wadeable streams and rivers, as of 2002, there are versions of the CSBP for non-wadeable streams (draft), citizen monitors, lentic environments (California Lentic Bioassessment Procedure), and there is also a modification of the CSBP in which samples are composited for sites that are part of an ambient bioassessment program (this CSBP modification has been adopted by the Nevada DEQ).

1) *Habitat selection:* Riffle habitat is the only habitat sampled using this method. A stream reach is chosen that contains at least five riffles within the same order and relative gradient. If no riffles are present, or less than five within a reasonable distance, the reach is determined as 40 times the wetted width with a minimum reach length of 150 m and a maximum length of 500 m.

2) *Sampling gear:* All samples are collected using a D-frame kicknet with 500 μm mesh netting.

3) *Sampling method:* CSBP utilizes separate point and non-point source sampling designs when conducting ambient bioassessments. When sampling for point source discharges, at least one riffle in the unaffected upstream portion of the reach and one or more riffles in the affected portion of the reach are sampled; one sample is collected from three randomly chosen transects in each riffle. On the other hand, when sampling for non-point source discharges, one sample is collected from the upstream third of 3 randomly chosen riffles.

   Point Source Design

   Step 1. A measuring tape is placed along the bank of the entire riffle selected. Each meter or 3 foot mark represents a possible transect location. Three transects perpendicular to the flow are selected from all possible meter marks along the measuring tape using a random number table.

   Step 2. Three locations are chosen along the transect where the samples are to be collected. If the substrate is fairly similar and there is no structure along the transect, the three locations will be on the side margins and the center of the stream. If there is substrate and structure complexity along the transect, the three locations are selected to best reflect it.

   Step 3. Starting downstream, collections are made by placing the D-frame kick-net onto the substrate and disturbing a one by two foot portion of substrate upstream of the kick-net to approximately 4-6 inches in depth. Large rocks are scrubbed by hand under water in front of the net. A consistent sampling effort (approximately one to three minutes) is maintained at each site. The 3 collections within the transect are combined to make one "composite" sample.

   Step 4. The contents of the kick-net are placed in a standard size 35 sieve (0.5 mm mesh) or white enameled tray. The larger twigs, leaves and rocks are removed by hand after carefully inspecting for clinging organisms. The sampled material and label are placed in a jar and completely fill with 95% ethanol.

   Step 5. Proceeding upstream, repeat Steps 2 and 3 for the next two randomly chosen transects within the riffle.

   Non-point Source Design

   Step 1. Three of the five riffles within the selected reach are randomly chosen using a random number table.

   Step 2. A measuring tape is placed along the bank of the entire riffle selected. One transect is selected from all possible meter marks along the top third of the riffle using a random number table.

   Steps 3-6. Follow steps 2-5 for point source sampling.

4) *Area sampled:* The total area sampled per composite sample, or transect, is 0.54 m^2. Since there are 3 transects sampled per site, the total area sampled at each site is 1.62 m^2.

5) *Replication:* Three replicate composite samples are collected from each site.

6) *Subsampling and enumeration:*

Step 1. The contents of the sample jar is emptied into the # 35 sieve (0.5 mm mesh) and thoroughly rinsed with water.

Step 2. Once the sample is rinsed, debris larger than 2 inch is removed. Green leaves, twigs and rocks are also discarded.

Step 3. The cleaned material is placed into a plastic tray marked with equally sized, numbered grids (approximately two by two inches). Do not allow any excess water into the tray. The moist, cleaned debris is spread on the bottom of the tray using as many grids necessary to obtain an approximate thickness of 2 inch.

Step 4. Randomly chosen grids are removed and sorted until 300 macroinvertebrates are counted. The specimens are placed in a clean petri dish containing 70% ethanol/5% glycerin. The remaining organisms in the last grid are counted but are not included with the 300 used for identification.

7) *Taxonomic identification:* 300 specimens from each sample are identified to the standardized level (genus and/or species) using appropriate taxonomic keys. Identified specimens are placed in individual glass vials for each taxon. Each vial contains a label with taxonomic name, bioassessment laboratory number, stream, county, collection date and collector's name. The voucher collection is labeled and returned to the Sample Depository.

8) *Quality assurance procedures:*

QA for Collecting Macroinvertebrate Samples

The following procedures are implemented to help field crews collect unbiased and consistent macroinvertebrate samples:

1. Most sampling reaches should contain riffles that are at least 10 meters long, one meter wide and have a homogenous gravel/cobble substrate with swift water velocity. However, there are approved modifications of the CSBP when these conditions do not exist.

2. A DFG biologist or project supervisor trains all field crews in the use of the macroinvertebrate sampling procedures described in the CSBP. Field personnel are to review the CSBPs before each field season.

3. During the training, crew members practice collecting BMI samples as described in the CSBP. The 2 ft^2 area upstream of the sampling device is delineated using the measuring tape or a metal grid and the collection effort is timed. The method is practiced repeatedly until each crew member has demonstrated sampling consistency. Throughout the sampling season, sampling effort is timed and sampled area is measured for approximately 20% of the sampling events.

QA for Measuring Physical/Habitat Quality

The following procedures will help to standardize individual observations to reduce differences in scores:

1. A DFG biologist or a project supervisor trains field crews in the use of the EPA physical/habitat assessment procedures. Field personnel are to review these procedures before each field season.

2. At the beginning of each field season, all crew members are to conduct a physical/habitat assessment of two practice stream reaches. The first stream reach is assessed as a team and each of the 10 physical/habitat parameters described in the EPA

procedure is discussed in detail. The second stream reach is assessed individually and when members are finished, the 10 parameters are discussed and discrepancies are resolved.

3.Crews or individuals assessing physical/habitat quality are to frequently mix personnel or alternate assessment responsibilities. At the end of each field day, crew members are to discuss habitat assessment results and resolve discrepancies.

4.The Project Supervisor randomly pre-selects 10 - 20% of the stream reaches where each crew member will be asked to assess the physical/habitat parameters separately. The discrepancies in individual crew member scores should be discussed and resolved with the Project Supervisor.

QA for the Laboratory

The CSBP uses the following procedures in the bioassessment laboratory to ensure that quality data is produced:

Subsampling - The Subsampling Technician systematically transfers organisms from the sample to a collection vial then transfers the processed sample debris (remnant) into a Remnant jar. At least 10% of the Remnant samples are examined by the QA Taxonomist for organisms that may have been overlooked during subsampling. For subsamples containing 300 or more organisms, the Remnant sample should contain fewer than 10% of the total organisms subsampled. The Remnant for samples containing fewer than 300 organisms should contain fewer than 30 organisms.

Taxonomic Identification and Enumeration - The QA Taxonomist checks at least 10% of the samples for taxonomic accuracy and enumeration of individuals within each taxon. The same sample numbers that were selected randomly for the subsampling quality control should be used for this procedure. Misidentifications and/or taxonomic discrepancies as well as enumeration errors are noted on the laboratory benchsheets. The Laboratory Supervisor determines if the errors warrant corrective action.

Organism Recovery - During the sorting and identification process organisms may be lost, miscounted or discarded. Taxonomists will record the number of organisms discarded and a justification for discarding on the laboratory benchsheets. Organisms may be discarded for several reasons including: 1) subsampler mistakes (e.g. inclusion of terrestrial or semi-aquatic organisms or exuviae), 2) small size (< 0.5 mm), 3) poor condition or 4) fragments of organisms. The number of organisms recovered at the end of sample processing is recorded and a percent recovery determined for all samples. Concern is warranted when organism recoveries fall below 90%. Samples with recoveries below 90% are checked for counting errors and laboratory benchsheets are checked to determine the number of discarded organisms. If the number of discarded organisms is high, then the technician that performed the subsampling is informed and re-trained if necessary.

Corrective Action - Any quality control parameter that is considered out of range is followed by a standard corrective action that includes two levels. Level I corrective action includes an investigation for the source of error or discrepancy derived from the quality control parameter. Level II corrective action includes checking all samples for the error derived from the quality control parameter but is initiated only after the results of the Level I process justify it. The decision to initiate Level II corrective action and reanalyze samples or conduct quality control on additional samples is made by the Laboratory Supervisor.

Interlaboratory Taxonomic Validation - An external laboratory or taxonomic specialist is consulted on a regular basis to verify taxonomic accuracy. External validation can be performed on selected taxa to help the laboratory taxonomists with problem groups of BMIs and to verify representative specimens of all taxa assembled in a reference collection.

Bioassessment Validation - The CSBP recommends at least 10% bioassessment validation where whole samples of 300 identified specimens are randomly selected from all samples either for a particular project or for all samples processed within a set time period such as each 6 months or a year. The labels are removed from the vials and replaced with a coded label that does not show the taxonomic name of the specimens. The validation laboratory or specialist is to identify and enumerate all specimens in each vial and produce a taxonomic list. There will inevitably be some disagreements between the bioassessment and the external laboratory on taxonomic identification. These taxa should be re-examined by both parties and a resolution reached before a final QA report is written.

9) *Data analysis/Metrics:* The CSBP analysis procedures are based on the EPA=s multi-metric approach to bioassessment data analysis. A taxonomic list of the macroinvertebrates identified in each sample is generated for each project along with a table of sample values and means for the biological metrics listed in the table below. Variability of the sample values are expressed as the CV. Significance testing is used for point source sampling programs and ranking procedures are used to compare sites sampled using the non-point sampling design.

10) *Habitat assessment:* Physical/habitat parameters are assessed using a ranking system ranging from optimal to poor condition. This rapid ranking system is derived from the procedures outline in the "Revised Rapid Bioassessment Protocols for use in Streams and Rivers" (Barbour et al. 1999), and relies on visual evaluation and is inherently subjective. The following ten parameters are evaluated and ranked: 1) epifaunal substrate/available cover, 2) embeddedness, 3) velocity/depth regimes, 4) sediment deposition, 5) channel flow status, 6) channel alteration, 7) frequency of riffles (or bends), 8) bank stability, 9) vegetative protection, 10) riparian vegetative zone width. In addition to EPA RBP habitat measures, the CSBP also evaluates measures cover, quantitative substrate, pebble count, substrate consolidation, depth and width, and velocity.

11) Purpose for monitoring:

- Enforcement and resource damage assessment
- Use attainability
- Ambient monitoring
- Special studies and research

United States Forest Service Pacific Southwest Region (California) Bioassessment Program

The US Forest Service uses a method developed at Utah State University by Charles Hawkins, Jeff Ostermiller, and Mark Vinson. The invertebrate protocols were modified from the designs used by the states of Oregon and Washington and the Bureau of Land Management's National Monitoring Center.

1) *Habitat selection:* Sampling is done at the first fast-water (e.g., riffles, runs) habitat encountered at the site and will continue upstream for the next three fast-water habitat units. If no fast-water habitats occur, eight constant area samples are taken from shallow, slow-water habitat units.

2) *Sampling gear:* All samples are collected using a Surber sampler ($0.09m^2$) with 500 μm mesh netting and a one meter long net to prevent backwashing.

3) *Sampling method:* Two types of samples are collected at each site: 1) a series of eight fixed area samples taken from four fast-water habitat units and 2) a single 10-minute qualitative sample taken from all major habitat types approximately in proportion to their occurrence.

   Fixed Area Samples
   Net placement within each habitat unit is determined by generating two pairs of random numbers between 0 and 9. The first number in each pair (multiplied by 10) represents the percent upstream along the habitat unit's length. The second number in each pair represents the percent of the stream's width from bank left. This process is repeated to locate the second sampling location. Samples are taken where the length and width distances intersect. If it is not possible to take a sample at one or both of these locations, additional random numbers are drawn. Invertebrates are collected from within the $0.09m^2$ area in front of the sampler starting from the upstream edge of the sampling plot and working downstream. Large stones are rubbed and inspected to ensure that all organisms are dislodge and collected. After removing all large stones, small substrates (i.e., sand or gravel) are disturbed to a depth of approximately 10 cm by raking and stirring until no additional organisms or organic matter is being washed into the net.

   10-Minute Qualitative Samples
   The area is visually appraised and the proportion of different habitat types is estimated. The 10-minute sampling period is apportioned so that each of the habitat types is sampled roughly in proportion to their occurrence.

4) *Area sampled:* The total area sampled per fixed area composite is $0.72m^2$. The total area for the fixed time sample is highly variable.

5) *Replication:* There are no replicate samples collected using this method.

6). *Subsampling and enumeration:* The following is a step-by-step description of how quantitative benthic macroinvertebrate samples are processed:

Step 1. The sample is poured through an appropriately sized 250 μm sieve. If the sample contains a lot of sand and gravel, the organic matter will need to be decanted. The entire sample is then poured from the sieve into a bucket partially filled with water. The bucket is swirled so that the organisms and organic matter become suspended in the water column and the heavier sand and gravel falls to the bottom. The water and floating organisms are carefully decanted back through the sieve. Water is continually added to the bucket and decanted until no organic matter remains in the bucket. When finished, the remaining material in the bucket is closely examined and any caddis flies, snails, clams, or other animals that remain are picked out. These organisms are added to those on the sieve.

Step 2. The sample on the sieve is rinsed under the faucet to wash additional fine particles and silt away.

Step 3. The sieve is then placed in an enamel pan or bucket that is partially filled with water and the sample is "floated" so that it becomes level within the sieve. Once leveled, the sieve is carefully removed from the enamel pan. An appropriately sized separator bar is placed into the sieve to split the material in the sieve in half.

Step 4. A coin is flipped to determine which half of the sample is to be processed (heads = right or top, tails = left or bottom). The portion of the sample to be processed is kept in the sieve, and the other half is transferred into a cup using a spoon or rinsed into the cup using an alcohol filled squeeze bottle. The cup is covered with ParaFilm and the portion or split of the sample is written on the lid, e.g., 50%. If it appears that less than 50% of the sample will be sorted, the sieve is placed back in the enamel pan and the material is re-floated to level it, and repeat the same process described above until it appears that approximately 500 organisms remain in one-half of the sieve. Once a split is started it must be finished to its entirety.

Step 5. The material to be sorted is placed little-by-little into a petri dish and all organisms within the petri dish are removed under a dissecting microscope at 7-20x magnification. As the organisms are removed, they are counted and separated into different taxonomic orders. Some representative individuals of the following groups are removed from the sample but not counted as part of the 500 bugs:

- eggs
- exuviae, molt skins
- adult insects – terrestrial or aquatic
- empty snail shells
- brooding juveniles, e.g., small amphipods
- zooplankton
- Collembola

All worms are put in the non-insect vial, but are not counted as part of the 500 bugs. Additional portions of the sample (splits) are sorted until at least 500 organisms are found. The target is to sort between 500 and 550 bugs. If 600 organisms are exceeded, the entire sample must be redone.

Step 6. When 500 bugs have been removed, the entire sample is spread evenly throughout a large white enamel pan. The pan is systematically searched for 10 minutes, and any organisms that have not been found in the split samples thus far are removed. These bugs are placed into a separate vial labeled "B/R" for "Big/Rare".

7) *Taxonomic identification*: Insects are primarily identified to the genus level, Chironomidae are identified to the sub-family level, and non-insect invertebrates are identified to various levels depending on available keys.

8) *Quality assurance procedures:* Not Avaliable.

9) *Data analysis/Metrics:* No standard data analysis procedure has been designated at this time. RIVPACS will be utilized to develop a model to determine the level of impact to the biological assemblage at the site.

10) *Habitat assessment:* Site evaluations are conducted to determine the suitability of reference sites and the degree or type of degradation occurring within test sites. Three major categories are evaluated: Riparian, bank, and channel.
Riparian – 1) vegetative condition, 2) percent historic floodplain remaining intact, 3) anthropogenic activity within the floodplain, 4) alteration of the vegetation within the floodplain, and 5) erosional deposition into stream from surrounding hillslopes.
Bank – 1) percent of streambank with deep, binding root mass, and 2) percent of stream with active lateral cutting.
Channel – 1) siltation, and 2) large woody debris. Additional measures are taken at each site for channel shade, width, depth, substrate, stream slope, dominant erosional habitat type, and dominant depositional habitat type.

11) *Purpose for monitoring:*
- Development of biocriteria and bioassessment protocol
- Monitoring of impacts from timber harvest, grazing and mining activities
- Ensure compliance with the Clean Water Act
- TMDL implementation

United States Geologic Survey - National Water Quality Assessment

The USGS National Water Quality Assessment (NAWQA) program uses a benthic macroinvertebrate sampling method developed by Thomas F. Cuffney, Martin E. Gurtz, and Michael R. Meador and revised method for characterizing stream habitat developed by Faith A. Fitzpatrick, Ian R. Waite, Patricia J. D'Arconte, Michael R. Meador, Molly A. Maupin, and Martin E. Gurtz. However, prior to 1998, when most of the California data was collected, NAWQA used a stream habitat assessment method developed by Michael R. Meador, Cliff R. Hupp, Thomas F. Cuffney, and Martin E. Gurtz.

1) *Habitat selection:* Two types of samples are collected at each site: 1) qualitative multi-habitat (QMH) sampling and 2) richest targeted habitat (RTH) sampling. For QMH samples, all habitat types present in the reach are selected. Semi-quantitative RTH sampling focuses on sampling a habitat supporting the faunistically richest community of benthic invertebrates, usually a fast-flowing, coarse-grained riffle. When riffles are not available, woody debris is sampled.

2) *Sampling gear:* The primary sampling gear used to collect QMH samples is a D-frame kick net equipped with a 210 μm mesh net. RTH samples are collected using a 0.5 m by 0.25 m rectangular frame net equipped with a 425 μm mesh net.

3) *Sampling method:* Two types of samples are collected at each site: 1) qualitative multi-habitat sampling (QMH) and 2) richest targeted habitat (RTH) sampling.

   Qualitative Multi-habitat
   QMH sampling effort is variable because it depends on the types of habitats present and their abundance within the sampling reach. A D-frame kick net is used to collect samples by kicking, dipping, or sweeping in a manner appropriate for the instream habitat type being sampled. When possible, equal sampling effort is applied to each habitat type within the sampling reach. This is usually accomplished by dividing the available 1-hour sampling time equally among the instream habitat types. The D-frame kick net collections are supplemented with visual collections and, where appropriate, with seines to collect highly-motile invertebrates. Visual collections involve manually collecting large rocks, coarse organic debris, clay from stream margins, root wads, and macrophytes or other substrates, and visually locating and removing any associated organisms.

   Richest Targeted Habitat
   The rectangular frame net is held perpendicular to the direction of flow and pressed tightly against the stream bottom. Benthic invertebrates are collected from an area of approximately 0.25 m^2 immediately upstream of the net. If 50 percent or more of a rock lies within the sampling area, it is removed and held in front of the net opening, and attached organisms are dislodged into the net by gently brushing the surface of the rock with the hand and then with a fingernail brush. After a rock is brushed, it is examined to determine if any closely adhering organisms are present. Such organisms are removed from the rock surfaces using forceps and placed into a separate vial holding the large-rare sample component. This sample component contains large organisms that can interfere with sample splitting and rare organisms that might be lost during sample splitting. After the large rocks (fist size and larger) are removed, the sampling area is dug to a depth of about 0.1 m. Any remaining organisms are dislodged into the net by kicking the substrate within the sample area for a period of 30 seconds. The material collected in the net is then transferred to an appropriate container, usually a 19-L (5-gal) plastic bucket or dishpan, for further field processing. Subsequent elements of the composite sample are added to this container and then processed, or the separate elements may be processed and then composited. A minimum of five samples, apportioned within and among examples of the targeted instream habitat type, are composited into a single RTH sample. Examples of the targeted habitat type are collected from across the length and width of the sampling reach.

4) *Area sampled:* The total area sampled per RTH composite is 1.25 m^2. The total area sampled for the QTH sample is variable.

5) *Replication:* More intensive sampling is conducted at a subset of four to six sites to assess spatial variability among reaches and short-term temporal variability at a site. At these sites, three sampling reaches are established to represent environmental conditions associated with the basic fixed site. One sampling reach is sampled in each of 3 successive years to estimate short-term temporal variability. Two additional sampling reaches are sampled in 1 year to assess the magnitude of reach-to-reach variability.

6) *Subsampling and enumeration:* Samples are field processed to reduce the volume of each sample component so that it fits in to a 1-L sample container with ample room for preservative. Sample volume reductions are accomplished by removing large debris, elutriating to remove inorganic sediments, and then splitting the elutriated samples. Field processing can result in the production of four sample components from each composite sample: large-rare, main-body, elutriate, and split-sample components.

   Field processing begins with the removal of large rocks and organic debris, such as leaves, twigs, and roots, from the sample. These materials are discarded after all attached invertebrates have been removed. The remaining material is examined for large, rare organisms that can be lost during subsequent sample splitting. These large-rare organisms are removed and placed in a separate, labeled container that is identified as the "large-rare" sample component. All organisms that are picked from the sample by hand prior to sample splitting are added to the large-rare sample component.

   The remaining sample material is elutriated onto an appropriately sized sieve (425-Φm mesh for semi-quantitative samples and 212-Φm mesh for qualitative samples) to separate the lighter organic material from the heavier sand and gravel. Elutriation is usually accomplished by placing the sample in a deep bucket filled about one-fourth to one-half with water. The contents of the bucket are stirred by hand to suspend as much material as possible. The bucket is picked up, swirled, and then gently decanted onto an appropriate sieve. The elutriation process is repeated until it appears that only sand and gravel remain in the elutriation bucket. The sand, gravel, and small pebbles remaining in the bucket are visually examined for invertebrates, particularly case-building caddisflies and small mollusks. Invertebrates that are removed during this process are added to the large-rare sample component. Once free of invertebrates, the left-over sand and gravel is retained as a quality-assurance check on the efficiency of elutriation.

   Elutriated material retained on the sieve is quickly examined for large, rare organisms that are added to the large-rare sample component. If, after elutriation and compositing, the volume of material constituting the main-body or elutriate sample component exceeds 0.75 L, that sample component is split in the field. Any debris or large organisms that remain in the sample is removed to simplify the sample-splitting process. Organisms so removed are added to the large-rare sample component, whereas debris is discarded after any attached invertebrates are removed.

   Sample splitting is accomplished by using either a special sieve sample splitter (Mason, 1991) or a sieve diameter splitting method. Once the sample has been split, one half of the sample is randomly selected. If the sample being processed is an elutriate sample, then the half of the sample selected is retained for analysis and the other half is discarded. If the sample being processed is a main-body sample, then the half of the sample selected is designated as the main-body component and the other half is designated as the "split" sample component. Some particularly large samples may require repeated splitting to obtain suitable volumes (less than or equal to 0.75 L) of main-body, split, and elutriate sample components. If the resulting split-sample component (elutriate, split, or main-body) exceeds 0.75 L, it is split again. Careful records of the number of splits performed and the portion of the original sample retained for analysis are kept and entered on the appropriate field data sheet.

After samples have been processed, they are transferred to appropriately sized plastic sample containers and an internal sample label is filled out and placed in the container. The sample should occupy approximately one-half to three-fourths of the container volume. A solution of 10% buffered formalin is added to bring the total volume to within 2 cm of the top of the jar. The jar is then capped and slowly inverted several times to mix the contents of the jar with the formalin solution and to remove any air trapped in the sample matrix. The jar is then opened and topped off with 10% buffered formalin.

Qualitative Visual Sort Method
The preservative is rinsed from the sample through a sieve that has a mesh size less than or equal to that used in the field. If necessary, the sample is elutriated to separate inorganic and organic detritus. The sample is then size-fractionated by using a 4.75-mm sieve. To ensure consistent and effective sorting, the sample is apportioned evenly among multiple white sorting trays. The number and size of the trays are adjusted so that about 50 percent of the bottom is visible in each tray. Total sorting time is limited to 2 hours. The coarse-size fraction is sorted for about 0.25 hour. The remaining time, about 1.75 hours, is apportioned between the fine-size fraction and any elutriated inorganic debris; however, if the taxonomist determines that the entire sample has been adequately sorted without adding different taxa, and then sorting is terminated at less than 2 hours. This action is approved by a second taxonomist and noted on the bench data sheet. If the volume of the fine-size fraction is such that it cannot be adequately sorted in about 1.75 hours, then the sample is divided directly on a sieve or on an appropriate sub-sampling frame so that at least 25 percent of this fine-size fraction can be sorted. The remaining unsorted remnant is quickly scanned and sorted for distinct taxa.

Each tray is sorted systematically by a taxonomist for mature, undamaged organisms. After one complete pass of the tray, the detritus is redistributed by rocking the tray and sorting continues. BMIs are sorted into gross taxonomic categories and placed into polyseal screw-cap vials that contain 70% ethanol. At least 50 Chironomidae larvae are sorted whenever possible. Visually distinguishing Genus- or Species-level diversity for some BMI taxa is often difficult; therefore, comparable numbers of organisms of these groups are sorted from each tray of each sample. All unique mollusk shells are sorted, even if the body of the organism is not present.

Quantitative Fixed-Count Subsampling Method
The principal objective of the fixed-count method is to identify and estimate the abundance of each BMI taxon sorted from the sample. This method is similar to the USEPA's RBP sample-processing procedure (Barbour et al. 1999; Plafkin et al. 1989).

The fixed count is based on a minimum number of organisms sorted from the sample and is defined by the study's data quality objectives (for example, 100-, 200-, or 300-organism fixed-count target).

Samples containing more organisms than the fixed-count target are subsampled by using a subsampling frame partitioned into 5.1- by 5.1-cm grids. However, uniformly distributing a sample in a subsampling frame is often difficult, and organisms in the sample matrix tend to have a clumped distribution. Therefore, subsampling by simply acquiring a single, very small portion from a subsampling frame could lead to extreme errors in estimating the abundance of taxa in the sample. The method described below uses multiple, randomly selected 5.1- by 5.1-cm portions of the original sample (stage-1 grids) to estimate abundance accurately. Large-rare organisms are sorted from any remaining portion(s) of the sample after the random subsampling is complete.

Total sorting time is limited up to a maximum of 8 hours, depending on the fixed-count target. The time limitation has been implemented to avoid spending too much time on samples that contain few or have exceedingly difficult detritus to sort. A generalized processing procedure is listed as follows:

- The sample is uniformly distributed in a subsampling frame (stage-1 subsampling frame).
- An estimate of the average number of organisms per stage-1 grid is obtained.
- By using the average number of organisms per stage-1 grid, an appropriate processing strategy is selected.
- The grids are randomly selected from either a stage-1 or a stage-2 subsampling frame, and organisms are sorted from each grid.
- Large-rare organisms are sorted from any remaining unsorted portion(s) of the sample.

Three sizes of gridded subsampling frames are used, 12 grid (15.2 cm X 20.3 cm X 3.8 cm), 24 grid (20.3 cm X 30.5 cm X 3.8 cm), and 42 grid (30.5 cm X 35.6 cm X 3.8 cm). The size of the subsampling frame chosen depends on the total sample volume and organism density; frame size increases with sample volume and density. If the volume of a sample is very low but the density of the BMIs is high, the subsampling frame size is dictated by the density of organisms in the sample. Occasionally, the volume of detritus is so small and the BMIs are so depauperate that the use of a sub-sampling frame is not necessary. The primary objective is to choose a frame size for uniform dispersal of the sample.

The mean number of organisms per stage-1 grid is used to determine the appropriate subsampling strategy. This mean is obtained by randomly selecting five grids from the stage-1 subsampling frame and uniformly distributing the material from each grid into separate, appropriately sized, estimation trays. Estimation trays with either 49 or 81 grids can be used to obtain a uniform distribution and density of sample material. The organisms in each of three randomly chosen estimation tray grids are counted and used to estimate the number of organisms in each estimation tray and, hence, each stage-1 grid. Separate estimates are made from each of the five estimation trays. The resulting five estimates are averaged to give an estimate of the number of organisms in each stage-1 grid. An informed processing decision can be made once the mean number of organisms per stage-1grid has been estimated. Sub-sampling may involve processing multiple randomly selected stage-1 grids from the stage-1 subsampling frame (1-stage sub-sampling) or a further subsampling of three to five stage-1 grids (2-stage subsampling). Numeric criteria are used to determine the appropriate subsampling strategy. Once the appropriate level of subsampling has been achieved, the approximate number of random grids are randomly selected for sorting. Additional grids are randomly selected as needed to reach the fixed-count target.

The contents of each randomly chosen stage-1 or stage-2 grid are sorted separately by using a dissecting microscope with X 10 magnification. All identifiable organisms are sorted. Mollusk shells are only sorted if the animals are present in the shells. Only a portion of colonial organisms, such as Bryozoa or Porifera, is sorted to document its presence in the sample. Vertebrates, exuviae, invertebrate eggs, microcrustaceans, and terrestrial organisms are not sorted. However, terrestrial insects that have an aquatic lifestage are sorted.

Once sorting has begun, the grid is sorted to completion even if numeric or time frame criteria are exceeded. Organisms are enumerated as they are removed from each grid and pre-sorted into categories. Organisms are placed in polyseal capped vials containing 70% ethanol. The sort-time criteria, excluding time required to prepare the sample and estimate grid densities, are 8 hours for a 300-organism fixed-count target and 3 hours for a 100-organism fixed-count target.

Some large-rare taxa may be present but at such low densities that it is unlikely that they will be encountered in the random subsamples. The quantitative sample-processing method accounts for these large-rare taxa by visually sorting them from the unsorted portion of the sample. This sorting is limited to 15 minutes. If inorganic debris is separated from the sample, this debris also is sorted for large-rare organisms.

7) *Taxonomic identification*: The National Water Quality Laboratory (NWQL) Biological Group (BG) provides three levels of taxonomic assessment for BMI samples. These levels include (1) the Standard Taxonomic Assessment (STA), (2) the Rapid Taxonomic Assessment (RTA), and (3) the Custom Taxonomic Assessment (CTA). Each provides a different basic level of taxonomic resolution to address various water-quality and related data-analysis objectives. The STA and RTA are adapted from the U.S. Environmental Protection Agency (USEPA) Rapid Bioassessment Protocols (RBP) (Barbour et al., 1999; Plafkin et al., 1989). The STA represents a taxonomic effort similar to that described in the USEPA RBP III (Barbour et al., 1999; Plafkin et al., 1989) and in many other state biomonitoring protocols. It is currently (2000) the level of resolution used by the USGS NAWQA Program for BMI samples. In general, mollusks, crustaceans and insects are identified to either the Genus or Species level. Aquatic worms are identified to the Family level. Other BMI groups, such as flatworms and nematodes, are typically identified at higher taxonomic levels (for example, Phylum or Class). The RTA represents a taxonomic effort similar to the USEPA RBP II (Barbour et al., 1999; Plafkin et al., 1989). In general, all BMI groups are identified to the Family level, except for

groups such as flatworms and nematodes, which are typically identified at higher taxonomic levels (for example, Phylum or Class). The CTA provides a customer-specified taxonomic effort that is not provided in the STA or RTA.

8) *Quality assurance procedures:* Not available.

9) *Data analysis/Metrics:* Not available.

10) *Habitat assessment:* Habitat is assessed using a first-level reach characterization and a more detailed second-level reach characterization.

<u>First-level reach characterization:</u>
Six transects, as a minimum, are established to collect information throughout the reach with two transects established at or near each boundary. If the reach is established on the basis of the presence of two examples of each of two types of geomorphic channel units, the remaining four transects are established at the middle of each geomorphic channel unit. If the reach is defined on the basis of channel width, then the remaining four transects are evenly spaced throughout the reach. Transects are oriented perpendicular to streamflow.

- Channel width: Measure the channel width along the transect from left edge of water to right edge of water.
- Bank width: Bank width is the distance between the channel bed and the flood plain. This distance is measured with a tape measure or rangefinder.
- Flood-plain width: Flood-plain width is measured as the distance between the significant changes in slope that distinguish the flood plain from terraces and riparian features. If this distance is less than 50 m, it can be measured with a tape measure or rangefinder. However, if the flood-plain width is greater than 50 m, it is determined from maps or aerial photographs, and indicated as greater than 50 m on the form.

For the next 3 items, data are collected at three points along each transect. These points should correspond to the thalweg, and to two locations that are equally spaced along the transect (or three equally spaced locations if no thalweg is apparent).

- Depth: In wadeable reaches, water depth between the water surface and the bed substrate is measured with a wading rod and recorded. In nonwadeable reaches, a sounding line or hydroacoustic depth meter may be necessary to determine depth. When using a hydroacoustic depth meter, the investigator maneuvers the boat along the transect with the meter operating, so as to produce a continuous recording of water depth along the transect. Three depth measurements, one at the thalweg and two at locations equally spaced along the transect, can be determined from the hydroacoustic chart.
- Velocity: In wadeable reaches, record velocity using a Price AA current meter, pygmy meter, or Gurley meter. In nonwadeable reaches, use a velocity meter appropriate for velocity determinations at that site. Velocity is recorded at 60% depth

where depth is less than 1 m. At depths greater than or equal to 1 m, two velocity measurements, one at 20% depth and the other at 80% depth, are recorded.

- Bed substrate: Determine the spatially dominant and subdominant substrates. In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained by using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge. In turbid wadeable reaches and in nonwadeable reaches, the presence of boulders and bedrock cannot be determined by sampling. However, in turbid wadeable reaches, the presence of these substrate types can be determined by touch. In nonwadeable reaches where sampling devices cannot yield a substrate sample, acoustic recording of the stream bottom along the transect can detect boulders and bedrock.

- Embeddedness: Embeddedness is measured by rating the percentage of the surface area of the larger-sized particles (by visual estimation) covered by fine sediment. To determine how much of the surface area of large particles is covered in order to provide a rating, select five relatively large (gravel to boulder size) substrate particles at the three sampling points along the transect and examine them on the sides. Note the percentage of each particle's height that was buried in sediment by the extent of discoloration on the particle. The rating is based on the percentage of coverage of fine sediment as determined from the average percentage of coverage for the five particles. In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge.

- Canopy angle: From the midpoint of the transect, use a clinometer to determine the angle from the line of sight of the investigator to the tallest structure (for example, tree, shrub, building, or grass) on the left bank (in the general area of the transect). The same procedure is done at the right bank. The sum of these angles is computed and subtracted from 180 degrees.

- Aspect: Record the aspect (0 to 360 degrees) of the downstream flow of the stream using a compass. At the midpoint of the transect, face downstream and point a compass parallel to streamflow.

- Habitat features: Determine the type and amount (two-dimensional area) of all habitat features that are partly or wholly within a 2-m zone on either side of the transect. Habitat features consist of any mineral or organic matter that produces shelter for aquatic organisms to rest, hide, or feed, and include natural features of a stream such as large boulders, woody debris, undercut banks, and aquatic macrophyte beds, as well as artificial structures such as discarded tires, appliances, and parts of automobiles. Habitat features are not counted when they are in insufficient depth (usually less than 20 cm).

- Bar/Shelf/Island: If channel bars, shelves, or islands are present, measure width using a tape measure or rangefinder. Determine the spatially dominant and subdominant substrates along the transect for the bars, shelves, and islands that occur. Also estimate the percentage of coverage of woody and herbaceous vegetation for the entire bar/shelf/island.

- Bank angle: A clinometer is used to measure the angle formed by the downward-sloping bank as it meets the stream bottom. The angle is determined directly from a clinometer placed on top of a surveyor's rod or meter stick that is aligned parallel to the bank along the transect. The clinometer reading is subtracted from 180 degrees to produce the bank angle. If the height and shape of the bank are such that more than one angle is produced, then an average of three readings is recorded. Both left bank and right bank (facing downstream) angles are recorded.

- Bank height: Determine the left and right distance from the channel bed to the top of the bank. A surveyor's rod and hand level can be used if this distance can be measured directly. If the bank height cannot be measured directly, then it can be estimated. Note that the bottom of the bank is the deepest part of the channel. At large, nonwadeable reaches, topographic maps may be useful in determining bank height.

- Bank vegetation stability: Bank vegetation stability is evaluated using a rating based on four classes that represent percent coverage of the bank surface. The rating includes only that part of the bank that is within 2 m of either side of the transect, to the top of the bank.

- Bank shape: Record the shape of the left and right banks as: concave upward, linear, or convex upward.

- Bank erosion: The types of bank material movement, if present, are noted. These types include mass wasting (debris avalanche, rotational failure, and slab failure), and cut-bank scalloping. Indicate the presence of bank erosion for the left and right banks as: debris avalanche, rotational failure, slab failure, cut-bank scalloping, or none.

- Bank substrate: Determine the spatially dominant and subdominant substrate types that are present in an area of the bank that is within 2 m of either side of the transect, to the top of the bank. This procedure is done for the left and right banks.

- Bank woody vegetation: The point-centered quarter method is used to evaluate density and dominance of bank woody vegetation (Mueller-Dombois and Ellenberg, 1974). Sampling points are established on both banks at the ends of the transect so as to include dominant bank woody vegetation. Four quarters are established at a sampling point at the intersection of two perpendicular lines, one of which is the transect. Trees and shrubs are included in the analysis. Trees are distinguished from shrubs in that trees are at least 2 m high and have a diameter at breast height (dbh) of at least 3 cm. The sampled trees or shrubs are identified to species, and the distance from the sampling point to the nearest tree or shrub in each quarter is measured, along with its dbh. Where bank woody vegetation is growing in narrow strips or rows, the two closest trees or shrubs on either side of the sampling point are measured. Where a single tree or shrub has developed many separate trunks, an average dbh for three trunks is recorded, along with the total number of trunks.

- Photodocumentation: Stream conditions at three transects, including the transects at or near the reach boundaries and one transect representative of reach conditions, are photographed. Semipermanent markers are established at these locations to facilitate taking repeat photographs. Color photographs, preferably slides, are taken that include upstream, transect, and downstream views of the channel and should include a scale reference in the image. The inclination and aspect of the camera lens are important and are measured with a compass. A level camera is preferred to an inclined one because inclination complicates the perspective of the view and makes accurate duplication of repeat photographs difficult. The aspect of the camera is noted by pointing a compass at the central aiming point in the view and recording the compass reading. Photographs are taken facing upstream, facing perpendicular to the channel, and facing downstream, from either the left or right banks.

- Diagrammatic mapping: Draw a schematic or representative map of the reach. The map should include location of geomorphic channel units, habitat features, and bank and flood-plain land use. Indicate the stream type and general shape of the channel.

- Aquatic and riparian vegetation species: Record the species name of all common aquatic (submerged, emergent, and floating) and riparian (bank--herbaceous and woody, and flood plain--herbaceous and woody) species. Be sure to note the five most common for each category.

<u>Second-level reach characterization</u>
A second-level reach characterization also is conducted at all fixed sites. This is a detailed reach characterization and is designed to provide additional quantitative data on geomorphic and hydraulic properties that are critical to the evaluation of temporal changes in the environmental setting and stream habitat. The second-level reach characterization consists of an analysis of hydraulic properties and channel geometry plus additional components tailored to enhance an understanding of temporal changes. The analysis of channel geometry consists of longitudinal profiles of the water surface, flood plain, and channel bed; cross-sectional surveys with levels; a map of the reach; and a quantitative analysis of bed and bank materials. Additional suggested components of the second-level reach characterization include permanent plot vegetation analysis and detailed quantitative mapping of habitat features throughout the reach. Study unit personnel are responsible for developing an appropriate form for recording the second-level reach characterization.

The longitudinal profile of the channel bed is conducted along the thalweg (or the approximate center of the channel if a thalweg is not apparent) on the basis of channel-bed elevations recorded at intervals equal to one channel width. This distance is generally sufficient to determine the mean slope of the reach. The water-surface profile can be determined simultaneously by having the rodman record the water depth at each location and add this value to the channel-bed elevation. Profiles of the flood plain along both banks also are conducted. In nonwadeable reaches, longitudinal profiles of the channel bed are determined using a hydroacoustic depth meter, and water-surface elevations are determined along one bank or both banks.

At a minimum of three locations (both reach boundaries and a location that includes a prominent geomorphic feature), leveled cross-sectional surveys are conducted from left flood plain to right flood plain. Each cross-sectional survey is plotted, with elevation recorded on the ordinate axis and distance in meters along the abscissa. All surveys are conducted in relation to the reference location. A map of the reach is constructed, indicating the locations of the longitudinal profiles and the cross-sect ional surveys. Cross-sectional surveys of nonwadeable reaches include as much information as can possibly be recorded.

In addition to an analysis of channel geometry, a quantitative analysis of channel substrate particle size is conducted. Pebble counts are conducted to determine bed material particle-size distribution in wadeable reaches. At the three surveyed cross sections, a pebble-count transect is established, and the pebble count is conducted in the following method:

(1) Begin the count at each transect at bankfull elevation on the left bank and proceed to bankfull elevation on the right bank.
(2) Proceed one step at a time, with each step constituting a sampling point.
(3) At each step, reach down to the tip of your boot and, with your finger extended, pick up the first pebble-size particle touched by the extended finger.
(4) To reduce sampling bias, look across and not down at the channel bottom when taking steps or retrieving bed material.
(5) As you retrieve each particle, measure the intermediate axis. If the intermediate axis cannot be determined easily, measure the long diameter and the short diameter of the particle, and determine the average of the two numbers.

Thus, the size distribution of particles is determined and expressed in percentage by number of particles. A count of 100 particles is recommended; however, to determine percentages of particle sizes, 50 or 25 particles can be measured. To obtain a quantitative determination of finer grained bed material, three samples of the bed material are collected along each transect and composited. In addition, samples of the bank substrate material can be collected from one bank or both banks. These samples are returned to the laboratory for sieve analysis.

Permanent plot vegetation analysis is also suggested as a component of the second- level reach characterization. To construct a permanent vegetation plot, select an area at the end of each of the surveyed cross sections. A 20- by 20-m plot is identified by using a tape measure to determine the appropriate distance and a compass to establish 90-degree angles at the corners of the plot. The corners are then marked with semipermanent boundary markers. The edge of the plot nearest the bank edge should be at least several meters from the bank. Sample the vegetation by determining the diameter and species of all trees and shrubs within the plot. Record only living trees and shrubs. If the riparian zone is narrow such that a 20- by 20-m plot cannot be established, then two or more smaller plots are established so that the total area sampled equals 400 m^2. Where herbaceous vegetation is clearly dominant, then a 10- by 10-m square plot is established. At herbaceous vegetation plots, the aerial coverage of up to five species is measured, and the percent coverage of these species within the plot is calculated.

Mapping of all geomorphic channel units and habitat features can also provide critical information needed to evaluate temporal trends in habitat. Though the diagrammatic stream map should indicate the presence of these units and features to approximate scale, the first-level reach characterization does not attempt to quantify the occurrence of all features throughout the reach. In the second-level reach characterization, the two-dimensional area of all significant geomorphic channel units and habitat features is determined.

11) Purpose for monitoring:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams.
- Describe how water quality is changing over time, and
- Improve our understanding of the primary natural and human factors affecting water quality.

United States Environmental Protection Agency - Environmental Monitoring and Assessment Program

EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. The objectives of REMAP are to: 1) evaluate and improve EMAP concepts for state and local use, 2) assess the applicability of EMAP indicators at differing spatial scales, and 3) demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

A Regional-EMAP (REMAP) study was conducted in 1994-1995 in Californina's Central Valley, which comprises more than 48,000 miles of surface water and 16 percent of the land area in the State and is one of the nation's most productive agricultural areas. The Central Valley REMAP Project was initiated to assess the biological integrity of agriculture-dominated waterbodies located throughout California's Central Valley. Moreover, USEPA is currently collecting additional bioassessment data in California as part of the EMAP Western Surface Water pilot study, which is a five-year research and monitoring project to assess the ecological condition of streams and rivers across the Western U.S.

Typically, EMAP and REMAP studies use the same sampling methods; however, the Central Valley REMAP study used an earlier method developed by Philip A. Lewis and Donald J. Klemm (see Klemm and Lazorchak 1995), while the Western EMAP study uses a revised method developed by D. J. Klemm, J.M. Lazorchak, and P.A. Lewis (see Lazorchak et al.1998). Only the revised (current) method will be discussed in this section.

1) *Habitat selection:* Each sampling reach is determined as 40 times the wetted width, with a minimum reach length of 150 m and a maximum length of 500 m. The habitats that are sampled are selected randomly by dividing the reach into 11 equidistant cross-sectional

transects, and randomly sampling at the left third, center, or right third from the interior nine transects. For each reach, riffle and run habitat samples are composited into a single "Riffle" sample whereas pool and glide samples are composited into a single "Pool" sample.

2) *Sampling gear:* The primary sampling gear used to collect samples is a modified 0.5 m by 0.3 m rectangular frame kick net equipped with a 595/600 μm mesh net.

3) *Sampling method:* As mentioned previously, the sampling reach is equally divided into 11 cross-sectional transects. At each of the nine interior transects, a sampling point (left, center, or right) is assigned. Once the first sampling point is randomly chosen, points at successive transects are assigned in order (left, center, right). Habitat type is sampled roughly in proportion to their occurrence.

4) *Area sampled:* The total area sampled per transect is 0.5 m^2, and the total area sampled per site is 4.5 m^2. The area sampled per composite sample is variable based on the distribution of habitats sampled at the site.

5) *Replication:* There are no site replicates collected; however, there are QA/QC replicates whereby a different team samples the same site and next year revisits at several sites.

6) *Subsampling and enumeration:* Random subsampling to 300 organisms.

7) *Taxonomic level:* Identification of all organisms to the lowest possible taxon, usually to genus, species, or species group (including Chironomids and Mites).

8) *Quality assurance procedures:* Not available.

9) *Data analysis/Metrics:* Not available.

10) *Habitat assessment:* See Lazorchak et al. 1998.

11) *Purpose for monitoring:*
- Evaluate and improve EMAP concepts for state and local use
- Assess the applicability of EMAP indicators at differing spatial scales, and
- Demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states.

University of California Sierra Nevada Aquatic Research Laboratory (SNARL)

1) *Habitat selection:* Only riffle habitat is sampled within a 150 m study reach.

2) *Sampling gear:* The primary sampling gear used to collect samples is a D-frame kicknet with 250 μm mesh netting.

3) *Sampling method:* Five riffles are selected from a random number table along the 150 meter reach. The D-net is used to collect kick samples at ¼, ½ and ¾ of the stream width (always start at the location furthest downstream and work up). Kick an area approximately 30 square centimeters directly above the net (a square area with sides equal to net width) is kicked to disturb the substrate and dislodge organisms. The kicking is maintained for a count of about 10-15 seconds, then the rocks are scrubbed by hand for an additional 10-15 seconds (total 20-30 seconds at each of 3 positions = 1-1.5 minutes). Large rocks or wood debris are removed after washing them in the current into the net following each sample position. For streams less than 1-2 meters wide, the 3 kick samples are taken from both sides and middle above or singly one above another at the random number location (instead of taking all 3 across the stream when widths are greater than 1-2 meters). Because the focus of the method is on sampling across different microhabitat types in the stream including varied depth, current, substrate types – the three composited samples should represent the variety of habitat present. One or two composites may be taken if samples are dense with debris.

   When sampling in pools, only a single collection is taken within the tail zone of the pool (i.e. downstream third of pool zone) by sweeping or brushing the sample area into the mouth of the net. The net is sometimes used to scoop through sample area after the sweep. More than a single area sampled usually produces too much sample volume to process and preserve.

   The net should be quickly dipped into the stream to consolidate the material to the bottom of the D-net. Any remaining large debris is removed. The net is inverted into a bucket with 1/4 to 1/3 full of water. The net is shaken out to collect all the debris and insects. The net is dipped into the stream again to consolidate remaining contents and the net is then inverted into the bucket.

   Lighter material is elutriated with a swirling motion into the other bucket five times. Only a small volume of water is used in each elutriation so the receiving bucket does not overflow. Only rocks and sand should be left in the original bucket. These rocks are emptied into a shallow white pan (or the bottom of the bucket is closely examined). Cased caddisflies/snails are examined for and added to sample if found.

   The debris is then strained through a fine mesh aquarium net supported on one bucket (this may also serve as an elutriation since some sand will have gotten into this debris). The contents of the aquarium net is emptied into a sample container. BioQuip forceps are used to scrape any remaining debris into vial. The container is filled with ethanol to preserve the bugs, and a small volume of rose bengal stain is added.

4) *Area sampled:* The total area sampled per composite is 0.27 m^2, and the total area sampled per site is 1.28 m^2.

5) *Replication:* Five replicate composite samples are collected from each site.

6) *Subsampling and enumeration:* Random subsampling to 300 organisms.

7) *Taxonomic level:* Identification of all organisms to the lowest possible taxon, usually to genus, species, or species group (including Chironomids and Mites).

8) *Quality assurance procedures:* See website for detailed information; http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm

9) *Data analysis/Metrics:* See website for detailed information; http://www.swrcb.ca.gov/rwqcb6/QAPP/QAPP_Index.htm

10) *Habitat assessment:* 15 transects are spaced at 10 meter intervals along the 150 meter delineated reach length (starting at 0). Bank and channel features are measured (wetted perimeter width, bank cover category, bank angles, and vegetation cover (using densiometer) across each transect and at 5 equal-spaced points within each transect the depth, current velocity (60% depth), and substrate type (size class) are measured. Location of each site (mid-reach) is determined with a GPS unit, and elevation determined from map location (and/or barometer). Slope is measured using a hand-held leveling scope sighted on a stadia rod over a series of intervals over the 150 meter reach length. Sinuosity is determined from the ratio of reach length to minimum linear distance from the bottom to top points of the reach. Percent riparian canopy cover by type (within 1 meter on the bank) is visually estimated for the reach. Temperature, pH, conductivity and turbidity are measured using calibrated field meters. Dissolved oxygen is determined in the field using a standard test kit. Alkalinity, nitrogen, phosphate, and hardness are measured in the lab from field samples. General types of algae present are noted for each reach (algae samples from rock surfaces are also collected and preserved). Photo documentation of each reach is also made at 4 points: mid-stream looking upstream at 0, 50, 100, and at 150 meters looking downsteam.

<u>Reach and Riffle-Pool Delineation</u>

The first step in description of physical habitat is delineation of the 150 meter length of the stream reach along an approximation of the thalweg of the channel. To the extent possible, this measurement should be made by following along the bank contours of the channel, laying out the meter tape (50 m on a reel). This may require crossing the channel or even walking in the stream if bank vegetation cover is too dense – but this should be kept to a minimum to avoid disturbance of benthic habitat. For each 25 meter length a flag should be placed to serve as a monument for marking locations and later measurement of gradient. Over the 150 meter reach delineation, the primary data to be recorded is the position along the meter tape (to the nearest meter) where erosional and depositional habitat types begin and end – riffles and pools, respectively. This data provides an indication of the distribution and length of these major geomorphic units within each reach. The position of these habitat features will also be used to determine where the benthic invertebrate samples are to be taken by using a random number table (0-150) to assign a riffle or pool location to be sampled. Any habitat not assigned to the riffle-pool categories may be regarded as transitional glide or run habitat type. Depending on the criteria for reach selection, the starting point of a reach may be established to maintain the reach within a certain zone defined by the problem of interest, the gradient, vegetation cover, or accessibility. Selection may also be random, using preliminary map information on the target area.

Bank and Channel Features
Bank features on each transect are identified according to bank cover categories (substrate type, vegetation present and eroded, stable or incised). The intersect of interest is between the water level and an approximation of the bank full height of the channel. Bank angle is also rated categorically as shallow (less than 30 degrees), moderate (30-90) or undercut (>90). Riparian vegetation cover over and next to the channel is determined using a concave mirror densiometer, taped to view the canopy in the facing direction of the measure. There are 17 grid points and vegetation reflected at those grid points is recorded at the left and right banks, and mid-stream facing up- and downstream.

Transect Measures
After measuring stream width (wetted perimeter), the transect is visually divided into 5 equally spaced points (visualize the mid-point as 3, and equally divide the left and right sides into points 1 and 2 and points 4 and 5). At each point, the depth and substrate type at the point of contact are recorded (recorder on bank) using a meter stick. Substrate types are grouped by size class for the mineral type, and also according to algal, vegetation or detrital components present at the point. At 60% depth the current velocity is also measured at each point (also record current meter type used and units). Discharge is calculated later for each of the 5 cells measured (current x cross-section area). Any cobble encountered is also rated according to the volume of rock embedded by fine / sand substrates (a visual estimate, calibrated among observers).

Overall Reach Features
The gradient of the channel is measured using a hand-held leveling scope (5X magnification) to sight off a 5 meter leveling rod. The observer serves as the tripod and so should find a position where both upstream and downstream position of the rod can be clearly observed without moving except to turn the upper body. Most readings will be taken over 25 meter intervals but where possible should be taken over 50 meter intervals to save time. The sum difference in up-down readings over 150 will give the percent slope or gradient. The sinuosity of the channel is measured as the ratio of the 150 meter thalweg stream length to the direct line distance from the top to bottom flags defining the reach. This is done by sighting to the leveling rod held at one end of the reach and walking a direct line of sight to the rod, measuring distance with a reel tape over the distance (a person to hold the tape end facilitates the several walks needed to measure the full distance). Riparian vegetation cover is visually estimated as morphological categories of cover (grass, bush, tree) and type. This provides another measure of shading, riparian development and potential inputs. Algae type present is also qualitatively scored. Notes should also be kept on any aquatic vegetation present.

11) *Purpose for monitoring:*
- Biocriteria development and assessment & monitoring.
- Livestock grazing stream restoration

- Acid Mine Drainage stream restoration monitoring.
- TMDL development for sediments.
- Reference condition sampling

Appendix C

Performance Characteristic Evaluation

Appendix C PERFORMANCE CHARACTERISTIC EVALUATION

To determine the method precision (i.e., measurement error within a site), we evaluated two data sets from SNARL, one from the Leviathan Mine study and another from the Upper Truckee River, and a large database (CalEDAS) from the California Department of Fish & Game containing CSBP data. The Leviathan Mine data set included a total of seven metrics, which were calculated from 54 sites (Table 1). On the other hand, the Upper Truckee River included a total of 15 metrics, which were calculated from 18 sites (Table 2). Where there were common metrics, the data was combined, and several metrics were calculated from a total of 72 sites (Table 3). The data set using the CSBP method was significantly larger (approximately 360 sites) and was much more widely distributed than the SNARL data; however, details on the exact site distribution across the state were not provided.

An analysis of variance (ANOVA) was conducted to compare the variability among replicates at each site. From the mean squared error (MSE), we calculated the root mean square error (RMSE), which can be used to compare precision between metrics, and the coefficient of variability (CV), which can be used to compare precision among metrics. The RMSE provides an estimate of the standard deviation of a population of observations; however, it is scale dependent, and therefore metrics that are on different scales cannot be directly compared. CV, on the other hand, is a unit-less measure calculated by dividing the RMSE by the mean of the dependent variable, which allows for direct comparison among means and indices. Because the CV takes into account the within site variability relative to the sample mean, it was chosen to be the better indicator of precision when comparing the two methods.

Tables 1 and 2 list ANOVA results of SNARL data from the Leviathan Mine dataset and the Upper Truckee River dataset, respectively. Unfortunately, the same metrics were not calculated for both studies; therefore, in our attempt to combine the datasets, the number of observations is not consistent among the different metrics (i.e., N = 18, N = 72)(Table 3). Table 4 lists the among season variability for data collected in the Upper Truckee River study using the SNARL method.

Table 1. ANOVA results of SNARL Leviathan Mine data (N = 54)

Metric	*MS Error*	*RMSE*	*Mean*	*CV*
Species Richness	12.05	3.47	23.52	14.76
EPT Taxa	2.98	1.73	9.00	19.18
Density (ind./m^2)	212000000.00	14551.03	15653.30	92.96
%Chironomidae	0.01	0.07	0.35	20.88
Ratio EPT/Chironomidae	1.38	1.17	1.34	87.24
Hilsenhoff Biotic Index	0.11	0.33	4.52	7.20
Dominance	0.01	0.08	0.40	20.50

Table 2. ANOVA results of SNARL Upper Truckee River data (N =18)

Metric	MS Error	RMSE	Mean	CV
Species Richness*	14.17	3.76	27.09	13.90
EPT TAXA*	3.42	1.85	11.10	16.67
No. EPHEMEROPTERA TAXA	1.07	1.03	6.77	15.26
No. PLECOPTERA TAXA	1.58	1.26	4.33	28.99
No. TRICHOPTERA TAXA	1.34	1.16	5.73	20.22
No. of CHIRONOMIDAE	5.98	2.45	11.22	21.80
No. of Individuals	49468.56	222.42	593.24	37.49
DENSITY* (#/m^2) @30x30 cm area	170000000.	13054.01	17948.72	72.73
%EPT	0.01	0.09	0.63	15.00
%CHIRONOMIDAE*	0.00	0.07	0.31	22.44
Chiro Richness / Chiro Density	0.00	0.00	0.01	62.39
Hilsenhoff Biotic Index*	0.13	0.36	4.26	8.46
%TOLERANT TAXA (7-8-9-10)	0.00	0.05	0.11	47.70
INTOLERANT TAXA (0-1-2)	4.66	2.16	14.41	14.98
DOMINANCE*	0.01	0.08	0.36	21.52
%FILTER-FEEDERS	0.00	0.05	0.08	60.62

Table 3. ANOVA results of combined SNARL data (N =18)

Metric	MS Error	RMSE	Mean	CV
Species Richness	19.76	4.44	36.80	12.08
EPT TAXA	4.61	2.15	16.83	12.75
No. EPHEMEROPTERA TAXA	1.07	1.03	6.77	15.26
No. PLECOPTERA TAXA	1.58	1.26	4.33	28.99
No. TRICHOPTERA TAXA	1.34	1.16	5.73	20.22
No. of CHIRONOMIDAE	5.98	2.45	11.22	21.80
No. of Individuals	49468.56	222.42	593.24	37.49
DENSITY (no./m^2) @30x30 cm area	61354347.0	7832.90	24197.34	32.37
%EPT	0.01	0.09	0.63	15.00
%CHIRONOMIDAE	0.01	0.08	0.20	38.18
Chiro Richness / Chiro Density	0.00	0.00	0.01	62.39
Hilsenhoff Biotic Index	0.19	0.44	3.58	12.31
%TOLERANT TAXA (7-8-9-10)	0.00	0.05	0.11	47.70
INTOLERANT TAXA (0-1-2)	4.66	2.16	14.41	14.98
DOMINANCE	0.00	0.06	0.25	25.46
%FILTER-FEEDERS	0.00	0.05	0.08	60.62

Table 5 lists the metrics used to describe the characteristics of the benthic macroinvertebrate communities sampled according to each method. It should be noted that the metrics listed in the table are not part of a biological index for either method, and the metrics calculated for each study does not necessarily remain consistent. Therefore, the suite of metrics listed in this table is not intended to be indicative of the analyses performed for each study.

Table 4. Among season CVs for SNARL Upper Truckee River data.

Metric	*Spring 95*	*Spring 97*	*Fall 98*	*Spring 99*	*Fall 99*
Species Richness	13.79	22.72	13.12	15.02	14.05
EPT TAXA	28.21	20.71	19.02	21.24	14.48
No. of Individuals	50.92	27.83	29.49	36.79	23.59
Density (ind / m^2)	50.92	27.83	35.61	47.55	72.93
%Chironomidae	19.58	24.74	21.13	13.80	21.56
Ratio EPT/Chironomidae	60.05	60.37	84.01	119.34	59.55
Hilsenhoff Biotic Index	4.86	11.50	8.66	6.63	4.90
Dominance	35.64	22.46	19.97	19.02	19.53

* N = 72 for these metrics.

Table 5. Metrics used to by each method to describe characteristics of Benthic Macroinvertebrate communities.

Metric	CSBP	SNARL	Metric	CSBP	SNARL
Taxa Richness	X	1	% Hydropsychidae	X	
EPT Taxa	X	X	% Baetidae	X	
Ephemeroptera Taxa	X	X	% Dominant Taxa	X	X
Plecoptera Taxa	X	X	% Collectors	X	
Trichoptera Taxa	X	X	% Filterers	X	X
Chironomidae Taxa		X	% Scrapers	X	
EPT Index (%)	X	X	% Predators	X	
Sensitive EPT Index	X	2	% Shredders	X	
Shannon Diversity Index	X		Density		X
Hilsenhoff Biotic Index		X	Estimated Abundance	X	X
Tolerance Value	X		Ratio EPT/ Chironimdae		X
% Intolerant Organisms	X		Chironomidae Richness/ Chironomidae Density		X
% Tolerant Organisms	X	X			

Footnotes:

1 Species Richness

2 Number of Intolerant Taxa

Table 6 lists the ANOVA results of the CSBP dataset. Table 7 shows the ANOVA results of both datasets and can be used to compare precision estimates between methods. Because the CSBP data set contained a much larger number of observations (N =300), we decided to standardize the number of observations and compare the results to see if observation size had any significant effect on differences in precision (Table 8). Furthermore, we standardized the number of replicates between the two datasets to see if replicate size had any effect on differences in precision (Table 9).

Table 6. ANOVA results of CSBP data (N = 300)*

Metric	MS Error	RMSE	MEAN	CV
TAXA RICHNESS	10.33	3.21	16.72	19.23
EPT Taxa	2.54	1.59	6.45	24.71
Ephemeroptera Taxa	0.53	0.72	2.97	24.44
Plecoptera Taxa	1.19	1.09	2.83	38.54
Trichoptera Taxa	1.01	1.00	2.82	35.65
Chironomid Taxa	0.46	0.68	2.46	27.47
%EPT	127.56	11.29	42.21	26.76
%Chironomidae	71.46	8.45	19.99	42.29
Hilsenhoff Biotic Index	0.63	0.79	5.77	13.70
% Tolerant Taxa	126.30	11.24	22.37	50.23
Intolerant Taxa	0.89	0.94	2.99	31.49
Dominance	138.83	11.78	43.45	27.12

* For plecoptera taxa metric, N = 168

Table 7. Comparison of ANOVA results between CSBP and SNARL methods.

Metric	CSBP			SNARL			% Difference
	RMSE	MEAN	CV	RMSE	MEAN	CV	
Richness	3.21	16.72	19.23	3.76	27.09	13.9	5.4
EPT Taxa	1.59	6.45	24.71	1.85	11.1	16.67	8.04
Ephemeroptera Taxa	0.72	2.97	24.44	1.03	6.77	15.26	9.18
Plecoptera Taxa	1.09	2.83	38.54	1.26	4.33	28.99	9.55
Trichoptera Taxa	1	2.82	35.65	1.16	5.73	20.22	15.43
Chironomid Taxa	0.68	2.46	27.47	2.45	11.22	21.8	5.67
%EPT	11.29	42.21	26.76	9.5	63.32	15	11.76
%Chironomidae	8.45	19.99	42.29	6.99	31.15	22.44	19.85
Hilsenhoff Biotic Index	0.79	5.77	13.7	0.36	4.26	8.46	5.24
% Tolerant Taxa	11.24	22.37	50.23	5.4	11.32	47.7	2.53
Intolerant Taxa	0.94	2.99	31.49	2.16	14.41	14.98	16.51
Dominance	11.78	43.45	27.12	7.78	36.16	21.52	5.6

Table 8. Comparison of precision estimates between CSBP and SNARL methods where population size is consistent (N = 18)

	CSBP				SNARL			
Metric	MS Error	RMSE	Mean	CV	MS Error	RMSE	Mean	CV
EPT Taxa	1.63	1.28	5.87	21.75	4.61	2.15	16.83	12.75
Ephemeroptera Taxa	0.31	0.56	2.65	21.19	1.07	1.03	6.77	15.26
Plecoptera Taxa	0.63	0.79	0.91	87.45	1.58	1.26	4.33	28.99
Trichoptera Taxa	0.67	0.82	2.04	40.08	1.34	1.16	5.73	20.22
Chironomidae Taxa	0.43	0.65	2.20	29.62	5.98	2.45	11.22	21.80
%EPT	102.42	10.12	47.88	21.14	0.90	9.50	63.32	15.00
%Chironomidae	76.66	8.76	20.10	43.55	0.60	7.74	20.27	22.44
Hilsenhoff Biotic Index	0.43	0.65	4.74	13.74	0.19	0.44	3.58	12.31

Table 9. Comparison of precision estimates between CSBP and SNARL methods where replicate size is consistent (replicates = 3).

	CSBP				SNARL			
Metric	MS Error	RMSE	Mean	CV	MS Error	RMSE	Mean	CV
EPT Taxa	2.54	1.59	6.45	24.71	3.14	1.77	10.66	16.60
Ephemeroptera Taxa	0.53	0.72	2.97	24.44	0.81	0.90	6.70	13.47
Plecoptera Taxa	1.19	1.09	2.83	38.54	1.11	1.05	4.28	24.64
Trichoptera Taxa	1.01	1.00	2.82	35.65	1.24	1.11	5.69	19.59
Chironomidae Taxa	0.46	0.68	2.46	27.47	4.67	2.16	11.00	19.64
%EPT	127.56	11.29	42.21	26.76	0.49	7.03	64.10	10.97
%Chironomidae	71.46	8.45	19.99	42.29	0.53	7.31	32.36	22.58
Hilsenhoff Biotic Index	0.63	0.79	5.77	13.70	0.17	0.41	4.31	9.45

Case Example Defining Method Performance Characteristics

While developing a statewide network for biomonitoring and bioassessment using macroinvertebrate data, Florida Department of Environmental Protection (DEP) rigorously examined performance characteristics of their collection and assessment methods in order to provide better overall quality assurance of their biomonitoring program and to provide defensible and appropriate assessments of the state's surface waters (Barbour et al. 1996b, c). This case example was summarized from Chapter 4 - Performance-Based Methods System in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour et al. 1999).

Characterizing Sampling Error (Method Precision on a Population of Reference Sites): A total of 56 reference sites were sampled in the Peninsula bioregion. The Florida Stream Condition Index (SCI) score could range from a minimum of 7 to a theoretical maximum of 31 based on the component metric scores. However, in the Peninsula, reference site SCI scores generally ranged between 21 and 31. A mean SCI score of 27.6 was observed with a CV of 12.0%.

Determining Method and Index Sensitivity: Distribution of SCI scores of the 56 reference sites showed that the 5th percentile was a score of 20. Thus, 95% of Peninsula reference sites had a score >20. Accuracy of the method, using known stressed sites, indicated that approximately 80% of the test sites had SCI scores ≤ 20. In other words, a stressed site would be assessed as impaired 80% of the time using the collection method in the Peninsula bioregion in the summer, and an impairment criterion of the 5th percentile of reference sites.

Determination of Method Bias and Relative Sensitivity in Different Site Classes: A comparative analysis of precision, sensitivity, and ultimately bias, was performed for the Florida DEP method and the SCI index. The mean SCI score in the Panhandle bioregion, during the same summer index period, was 26.3 with a CV = 12.8% based on 16 reference sites. Comparing this CV to the one reported for the Peninsula above, it is apparent that the precision of this method in the Panhandle was similar to that observed in the Peninsula bioregion. On the other hand, the 5th percentile of the Panhandle reference sites was an SCI score of 17, such that actual sensitivity of the method in the Panhandle was slightly lower than in the Peninsula bioregion. An impaired site would be assessed as such only 50% of the time in the Panhandle bioregion during the summer as opposed to 80% of the time in the Peninsula bioregion during the same index period.

Bioassessment In Low Gradient Streams

State Water Resources Control Board Agreement No. 03-196-250-0

Quality Assurance Project Plan

Southern California Coastal Water Research Project
7171 Fenwick Lane
Westminster, CA 92683

August 2005

Quality Assurance Project Plan

Southern California Coastal Water Research Project

PROJECT: Bioassessment in low gradient streams
State Water Resources Control Board Agreement No. 03-196-250-0

PREPARED BY: Southern California Coastal Water Research Project
7171 Fenwick Lane
Westminster, CA 92683

1. APPROVED BY:

Grant Organization

Ken Schiff, Project Director Southern California Coastal Water Research Project	Date
James Harrington, QA Officer California Department of Fish and Game	Date
Joe Sluzark, Laboratory Analysis Chico Research Foundation	Date

Funding Organization (SWRCB)

Erick Burres, Contract Manager State Water Resources Control Board	Date
First Last, QA Officer State Water Resources Control Board	Date

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3. DISTRIBUTION LIST

The final QAPP will be kept on file at SCCWRP. The following individuals will receive copies of the approved QAPP and any subsequent revisions:

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4. PROJECT/TASK ORGANIZATION

4.1 Involved Parties and Roles.

Southern California Coastal Water Research Project (SCCWRP) is a joint powers agency that was formed by several government agencies with a common mission to gather the necessary scientific information to effectively, and cost-efficiently, protect the Southern California aquatic environment. As the lead agency in this project, SCCWRP will organize the sample collection, analysis of samples and data, the maintenance of contracts with Chico Research Foundation (Chico), and all report preparation.

The Chico Research Foundation is the premier agency in the State for bioassessments laboratory analysis including ambient monitoring and assessments, field and laboratory training and support, enforcement actions, spill response, information management, biocriteria development and research.

Ken Schiff will be the SCCWRP Project Director for this study and will establish a project team for planning and conducting the study (Table 1, Figure 1).

The Chico Research Foundation laboratory located in Chico will perform the biological analyses of the bioassessment samples. Joe Sluzark will oversee these analyses.

4.2 Quality Assurance Officer Role

Jim Harrington will be the Quality Assurance Officer. Jim's role is to establish the quality assurance and quality control procedures found in this QAPP as part of the sampling and analysis procedures. Jim will work with field and laboratory managers by communicating all quality assurance and quality control issues contained in this QAPP.

Jim will also review and assess all procedures during the life of the contract against QAPP requirements. Jim will report all findings to Ken Schiff, including all requests for corrective action. Jim may stop all actions, including those conducted by SCCWRP or Chico if there are significant deviations from required practices or if there is evidence of a systematic failure.

4.3 Persons Responsible for QAPP Update and Maintenance.

Changes and updates to this QAPP may be made after a review of the evidence for change by the Project Director and Quality Assurance Officer, and with the concurrence of the both SWRCB's Contract Manager and Quality Assurance Officer. The Project Director will be responsible for making the changes, submitting drafts for review, preparing a final copy, and submitting the final for signature.

Table 1. (Element 4) Personnel responsibilities.

Name	Organizational Affiliation	Title	Contact Information (Telephone number, fax number, email address)
Ken Schiff	SCCWRP	Project Director	Tel: (714) 372-9202 Fax: (714) 894-9699 kens@sccwrp.org
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First Last	SWRCB	Contract QA officer	Tel: Fax: email

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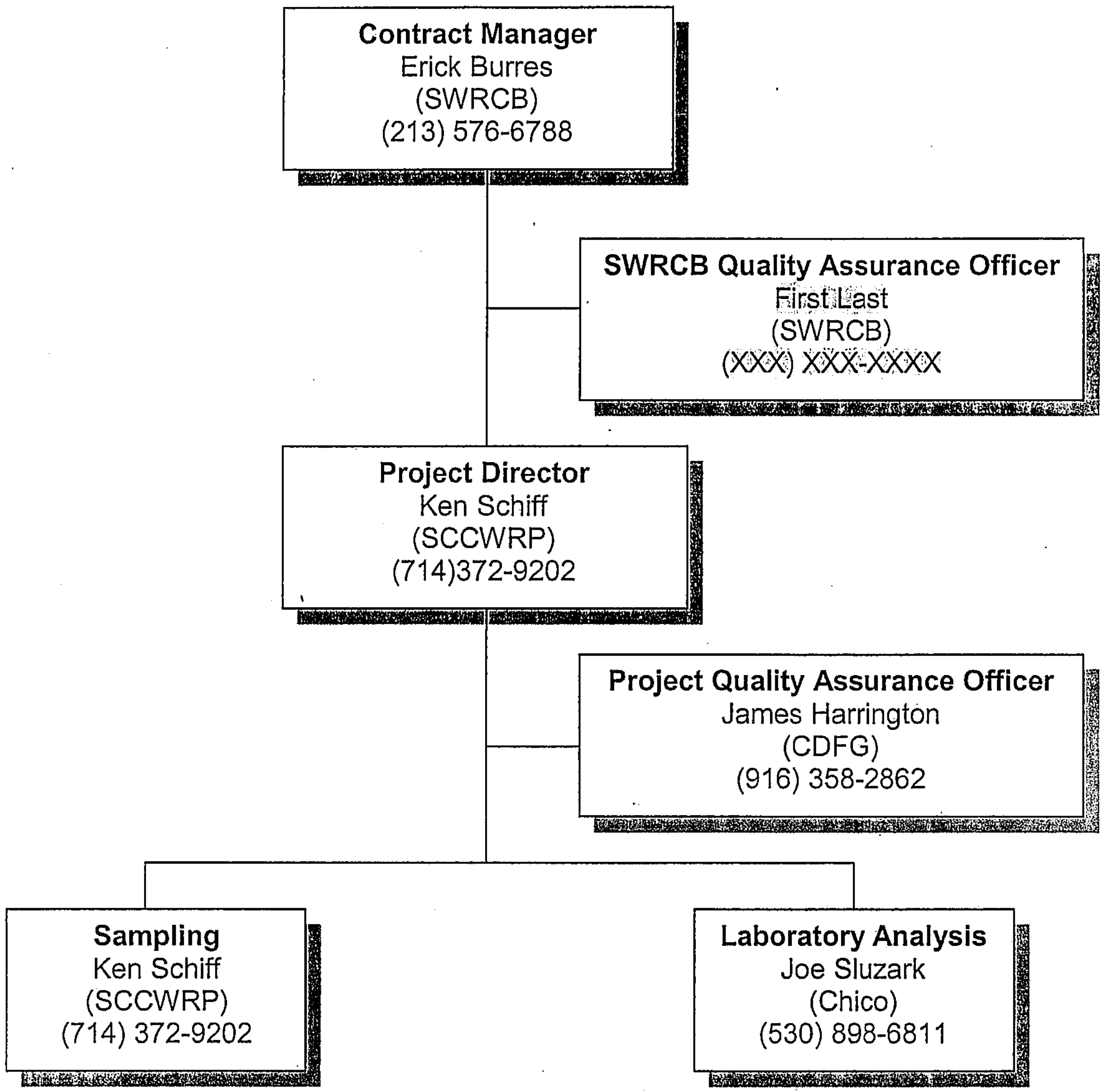
4.4 Organizational Chart and Responsibilities

Figure 1. Organization chart



5. PROBLEM DEFINITION / BACKGROUND

5.1 Problem Statement

Bioassessments that focus on benthic macroinvertebrates in freshwater streams are a powerful tool for evaluating health of a waterbody. The State of California, recognizing the value for such a monitoring tool, has been developing and testing bioassessment protocols over the last 10 years. As a result, more than 211,500 stream miles are currently monitored annually within California. Historically, the State has recommended the California Stream Bioassessment Protocol (CSBP). This method has been successfully applied in both high and low gradient streams.

The State has been so successful in growing its bioassessment monitoring program that two important evolutions have occurred. First is the development of regional indices of biological integrity (IBIs) for both the southern and northern California coastal regions. The second is the desire to produce a statewide condition assessment of wadeable streams and compare the results with other assessments being conducted around the country. Unfortunately, federally funded monitoring programs across the west and the rest of the nation, including the US Forest Service and US EPA, do not use the CSBP.

In order to maintain consistency with federally funded monitoring programs, the State is recommending the adoption of the targeted riffle composite method (TRC) in high gradient streams. The TRC is the method used by the US Forest Service, and in addition to a multihabitat (MH) sample, was collected by the EPA in the EMAP western pilot as part of a methods comparison,. The TRC methodological approach is similar to the CSPB and coincident sampling has demonstrated that the resulting data are similar as well.

Less effort has been directed at comparison of sampling methods in low gradient streams. The state is considering adoption of the EPA's MH sampling method for low gradient streams, but no thorough side-by-side comparison of the MH and CSBP methods has been conducted. Moreover, the methodological approaches between the MH and CSBP are less similar than the two targeted riffle methods used in high gradient streams. For example, the CSBP enables flexibility to target the richest habitat such as the margins in low gradient streams. In contrast, the MH specifically avoids flexibility to ensure consistency and, as a result, may miss the richest habitat in low gradient streams. Our lack of knowledge regarding comparability between the MH and CSBP precludes a decision about which method provides the most effective monitoring strategy in low gradient streams. Low gradient streams comprise a significant portion of the state's stream reaches, and since they typically occur in lower portions of watersheds, are often subjected to a number of stressors including inputs from urban and agricultural land uses.

5.2 Decisions or Outcomes

The objective of this study is to compare the MH and CSBP in low gradient streams in southern coastal California. The goal is to use both methods side-by-side in low gradient streams, then examine within reach variability in southern California IBI scores. Using this approach, we intend to assess if significant differences occur that would impact the transition from CSBP to MH methodology in low gradient streams.

5.3 Water Quality Regulatory Criteria

No numerical water quality criteria exist for bioassessments.

6. PROJECT/TASK DESCRIPTION

6.1 Work Statement and Produced Products

An analysis of variance design will be used for estimating potential differences in sampling methodologies. Within-site variance in IBI scores due to sampling error will be estimated for both the MH and CSBP protocols by taking triplicate samples of each at 15 reaches. These variance estimates will be used to determine method precision (see below). The nested, side-by-side sampling design will also allow detection of any differences in characterization of benthic assemblages due to sampling protocol.

For the MH protocol, 1 ft^2 of substrate will be sampled at each of 11 evenly spaced transects per 150m reach. Sampling position at each transect will alternate between 25%, 50 % and 75% of stream width. A total of 11 ft^2 per replicate will be composited into a single sample for laboratory analysis. This will result in a cumulative 33 total transects for the three replicates. For the CSBP protocol, each replicate will be comprised of three randomly selected transects from which 3 ft^2 will be cleared including 1 ft^2 at the right margin, 1 ft^2 at the thalweg, and 1 ft^2 at the left margin. A total of 9 ft^2 per replicate will be composited into a single sample for laboratory analysis. 500 organisms will be sub-sampled from each composite and identified to CSBP "Level I" Standard Taxonomic Effort

Reach selection will focus on identifying low gradient streams that encompass a range of potential impacts. In order to understand how each method will respond under the variety of stressors that are encountered in low-gradient streams, it is important to collect the side-by-side data from sites that represent both reference and altered conditions. In this way we can critically quantify method comparability and determine if assessment endpoints will vary due to method-specific sampling bias. Many of these sites may already be part of an ongoing monitoring program, but we will likely need to select additional sites to satisfy our need for a range of environmental stressors.

6.2 Constituents to be Monitored and Measurement Techniques

Bioassessments will measure benthic invertebrate communities. We will use existing SWAMP defined methodologies as defined in the SWAMP QAPP (2002).

Table 2. (Element 6) Analytical constituents and method requirements.

Analyte	Method
Biological communities	SWAMP QAPP, Appdx G- SOP for biological assessment

6.3 Project Schedule

Table 3. (Element 6) Project schedule.

Activity	Anticipated date of completion	Deliverable	Deliverable due date
QAPP Production	8/31/05	QAPP	8/31/05
Sampling & Analysis	12/31/05	Sample event summary	12/31/05
Draft Report	4/31/06	Draft Report	4/31/06
Final Report	5/30/06	Final report	5/30/06

6.4 Geographic Setting

This study extends throughout coastal southern California watersheds from Ventura to San Diego counties. This includes the Santa Clara River, Conejo Creek and Las Vrigenes Creek (Malibu Creek), Los Angeles River, Rio Hondo River, Santa Ana River, Aqua Hedionda Creek, San Juan Creek, Santa Margarita River, and San Luis Rey River watersheds (Figure 2).

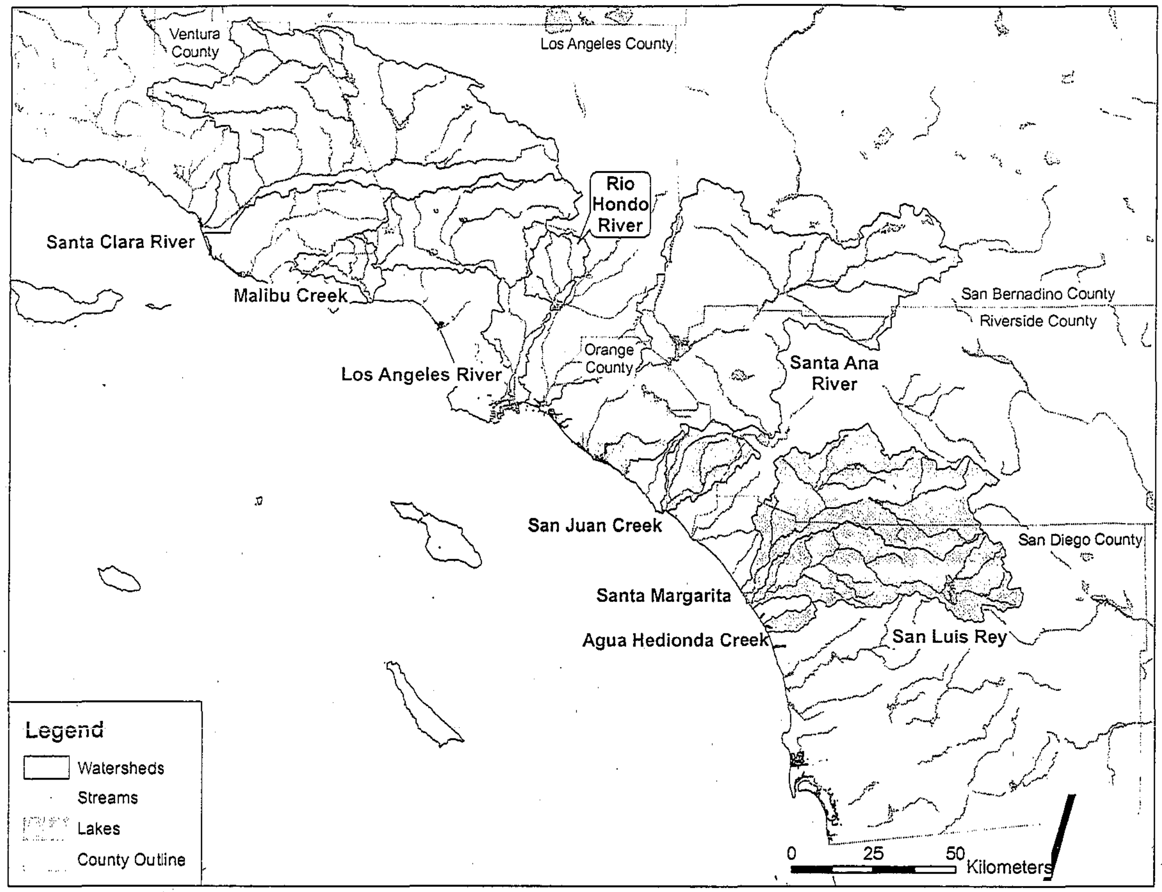


Figure 2. Study watersheds.

6.5 Constraints

The main constraint for this study is to sample only low gradient sites that exhibit a range of human impact. To resolve this issue, we will use a directed sample design whereby we focus on sites that have been sampled by others and we have an expectation of habitat and community health.

7. QUALITY OBJECTIVES AND CRITERIA

Data Quality Objectives (DQOs) are quantitative and qualitative statements that specify the tolerable levels of potential errors in the data (U. S. EPA, 2000) and ensure that the data generated meet the standards for published data in the peer-reviewed literature. As defined in this plan, DQOs specify the quantity and quality of data required to support the study objectives. Each data quality category is described below. Numerical DQOs for the constituents being sampled are listed in Table 4.

The group philosophy was to use existing SWAMP QA standards. The data quality objectives included: 1) 90% completeness of field and lab activities; 2) lab re-sort frequency of 100% and accuracy of 95%; 3) DFG re-ID frequency of 10% and accuracy of 95%; 4) field duplicate frequency already exceeds SWAMP standards; and data review frequency of $\geq$ 50% with 90% accuracy-accuracies <90% will lead to 100% data audits. Additional QA measures include field audits of each agency currently scheduled for the week of Sept 12-16. A field training day for all participants is currently scheduled for Aug 25th in San Luis Obispo.

7.1 Precision

Precision describes how well repeated measurements agree. The precision objectives in this study apply to field duplicate samples (see Section 14). Precision for bioassessments is quantified using relative variance such as standard deviations (SD) and/or coefficients of variation (CV). The frequency of field duplicates shall be at least 10%. No specific criterion for precision is given in the SWAMP QAPP, but shall be quantified for evaluation (Table 4).

7.2 Accuracy

Accuracy describes how close the measurement is to its true value. The accuracy of bioassessments in this study applies to sample sorting and identification (See section 14). The frequency of sorting accuracy evaluation shall be 100%. The accuracy of sample sorting shall be equal to or greater than 95% (Table 4). The frequency of identification accuracy evaluation shall be 10%. The accuracy of sample identification shall be equal to or greater than 95% (Table 4).

7.3 Completeness

Completeness describes the success of sample collection and laboratory analysis, which should be sufficient to fulfill the statistical criteria of the project (Table 4). Completeness is measured as the fraction of samples sampled and/or analyzed relative to the quantity targeted in the study design (See Section 10). While no specific statistical criteria have been established for this study, it is expected that 90%

of all measurements could be taken when anticipated. This DQO accounts for adverse weather conditions, safety concerns, and equipment problems. A loss of 10% of the samples in this study would represent a minimal loss in statistical power to address the study objectives.

7.4 Targeted Reporting Level

The reporting level for bioassessments applies complexity of taxonomic resolution. In this study, we will use the standard taxonomic level established by the California Macroinvertebrate Laboratory Network (CAMLnet). This guidance recommends identification to genus or lowest level possible.

Table 4. (Element 7) Measurement quality objectives.

Analyte	Accuracy	Precision	Target Reporting Level	Completeness
Biological Assessments	Re-sort Frequency: 100% Re-sort Accuracy: ≥ 95% Lab ID Frequency: 10% Lab ID Accuracy: ≥ 95%	Field Duplicates: 10%	CAMLnet Standardized Taxonomic Effort Manual (2001)	90%

8. SPECIAL TRAINING NEEDS/CERTIFICATION

8.1 Specialized Training or Certifications

Both sampling and laboratory analysis require specialized training. Field sampling training can be provided during short courses offered by the CDFG or similar agency. Laboratory analysis requires years of experience and mentoring by a qualified taxonomist. Field sampling during this study will be coordinated by personnel with several years experience. All samples will be analyzed by the CDFG laboratory, which has the most experienced laboratory in the State of California. Both SCCWRP and Chico are members of CAMLnet. No formal certifications are available for either field sampling or laboratory analysis.

8.2 Training and Certification Documentation

Both SCCWRP and the Chico maintain records of their training. Those records can be obtained, if needed, through the Project or Laboratory Directors.

8.3 Training Personnel

SCCWRP and CFF&G maintain rigorous field and laboratory training programs based on written, oral and performance-based guidelines. Training and performance are also evaluated on an ongoing basis based, in part, on the QA parameters defined in this plan. Standard Operating Procedures (SOPs) for field, laboratory, and data management tasks have been developed and will be updated on a regular basis in order to maintain procedural consistency (see Appendices). The maintenance of an SOP Manual will provide project personnel with a reference guide for training new personnel as well as a standardized information source that personnel can access.

To ensure consistent and comparable field techniques, this study will include a presurvey field training and in-situ field audits. The presurvey training will focus on sampling design and field logistics including compositing and netting patterns. In-situ audits will consist of equipment checks, good sampling practices, record-keeping, and health and safety.

9. DOCUMENTS AND RECORDS

All documents generated by this project will be stored at SCCWRP or Chico (Table 5). Sampling records will be stored and maintained at SCCWRP. Laboratory analysis records pertinent to this study will be maintained at the Chico laboratory. Copies of all records held by Chico or SCCWRP will be provided to the Project QA Officer or Project Director upon request.

Persons responsible for maintaining records for this project are as follows. Ken Schiff will maintain all sample collection, sample transport, chain of custody, field analyses forms, all records associated with the receipt and analysis of samples analyzed for all parameters, and all records submitted by Chico. Joe Sluzark will maintain Chico's records including sorting and laboratory bench sheets. Ken Schiff will oversee the actions of these persons and will arbitrate any issues relative to records retention and any decisions to discard records.

All field results will be recorded at the time of completion, using standardized field data sheets. Data sheets will be reviewed for outliers and omissions before leaving the sample site. Chain of custody forms will be completed for all samples before leaving each sampling site. Data sheets and chains of custody will be stored by SCCWRP in hard copy form for five years from the time the study is completed. The directory where electronic files are stored will be backed up nightly on a second hard drive, and backed up monthly off-site.

All data from this project will be made publicly available. Release of data will include comprehensive documentation. This documentation will include database table structures (including table relationships) and lookup tables used to populate specific fields in specific tables. Release to the public will also include quality assurance classifications of the data (i.e. flags, as appropriate) and documentation of the methods by which the data were collected (metadata). Data will be released to the general public once a final report documenting the study has been prepared. Final deposition of databases and reports will be passed to the Contract Manger on CD.

Table 5. (Element 9) Document and record retention, archival, and disposition information.

	Identify Type Needed	Retention	Archival	Disposition
Station Occupation Log	Notebook	Paper	Notebook	5 years
	Field data sheet	Paper	Notebook	5 years
Sample Collection Records	Chain of Custody	Paper	Notebook	5 years
Analytical Records	Lab notebooks	Paper	Notebook	3 years

	Lab Results QA/QC	Paper and electronic	Notebook/Excel	3 years
	Electronic data file	Electronic	Database	3 years
Data Records	Data Entry	Electronic	Database	Indefinite
Assessment Records	QA/QC assessment	Paper and electronic	Document	Indefinite
	Final Report	Paper and electronic	Document	Indefinite

GROUP B DATA GENERATION AND ACQUISITION

10. SAMPLING PROCESS DESIGN

A total of 15 sites allocated using a deterministic design will be selected throughout the Southern California coastal watersheds (Table 6). Each site will be sampled during a single visit during the index period of September 1 to October 31, 2005, or until the first significant rainfall, whichever comes first.

Table 6. (Element 10). Number and frequency of sample sites.

Watershed	SiteID	Level of Disturbance (1 to 5, 5 worst)	Soft or Cement?	Flowing or Impound?	Access and permission	Notes
Rio Hondo	RD	4	S	F	Y	
Santa Clara	RB	3	S	F	Y	
Santa Clara	RC	3	S	F	Y	
Santa Clara	RD	3	S	F	Y	
Santa Clara	NR1	4	S	F	Y	Located 300 ft. upstream of the Los Angeles/Ventura County Line
Santa Clara	NR3	4	S	F	Y	2.74 mi. downstream of the Los Angeles/Ventura County Line
Santa Clara	@ Piru Ck	4	S	F	Y	
Santa Margarita	SMR-CP	2	S	F	Y	On Camp Pendleton, near hospital
Santa Margarita	SMD-DS	2	S	F	Y	On Camp Pendleton, along Admiral Way
San Luis Rey	SLRR-MR	3.5	S	F	Y	At Mission Road bridge
Aqua Hedionda	AHS-ECR	4.5	S	F	Y	At El Camino Real
San Juan Ck		1 to 5	S	F	Y	One of the less impacted sites
La River	@Victory	5	S	F	Y	
Santa Ana Rvr	SNA	3	S	F	waiting	
Conejo Creek	R1	4.5	S	F	Y	on the Oxnard plain with heavy agriculture and a lot of erosion
Las Virgenes Creek	LV2	3	S	F	waiting	relatively natural except for human recreational activity

11. SAMPLING METHODS

Sampling requires the manual collection of composite benthic samples using a D-shaped kick net at each of the monitoring locations. The complete sampling SOP, as defined in the SWAMP QAPP, appears in Appendix A.

Sample containers and preservatives are identified in Table 7. Appropriate pre-cleaned sample containers will be used.

The sampling coordinator has responsibility for assessing the safety of sampling teams. A two-person team will conduct all sampling, and the sampling team will have access to a cellular phone in order to alert rescue agencies should an accident occur. Sampling will be postponed if the sampling team determines that the conditions are unsafe.

Failure to collect a sample due to safety concerns or technical issues will be promptly reported to the Project Director, who will determine if any corrective action is needed and make arrangements to collect a replacement sample (if possible). The Quality Assurance Officer will document sampling failures and the effectiveness of corrective actions.

Table 7. (Element 11) Sample handling.

Analyte	Bottle Type/Size	Preservative	Maximum Holding Time
Bioassessment	0.5 L Plastic wide mouth with screw top lids	95% Ethanol	5 years

12. SAMPLE HANDLING AND CUSTODY

Samples will be kept in 95% ethanol and will be transferred to the analytical laboratories within the holding times specified in Table 7. To provide for proper tracking and handling of the samples, documentation will accompany the samples from the initial collection to the final identification and analysis.

All bottles will be labeled according to the SOP in Appendix A. Field data sheets and chains of custody will accompany the collection of samples. An example of the Chain-of-Custody form is also shown in Appendix A.

All samples will be marked with a unique number to track their analysis. These identification labels will also be entered directly on to field and laboratory data sheets. All observations recorded in the field as well as information recorded in processing all field samples in the laboratory will be tracked using these identification labels.

The SOP details the procedures for submitting samples to the Chico laboratory. These procedures reinforce the use of proper sample containers, chain of custody procedures, and unique station codes and sampling agency identifiers.

13. ANALYTICAL METHODS

13.1 Analysis Methods

The samples will be analyzed for biological identification according to the SWAMP standardized methods (SWAMP 2002). Specific details regarding analysis are provided in Appendix A. These details include subsampling, sorting, and identification.

Table 8. (Element 13). Analytical methods. NA = not applicable.

Analyte	**Method**	**Modifications to Method**	**Method Detection Limit**
Biological identification and enumeration	SWAMP QAPP (2002)	none	N/A

13.2 Sample Disposal

After analysis, including QA/QC procedures, sample disposal will follow laboratory protocols (SWAMP 2002). The retention of samples shall include unsorted sample, sorted remnants, identified sample partitioned into taxa groups, and a reference collection.

13.3 Corrective Action

Corrective action is taken when an analysis is deemed suspect for some reason. These reasons include exceeding accuracy ranges and/or problems with sorting and identification. The corrective action will vary on a case-by-case basis, but at a minimum involves the following:

- A check of procedures.
- A review of documents and calculations to identify possible errors.
- Correction of errors based on discussions among taxonomists.
- A complete re-identification of the sample.

The field and laboratory coordinators each have systems in place to document problems and make corrective actions. All corrective actions will be documented to the Project Manager.

14. QUALITY CONTROL

Samples for QA/QC will be collected both in the field and in the lab. Field QA/QC samples are used to evaluate precision due to sampling bias or field variability. Field QA/QC samples include field duplicates. Lab QA/QC samples are used to evaluate the analytical process for precision and accuracy. Internal laboratory quality control checks will include sample re-sorts and re-identification (See Section 7). These QA/QC activities are discussed below.

14.1 Field Duplicates

Field duplicates help quantify potential bias associated with sampling activities. Field duplicates are comprised of a replicate sample taken at the same site. There are no specific criteria for field duplicate precision, but these data are evaluated in the data analysis/assessment process.

14.2 Sample Re-sorting

Sample re-sorting is used to quantify the sorting accuracy of the laboratory. Once samples are sorted, a second technician will re-sort the sample remnants to ensure that all organisms have been removed. The acceptable accuracy limits are shown in Table 4. Percent sorting accuracy is calculated as:

Percent Sorting Accuracy = ((number of organisms in re-sort *100)/ number of organisms in original sort)

14.3 Sample identification

Sample re-identification is used to quantify the identification and enumeration accuracy of the laboratory. Once samples are identified, a second technician will re-identify the sample to ensure that all organisms have been accurately identified and enumerated. The acceptable accuracy limits are shown in Table 4. Percent identification accuracy is calculated as:

Percent Identification Accuracy = ((number of organisms in re-ID *100)/ number of organisms in original ID)

Typically, the number of organisms identified is approximately 500.

15. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

15.1 Sampling Equipment

SWAMP has established standard operating procedures for each piece of field equipment (Table 9). See Appendix A for a complete listing of equipment and maintenance schedule.

Table 9. (Element 15). Testing, inspection and maintenance of sampling equipment and analytical instruments.

Equipment Item	Inspection Schedule
D-shaped Kick Net (0.5mm mesh)	Each sampling event
Standard Size 35 Sieve (0.5 mm)	Each sampling event
Wide-mouth Plastic Jars	Each sampling event
Measuring Tape (100 meter)	Each sampling event
Pencils/Permanent Markers	Each sampling event
Flagging	Each sampling event
Forceps	Each sampling event
Water-proof Paper	Each sampling event
Gridded White Enameled Pan	Each sampling event
YSI 85	Each sampling event
pH Meter	Each sampling event
Thermometer	Each sampling event
Flow Meter	Each sampling event
GPS Unit	Each sampling event
Digital Camera	Each sampling event
Stadia Rod	Each sampling event

15.2 Analytical Instruments

The Chico lab maintains its equipment in accordance with its SOPs, which include those specified by the manufacturer and those specified by the method.

16. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

All laboratory equipment is calibrated based on manufacturer recommendations and accepted laboratory protocol. The Chico laboratory maintains calibration practices as part of the method SOPs.

17. INSPECTION/ACCEPTANCE FOR SUPPLIES AND CONSUMABLES

Glassware, sample bottles, and collection equipment will all be inspected prior to their use for chips, cracks, leaks, contamination, and other deformities that can affect the outcome of the study results. Sampling bottles will be purchased from VWR (vwr.com, 800-932-2500). Supplies will be examined for damage as they are received.

18. NON-DIRECT MEASUREMENTS

Previous studies that have performed bioassessment measurements in the study areas will be referred to in the study report, but this study will not incorporate existing data or other non-direct measurements.

19. DATA MANAGEMENT

The management of bioassessment data will be initiated with the use of field and laboratory data sheets. Analysis results will be electronically sent to the Project Director following the completion of quality control checks by each of the laboratories. Data will be screened for the following major items:

- A 100 percent check between electronic data provided by the laboratory and the hard copy reports
- Conformity check between the Chain-of-Custody Forms and laboratory reports
- A check for laboratory data report completeness
- A check for typographical errors on the laboratory reports
- A check for suspect values

The laboratory will provide data in electronic format. The required form of electronic submittals will be provided to the laboratories to ensure the files can be imported into the project database with a minimum of editing. The data will be managed in SCCWRP's project database, which has a relational structure and is compatible for incorporation into the SWAMP database.

Following the initial screening, a more complete QA/QC review process will be performed, which will include an evaluation of analytical accuracy and precision. Accuracy will be evaluated by reviewing re-sort and re-identification; precision will be evaluated by reviewing field duplicates, and sample completeness will be evaluated by comparing results to chain-of-custody forms.

GROUP C ASSESSMENT AND OVERSIGHT

20. ASSESSMENTS AND RESPONSE ACTIONS

The Project Director will be responsible for the day-to-day oversight of the project. The Project QA Officer will conduct periodic reviews of the data and relay any problems to the Project Director. The QA Officer has the power to halt all sampling and analytical work by the Chico lab or SCCWRP if the deviation(s) noted are considered detrimental to data quality.

21. REPORTS TO MANAGEMENT

The status of data collection during this project will be reported by the Project Director to the Contract Manager on a quarterly basis beginning April 15, 2005 and continuing until the completion of the project in June 2006. A draft final project report will be filed no later than April 30, 2006. The Project QA Officer has complete access to the Project Director on an ongoing basis. Any QA deviations will be detailed in the sample event summary report and draft/final report.

Table 10. (Element 21) QA management report

Report	**Due by**
Quarterly progress reports	April 15, 2005 and quarterly thereafter
Sample event summary	December 31, 2005
Draft final report for review	April 30, 2006
Final Report	May 31, 2006

GROUP D DATA VALIDATION AND USABLILITY

22. DATA REVIEW, VERIFICATION, AND VALIDATION

Laboratory validation and verification of the data generated is the responsibility of the laboratory. The laboratory manager will maintain analytical reports in a database format as well as all QA/QC documentation for the laboratory.

SCCWRP will review all data packages received for adherence to guidelines set forth in this QAPP. COC forms will be reviewed to ensure adherence to collection, transport, and receipt requirements, including test initiation within the required holding time. Toxicity data will be evaluated for completeness, adherence to test methodology, passing acceptability criteria, choice of appropriate statistical methods, and proper reporting.

Laboratories will conduct a 50 percent raw data versus electronic data audit before delivering results to SCCWRP. If their error rate is greater than 5%, a 100% raw data audit will be triggered.

23. VERIFICATION AND VALIDATION METHODS

Data collected in the field will be validated and verified by the field coordinator. The laboratory maintains chain of custody and sample manifests.

Laboratory validation and verification of the data generated is the responsibility of the laboratory. The laboratory supervisor will maintain analytical reports in a database format as well as all QA/QC documentation for the laboratory.

Ken Schiff is responsible for oversight of data collection and the initial analysis of the raw data obtained from the field and the laboratory. His responsibilities also include the generation of rough drafts of quarterly and final reports. Ken has final oversight on the submission of quarterly and final reports.

24. RECONCILIATION WITH USER REQUIREMENTS

For data that do not meet DQOs, management has two options:

1. Retain the data for analytical purposes, but flag these data for QA deviations.
2. Do not retain the data and exclude them from all calculations and interpretations.

The choice of option is the decision of the Project Director. If qualified data are to be used, then it must be made clear in the final report that these deviations do not alter the conclusions of the study.

Appendix A.

Quality Assurance and Standard Operating Procedure for Bioassessments in the State of California's Surface Water Ambient Monitoring Program (SWAMP)

CALIFORNIA DEPARTMENT OF FISH AND GAME
WATER POLLUTION CONTROL LABORATORY
AQUATIC BIOASSESSMENT LABORATORY
REVISION DATE – January 15, 2002.

QUALITY ASSURANCE PROJECT PLAN FOR THE CALIFORNIA STREAM BIOASSESSMENT PROCEDURE (CSBP)

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PROJECT/TASK ORGANIZATION

Program Manager:
Jim Harrington

Project Manager, Data Analysis/Reporting:
Peter Ode

Taxonomists:
Dan Pickard
Doug Post
Andrew Rehn
Brady Richards
Joe Slusark

Enforcement Cases:
Angie Montalvo

Field Sampling/Site Reconnaissance:
Mike Dawson
Shawn McBride
Jennifer Lenz
Jennifer Lane

Sample Processing:
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PROBLEM DEFINITION AND BACKGROUND

California's streams and lakes provide essential habitat for freshwater plants and animals and provide important recreation opportunities. Identifying unique aquatic habitats, recognizing endemic species of plants and animals and assessing whether our streams and lakes are healthy or impaired is an important part of water resource management. However, California water resource agencies currently do not provide sufficient data to document the physical and biological condition of the state's water bodies.

Bioassessment, a tool for measuring stream water and habitat quality based on the kinds of organisms living there, has recently been implemented in California with the goal of incorporating biological criteria into water quality standards. Such criteria can be used to protect biological resources, report on the condition of water bodies, identify impaired water bodies and set restoration goals for impaired sites. In fact, the Clean Water Act mandates that "States shall adopt [water quality] criteria based on biological monitoring or assessment methods" (Section 303(c)(2)(B)), and that "States shall develop and publish criteria for water quality accurately reflecting the latest scientific knowledge... on the effects of pollutants on biological community diversity, productivity and stability" (Section 304 (a)(1)).

Only in recent years, with encouragement from the EPA, have states started to collect adequate data on the physical and biological health of their water bodies. In 1993 California initiated the first step in developing a state-wide bioassessment program by introducing the California Stream Bioassessment Procedure (CSBP). The CSBP is a standardized protocol for assessing biological and physical/habitat conditions of wadeable streams in California, and is a regional adaptation of the national Rapid Bioassessment Protocols outlined by the U.S. Environmental Protection Agency (EPA 841-D-97-002). The CSBP is a cost-effective tool that utilizes measures of a stream's benthic macroinvertebrate (BMI) community and its physical/habitat characteristics to determine the stream's biological and physical integrity. BMIs can have a diverse community structure with individual species residing within the stream for a period of months to several years. They are also sensitive in varying degrees to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution. Biological and physical assessment measures integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality and can provide the public with a familiar expression of ecological health. Now in its third edition, the CSBP is recognized as California's standard protocol for conducting physical and biological surveys, and forms the basis of California's effort to develop a state-wide bioassessment program (Davis et al. 1996).

Bioassessment studies can normally be divided into two types: ambient monitoring and point source monitoring. Ambient monitoring consists of regular sampling within watersheds to establish baseline (i.e., current) conditions so that future changes can be evaluated for compliance with legally mandated water quality standards. Point-source monitoring involves surveys done before and after (or upstream and downstream) of a specific impact to determine the effects of that impact on aquatic communities.

In either case, our ability to recognize degradation at potentially damaged sites relies on our understanding of conditions expected in the absence of disturbance. In point-source monitoring, biological conditions observed upstream of an impact can be used as a reliable indicator in defining community recovery downstream. In ambient monitoring, expected conditions must usually be inferred from "reference sites". In some studies, it is possible to select sites that have experienced minimal human impact and thus reflect pristine conditions. In areas where human alteration of the landscape is significant, reference sites are likely to be "least impaired sites", and thus reflect the best conditions possible given the extent and duration of human activity (Hawkins et al., 2000).

The DFG-ABL has collected bioassessment data for thousands of stream study sites in California since 1993. The objectives of the bioassessment program outlined herein are as follows:

1) Establish appropriate biocriteria (e.g., Indexes of Biological Integrity, [IBI's]) on a regional basis by defining reference stream conditions for different stream types in each of California's ecoregions. Regional reference conditions are essential for assessing the status of streams that may have degraded ecological integrity, and are also essential in monitoring the success of restoration efforts.
2) Provide field and analytical support for California's Regional Water Quality Control Boards as they incorporate ambient biological monitoring into water quality management. In addition to establishing regional IBI's, this includes developing lists of BMI's known from various regions, determining the best index periods for sampling BMI's and identifying highly impacted streams so that restoration efforts can be prioritized. Examples include ongoing projects for the San Diego and Bay Area Regional Water Quality Control Boards.
3) Evaluate the biological integrity of streams exposed to various point-source impacts (enforcement cases). Site-specific baseline data are used to monitor the success of management actions taken.
4) Offer technical support for other agencies conducting bioasessment in California by establishing standardized field and laboratory protocols, taxonomic expertise and Quality Assurance/Quality Control services.
5) Comparison of various bioassessment sampling protocols (e.g., CSBP, RIVPACS, EMAP).

PROJECT/TASK DESCRIPTION

DATA QUALITY OBJECTIVES

Data collected will allow assessment of the integrity of BMI communities throughout California, and will thereby facilitate the development of water quality criteria and the evaluation of impaired water bodies in the context of those criteria. Data from reference sites, or minimally impaired sites in highly impacted areas, is essential in the development of biocriteria. The total number of sites sampled, including the number of minimally impacted sites required to establish reference conditions and the number of impacted sites that will require future monitoring to assess compliance with legally mandated water quality objectives, will vary depending on the scope and goals of individual projects.

The CSBP targets BMI communities that occur in riffle habitats within streams. Riffles are the most productive microhabitats within in a stream in terms of taxonomic diversity, and sampling within a specific microhabitat facilitates comparison of community composition between streams (such comparisons can be confounded by multi-habitat sampling approaches when study streams vary significantly in types of habitat available). In order to reduce the likelihood of inaccurate assessment of benthic communities due to sampling error and the "patchiness" that often characterizes the distribution of BMI's, the CSBP utilizes triplicate measures of BMI community composition by sampling three different riffles within a stream reach.

BMI communities should be sampled when streams are at base flow and before mass seasonal emergences have occurred (sampling index periods will vary with region). Furthermore, evaluation of BMI community composition relies on accurate taxonomic identifications and a standard level of identification (e.g., genus) that allows discrimination among sites. A guidance document outlining the desired level of taxonomic effort has been established by the California Aquatic Bioassessment Laboratory. Because accurate taxonomy is imperative in bioassessment, a minimum of 95% accuracy in taxonomic identifications is required. Taxonomic accuracy is evaluated according to the QC protocol outlined below.

Assessment of physical habitat quality is inherently more subjective than taxonomic identification. The QA procedure outlined below has been designed to maximize accuracy and consistency in physical habitat assessment. Error rates of approximately 25% are considered acceptable for physical habitat assessment, i.e., independent evaluations of physical habitat at a given site should rank the site in the same broad quality category, of which there are four (see the attached sheet that outlines physical habitat parameters assessed per site).

SPECIAL TRAINING REQUIREMENTS

All ABL staff members are trained in the use of the protocols outlined below. New field staff members are trained by experienced members or by project managers. Before each field season, all staff members are involved in training sessions to review protocols used in physical habitat, chemical and biological surveys. These training sessions involve practice sampling and habitat assessment.

Most of the taxonomists in the lab have graduate degrees (M.S. or Ph.D.) in Entomology or Ecology, and have many years of experience in invertebrate taxonomy and identification. Lab technicians receive training and direct oversight from taxonomists.

DOCUMENTATION AND RECORDS

All field data (physical habitat and water chemistry measurements) are entered on standardized forms that are completed at the time of sampling (see attached forms). Laboratory records (e.g., COC's and sample processing information) are also standardized (see attached forms) and are kept in clearly labeled files in the ABL lab. Lists of all identified taxa and the ABL Sample Inventory are stored by project in CAL EDAS, an ACCESS© data base that facilitates the archiving and retrieval of taxonomic information. Vouchers of all identified BMI's are kept for every project, and a reference collection of macroinvertebrates found in California has been established.

SAMPLING PROCESS DESIGN

Water quality assessment on a watershed basis requires at least one or two years of sampling effort by a water resource agency. This allows the establishment of baseline physical and biological information, and allows the development of a reference framework (IBI) to assess the present and long-term condition of water resources within the watershed. Our ability to accurately characterize the biological integrity of sites, and thereby quantify impairment when it exists, relies on the development of this framework.

Sample Site Selection: The primary goal in selecting sampling sites is to represent the major stream systems, ecoregion subsections, vegetation zones, stream orders and elevations within the watershed. Factors that may limit the number of study reaches include accessibility (physical and legal) and suitable riffle habitat. Land ownership throughout the watershed can limit site selection to areas where written permission is granted. Land owners bordering potential sampling sites can be identified through the local county assessors office, and contacts with property owners should utilize a standardized form. Sample site selection should include input form the Watershed Advisory Group and any public land agency located in the watershed.

Reach length depends on the frequency of riffle/run habitat units and uniformity of channel type. The objective in BMI sampling is to establish reaches that contain at least five riffle/run habitat units within the same channel type. If the reach length is limited by private land, at least three riffle/run habitat units should be delineated.

A Global positioning system (GPS) is used to determine the coordinates of the sites whenever possible. Manual mapping of the sites is also done using major landmarks, 7.5 minute USGS (1:24,000 scale) and USFS topographical maps. Latitude and longitude are determined to the nearest second.

Once sampling sites are determined the following generalized tasks are performed:

1) Summarize historic data and published information on watershed (non-critical)
2) Determine site ownership (non-critical)
3) Contact owners for access approval and education (non-critical)
4) Describe site location in detail including GPS (non-critical)
5) Photo-document study reaches (non-critical)
6) Define study reach through channel typing (critical)
7) Describe watershed characteristics (critical)
8) Measure habitat integrity using the CSBP (critical)
9) Measure biological integrity (critical)
10) Measure ambient water chemistry (critical)
 - temp, DO, conductivity, turbidity, pH
11) Determine land-use activities (non-critical)
12) Build GIS overlays of gathered information (non-critical)
13) Rank areas of watershed degradation (critical)

14) Test bioassessment metrics using land-use activities and ranking (critical)
15) Validate CSBP bioassessment metrics (critical)
- within reaches
- between reaches
- seasonality
16) Test available biotic indices (Moyle IBI, EPA, CSBP) (critical)
17) Develop framework for biotic index for watershed (critical)
18) Finalize data analysis and reduction (critical)
19) Make project description and data available on CABW homepage (non-critical)
20) Train and integrate watershed advisory group into a long-term monitoring program (critical)

SAMPLING METHODS REQUIREMENTS

Field Procedures For Collecting BMI Samples and Assessing Physical Habitat Quality

The CSBP can be used to detect aquatic impacts from point and non-point sources of pollution and for assessing ambient biological condition. The sampling unit is an individual riffle or riffles within a reach of stream depending on the type of sampling design used. Riffles are used for collecting biological samples because they are the richest habitat for BMIs in wadeable streams. The BMI sampling procedures described in this Protocol Brief are intended for sampling wadeable, running water streams with available riffle habitats. There are approved modifications of this procedure for narrow (< 1m) streams, wadeable streams with sand or mud bottoms and channelized streams. There are also procedures for lentic or still water environments. Contact DFG for copies of any of these protocols, or visit the California Aquatic Bioassessment Web Site for more information, at http://www.dfg.ca.gov/cabw/cabw/csbp.html

It is important that BMI's are collected when streams are at base flow, as high flows can dramatically alter local community composition and can thus produce unrepresentative results.

Field Equipment and Supplies
- Measuring tape
- D-shaped kick net (0.5mm mesh)
- Standard Size 35 sieve (0.5mm mesh)
- Wide-mouth 500 ml plastic jars
- White sorting pan and forceps
- 95% ethanol
- California Bioassessment Worksheet (CBW)
- Physical/ Habitat Quality form
- Flow meter
- Random number table
- pH, temperature, DO and conductivity meter
- Stadia rod and hand level/ clinometer
- Densiometer/ Solar Pathfinder
- GPS unit or watershed topographic map

Point Source Sampling Design
There will be discernable perturbations, impacting structures or discharges into the stream with point sources of pollution. The sampling units will be individual riffles within the affected section of stream and an upstream unaffected section. At least one riffle in the unaffected section should be sampled and one or more riffles in the affected section depending on the amount of detail that is required on downstream recovery. The riffles used for sampling BMIs should have relatively similar gradient, substrate and physical/habitat characteristics and quality.One sample will be collected from 3 randomly chosen transects in each riffle.

Use the following step-by-step procedures for collecting BMIs using the point source sampling design:

Step 1. Place the measuring tape along the bank of the entire riffle while being careful not to walk in the stream. Each meter or 3 foot mark represents a possible transect location. Select 3 transects from all possible meter marks along the measuring tape using a random number table. Walk to the lowest transect before proceeding to Step 2.

Step 2. Inspect the transect before collecting BMIs by imagining a line going from one bank to the other, perpendicular to the flow. Choose 3 locations along that line where you will place your net to collect BMIs. If the substrate is fairly similar and there is no structure along the transect, the 3 locations will be on the side margins and the center of the stream. If there is substrate and structure complexity along the transect, then as much as possible, select the 3 collections to reflect it.

Step 3. After mentally locating the 3 areas, collect BMIs by placing the D-shaped kick net on the substrate and disturbing a 1x2 foot portion of substrate upstream of the kick-net to approximately 4-6 inches in depth. Pick-up and scrub large rocks by hand under water in front of the net. Maintain a consistent sampling effort (approximately 1-3 minutes) at each site. Combine the 3 collections within the kick-net to make one composite sample.

Step 4. Place the contents of the kick-net in a standard size 35 sieve (0.5 mm mesh) or white enameled tray. Remove the larger twigs, leaves and rocks by hand after carefully inspecting for clinging organisms. If the pan is used, place the material through the sieve to remove the water before placing the material in the jar. Place the sampled material
and label (see below) in a jar and completely fill with 95% ethanol. Never fill a jar more than 2/3 full with sampled material and gently agitate jars that contain primarily mud or sand.

Bioassessment Sample Label
County:___________
Stream Name: ______________
Site Code/Locality: ________________
Date/ Time: __________________
Sample by: ___________________

Step 5. Proceeding upstream, repeat Steps 2 through 4 for the next two randomly chosen transects within the riffle.

Non-point Source Sampling Design
There will be no obvious perturbations or discharges into the stream with non-point sources of pollution. This sampling design is appropriate for assessing an entire stream or large section of stream. The sampling units will be riffles within a reach of stream. The stream reach must contain at least 5 riffles within the same stream order and relative gradient. One sample will be collected from the upstream third of 3 randomly chosen riffles.

Use the following step-by-step procedures for collecting BMIs using the non-point source sampling design:

Step 1. Randomly choose 3 of the 5 riffles within the stream reach using the random number table.

Step 2. Starting with the downstream riffle, place the measuring tape along the bank of the entire riffle while being careful not to walk in the stream. Select 1 transect from all possible meter marks along the top third of the riffle using a random number table.

Step 3. (See Point Source Sampling Design Step 2)

Step 4. (See Point Source Sampling Design Step 3)

Step 5. (See Point Source Sampling Design Step 4)

Step 6. Proceeding upstream, Repeat Steps 2 through 5 for the next two riffles within the stream reach.

Sampling Design for Assessing Ambient Biological Conditions

Assessment of ambient biological condition utilizes both the point and non-point source sampling designs to cover an entire watershed or larger regional area. Ambient bioassessment programs are used to evaluate the biological and physical integrity of targeted inland surface waters. Stream reaches should be established in the upper, middle and lower portions of each watershed and above and below areas of particular interest. Quite often bioassessment is incorporated into an existing chemical or toxicological sampling design. In most cases, the water quality information is being collected at a particular point on the stream. Although there will be the tendency to use the point source design, try to convert to a non-point reach design for biological sampling.

Measuring Chemical and Physical/Habitat Quality

Measurements of chemical and physical/habitat characteristics are used to describe the riffle environment and help water resource specialists interpret BMI data. The information can be used to classify stream reaches and to explain anomalies that might occur in the data.

The physical/habitat scoring criteria are based on the EPA's nationally standardized methods. They are used to measure the physical integrity of a stream, and can be a stand-alone evaluation or used in conjunction with a bioassessment sampling event. DFG recommends that this procedure be conducted on every reach of stream sampled as part of a bioassessment program. Fill out the Physical/Habitat Quality Form (see attached) for the entire reach where BMI samples are collected as part of a non-point source sampling design. Some of the parameters do not apply to a single riffle, so this procedure is usually not performed as part of the point source sampling design. This procedure is an effective measure of a stream=s physical/habitat quality, but requires field training prior to using it and implementation of quality assurance measures throughout the field season. A detailed description of the scoring criteria is provided at the end of this document.

A Physical/Habitat Quality Form should be filled out for each individual riffle when following the Point Source Sampling Design and for the entire reach when using the Non-point Sampling Design. Use the following step-by-step procedures for filling out the form:

Step 1. At the top of the form, enter basic information about the sampling event. This includes watershed and stream name, site code (if available) date and time of sample collection, name of the company or agency collecting the samples, names of each crew member, latitude and longitude and elevation.

Step 2. Record the water temperature, specific conductance, pH and dissolved oxygen measurements in the appropriate place. These measurements should be taken using standardized methods and approved equipment (see above).

Step 3. Estimate or measure the entire length of the reach where the three riffles were chosen as part of the non-point source sampling design. For point-source sampling, estimate or measure the length of the riffle sampled.

Step 4. For each riffle:

- Measure the riffle velocity and depth using a flow meter placed in front of the three locations along the transect(s) where the BMI samples were collected. Average the readings.
- Estimate the percent of the riffle surface that is covered by shade from streamside vegetation (canopy cover) using a densiometer at several places along the riffle. Average the readings.
- Measure the length and width of each of the three riffles. If width is not uniform, take several measurements and average them.
- Visually estimate the percent of riffle in each of the following substrate categories: fines (<0.1"), gravel (0.1-2"), cobble (2-10"), boulder (>10") and bedrock (solid). Use the entire riffle to assess this parameter and make note if the area along the transect(s) is considerable different from the rest of the riffle.
- Estimate substrate consolidation by kicking the substrate with the heel of your wader boots to note whether it is loosely, moderately or tightly cemented. The estimate should take into consideration the hands-on experience obtained from collecting the BMI sample.
- Determine substrate complexity and embeddedness within the riffle (Parameters 1 and 2, respectively, from the Habitat Parameter Guidelines). Use the entire riffle to assess these parameters, and make note if the area along the transect(s) is considerably different from the rest of the riffle.
- Measure the gradient or slope of the riffle using a stadia rod and a hand level or a clinometer.

Step 5. For the entire reach:

• Using the Habitat Parameter Guidelines (see attached), estimate items 1-10 on the Physical Habitat Form (epifaunal substrate, embeddedness, etc.) Note that items 8-10 require a separate estimate for each bank.
• Draw a map of the reach indicating location of the riffles and any access points on the back of the Physical Habitat Quality Form.

SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Sample Log-in Procedures: Initial ABL Sample Handling and Chain of Custody (COC) Form: Each set of samples submitted to the Aquatic Bioassessment Laboratory must be accompanied by a complete COC form (see attached). In most cases samples are collected by ABL staff, but we occasionally receive samples collected by other agencies. Procedures for generating a COC under either circumstance are listed below.

SAMPLES COLLECTED BY ABL STAFF

When samples arrive at the ABL the first priority is to log the samples into the electronic ABL Sample Inventory Database (CAL EDAS). The information entered into this database is then used to generate a COC form. The inventory log contains the following information:

1. The project name and the watershed name.
2. Complete locality information for each sample, including county where sampling occurred, site description (e.g., Pine Creek at Centerville Road), transect information, sampling date and name of collector.
3. Date and time samples arrived at the ABL.
4. Total number of samples (and total number of jars if different from total samples due to single samples occupying more than one jar).
5. Sample ID numbers ("ML numbers"). These are assigned to each sample during the log in procedure.
6. (Optional) Site descriptions for each individual sample (the site description is an abbreviated code derived from the original sampling location; for example, Santa Margarita at Camp Pendleton= SMR-CP).

All samples from a given project are logged in at once so that the ABL numbers generated for that project are consecutive. When more than one watershed is sampled in a project, all samples from each watershed should be grouped so that ABL numbers are consecutive within watersheds. It is desirable to have samples within a watershed logged in according to elevation so that upstream sites receive the lowest numbers in a series.

Once all samples have been logged into the ABL Sample Inventory Database, the sample information is printed as a COC using the Access report function. The COC is signed by one of the ABL staff members. Following completion of the COC form, the appropriate ML number is affixed to each sample container.

SAMPLES COLLECTED BY OTHER AGENCIES

Samples delivered form other agencies must be accompanied by a COC form at the time of delivery (note: a page of instructions for agencies that want to submit samples is attached), and must contain the following information in addition to that listed above:

1. The name of the agency that completed the original sampling, the name of that agencies' project advisor, the name of at least one crew member that participated in sampling, and address/telephone numbers for both.
2. A list of sample ID numbers (if ID numbers have been assigned by the originating agency; otherwise, ID numbers are assigned to each sample during sample log in .

Upon transfer of samples, the presence of each sample listed on the COC form is verified by ABL staff. After verification the relinquisher signs and dates that portion of the COC form titled "Relinquished by", and the ABL lab technician signs and dates the section titled "Received by" to complete this stage of the COC procedure.

All COC forms are kept in a clearly marked file folder in the general files of the ABL. Three separate COC files have been established as follows:

1. QA-QC projects
2. Enforcement cases
3. All other standard bioassessment projects.

At all times the original COC will accompany the samples. Once subsampling has been completed, the original COC accompanies the subsampled macroinvertebrates, and a photocopy of the COC will remain with the original samples and subsampling remnants. Any time a sample or set of samples is removed from the lab for any reason, the transfer is noted on the appropriate COC, including the date and personal responsible for transfer.

ANALYTICAL METHODS REQUIREMENTS

Subsampling

Find the sample identification label on the sample jar lid and confirm that it matches the sample description label inside the jar and the information recorded in the Macroinvertebrate Sample Inventory Log. Keep track of the location information, as it will be duplicated and used repeatedly in all subsequent steps, and therefore must be accurate.

Place a 2000 ml glass beaker beneath a #35 standard sieve (0.5 mm mesh). Pour contents of sample jar into sieve. Be aware that there may be more than one jar for a sample. Rinse any excess material from sample jar into sieve with tap water. Record the approximate volume of waste alcohol produced during the day on the "Evaporation Pond Chemical Disposal" form. The waste alcohol is dumped down the sink drain and collects in an evaporation pond. After disposing waste alcohol rinse the sink with tap water to flush the alcohol completely.

Rinse sample in sieve with tap water to remove fine particles (<0.5mm). Positioning an enamel tray under the sieve during the washing process serves two functions: (1) it allows the lab technician to determine when the sample is adequately rinsed of fine sediment and (2) organic detritus can be teased apart and more easily distributed throughout the sample if the sieve is placed into a tray full of water, thereby suspending such material. The stage of rinsing should be done carefully so damage to organisms is minimized.

After rinsing sample with water, inspect any large rocks (gravel size) or large leaves that have not begun to decompose for attached invertebrates. Clinging invertebrates should be removed and placed in the sieve, after which these larger materials can be placed in a "remnant jar" (see below). Decayed leaves and twigs are left in the sieve and should be carefully inspected for invertebrates with the aid of a stereo microscope during subsampling (see below). Drain excess water from the sieve.

Transfer the contents of the sieve to a subdivided 8" X 10" tray (the tray should be subdivided into twenty 25cm^2 squares and numbered so each square can be identified). One technique for transfer is to first quickly invert the sieve over the tray and tap on the sieve to dislodge the material. Then concentrate any sample that remains in the sieve into one portion at one end of the sieve with tap water. This portion may then be rinsed into the tray with small portions of 70% ethanol/ 3% glycerol solution. Inspect the sieve for attached invertebrates and transfer any that are found to the tray with the rest of the material.

While being careful not to damage organisms, distribute the sample evenly throughout the tray so that different material types are dispersed homogeneously. This step is critical to a good subsample, so take several minutes to do it right!

Add enough 70% ethanol/ 3% glycerol solution to the sample so that tray contents are wetted but not completely submerged. Do not overfill the tray because organisms tend to float to other grids.

Randomly select at least 5 numbers from 1 to 20 using a random number table, or use some other random number generator. Record these numbers on the ABL Subsampling Worksheet (see attached). These numbers define which grids in the grid tray you will actually sample from.

To begin, divide the material from within the first randomly chosen grid into quarter grids. Quarter grids are made by carefully cutting through or teasing the sample apart diagonally with a one-sided razor blade. Transfer the contents of the first quarter grid to a petri dish using the razor blade.

With the aid of a stereo microscope at a minimum of 10 X magnification, transfer invertebrates from the petri dish to a screw top 25 ml glass vial containing 70% ethanol/ 3% glycerol. This vial should include a proper locality label. The label includes the state, county, sampling site (i.e., name of stream or lake and the point at which it was sampled), replicate # (e.g., T1), date collected, ML number, and field collector initials (see below for additional notes about labels). This label is used in all subsequent handling of the samples.

Count the number of invertebrates removed from the tray with an auto- counter. If you suspect a counting error, recount. Note: remove macroinvertebrates from the petri dish in a consistent, uniform manner. Process grids from left to right, top to bottom, and do not remove larger invertebrates first.

Grids are processed until 300 invertebrates are obtained. It is important to subsample from at least three different grids in the grid tray. If the first quarter grid contains over 100 organisms, then EIGHTH GRIDS should be used thereafter. If between 50 and 100 organisms are encountered in the first quarter grid, then continue to use quarter grids until 300 organisms have been picked. If very few organisms are encountered in the first quarter grid (e.g., 20 or less), then half grids or even whole grids should be used. Remember, the key is to sample from at least three different grids. Obviously samples with high numbers of organisms will require subsampling from fewer total grids before 300 organisms are picked. Always decide which side of the grid you will process before subsampling and be consistent with each grid.

When 300 organisms are obtained before the last grid is completely processed, the remaining organisms in the grid are totaled and transferred to a separate vial with a location label and a label identifying them as "extra bugs". These "extra bugs" are used in the abundance calculations, but are not identified. Record the number of invertebrates removed from each grid on the ABL Subsampling Worksheet.

The following must not be included in the invertebrate count and should be placed in the remnant container (if there is any doubt about what to include, consult with a taxonomist):

1) organisms that were dead before sampling (these can be recognized by

their generally decayed "husk-like" and frail appearance, and will often lack one or more body parts).
2) exuviae
3) organisms with incomplete bodies (a head, thorax and most of the abdomen should be present)
4) terrestrial invertebrates
5) semi-aquatic insects including Collembola and surface hemipterans

CA: Tehama Co.
10/19/99
Dry Creek at Stewart Rd.
ML# 3519 T1
Coll. MD,CS

6) worm fragments - this may depend on the project. If oligochaetes are to be identified to family, only heads should be counted, or count heads and tails and divide by two.
7) empty shells and cases (e.g., gastropods, ostracods, clams, caddisflies, chironomids)

Place the residual material from the processed grids into a separate half pint or pint size mason jar. Include a location label. This processed residue is considered the remnant material of the sample. Affix a label to the outside of the remnant jar that includes the ML # and description: "Remnant". The remainder of the original sample material that is left over in the subdivided tray is placed in a half pint or pint size mason jar and labeled as "original". Again, make sure there is a location label inside the mason jar and the outside of the jar is labeled with the correct ML # and description: "original".

Estimated abundance calculation - The information from the subsampling procedure is recorded on the ABL Subsampling Worksheet. Record the following:
1) date
2) actual time required to pick sample (not elapsed time)
3) total number of invertebrates recovered (include extra bugs)
4) number of grids possible on 20 grid subdivided tray (N.B.- the number of grids possible may differ from 20 for various reasons. For example, not enough sample may be present to cover the entire bottom of the tray, or if quarter grids are processed out of twenty full grids, then a total of 80 grids are possible.

Example: # whole grids X 1 =

half grids X 0.5 = TOTAL GRIDS PROCESSED
quarter grids X 0.25 =

5) the number and size of grids processed (full, half, quarter, etc.) on the 20 grid subdivided tray.

Sorting Procedure

Transfer the contents of a picked sample vial containing 300 organisms into a petri dish. Sort the invertebrates into taxonomic groups (usually to order for insects, but the taxonomic rank to which various non-insect groups are sorted varies). The major groups are listed on the sorting worksheet. One easy way is to remove all specimens of the most common taxon, then move on to the next most common taxon, etc. Place each different taxon in a 1 dram shell vial with 70% ethanol/ 3% glycerol solution; include a correct location and taxon label. This step should be done carefully so that taxa are not mixed. If any invertebrates are encountered that match descriptions above, discard them and record the number discarded on the sorting worksheet.

All vials containing sorted taxa from a given site should be bundled together for identification.

Identification

Specimens are identified to the lowest possible taxonomic rank using appropriate taxonomic keys (see CAMLnet document titled "List of California Macroinvertebrate Taxa and Standard Taxonomic Effort"). The number of specimens in each taxon (usually genus for insects) is counted with a laboratory counter, and the results are recorded directly into a computer file (California EDAS, a Microsoft Access© database). If any specimens are discarded (see reasons for discarding specimens above), the number of discards should be recorded per sample on an ABL discard worksheet (see attached).

Each taxon (e.g., genus) within a sample is placed in a separate vial containing a locality label and a taxonomic identification label that includes order, family, genus, number of specimens, and name of taxonomist (see below). Coleopteran larvae and adults are placed in separate vials and recorded separately into CAL EDAS. An organism that cannot be identified to standard taxonomic rank should be recorded as "Undetermined" to the rank of family, order, etc. Identified samples are placed in the WPCL Sample Repository.

Organism Recovery - During the sorting and identification process organisms may be lost, miscounted or discarded. Taxonomists will record the number of organisms discarded and a justification for discarding on the laboratory benchsheets. Organisms may be discarded for several reasons including: 1) subsampler mistakes (e.g. inclusion of terrestrial or semi-aquatic organisms or exuviae), 2) small size (< 0.5 mm), 3) poor condition or 4) fragments of organisms. The number of organisms recovered at the end of sample processing will also be recorded and a percent recovery determined for all samples. Concern is warranted when organism recoveries fall below 90%. Samples with recoveries below 90% should be checked for counting errors and laboratory benchsheets should be checked to determine the number of discarded organisms. If the number of discarded organisms is high, then the technician that performed the subsampling should be informed and re-trained if necessary.

Metrics: The ABL uses a combination of basic descriptive statistics, often referred to as biological metrics, in combination with physical habitat and water chemistry data, to assess the biological integrity of BMI communities. The following table lists the metrics used to describe these communities. Also listed is the expected response of the various measures to impairment:

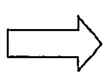
BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable

Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of macroinvertebrates in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

Reference Collection: A taxonomic reference collection has been established for use in identification of invertebrates. Reference specimens of most taxa are currently available. Specimens of newly encountered taxa should be added whenever possible. When a new taxon is identified, the specimen(s) should be pulled from the bulk samples, labeled and placed in the reference cabinet. The taxon will be entered into CAL EDAS as usual, and it will be indicated that those specimens have been placed in the reference collection.

Labels

Locality Labels: The standard format for location labels is outlined above.
This format is used for labeling all vials that contain specimens identified to lowest taxonomic rank. In some cases, the full name of the sampling site may be too lengthy to fit on a label of appropriate width. In such cases, the abbreviated site description may replace the full site name. For example:



Labels are created in Word Perfect. Current labels are stored on the networked lab computers under C: My Documents/Labels. For consistency use the following setup:
From the Word Perfect menu select "Format" "Columns"
In the "Number of Columns" box enter "5"
In the "Space Between" box enter "0.100"
This set up, with a font size of 6, will work for most location labels.

For any given project, it is the responsibility of the person(s) picking the samples to make a batch of labels for that project. Each site within a project has a corresponding column of labels. Labels should be kept in a common-access computer file so that all lab personnel have access to them at all times.

Taxa Labels: In addition to a locality label, each vial of specimens identified to lowest taxonomic rank contains an identification label. The label can be hand-written or pre-printed depending on the preference of the taxonomist. The following is an example of a pre-printed label:

The number of organisms contained in the vial should be hand-written on the label by the taxonomist.

Sample Storage

Original Sample
After a BMI sample has been subsampled the remaining sample is returned to a mason jar with its label, and is kept in storage at the Chico State Lab Facility. The original sample jars are stored in large plastic containers, each of which has a unique number. A storage log has been established that lists the contents of each numbered container so that original samples may be easily recovered.

EPHEMEROPTERA
Ephemerellidae
Attenella sp.
det. D. Post

CA Tehama Co. T1
Dry Creek DC-SR
ML-3519 M.D., C.S. 10/19/99

CA Tehama Co. T1
Dry Creek at Stewart Rd.
ML-3519 M.D., C.S. 10/19/99

Original samples are kept until the contracting agency has received the final bioassessment report as specified by an existing contract. Once the final report is delivered, the original samples are returned to the contracting agency at their expense. If the contracting agency does not want the samples, they are disposed of as hazardous waste at the expense of the contractor.

Subsample Remnants
Remnants from the subsampling process are stored only until remnant QC procedures have been completed (see below), after which the subsampled remants may be discarded.

QUALITY CONTROL REQUIREMENTS

QA for Collecting BMIs

The CSBP is designed to produce consistent, random samples of BMIs. It is important to prevent bias in riffle choice and transect placement. The following procedures will help field crews collect unbiased and consistent BMI samples:

1. In using the CSBP, most sampling reaches should contain riffles that are at least 10 meters long, one meter wide and have a homogenous gravel/cobble substrate with swift water velocity. There are approved modifications of the CSBP when these conditions do not exist. Contact DFG or visit the California Aquatic Bioassessment Web Site for methods to sample narrow streams, wadeable streams with muddy bottoms and channelized streams.

2. A DFG biologists or project supervisor should train field crews in the use of the BMI sampling procedures described in the CSBP. Field personnel should review the CSBPs before each field season.

3. During the training, crew members should practice collecting BMI samples as described in the CSBP. The 2 ft^2 area upstream of the sampling device should be delineated using the measuring tape or a metal grid and the collection effort should be timed. Practice repeatedly until each crew member has demonstrated sampling consistency. Throughout the sampling season, assure that effort and sampling area remain consistent by timing sampling effort and measuring sampled area for approximately 20% of the sampling events. The results should be discussed immediately and need not be reported.

QA for Measuring Physical/Habitat Quality

Physical/habitat parameters are assessed using a ranking system ranging from optimal to poor condition. This rapid ranking system relies on visual evaluation and is inherently subjective. The following procedures will help to standardize individual observations to reduce differences in scores:

1. A DFG biologist or a project supervisor should train field crews in the use of the EPA physical/habitat assessment procedures. Field personnel should review these procedures before each field season.

2. At the beginning of each field season, all crew members should conduct a physical/habitat assessment of two practice stream reaches. Assess the first stream reach as a team and discuss in detail each of the 10 physical/habitat parameters described in the EPA procedure. Assess the second stream reach individually and when members are finished, discuss the 10 parameters and resolve discrepancies.

3.Crews or individuals assessing physical/habitat quality should frequently mix personnel or alternate assessment responsibilities. At the end of each field day, crew members should discuss habitat assessment results and resolve discrepancies.

4.The Project Supervisor should randomly pre-select 10 - 20% of the stream reaches where each crew member will be asked to assess the physical/habitat parameters separately. The discrepancies in individual crew member scores should be discussed and resolved with the Project Supervisor.

Analytical Quality Control
Internal QC is conducted by ABL taxonomists on samples that have been processed by the ABL itself. Internal QC procedures target two specific stages of sample processing: the subsampling ("picking") stage and the identification stage.

Subsampling QA (Remnant Evaluation): Ten percent of the remnant samples from every project are examined by a QC taxonomist for organisms that may have been overlooked during subsampling. The number of unpicked BMI's (if any) and their identity is recorded in the ABL Quality Control Worksheet. For subsamples containing 300 or more organisms, the remnant sample should contain fewer than 10% of the total organisms subsampled. The remnant should contain fewer than 30 organisms for samples containing fewer than 300 organisms. IF these criteria are not met, then corrective action is initiated. For example, student pickers are currently paid on a per sample basis, which means that they earn more per hour if they process samples quickly. Error rates greater than 10% result in a student earning minimum wage for the time spent processing that sample (or samples).

Internal Taxonomic Identification QA: Taxonomic identifications are evaluated by the ABL's QC taxonomist with the goal of checking the accuracy and consistency of individual taxonomists. Ten percent of the samples from any given project are randomly selected and then checked for taxonomic accuracy. All taxa from each of the randomly selected samples are re-identified by the QC taxonomist, and the number of specimens in each vial is re-checked. Any errors in taxonomy, including misidentification, multiple taxa per vial, counting error and deviation from standard taxonomic effort are recorded in spreadsheet form, and then are analyzed with QC MANAGER, an ACCESS© program that summarizes the types of discrepancy and their frequencies. If a taxonomist is discovered to consistently misidentify a particular taxon, that person will receive instruction from the QC taxonomist about how to properly identify specimens in that group, and all future ID's involving that taxon will be checked until the problem is resolved.

External Quality Control
The ABL has the option of sending all processed samples to an independently contracted lab for external QA/QC of identified specimens. When external QC is performed, 10 percent of all samples are evaluated for taxonomic accuracy and accuracy of specimen counts.

Contract QA
The ABL is sometimes contracted to perform external QA/QC for other independent labs. The protocol outlined above, where 10% of total samples are evaluated for accuracy of taxonomic identifications and specimen counts, is generally followed. QC identifications and counts are compared with the original identifications, any discrepancies are checked to verify that the ABL is not responsible for the error, and a final report is sent to the contracting agency.

INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE REQUIREMENTS

The following field equipment and inspection schedule is required for biological sampling:

Equipment Item	Inspection Schedule
D-shaped Kick Net (0.5mm mesh)	Each sampling event
Standard Size 35 Sieve (0.5 mm)	Each sampling event
Wide-mouth Plastic Jars	Each sampling event
Measuring Tape (100 meter)	Each sampling event
Pencils/Permanent Markers	Each sampling event
Flagging	Each sampling event
Forceps	Each sampling event
Water-proof Paper	Each sampling event
Gridded White Enameled Pan	Each sampling event
YSI 85	Each sampling event
pH Meter	Each sampling event
Thermometer	Each sampling event
Flow Meter	Each sampling event
GPS Unit	Each sampling event
Digital Camera	Each sampling event
Stadia Rod	Each sampling event

INSTRUMENT CALIBRATION AND FREQUENCY

The primary field instruments that require regular calibration are the VWR brand pHastchek Pocket ph Meter and the YSI Model 85 (Oxygen, Conductivity, Salinity, and Temperature System). The pH meter used in field surveys involves a two point calibration (pH 7.0 and 10.0), and the YSI Model 85 requires calibration for conductivity against standard solutions (1000 microsiemens +/- 1% at 25 degrees C). and for Dissolved Oxygen on a per use basis. These instruments are calibrated at the beginning of each field season, and at 2-3 week intervals thereafter. Prior to taking measurements with these instruments in the field, they are allowed to equilibrate for 15 minutes. Note: the YSI must be calibrated for Dissolved Oxygen before each use if elevation changes significantly between sampling sites.

DATA DEVELOPMENT AND ANALYSIS

The EPA is developing procedures for multivariate analysis of bioassessment data, but that method is not presented here. However, the sampling protocols presented in this document were designed to facilitate the use of multivariate analysis, and more information will be presented when standardizes techniques for California become available.

A taxonomic list of the BMIs identified for each sample should be generated for each project along with a table of sample values and means for the biological metrics listed on the last page of this document. Variability of the sample values should be expressed as the coefficient of variability (CV). Significance testing can be used for point source sampling programs, and ranking procedures can be used to compare sites sampled using the non-point sampling design (contact DFG for information on ranking formulas).

Starting in summer 2001, an Access7 database program to store, process and return a copy of the collected data will be available. Contact DFG or visit the California Aquatic Bioassessment Web Site at http://www.dfg.ca.gov/cabw/cabw/csbp.html to learn more about the availability of regional IBI's and the database program.

California Department of Fish and Game

revision date: January 1, 2002

WATER POLLUTION CONTROL LABORATORY

Aquatic Bioassessment Laboratory

CSBP Stream Habitat Characterization Form

Project Name:	Date:
Stream Name:	Time:
Site Code:	Crew Members

GPS Latitude: °N
GPS Longitude: °W

SECTION 1. REACH-WIDE PHYSICAL HABITAT SCORES (scores are based on overall reach characteristics and range between 0-20. See EPA's RBP habitat scoring guide for detailed scoring guidelines)

HABITAT MEASURE		SCORE		COMMENTS	TOTAL P-HAB SCORE:
Epifaunal Substrate					
Embeddedness					
Velocity/ Depth Regimes					
Sediment Deposition					
Channel Flow					
Channel Alteration					
Riffle Frequency					
Bank Vegetation	Left Bank		Right Bank		
Bank Stability	Left Bank		Right Bank		
Riparian Zone	Left Bank		Right Bank		

SECTION 2. TRANSECT-SCALE PHYSICAL HABITAT CHARACTERISTICS (measures relate to individual riffles or transects from which each replicate sample is taken)

	T1	T2	T3		T1	T2	T3			T1	T2	T3
Average Depth (cm)				Riffle Length (m)				Substrate Composition (percentage composition measured along transect)	Fines (<0.1″)			
Average Velocity (m/s)				Riffle Width (m)					Gravel (0.1-2″)			
Riffle Embededness (0-20 scale)				Canopy Cover (%)					Cobble (2-10″)			
Substrate Consolidation (low, med, high)				Substrate Complexity (0-20 scale)					Boulder (>10″)			
Riffle Gradient (this should be recorded as % slope (rise/ run), not degrees of slope or inches of drop)									Bedrock (solid)			

SECTION 3. CHEMICAL CHARACTERISTICS (one record per site)

Specific Conductance (µmhos/cm@25°C)		pH	
Water Temperature (°C)		Salinity (ppt)	
DO (mg/L)		Alkalinity	

SECTION 4. REACH PHYSICAL CHARACTERISTICS

Reach Length (m)	
Photo Exposures	

Habitat Parameter	Category Category Optimal Optimal O	Suboptimal Suboptimal	Marginal Marginal m	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; most favorable is a mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2a. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2b. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or submerged vegetation.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3a. Velocity/ Depth Regimes	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3b. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small- deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small- shallow or pools absent.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7a. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7b. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

8. Bank Stability (score each bank) Note: determine left of right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.			Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.			Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.			Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.		
SCORE ___(LB)	Left Bank	10	9	8	7	6	5	4	3	2	1	0
SCORE ___(RB)	Right Bank	10	9	8	7	6	5	4	3	2	1	0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.			70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one- half of the potential plant stubble height remaining.			50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.			Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.		
SCORE ___(LB)	Left Bank	10	9	8	7	6	5	4	3	2	1	0
SCORE ___(RB)	Right Bank	10	9	8	7	6	5	4	3	2	1	0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.			Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.			Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.			Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.		
SCORE ___(LB)	Left Bank	10	9	8	7	6	5	4	3	2	1	0
SCORE ___(RB)	Right Bank	10	9	8	7	6	5	4	3	2	1	0

CHAIN OF CUSTODY RECORD

DFG Aquatic Bioassessment Laboratory

Sampling Agency: Project Name:

Address/Phone of Project Supervisor: Crew Member:(Sign and Date)

Address/Phone of Project Supervisor	Crew Member (Sign and Date)

Sample # ABL # Date Col. Waterbody SiteLocation #ofJars

Relinquished By: (Sign and Date) Received By: (Sign and Date) Sample Location

Relinquished By: (Sign and Date)	Received By: (Sign and Date)	Sample Location

Page ____of ____

Instructions for Submitting Benthic Samples to California Fish and Game Aquatic Bioassessment Lab

All samples submitted to the Aquatic Bioassessment Lab (ABL) must be accompanied by a complete Chain of Custody form. This form must contain the following information:

1. The project name and the watershed name.

2. The name of the agency that completed the original sampling, the name of that agencies' project advisor, the name of at least one crew member that participated in sampling, and address/telephone numbers for both.

3. Complete locality information for each sample, including county where sampling occurred, site description (e.g., Pine Creek at Centerville Road), transect information (T1, T2, etc.), sampling date and name of collector.

4. Total number of samples (and total number of jars if different from total samples due to single samples occupying more than one jar).

5. A list of sample ID numbers (if ID numbers have been assigned by the originating agency; otherwise, ID numbers are assigned to each sample by the ABL .

When samples are delivered to the ABL, the delivering agent will be expected to remain at the lab until a member of the ABL staff verifies that all the samples being delivered are listed on the COC form. Any discrepancies will be noted and resolved at the time of delivery. ABL staff will not sign a COC until all discrepancies are resolved. If samples are delivered in the absence of ABL staff, or without the verification of COC contents by ABL staff, the ABL is not responsible for discrepancies (i.e., samples listed on the COC but not actually delivered, or samples delivered without proper documentation on the COC). Samples will not be accepted without appropriate COC forms.

CDFG/ CSU AQUATIC BIOASSESSMENT LABORATORY SUBSAMPLING WORKSHEET

Project Name: ______________________ Project Code: _____________ Object Code: _____________

ABL #: Date: Technician Name:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
random grid #																				
half /whole grid																				
# per grid																				
cumulative #																				

Grids Picked: Total Total Time: Notes:
Grids: Count:Comments

ABL #: Date: Technician Name:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
random grid #																				
half /whole grid																				
# per grid																				
cumulative #																				

Grids Picked: Total Total Time: Notes:
Grids: Count:Comments

ABL #: Date: Technician Name:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
random grid #																				

half
/whole
grid
per grid
cumulative
#

Grids Picked: Total Grids: Total Count: Comments Time: Notes:

ABL #: Date: Technician Name:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
random grid #																				
half /whole grid																				
# per grid																				
cumulative #																				

Grids Picked: Total Grids: Total Count: Comments Time: Notes:

\Datasheets\Lab\Labforms\subsampling form2.wpd

CDFG/ CSU Aquatic Bioassessment Laboratory

Picking-Sorting Worksheet

Project Name: Project Code: Date:

Picking									Sorting			
ABL#	Date	Time	# Bugs	# Extra Bugs	Total Bugs includes extras	# Grids Used	# Grids Processed	Initials	Date	# Bugs	# Discards	Initials

California Stream Bioassessment Procedure (CSBP) for Measuring Basic Characterization of Stream Habitat and Sampling Benthic Macroinvertebrates

Project Name:	Date:	
Stream Name:	Time:	
Site Code:	Crew Members	
GPS Latitude: °N		
GPS Longitude: °W		

In Situ Measurements									
Stream Temp. (°C):		pH:				Salinity (ppt):			
Stream DO mg/L:		Conductivity (μs)				Alkalinity ():			
Photograph Numbers:	Trans A up:		Trans D up:		Trans G up:		Trans I up:		Trans K dwn:
Additional Photographs (Optional):									

Protocol Brief for Measuring Basic Characterization of Stream Habitat:

Step 1. Establish a 150 meter reach of stream.
Step 2. Fill in the first box on page 1 with site location information.
Step 3. Measure ambient water column chemistry specified in the **In Situ Measurement** on page 1 before disturbing the benthos.
Step 4. Starting at the bottom of the reach, estimate the stream width and record it in the **Substrate Cross-Sectional Information** box on page 2, Transect A.
Step 5. Starting at the right or left bank, record the depth and substrate size using the codes in the **Substrate Cross-Sectional Information** box on page 2, Transect A. By pacing off the distance, repeat the measures at 25%, 50%, and 75% of the stream width and at the opposite bank. Estimate percent embeddedness whenever a cobble size substrate is encountered and record in the same box.
Step 6. Using the EMAP modified convex densiometer (17 point), measure canopy cover facing the left bank, upstream at 50%, downstream at 50% and the right bank and record in the **Densiometer Box** Transect A.
Step 7. Take a photograph facing upstream and record the digital photo number in the **In Situ Measurement** box on page 1.
Step 8. Pace off 7 ½ meters upstream of Transect A and repeat Step 5 without estimating depth. Record the information in the **Inter-Transect Substrate Cross-Sectional Information** box for Transect A.
Step 9. Pace off an additional 7 ½ meters upstream and repeat steps 4, 5, 6 and 8. Only repeat step 7 when prompted by the **Photograph at Transect** box.
Step 10. After completing Transect K, proceed downstream measuring the total reach gradient by recording % slope for manageable sections of channel and then averaging the measurements in the **Slope Measurements** box. This procedure is best done with two people and a clinometer.
Step 11. While proceeding downstream measuring gradient, record approximate proportions of the stream channel in the habitat types listed in the **Flow Habit Delineation** box.
Step 12. Complete the U.S. EPA Rapid Bioassessment Protocol Physical/Habitat Sheet and record on page 8.

Protocol Brief for Sampling Benthic Macroinvertebrates:

Targeted Riffle – Composite 1 ft^2 of substrate from 8 fast water habitats distributed throughout the reach. To determine the sampling position within the riffle, take two random numbers between 1 and 10 with the first number representing the percent of the length (from the bottom), and the second number representing the percent of the width (from the right bank).
Multi-Habitat - Composite 1 ft^2 of substrate from the 11 transects alternation from right, center and left margins. The position of the first sample is decided by flipping a coin for either left and right.

Site Code: ______________________ Page 2 Date: __/__/2005

Substrate Cross-Sectional Information				
Estimated stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)

* Cobble Embeddedness on first 25 cobbles only.

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

TRANSECT A

Photograph at Transect

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Comments: ____

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Substrate Cross-Sectional Information				
Estimated stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

Comments: ______________________

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TRANSECT B

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Site Code: ______________________ Page 3 Date: __/__/2005

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			
Substrate Size Class Codes				
RS = Bedrock (Smooth) - Larger Than a Car				
RR = Bedrock (Rough) - Larger Than a Car				
RC = Concrete/ Asphalt				
LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car				
SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick				
CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball				
GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball				
GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble				
SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug				
FN = Silt/ Clay/ Muck - Not Gritty				
HP = Hardpan - Firm Consolidated Fine Substrate				
WD = Wood - Any Size				
OT = Other (Write comment below)				
* Cobble Embeddedness on first 25 cobbles only.				

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

TRANSECT C

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Comments: ____

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

Comments: ______________________

TRANSECT D

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Photograph at Transect

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)

Cobble Embeddedness on first 25 cobbles only.

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

TRANSECT E

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Comments: ____

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Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

Comments: ______________________

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TRANSECT F

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)

* Cobble Embeddedness on first 25 cobbles only.

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

TRANSECT G

Photograph at Transect

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Comments: ____

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Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Inter-Transect Substrate Cross-Sectional Information			
Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

Comments: ______________________

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TRANSECT H

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Site Code: ______________________ Page 6 Date: __/__/2005

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Substrate Size Class Codes

RS = Bedrock (Smooth) - Larger Than a Car
RR = Bedrock (Rough) - Larger Than a Car
RC = Concrete/ Asphalt
LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
FN = Silt/ Clay/ Muck - Not Gritty
HP = Hardpan - Firm Consolidated Fine Substrate
WD = Wood - Any Size
OT = Other (Write comment below)
* Cobble Embeddedness on first 25 cobbles only.

Inter-Transect Substrate Cross-Sectional Information — Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

TRANSECT I

Photograph at Transect

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Comments: ____

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Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			

Inter-Transect Substrate Cross-Sectional Information — Taken 7.5m above Transect			
Estimated Stream Width		Size Class Code	Cobble Embed. 0-100%
Left	bank		
LCtr	25%		
Ctr	50%		
RCrt	75%		
Right	bank		

Comments: ______________________

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TRANSECT J

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

Substrate Cross-Sectional Information				
Estimated Stream Width		Depth XXX cm	Size Class Code	Cobble Embed. 0-100% *
Left	bank			
LCtr	25%			
Ctr	50%			
RCrt	75%			
Right	bank			
Substrate Size Class Codes				
RS = Bedrock (Smooth) - Larger Than a Car				
RR = Bedrock (Rough) - Larger Than a Car				
RC = Concrete/ Asphalt				
LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car				
SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick				
CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball				
GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball				
GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble				
SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug				
FN = Silt/ Clay/ Muck - Not Gritty				
HP = Hardpan - Firm Consolidated Fine Substrate				
WD = Wood - Any Size				
OT = Other (Write comment below)				
Cobble Embeddedness on first 25 cobbles only.				

TRANSECT K

Photograph at Transect

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Rt. Bank	

REACH WIDE ESTIMATES OF SLOPE AND FLOW HABITAT TYPES

Slope Measurements								
Take as few measurement as are necessary to cover the entire 150m reach.								
	Slope %	Section Length		Slope %	Section Length		Slope %	Section Length
1			5			9		
2			6			10		
3			7			11		
4			8			12		

Flow Habitat Delineation		
Measure the lengths of each habitat type within the reach.		
Habitat Type	Distance (in meters)	Total
Pool		
Glide		
Run		
Riffle		
Cascade/ Falls		
Dry Channel		
	Sum	

Project Name:	Date:	
Stream Name:	Time:	
Site Code:	Crew Members	
GPS Latitude: °N		
GPS Longitude: °W		

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Epifaunal bstrate/ ailable Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
'ORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
'ORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Velocity/Depth gime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Sow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
'ORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Sediment position	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
'ORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Channel Flow itus	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
'ORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score _________

NOTES

STREAM MAP

CSBP Stream Habitat Characterization Form

Standard Reach Length - 150 m., distance between transects 15 m.

Project Name:	Date:	
Stream Name:	Time:	
Site Code:	Crew Members	
GPS Latitude: °N		
GPS Longitude: °W		

In Situ Measurements					
Stream Temp. (°C):		pH:		Salinity (ppt):	
Stream DO mg/L:		Conductivity (µs)		Alkalinity ():	
Photograph Numbers:	0 up:	45 up:	90 up:	120 up:	150 dwn:
Additional Photographs (Optional):					

General Habitat Characterization (Reach Wide)				
Habitat Parameter	Optimal	Suboptimal	Marginal	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; most favorable is a mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Comments: ____

Site Code:	Date: __ / __ / 2005

Targetted Riffle - 1 (1 square foot) sample taken from up to 8 riffle units for a total of 8 samples.
To determine the sampling position with in the riffle, take two random numbers between 1 and 10. Multiply the numbers by ten. The first number represents the percent of the length (from the bottom) where to sample, and the second number represents the percent of the width (from the right bank) where to sample.
Multi-Habitat - 1 (1 square foot) sample taken 1m below each of the 11 transects.

Substrate (Optional)

Visual Percent Cover of substrate size classes at sampling locations.

	1	2	3	4	5	6	7	8	9	10	11
Fines and Sand											
Gravel											
Cobble											
Boulder											
Bedrock											

Slope Measurements

Take as few measurement as are necessary to cover the entire 150m reach.

	Slope %	Section Length		Slope %	Section Length		Slope %	Section Length
1			5			9		
2			6			10		
3			7			11		
4			8			12		

Flow Habitat Delineation

Measure the lengths of each habitat type within the reach.

Habitat Type	Distance (in meters)	Total
Pool		
Glide		
Run		
Riffle		
Cascade/ Falls		
Dry Channel		
	Sum	

Comments: ____

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CHANNEL/RIPARIAN TRANSECT FORM

Site Code:	Date: ___/___/ 2005	Transect: A

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)

* Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank.

Vegetation Cover	Left Bank	Right Bank
Canopy (>5 m High)		
BIG Trees (Trunk >0.3m DBH)	0 1 2 3 4	0 1 2 3 4
SMALL Trees (Trunk <0.3m DBH)	0 1 2 3 4	0 1 2 3 4
Understory (0.5 to 5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Ground Cover (<0.5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4

Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Cover in Channel

Estimate channel features for the stream section 5m above and 5m below transect.

Filamentous Algae	0 1 2 3 4
Macrophytes	0 1 2 3 4
Woody Debris >0.3 m (Big)	0 1 2 3 4
Brush/ Woody Debris <0.3 m (Small)	0 1 2 3 4
Live Tree Roots	0 1 2 3 4
Overhanging Veg. <1m of Surface	0 1 2 3 4
Undercut Banks	0 1 2 3 4
Boulders	0 1 2 3 4
Artificial Structures	0 1 2 3 4

Comments: ______________________

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

	Left Bank		Right Bank
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0 B C P	CH	0 B C P
Buildings	0 B C P	CH	0 B C P
Pavement/ Cleared Lot	0 B C P	CH	0 B C P
Road/ Railroad	0 B C P	CH	0 B C P
Pipes (Inlet/ Outlet)	0 B C P	CH	0 B C P
Landfill/ Trash	0 B C P	CH	0 B C P
Park/ Lawn	0 B C P	CH	0 B C P
Row Crops	0 B C P	CH	0 B C P
Pasture/ Range/ Hayfield	0 B C P	CH	0 B C P
Logging Operations	0 B C P	CH	0 B C P
Mining Activity	0 B C P	CH	0 B C P

Densiometer (0-17 Max) at Transect

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

CHANNEL/RIPARIAN TRANSECT FORM

Site C	Date: ___/___/ 2005	Trans[illegible] 3

A009583

CHANNEL/RIPARIAN TRANSECT FORM

Site Code:

Date: __ / __ / 2005

Transect: C

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Vegetation Cover	Left Bank	Right Bank
Canopy (>5 m High)		
BIG Trees (Trunk >0.3 m DBH)	0 1 2 3 4	0 1 2 3 4
SMALL Trees (Trunk <0.3 m DBH)	0 1 2 3 4	0 1 2 3 4
Understory (0.5 to 5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Ground Cover (<0.5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4

Fish Cover/ Other — Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Cover in Channel

Estimate channel features for the stream section 5m above and 5m below transect.

Filamentous Algae	0 1 2 3 4
Macrophytes	0 1 2 3 4
Woody Debris >0.3 m (Big)	0 1 2 3 4
Brush/ Woody Debris <0.3 m (Small)	0 1 2 3 4
Live Tree Roots	0 1 2 3 4
Overhanging Veg. <1 m of Surface	0 1 2 3 4
Undercut Banks	0 1 2 3 4
Boulders	0 1 2 3 4
Artificial Structures	0 1 2 3 4

Comments:

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Densiometer (0-17 Max)

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

Comments:

CHANNEL/RIPARIAN TRANSECT FORM

Date:	___ / ___ / 2005		Transect: D	

Substrate Cross-Sectional Information

Site Code	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left		.		
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Vegetation Cover	Left Bank					Right Bank				
Canopy (>5 m High)										
BIG Trees (Trunk >0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
SMALL Trees (Trunk <0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
Understory (0.5 to 5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Ground Cover (<0.5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Barren, Bare Dirt or Duff	0	1	2	3	4	0	1	2	3	4

Habitat Complexity

Cover in Channel

Estimate channel features for the stream section 5m above and 5m below transect.

Feature					
Filamentous Algae	0	1	2	3	4
Macrophytes	0	1	2	3	4
Woody Debris >0.3 m (Big)	0	1	2	3	4
Brush/ Woody Debris <0.3 m (Small)	0	1	2	3	4
Live Tree Roots	0	1	2	3	4
Overhanging Veg. <1m of Surface	0	1	2	3	4
Undercut Banks	0	1	2	3	4
Boulders	0	1	2	3	4
Artificial Structures	0	1	2	3	4

Comments: ____________________

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

Human Influence	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Photograph at Transect

Densiometer (0-17 Max)

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

Site Code:	Date: __ __/__ __/ 2005	Transect: E

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Vegetation Cover	Left Bank					Right Bank				
Canopy (>5 m High)										
BIG Trees (Trunk >0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
SMALL Trees (Trunk <0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
Understory (0.5 to 5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Ground Cover (<0.5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Barren, Bare Dirt or Duff	0	1	2	3	4	0	1	2	3	4

Fish Cover/ Other Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Estimate channel features for the stream section 5m above and 5m below transect.

	Cover in Channel				
Filamentous Algae	0	1	2	3	4
Macrophytes	0	1	2	3	4
Woody Debris >0.3 m (Big)	0	1	2	3	4
Brush/ Woody Debris <0.3 m (Small)	0	1	2	3	4
Live Tree Roots	0	1	2	3	4
Overhanging Veg. <1 m of Surface	0	1	2	3	4
Undercut Banks	0	1	2	3	4
Boulders	0	1	2	3	4
Artificial Structures	0	1	2	3	4

Comments:

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Densiometer (0-17 Max)

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

CHANNEL/RIPARIAN TRANSECT FORM

Site Code:	Date: __ __/__ __/ 2005	Transect: F

A009985

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed.* 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates / Instream Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Cover in Channel: Estimate channel features for the stream section 5m above and 5m below transect.

Vegetation Cover	Left Bank	Right Bank
Canopy (>5 m High)		
BIG Trees (Trunk >0.3 m DBH)	0 1 2 3 4	0 1 2 3 4
SMALL Trees (Trunk <0.3 m DBH)	0 1 2 3 4	0 1 2 3 4
Understory (0.5 to 5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Ground Cover (<0.5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4

Cover in Channel		
Filamentous Algae	0 1 2 3 4	
Macrophytes	0 1 2 3 4	
Woody Debris >0.3 m (Big)	0 1 2 3 4	
Brush/ Woody Debris <0.3 m (Small)	0 1 2 3 4	
Live Tree Roots	0 1 2 3 4	
Overhanging Veg. =1 m of Surface	0 1 2 3 4	
Undercut Banks	0 1 2 3 4	
Boulders	0 1 2 3 4	
Artificial Structures	0 1 2 3 4	

Comments:

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

Human Influence	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Site Code:

Photograph at Transect

Densiometer (0-17 Max)

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

CHANNEL/RIPARIAN TRANSECT FORM

Date: __ __ / __ __ / 2005

Transect: G

96556A

A009987

Site Code:

Date: ___ / ___ / 2005

Transect: H

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Vegetation Cover	Left Bank					Right Bank				
Canopy (>5 m High)										
BIG Trees (Trunk >0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
SMALL Trees (Trunk <0.3 m DBH)	0	1	2	3	4	0	1	2	3	4
Understory (0.5 to 5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Ground Cover (<0.5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Barren, Bare Dirt or Duff	0	1	2	3	4	0	1	2	3	4

Fish Cover/ Other Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Cover in Channel
Estimate channel features for the stream section 5m above and 5m below transect.

Cover in Channel					
Filamentous Algae	0	1	2	3	4
Macrophytes	0	1	2	3	4
Woody Debris >0.3 m (Big)	0	1	2	3	4
Brush/ Woody Debris <0.3 m (Small)	0	1	2	3	4
Live Tree Roots	0	1	2	3	4
Overhanging Veg. <1 m of Surface	0	1	2	3	4
Undercut Banks	0	1	2	3	4
Boulders	0	1	2	3	4
Artificial Structures	0	1	2	3	4

Comments:

CHANNEL/RIPARIAN CROSS-SECTION FORM

Human Influence

0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Comments:

Densiometer (0-17 Max)

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

CHANNEL/RIPARIAN TRANSECT FORM

Site Code	Date: __ __ / __ __ / 2005	Transect: I

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes

- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Visual Riparian Estimates

0 = Absent (0%) 1 = Sparse (<10%) 2 = Moderate (10-40%) 3 = Heavy (40-75%) 4 = Very Heavy (>75%) (Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Vegetation Cover	Left Bank					Right Bank				
Canopy (>5 m High)										
BIG Trees (Trunk >0.3m DBH)	0	1	2	3	4	0	1	2	3	4
SMALL Trees (Trunk <0.3m DBH)	0	1	2	3	4	0	1	2	3	4
Understory (0.5 to 5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Ground Cover (<0.5 m High)										
Woody Shrubs and Saplings	0	1	2	3	4	0	1	2	3	4
Non-Woody Herbs, Grasses and Forbs	0	1	2	3	4	0	1	2	3	4
Barren, Bare Dirt or Duff	0	1	2	3	4	0	1	2	3	4

Instream Habitat Complexity

0 = Absent (0%) 1 = Sparse (<10%) 2 = Moderate (10-40%) 3 = Heavy (40-75%) 4 = Very Heavy (>75%) (Circle one)

Cover in Channel: Estimate channel features for the stream section 5m above and 5m below transect.

Filamentous Algae	0	1	2	3	4
Macrophytes	0	1	2	3	4
Woody Debris >0.3 m (Big)	0	1	2	3	4
Brush/ Woody Debris <0.3 m (Small)	0	1	2	3	4
Live Tree Roots	0	1	2	3	4
Overhanging Veg. <1m of Surface	0	1	2	3	4
Undercut Banks	0	1	2	3	4
Boulders	0	1	2	3	4
Artificial Structures	0	1	2	3	4

Comments:

Human Influence

0 = Not Present CH - Within Channel B = On Bank C = Within 10m of Channel P = >10m of Channel

	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Densiometer (0-17 Max) at Transect

Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Inter-Transect Substrate Cross-Sectional Information

Taken 7.5m above Transect

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

CHANNEL/RIPARIAN TRANSECT FORM

Site C	Date: __ __ / __ __ / 2005	Trans I

Substrate Cross-Sectional Information

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Cobble Embed. 0-100%
Left				
LCtr				
Ctr				
RCrt				
Right				

Substrate Size Class Codes
- RS = Bedrock (Smooth) - Larger Than a Car
- RR = Bedrock (Rough) - Larger Than a Car
- RC = Concrete/ Asphalt
- LB = Larger Boulder (1000 to 4000 mm) - Meterstick to Car
- SB = Small Boulder (250 to 1000 mm) - Basketball to Meterstick
- CB = Cobble (64 to 250 mm) - Tennis Ball to Basketball
- GC = Coarse Gravel (16 to 64 mm) - Marble to Tennis Ball
- GF = Fine Gravel (2 to 16 mm) - Ladybug to Marble
- SA = Sand (0.06 to 2 mm) - Gritty up to Lady Bug
- FN = Silt/ Clay/ Muck - Not Gritty
- HP = Hardpan - Firm Consolidated Fine Substrate
- WD = Wood - Any Size
- OT = Other (Write comment below)
- * Cobble Embeddedness on first 25 cobbles only.

Site Code:

Visual Riparian Estimates / Instream Habitat Complexity

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(Circle one)

Visual Riparian Estimates made 5m above and 5m below the transect and 10m to the side starting at the bank. Orientation is looking downstream.

Cover in Channel: Estimate channel features for the stream section 5m above and 5m below transect.

Vegetation Cover	Left Bank	Right Bank
Canopy (>5 m High)		
BIG Trees (Trunk >0.3m DBH)	0 1 2 3 4	0 1 2 3 4
SMALL Trees (Trunk <0.3m DBH)	0 1 2 3 4	0 1 2 3 4
Understory (0.5 to 5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Ground Cover (<0.5 m High)		
Woody Shrubs and Saplings	0 1 2 3 4	0 1 2 3 4
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 4	0 1 2 3 4
Barren, Bare Dirt or Duff	0 1 2 3 4	0 1 2 3 4

Cover in Channel	
Filamentous Algae	0 1 2 3 4
Macrophytes	0 1 2 3 4
Woody Debris >0.3 m (Big)	0 1 2 3 4
Brush/ Woody Debris <0.3 m (Small)	0 1 2 3 4
Live Tree Roots	0 1 2 3 4
Overhanging Veg. <1 m of Surface	0 1 2 3 4
Undercut Banks	0 1 2 3 4
Boulders	0 1 2 3 4
Artificial Structures	0 1 2 3 4

Comments:

Date: / / 2005 Transect: K

CHANNEL/RIPARIAN TRANSECT FORM

Human Influence
0 = Not Present CH - Within Channel B = On Bank
C = Within 10m of Channel P = >10m of Channel

Human Influence	Left Bank					Right Bank			
Wall/ Dyke/ Rip-rap/ Revetment/ Dam	0	B	C	P	CH	0	B	C	P
Buildings	0	B	C	P	CH	0	B	C	P
Pavement/ Cleared Lot	0	B	C	P	CH	0	B	C	P
Road/ Railroad	0	B	C	P	CH	0	B	C	P
Pipes (Inlet/ Outlet)	0	B	C	P	CH	0	B	C	P
Landfill/ Trash	0	B	C	P	CH	0	B	C	P
Park/ Lawn	0	B	C	P	CH	0	B	C	P
Row Crops	0	B	C	P	CH	0	B	C	P
Pasture/ Range/ Hayfield	0	B	C	P	CH	0	B	C	P
Logging Operations	0	B	C	P	CH	0	B	C	P
Mining Activity	0	B	C	P	CH	0	B	C	P

Densiometer (0-17 Max)	
Left Bank	
CenUp	
CenDwn	
Right Bank	
CenL*	
CenR *	

*Center Left and Center Right Optional

Photograph Taken 7.5m above Transect at Transect

Inter-Transect Substrate Cross-Sectional Information

	Dist LB XX.XX m	Size Class Code	Cobble Embed. 0-100%
Left			
LCtr			
Ctr			
RCrt			
Right			

Comments:

STREAM DISCHARGE FORM

Site Code:	Date: __ __ / __ __ / 2005

Discharge: Velocity Area is the preferred option. Neutral Bouyant Object or Time Filled should only if Velocity Area will not work.

Velocity Area			
(Final Measurement Should Be Left Bank)			
	Distance from Bank (cm)	Depth (cm)	Velocity (m/sec)
1	0		
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

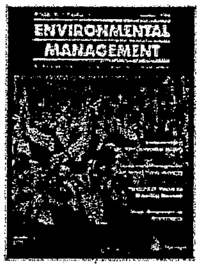
Neutral Bouyant Object			
	Float 1	Float 2	Float 3
Float Dist. (m)			
Float Time			
Cross Section on Float Reach			
	Upper Section	Middle Section	Lower Section
Width (m)			
Depth 1 (cm)			
Depth 2 (cm)			
Depth 3 (cm)			
Depth 4 (cm)			
Depth 5 (cm)			

Time Filled		
Repeat	Volume (L)	Time (sec)
1		
2		
3		
4		
5		

Comments:

A009990

Article



Environmental Management
Publisher: Springer-Verlag New York
ISSN: 0364-152X (Paper) 1432-1009 (Online)
DOI: 10.1007/s00267-004-0035-8
Issue: Volume 35, Number 4
Date: April 2005
Pages: 493 - 504

ENVIRONMENTAL ASSESSMENT

A Quantitative Tool for Assessing the Integrity of Southern Coastal California Streams

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Published online: 10 May 2005

ABSTRACT We developed a benthic macroinvertebrate index of biological integrity (B-IBI) for the semiarid and populous southern California coastal region. Potential reference sites were screened from a pool of 275 sites, first with quantitative GIS landscape analysis at several spatial scales and then with local condition assessments (in-stream and riparian) that quantified stressors acting on study reaches. We screened 61 candidate metrics for inclusion in the B-IBI based on three criteria: sufficient range for scoring, responsiveness to watershed and reach-scale disturbance gradients, and minimal correlation with other responsive metrics. Final metrics included: percent collector-gatherer + collector-filterer individuals, percent noninsect taxa, percent tolerant taxa, Coleoptera richness, predator richness, percent intolerant individuals, and EPT richness. Three metrics had lower scores in chaparral reference sites than in mountain reference sites and were scored on separate scales in the B-IBI. Metrics were scored and assembled into a composite B-IBI, which was then divided into five roughly equal condition categories. PCA analysis was used to demonstrate that the B-IBI was sensitive to composite stressor gradients; we also confirmed that the B-IBI scores were not correlated with elevation, season, or watershed area. Application of the B-IBI to an independent validation dataset (69 sites) produced results congruent with the development dataset and a separate repeatability study at four sites in the region confirmed that the B-IBI scoring is precise. The SoCal B-IBI is an effective tool with strong performance characteristics and provides a practical means of evaluating biotic condition of

DOI: 10.1007/s00267-004-0035-8

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Assemblages of freshwater organisms (e.g., fish, macroinvertebrates, and periphyton) are commonly used to assess the biotic condition of streams, lakes, and wetlands because the integrity of these assemblages provides a direct measure of ecological condition of these water bodies (Karr and Chu 1999). Both multimetric (Karr and others 1986; Kerans and Karr 1994; McCormick and others 2001; Klemm and others 2003) and multivariate (Wright and others 1983; Hawkins and others 2000; Reynoldson and others 2001) methods have been developed to characterize biotic condition and to establish thresholds of ecological impairment. In both approaches, the ability to recognize degradation at study sites relies on an understanding of the organismal assemblages expected in the absence of disturbance. Thus, the adoption of a consistent and quantifiable method for defining reference condition is fundamental to any biomonitoring program (Hughes 1995).

KEY WORDS: Benthic macroinvertebrates; B-IBI; Biomonitoring; Mediterranean climate

Published online May 10, 2005.

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Southern California faces daunting challenges in the conservation of its freshwater resources due to its aridity, its rapidly increasing human population, and its role as one of the world's top agricultural producers. In recent years, several state and federal agencies have become increasingly involved in developing analytical tools that can be used to assess the biological and physical condition of California's streams and rivers. For example, the US Environmental Protection Agency (EPA), the US Forest Service (USFS), and California's state and regional Water Quality Control Boards (WQCBs) have collected fish, periphyton and benthic macroinvertebrates (BMIs) from California streams and rivers as a critical component of regional water quality assessment and management programs. Together, these agencies have sampled BMIs from thousands of sites in California, but no analysis of BMI assemblage datasets based on comprehensively defined regional reference conditions has yet been undertaken. In the only other large-scale study within the state, Hawkins and others (2000) developed a predictive model of biotic integrity for third- to fourth-order streams on USFS lands in three montane regions in northern California. This ongoing effort (Hawkins unpublished) is an important contribution to bioassessment in the state, but the emphasis of this work has been concentrated on logging impacts within USFS lands. The lack of a broadly defined context for interpretation of BMI-based bioassessment remains the single largest impediment to the development of biocriteria for the majority of California streams and rivers. This article presents a benthic index of biotic integrity (B-IBI) for wadeable streams in southern coastal California assembled from BMI data collected in the region by the USFS, EPA, and state and regional WQCBs between 2000 and 2003.

Methods

Study Area

The Southern Coastal California B-IBI (SoCal B-IBI) was developed for the region bounded by Monterey County in the north, the Mexican border in the south, and inland by the eastern extent of the southern Coast Ranges (Figure 1). This Mediterranean climate region comprises two Level III ecoregions (Figure 1; Omernik 1987) and shares a common geology (dominated by recently uplifted and poorly consolidated marine sediments) and hydrology (precipitation averages 10–20 in./year in the lower elevations and 20–30 in./year in upper elevations, reaching 30–40 in./year in the highest elevations and in some isolated coastal watersheds (Spatial Climate Analysis Service, Oregon State University, www.climatesource.com). The human population in the region was approximately 20 million in 2000 and is projected to exceed 28 million by 2025 (California Department of Finance, Demographic Research Unit, www.dof.ca.gov).

Field Protocols and Combining Datasets

The SoCal B-IBI is based on BMI and physical habitat data collected from 275 sites (Figure 1) using the 3 protocols described in the following subsections. Sites were sampled during base flow periods between April and October of 2000–2003.

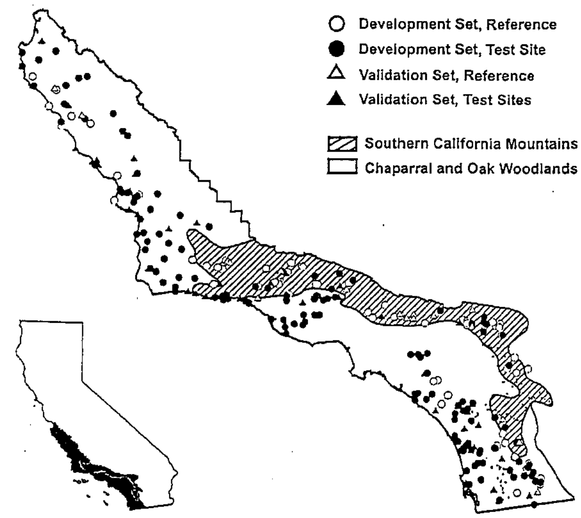

Figure 1. Map of study area showing the location of the study area within California, the distribution of test and reference sites and development and validation sites, and the boundaries of the two main ecoregions in the study area.

California Stream Bioassessment Protocol (CSBP, 144 sites). Several of the regional WQCBs in southern coastal California have implemented biomonitoring programs in their respective jurisdictions and have collected BMIs according to the CSBP (Harrington 1999). At CSBP sites, three riffles within a 100-m reach were randomly selected for sampling. At each riffle, a transect was established perpendicular to the flow, from which three separate areas of 0.18 m^2 each were sampled upstream of a 0.3-m-wide D-frame net and composited by transect. A total of 1.82 m^2 of substrate was sampled per reach and 900 organisms were subsampled from this material (300 organisms were processed separately from each of 3 transects). Water chemistry data were collected in accordance with the protocols of the different regional WQCBs (Puckett 2002) and qualitative physical habitat characteristics were measured according to Barbour and others (1999) and Harrington (1999).

USFS (56 sites). The USFS sampled streams on national forest lands in southern California in 2000 and 2001 using the targeted riffle protocol of Hawkins and others (2001). All study reaches were selected nonrandomly as part of a program to develop an interpretive (reference) framework for the results of stream biomonitoring studies on national forests in California. BMIs were sampled at study reaches (containing at least four fast-water habitat units) by disturbing two separate 0.09-m^2 areas of substrate upstream of a 0.3-m-wide D-frame net in each of four separate fast-water units; a total of 0.72 m^2 was disturbed and all sample material from a reach was composited. Field crews used a combination of qualitative and quantitative measures to collect physical habitat and water chemistry data (Hawkins and others 2001). A 500-organism subsample was processed from the composite sample and identified following methods described by Vinson and Hawkins (1996).

Environmental Monitoring and Assessment Program (EMAP, 75 sites). The EPA sampled study reaches in southern coastal California from 2000 through 2003 as part of its Western EMAP pilot project. A sampling reach was defined as 40 times the average stream width at the center of the reach, with a minimum reach length of 150-m and maximum length of 500-m. A BMI sample was collected at each site using the USFS methodology described earlier (Hawkins and others 2001) in addition to a standard EMAP BMI sample (not used in this analysis). A 500-organism subsample was processed in the laboratory according to EMAP standard taxonomic effort levels (Klemm and others 1990). Water chemistry samples were collected from the midpoint of each reach and analyzed using EMAP protocols (Klemm and Lazorchak 1994). Field crews recorded physical habitat data using EPA qualitative methods (Barbour and others 1999) and quantitative methods (Kaufmann and others 1999).

As part of a methods comparison study, 77 sites were sampled between 2000 and 2001 with both the CSBP and USFS protocols. The two main differences between the methods are the area sampled and the number of organisms subsampled (discussed earlier). To determine the effect of sampling methodology on assessment of biotic condition, we compared the average difference in a biotic index score between the two methods at each site. Biotic index scores were computed with seven commonly used biotic metrics (taxonomic richness, Ephemoptera, Plecoptera, and Trichoptera (EPT) richness, percent dominant taxon, sensitive EPT individuals, Shannon diversity, percent intolerant taxa, and percent scraper individuals) according to the following equation:

$$Score = \sum (x_i - \bar{x})/sem_i$$

where x_i is the site value for the *i*th metric, x is the overall mean for the *i*th metric, and SEM_i is the standard error of the mean for the *i*th metric. A score of zero is the mean value.

Because USFS-style riffle samples were collected at all EMAP sites, only two field methods were combined in this study. All EMAP and CSBP samples were collected and processed by the California Department of Fish and Game's Aquatic Bioassessment Laboratory (ABL) and all USFS samples were processed by the US Bureau of Land Management's Bug Lab in Logan, Utah. Taxonomic data from both labs were combined in an MS Access© database application that standardized BMI taxonomic effort levels and metric calculations, allowing us to minimize any differences between the two labs that processed samples. Taxonomic effort followed standards defined by the California Aquatic Macroinvertebrate Laboratory Network (CAMLnet 2002; www.dfg.ca.gov/cabw/camlnetste.pdf). Sites with fewer than 450 organisms sampled were omitted from the analyses.

Screening Reference Sites

We followed an objective and quantitative reference site selection procedure in which potential reference sites were first screened with quantitative Geographical Information System (GIS) land-use analysis at several spatial scales and then local condition assessments (instream and riparian) were used to quantify stressors acting within study reaches. We calculated the proportions of different land-cover classes and other measures of human activity upstream of each site at four spatial scales that give unique information about potential stressors acting on each site: (1) within polygons delimiting the entire watershed upstream of each sampling site, (2) within polygons representing local regions (defined as the intersection of a 5-km-radius circle around each site and the primary watershed polygon), (3) within a 120-m riparian zone on each side of all streams within each watershed, and (4) within a 120-m riparian zone in the local region. We used the ArcView® (ESRI 1999) extension ATtILA (Ebert and Wade 2002) to calculate the percentage of various land-cover classes (urban, agriculture, natural, etc.) and other measures of human activity (population density, road density, etc.) in each of the four spatial areas defined for each site. Two satellite imagery datasets from the mid-1990s were combined for the land-cover analyses: California Land Cover Mapping & Monitoring Program (LCMMP) vegetation data (CalVEG) and a recent dataset produced by the Central Coast Watershed Group (Newman and Watson 2003). Population data were derived from the 2000 migrated TIGER dataset (California Department of Forestry and Fire Protection, www.cdf.ca.gov). Stream layers were obtained from the US Geological Survey (USGS) National Hydrography Dataset (NHD). The road network was obtained from the California Spatial Information Library (CaSIL, gis.ca.gov) and elevation was based on the USGS National Elevation Dataset (NED). Frequency histograms of land-use percentages for all sites were used to establish subjective thresholds for elim-

Table 1. List of minimum or maximum landuse thresholds used for rejecting potential reference sites

Stressor metric	Definition	Threshold
N_index_L	Percentage of natural land use at the local scale	≤ 95%
Purb_L	Percental of urban land use at the local scale	> 3%
Pagt_L	Percentage of total agriculture at the local scale	> 5%
Rddens_L	Road density at the local scale	> 2.0 km/km^2
PopDens_L	Population density (2000 census) at the local scale	> 150 indiv./km^2
N_index_W	Percentage of natural landuse at the watershed scale	≤ 95%
Purb_W	Percentage of urban landuse at the watershed scale	> 5%
Pagt_W	Percentage of total agriculture at the watershed scale	> 3%
Rddens_W	Road density at the watershed scale	> 2.0 km/km^2
PopDens_W	Population density (2000 census) at the watershed scale	> 150 indiv./km^2

inating sites from the potential reference pool (Table 1). Sites were further screened from the reference pool on the basis of reach-scale conditions (obvious bank instability or erosion/ sedimentation problems, evidence of mining, dams, grazing, recent fire, recent logging).

Eighty-eight sites passed all the land-use and local condition screens and were selected as reference sites, leaving 187 sites in the test group. We randomly divided the full set of sites into a development set (206 sites total: 66 reference/140 test) and a validation set (69 sites total: 22 reference/47 test). The development set was used to screen metrics and develop scoring ranges for component B-IBI metrics; the validation set was used for an independent evaluation of B-IBI performance.

Screening Metrics and Assembling the B-IBI

Sixty-one metrics were evaluated for possible use in the SoCal B-IBI (Table 2). A multistep screening process was used to evaluate each metric for (1) sufficient range to be used in scoring, (2) responsiveness to watershed-scale and reach-scale disturbance variables, and (3) lack of correlation with other responsive metrics.

Pearson correlations between all watershed-scale and reach-scale disturbance gradients were used to define the smallest suite of independent (nonredundant) disturbance variables against which to test biological metric response. Disturbance variables with correlation coefficients $|r| \geq 0.7$ were considered redundant. Responsiveness was assessed using visual inspection of biotic metric versus disturbance gradient scatterplots and linear regression coefficients. Metrics were selected as responsive if they showed either a linear or a "wedge-shaped" relationship with disturbance gradients. Biological metrics often show a "wedge-shaped" response rather than a linear response to single disturbance gradients because the single gradient only defines the upper boundary of the biological response; other independent disturbance gradients and natural limitations on species distributions might result in lower metric values than expected from response to the single gradient. Biotic metrics and disturbance gradients were log-transformed when necessary to improve normality and equalize variances. Metrics that passed the range and responsiveness tests were tested for redundancy. Pairs of metrics with product–moment correlation coefficients $|r| \geq 0.7$ were considered redundant and the least responsive metric of the pair was eliminated.

Scoring ranges were defined for each metric using techniques described in Hughes and others (1998), McCormick and others (2001), and Klemm and others (2003). Metrics were scored on a 0–10 scale using statistical properties of the raw metric values from both reference and nonreference sites to define upper and lower thresholds. For positive metrics (those that increase as disturbance decreases), any site with a metric value equal to or greater than the 80th percentile of reference sites received a score of 10; any site with a metric value equal to or less than the 10th percentile of the nonreference sites received a score of 0; these thresholds were reversed for negative metrics (20th percentile of reference and 90th percentile of nonreference). In both cases, the remaining range of intermediate metric values was divided equally and assigned scores of 1 through 9. Before assembling the B-IBI, we tested whether any of the final metrics were significantly different between chaparral and mountain reference sites in the southern California coastal region, in which case they would require separate scoring ranges in the B-IBI. Finally, an overall B-IBI score was calculated for each site by summing the constituent metric scores and adjusting the B-IBI to a 100-point scale.

Table 2. The 61 BMI metrics screened for use in the SoCal IBI

	Disturbance variables										
Candidate metrics	U_index_W	Pagt_W	Purb_L	RdDens_L	Channel Alteration	Bank Stability	Percent Fines	Total Dissolved Solids	Total Phosphorus	Total Nitrogen	Range Test
Taxonomic group metrics											
Coleoptera richness*	M	w	M	S	S	—	—	—	—	—	P
Crustacea + Mollusca richness	—	—	—	—	—	—	—	—	—	—	F
Diptera richness	—	—	—	—	—	—	—	—	—	—	P
Elmidae richness	w	—	w	M	S	M	S	M	—	—	F
Ephemerellidae richness					S	M	M	S	—	M	F
Ephemeroptera richness	S	S	M	S	w	M	S	S	—	S	P
EPT richness*	S	S	S	S	S	S	S	S	—	S	P
Hydropsychidae richness	—	—	w	—	S	—	—	—	—	—	F
Percent Amphipoda individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Baetidae individuals	—	—	—	—	w	—	—	—	—	—	P
Percent Chironomidae individuals	—	—	—	—	—	—	—	—	M	—	P
Percent Corbicula individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Crustacea individuals	—	—	—	—	—	—	—	—	—	—	P
Percent Diptera individuals	—	w	—	—	—	—	—	—	—	—	P
Percent Elmidae individuals	—	—	—	w	M	S	S	w	—	M	P
Percent Ephemeroptera individuals	—	w	w	—	M	w	—	—	—	—	P
Percent EPT individuals	—	—	M	M	M	M	—	—	—	—	P
Percent Gatropoda individuals	—	—	—	w	—	—	—	—	—	—	P
Percent Glossosomatidae individuals	—	—	—	—	w	—	—	—	—	M	F
Percent Hydropsychidae individuals	—	—	—	M	w	M	—	—	—	—	P
Percent Hydroptilidae individuals	—	—	—	M	—	w	—	—	—	—	F
Percent Mollusca individuals	—	—	—	w	w	—	—	—	—	—	P
Percent non-*Baetis/Fallceon* Ephemeroptera individuals	w	w	—	M	w	M	—	—	w	—	P
Percent non-*Hydropsyche* Hydropsychidae individuals	—	—	—	M	w	w	—	—	—	—	F
Percent non-*Hydropsyche/Cheumatopsyche* Trichoptera individuals	w	w	—	M	w	M	M	w	—	—	P
Percent non-insect Taxa*	M	w	M	M	w	—	—	—	w	M	F
Percent Oligochaeta individuals	—	—	—	—	w	—	—	—	—	—	P
Percent Perlodidae individuals	—	—	—	w	w	—	—	—	—	—	F
Percent Plecoptera individuals	—	—	—	M	M	M	M	M	w	S	P
Percent Rhyacophilidae individuals	—	—	—	w	S	S	w	—	—	M	F
Percent Simuliidae individuals	—	w	—	w	S	w	—	—		—	P
Percent Trichoptera	w	—	—	M	M	M	M	w	w	—	P
Plecoptera richness	M	S	w	M	w	w	M	S	—	S	F
Total taxa richness	M	M	w	S	w	w	w	w	w	M	P
Trichoptera richness	S	S	S	S	S	M	S	w	—	w	P

Table 2. Continued.

Candidate metrics	Disturbance variables U_index_W	Pagt_W	Purb_L	RdDens_L	Channel Alteration	Bank Stability	Percent Fines	Total Dissolved Solids	Total Phosphorus	Total Nitrogen	Range Test
Functional feeding metrics											
Collector (filterers) richness	w	—	M	S	S	M	w	—	—	—	F
Collector (gatherers) richness	—	—	—	—	—	—	—	—	—	w	P
Percent collector (filterer) + collector (gatherer) individuals*	M	—	—	S	—	w	—	M	w	M	P
Percent collector (filterer) individuals	—	—	—	w	M	M	w	—	—	—	P
Percent collector (gatherer) individuals	—	—	—	w	M	—	—	w	M	w	P
Percent predator individuals	—	—	—	w	M	—	—	—	—	—	P
Percent scraper individuals	w	w	—	M	M	w	w	—	—	—	P
Percent scraper minus snails individuals	—	—	—	w	—	w	—	—	—	—	P
Percent shredder individuals	—	—	—	w	w	—	—	—	—	—	P
Predator richness*	S	S	w	M	w	—	—	S	—	M	P
Scraper richness	S	M	M	S	S	S	S	S	—	S	P
Shredder richness	M	M	—	M	S	—	—	—	—	M	F
Tolerance metrics											
Average tolerance value	M	w	w	S	w	—	M	—	—	w	P
Intolerant EPT richness	M	w	w	M	S	—	S	S	—	S	P
Intolerant taxa richness	M	w	w	M	S	M	S	S	—	S	P
Percent intolerant Diptera individuals	—	—	—	—	—	—	—	—	—	—	F
Percent intolerant individuals*	M	w	—	M	S	M	M	S	—	M	P
Percent intolerant scraper individuals	—	—	—	w	M	w	w	w	—	—	P
Percent of intolerant Ephemeroptera individuals	—	—	—	w	w	—	w	w	—	—	P
Percent of intolerant Trichoptera individuals	—	w	—	—	w	w	w	w	—	—	P
Percent sensitive EPT individuals	w	w	—	M	M	M	M	M	w	M	P
Percent tolerant individuals	—	—	—	—	—	—	w	w	—	—	P
Percent tolerant taxa*	w	—	w	M	—	—	—	w	—	M	P
Tolerant taxa richness	—	—	—	—	—	M	—	—	—	—	P
Others											
Percent dominant taxon	—	—	—	—	—	—	—	—	—	—	P
Shannon Diversity Index	w	w	w	M	M	w	—	w	w	w	P

Note: Each metric is indicated as having either no response (—), weak response (w), moderate response (M), or strong response (S) to each of eleven minimally correlated disturbance variables and whether each metric passed (P) or failed (F) the range test. The final seven minimally correlated metrics are indicated with an asterisk (*).

Table 3. Scoring ranges for seven component metrics in the SoCal B-IBI

Metric score	Coleoptera taxa (all sites)	EPT taxa 6	EPT taxa 8	Predator taxa (all sites)	% Collector individuals 6	% Collector individuals 8	% Intolerant individuals 6	% Intolerant individuals 8	% Noninsect taxa (all sites)	% Tolerant taxa (all sites)
10	>5	>17	>18	>12	0–59	0–39	25–100	42–100	0–8	0–4
9		16–17	17–18	12	60–63	40–46	23–24	37–41	9–12	5–8
8	5	15	16	11	64–67	47–52	21–22	32–36	13–17	9–12
7	4	13–14	14–15	10	68–71	53–58	19–20	27–31	18–21	13–16
6		11–12	13	9	72–75	59–64	16–18	23–26	22–25	17–19
5	3	9–10	11–12	8	76–80	65–70	13–15	19–22	26–29	20–22
4	2	7–8	10	7	81–84	71–76	10–12	14–18	30–34	23–25
3		5–6	8–9	6	85–88	77–82	7–9	10–13	35–38	26–29
2	1	4	7	5	89–92	83–88	4–6	6–9	39–42	30–33
1		2–3	5–6	4	93–96	89–94	1–3	2–5	43–46	34–37
0	0	0–1	0–4	0–3	97–100	95–100	0	0–1	47–100	38–100

Note: Three metrics have separate scoring ranges for the two Omernik Level III ecoregions in southern coastal California region (6 = chaparral and oak woodlands, 8 = Southern California mountains).

Validation of B-IBI and Measurement of Performance Characteristics

To test whether the distribution of B-IBI scores in reference and test sites might have resulted from chance, we compared score distributions in the development set to those in the validation set. We also investigated a separate performance issue that ambient bioassessment studies often neglect: spatial variation at the reach scale. Although our use of a validation dataset tests whether the B-IBI scoring range is repeatable (Fore and others 1996; McCormick and others 2001), we designed a separate experiment to explicitly measure index precision. Four sites were resampled in May 2003. At each site, nine riffles were sampled following the CSBP, and material from randomly selected riffles was combined into three replicates of three riffles each. B-IBI scores were then calculated for each replicate. Variance among these replicates was used to calculate the minimum detectable difference (MDD) between two B-IBI scores based on a two-sample t-test model (Zar 1999). The index range can be divided by the MDD to estimate the number of stream condition categories detectable by the B-IBI (Doberstein and others 2000; Fore and others 2001).

Results

Combining Datasets

Unmodified CSBP samples (900 count) had significantly higher biotic condition scores ($t = -6.974$, $P < 0.0001$) than did USFS samples (500 count). However, there was no difference in biotic condition scores between USFS samples and CSBP samples that were randomly subsampled to reduce the 900 count to 500 ($t = -0.817$, $P = 0.416$). Thus, data from both targeted-riffle protocols were combined in B-IBI development.

Selected Metrics

Ten nonredundant stressor gradients were selected for metric screening: percent watershed unnatural, percent watershed in agriculture, percent local watershed in urban, road density in local watershed, qualitative channel alteration score, qualitative bank stability score, percent fine substrates, total dissolved solids, total nitrogen, and total phosphorous. Twenty-three biotic metrics that passed the first two screens (range and dose response) were analyzed for redundancy with Pearson product–moment correlation, and a set of seven minimally correlated metrics was selected for the B-IBI: percent collector-gatherer + collector-filterer individuals (% collectors), percent noninsect taxa, percent tolerant taxa, Coleoptera richness, predator richness, percent intolerant individuals, and EPT richness (Table 3). All metrics rejected as redundant were derived from taxa similar to those of selected metrics, but they had weaker relationships with stressor gradients. Dose–response relationships of the selected metrics to the 10 minimally correlated stressor variables are shown in Figure 2 and reasons for rejection or acceptance of all metrics are listed in Table 2. Regression coefficients were significant at the $P \leq 0.0001$ level among all seven selected metrics and at least two stressor gradients: percent watershed unnatural and road density in local watershed (Table 4). The final seven metrics included several metric types: richness, composition, tolerance measures, and func-

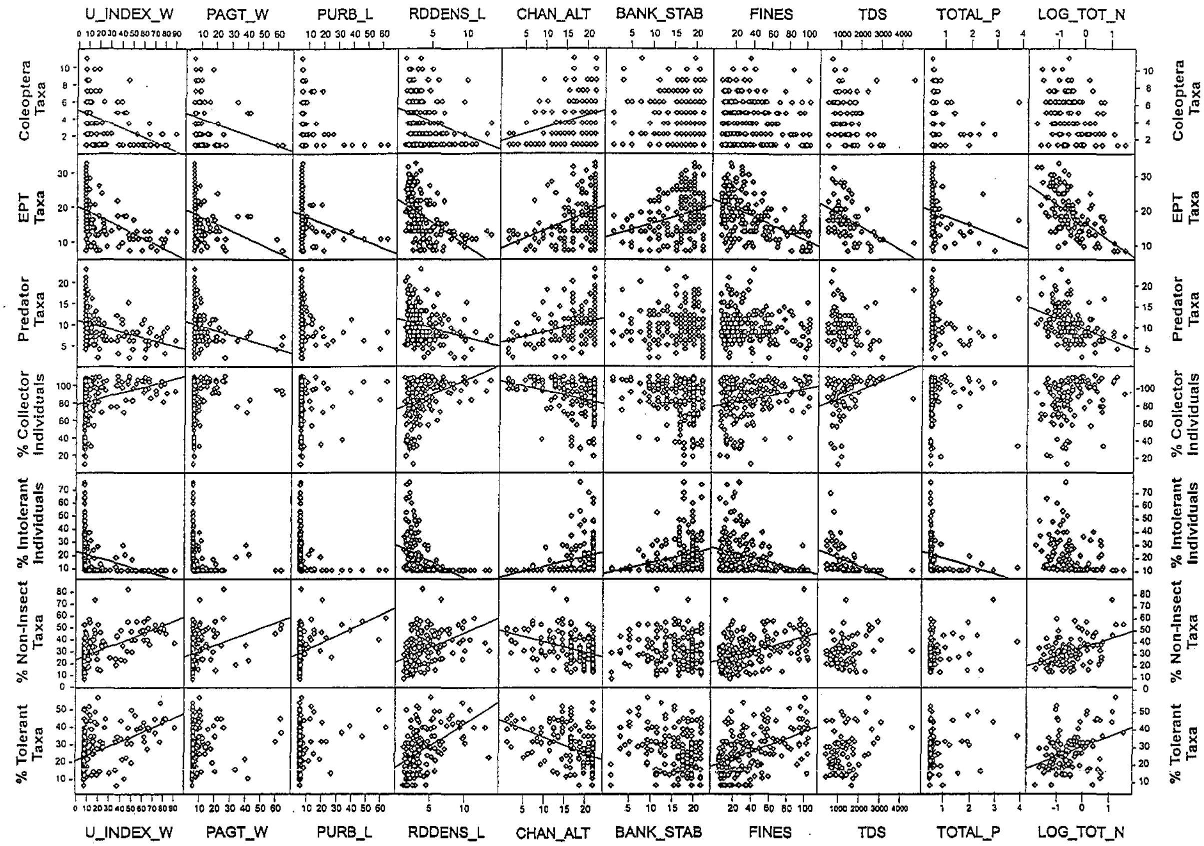

Figure 2. Scatterplots of dose–response relationships among 10 stressor gradients and 7 macroinvertebrate metrics (lines represent linear "best-fit" relationships; see text for abbreviations).

Table 4. Significance levels of linear regression relationships among 10 stressor metrics and 7 biological metrics

Metric	Coleoptera taxa	EPT taxa	Predator taxa	% Collector individuals	% Intolerant individuals	% Noninsect taxa	% Tolerant taxa
Bank Stability	0.813	**<0.0001**	0.3132	0.0009	0.0001	0.1473	0.0013
Fines	0.0017	**<0.0001**	0.0171	**0.0003**	**<0.0001**	**<0.0001**	**<0.0001**
Chan_Alt	**<0.0001**	**<0.0001**	**<0.0001**	**0.0003**	**<0.0001**	**<0.0001**	**<0.0001**
Log_U_Index_W	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Log_PAgT_W	**0.0007**	**<0.0001**	**0.0004**	0.0054	0.0014	**<0.0001**	0.0012
Log_PUrb_L	0.0367	**0.0007**	0.0344	0.6899	0.0045	**0.0002**	0.0215
Log RdDens_L	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Log_TDS	0.0094	**<0.0001**	0.0035	**0.0005**	**<0.0001**	0.0271	0.004
Log_Tot_N	0.0019	**<0.0001**	**<0.0001**	0.0078	0.0019	**<0.0001**	**<0.0001**
Log_Tot_P	0.062	**<0.0001**	0.0085	0.0162	**0.0001**	0.0018	0.0059

Note: Significant *P*-values corrected for 70 simultaneous comparisons ($P < 0.0007$) are highlighted in bold. Abbreviations are defined in Table 1 and in the text.

tional feeding groups. Because there are only seven metrics in the B-IBI, final scores calculated using this IBI are multiplied by 1.43 to adjust the scoring range to a 100-point scale.

The B-IBI scores were lower in chaparral reference sites than in mountain reference sites when calculated using unadjusted metric scores (Mann–Whitney *U*-test; $P = 0.02$). Although none of the final seven metrics

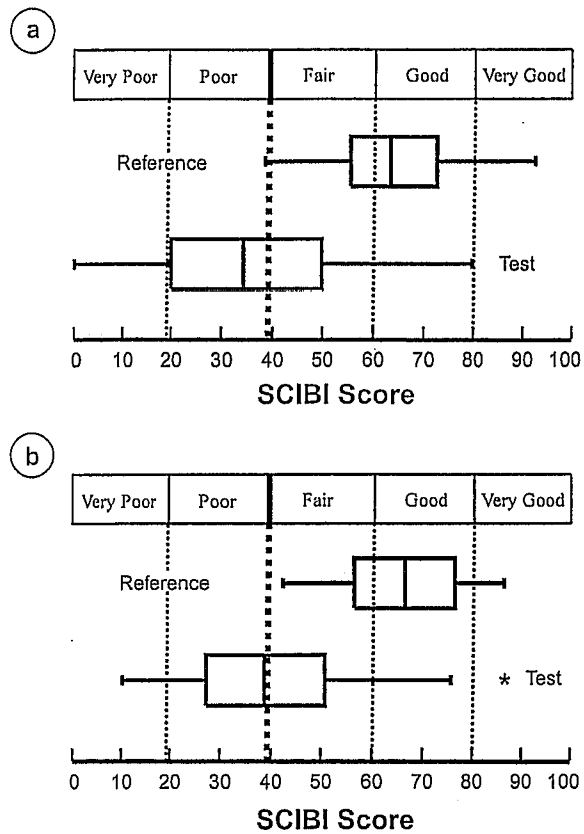

Figure 3. Box plots of B-IBI site scores for reference and test groups showing B-IBI scoring categories: (a) development sites and (b) validation sites. Dotted lines indicate condition category boundaries and heavy dotted lines indicate impairment thresholds.

were significantly different between chaparral reference sites and mountain reference sites at the $P = 0.05$ level ($P < 0.007$ after Bonferroni correction), scores for three metrics (EPT richness, percent collector-gatherer + collector-filterer individuals, and percent intolerant individuals) were substantially lower in chaparral reference sites than in mountain reference sites. We adjusted for this difference by creating separate scoring scales for the three metrics in the two ecoregions (Table 3). There was no difference in B-IBI scores between reference sites in the two ecoregions after the adjustment (Mann–Whitney U-test, $P = 0.364$).

Validation of B-IBI and Measurement of Performance Characteristics

The distribution of B-IBI scores at reference and nonreference sites was nearly identical between the development and validation data sets (Figure 3), indicating that our characterization of reference conditions and subsequent B-IBI scoring was repeatable and not likely due to chance. Based on a two-sample t-test model (setting $\alpha = 0.05$ and $\beta = 0.20$), the MDD for the SoCal IBI is 13.1. Thus, we have an 80% chance of detecting a 13.1-point difference between sites at the $P = 0.05$ level. Dividing the 100-point B-IBI scoring range by the MDD indicates that the SoCal B-IBI can detect a maximum of seven biological condition categories, a result similar to or more precise than other recent estimates of B-IBI precision (Barbour and others 1999; Fore and others 2001). We used a statistical criterion (two standard deviations below the mean reference site score) to define the boundary between "fair" and "poor" conditions, thereby setting B-IBI = 39 as an impairment threshold. The scoring range below 39 was divided into two equal condition categories, and the range above 39 was divided into three equal condition categories: 0–19 = "very poor", 20–39 = "poor", 40–59 = "fair", 60-79 = "good", and 80–100 = "very good" (Figure 3).

We ran two principle components analyses (PCAs) on the environmental stressor values used for testing metric responsiveness: 1 that included all 275 sites for which we calculated 4 watershed scale stressor values and another based on 124 sites for which we had measurements of 9 of the 10 minimally correlated stressor variables. We plotted B-IBI scores as a function of the first multivariate stressor axis from each PCA. We log-transformed percent watershed unnatural, percent watershed in agriculture, percent local watershed in urban, road density in local watershed, total nitrogen, and total phosphorous. Only PCA Axis 1 was significant in either analysis, having eigenvalues larger than those predicted from the broken-stick model (McCune and Grace 2002). In both PCAs, the B-IBI score decreased with increasing human disturbance (Figure 4) and was correlated (Spearman ρ) with PCA Axis 1 ($r = -0.652$, $P < 0.0001$ for all 275 sites; $r = -0.558$, $P \leq 0.0001$ for 124 sites). In the analysis of all 275 sites, all 4 watershed-scale stressors had high negative loadings, with percent watershed unnatural and local road density being the highest (Figure 5a). In the analysis of 124 sites, percent watershed unnatural, percent watershed in agriculture, and local road density had the highest negative loadings on the first axis, and channel alteration had the highest positive loading (Figure 4b).

Finally, we found no relationship between B-IBI scores and ecoregion (Mann–Whitney U, $P = 0.364$), Julian date ($R^2 = 0.01$, $P = 0.349$), watershed area ($R^2 = 0.002$, $P = 0.711$), or elevation ($R^2 = 0.01$, $P = 0.349$), indicating that the B-IBI scoring is robust with respect to these variables (Figure 5). Our ecoregion scoring adjustment probably corrects for the

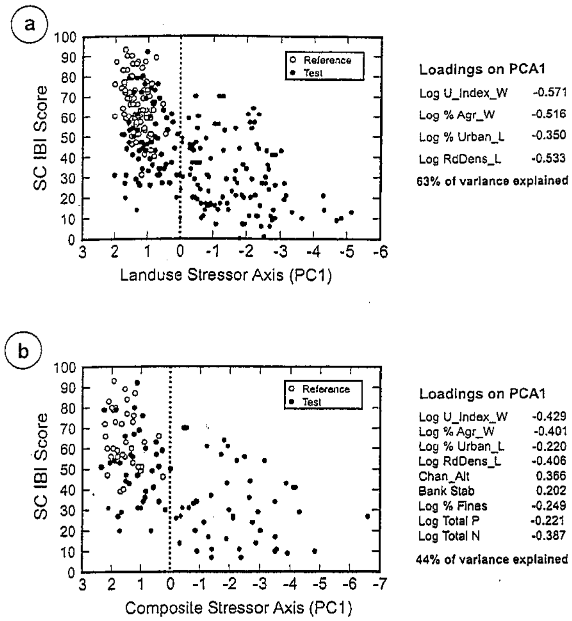

Figure 4. Scatterplots of SoCal B-IBI scores against two composite stressor axes from PCA: (a) values for all 275 sites; composite axis includes 4 land-use gradients; (b) values for 124 sites; composite axis includes 9 local and watershed scale stressor gradients.

strongest elevation effects, but there is no evidence that B-IBI scores are related to elevation differences within each ecoregion.

Discussion

The SoCal B-IBI is the most comprehensive assessment to date of freshwater biological integrity in California. As in other Mediterranean climate regions, the combination of aridity, geology, and high-amplitude cycles of seasonal flooding and drying in southern coastal California makes its streams and rivers particularly sensitive to disturbance (Gasith and Resh 1999). This sensitivity, coupled with the burgeoning human population and vast conversion of natural landscapes to agriculture and urban areas, has made it the focus of both state and federal attempts to maintain the ecological integrity of these strained aquatic resources.

Unfortunately, growing interest in biomonitoring is unmatched by financial resources available for this monitoring. Thus, combination of data among programs is very desirable, although this goal is rarely achieved in practice. We demonstrated that macroinvertebrate bioassessment data from multiple agencies could be successfully combined to produce a regional index that is useful to all agencies involved. This index is easy to apply, its fundamental assumptions are transparent, it provides precise condition assessments, and it is demonstrated to be responsive to a wide range of anthropogenic stressors. The index can also be applied throughout a long index period (mid-spring to mid-fall): Just as biotic factors tend to have more influence on assemblage structure during the summer dry period of Mediterranean climates than during the wet season when abiotic factors dominate (Cooper and others 1986; Gasith and Resh 1999), it is likely that our biotic index is more sensitive to anthropogenic stressors during the summer dry period. Because of these qualities, we expect the SoCal B-IBI to be a practical management tool for a wide range of water quality applications in the region.

This B-IBI is a regional adaptation of an approach to biotic assessment developed by Karr (1981) and subsequently extended and refined by many others (Kerans and Karr 1994; Barbour and others 1996; Fore and others 1996; Hughes and others 1998). We drew heavily upon recent refinements in multimetric index methodology that improve the objectivity and defensibility of these indices (McCormick and others 2001; Klemm and others 2003). A central goal of bioassessment is to select metrics that maximize the detection of anthropogenic stress while minimizing the noise of natural variation. One of the most important recent advances in B-IBI methods is the emphasis on quantitative screening tools for selecting appropriate metrics. We also minimized sources of redundancy in the analysis: (1) between watershed and local-scale stressor gradients for dose–response screening of biotic metrics and (2) in the final selection of metrics. The former guards against a B-IBI that is biased toward a set of highly correlated stressors and is, therefore, of limited sensitivity; the latter assures a compact B-IBI with component metrics that contribute independent information about stream condition. Combined with an assessment of responsiveness to specific regional disturbance gradients, these screening tools minimize the variability of B-IBI scores and improve its sensitivity.

The seven component metrics used in this B-IBI are similar to those selected for other B-IBIs (DeShon 1995; Barbour and others 1995, 1996; Fore and others 1996; Klemm and others 2003), but some of the metrics are either unique or are variations on other commonly used metrics. Like Klemm and others (2003), we found noninsect taxa to be responsive to human stressors, but richness was more responsive than percent of individuals. Some authors have separated the EPT metric into two or three metrics based on its component orders because the orders provided unique signals (Clements 1994; Fore and others 1996; Klemm

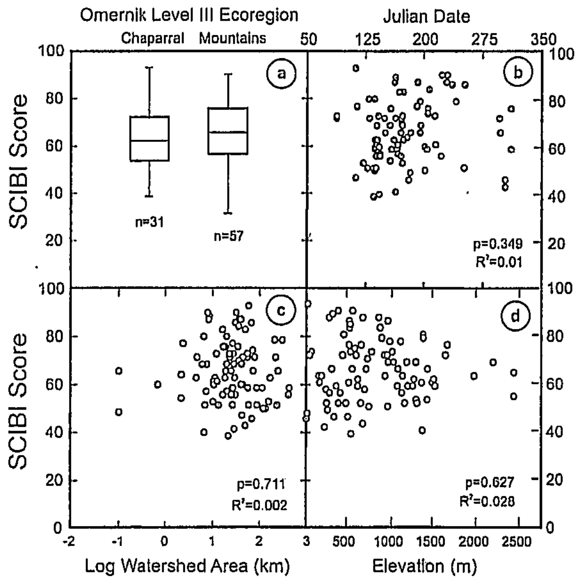

Figure 5. Relationship between B-IBI scores at 88 reference sites and (a) Omernik Level III ecoregion, (b) Julian date, (c) log watershed area, and (d) elevation.

and others 2003), but we found very similar patterns in these orders' response to various stressors we measured. To our knowledge, Coleoptera richness has not previously been included in a B-IBI, but beetle taxa might be a good indicator of the effects of fine sediments at impaired sites in this region (Brown 1973). A recent study of benthic assemblages in North Africa noted a high correspondence between EPT and EPTC (EPT + Coleoptera) (Beauchard and others 2003), but these orders were not highly correlated in our dataset. Feeding groups appear less often in B-IBIs than other metric types (Klemm and others 2003), but they were represented by two metrics in this B-IBI: predator richness and percent collectors (gatherers and filterers combined). Scraper richness was also responsive, but was rejected here because it was highly correlated with EPT richness.

The SoCal IBI should prove useful as a foundation for state and regional ambient water quality monitoring programs. Because the 75 EMAP sites were selected using a probabilistic statistical design, it will also be possible to use those samples to estimate the percentage of stream miles that are in "good", "fair", and "poor" condition in the southern California coastal region. These condition estimates, combined with stressor association techniques, have great potential to serve as a scientifically defensible basis for allocating precious monitoring resources in this region.

Acknowledgments

Major funding for this study was provided by David Gibson of the San Diego WQCB and Joseph Furnish of the USFS, with supplemental funding from other regional WQCBs in southern California. We thank James Harrington and other staff of California Department of Fish and Game's Aquatic Bioassessment Laboratory for efforts that contributed to the success of this project. Biologists Mike Dawson, Shawn McBride, and Jennifer York collected much of the field data; taxonomists Dan Pickard, Doug Post, Brady Richards, and Joe Slusark performed most of the taxonomy, except for the USFS samples, which were processed by the Bug Lab at Utah State University. Dan Heggem (US EPA, Landscape Ecology Branch), Mark Rosenberg (California Department of Forestry), and Mark Angelo (Central Coast WQCB) helped identify appropriate GIS land-use layers, and Glenn Sibbald (CDFG) assisted with watershed delineation. Mary Adams (Central Coast WQCB) collected invertebrate samples and provided local site condition data for sites in the Central Coast region. This manuscript was greatly improved by comments from Larry Brown, Joseph Furnish, Robert Hughes, Leska Fore, and three anonymous reviewers.

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EPA 841-B-99-002

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers:

Periphyton, Benthic Macroinvertebrates, and Fish
Second Edition

http://www.epa.gov/OWOW/monitoring/techmon.html

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Appropriate Citation:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

This entire document, including data forms and other appendices, can be downloaded from the website of the USEPA Office of Wetlands, Oceans, and Watersheds:

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FOREWORD

In December 1986, U.S. EPA's Assistant Administrator for Water initiated a major study of the Agency's surface water monitoring activities. The resulting report, entitled "Surface Water Monitoring: A Framework for Change" (U.S. EPA 1987), emphasizes the restructuring of existing monitoring programs to better address the Agency's current priorities, e.g., toxics, nonpoint source impacts, and documentation of "environmental results." The study also provides specific recommendations on effecting the necessary changes. Principal among these are:

1. To issue guidance on cost-effective approaches to problem identification and trend assessment.

2. To accelerate the development and application of promising biological monitoring techniques.

In response to these recommendations, the Assessment and Watershed Protection Division developed the rapid bioassessment protocols (RBPs) designed to provide basic aquatic life data for water quality management purposes such as problem screening, site ranking, and trend monitoring, and produced a document in 1989 (Plafkin et al. 1989). Although none of the protocols were meant to provide the rigor of fully comprehensive studies, each was designed to supply pertinent, cost-effective information when applied in the appropriate context.

As the technical guidance for biocriteria has been developed by EPA, states have found these protocols useful as a framework for their monitoring programs. This document was meant to have a self-corrective process as the science advances; the implementation by state water resource agencies has contributed to refinement of the original RBPs for regional specificity. This revision reflects the advancement in bioassessment methods since 1989 and provides an updated compilation of the most cost-effective and scientifically valid approaches.

DEDICATION

All of us who have dealt with the evaluation and diagnosis of perturbation to our aquatic resources owe an immeasurable debt of gratitude to *Dr. James L. Plafkin*. In addition to developing the precursor to this document in 1989, Jim was a driving force within EPA to increase the use of biology in the water pollution control program until his untimely death on February 6, 1990. Throughout his decade-long career with EPA, his expertise in ecological assessment, his dedication, and his vision were instrumental in changing commonly held views of what constitutes pollution and the basis for pollution control programs. Jim will be remembered for his love of life, his enthusiasm, and his wit. As a small token of our esteem, we dedicate this revised edition of the RBPs to his memory.

ACKNOWLEDGMENTS

Dr. James L. Plafkin of the Assessment and Watershed Protection Division (AWPD) in USEPA's Office of Water, served as principal editor and coauthor of the original Rapid Bioassessment Protocols document in 1989. Other coauthors of the original RBPs were consultants to the AWPD, Michael T. Barbour, Kimberly D. Porter, Sharon Gross and Robert M. Hughes. Principal authors of this revision are Michael T. Barbour, James (Sam) Stribling, Jeroen Gerritsen, and Blaine D. Snyder. Many others also contributed to the development of the original RBP document. Special thanks goes to the original Rapid Bioassessment Workgroup. The Workgroup, composed of both State and USEPA Regional biologists (listed in Chapter 1), was instrumental in providing a framework for the basic approach and served as primary reviewers of various drafts. Dr. Kenneth Cummins and Dr. William Hilsenhoff provided invaluable advice on formulating certain assessment metrics in the original RBP approach. Dr. Vincent Resh also provided a critical review that helped strengthen the RBP approach. While not directly involved with the development of the RBPs, Dr. James Karr provided the framework (Index of Biotic Integrity) and theoretical underpinnings for "re-inventing" bioassessment for water resource investigations. Since 1989, extensive use and application of the IBI and RBP concept has helped to refine specific elements and strengthen the overall approach. The insights and consultation provided by these numerous biologists have provided the basis for the improvements presented in this current document.

This revision of the RBPs could not have been accomplished without the support and oversight of Chris Faulkner of the USEPA Office of Water. Special thanks go to Ellen McCarron and Russell Frydenborg of Florida DEP, Kurt King of Wyoming DEQ, John Maxted of Delaware DNREC, Dr. Robert Haynes of Massachusetts DEP, and Elaine Major of University of Alaska, who provided the opportunity to test and evaluate various technical issues and regional specificity of the protocols in unique stream systems throughout the United States. Editorial and production support, report design, and HTML formatting were provided by a team of Tetra Tech staff — Brenda Fowler, Michael Bowman, Erik Leppo, James Kwon, Amanda Richardson, Christiana Daley, and Abby Markowitz. Technical assistance and critical review was provided by Dr. Jerry Diamond of Tetra Tech.

A Technical Experts Panel was convened by the USEPA to provide an in-depth review and recommendations for revisions to this document. This group of esteemed scientists provided not only useful comments, but assisted in revising sections of the document. In particular, Drs. Jan Stevenson and Loren Bahls revised the periphyton chapter; and Dr. Phil Kaufmann provided assistance on the habitat chapter. The Technical Experts Panel included:

- Dr. Reese Voshell, Virginia Tech University (Chair)
- Dr. Loren Bahls, University of Montana
- Dr. David Halliwell, Aquatic Resources Conservation Systems
- Dr. James Karr, University of Washington
- Dr. Phil Kaufmann, Oregon State University
- Dr. Billie Kerans, Montana State University
- Dr. Jan Stevenson, University of Louisville

Dr. Charles Hawkins (Utah State University) and Dr. Vincent Resh (University of California, Berkeley) served as outside readers.

Much appreciation is due to the biologists in the field (well over a hundred) who contributed their valuable time to review both the original and current documents and provide constructive input. Their help in this endeavor is sincerely appreciated.

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Acronym	**Full Name (acronym stands for)**
AFDM	Ash Free Dry Mass
ANOVA	Analysis of Variance
APHA	American Public Health Association
ASTM	American Society of Testing and Materials
AUSRIVAS	Australian River Assessment System
AWPD	Assessment and Watershed Protection Division
BEAST	Benthic Assessment of Sediment
BMP	Best Management Practices
CBWD	Chesapeake Bay and Watershed Programs
CWA	Clean Water Act
DEC	Department of Environmental Conservation
DEM	Department of Environmental Management
DEM	Division of Environmental Management
DEP	Department of Environmental Protection
DEQ	Department of Environmental Quality
DHEC	Department of Health and Environmental Control
DNR	Department of Natural Resources
DNREC	Department of Natural Resources and Environmental Control
DQO	Data Quality Objectives
EDAS	Ecological Data Application System
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
GIS	Geographic Information System
GPS	Global Positioning System
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
ITFM	Intergovernmental Task Force on Monitoring
ITIS	Integrated Taxonomic Information Service

Acronym	Full Name (acronym stands for)
IWB	Index of Well Being
MACS	Mid-Atlantic Coastal Systems
MBSS	Maryland Biological Stream Survey
MIWB	Modified Index of Well Being
NAWQA	National Water Quality Assessment Program
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source pollution
PASS	Preliminary Assessment Scoresheet
PCE	Power Cost Efficiency
POTWS	Publicly Owned Treatment Works
PTI	Pollution Tolerance Index
QA	Quality Assurance
QC	Quality Control
QHEI	Qualitative Habitat Evaluation Index
RBP	Rapid Bioassessment Protocols
RDMS	Relational Database Management System
RM	River Mile
RPS	Rapid Periphyton Survey
SAB	Science Advisory Board
SCI	Stream Quality Index
SOP	Standard Operating Procedures
STORET	Data Storage and Retrieval System
SWCB	State Water Control Board
TCR	Taxonomic Certainty Rating
TMDL	Total Maximum Daily Load
TSN	Taxonomic Serial Number
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPA	Watershed Protection Approach
WQD	Water Quality Division

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1 THE CONCEPT OF RAPID BIOASSESSMENT

1.1 PURPOSE OF THE DOCUMENT

> *Biological assessment* is an evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota in surface waters.

The primary purpose of this document is to describe a practical technical reference for conducting cost-effective biological assessments of lotic systems. The protocols presented are not necessarily intended to replace those already in use for bioassessment nor is it intended to be used as a rigid protocol without regional modifications. Instead, they provide options for agencies or groups that wish to implement rapid biological assessment and monitoring techniques. This guidance, therefore, is intended to provide basic, cost-effective biological methods for states, tribes, and local agencies that (1) have no established bioassessment procedures, (2) are looking for alternative methodologies, or (3) may need to supplement their existing programs (not supersede other bioassessment approaches that have already been successfully implemented).

The Rapid Bioassessment Protocols (RBPs) are essentially a synthesis of existing methods that have been employed by various State Water Resource Agencies (e.g., Ohio Environmental Protection Agency [EPA], Florida Department of Environmental Protection [DEP], Delaware Department of Natural Resources and Environmental Control [DNREC], Massachusetts DEP, Kentucky DEP, and Montana Department of Environmental Quality [DEQ]). Protocols for 3 aquatic assemblages (i.e., periphyton, benthic macroinvertebrates, fish) and habitat assessment are presented. All of these protocols have been tested in streams in various parts of the country. The choice of a particular protocol should depend on the purpose of the bioassessment, the need to document conclusions with confirmational data, and available resources. The original Rapid Bioassessment Protocols were designed as inexpensive screening tools for determining if a stream is supporting or not supporting a designated aquatic life use. The basic information generated from these methods would enhance the coverage of broad geographical assessments, such as State and National 305(b) Water Quality Inventories. However, members of a 1986 benthic Rapid Bioassessment Workgroup and reviewers of this document indicated that the Rapid Bioassessment Protocols can also be applied to other program areas, for example:

- ! Characterizing the existence and severity of impairment to the water resource
- ! Helping to identify sources and causes of impairment
- ! Evaluating the effectiveness of control actions and restoration activities
- ! Supporting use attainability studies and cumulative impact assessments
- ! Characterizing regional biotic attributes of reference conditions

Therefore, the scope of this guidance is considered applicable to a wider range of planning and management purposes than originally envisioned, i.e., they may be appropriate for priority setting, point and nonpoint-source evaluations, use attainability analyses, and trend monitoring, as well as initial screening.

1.2 HISTORY OF THE RAPID BIOASSESSMENT PROTOCOLS

In the mid-1980's, the need for cost-effective biological survey techniques was realized because of rapidly dwindling resources for monitoring and assessment and the extensive miles of un-assessed stream miles in the United States. It was also recognized that the biological data needed to make informed decisions relevant to the Nation's waters were greatly lacking across the country. It was further recognized that it was crucial to collect, compile, analyze, and interpret environmental data rapidly to facilitate management decisions and resultant actions for control and/or mitigation of impairment. Therefore, the principal conceptual underpinnings of the RBPs were:

- Cost-effective, yet scientifically valid, procedures for biological surveys
- Provisions for multiple site investigations in a field season
- Quick turn-around of results for management decisions
- Scientific reports easily translated to management and the public
- Environmentally-benign procedures.

The original RBPs were developed in two phases. The first phase centered on the development and refinement of the benthic macroinvertebrate protocols. The second phase involved the addition of analogous protocols pertinent to the assessment of fish assemblages.

The benthic macroinvertebrate protocols were originally developed by consolidating procedures in use by various State water quality agencies. In 1985, a survey was conducted to identify States that routinely perform screening-level bioassessments and believed that such efforts were important to their monitoring programs. Guidance documents and field methods in common use were evaluated in an effort to identify successful bioassessment methods that used different levels of effort. Original survey materials and information obtained from direct personal contacts were used to develop the draft protocols.

Missouri Department of Natural Resources (DNR) and Michigan Department of Natural Resources both used an approach upon which the screening protocol (RBP I) in the original document was based. The second (RBP II) was more time and labor intensive, incorporating field sampling and family-level taxonomy, and was a less intense version of RBP III. The concept of family-level taxonomy was based on the approach used by the Virginia State Water Control Board (SWCB) in the late 1980s. The third protocol (RBP III) incorporated certain aspects of the methods used by the North Carolina Division of Environmental Management (DEM) and the New York Department of Environmental Conservation (DEC) and was the most rigorous of the 3 approaches.

In response to a number of comments received from State and USEPA personnel on an earlier version of the RBPs, a set of fish protocols was also included. Fish protocol V was based on Karr's work (1981) with the Index of Biological Integrity (IBI), Gammon's Index of Well Being (1980), and standard fish population assessment models, coupled with certain modifications for implementation in different geographical regions. During the same time period as the development of the RBPs, Ohio EPA developed precedent-setting biological criteria using the IBI and Index of Well Being (IWB), as well as a benthic macroinvertebrate index, called the Invertebrate Community Index (ICI), and published methods and supporting documentation (Ohio EPA 1987). A substantial database on their use for site-specific fish and benthic macroinvertebrate assessments exists, and has been published (DeShon 1995, Yoder 1995, Yoder and Rankin 1995a,b). In the intervening years since 1989, several other states have followed suit with similar methods (Davis et al. 1996).

A workgroup of State and USEPA Regional biologists (listed below) was formed in the late 1980's to review and refine the original draft protocols. The Rapid Bioassessment Workgroup was convened from 1987 through 1989 and included biologists using the State methods described above and biologists from other regions where pollution sources and aquatic systems differed from those areas for which the draft protocols were initially developed.

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2 APPLICATION OF RAPID BIOASSESSMENT PROTOCOLS (RBPS)

2.1 A FRAMEWORK FOR IMPLEMENTING THE RAPID BIOASSESSMENT PROTOCOLS

The Rapid Bioassessment Protocols advocate an integrated assessment, comparing habitat (e.g., physical structure, flow regime), water quality and biological measures with empirically defined reference conditions (via actual reference sites, historical data, and/or modeling or extrapolation). Reference conditions are best established through systematic monitoring of actual sites that represent the natural range of variation in "minimally" disturbed water chemistry, habitat, and biological conditions (Gibson et al. 1996). Of these 3 components of ecological integrity, ambient water chemistry may be the most difficult to characterize because of the complex array of possible constituents (natural and otherwise) that affect it. The implementation framework is enhanced by the development of an empirical relationship between habitat quality and biological condition that is refined for a given region. As additional information is obtained from systematic monitoring of potentially impacted and site-specific control sites, the predictive power of the empirical relationship is enhanced. Once the relationship between habitat and biological potential is understood, water quality impacts can be objectively discriminated from habitat effects, and control and rehabilitation efforts can be focused on the most important source of impairment.

2.2 CHRONOLOGY OF TECHNICAL GUIDANCE

A substantial scientific foundation was required before the USEPA could endorse a bioassessment approach that was applicable on a national basis and that served the purpose of addressing impacts to surface waters from multiple stressors (see Stribling et al. 1996a). Dr. James Karr is credited for his innovative thinking and research in the mid-1970's and early 1980's that provided the formula for developing bioassessment strategies to address issues mandated by the Clean Water Act. The USEPA convened a few key workshops and conferences during a period from the mid-1970's to mid-1980's to provide an initial forum to discuss aspects of the role of biological indicators and assessment to the integrity of surface water. These workshops and conferences were attended by National scientific authorities who contributed immensely to the current bioassessment approaches advocated by the USEPA. The early RBPs benefitted from these activities, which fostered attention to biological assessment approaches. The RBPs embraced the multimetric approach described in the IBI (see Karr 1981, Karr et al. 1986) and facilitated the implementation of bioassessment into monitoring programs across the country.

Since the publication of the original RBPs in 1989, U.S. Environmental Protection Agency (USEPA) has produced substantial guidance and documentation on both bioassessment strategies and implementation policy on biological surveys and criteria for water resource programs. Much of this effort was facilitated by key scientific researchers who argued that bioassessment was crucial to the underpinnings of the Clean Water Act. The work of these researchers that led to these USEPA documents resulted in the national trend of adapting biological assessment and monitoring approaches for detecting problems, evaluating Best Management Practices (BMPs) for mitigation of nonpoint source impacts, and monitoring ecological health over time. The chronology of the crucial USEPA guidance, since the mid-1980's, relevant to bioassessment in streams and rivers is presented in Table 2-1. (See Chapter 11 [Literature Cited] for EPA document numbers.)

Table 2-1. Chronology of USEPA bioassessment guidance (relevant to streams and rivers).

Year	Document Title	Relationship to Bioassessment	Citation
1987	Surface Water Monitoring: A Framework for Change	USEPA calls for efficacious methods to assess and determine the ecological health of the nation's surface waters.	USEPA 1987
1988	Proceedings of the First National Workshop on Biological Criteria (Lincolnwood, Illinois)	USEPA brings together agency biologists and "basic" researchers to establish a framework for the initial development of biological criteria and associated biosurvey methods.	USEPA 1988
1989	Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish	The initial development of cost-effective methods in response to the mandate by USEPA (1987), which are to provide biological data on a national scale to address the goals of the Clean Water Act.	Plafkin et al. 1989
1989	Regionalization as a Tool for Managing Environmental Resources	USEPA develops the concept of ecoregions and partitions the contiguous U.S. into homogeneous regions of ecological similarity, providing a basis for establishment of regional reference conditions.	Gallant et al. 1989
1990	Second National Symposium on Water Quality Assessment: Meeting Summary	USEPA holds a series of National Water Quality Symposia. In this second symposium, biological monitoring is introduced as an effective means to evaluating the quality of water resources.	USEPA 1990a
1990	Biological Criteria: National Program Guidance for Surface Waters	The concept of biological criteria is described for implementation into state water quality programs. The use of biocriteria for evaluating attainment of "aquatic life use" is discussed.	USEPA 1990b
1990	Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters	This USEPA document is a compilation of the current "state-of-the-art" field and laboratory methods used for surveying benthic macroinvertebrates in all surface waters (i.e., streams, rivers, lakes, and estuaries).	Klemm et al. 1990
1991	Biological Criteria: State Development and Implementation Efforts	The status of biocriteria and bioassessment programs as of 1990 is summarized here.	USEPA 1991a
1991	Biological Criteria Guide to Technical Literature	A limited literature survey of relevant research papers and studies is compiled for use by state water resource agencies.	USEPA 1991b
1991	Technical Support Document for Water Quality–Based Toxics Control	USEPA describes the approach for implementing water quality-based toxics control of the nation's surface waters, and discusses the value of integrating three monitoring tools, i.e., chemical analyses, toxicity testing, and biological surveys.	USEPA 1991c
1991	Biological Criteria: Research and Regulation, Proceedings of the Symposium	This national symposium focuses on the efficacy of implementing biocriteria in all surface waters, and the proceedings documents the varied applicable approaches to bioassessments.	USEPA 1991d

Table 2-1. Chronology of USEPA bioassessment guidance (relevant to streams and rivers) (Continued).

Year	Document Title	Relationship to Bioassessment	Citation
1991	Report of the Ecoregions Subcommittee of the Ecological Processes and Effects Committee	The SAB (Science Advisory Board) reports favorably that the use of ecoregions is a useful framework for assessing regional fauna and flora. Ecoregions become more widely viewed as a basis for establishing regional reference conditions.	USEPA 1991e
1991	Guidance for the Implementation of Water Quality–Based Decisions: The TMDL Process	The establishment of the TMDL (total maximum daily loads) process for cumulative impacts (nonpoint and point sources) supports the need for more effective monitoring tools, including biological and habitat assessments.	USEPA 1991f
1991	Design Report for EMAP, the Environmental Monitoring and Assessment Program	USEPA's Environmental Monitoring and Assessment Program (EMAP) is designed as a rigorous national program for assessing the ecological status of the nation's surface waters.	Overton et al. 1991
1992	Procedures for Initiating Narrative Biological Criteria	A discussion of the concept and rationale for establishing narrative expressions of biocriteria is presented in this USEPA document.	Gibson 1992
1992	Ambient Water-Quality Monitoring in the U.S. First Year Review, Evaluation, and Recommendations	Provide first-year summary of task force efforts to develop and recommend framework and approach for improving water resource quality monitoring.	ITFM 1992
1993	Fish Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters	A compilation of the current "state-of-the-art" field and laboratory methods used for surveying the fish assemblage and assessing fish health is presented in this document.	Klemm et al. 1993
1994	Surface Waters and Region 3 Regional Environmental Monitoring and Assessment Program: 1994 Pilot Field Operations and Methods Manual for Streams	USEPA focuses its EMAP program on streams and wadeable rivers and initiates an approach in a pilot study in the Mid-Atlantic Appalachian mountains.	Klemm and Lazorchak 1994
1994	Watershed Protection: TMDL Note #2, Bioassessment and TMDLs	USEPA describes the value and application of bioassessment to the TMDL process.	USEPA 1994a
1994	Report of the Interagency Biological Methods Workshop	Summary and results of workshop designed to coordinate monitoring methods among multiple objectives and states. [Sponsored by the USGS]	Gurtz and Muir 1994
1995	Generic Quality Assurance Project Plan Guidance for Programs Using Community Level Biological Assessment in Wadeable Streams and Rivers	USEPA develops guidance for quality assurance and quality control for biological survey programs.	USEPA 1995a
1995	The Strategy for Improving Water Quality Monitoring in the United States: Final Report of the Intergovernmental Task Force on Monitoring Water Quality	An Intergovernmental Task Force (ITFM) comprised of several federal and state agencies draft a monitoring strategy intended to provide a cohesive approach for data gathering, integration, and interpretation.	ITFM 1995a
1995	The Strategy for Improving Water Quality Monitoring in the United States: Final Report of the Intergovernmental Task Force on Monitoring Water Quality, Technical Appendices	Various issue papers are compiled in these technical appendices associated with ITFM's final report.	ITFM 1995b

Table 2-1. Chronology of USEPA bioassessment guidance (relevant to streams and rivers) (Continued).

Year	Document Title	Relationship to Bioassessment	Citation
1995	Environmental Monitoring and Assessment Program Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams	A revision and update of the 1994 Methods Manual for EMAP.	Klemm and Lazorchak 1995
1996	Biological Assessment Methods, Biocriteria, and Biological Indicators: Bibliography of Selected Technical, Policy, and Regulatory Literature	USEPA compiles a comprehensive literature survey of pertinent research papers and studies for biological assessment methods. This document is expanded and updated from USEPA 1991b.	Stribling et al. 1996a
1996	Summary of State Biological Assessment Programs for Wadeable Streams and Rivers	The status of bioassessment and biocriteria programs in state water resource programs is summarized in this document, providing an update of USEPA 1991a.	Davis et al. 1996
1996	Biological Criteria: Technical Guidance for Streams and Small Rivers	Technical guidance for development of biocriteria for streams and wadeable rivers is provided as a follow-up to the Program Guidance (USEPA 1990b). This technical guidance serves as a framework for developing guidance for other surface water types.	Gibson et al. 1996
1996	The Volunteer Monitor's Guide to Quality Assurance Project Plans	USEPA develops guidance for quality assurance for citizen monitoring programs.	USEPA 1996a
1996	Nonpoint Source Monitoring and Evaluation Guide	USEPA describes how biological survey methods are used in nonpoint-source investigations, and explains the value of biological and habitat assessment to evaluating BMP implementation and identifying impairment.	USEPA 1996b
1996	Biological Criteria: Technical Guidance for Survey Design and Statistical Evaluation of Biosurvey Data	USEPA describes and define different statistical approaches for biological data analysis and development of biocriteria.	Reckhow and Warren-Hicks 1996
1997	Estuarine/Near Coastal Marine Waters Bioassessment and Biocriteria Technical Guidance	USEPA provides technical guidance on biological assessment methods and biocriteria development for estuarine and near coastal waters.	USEPA 1997a
1997	Volunteer Stream Monitoring: A Methods Manual	USEPA provides guidance for citizen monitoring groups to use biological and habitat assessment methods for monitoring streams. These methods are based in part on the RBPs.	USEPA 1997b
1997	Guidelines for Preparation of Comprehensive State Water Quality Assessments (305[b] reports)	USEPA provides guidelines for states for preparing 305(b) reports to Congress.	USEPA 1997c
1997	Biological Monitoring and Assessment: Using Multimetric Indexes Effectively	An explanation of the value, use, and scientific principles associated with using a multimetric approach to bioassessment is provided by Drs. Karr and Chu.	Karr and Chu 1999
1998	Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document	USEPA provides technical guidance on biological assessment methods and biocriteria development for lakes and reservoirs.	USEPA 1998

Year	Document Title	Relationship to Bioassessment	Citation
1998	Environmental Monitoring and Assessment Program Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams	A revision and update of the 1995 Methods Manual for EMAP.	Lazorchak et al. 1998

2.3 PROGRAMMATIC APPLICATIONS OF BIOLOGICAL DATA

States (and tribes to a certain extent) are responsible for identifying water quality problems, especially those waters needing Total Maximum Daily Loads (TMDLs), and evaluating the effectiveness of point and nonpoint source water quality controls. The biological monitoring protocols presented in this guidance document will strengthen a state's monitoring program if other bioassessment and monitoring techniques are not already in place. An effective and thorough biological monitoring program can help to improve reporting (e.g., 305(b) reporting), increase the effectiveness of pollution prevention efforts, and document the progress of mitigation efforts. This section provides suggestions for the application of biological monitoring to wadeable streams and rivers through existing state programs.

2.3.1 CWA Section 305(b)—Water Quality Assessment

Section 305(b) establishes a process for reporting information about the quality of the Nation's water resources (USEPA 1997c, USEPA 1994b). States, the District of Columbia, territories, some tribes, and certain River Basin Commissions have developed programs to monitor surface and ground waters and to report the current status of water quality biennially to USEPA. This information is compiled into a biennial *National Water Quality Inventory* report to Congress.

Use of biological assessment in section 305(b) reports helps to define an understandable endpoint of relevance to society—the biological integrity of waterbodies. Many of the better-known and widely reported pollution cleanup success stories have involved the recovery or reappearance of valued sport fish and other pollution-intolerant species to systems from which they had disappeared (USEPA 1980). Improved coverage of biological integrity issues, based on monitoring protocols with clear bioassessment endpoints, will make the section 305(b) reports more accessible and meaningful to many segments of the public.

Biological monitoring provides data that augment several of the section 305(b) reporting requirements. In particular, the following assessment activities and reporting requirements are enhanced through the use of biological monitoring information:

! Determine the status of the water resource (Are the designated/beneficial and aquatic life uses being met?).

! Evaluate the causes of degraded water resources and the relative contributions of pollution sources.

! Report on the activities underway to assess and restore water resource integrity.

! Determine the effectiveness of control and mitigation programs.

! Measure the success of watershed management plans.

2.3.2 CWA Section 319—Nonpoint Source Assessment

The 1987 Water Quality Act Amendments to the Clean Water Act (CWA) added section 319, which established a national program to assess and control nonpoint source (NPS) pollution. Under this program, states are asked to assess their NPS pollution problems and submit these assessments to USEPA. The assessments include a list of "navigable waters within the state which, without additional action to control nonpoint source of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards or the goals and requirements of this Act." Other activities under the section 319 process require the identification of categories and subcategories of NPS pollution that contribute to the impairment of waters, descriptions of the procedures for identifying and implementing BMPs, control measures for reducing NPS pollution, and descriptions of state and local programs used to abate NPS pollution. Based on the assessments, states have prepared nonpoint source management programs.

Assessment of biological condition is the most effective means of evaluating cumulative impacts from nonpoint sources, which may involve habitat degradation, chemical contamination, or water withdrawal (Karr 1991). Biological assessment techniques can improve evaluations of nonpoint source pollution controls (or the combined effectiveness of current point and nonpoint source controls) by comparing biological indicators before and after implementation of controls. Likewise, biological attributes can be used to measure site-specific ecosystem response to remediation or mitigation activities aimed at reducing nonpoint source pollution impacts or response to pollution prevention activities.

2.3.3 Watershed Protection Approach

Since 1991, USEPA has been promoting the Watershed Protection Approach (WPA) as a framework for meeting the Nation's remaining water resource challenges (USEPA 1994c). USEPA's Office of Water has taken steps to reorient and coordinate point source, nonpoint source, surface waters, wetlands, coastal, ground water, and drinking water programs in support of the watershed approach. USEPA has also promoted multi-organizational, multi-objective watershed management projects across the Nation.

The watershed approach is an integrated, inclusive strategy for more effectively protecting and managing surface water and ground water resources and achieving broader environmental protection objectives using the naturally defined hydrologic unit (the watershed) as the integrating management unit. Thus, for a given watershed, the approach encompasses not only the water resource, such as a stream, river, lake, estuary, or aquifer, but all the land from which water drains to the resource. The watershed approach places emphasis on all aspects of water resource quality—physical (e.g., temperature, flow, mixing, habitat); chemical (e.g., conventional and toxic pollutants such as nutrients and pesticides); and biological (e.g., health and integrity of biotic communities, biodiversity).

As states develop their Watershed Protection Approach (WPA), biological assessment and monitoring offer a means of conducting comprehensive evaluations of ecological status and improvements from restoration/rehabilitation activities. Biological assessment integrates the condition of the watershed from tributaries to mainstem through the exposure/response of indigenous aquatic communities.

2.3.4 CWA Section 303(d)—The TMDL Process

The technical backbone of the WPA is the TMDL process. A total maximum daily load (TMDL) is a tool used to achieve applicable water quality standards. The TMDL process quantifies the loading capacity of a waterbody for a given stressor and ultimately provides a quantitative scheme for allocating loadings (or external inputs) among pollutant sources (USEPA 1994a). In doing so, the TMDL quantifies the relationships among sources, stressors, recommended controls, and water quality conditions. For example, a TMDL might mathematically show how a specified percent reduction of a pollutant is necessary to reach the pollutant concentration reflected in a water quality standard.

Section 303(d) of the CWA requires each state to establish, in accordance with its priority rankings, the total maximum daily load for each waterbody or reach identified by the state as failing to meet, or not expected to meet, water quality standards after imposition of technology-based controls. In addition, TMDLs are vital elements of a growing number of state programs. For example, as more permits incorporate water quality-based effluent limits, TMDLs are becoming an increasingly important component of the point-source control program.

TMDLs are suitable for nonchemical as well as chemical stressors (USEPA 1994a). These include all stressors that contribute to the failure to meet water quality standards, as well as any stressor that presently threatens but does not yet impair water quality. TMDLs are applicable to waterbodies impacted by both point and nonpoint sources. Some stressors, such as sediment deposition or physical alteration of instream habitat, might not clearly fit traditional concepts associated with chemical stressors and loadings. For these nonchemical stressors, it might sometimes be difficult to develop TMDLs because of limitations in the data or in the technical methods for analysis and modeling. In the case of nonpoint source TMDLs, another difficulty arises in that the CWA does not provide well-defined support for regulatory control actions as it does for point source controls, and controls based on another statutory authority might be necessary.

Biological assessments and criteria address the cumulative impacts of all stressors, especially habitat degradation, and chemical contamination, which result in a loss of biological diversity. Biological information can help provide an ecologically based assessment of the status of a waterbody and as such can be used to decide which waterbodies need TMDLs (USEPA 1997c) and aid in the ranking process by targeting waters for TMDL development with a more accurate link between bioassessment and ecological integrity.

Finally, the TMDL process is a geographically-based approach to preparing load and wasteload allocations for sources of stress that might impact waterbody integrity. The geographic nature of this process will be complemented and enhanced if ecological regionalization is applied as part of the bioassessment activities. Specifically, similarities among ecosystems can be grouped into homogeneous classes of streams and rivers that provides a geographic framework for more efficient aquatic resource management.

2.3.5 CWA Section 402—NPDES Permits and Individual Control Strategies

All point sources of wastewater must obtain a National Pollutant Discharge Elimination System (NPDES) permit (or state equivalent), which regulates the facility's discharge of pollutants. The approach to controlling and eliminating water pollution is focused on the pollutants determined to be harmful to receiving waters and on the sources of such pollutants. Authority for issuing NPDES permits is established under Section 402 of the CWA (USEPA 1989).

Point sources are generally divided into two types—industrial and municipal. Nationwide, there are approximately 50,000 industrial sources, which include commercial and manufacturing facilities. Municipal sources, also known as publicly owned treatment works (POTWs), number about 15,700 nationwide. Wastewater from municipal sources results from domestic wastewater discharged to POTWs, as well as the "indirect" discharge of industrial wastes to sewers. In addition, stormwater may be discrete or diffuse, but is also covered by NPDES permitting regulations.

USEPA does not recommend the use of biological survey data as the basis for deriving an effluent limit for an NPDES permit (USEPA 1994d). Unlike chemical-specific water quality analyses, biological data do not measure the concentrations or levels of chemical stressors. Instead, they directly measure the impacts of any and all stressors on the resident aquatic biota. Where appropriate, biological assessment can be used within the NPDES process (USEPA 1994d) to obtain information on the status of a waterbody where point sources might cause, or contribute to, a water quality problem. In conjunction with chemical water quality and whole-effluent toxicity data, biological data can be used to detect previously unmeasured chemical water quality problems and to evaluate the effectiveness of implemented controls.

Some states have already demonstrated the usefulness of biological data to indicate the need for additional or more stringent permit limits (e.g., sole-source discharge into a stream where there is no significant nonpoint source discharge, habitat degradation, or atmospheric deposition) (USEPA 1994d). In these situations, the biological findings triggered additional investigations to establish the cause-and-effect relationship and to determine the appropriate limits. In this manner, biological data support regulatory evaluations and decision making. Biological data can also be useful in monitoring highly variable or diffuse sources of pollution that are treated as point sources such as wet-weather discharges and stormwater runoff (USEPA 1994d). Traditional chemical water quality monitoring is usually only minimally informative for these types of point source pollution, and a biological survey of their impact might be critical to effectively evaluate these discharges and associated treatment measures.

2.3.6 Ecological Risk Assessment

Risk assessment is a scientific process that includes stressor identification, receptor characterization and endpoint selection, stress-response assessment, and risk characterization (USEPA 1992, Suter et al. 1993). Risk management is a decision-making process that involves all the human-health and ecological assessment results, considered with political, legal, economic, and ethical values, to develop and enforce environmental standards, criteria, and regulations (Maughan 1993). Risk assessment can be performed on an on-site basis or can be geographically-based (i.e., watershed or regional scale), and it can be used to assess human health risks or to identify ecological impairments. In early 1997, a report prepared by a Presidential/Congressional Commission on risk enlarged the context of risk to include ecological as well as public health risks (Karr and Chu 1997).

Biological monitoring is the essential foundation of ecological risk assessment because it measures present biological conditions — not just chemical contamination — and provides the means to compare them with the conditions expected in the absence of humans (Karr and Chu 1997). Results of regional bioassessment studies can be used in watershed ecological risk assessments to develop broad scale (geographic) empirical models of biological responses to stressors. Such models can then be used, in combination with exposure information, to predict risk due to stressors or to alternative management actions. Risks to biological resources are characterized, and sources of stress can be prioritized. Watershed risk managers can and should use such results for critical management decisions.

2.3.7 USEPA Water Quality Criteria and Standards

The water quality standards program, as envisioned in Section 303(c) of the Clean Water Act, is a joint effort between the states and USEPA. The states have primary responsibility for setting, reviewing, revising, and enforcing water quality standards. USEPA develops regulations, policies, and guidance to help states implement the program and oversees states' activities to ensure that their adopted standards are consistent with the requirements of the CWA and relevant water quality standards regulations (40 CFR Part 131). USEPA has authority to review and approve or disapprove state standards and, where necessary, to promulgate federal water quality standards.

A water quality standard defines the goals of a waterbody, or a portion thereof, by designating the use or uses to be made of the water, setting criteria necessary to protect those uses, and preventing degradation of water quality through antidegradation provisions. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and protect biological integrity.

Chemical, physical, or biological stressors impact the biological characteristics of an aquatic ecosystem (Gibson et al. 1996). For example, chemical stressors can result in impaired functioning or loss of a sensitive species and a change in community structure. Ultimately, the number and intensity of all stressors within an ecosystem will be evidenced by a change in the condition and function of the biotic community. The interactions among chemical, physical, and biological stressors and their cumulative impacts emphasize the need to directly detect and assess the biota as indicators of actual water resource impairments.

Sections 303 and 304 of the CWA require states to protect biological integrity as part of their water quality standards. This can be accomplished, in part, through the development and use of biological criteria. As part of a state or tribal water quality standards program, biological criteria can provide scientifically sound and detailed descriptions of the designated aquatic life use for a specific waterbody or segment. They fulfill an important assessment function in water quality-based programs by establishing the biological benchmarks for (1) directly measuring the condition of the aquatic biota, (2) determining water quality goals and setting priorities, and (3) evaluating the effectiveness of implemented controls and management actions.

Biological criteria for aquatic systems provide an evaluation benchmark for direct assessment of the condition of the biota that live either part or all of their lives in aquatic systems (Gibson et al. 1996) by describing (in narrative or numeric criteria) the expected biological condition of a minimally impaired aquatic community (USEPA 1990b). They can be used to define ecosystem rehabilitation goals and assessment endpoints. Biological criteria supplement traditional measurements (for example, as backup for hard-to-detect chemical problems) and will be particularly useful in assessing impairment due to nonpoint source pollution and nonchemical (e.g., physical and biological) stressors. Thus, biological criteria fulfill a function missing from USEPA's traditionally chemical-oriented approach to pollution control and abatement (USEPA 1994d).

Biological criteria can also be used to refine the aquatic life use classifications for a state. Each state develops its own designated use classification system based on the generic uses cited in the CWA, including protection and propagation of fish, shellfish, and wildlife. States frequently develop subcategories to refine and clarify designated use classes when several surface waters with distinct characteristics fit within the same use class or when waters do not fit well into any single category. As data are collected from biosurveys to develop a biological criteria program, analysis may reveal unique and consistent differences between aquatic communities that inhabit different waters with the same designated use. Therefore, measurable biological attributes can be used to refine aquatic life use or to separate 1 class of aquatic life into 2 or more subclasses. For example, Ohio has established an *exceptional warmwater* use class to include all *unique waters* (i.e., not representative of regional streams and different from their standard warmwater class).

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3 ELEMENTS OF BIOMONITORING

3.1 BIOSURVEYS, BIOASSAYS, AND CHEMICAL MONITORING

The water quality-based approach to pollution assessment requires various types of data. Biosurvey techniques, such as the Rapid Bioassessment Protocols (RBPs), are best used for detecting aquatic life impairments and assessing their relative severity. Once an impairment is detected, however, additional ecological data, such as chemical and biological (toxicity) testing is helpful to identify the causative agent, its source, and to implement appropriate mitigation (USEPA 1991c). Integrating information from these data types as well as from habitat assessments, hydrological investigations, and knowledge of land use is helpful to provide a comprehensive diagnostic assessment of impacts from the 5 principal factors (see Karr et al. 1986, Karr 1991, Gibson et al. 1996 for description of water quality, habitat structure, energy source, flow regime, and biotic interaction factors). Following mitigation, biosurveys are important for evaluating the effectiveness of such control measures. Biosurveys may be used within a planning and management framework to prioritize water quality problems for more stringent assessments and to document "environmental recovery" following control action and rehabilitation activities. Some of the advantages of using biosurveys for this type of monitoring are:

! Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity). Therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act (CWA).

! Biological communities integrate the effects of different stressors and thus provide a broad measure of their aggregate impact.

! Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

! Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to the cost of assessing toxic pollutants, either chemically or with toxicity tests (Ohio EPA 1987).

! The status of biological communities is of direct interest to the public as a measure of a pollution free environment.

! Where criteria for specific ambient impacts do not exist (e.g., nonpoint-source impacts that degrade habitat), biological communities may be the only practical means of evaluation.

Biosurvey methods have a long-standing history of use for "before and after" monitoring. However, the intermediate steps in pollution control, i.e., identifying causes and limiting sources, require integrating information of various types—chemical, physical, toxicological, and/or biosurvey data. These data are needed to:

Identify the specific stress agents causing impact: This may be a relatively simple task; but, given the array of potentially important pollutants (and their possible combinations), it is likely to be both difficult and costly. In situations where specific chemical stress agents are either poorly understood or too varied to assess individually, toxicity tests can be used to focus specific chemical investigations or to characterize generic stress agents (e.g., whole effluent or ambient toxicity). For situations where habitat degradation is prevalent, a combination of biosurvey and physical habitat assessment is most useful (Barbour and Stribling 1991).

Identify and limit the specific sources of these agents: Although biosurveys can be used to help locate the likely origins of impact, chemical analyses and/or toxicity tests are helpful to confirm the point sources and develop appropriate discharge limits. Impacts due to factors other than chemical contamination will require different ecological data.

Design appropriate treatment to meet the prescribed limits and monitor compliance: Treatment facilities are designed to remove identified chemical constituents with a specific efficiency. Chemical data are therefore required to evaluate treatment effectiveness. To some degree, a biological endpoint resulting from toxicity testing can also be used to evaluate the effectiveness of prototype treatment schemes and can serve as a design parameter. In most cases, these same parameters are limited in discharge permits and, after controls are in place, are used to monitor for compliance. Where discharges are not controlled through a permit system (e.g., nonpoint-source runoff, combined sewer outfalls, and dams) compliance must be assessed in terms of ambient standards. Improvement of the ecosystem both from restoration or rehabilitation activities are best monitored by biosurvey techniques.

Effective implementation of the water quality-based approach requires that various monitoring techniques be considered within a larger context of water resource management. Both biological and chemical methods play critical roles in a successful pollution control program. They should be considered complementary rather than mutually exclusive approaches that will enhance overall program effectiveness when used appropriately.

3.2 USE OF DIFFERENT ASSEMBLAGES IN BIOSURVEYS

The techniques presented in this document focus on the evaluation of water quality (physicochemical constituents), habitat parameters, and analysis of the periphyton, benthic macroinvertebrate, and fish assemblages. Many State water quality agencies employ trained and experienced benthic biologists, have accumulated considerable background data on macroinvertebrates, and consider benthic surveys a useful assessment tool. However, water quality standards, legislative mandate, and public opinion are more directly related to the status of a waterbody as a fishery resource. For this reason, separate protocols were developed for fish and were incorporated as Chapter 8 in this document. The fish survey protocol is based largely on Karr's Index of Biotic Integrity (IBI) (Karr 1981, Karr et al. 1986, Miller et al. 1988), which uses the structure of the fish assemblage to evaluate water quality. The integration of functional and structural/compositional metrics, which forms the basis for the IBI, is a common element to the rapid bioassessment approaches.

The periphyton assemblage (primarily algae) is also useful for water quality monitoring, but has not been incorporated widely in monitoring programs. They represent the primary producer trophic level, exhibit a different range of sensitivities, and will often indicate effects only indirectly observed in the benthic and fish communities. As in the benthic macroinvertebrate and fish assemblages, integration of structural/compositional and functional characteristics provides the best means of assessing impairment (Rodgers et al. 1979).

In selecting the aquatic assemblage appropriate for a particular biomonitoring situation, the advantages of using each assemblage must be considered along with the objectives of the program. Some of the advantages of using periphyton, benthic macroinvertebrates, and fish in a biomonitoring program are presented in this section. References for this list are Cairns and Dickson (1971), American Public Health Association et al. (1971), Patrick (1973), Rodgers et al. (1979), Weitzel (1979), Karr (1981), USEPA (1983), Hughes et al. (1982), and Plafkin et al. (1989).

3.2.1 Advantages of Using Periphyton

- Algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

- As primary producers, algae are most directly affected by physical and chemical factors.

- Sampling is easy, inexpensive, requires few people, and creates minimal impact to resident biota.

- Relatively standard methods exist for evaluation of functional and non-taxonomic structural (biomass, chlorophyll measurements) characteristics of algal communities.

- Algal assemblages are sensitive to some pollutants which may not visibly affect other aquatic assemblages, or may only affect other organisms at higher concentrations (i.e., herbicides).

3.2.2 Advantages of Using Benthic Macroinvertebrates

- Macroinvertebrate assemblages are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream-downstream studies).

- Macroinvertebrates integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly.

- Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic macroinvertebrate assemblage. Macroinvertebrates are relatively easy to identify to family; many "intolerant" taxa can be identified to lower taxonomic levels with ease.

- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects.

- Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effect on the resident biota.

- Benthic macroinvertebrates serve as a primary food source for fish, including many recreationally and commercially important species.

- Benthic macroinvertebrates are abundant in most streams. Many small streams (1st and 2nd order), which naturally support a diverse macroinvertebrate fauna, only support a limited fish fauna.

- Most state water quality agencies that routinely collect biosurvey data focus on macroinvertebrates (Southerland and Stribling 1995). Many states already have background macroinvertebrate data. Most state water quality agencies have more expertise with invertebrates than fish.

3.2.3 Advantages of Using Fish

- Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al. 1986).

- Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores). They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.

- Fish are at the top of the aquatic food web and are consumed by humans, making them important for assessing contamination.

- Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field by experienced fisheries professionals, and subsequently released unharmed.

- Environmental requirements of most fish are comparatively well known. Life history information is extensive for many species, and information on fish distributions is commonly available.

- Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (coldwater, coolwater, warmwater, sport, forage). Monitoring fish provides direct evaluation of "fishability" and "fish propagation", which emphasizes the importance of fish to anglers and commercial fishermen.

- Fish account for nearly half of the endangered vertebrate species and subspecies in the United States (Warren and Burr 1994).

3.3 IMPORTANCE OF HABITAT ASSESSMENT

The procedure for assessing physical habitat quality presented in this document (Chapter 5) is an integral component of the final evaluation of impairment. The matrix used to assess habitat quality is based on key physical characteristics of the waterbody and surrounding land, particularly the catchment of the site under investigation. All of the habitat parameters evaluated are related to overall aquatic life use and are a potential source of limitation to the aquatic biota.

The alteration of the physical structure of the habitat is one of 5 major factors from human activities described by Karr (Karr et al. 1986, Karr 1991) that degrade aquatic resources. Habitat, as structured by instream and surrounding topographical features, is a major determinant of aquatic community potential (Southwood 1977, Plafkin et al. 1989, and Barbour and Stribling 1991). Both the quality and quantity of available habitat affect the structure and composition of resident biological communities. Effects of such features on biological assessment results can be minimized by sampling similar habitats at all stations being compared. However, when all stations are not physically comparable, habitat characterization is particularly important for proper interpretation of biosurvey results.

Where physical habitat quality at a test site is similar to that of a reference, detected impacts can be attributed to water quality factors (i.e., chemical contamination) or other stressors. However, where habitat quality differs substantially from reference conditions, the question of appropriate aquatic life use designation and physical habitat alteration/restoration must be addressed. Final conclusions regarding the presence and degree of biological impairment should thus include an evaluation of habitat quality to determine the extent that habitat may be a limiting factor. The habitat characterization matrix included in the Rapid Bioassessment Protocols provides an effective means of evaluating and documenting habitat quality at each biosurvey station.

3.4 THE REGIONAL REFERENCE CONCEPT

The issue of reference conditions is critical to the interpretation of biological surveys. Barbour et al. (1996a) describe 2 types of reference conditions that are currently used in biological surveys: site-specific and regional reference. The former typically consists of measurements of conditions upstream of a point source discharge or from a "paired" watershed. Regional reference conditions, on the other hand, consist of measurements from a population of relatively unimpaired sites within a relatively homogeneous region and habitat type, and therefore are not site-specific.

The reference condition establishes the basis for making comparisons and for detecting use impairment; it should be applicable to an individual waterbody, such as a stream segment, but also to similar waterbodies on a regional scale (Gibson et al. 1996).

Although both site-specific and ecoregional references represent conditions without the influence of a particular discharge, the 2 types of references may not yield equivalent measurements (Barbour et al. 1996a). While site-specific reference conditions represented by the upstream, downstream, or paired-site approach are desirable, they are limited in their usefulness. Hughes (1995) points out three problems with site-specific reference conditions: (1) because they typically lack any broad study design, site-specific reference conditions possess limited capacity for extrapolation— they have only site-specific value; (2) usually site-specific reference conditions allow limited variance estimates; there are too few sites for robust variance evaluations because each site of concern is typically represented by one-to-three reference sites; the result could be an incorrect assessment if the upstream site has especially good or especially poor habitat or chemical quality; and (3) they involve a substantial assessment effort when considered on a statewide basis.

The advantages of measuring upstream reference conditions are these: (1) if carefully selected, the habitat quality is often similar to that measured downstream of a discharge, thereby reducing complications in interpretation arising from habitat differences, and (2) impairments due to upstream influences from other point and nonpoint sources are already factored into the reference condition (Barbour et al. 1996a). New York DEC has found that an upstream-downstream approach aids in diagnosing cause-and-effect to specific discharges and increase precision (Bode and Novak 1995).

Where feasible, effects should be bracketed by establishing a series or network of sampling stations at points of increasing distance from the impact source(s). These stations will provide a basis for delineating impact and recovery zones. In significantly altered systems (i.e., channelized or heavily urbanized streams), suitable reference sites are usually not available (Gibson et al. 1996). In these cases, historical data or simple ecological models may be necessary to establish reference conditions. See Gibson et al. (1996) for more detail.

Innate regional differences exist in forests, lands with high agricultural potential, wetlands, and waterbodies. These regional differences have been mapped by Bailey (1976), U.S. Department of Agriculture (USDA) Soil Conservation Service (1981), Energy, Mines and Resources Canada (1986), and Omernik (1987). Waterbodies reflect the lands they drain (Omernik 1987, Hunsaker and Levine 1995) and it is assumed that similar lands should produce similar waterbodies. This ecoregional approach provides robust and ecologically-meaningful regional maps that are based on an examination of several mapped land variables. For example, hydrologic unit maps are useful for mapping drainage patterns, but have limited value for explaining the substantial changes that occur in water quality and biota independent of stream size and river basin.

Omernik (1987) provided an ecoregional framework for interpreting spatial patterns in state and national data. The geographical framework is based on regional patterns in land-surface form, soil, potential natural vegetation, and land use, which vary across the country. Geographic patterns of similarity among ecosystems can be grouped into ecoregions or subecoregions. Naturally occurring biotic assemblages, as components of the ecosystem, would be *expected* to differ among ecoregions but be relatively similar within a given ecoregion. The ecoregion concept thus provides a geographic framework for efficient management of aquatic ecosystems and their components (Hughes 1985, Hughes et al. 1986, and Hughes and Larsen 1988). For example, studies in Ohio (Larsen et al. 1986), Arkansas (Rohm et al. 1987), and Oregon (Hughes et al. 1987, Whittier et al. 1988) have shown that distributional patterns of fish communities approximate ecoregional boundaries as defined *a priori* by Omernik (1987). This, in turn, implies that similar water quality standards, criteria, and monitoring strategies are likely to be valid throughout a given ecoregion, but should be tailored to accommodate the innate differences among ecoregions (Ohio EPA 1987).

However, some programs, such as EMAP (Klemm and Lazorchak 1994) and the Maryland Biological Stream Survey (MBSS) (Volstad et al. 1995) have found that a surrogate measure of stream size (catchment size) is useful in partitioning the variability of stream segments for assessment. Hydrologic regime can include flow regulation, water withdrawal, and whether a stream is considered intermittent or perennial. Elevation has been found to be an important classification variable when using the benthic macroinvertebrate assemblage (Barbour et al. 1992, Barbour et al. 1994, Spindler 1996). In addition, descriptors at a smaller scale may be needed to characterize streams within regions or classes. For example, even though a given stream segment is classified within a subecoregion or other type of stream class, it may be wooded (deciduous or coniferous) or open within a perennial or intermittent flow regime, and represent one of several orders of stream size.

Individual descriptors *will not apply to all regional reference streams,* nor will all conditions (i.e., deciduous, coniferous, open) be present in all streams. Those streams or stream segments that represent characteristics atypical for that particular ecoregion should be excluded from the regional aggregate of sites and treated as a special situation. For example, Ohio EPA (1987) considered aquatic systems with unique (i.e., unusual for the ecoregion) natural characteristics to be a separate aquatic life use designation (exceptional warmwater aquatic life use) on a statewide basis.

Although the final rapid bioassessment guidance should be generally applicable to all regions of the United States, each agency will need to evaluate the generic criteria suggested in this document for inclusion into specific programs. To this end, the application of the regional reference concept versus the site-specific control approach will need to be examined. When Rapid Bioassessment Protocols (RBPs) are used to assess impact sources (upstream-downstream studies), regional reference criteria may not be as important if an unimpacted site-specific control station can be sampled. However, when a synoptic ("snapshot") or trend monitoring survey is being conducted in a watershed or river basin, use of regional criteria may be the only means of discerning use impairment or assessing impact. Additional investigation will be needed to: delineate areas (classes of streams)that differ significantly in their innate biological potential; locate reference sites within each stream class that fully support aquatic life uses; develop biological criteria (e.g., define optimal values for the metrics) using data generated from each of the assemblages.

3.5 STATION SITING

Site selection for assessment and monitoring can either be "targeted", i.e., relevant to special studies that focus on potential problems, or "probabilistic", which provides information of the overall status or condition of the watershed, basin, or region. In a probabilistic or random sampling regime, stream characteristics may be highly dissimilar among the sites, but will provide a more accurate assessment of biological condition throughout the area than a targeted design. Selecting sites randomly provides an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream. Thus, an agency can address questions at multiple scales. Studies for 305(b) status and trends assessments are best done with a probabilistic design.

Most studies conducted by state water quality agencies for identification of problems and sensitive waters are done with a targeted design. In this case, sampling sites are selected based on known existing problems, knowledge of upcoming events that will adversely affect the waterbody such as a development or deforestation; or installation of BMPs or habitat restoration that are intended to improve waterbody quality. This method provides assessments of individual sites or stream reaches. Studies for aquatic life use determination and those related to TMDLs can be done with a random (watershed or higher level) or targeted (site-specific) design.

To meaningfully evaluate biological condition in a targeted design, sampling locations must be similar enough to have similar biological expectations, which, in turn, provides a basis for comparison of impairment. If the goal of an assessment is to evaluate the effects of water chemistry degradation, comparable physical habitat should be sampled at all stations, otherwise, the differences in the biology attributable to a degraded habitat will be difficult to separate from those resulting from chemical pollution water quality degradation. Availability of appropriate habitat at each sampling location can be established during preliminary reconnaissance. In evaluations where several stations on a waterbody will be compared, the station with the greatest habitat constraints (in terms of productive habitat availability) should be noted. The station with the least number of productive habitats available will often determine the type of habitat to be sampled at all sample stations.

Locally modified sites, such as small impoundments and bridge areas, should be avoided unless data are needed to assess their effects. Sampling near the mouths of tributaries entering large waterbodies should also be avoided because these areas will have habitat more typical of the larger waterbody (Karr et al. 1986).

For bioassessment activities where the concern is non-chemical stressors, e.g., the effects of habitat degradation or flow alteration, or cumulative impacts, a different approach to station selection is used. Physical habitat differences between sites can be substantial for two reasons: (1) one or a set of sites is more degraded (physically) than another, or (2) is unique for the stream class or region due to the essential natural structure resulting from geological characteristics. Because of these situations, the more critical part of the siting process comes from the recognition of the habitat features that are representative of the region or stream class. In basin-wide or watershed studies, sample locations should not be avoided due to habitat degradation or to physical features that are well-represented in the stream class.

3.6 DATA MANAGEMENT AND ANALYSIS

USEPA is developing a biological data management system linked to STORET, which provides a centralized system for storage of biological data and associated analytical tools for data analysis. The field survey file component of STORET provides a means of storing, retrieving, and analyzing biosurvey data, and will process data on the distribution, abundance, and physical condition of aquatic organisms, as well as descriptions of their habitats. Data stored in STORET become part of a comprehensive database that can be used as a reference, to refine analysis techniques or to define ecological requirements for aquatic populations. Data from the Rapid Bioassessment Protocols can be readily managed with the STORET field survey file using header information presented on the field data forms (Appendix A) to identify sampling stations.

Habitat and physical characterization information may also be stored in the field survey file with organism abundance data. Parameters available in the field survey file can be used to store some of the environmental characteristics associated with the sampling event, including physical characteristics, water quality, and habitat assessment. Physical/chemical parameters include stream depth, velocity, and substrate characteristics, as well as many other parameters. STORET also allows storage of other pertinent station or sample information in the comments section.

Entering data into a computer system can provide a substantial time savings. An additional advantage to computerization is analysis documentation, which is an important component for a Quality Assurance/Quality Control (QA/QC) plan. An agency conducting rapid bioassessment programs can choose an existing system within their agency or utilize the STORET system developed as a national database system.

Data collected as part of state bioassessment programs are usually entered, stored and analyzed in easily obtainable spreadsheet programs. This method of data management becomes cumbersome as the database grows in volume. An alternative to spreadsheet programs is a multiuser relational database management system (RDMS). Most relational database software is designed for the Windows operating system and offer menu driven interfaces and ranges of toolbars that provide quick access to many routine database tasks. Automated tools help users quickly create forms for data input and lookup, tables, reports, and complex queries about the data. The USEPA is developing a multiuser relational database management system that can transfer sampling data to STORET. This relational database management system is EDAS (Ecological Data Application System) and allows the user to input, compile, and analyze complex ecological data to make assessments of ecosystem condition. EDAS includes tools to format sampling data so it may be loaded into STORET as a batch file. These batch files are formatted as flat ASCII text and can be loaded (transferred) electronically to STORET. This will eliminate the need to key sample data into STORET.

By using tables and queries as established in EDAS, a user can enter, manipulate, and print data. The metrics used in most bioassessments can be calculated with simple queries that have already been created for the user. New queries may be created so additional metrics can be calculated at the click of the mouse each time data are updated or changed. If an operation on the data is too complex for one of the many default functions then the function can be written in code (e.g., visual basic access) and stored in a module for use in any query. Repetitive steps can be handled with macros. As the user develops the database other database elements such as forms and reports can be added.

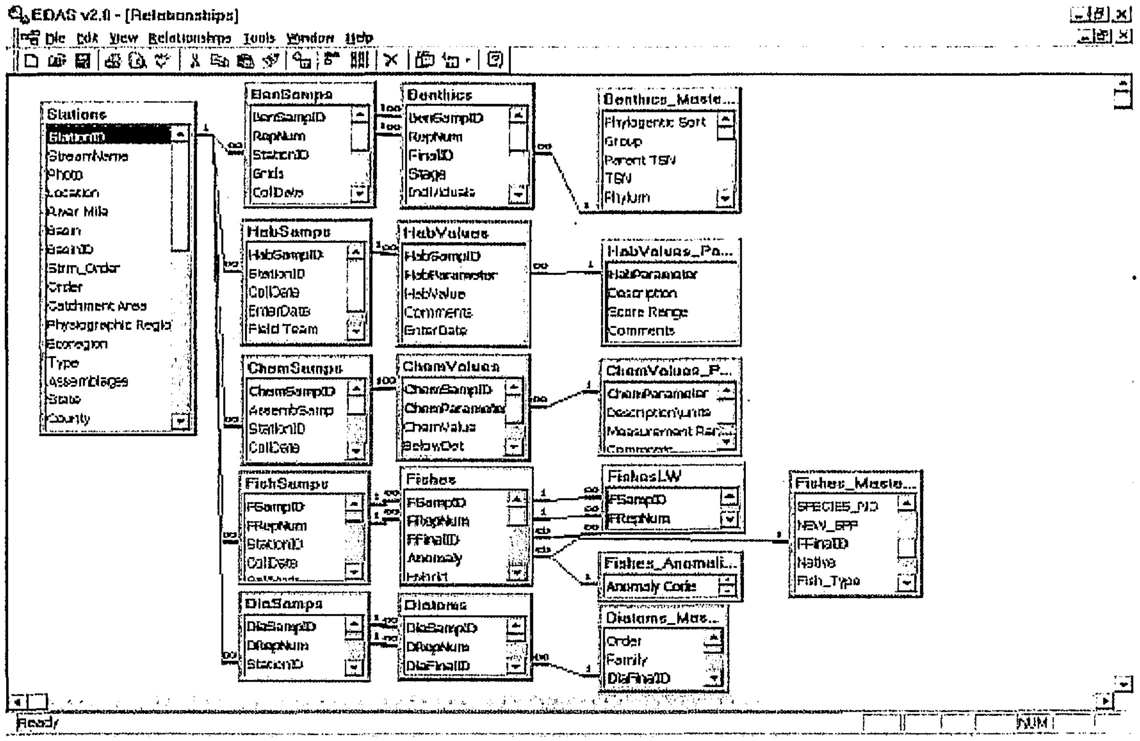

Figure 3-1. Example of the relationship of data tables in a typical relational database.

Table design is the foundation of the relational database, such as EDAS (Figure 3-1), because they function as data containers. Tables are related through the use of a unique identifier or index. In the example database "StationId" links the tables "ChemSamps", "HabSamps", and "BenSamps" to the "Stations" table. The chemical parameters and habitat parameters table act as reference tables and contain descriptive data (e.g., measurement units, detection limits). This method of storing data is more efficient than spreadsheets, because it eliminates a lot of redundant data. Master Taxa tables are created for the biological data to contain all relevant information about each taxon. This information does not have to be repeated each time a taxon is entered into the database.

Input or lookup forms (Figure 3-2) are screens that are designed to aid in entering or retrieving data. Forms are linked to tables so data go to the right cell in the right table. Because of the relationships among the tables, data can be updated across all the tables that are linked to the form. Reports can be generated in a variety of styles, and data can be exported to other databases or spreadsheet programs.

3.7 TECHNICAL ISSUES FOR SAMPLING THE PERIPHYTON ASSEMBLAGE

3.7.1 Seasonality

Stream periphyton have distinct seasonal cycles, with peak abundance and diversity typically occurring in late summer or early fall (Bahls 1993). High flows may scour and sweep away periphyton. For these reasons, the index period for periphyton sampling is usually late summer or early fall, when stream flow is relatively stable (Kentucky DEP 1993, Bahls 1993).

Algae are light limited, and may be sparse in heavily shaded streams. Early spring, before leafout, may be a better sampling index period in shaded streams.

Finally, since algae have short generation times (one to several days), they respond rapidly to environmental changes. Samples of the algal community are "snapshots" in time, and do not integrate environmental effects over entire seasons or years.

3.7.2 Sampling Methodology

Artificial substrates (periphytometers) have long been used in algal investigations, typically using glass slides as the substrate, but also with glass rods, plastic plates, ceramic tiles and other substances. However, many agencies are sampling periphyton from natural substrates to characterize

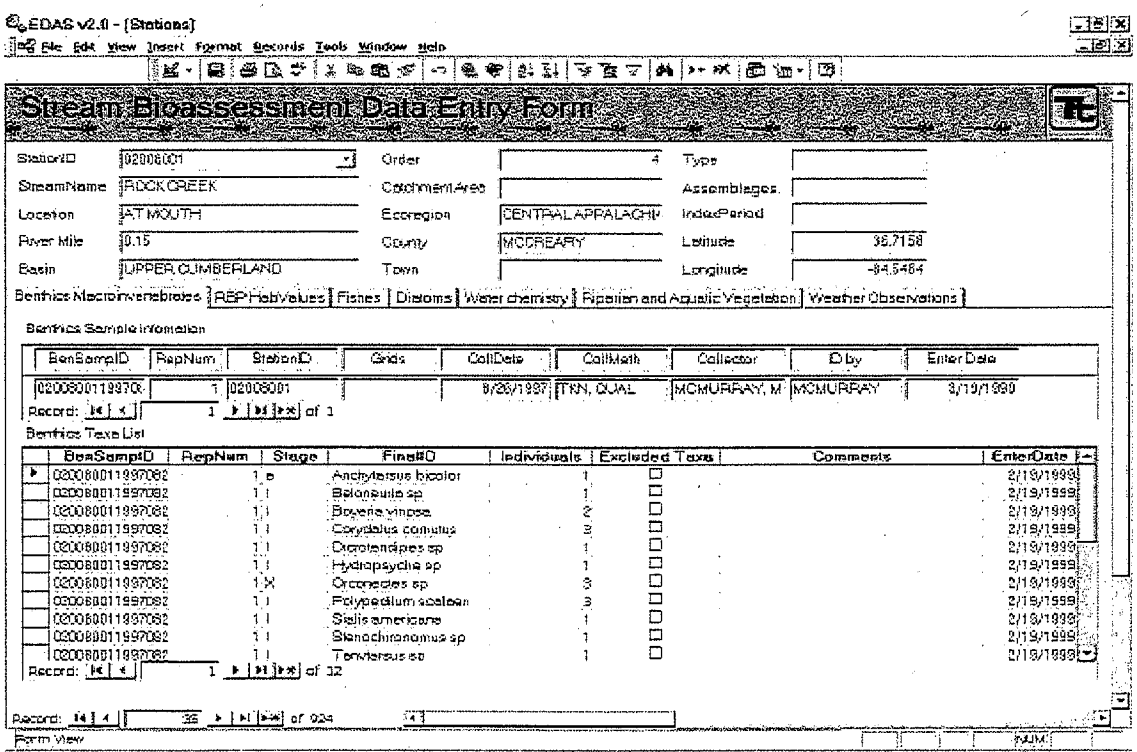

Figure 3-2. Example input or lookup form in a typical relational database.

the natural community. Advantages of artificial and natural substrates are summarized below (Cairns 1982, Bahls 1993).

Advantages of Artificial Substrates:

- Artificial substrates allow sample collection in locations that are typically difficult to sample effectively (e.g., bedrock, boulder, or shifting substrates; deep or high velocity water).

- As a "passive" sample collection device, artificial substrates permit standardized sampling by eliminating subjectivity in sample collection technique. Direct sampling of natural substrate requires similar effort and degree of efficiency for the collection of each sample. Use of artificial substrates requires standardization of setting and retrieval; however, colonization provides the actual sampling mechanism.

- Confounding effects of habitat differences are minimized by providing a standardized microhabitat. Microhabitat standardization may promote selectivity for specific organisms if the artificial substrate provides a different microhabitat than that naturally available at a site.
- Sampling variability is decreased due to a reduction in microhabitat patchiness, improving the potential for spatial and temporal similarity among samples.

- Sample collection using artificial substrates may require less skill and training than direct sampling of natural substrates.

Disadvantages of Artificial Substrates:

- Artificial substrates require a return trip; this may be a significant consideration in large states or those with limited technical resources.

- Artificial substrates are prone to loss, natural damage or vandalism.

- The material of the substrate will influence the composition and structure of the community; solid artificial substrates will favor attached forms over motile forms and compromise the usefulness of the siltation index.

- Orientation and length of exposure of the substrate will influence the composition and structure of the community.

3.8 TECHNICAL ISSUES FOR SAMPLING THE BENTHIC MACROINVERTEBRATE ASSEMBLAGE

3.8.1 Seasonality for Benthic Collections (adapted from Gibson et al. 1996)

The ideal sampling procedure is to survey the biological community with each change of season, then select the appropriate sampling periods that accommodate seasonal variation. Such indexing makes the best use of the biological data. However, resident assemblages integrate stress effects over the course of the year, and their seasonal cycles of abundance and taxa composition are fairly predictable within the limits of interannual variability.

Many programs have found that a single index period provides a strong database that allows all of their management objectives to be addressed. However, if one goal of a program is to understand seasonal variability, then establishing index periods during multiple seasons is necessary. Although a single index period would not likely be adequate for assessing the effects of catastrophic events, such as spill, those assessments should be viewed as special studies requiring sampling of reference sites during the same time period.

Ultimately, selection of the appropriate sampling period should be based on 3 factors that reflect efforts to:

1. minimize year-to-year variability resulting from natural events,

2. maximize gear efficiency, and

3. maximize accessibility of targeted assemblage.

Sampling and comparisons of data from the same seasons (or index periods) as the previous year's sampling provides some correction and minimization of annual variability. The season of the year during which sampling gear is most effective is an important consideration for selecting an index period. For example, low flow or freezing conditions may hamper an agency's ability to sample with its selected gear. Seasons where those conditions are prevalent should be avoided. The targeted assemblage(s) should be accessible and not be inhabiting hard-to-reach portions of the sampling area. For example, if benthos are primarily deep in the substrate in winter, beyond normal sampling depth, that period should be avoided and another index period chosen. If high flows are typical of spring runoff periods, and sampling cannot occur, the index period should be established during typical or low flow periods.

3.8.2 Benthic Sampling Methodology

The benthic RBPs employ direct sampling of natural substrates. Because routine evaluation of a large number of sites is a primary objective of the RBPs, artificial substrates were eliminated from consideration due to time required for both placement and retrieval, and the amount of exposure time required for colonization. However, where conditions are inappropriate for the collection of natural substrate samples, artificial substrates may be an option. The Science Advisory Board (SAB 1993) cautioned that the only appropriate type of artificial substrates to be used for assessment are those that are "introduced substrates", i.e., substrates that are representative of the natural substrate of the stream system, such as rock-filled baskets in cobble- or gravel-bottomed streams. Ohio EPA and Maine DEP, are examples of states that use artificial substrates for their water resource investigations (Davis et al. 1996).

Advantages and disadvantages of artificial substrates (Cairns 1982) relative to the use of natural substrates are presented below.

Advantages of Artificial Substrates:

! Artificial substrates allow sample collection in locations that are typically difficult to sample effectively (e.g., bedrock, boulder, or shifting substrates; deep or high velocity water).

- As a "passive" sample collection device, artificial substrates permit standardized sampling by eliminating subjectivity in sample collection technique. Direct sampling of natural substrate requires similar effort and degree of efficiency for the collection of each sample. Use of artificial substrates requires standardization of setting and retrieval; however, colonization provides the actual sampling mechanism.

- Confounding effects of habitat differences are minimized by providing a standardized microhabitat. Microhabitat standardization may promote selectivity for specific organisms if the artificial substrate provides a different microhabitat than that naturally available at a site (see second bullet under Disadvantages below). Most artificial substrates, by design, select for the Scraper and Filterer components of the benthic assemblages or for Collectors if accumulation of debris has occured in the substrates.

- Sampling variability is decreased due to a reduction in microhabitat patchiness, improving the potential for spatial and temporal similarity among samples.

- Sample collection using artificial substrates may require less skill and training than direct sampling of natural substrates. Depending on the type of artificial substrate used, properly trained technicians could place and retrieve the substrates. However, an experienced specialist should be responsible for the selection of habitats and sample sites.

Disadvantages of Artificial Substrates:

- Two trips (one to set and one to retrieve) are required for each artificial substrate sample; only one trip is necessary for direct sampling of the natural substrate. Artificial substrates require a long (8-week average) exposure period for colonization. This decreases their utility for certain rapid biological assessments.

- Samples may not be fully representative of the benthic assemblage at a station if the artificial substrate offers different microhabitats than those available in the natural substrate. Artificial substrates often selectively sample certain taxa, misrepresenting relative abundances of these taxa in the natural substrate. Artificial substrate samples would thus indicate colonization potential rather than the resident community structure. This could be advantageous if a study is designed to isolate water quality effects from substrate and other microhabitat effects. Where habitat quality is a limiting factor, artificial substrates could be used to discriminate between physical and chemical effects and assess a site's potential to support aquatic life on the basis of water quality alone.

- Sampler loss or perturbation commonly occurs due to sedimentation, extremely high or low flows, or vandalism during the relatively long (at least several weeks) exposure period required for colonization.

- Depending on the configuration of the artificial substrate used, transport and storage can be difficult. The number of artificial substrate samplers required for sample collection increases such inconvenience.

3.9 TECHNICAL ISSUES FOR THE SURVEY OF THE FISH ASSEMBLAGE

3.9.1 Seasonality for Fish Collections

Seasonal changes in the relative abundances of the fish community primarily occur during reproductive periods and (for some species) the spring and fall migratory periods. However, because larval fish sampling is not recommended in this protocol, reproductive period changes in relative abundance are not of primary importance.

Generally, the preferred sampling season is mid to late summer, when stream and river flows are moderate to low, and less variable than during other seasons. Although some fish species are capable of extensive migration, fish populations and individual fish tend to remain in the same area during summer (Funk 1957, Gerking 1959, Cairns and Kaesler 1971). The Ohio Environmental Protection Agency (1987) stated that few fishes in perennial streams migrate long distances. Hill and Grossman (1987) found that the three dominant fish species in a North Carolina stream had home ranges of 13 to 19 meters over a period of 18 months. Ross et al. (1985) and Matthews (1986) found that stream fish assemblages were stable and persistent for 10 years, recovering rapidly from droughts and floods indicating that substantial population fluctuations are not likely to occur in response to purely natural environmental phenomena. However, comparison of data collected during different seasons is discouraged, as are data collected during or immediately after major flow changes.

3.9.2 Fish Sampling Methodology

Although various gear types are routinely used to sample fish, electrofishing equipment and seines are the most commonly used collection methods in fresh water habitats. Each method has advantages and disadvantages (Hendricks et al. 1980, Nielsen and Johnson 1983). However, electrofishing is recommended for most fish field surveys because of its greater applicability and efficiency. Local conditions may require consideration of seining as an optional collection method. Advantages and disadvantages of each gear type are presented below.

3.9.2.1 Advantages and Disadvantages of Electrofishing

Advantages of Electrofishing:

! Electrofishing allows greater standardization of catch per unit of effort.

! Electrofishing requires less time and a reduced level of effort than some sampling methods (e.g., use of ichthyocides) (Hendricks et al. 1980).

! Electrofishing is less selective than seining (although it is selective towards size and species) (Hendricks et al. 1980). (See second bullet under Disadvantages below).

! If properly used, adverse effects on fish are minimized.

! Electrofishing is appropriate in a variety of habitats.

Disadvantages of Electrofishing:

- Sampling efficiency is affected by turbidity and conductivity.

- Although less selective than seining, electrofishing is size and species selective. Effects of electrofishing increase with body size. Species specific behavioral and anatomical differences also determine vulnerability to electroshocking (Reynolds 1983).

- Electrofishing is a hazardous operation that can injure field personnel if proper safety procedures are ignored.

3.9.2.2 Advantages and Disadvantages of Seining

Advantages of Seining:

- Seines are relatively inexpensive.

- Seines are lightweight and are easily transported and stored.

- Seine repair and maintenance are minimal and can be accomplished onsite.

- Seine use is not restricted by water quality parameters.

- Effects on the fish population are minimal because fish are collected alive and are generally unharmed.

Disadvantages of Seining:

- Previous experience and skill, knowledge of fish habitats and behavior, and sampling effort are probably more important in seining than in the use of any other gear (Hendricks et al. 1980).

- Sample effort and results for seining are more variable than sampling with electrofishing.

- Use of seines is generally restricted to slower water with smooth bottoms, and is most effective in small streams or pools with little cover.

- Standardization of unit of effort to ensure data comparability is difficult.

3.10 SAMPLING REPRESENTATIVE HABITAT

Effort should be made when sampling to avoid regionally unique natural habitat. Samples from such situations, when compared to those from sites lacking the unique habitat, will appear different, i.e., assess as in either better or worse condition, than those not having the unique habitat. This is due to the usually high habitat specificity that different taxa have to their range of habitat conditions; unique habitat will have unique taxa. Thus, all RBP sampling is focused on sampling of representative habitat.

Composite sampling is the norm for RBP investigations to characterize the reach, rather than individual small replicates. However, a major source of variance can result from taking too few samples for a composite. Therefore, each of the protocols (i.e., for periphyton, benthos, fish) advocate compositing several samples or efforts throughout the stream reach. Replication is strongly encouraged for precision evaluation of the methods.

When sampling wadeable streams, rivers, or waterbodies with complex habitats, a complete inventory of the entire reach is not necessary for bioassessment. However, the sampling area should be representative of the reach, incorporating riffles, runs, and pools if these habitats are typical of the stream in question. Midchannel and wetland areas of large rivers, which are difficult to sample effectively, may be avoided. Sampling effort may be concentrated in near-shore habitats where most species will be collected. Although some deep water or wetland species may be undersampled, the data should be adequate for the objective of bioassessment.

4 PERFORMANCE-BASED METHODS SYSTEM (PBMS)

Determining the performance characteristics of individual methods enables agencies to share data to a certain extent by providing an estimate of the level of confidence in assessments from one method to the next. The purpose of this chapter is to provide a framework for measuring the performance characteristics of various methods. The contents of this chapter are taken liberally from Diamond et al. 1996, which is a refinement of the PBMS approach developed for ITFM (1995b). This chapter is best assimilated if the reader is familiar with data analysis for bioassessment. Therefore, the reader may wish to review Chapter 9 on data analysis before reading this PBMS material. Specific quality assurance aspects of the methods are included in the assemblage chapters.

Regardless of the type of data being collected, field methods share one important feature in common—they cannot tell whether the information collected is an accurate portrayal of the system of interest (Intergovernmental Task Force on Monitoring Water Quality [ITFM] 1995a). Properties of a given field sample can be known, but research questions typically relate to much larger spatial and temporal scales. It is possible to know, with some accuracy, properties or characteristics of a given sample taken from the field; but typically, research questions relate to much larger spatial and temporal scales. To grapple with this problem, environmental scientists and statisticians have long recognized that field methods must strive to obtain information that is representative of the field conditions at the time of sampling.

An accurate assessment of stream biological data is difficult because natural variability cannot be controlled (Resh and Jackson 1993). Unlike analytical assessments conducted in the laboratory, in which accuracy can be verified in a number of ways, the accuracy of macroinvertebrate assessments in the field cannot be objectively verified. For example, it isn't possible to "spike" a stream with a known species assemblage and then determine the accuracy of a bioassessment method. This problem is not theoretical. Different techniques may yield conflicting interpretations at the same sites, underscoring the question of accuracy in bioassessment. Depending on which methods are chosen, the actual structure and condition of the assemblage present, or the trends in status of the assemblage over time may be misinterpreted. Even with considerable convergence in methods used in the U.S. by states and other agencies (Southerland and Stribling 1995, Davis et al. 1996), direct sharing of data among agencies may cause problems because of the uncertainty associated with unfamiliar methods, misapplication of familiar methods, or varied data analyses and interpretation (Diamond et al. 1996).

4.1 APPROACHES FOR ACQUIRING COMPARABLE BIOASSESSMENT DATA

Water quality management programs have different reasons for doing bioassessments which may not require the same level or type of effort in sample collection, taxonomic identification, and data analysis (Gurtz and Muir 1994). However, different methods of sampling and analysis may yield comparable data for certain objectives despite differences in effort. There are 2 general approaches for acquiring comparable bioassessment data among programs or among states. The first is for everyone to use the same method on every study. Most water resource agencies in the U.S. have developed standard operating procedures (SOPs). These SOPs would be adhered to throughout statewide or regional areas to provide comparable assessments within each program. The Rapid Bioassessment Protocols (RBPs) developed by Plafkin et al. (1989) and refined in this document are attempts to provide a framework for agencies to develop SOPs. However, the use of a single method, even for a particular type of habitat, is probably not likely among different agencies, no matter how exemplary (Diamond et al. 1996).

The second approach to acquiring comparable data from different organizations, is to encourage the documentation of performance characteristics (e.g., precision, sensitivity) for all methods and to use those characteristics to determine comparability of different methods (ITFM 1995b). This documentation is known as a performance-based method system (PBMS) which, in the context of biological assessments, is defined as a system that permits the use of any method (to sample and analyze stream assemblages) that meets established requirements for data quality (Diamond et al. 1996). Data quality objectives (DQOs) are qualitative and quantitative expressions that define requirements for data precision, bias, method sensitivity, and range of conditions over which a method yields satisfactory data (Klemm et al. 1990). The determination of DQOs for a given study or agency program is central to all data collection and to a PBMS, particularly, because these objectives establish not only the necessary quality of a given method (Klemm et al. 1990) but also the types of methods that are likely to provide satisfactory information.

In practice, DQO's are developed in 3 stages: (1) determine what information is needed and why and how that information will be used; (2) determine methodological and practical constraints and technical specifications to achieve the information desired; and (3) compare different available methods and choose the one that best meets the desired specifications within identified practical and technical limitations (USEPA 1984, 1986, Klemm et al. 1990, USEPA 1995a, 1997c). It is difficult to make an informed decision regarding which methods to use if data quality characteristics are unavailable. The successful introduction of the PBMS concept in laboratory chemistry, and more recently in laboratory toxicity testing (USEPA 1990c, American Society of Testing and Materials [ASTM] 1995), recommends adapting such a system for biological monitoring and assessment.

If different methods are similar with respect to the quality of data each produces, then results of an assessment from those methods may be used interchangeably or together. As an example, a method for sample sorting and organism identification, through repeated examination using trained personnel, could be used to determine that the proportion of missed organisms is less than 10% of the organisms present in a given sample and that taxonomic identifications (to the genus level) have an accuracy rate of at least 90% (as determined by samples verified by recognized experts). A study could require the above percentages of missed organisms and taxonomic accuracy as DQOs to ensure the collection of satisfactory data (Ettinger 1984, Clifford and Casey 1992, Cuffney et al. 1993a). In a PBMS approach, any laboratory sorting and identification method that documented the attainment of these DQOs would yield comparable data and the results would therefore be satisfactory for the study.

For the PBMS approach to be useful, 4 basic assumptions must be met (ITFM 1995b):

1. DQOs must be set that realistically define and measure the quality of the data needed; reference (validated) methods must be made available to meet those DQOs;

2. to be considered satisfactory, an alternative method must be as good or better than the reference method in terms of its resulting data quality characteristics;

3. there must be proof that the method yields reproducible results that are sensitive enough for the program; and

4. the method must be effective over the prescribed range of conditions in which it is to be used. For bioassessments, the above assumptions imply that a given method for sample collection and analysis produces data of known quality, including precision, the range of habitats over which the collection method yields a specified precision, and the magnitude of difference in data among sites with different levels or types of impairment (Diamond et al. 1996).

PERFORMANCE CHARACTERISTICS

- **Precision**
- **Bias**
- **Performance range**
- **Interferences**
- **Sensitivity**

Thus, for multimetric assessment methods, such as RBPs, the precision of the total multimetric score is of interest as well as the individual metrics that make up the score (Diamond et al. 1996). Several performance characteristics must be characterized for a given method to utilize a PBMS approach. These characteristics include method precision, bias, performance range, interferences, and sensitivity (detection limit). These characteristics, as well as method accuracy, are typically demonstrated in analytical chemistry systems through the use of blanks, standards, spikes, blind samples, performance evaluation samples, and other techniques to compare different methods and eventually derive a reference method for a given analyte. Many of these performance characteristics are applicable to biological laboratory and field methods and other prelaboratory procedures as well (Table 4-1). It is known that a given collection method is not equally accurate over all ecological conditions even within a general aquatic system classification (e.g., streams, lakes, estuaries). Therefore, assuming a given method is a "reference method" on the basis of regulatory or programmatic reasons does not allow for possible translation or sharing of data derived from different methods because the performance characteristics of different methods have not been quantified. One can evaluate performance characteristics of methods in 2 ways: (1) with respect to the collection method itself and, (2) with respect to the overall assessment process. Method performance is characterized using quantifiable data (metrics, scores) derived from data collection and analysis. Assessment performance, on the other hand, is a step removed from the actual data collected. Interpretive criteria (which may be based on a variety of approaches) are used to rank sites and thus, PBMS in this case is concerned with performance characteristics of the ranking procedures as well as the methods that lead to the assessment.

Table 4-1. Progression of a generic bioassessment field and laboratory method with associated examples of performance characteristics.

Step	Procedure	Examples of Performance Characteristics
1	Sampling device	***Precision***—repeatability in a habitat. ***Bias***—exclusion of certain taxa (mesh size). ***Performance range***—different efficiency in various habitat types or substrates. ***Interferences***—matrix or physical limitations (current velocity, water depth).
2	Sampling method	***Precision***—variable metrics or measures among replicate samples at a site. ***Bias***—exclusion of certain taxa (mesh size) or habitats. ***Performance range***—limitations in certain habitats or substrates. ***Interferences***—high river flows, training of personnel.

Table 4-1. Progression of a generic bioassessment field and laboratory method with associated examples of performance characteristics. (Continued)

Step	Procedure	Examples of Performance Characteristics
3	Field sample processing (subsampling, sample transfer, preservation)	*Precision*—variable metrics among splits of subsamples. *Bias*— efficiency of locating small organisms. *Performance range*—sample preservation and holding time. *Interferences*—Weather conditions. **Additional characteristics:** *Accuracy*—of sample transfer process and labeling.
4	Laboratory sample processing (sieving, sorting)	*Precision*—split samples. *Bias*—sorting certain taxonomic groups or organism size. *Performance range*—sorting method depending on sample matrix (detritus, mud). *Interferences*—distractions; equipment. **Additional characteristics:** *Accuracy*—sorting method; lab equipment.
5	Taxonomic enumeration	*Precision*—split samples. *Bias*—counts and identifications for certain taxonomic groups. *Performance range*—dependent on taxonomic group and (or) density. *Interferences*—appropriateness of taxonomic keys. *Sensitivity*— level of taxonomy related to type of stressor **Additional characteristics:** *Accuracy*—identification and counts.

Data quality and performance characteristics of methods for analytical chemistry are typically validated through the use of quality control samples including blanks, calibration standards, and samples spiked with a known quantity of the analyte of interest. Table 4-2 summarizes some performance characteristics used in analytical chemistry and how these might be translated to biological methods.

The collection of high-quality data, particularly for bioassessments, depends on having adequately trained people. One way to document satisfactory training is to have newly trained personnel use the method and then compare their results with those previously considered acceptable. Although field crews and laboratory personnel in many organizations are trained in this way (Cuffney et al. 1993b), the results are rarely documented or quantified. As a result, an organization cannot assure either itself or other potential data users that different personnel performing the same method at the same site yield comparable results and that data quality specifications of the method (e.g., precision of metrics or scores) are consistently met. Some of this information is published for certain bioassessment sampling methods, but is defined qualitatively (see Elliott and Tullett 1978, Peckarsky 1984, Resh et al. 1990, Merritt et al. 1996 for examples), not quantitatively. Quantitative information needs to be more available so that the quality of data obtained by different methods is documented.

Table 4-2. Translation of some performance characteristics, derived for laboratory analytical systems, to biological laboratory systems (taken from Diamond et al. 1996).

Performance Characteristics	Analytical Chemical Methods	Biological Methods
Precision	Replicate samples	Multiple taxonomists identifying 1 sample; split sample for sorting, identification, enumeration; replicate samples within sites; duplicate reaches
Bias	Matrix-spiked samples; standard reference materials; performance evaluation samples	Taxonomic reference samples; "spiked" organism samples
Performance range	Standard reference materials at various concentrations; evaluation of spiked samples by using different matrices	Efficiency of field sorting procedures under different sample conditions (mud, detritus, sand, low light)
Interferences	Occurrence of chemical reactions involved in procedure; spiked samples; procedural blanks; contamination	Excessive detrital material or mud in sample; identification of young life stages; taxonomic uncertainty
Sensitivity	Standards; instrument calibration	Organism-spiked samples; standard level of identification
Accuracy	Performance standards; procedural blanks	Confirmation of identification, percentage of "missed" specimens

It is imperative that the specific range of environmental conditions (or performance range) is quantitatively defined for a sampling method (Diamond et al. 1996). As an example, the performance range for macroinvertebrate sampling is usually addressed qualitatively by characterizing factors such as stream size, hydrogeomorphic reach classification, and general habitat features (riffle vs. pool, shallow vs. deep water, rocky vs. silt substrate; Merritt et al. 1996). In a PBMS framework, different methods could be classified based on the ability of the method to achieve specified levels of performance characteristics such as data precision and sensitivity to impairment over a range of appropriate habitats. Thus, the precision of individual metrics or scores obtained by different sampling methods can be directly and quantitatively compared for different types of habitats.

4.2 ADVANTAGES OF A PBMS APPROACH FOR CHARACTERIZING BIOASSESSMENT METHODS

Two fundamental requirements for a biological assessment are: (1) that the sample taken and analyzed is representative of the site or the assemblage of interest and, (2) that the data obtained are an accurate reflection of the sample. The latter requirement is ensured using proper quality control (QC) in the laboratory including the types of performance characteristics summarized in Table 4-2. The first requirement is met through appropriate field sampling procedures, including random selection of sampling locations within the habitat type(s) of interest, choice of sampling device, and sample preservation methods. The degree to which a sample is representative of the environment depends on the type of sampling method used (including subsampling) and the ecological endpoint being measured. For example, many benthic samples may be needed from a stream to obtain 95% confidence intervals that are within 50% of the mean value for macroinvertebrate density, whereas fewer benthic samples may be needed to determine the dominant species in a given habitat type at a particular time (Needham and Usinger 1956, Resh 1979, Plafkin et al. 1989).

Several questions have been raised concerning the appropriateness or "accuracy" of methods such as RBPs, which take few samples from a site and base their measures or scores on subsamples. Subsampling methods have been debated relevant to the "accuracy" of data derived from different methods (Courtemanch 1996, Barbour and Gerritsen 1996, Vinson and Hawkins 1996). Using a PBMS framework, the question is not which subsampling method is more "accurate" or precise but rather what accuracy and precision level can a method achieve, and do those performance characteristics meet the DQOs of the program? Looking at bioassessment methods in this way, (including subsampling and taxonomic identification), forces the researcher or program manager to quantitatively define beforehand the quality control characteristics necessary to make the type of interpretive assessments required by the study or program.

Once the objectives and data quality characteristics are defined for a given study, a method is chosen that meets those objectives. Depending on the data quality characteristics desired, several different methods for collecting and sorting macroinvertebrates may be suitable. Once data precision and "accuracy" are quantified for measures derived from a given bioassessment method, the method's sensitivity (the degree of change in measures or endpoints between a test site and a control or reference site that can be detected as a difference) and reliability (the degree to which an objectively defined impaired site is identified as such) can be quantified and compared with other methods. A method may be modified (e.g., more replicates or larger samples taken) to improve the precision and "accuracy" of the method and meet more stringent data requirements. Thus, a PBMS framework has the advantage of forcing scientists to focus on the ever-important issue: what type of sampling program and data quality are needed to answer the question at hand?

A second advantage of a PBMS framework is that data users and resource managers could potentially increase the amount of available information by combining data based on known comparable methods. The 305(b) process of the National Water Quality Inventory, (USEPA 1997c) is a good example of an environmental program that would benefit from a PBMS framework. This program is designed to determine status and trends of surface water quality in the U.S. A PBMS framework would make explicit the quality and comparability of data derived from different bioassessment methods, would allow more effective sharing of information collected by different states, and would improve the existing national database. Only those methods that met certain DQOs would be used. Such a decision might encourage other organizations to meet those minimum data requirements, thus increasing the amount of usable information that can be shared. For example, the RBPs used by many state agencies for water resources (Southerland and Stribling 1995) could be modified for field and laboratory procedures and still meet similar data quality objectives. The overall design steps of the RBPs, and criteria for determining useful metrics or community measures, would be relatively constant across regions and states to ensure similar quality and comparability of data.

4.3 QUANTIFYING PERFORMANCE CHARACTERISTICS

The following suggested sampling approach (Figure 4-1) need only be performed once for a particular method and by a given agency or research team; it need not be performed for each bioassessment study. Once data quality characteristics for the method are established, limited quality control (QC) sampling and analysis should supplement the required sampling for each bioassessment study to ensure that data quality characteristics of the method are met (USEPA 1995a). The additional effort and expense of such QC are negligible in relation to the potential environmental cost of producing data of poor or unknown quality.

The first step is to define precision of the collection method, also known as "measurement error". This is accomplished by replicate sampling within sites (see Hannaford and Resh 1995). The samples collected are processed and analyzed separately and their metrics compared to obtain a more realistic measure of the method precision and consistency. Repeated samples within sites estimate the precision of the entire method, comprising variability due to several sources including small-scale spatial variability within a site; operator consistency and bias; and laboratory consistency. Finally, it is desirable to sample a range of site classes (stream size, habitat type) over which the method is likely to be used. This kind of sampling, processing, and analysis should reveal potential biases.

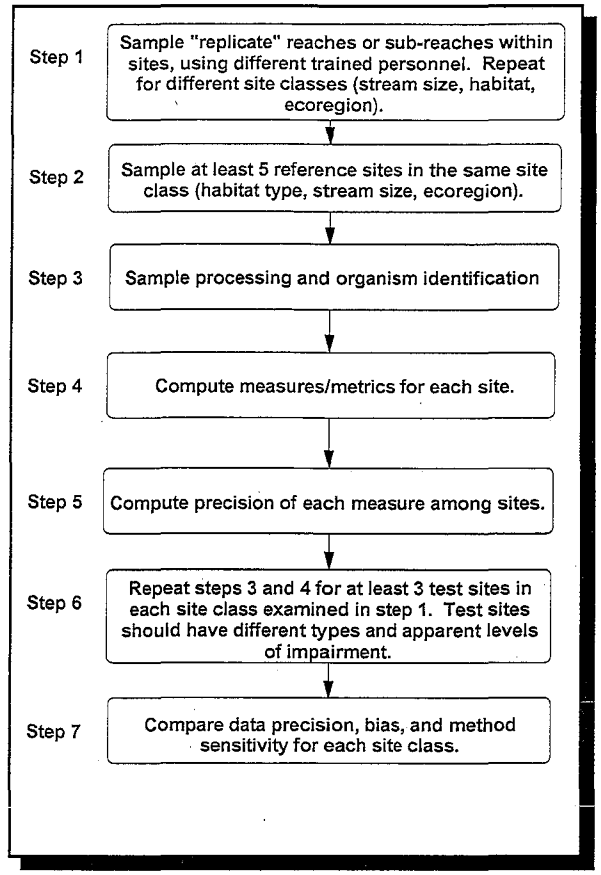

Figure 4-1. Flow chart summarizing the steps necessary to quantify performance characteristics of a bioassessment method (modified from Diamond et al. 1996).

Once the precision of the method is known, one can determine the actual variability associated with sampling "replicate" reference sites within an ecoregion or habitat type. This is known as sampling error, referring to the sample (of sites) drawn from a subpopulation (sites in a region). The degree of assemblage similarity observed among "replicate" reference streams, along with the precision of the collection method itself, will determine the overall precision, accuracy, and sensitivity of the bioassessment approach as a whole. This kind of checking has been done, at least in part, by several states (Bode and Novak 1995; Yoder and Rankin 1995a; Hornig et al. 1995; Barbour et al. 1996b), some USEPA programs (Gibson et al. 1996), and the U.S. Geological Survey (USGS) National Water Quality Assessment Program (Cuffney et al. 1993b, Gurtz 1994). Evaluation of metric or score variability among replicate reference sites can result in improved data precision and choices of stream classification. For example, the Arizona Department of Environmental Quality (DEQ) determined that macroinvertebrate assemblage structure varied substantially within ecoregions resulting in large metric variability among reference sites and poor classification (Spindler 1996). Using detrended correspondence and cluster analysis, the state agency determined that discrimination of sites by elevation and watershed area, corresponding to montane upland, desert lowland, and transition zones, resulted in much lower variability among reference sites and a better classification scheme to measure sensitivity to impairment.

If multiple reference sites are sampled in different site classes (where the sampling method is judged to be appropriate), several important method performance characteristics can be quantified, including: (1) precision for a given metric or assessment score across replicate reference sites within a site class; (2) relative precision of a given metric or score among reference sites in different classes; (3) range of classes over which a given method yields similar precision and "accuracy"; (4) potential interferences to a given method that are related to specific class characteristics and qualities; and (5) bias of a given metric, method, or both, owing to differences in classes (Diamond et al. 1996).

A study by Barbour et al. (1996b) for Florida streams, illustrates the importance of documenting method performance characteristics using multiple reference sites in different site classes. Using the same method at all sites, fewer taxa were observed in reference sites from the Florida Peninsula (one site class) compared to the Florida Panhandle (another site class), resulting in much lower reference values for taxa richness metrics in the Peninsula. Although metric precision was similar among reference sites in each site class, method sensitivity (i.e., the ability of a metric to discern a difference between reference and stressed sites) was poorer in the Peninsula for taxa richness. Thus, bioassessment "accuracy" may be more uncertain for the Florida Peninsula; that is, the probability of committing a Type II error (concluding a test site is no different from reference — therefore minimally impaired — when, in fact, it is) may be greater in the Peninsula region. In the context of a PBMS, the state agency can recognize and document differences in method performance characteristics between site classes and incorporate them into their DQOs. The state in this case can also use the method performance results to identify those site classes for which the biological indicator (index, metric, or other measurement endpoint) may not be naturally sensitive to impairment; i.e., the fauna is naturally species-poor and thus less likely to reflect impacts from stressors. If the state agency desires greater sensitivity than the current method provides, it may have to develop and test different region-specific methods and perhaps different indicators.

In the last step of the process, a method is used over a range of impaired conditions so as to determine the method's sensitivity or ability to detect impairment. As discussed earlier, sites with known levels of impairment or analogous standards by which to create a calibration curve for a given bioassessment method are lacking. In lieu of this limitation, sampling sites are chosen that have known stresses (e.g., urban runoff, toxic pollutants, livestock intrusion, sedimentation, pesticides). Because different sites may or may not have the same level of impairment within a site class (i.e., they are not replicate sites), precision of a method in impaired sites may best be examined by taking and analyzing multiple samples from the same site or adjacent reaches (Hannaford and Resh 1995).

The quantification of performance characteristics is a compromise between statistical power and cost while maintaining biological relevance. Given the often wide variation of natural geomorphic conditions and landscape ecology, even within supposedly "uniform" site classes (Corkum 1989, Hughes 1995), it is desirable to examine 10 or more reference sites (Yoder and Rankin 1995a, Gibson et al. 1996). More site classes in the evaluation process would improve documentation of the performance range and bias for a given method. Using the sampling design suggested in Figure 4-1, data from at least 30 sites (reference and test sites combined), sampled within a brief time period (so as to minimize seasonal changes in the target assemblage), are needed to define performance characteristics. An alternative approach might be to use bootstrap resampling of fewer sites to evaluate the nature of variation of these samples (Fore et al. 1996).

A range of "known" stressed sites within a site class is sampled to test the performance characteristics of a given method. It is important that stressed sites meet the following criteria: (1) they belong to the same site class as the reference sites examined; (2) they clearly have been receiving some chemical, physical, or biological stress(es) for some time (months at least); and (3) impairment is not obvious without sampling; i.e., impairment is not severe.

The first criterion is necessary to reduce potential interferences owing to class differences between the test and reference sites. Thus, the condition of the reference site will have high probability of serving as a true blank as discussed earlier. For example, it is clearly inappropriate to use high gradient mountain streams as references for assessing plains streams.

The second criterion, which is the documented presence of potential stresses, is necessary to ensure the likelihood that the test site is truly impaired (Resh and Jackson 1993). A potential test site might include a body of water that receives toxic chemicals from a point-source discharge or from nonpoint sources, or a water body that has been colonized by introduced or exotic "pest" species (for example, zebra mussel or grass carp). Stresses at the test site should be measured quantitatively to document potential cause(s) of impairment.

The third criterion, that the site is not obviously impaired, provides a reasonable test of method sensitivity or "detection limit." Severe impairment (e.g., a site that is dominated by 1 or 2 invertebrate species, or a site apparently devoid of aquatic life) generally requires little biological sampling for detection.

4.4 RECOMMENDED PROCESS FOR DOCUMENTATION OF METHOD COMPARABILITY

Although a comparison of methods at the same reference and test sites at the same time is preferable (same seasons and similar conditions), it is not essential. The critical requirement when comparing different sampling methods is that performance characteristics for each method are derived using similar habitat conditions and site classes at similar times/seasons (Diamond et al. 1996). This approach is most useful when examining the numeric scores upon which the eventual assessment is based. Thus, for a method such as RBP that sums the values of several metrics to derive a single score for a site, the framework described in Figure 4-1 should use the site scores. If one were interested in how a particular multimetric scoring system behaves, or one wishes to compare the same metric across methods, then individual metrics could be examined using the framework in Figure 4-1. For multivariate assessment methods that do not compute metric scores, one could instead examine a measure of community similarity or other variable that the researcher uses in multivariate analyses (Norris 1995).

Method comparability is based on 2 factors: (1) the relative magnitude of the coefficients of variation in measurements within and among site classes, and (2) the relative percent differences in measurements between reference and test sites. It is important to emphasize that comparability is not based on the measurements themselves, because different methods may produce different numeric scores or metrics and some sampling methods may explicitly ignore certain taxonomic groups, which will influence the metrics examined. Instead, detection of a systematic relationship among indices or the same measures among methods is advised. If 2 methods are otherwise comparable based on similar performance characteristics, then results of the 2 methods can be numerically related to each other. This outcome is a clear benefit of examining method comparability using a PBMS framework.

Figure 4-1 summarizes a suggested test design, and Table 4-3 summarizes recommended analyses for documenting both the performance characteristics of a given method, and the degree of data comparability between 2 or more methods. The process outlined in Figure 4-1 is not one that is implemented with every study. Rather, the process should be performed at least once to document the limitations and range of applicability of the methods, and should be cited with subsequent uses of the method(s).

The following performance characteristics are quantified for each bioassessment method and compared: (1) the within-class coefficient of variation for a given metric score or index by examining reference-site data for each site class separately (e.g., CV_{A1r} and CV_{B1r}; Fig. 4-1); (2) difference or bias in precision related to site class for a given metric or index (by comparing reference site coefficient of variation from each class: CV_{A1r}/CV_{B1r}; Table 4-3); and (3) estimates of method sensitivity or discriminatory power, by comparing test site data with reference site data

Table 4-3. Suggested arithmetic expressions for deriving performance characteristics that can be compared between 2 or more methods. In all cases, $\bar{x}$ = mean value, X = test site value, s = standard deviation. Subscripts are as follows: capital letter refers to site class (A or B); numeral refers to method 1 or 2; and lower case letter refers to reference (r) or test site (t) (modified from Diamond et al. 1996).

Performance Characteristic	Parameters for Quantifying Method Comparability	Desired Outcome
Relative *precision* of metric or index *within* a site class	CV_{A1r} and CV_{A2r} ; CV_{B1r} and CV_{B2r}	Low values
Relative *precision* of metric or index *between* sites (population of samples at a site) or site classes (population of sites)	$\frac{CV_{A1r}}{CV_{B1r}}$; $\frac{CV_{A2r}}{CV_{B2r}}$	High ratio
Relative *sensitivity* or "detection limit" of metric or index *within* a site class. Comparison of those values between methods reveals the most sensitive method	$\frac{\bar{x}_{A1r}-X_{A1t}}{s_{A1r}}$; $\frac{\bar{x}_{A2r}-X_{A2t}}{s_{A2r}}$ $\frac{\bar{x}_{B1r}-X_{B1t}}{s_{B1r}}$; $\frac{\bar{x}_{B2r}-X_{B2t}}{s_{B2r}}$	High ratio
Relative *sensitivity* of metric or index *between* site classes	$\frac{\bar{x}_{A1r}-X_{A1t}}{s_{A1r}}$; $\frac{\bar{x}_{B1r}-X_{B1t}}{s_{B1r}}$ $\frac{\bar{x}_{A2r}-X_{A2t}}{s_{A2r}}$; $\frac{\bar{x}_{B2r}-X_{B2t}}{s_{B2r}}$	High ratio

within each site class as a function of reference site variability (Table 4-3), e.g.,

$$\frac{\bar{x}_{A1r}-X_{A1t}}{s_{A1r}}$$

A method that yields a smaller difference between test and reference sites in relation to the reference site variability measured (Table 4-3) would indicate less discriminatory power or sensitivity; that is, the test site is erroneously perceived to be similar to or better than the reference condition and not impaired (Type II error).

Relatively few methods may be able to consistently meet the above data quality criterion and also maintain high sensitivity to impairment because both characteristics require a method that produces relatively precise, accurate data. For example, if the agency's intent is to screen many sites so as to prioritize "hot spots" or significant impairment in need of corrective action, then a method that is inexpensive, quick, and tends to show impairment when significant impairment is actually present (such as some volunteer monitoring methods) (Barbour et al. 1996a) can meet prescribed DQOs with less cost and effort. In this case, the data requirements dictate high priority for method sensitivity or discriminatory power (detection if impaired sites), understanding that there is likely also to be a high Type I error rate (misidentification of unimpaired sites).

Relative accuracy of each method is addressed to the extent that the test sites chosen are likely to be truly impaired on the basis of independent factors such as the presence of chemical stresses or suboptimal habitat. A method with relatively low precision (high variance) among reference sites compared with another method may suggest lower method accuracy. Note that a method having lower precision may still be satisfactory for some programs if it has other advantages, such as high ability to detect impaired sites with less cost and effort to perform.

Once performance characteristics are defined for each method, data comparability can be determined. If 2 methods are similarly precise, sensitive, and biased over the habitat types sampled, then the different methods should produce comparable data. Interpretive judgements could then be made concerning the quality of aquatic life using data produced by either or both methods combined. Alternatively, the comparison may show that 2 methods are comparable in their performance characteristics in certain habitats or regions and not others. If this is so, results of the 2 methods can be combined for the type for the types of habitats in which data comparability was demonstrated, but not for other regions or habitat types.

In practice, comparability of bioassessment methods would be judged relative to a reference method that has already been fully characterized (using the framework summarized in Figure 4-1) and which produces data with the quality needed by a certain program or agency. The qualities of this reference method are then defined as method performance criteria. If an alternative method yields less precision among reference sites within the same site class than the reference method (e.g., $CV_{A1r} > CV_{A2r}$ in Table 4-3), then the alternative method probably is not comparable to the reference method. A program or study could require that alternative methods are acceptable only if they are as precise as the reference method. A similar process would be accomplished for other performance characteristics that a program or agency deems important based on the type of data required by the program or study.

4.5 CASE EXAMPLE DEFINING METHOD PERFORMANCE CHARACTERISTICS

Florida Department of Environmental Protection (DEP) has developed a statewide network for monitoring and assessing the state's surface waters using macroinvertebrate data. Florida DEP has rigorously examined performance characteristics of their collection and assessment methods to provide better overall quality assurance of their biomonitoring program and to provide defensible and appropriate assessments of the state's surface waters (Barbour et al. 1996b, c). Much of the method characterization process developed for Florida DEP is easily communicated in the context of a PBMS approach.

In addition to characterizing data quality and method performance based on ecoregional site classes, Florida DEP also characterized their methods based on season (summer vs. winter sampling index periods), and size of subsample analyzed (100, 200, or 300-organism subsample). In addition, analyses were performed on the individual component metrics which composed the Florida stream condition index (SCI). For the sake of brevity, the characterization process and results for the SCI in the summer index period and the Peninsula and Northeast bioregions are summarized. The same process was used for other bioregions in the state and in the winter index period.

Performance Criteria Characteristics of Florida SCI (see Figure 4-1 for process)

Characterize Measurement Error (Method Precision Within a Site)—A total of 7 sites in the Peninsula bioregion were subjected to multiple sampling (adjacent reaches). The DEP observed a mean SCI = 28.4 and a CV (within a stream) = 6.8%. These data suggest low measurement error associated with the method and the index score. Given this degree of precision in the reference condition SCI score, power analysis indicated that 80% of the time, a test site with an SCI 5 points less (based on only a single sample at the test site) than the reference criterion, could be distinguished as impaired with 95% confidence. This analysis also indicated that if duplicate samples were taken at the test site, a difference of 3 points in the SCI score between the test site and the reference criterion could be distinguished as impaired with 95% confidence.

Characterize Sampling Error (Method Precision on a Population of Reference Sites)—A total of 56 reference sites were sampled in the Peninsula bioregion (Step 1, Figure 4-1). The SCI score could range from a minimum of 7 to a theoretical maximum of 31 based on the component metric scores. However, in the Peninsula, reference site SCI scores generally ranged between 21 and 31. A mean SCI score of 27.6 was observed with a CV of 12.0%.

Determine Method and Index Sensitivity—Distribution of SCI scores of the 56 reference sites showed that the 5th percentile was a score of 20. Thus, 95% of Peninsula reference sites had a score >20. Accuracy of the method, using known stressed sites, indicated that approximately 80% of the test sites had SCI scores ≤ 20 (Fig. 4-2). In other words, a stressed site would be assessed as impaired 80% of the time using the collection method in the Peninsula bioregion in the summer, and an impairment criterion of the 5th percentile of reference sites. The criterion could also be raised to, say, the 25th percentile of reference sites, which would increase accuracy of correctly classifying stressed sites to approximately 90%, but would decrease accuracy of correctly assessing unimpaired sites to 75%.

Determination of Method Bias and Relative Sensitivity in Different Site Classes—A comparative analysis of precision, sensitivity, and ultimately bias, can be performed for the Florida DEP method and the SCI index outlined in Table 4-3. For example, the mean SCI score in the Panhandle bioregion, during the same summer index period, was 26.3 with a CV = 12.8% based on 16 reference sites. Comparing this CV to the one reported for the Peninsula in the previous step, it is apparent that the precision of this method in the Panhandle was similar to that observed in the Peninsula bioregion.

The 5th percentile of the Panhandle reference sites was an SCI score of 17, such that actual sensitivity of the method in the Panhandle was slightly lower than in the Peninsula bioregion (Figure 4-2). An impaired site would be assessed as such only 50% of the time in the Panhandle bioregion in the summer as opposed to 80% of the time in the Peninsula bioregion during the same index period. Part of the difference in accuracy of the method among the 2 bioregions can be attributed to differences in sample size. Data from only 4 "known" impaired sites were available in the Panhandle bioregion while the Peninsula bioregion had data from 12 impaired sites. The above analyses show, however, that there may be differences in method performance between the 2 regions (probably attributable to large habitat differences between the regions) which should be further explored using data from additional "known" stressed sites, if available.

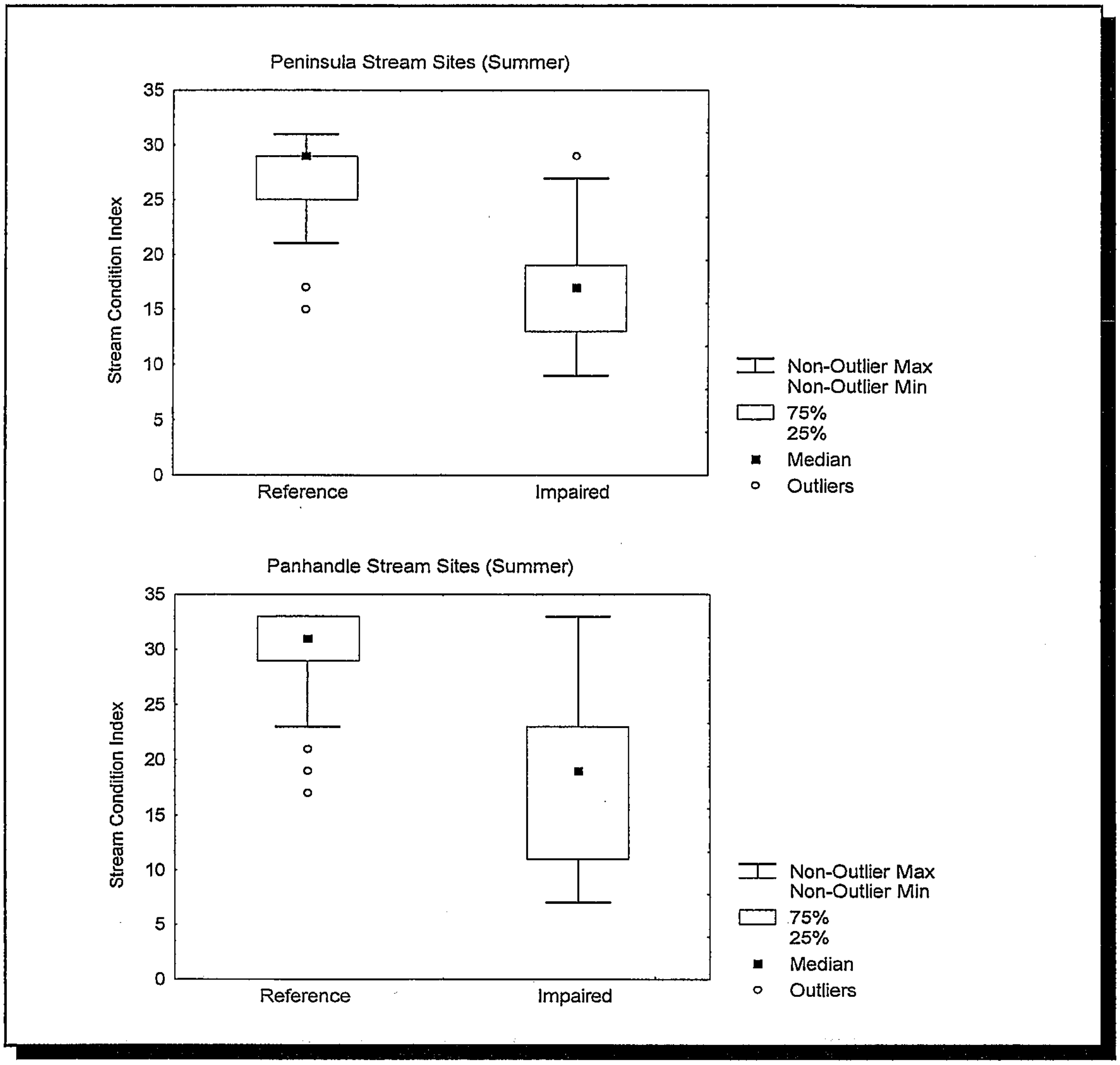

Figure 4-2. Comparison of the discriminatory ability of the SCI between Florida's Peninsula and Panhandle Bioregions. Percentiles used (not $\bar{x}$, sd) to depict relationship.

4.6 APPLICATION OF THE PBMS

The PBMS approach is intended to provide information regarding the confidence of an assessment, given a particular method. By having some measure of confidence in the endpoint and the subsequent decision pertinent to the condition of the water resource, assessment and monitoring programs are greatly strengthened. Three primary questions can be identified that enable agencies to ascertain the value and scientific validity of using information derived from different methods. Use of PBMS is necessary for these questions to be answered.

Question 1 — How rigorous must a method be to accurately detect impairment?

The analyses of Ohio EPA (1992) reveal that the power and ability of a bioassessment technique to accurately portray biological community performance and ecological integrity, and to discriminate even finer levels of aquatic life use impairments, are directly related to the data dimensions (i.e., ecological complexity, environmental accuracy, discriminatory power) produced by each (Barbour et al. 1996b). For example, a technique that includes the identification of macroinvertebrate taxa to genus and species will produce a higher attainment of data dimensions than a technique that is limited to family-level taxonomy. In general, this leads to a greater discrimination of the biological condition of sites.

Some states use one method for screening assessments and a second method for more intensive and confirmatory assessments. Florida DEP uses a BioRecon (see description in Chapter 7) to conduct statewide screening for their watershed-based monitoring. A more rigorous method based on a multihabitat sampling (see Chapter 7) is used for targeted surveys related to identified or suspected problem areas. North Carolina Water Quality Division (WQD) has a rapid EPT index (cumulative number of species of Ephemeroptera, Plecoptera, Trichoptera) to conduct screening assessments. Their more intensive method is used to monitor biological condition on a broader basis.

Use of various methods having differing levels of rigor can be examined with estimates of precision and sensitivity. These performance characteristics will help agencies make informed decisions of how resulting data can be used in assessing condition.

Question 2 — How can data derived from different methods be compared to locate additional reference sites?

Many agencies are increasingly confronted with the issue of locating appropriate reference sites from which to develop impairment/unimpairment thresholds. In some instances, sites outside of jurisdictional boundaries are needed to refine the reference condition. As watershed-based monitoring becomes implemented throughout the U.S., jurisdictional boundaries may become impediments to effective monitoring. County governments, tribal associations, local environmental interest groups, and state water resource agencies are all examples of entities that would benefit from collaborative efforts to identify common reference sites.

In most instances, all of the various agencies conducting monitoring and assessment will be using different methods. A knowledge of the precision and sensitivity of the methods will allow for an agency to decide whether the characterization of a site as reference or minimally impaired by a second agency or other entity fits the necessary criteria to be included as an additional reference site.

Question 3 — How can data from different methods be combined or integrated for increasing a database for assessment?

The question of combining data for a comprehensive assessment is most often asked by states and tribes that want to increase the spatial coverage of an assessment beyond their own limited datasets. From a national or regional perspective, the ability to combine datasets is desirable to make judgements on the condition of the water resource at a higher geographical scale. Ideally, each dataset will have been collected with the same methods.

This question is the most difficult to answer even with a knowledge of the precision and sensitivity. Widely divergent methodologies having highly divergent performance characteristics are not likely to be appropriate for combining under any circumstances. The risk of committing error in judgement of biological condition from a combined dataset of this sort would be too high.

Divergent methodologies with similar or nearly identical performance characteristics are plausible candidates for combining data at metric or index levels. However, a calibration of the methods is necessary to ensure that extrapolations of data from one method to the other is scientifically valid. The best fit for a calibrated model is a 1:1 ratio for each metric and index. Realistically, the calibration will be on a less-than-perfect relationship; extrapolations may be via range of values rather than absolute numbers. Thus, combining datasets from dissimilar methods may be valuable for characterizing severe impairment or sites of excellent condition. However, sites with slight to moderate impairment might not be detected with a high level of confidence.

For example, a 6-state collaborative study was conducted on Mid-Atlantic coastal plain streams to determine whether a combined reference condition could be established (Maxted et al. in review). In this study, a single method was applied to all sites in the coastal plain in all 6 states (New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina). The results indicated that two Bioregions exist for the coastal plain ecoregion—the northern portion, including coastal plain streams in New Jersey, Delaware, and Maryland; and the southern portion that includes Virginia, North Carolina, and South Carolina. In most situations, agencies have databases from well-established methods that differ in specific ways. The ability to combine unlike datasets has historically been a problem for scientific investigations. The usual practice has been to aggregate the data to the least common denominator and discard data that do not fit the criteria.

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5 HABITAT ASSESSMENT AND PHYSICOCHEMICAL PARAMETERS

An evaluation of habitat quality is critical to any assessment of ecological integrity and should be performed at each site at the time of the biological sampling. In general, habitat and biological diversity in rivers are closely linked (Raven et al. 1998). In the truest sense, "habitat" incorporates all aspects of physical and chemical constituents along with the biotic interactions. In these protocols, the definition of "habitat" is narrowed to the quality of the instream and riparian habitat that influences the structure and function of the aquatic community in a stream. The presence of an altered habitat structure is considered one of the major stressors of aquatic systems (Karr et al. 1986). The presence of a degraded habitat can sometimes obscure investigations on the effects of toxicity and/or pollution. The assessments performed by many water resource agencies include a general description of the site, a physical characterization and water quality assessment, and a visual assessment of instream and riparian habitat quality. Some states (e.g., Idaho DEQ and Illinois EPA) include quantitative measurements of physical parameters in their habitat assessment. Together these data provide an integrated picture of several of the factors influencing the biological condition of a stream system. These assessments are not as comprehensive as needed to adequately identify all causes of impact. However, additional investigation into hydrological modification of water courses and drainage patterns can be conducted, once impairment is noted.

The habitat quality evaluation can be accomplished by characterizing selected physicochemical parameters in conjunction with a systematic assessment of physical structure. Through this approach, key features can be rated or scored to provide a useful assessment of habitat quality.

5.1 PHYSICAL CHARACTERISTICS AND WATER QUALITY

Both physical characteristics and water quality parameters are pertinent to characterization of the stream habitat. An example of the data sheet used to characterize the physical characteristics and water quality of a site is shown in Appendix A. The information required includes measurements of physical characterization and water quality made routinely to supplement biological surveys.

Physical characterization includes documentation of general land use, description of the stream origin and type, summary of the riparian vegetation features, and measurements of instream parameters such as width, depth, flow, and substrate. The water quality discussed in these protocols are *in situ* measurements of standard parameters that can be taken with a water quality instrument. These are generally instantaneous measurements taken at the time of the survey. Measurements of certain parameters, such as temperature, dissolved oxygen, and turbidity, can be taken over a diurnal cycle and will require instrumentation that can be left in place for extended periods or collects water samples at periodic intervals for measurement. In addition, water samples may be desired to be collected for selected chemical analysis. These chemical samples are transported to an analytical laboratory for processing. The combination of this information (physical characterization and water quality) will provide insight as to the ability of the stream to support a healthy aquatic community, and to the presence of chemical and non-chemical stressors to the stream ecosystem. Information requested in this section (Appendix A-1, Form 1) is standard to many aquatic studies and allows for some comparison among sites. Additionally, conditions that may significantly affect aquatic biota are documented.

5.1.1 Header Information (Station Identifier)

The header information is identical on all data sheets and requires sufficient information to identify the station and location where the survey was conducted, date and time of survey, and the investigators responsible for the quality and integrity of the data. The stream name and river basin identify the watershed and tributary; the location of the station is described in the narrative to help identify access to the station for repeat visits. The rivermile (if applicable) and latitude/longitude are specific locational data for the station. The station number is a code assigned by the agency that will associate the sample and survey data with the station. The STORET number is assigned to each datapoint for inclusion in USEPA's STORET system. The stream class is a designation of the grouping of homogeneous characteristics from which assessments will be made. For instance, Ohio EPA uses ecoregions and size of stream, Florida DEP uses bioregions (aggregations of subecoregions), and Arizona DEQ uses elevation as a means to identify stream classes. Listing the agency and investigators assigns responsibility to the data collected from the station at a specific date and time. The reason for the survey is sometimes useful to an agency that conducts surveys for various programs and purposes.

5.1.2 Weather Conditions

Note the present weather conditions on the day of the survey and those immediately preceding the day of the survey. This information is important to interpret the effects of storm events on the sampling effort.

5.1.3 Site Location/Map

To complete this phase of the bioassessment, a photograph may be helpful in identifying station location and documenting habitat conditions. Any observations or data not requested but deemed important by the field observer should be recorded. A hand-drawn map is useful to illustrate major landmarks or features of the channel morphology or orientation, vegetative zones, buildings, etc. that might be used to aid in data interpretation.

5.1.4 Stream Characterization

Stream Subsystem: In regions where the perennial nature of streams is important, or where the tidal influence of streams will alter the structure and function of communities, this parameter should be noted.

Stream Type: Communities inhabiting coldwater streams are markedly different from those in warmwater streams, many states have established temperature criteria that differentiate these 2 stream types.

Stream Origin: Note the origination of the stream under study, if it is known. Examples are glacial, montane, swamp, and bog. As the size of the stream or river increases, a mixture of origins of tributaries is likely.

5.1.5 Watershed Features

Collecting this information usually requires some effort initially for a station. However, subsequent surveys will most likely not require an in-depth research of this information.

Predominant Surrounding Land Use Type: Document the prevalent land-use type in the catchment of the station (noting any other land uses in the area which, although not predominant, may potentially affect water quality). Land use maps should be consulted to accurately document this information.

Local Watershed Nonpoint Source Pollution: This item refers to problems and potential problems in the watershed. Nonpoint source pollution is defined as diffuse agricultural and urban runoff. Other compromising factors in a watershed that may affect water quality include feedlots, constructed wetlands, septic systems, dams and impoundments, mine seepage, etc.

Local Watershed Erosion: The existing or potential detachment of soil within the local watershed (the portion of the watershed or catchment that directly affects the stream reach or station under study) and its movement into the stream is noted. Erosion can be rated through visual observation of watershed and stream characteristics (note any turbidity observed during water quality assessment below).

5.1.6 Riparian Vegetation

An acceptable riparian zone includes a buffer strip of a minimum of 18 m (Barton et al. 1985) from the stream on either side. The acceptable width of the riparian zone may also be variable depending on the size of the stream. Streams over 4 m in width may require larger riparian zones. The vegetation within the riparian zone is documented here as the dominant type and species, if known.

5.1.7 Instream Features

Instream features are measured or evaluated in the sampling reach and catchment as appropriate.

Estimated Reach Length: Measure or estimate the length of the sampling reach. This information is important if reaches of variable length are surveyed and assessed.

Estimated Stream Width (in meters, m): Estimate the distance from bank to bank at a transect representative of the stream width in the reach. If variable widths, use an average to find that which is representative for the given reach.

Sampling Reach Area (m^2): Multiply the sampling reach length by the stream width to obtain a calculated surface area.

Estimated Stream Depth (m): Estimate the vertical distance from water surface to stream bottom at a representative depth (use instream habitat feature that is most common in reach) to obtain average depth.

Velocity: Measure the surface velocity in the thalweg of a representative run area. If measurement is not done, estimate the velocity as slow, moderate, or fast.

Canopy Cover: Note the general proportion of open to shaded area which best describes the amount of cover at the sampling reach or station. A densiometer may be used in place of visual estimation.

High Water Mark (m): Estimate the vertical distance from the bankfull margin of the stream bank to the peak overflow level, as indicated by debris hanging in riparian or floodplain vegetation, and deposition of silt or soil. In instances where bank overflow is rare, a high water mark may not be evident.

Proportion of Reach Represented by Stream Morphological Types: The proportion represented by riffles, runs, and pools should be noted to describe the morphological heterogeneity of the reach.

Channelized: Indicate whether or not the area around the sampling reach or station is channelized (e.g., straightening of stream, bridge abutments and road crossings, diversions, etc.).

Dam Present: Indicate the presence or absence of a dam upstream in the catchment or downstream of the sampling reach or station. If a dam is present, include specific information relating to alteration of flow.

5.1.8 Large Woody Debris

Large Woody Debris (LWD) density, defined and measured as described below, has been used in regional surveys (Shields et al. 1995) and intensive studies of degraded and restored streams (Shields et al. 1998). The method was developed for sand or sand-and-gravel bed streams in the Southeastern U.S. that are wadeable at baseflow, with water widths between 1 and 30 m (Cooper and Testa 1999).

Cooper and Testa's (1999) procedure involves measurements based on visual estimates taken by a wading observer. Only woody debris actually in contact with stream water is counted. Each woody debris formation with a surface area in the plane of the water surface >0.25 m^2 is recorded. The estimated length and width of each formation is recorded on a form or marked directly onto a stream reach drawing. Estimates are made to the nearest 0.5 m , and formations with length or width less than 0.5 m are not counted. Recorded length is maximum width in the direction perpendicular to the length. Maximum actual length and width of a limb, log, or accumulation are not considered.

If only a portion of the log/limb is in contact with the water, only that portion in contact is measured. Root wads and logs/limbs in the water margin are counted if they contact the water, and are arbitrarily given a width of 0.5 m Lone individual limbs and logs are included in the determination if their diameter is 10 cm or larger (Keller and Swanson 1979, Ward and Aumen 1986). Accumulations of smaller limbs and logs are included if the formation total length or width is 0.5 m or larger. Standing trees and stumps within the stream are also recorded if their length and width exceed 0.5 m.

The length and width of each LWD formation are then multiplied, and the resulting products are summed to give the aquatic habitat area directly influenced. This area is then divided by the water surface area (km^2) within the sampled reach (obtained by multiplying the average water surface width by reach length) to obtain LWD density. Density values of 10^3 to 10^4 m^2/km^2 have been reported for channelized and incised streams and on the order of 10^5 m^2/km^2 for non-incised streams (Shields et al. 1995 and 1998). This density is not an expression of the volume of LWD, but rather a measure of LWD influence on velocity, depth, and cover.

5.1.9 Aquatic Vegetation

The general type and relative dominance of aquatic plants are documented in this section. Only an estimation of the extent of aquatic vegetation is made. Besides being an ecological assemblage that responds to perturbation, aquatic vegetation provides refugia and food for aquatic fauna. List the species of aquatic vegetation, if known.

5.1.10 Water Quality

Temperature (°C), Conductivity or "Specific Conductance" (µohms), Dissolved Oxygen (µg/L), pH, Turbidity: Measure and record values for each of the water quality parameters indicated, using the appropriate calibrated water quality instrument(s). Note the type of instrument and unit number used.

Water Odors: Note those odors described (or include any other odors not listed) that are associated with the water in the sampling area.

Water Surface Oils: Note the term that best describes the relative amount of any oils present on the water surface.

Turbidity: If turbidity is not measured directly, note the term which, based upon visual observation, best describes the amount of material suspended in the water column.

5.1.11 Sediment/Substrate

Sediment Odors: Disturb sediment in pool or other depositional areas and note any odors described (or include any other odors not listed) which are associated with sediment in the sampling reach.

Sediment Oils: Note the term which best describes the relative amount of any sediment oils observed in the sampling area.

Sediment Deposits: Note those deposits described (or include any other deposits not listed) that are present in the sampling reach. Also indicate whether the undersides of rocks not deeply embedded are black (which generally indicates low dissolved oxygen or anaerobic conditions).

Inorganic Substrate Components: Visually estimate the relative proportion of each of the 7 substrate/particle types listed that are present over the sampling reach.

Organic Substrate Components: Indicate relative abundance of each of the 3 substrate types listed.

5.2 A VISUAL-BASED HABITAT ASSESSMENT

Biological potential is limited by the quality of the physical habitat, forming the template within which biological communities develop (Southwood 1977). Thus, habitat assessment is defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour et al. 1996a). For streams, an encompassing approach to assessing structure of the habitat includes an evaluation of the variety and quality of the substrate, channel morphology, bank structure, and riparian vegetation. Habitat parameters pertinent to the assessment of habitat quality include those that characterize the stream "micro scale" habitat (e.g., estimation of embeddeddness), the "macro scale" features (e.g., channel morphology), and the riparian and bank structure features that are most often influential in affecting the other parameters.

Rosgen (1985, 1994) presented a stream and river classification system that is founded on the premise that dynamically-stable stream channels have a morphology that provides appropriate distribution of flow energy during storm events. Further, he identifies 8 major variables that affect the stability of channel morphology, but are not mutually independent: channel width, channel depth, flow velocity, discharge, channel slope, roughness of channel materials, sediment load and sediment particle size distribution. When streams have one of these characteristics altered, some of their capability to dissipate energy properly is lost (Leopold et al. 1964, Rosgen 1985) and will result in accelerated rates of channel erosion. Some of the habitat structural components that function to dissipate flow energy are:

EQUIPMENT/SUPPLIES NEEDED FOR HABITAT ASSESSMENT AND PHYSICAL/WATER QUALITY CHARACTERIZATION

- Physical Characterization and Water Quality Field Data Sheet*
- Habitat Assessment Field Data Sheet*
- clipboard
- pencils or waterproof pens
- 35 mm camera (may be digital)
- video camera (optional)
- upstream/downstream "arrows" or signs for photographing and documenting sampling reaches
- Flow or velocity meter
- *In situ* water quality meters
- Global Positioning System (GPS) Unit

* It is helpful to copy field sheets onto water-resistant paper for use in wet weather conditions

! sinuosity

! roughness of bed and bank materials

! presence of point bars (slope is an important characteristic)

! vegetative conditions of stream banks and the riparian zone

! condition of the floodplain (accessibility from bank, overflow, and size are important characteristics).

Measurement of these parameters or characteristics serve to stratify and place streams into distinct classifications. However, none of these habitat classification techniques attempt to differentiate the quality of the habitat and the ability of the habitat to support the optimal biological condition of the region. Much of our understanding of habitat relationships in streams has emerged from comparative studies that describe statistical relationships between habitat variables and abundance of biota (Hawkins et al. 1993). However, in response to the need to incorporate broader scale habitat assessments in water resource programs, 2 types of approaches for evaluating habitat structure have been developed. In the first, the Environmental Monitoring and Assessment Program (EMAP) of the USEPA and the National Water-Quality Assessment Program (NAWQA) of the USGS developed techniques that incorporate measurements of various features of the instream, channel, and bank morphology (Meader et al. 1993, Klemm and Lazorchak 1994). These techniques provide a relatively comprehensive characterization of the physical structure of the stream sampling reach and its surrounding floodplain. The second type was a more rapid and qualitative habitat assessment approach that was developed to describe the overall quality of the physical habitat (Ball 1982, Ohio EPA 1987, Plafkin et al. 1989, Barbour and Stribling 1991, 1994, Rankin 1991, 1995). In this document, the more rapid visual-based approach is described. A cursory overview of the more quantitative approaches to characterizing the physical structure of the habitat is provided.

The habitat assessment matrix developed for the Rapid Bioassessment Protocols (RBPs) in Plafkin et al. (1989) were originally based on the Stream Classification Guidelines for Wisconsin developed by Ball (1982) and "*Methods of Evaluating Stream, Riparian, and Biotic Conditions*" developed by Platts et al. (1983). Barbour and Stribling (1991, 1994) modified the habitat assessment approach originally developed for the RBPs to include additional assessment parameters for high gradient streams and a more appropriate parameter set for low gradient streams (Appendix A-1, Forms 2,3). All parameters are evaluated and rated on a numerical scale of 0 to 20 (highest) for each sampling reach. The ratings are then totaled and compared to a reference condition to provide a final habitat ranking. Scores increase as habitat quality increases. To ensure consistency in the evaluation procedure, descriptions of the physical parameters and relative criteria are included in the rating form.

The Environmental Agency of Great Britain (Environment Agency of England and Wales, Scottish Environment Protection Agency, and Environment and Heritage Service of Northern Ireland) have developed a River Habitat Survey (RHS) for characterizing the quality of their streams and rivers (Raven et al. 1998). The approach used in Great Britain is similar to the visual-based habitat assessment used in the US in that scores are assigned to ranges of conditions of various habitat parameters.

A biologist who is well versed in the ecology and zoogeography of the region can generally recognize optimal habitat structure as it relates to the biological community. The ability to accurately assess the quality of the physical habitat structure using a visual-based approach depends on several factors:

- the parameters selected to represent the various features of habitat structure need to be relevant and clearly defined
- a continuum of conditions for each parameter must exist that can be characterized from the optimum for the region or stream type under study to the poorest situation reflecting substantial alteration due to anthropogenic activities

- ! the judgement criteria for the attributes of each parameter should minimize subjectivity through either quantitative measurements or specific categorical choices

- ! the investigators are experienced in or adequately trained for stream assessments in the region under study (Hannaford et al. 1997)

- ! adequate documentation and ongoing training is maintained to evaluate and correct errors resulting in outliers and aberrant assessments.

Habitat evaluations are first made on instream habitat, followed by channel morphology, bank structural features, and riparian vegetation. Generally, a single, comprehensive assessment is made that incorporates features of the entire sampling reach as well as selected features of the catchment. Additional assessments may be made on neighboring reaches to provide a broader evaluation of habitat quality for the stream ecosystem. The actual habitat assessment process involves rating the 10 parameters as optimal, suboptimal, marginal, or poor based on the criteria included on the Habitat Assessment Field Data Sheets (Appendix A-1, Forms 2,3). Some state programs, such as Florida Department of Environmental Protection (DEP) (1996) and Mid-Atlantic Coastal Streams Workgroup (MACS) (1996) have adapted this approach using somewhat fewer and different parameters.

Reference conditions are used to scale the assessment to the "best attainable" situation. This approach is critical to the assessment because stream characteristics will vary dramatically across different regions (Barbour and Stribling 1991). The ratio between the score for the test station and the score for the reference condition provides a percent comparability measure for each station. The station of interest is then classified on the basis of its similarity to expected conditions (reference condition), and its apparent potential to support an acceptable level of biological health. Use of a percent comparability evaluation allows for regional and stream-size differences which affect flow or velocity, substrate, and channel morphology. Some regions are characterized by streams having a low channel gradient, such as coastal plains or prairie regions.

Other habitat assessment approaches or a more rigorously quantitative approach to measuring the habitat parameters may be used (See Klemm and Lazorchak 1994, Kaufmann and Robison 1997, Meader et al. 1993). However, holistic and rapid assessment of a wide variety of habitat attributes along with other types of data is critical if physical measurements are to be used to best advantage in interpreting biological data. A more detailed discussion of the relationship between habitat quality and biological condition is presented in Chapter 10.

A generic habitat assessment approach based on visual observation can be separated into 2 basic approaches—one designed for high-gradient streams and one designed for low-gradient streams. High-gradient or riffle/run prevalent streams are those in moderate to high gradient landscapes. Natural high-gradient streams have substrates primarily composed of coarse sediment particles (i.e., gravel or larger) or frequent coarse particulate aggregations along stream reaches. Low-gradient or glide/pool prevalent streams are those in low to moderate gradient landscapes. Natural low-gradient streams have substrates of fine sediment or infrequent aggregations of more coarse (gravel or larger) sediment particles along stream reaches. The entire sampling reach is evaluated for each parameter. Descriptions of each parameter and its relevance to instream biota are presented in the following discussion. Parameters that are used only for high-gradient prevalent streams are marked with an "a"; those for low-gradient dominant streams, a "b". If a parameter is used for both stream types, it is not marked with a letter. A brief set of decision criteria is given for each parameter corresponding to each of the 4 categories reflecting a continuum of conditions on the field sheet (optimal, suboptimal, marginal, and poor). Refer to Appendix A-1, Forms 2 and 3, for a complete field assessment guide.

PROCEDURE FOR PERFORMING HABITAT ASSESSMENT

1. Select the reach to be assessed. The habitat assessment is performed on the same 100 m reach (or other reach designation [e.g., 40 x stream wetted width]) from which the biological sampling is conducted. Some parameters require an observation of a broader section of the catchment than just the sampling reach.

2. Complete the station identification section of each field data sheet and habitat assessment form.

3. It is best for the investigators to obtain a close look at the habitat features to make an adequate assessment. If the physical and water quality characterization and habitat assessment are done before the biological sampling, care must be taken to avoid disturbing the sampling habitat.

4. Complete the **Physical Characterization and Water Quality Field Data Sheet.** Sketch a map of the sampling reach on the back of this form.

5. Complete the **Habitat Assessment Field Data Sheet,** in a team of 2 or more biologists, if possible, to come to a consensus on determination of quality. Those parameters to be evaluated on a scale greater than a sampling reach require traversing the stream corridor to the extent deemed necessary to assess the habitat feature. As a general rule-of-thumb, use 2 lengths of the sampling reach to assess these parameters.

QUALITY ASSURANCE PROCEDURES

1. Each biologist is to be trained in the visual-based habitat assessment technique for the applicable region or state.

2. The judgment criteria for each habitat parameter are calibrated for the stream classes under study. Some text modifications may be needed on a regional basis.

3. Periodic checks of assessment results are completed using pictures of the sampling reach and discussions among the biologists in the agency.

Parameters to be evaluated in sampling reach:

1 EPIFAUNAL SUBSTRATE/AVAILABLE COVER

high and low gradient streams

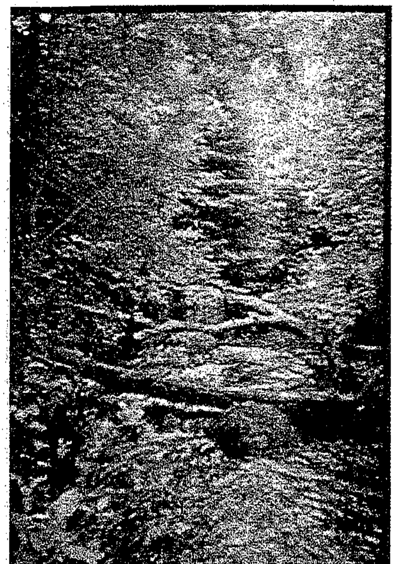
Includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs are critical for maintaining a variety and abundance of insects in most high-gradient streams and serving as spawning and feeding refugia for certain fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in high-gradient streams. Riffles and runs offer a diversity of habitat through variety of particle size, and, in many small high-gradient streams, will provide the most stable habitat. Snags and submerged logs are among the most productive habitat structure for macroinvertebrate colonization and fish refugia in low-gradient streams. However, "new fall" will not yet be suitable for colonization.

Selected References

Wesche et al. 1985, Pearsons et al. 1992, Gorman 1988, Rankin 1991, Barbour and Stribling 1991, Plafkin et al. 1989, Platts et al. 1983, Osborne et al. 1991, Benke et al. 1984, Wallace et al. 1996, Ball 1982, MacDonald et al. 1991, Reice 1980, Clements 1987, Hawkins et al. 1982, Beechie and Sibley 1997.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover **(high and low gradient)**	Greater than 70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

1a. Epifaunal Substrate/Available Cover—High Gradient


Optimal Range


Poor Range

1b. Epifaunal Substrate/Available Cover—Low Gradient


Optimal Range (*Mary Kay Corazalla, U. of Minn.*)


Poor Range

2a EMBEDDEDNESS

high gradient streams

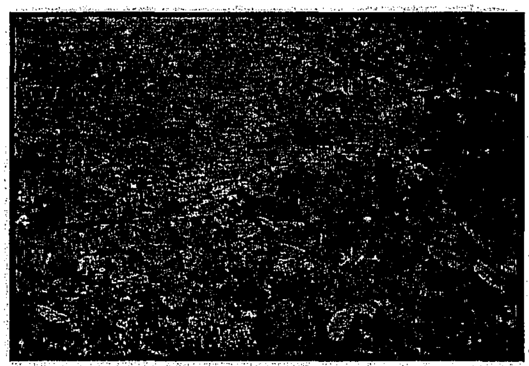
Refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (shelter, spawning, and egg incubation) is decreased. Embeddedness is a result of large-scale sediment movement and deposition, and is a parameter evaluated in the riffles and runs of high-gradient streams. The rating of this parameter may be variable depending on where the observations are taken. To avoid confusion with sediment deposition (another habitat parameter), observations of embeddedness should be taken in the upstream and central portions of riffles and cobble substrate areas.

Selected References

Ball 1982, Osborne et al. 1991, Barbour and Stribling 1991, Platts et al. 1983, MacDonald et al. 1991, Rankin 1991, Reice 1980, Clements 1987, Benke et al. 1984, Hawkins et al. 1982, Burton and Harvey 1990.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
2.a Embeddedness (high gradient)	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

2a. Embeddedness—High Gradient



Optimal Range *(William Taft, MI DNR)*

Poor Range *(William Taft, MI DNR)*

2b POOL SUBSTRATE CHARACTERIZATION

low gradient streams

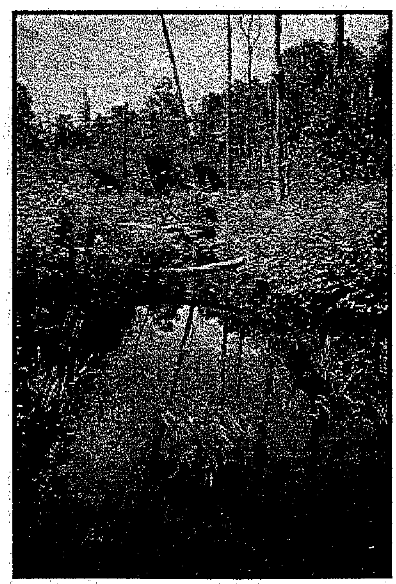
Evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support far fewer types of organisms than a stream that has a variety of substrate types.

Selected References

Beschta and Platts 1986, U.S. EPA 1983.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
2b. Pool Substrate Characterization (**low gradient**)	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or submerged vegetation.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

2b. Pool Substrate Characterization—Low Gradient



Optimal Range

(Mary Kay Corazalla, U. of Minn.)

Poor Range

3a VELOCITY/DEPTH COMBINATIONS

high gradient streams

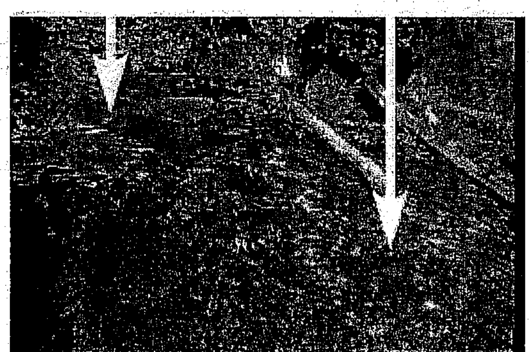
Patterns of velocity and depth are included for high-gradient streams under this parameter as an important feature of habitat diversity. The best streams in most high-gradient regions will have all 4 patterns present: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. The general guidelines are 0.5 m depth to separate shallow from deep, and 0.3 m/sec to separate fast from slow. The occurrence of these 4 patterns relates to the stream's ability to provide and maintain a stable aquatic environment.

Selected References

Ball 1982, Brown and Brussock 1991, Gore and Judy 1981, Oswood and Barber 1982.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
3a. Velocity/ Depth Regimes **(high gradient)**	All 4 velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (slow is <0.3 m/s, deep is >0.5 m)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

3a. Velocity/Depth Regimes—High Gradient



Optimal Range *(Mary Kay Corazalla, U. of Minn.)*
(arrows emphasize different velocity/depth regimes)

Poor Range *(William Taft, MI DNR)*

3b POOL VARIABILITY

low gradient streams

Rates the overall mixture of pool types found in streams, according to size and depth. The 4 basic types of pools are large-shallow, large-deep, small-shallow, and small-deep. A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community. General guidelines are any pool dimension (i.e., length, width, oblique) greater than half the cross-section of the stream for separating large from small and 1 m depth separating shallow and deep.

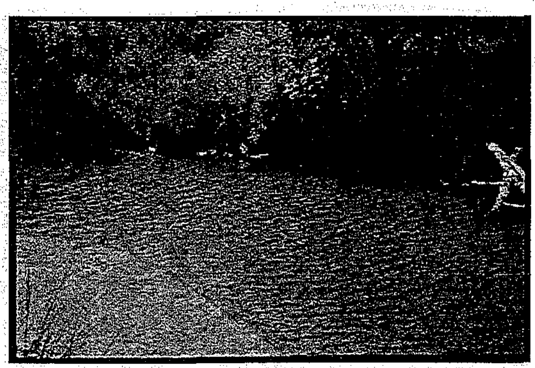
Selected References

Beschta and Platts 1986, USEPA 1983.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
3b. Pool Variability (low gradient)	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

3b. Pool Variability—Low Gradient

Optimal Range *(Peggy Morgan, FL DEP)*



Poor Range *(William Taft, MI DNR)*

4 SEDIMENT DEPOSITION

high and low gradient streams

Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. Deposition occurs from large-scale movement of sediment. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow decreases, such as bends. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.

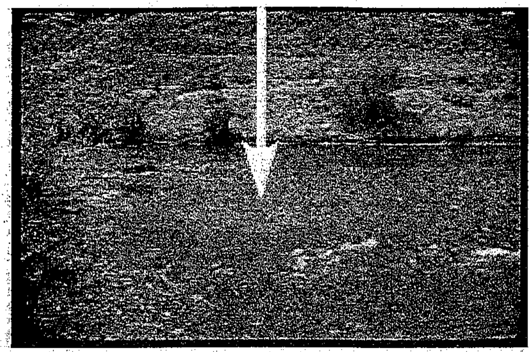
Selected References

MacDonald et al. 1991, Platts et al. 1983, Ball 1982, Armour et al. 1991, Barbour and Stribling 1991, Rosgen 1985.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
4. Sediment Deposition **(high and low gradient)**	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

4a. **Sediment Deposition—High Gradient**

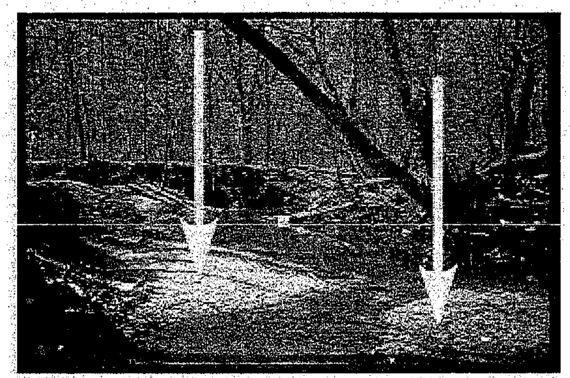
Optimal Range



Poor Range
(arrow pointing to sediment deposition)

4b. **Sediment Deposition—Low Gradient**

Optimal Range



Poor Range
(arrows pointing to sediment deposition)

5 CHANNEL FLOW STATUS

high and low gradient streams

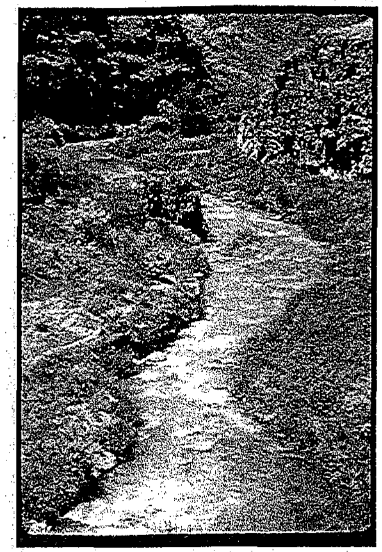
The degree to which the channel is filled with water. The flow status will change as the channel enlarges (e.g., aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed, the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, riffles and cobble substrate are exposed; in low-gradient streams, the decrease in water level exposes logs and snags, thereby reducing the areas of good habitat. Channel flow is especially useful for interpreting biological condition under abnormal or lowered flow conditions. This parameter becomes important when more than one biological index period is used for surveys or the timing of sampling is inconsistent among sites or annual periodicity.

Selected References

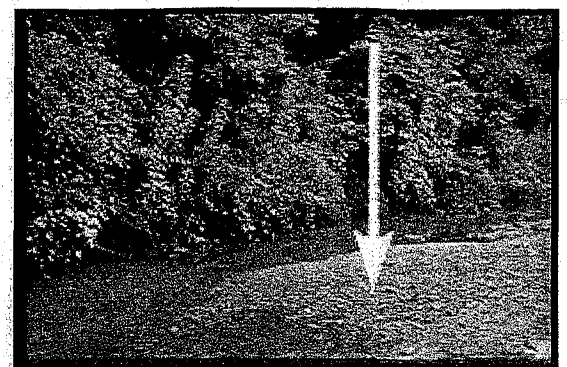
Rankin 1991, Rosgen 1985, Hupp and Simon 1986, MacDonald et al. 1991, Ball 1982, Hicks et al. 1991.

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
5. Channel Flow Status **(high and low gradient)**	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

5a. **Channel Flow Status—High Gradient**



Optimal Range



Poor Range
(arrow showing that water is not reaching both banks; leaving much of channel uncovered)

5b. **Channel Flow Status—Low Gradient**

Optimal Range

Poor Range *(James Stahl, IN DEM)*

Parameters to be evaluated broader than sampling reach:

6 CHANNEL ALTERATION

high and low gradient streams

Is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control or irrigation purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than do naturally meandering streams. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances; when dams and bridges are present; and when other such changes have occurred. Scouring is often associated with channel alteration.

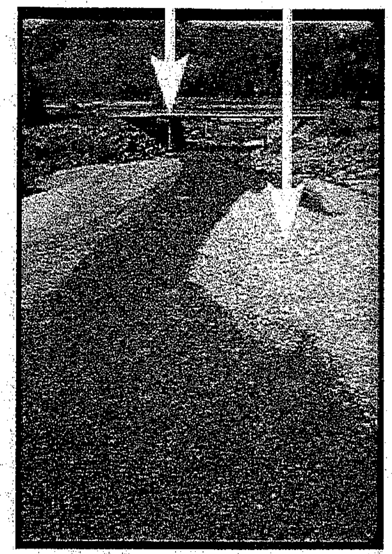
Selected References

Barbour and Stribling 1991, Simon 1989a, b, Simon and Hupp 1987, Hupp and Simon 1986, Hupp 1992, Rosgen 1985, Rankin 1991, MacDonald et al. 1991.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration **(high and low gradient)**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

6a. Channel Alteration—High Gradient

Optimal Range



Poor Range
(arrows emphasizing large-scale channel alterations)

6b. Channel Alteration—Low Gradient

Optimal Range

Poor Range *(John Maxted, DE DNREC)*

7a FREQUENCY OF RIFFLES (OR BENDS)

high gradient streams

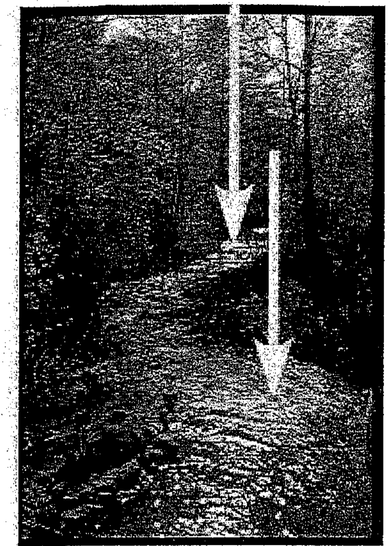
Is a way to measure the sequence of riffles and thus the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna, therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community. For high gradient streams where distinct riffles are uncommon, a run/bend ratio can be used as a measure of meandering or sinuosity (see 7b). A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in some streams, a longer segment or reach than that designated for sampling should be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps. The "sequencing" pattern of the stream morphology is important in rating this parameter. In headwaters, riffles are usually continuous and the presence of cascades or boulders provides a form of sinuosity and enhances the structure of the stream. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).

Selected References

Hupp and Simon 1991, Brussock and Brown 1991, Platts et al. 1983, Rankin 1991, Rosgen 1985, 1994, 1996, Osborne and Hendricks 1983, Hughes and Omernik 1983, Cushman 1985, Bain and Boltz 1989, Gislason 1985, Hawkins et al. 1982, Statzner et al. 1988.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
7a. Frequency of Riffles (or bends) **(high gradient)**	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

7a. Frequency of Riffles (or bends)—High Gradient



Optimal Range
(arrows showing frequency of riffles and bends)

Poor Range

7b CHANNEL SINUOSITY

low gradient streams

Evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in low gradient streams, a longer segment or reach than that designated for sampling may be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps. The "sequencing" pattern of the stream morphology is important in rating this parameter. In "oxbow" streams of coastal areas and deltas, meanders are highly exaggerated and transient. Natural conditions in these streams are shifting channels and bends, and alteration is usually in the form of flow regulation and diversion. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).

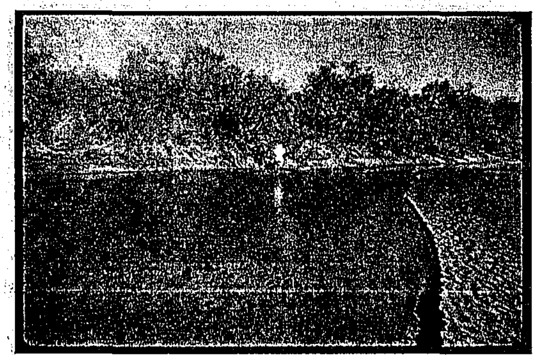
Selected References

Hupp and Simon 1991, Brussock and Brown 1991, Platts et al. 1983, Rankin 1991, Rosgen 1985, 1994, 1996, Osborne and Hendricks 1983, Hughes and Omernik 1983, Cushman 1985, Bain and Boltz 1989, Gislason 1985, Hawkins et al. 1982, Statzner et al. 1988.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
7b. Channel Sinuosity **(low gradient)**	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

7b. Channel Sinuosity—Low Gradient

Optimal Range



Poor Range

8 BANK STABILITY (condition of banks)

high and low gradient streams

Measures whether the stream banks are eroded (or have the potential for erosion). Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

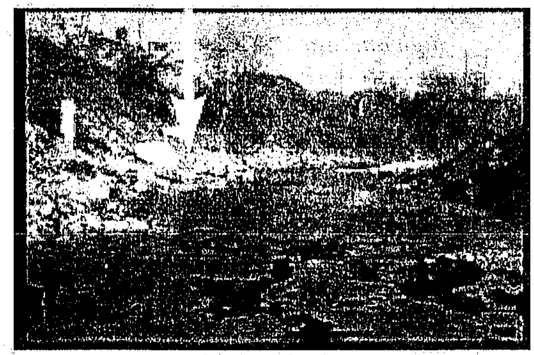
Selected References

Ball 1982, MacDonald et al. 1991, Armour et al. 1991, Barbour and Stribling 1991, Hupp and Simon 1986, 1991, Simon 1989a, Hupp 1992, Hicks et al. 1991, Osborne et al. 1991, Rosgen 1994, 1996.

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
8. Bank Stability (score each bank) **Note: determine left or right side by facing downstream** **(high and low gradient)**	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

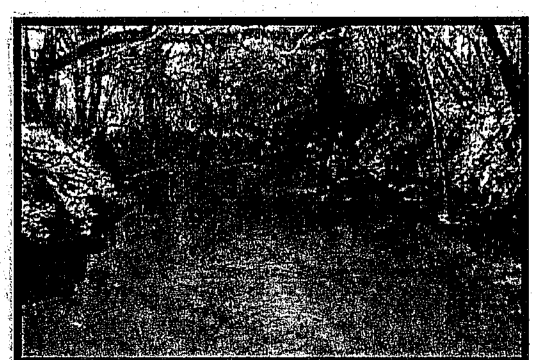
8a. **Bank Stability (condition of banks)—High Gradient**

Optimal Range
(arrow pointing to stable streambanks)

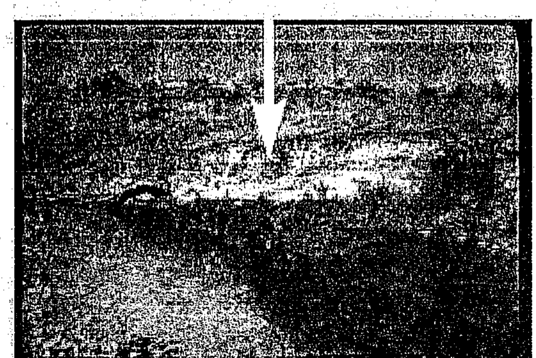


Poor Range *(MD Save Our Streams)*
(arrow highlighting unstable streambanks)

8b. **Bank Stability (condition of banks)—Low Gradient**



Optimal Range *(Peggy Morgan, FL DEP)*



Poor Range
(arrow highlighting unstable streambanks)

9 BANK VEGETATIVE PROTECTION

high and low gradient streams

Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. This parameter is made more effective by defining the native vegetation for the region and stream type (i.e., shrubs, trees, etc.). In some regions, the introduction of exotics has virtually replaced all native vegetation. The value of exotic vegetation to the quality of the habitat structure and contribution to the stream ecosystem must be considered in this parameter. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Selected References

Platts et al. 1983, Hupp and Simon 1986, 1991, Simon and Hupp 1987, Ball 1982, Osborne et al. 1991, Rankin 1991, Barbour and Stribling 1991, MacDonald et al. 1991, Armour et al. 1991, Myers and Swanson 1991, Bauer and Burton 1993.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
9. Vegetative Protection (score each bank) **Note: determine left or right side by facing downstream.** **(high and low gradient)**	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

A010101

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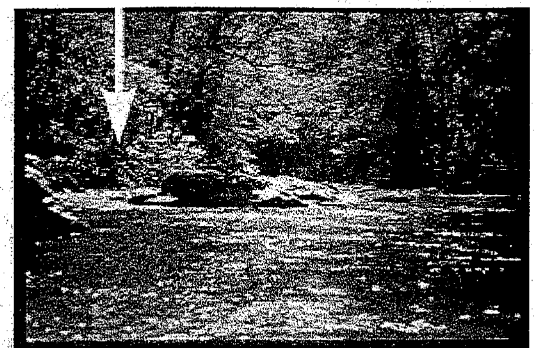
9a. Bank Vegetative Protection—High Gradient



Optimal Range
(arrow pointing to streambank with high level of vegetative cover)

Poor Range
(arrow pointing to streambank with almost no vegetative cover)

9b. Bank Vegetative Protection—Low Gradient

Optimal Range *(Peggy Morgan, FL DEP)*

Poor Range *(MD Save Our Streams)*
(arrow pointing to channelized streambank with no vegetative cover)

A010103

10 RIPARIAN VEGETATIVE ZONE WIDTH

high and low gradient streams

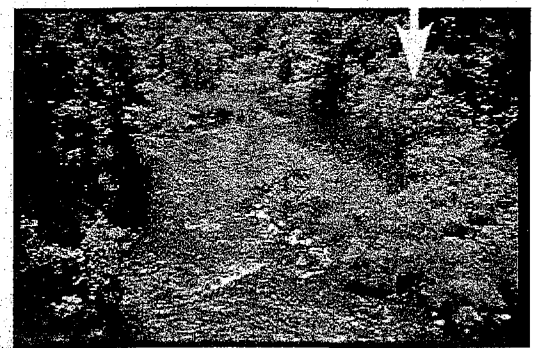
Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and rangeland are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores. For variable size streams, the specified width of a desirable riparian zone may also be variable and may be best determined by some multiple of stream width (e.g., 4 x wetted stream width). Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Selected References

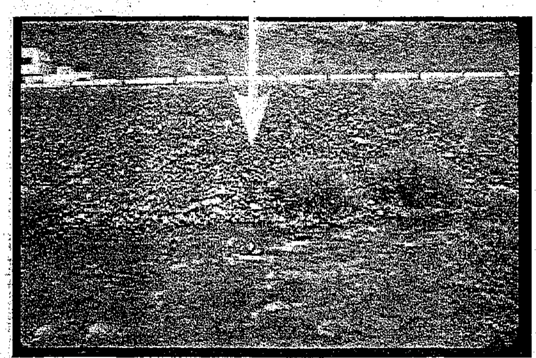
Barton et al. 1985, Naiman et al. 1993, Hupp 1992, Gregory et al. 1991, Platts et al. 1983, Rankin 1991, Barbour and Stribling 1991, Bauer and Burton 1993.

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
10. Riparian Vegetative Zone Width (score each bank riparian zone) **(high and low gradient)**	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

10a. Riparian Vegetative Zone Width—High Gradient



Optimal Range
(arrow pointing out an undisturbed riparian zone)



Poor Range
(arrow pointing out lack of riparian zone)

10b. Riparian Vegetative Zone Width—Low Gradient

Optimal Range
(arrow emphasizing an undisturbed riparian zone)

Poor Range *(MD Save Our Streams)*
(arrow emphasizing lack of riparian zone)

5.3 ADDITIONS OF QUANTITATIVE MEASURES TO THE HABITAT ASSESSMENT

Kaufmann (1993) identified 7 general physical habitat attributes important in influencing stream ecology. These include:

- channel dimensions
- channel gradient
- channel substrate size and type
- habitat complexity and cover
- riparian vegetation cover and structure
- anthropogenic alterations
- channel-riparian interaction.

All of these attributes vary naturally, as do biological characteristics; thus expectations differ even in the absence of anthropogenic disturbances. Within a given physiographic-climatic region, stream drainage area and overall stream gradient are likely to be strong natural determinants of many aspects of stream habitat, because of their influence on discharge, flood stage, and stream power (the product of discharge times gradient). In addition, all of these attributes may be directly or indirectly altered by anthropogenic activities.

In Section 5.2, an approach is described whereby habitat quality is interpreted directly in the field by biologists while sampling the stream reach. This Level 1 approach is observational and requires only one person (although a team approach is recommended) and takes about 15 to 20 minutes per stream reach. This approach more quickly yields a habitat quality assessment. However, it depends upon the knowledge and experience of the field biologist to make the proper interpretation of observed of both the natural expectations (potentials) and the biological consequences (quality) that can be attributed to the observed physical attributes. Hannaford et al. (1997) found that training in habitat assessment was necessary to reduce the subjectivity in a visual-based approach. The authors also stated that training on different types of streams may be necessary to adequately prepare investigators.

The second conceptual approach described here confines observations to habitat characteristics themselves (whether they are quantitative or qualitative), then later ascribing quality scoring to these measurements as part of the data analysis process. Typically, this second type of habitat assessment approach employs more quantitative data collection, as exemplified by field methods described by Kaufmann and Robison (1997) for EMAP, Simonson et al. (1994), Meador et al. (1993) for NAWQA, and others cited by Gurtz and Muir (1994). These field approaches typically define a reach length proportional to stream width and employ transect measurements that are systematically spaced (Simonson et al. 1994, Kaufmann and Robison 1997) or spaced by judgement to be representative (Meador et al. 1993). They usually include measurement of substrate, channel and bank dimensions, riparian canopy cover, discharge, gradient, sinuosity, in-channel cover features, and counts of large woody debris and riparian human disturbances. They may employ systematic visual estimates of substrate embeddedness, fish cover features, habitat types, and riparian vegetation structure. The time commitment in the field to these more quantitative habitat assessment methods is usually 1.5 to 3 hours with a crew of two people. Because of the greater amount of data collected, they also require more time for data summarization, analysis, and interpretation. On the other hand, the more quantitative methods and less ambiguous field parameters result in considerably greater precision. The USEPA applied both quantitative and visual-based (RBPs) methods in a stream survey undertaken over 4 years in the mid-Atlantic region of the Appalachian Mountains. An earlier version of the RBP techniques were applied on 301 streams with repeat visits to 29 streams; signal-to-noise ratios varied from 0.1 to 3.0 for the twelve RBP metrics and averaged (1.1 for the RBP total habitat quality score). The quantitative methods produced a higher level of precision; signal-to-noise ratios were typically between 10 and 50, and sometimes in excess of 100 for quantitative measurements of channel morphology, substrate, and canopy densiometer measurements made on a random subset of 186 streams with 27 repeat visits in the same survey. Similarly, semi-quantitative estimates of fish cover and riparian human disturbance estimates obtained from multiple, systematic visual observations of otherwise measurable features had signal:noise ratios from 5 to 50. Many riparian vegetation cover and structure metrics were moderately precise (signal:noise ranging from 2 to 30). Commonly used flow dependent measures (e.g., riffle/pool and width/depth ratios), and some visual riparian cover estimates were less precise, with signal:noise ratios more in the range of those observed for metrics of the EPA's RBP habitat score (<2).

The USEPA's EMAP habitat assessment field methods are presented as an option for a second level (II) of habitat assessment. These methods have been applied in numerous streams throughout the Mid-Atlantic region, the Midwest, Colorado, California, and the Pacific Northwest. Table 5-1 is a summary of these field methods; more detail is presented in the field manual by Kaufmann and Robison (1997).

Table 5-1. Components of EMAP physical habitat protocol.

Component	Description
1. Thalweg Profile	Measure maximum depth, classify habitat, determine presence of soft/small sediment at 10-15 equally spaced intervals between each of 11 channel cross-sections (100-150 along entire reach). Measure wetted width at 11 channel cross-sections and mid-way between cross-sections (21 measurements).
2. Woody Debris	Between each of the channel cross sections, tally large woody debris numbers within and above the bankfull channel according to size classes.
3. Channel and Riparian Cross-Sections	At 11 cross-section stations placed at equal intervals along reach length: • **Measure**: channel cross section dimensions, bank height, undercut, angle (with rod and clinometer); gradient (clinometer), sinuosity (compass backsite), riparian canopy cover (densiometer). • **Visually Estimate***: substrate size class and embeddedness; areal cover class and type (e.g., woody) of riparian vegetation in Canopy, Mid-Layer and Ground Cover; areal cover class of fish concealment features, aquatic macrophytes and filamentous algae. • **Observe & Record***: human disturbances and their proximity to the channel.
4. Discharge	In medium and large streams (defines later) measure water depth and velocity @ 0.6 depth (with electromagnetic or impeller-type flow meter) at 15 to 20 equally spaced intervals across one carefully chosen channel cross-section. In very small streams, measure discharge with a portable weir or time the filling of a bucket.

* Substrate size class and embeddedness are estimated, and depth is measured for 55 particles taken at 5 equally-spaced points on each of 11 cross-sections. The cross-section is defined by laying the surveyor's rod or tape to span the wetted channel. Woody

debris is tallied over the distance between each cross-section and the next cross-section upstream. Riparian vegetation and human disturbances are observed 5 m upstream and 5 m downstream from the cross section station. They extend shoreward 10 m from left and right banks. Fish cover types, aquatic macrophytes, and algae are observed within channel 5 m upstream and 5 m downstream from the cross section stations. These boundaries for visual observations are estimated by eye.

Table 5-2 lists the physical habitat metrics that can be derived from applying these field methods. Once these habitat metrics are calculated from the available physical habitat data, an assessment would be obtained from comparing these metric values to those of known reference sites. A strong deviation from the reference expectations would indicate a habitat alteration of the particular parameter. The close connectivity of the various attributes would most likely result in an impact on multiple metrics if habitat alteration was occurring. The actual process for interpreting a habitat assessment using this approach is still under development.

Table 5-2. Example of habitat metrics that can be calculated from the EMAP physical habitat data.

Channel mean width and depth
Channel volume and Residual Pool volume
Mean channel slope and sinuosity
Channel incision, bankfull dimensions, and bank characteristics
Substrate mean diameter, % fines, % embeddedness
Substrate stability
Fish concealment features (areal cover of various types, e.g., undercut banks, brush)
Large woody debris (volume and number of pieces per 100 m)
Channel habitat types (e.g., % of reach composed of pools, riffles, etc.)
Canopy cover
Riparian vegetation structure and complexity
Riparian disturbance measure (proximity-weighted tally of human disturbances)

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6 PERIPHYTON PROTOCOLS

By R. Jan Stevenson, University of Louisville, and
Loren L. Bahls, University of Montana

Benthic algae (periphyton or phytobenthos) are primary producers and an important foundation of many stream food webs. These organisms also stabilize substrata and serve as habitat for many other organisms. Because benthic algal assemblages are attached to substrate, their characteristics are affected by physical, chemical, and biological disturbances that occur in the stream reach during the time in which the assemblage developed.

Diatoms in particular are useful ecological indicators because they are found in abundance in most lotic ecosystems. Diatoms and many other algae can be identified to species by experienced algologists. The great numbers of species provide multiple, sensitive indicators of environmental change and the specific conditions of their habitat. Diatom species are differentially adapted to a wide range of ecological conditions.

Periphyton indices of biotic integrity have been developed and tested in several regions (Kentucky Department of Environmental Protection 1993, Hill 1997). Since the ecological tolerances for many species are known (see section 6.1.4), changes in community composition can be used to diagnose the environmental stressors affecting ecological health, as well as to assess biotic integrity (Stevenson 1998, Stevenson and Pan 1999).

Periphyton protocols may be used by themselves, but they are most effective when used with one or more of the other assemblages and protocols. They should be used with habitat and benthic macroinvertebrate assessments particularly because of the close relation between periphyton and these elements of stream ecosystems.

Presently, few states have developed protocols for periphyton assessment. Montana, Kentucky, and Oklahoma have developed periphyton bioassessment programs. Others states are exploring the possibility of developing periphyton programs. Algae have been widely used to monitor water quality in rivers of Europe, where many different approaches have been used for sampling and data analysis (see reviews in Whitton and Rott 1996, Whitton et al. 1991). The protocols presented here are a composite of the techniques used in Kentucky, Montana, and Oklahoma (Bahls 1993, Kentucky Department of Environmental Protection 1993, Oklahoma Conservation Commission 1993).

Two Rapid Bioassessment Protocols for periphyton are presented. These protocols are meant to provide examples of methods that can be used. Other methods are available and should be considered based on the objectives of the assessment program, resources available for study, numbers of streams sampled, hypothesized stressors, and the physical habitat of the streams studied. Examples of other methods are presented in textboxes throughout the chapter.

The first protocol (6.1) is a standard approach in which species composition and/or biomass of a sampled assemblage is assessed in the laboratory. The second protocol (6.2) is a field-based rapid survey of periphyton biomass and coarse-level taxonomic composition (e.g., diatoms, filamentous greens, blue-green algae) and requires little taxonomic expertise. The two protocols can be used together. The first protocol has the advantage of providing much more accuracy in assessing biotic integrity and in diagnosing causes of impairment than the second protocol, but it requires more effort than the second protocol. Additionally, the first protocol provides the option of sampling the natural substrate of the stream or placing artificial substrates for colonization.

6.1 STANDARD LABORATORY-BASED APPROACH

6.1.1 Field Sampling Procedures: Natural Substrates

Periphyton samples should be collected during periods of stable stream flow. High flows can scour the stream bed, flushing the periphyton downstream. Recolonization of substrates will be faster after less severe floods and in streams with nutrient enrichment. Peterson and Stevenson (1990) recommend a three-week delay following high, bottom-scouring stream flows to allow for recolonization and succession to a mature periphyton community. However, recovery after high discharge can be as rapid as 7 days if severe scouring of substrata did not occur (Stevenson 1990).

Two sampling approaches are described for natural substrate sampling. Multihabitat sampling best characterizes the benthic algae in the reach, but results may not be sensitive to subtle water quality changes because of habitat variability between reaches. Species composition of assemblages from a single habitat should reflect water quality differences among streams more precisely than multi-habitat sampling, but impacts in other habitats in the reach may be missed.

The length of stream sampled depends upon the objectives of the project, budget, and expected results. Multihabitat sampling should be conducted at the reach scale (30-40 stream widths) to ensure sampling the diversity of habitats that occur in the stream. Ideally, single habitat sampling should also be conducted at the reach scale. A shorter length of stream can probably be sampled for single habitat samples than multihabitat samples because the chosen single habitat (e.g., riffles) is usually common within the study streams.

6.1.1.1 Multihabitat Sampling

The following procedures for multihabitat sampling of algae have been adapted from the Kentucky and Montana protocols (Kentucky DEP 1993, Bahls 1993). These procedures are recommended when subsequent laboratory assessments of species composition of algal assemblages will be performed.

1. Establish the reach for multihabitat sampling as per the macroinvertebrate protocols (Chapter 7). In most cases, the reach required for periphyton sampling will be the same size as the reach required for

FIELD EQUIPMENT FOR PERIPHYTON SAMPLING--NATURAL SUBSTRATES

- stainless steel teaspoon, toothbrush, or similar brushing and scraping tools
- section of PVC pipe (3" diameter or larger) fitted with a rubber collar at one end
- field notebook or field forms*; pens and pencils
- white plastic or enamel pan
- petri dish and spatula (for collecting soft sediment)
- forceps, suction bulb, and disposable pipettes
- squeeze bottle with distilled water
- sample containers (125 ml wide-mouth jars)
- sample container labels
- preservative [Lugol's solution, 4% buffered formalin, "M3" fixative, or 2% glutaraldehyde (APHA 1995)]
- first aid kit
- cooler with ice

* During wet weather conditions, waterproof paper is useful or copies of field forms can be stored in a metal storage box (attached to a clip-board).

macroinvertebrate or fish sampling (30-40 stream widths) so that as many algal habitats can be sampled as is practical.

2. Before sampling, complete the physical/chemical field sheet (see Chapter 5; Appendix A-1, Form 1) and the periphyton field data sheet (Appendix A-2, Form 1). Visual estimates or quantitative transect-based assessments can be used to determine the percent coverage of each substrate type and the estimated relative abundance of macrophytes, macroscopic filamentous algae, diatoms and other microscopic algal accumulations (periphyton), and other biota (see section 6.2).

3. Collect algae from all available substrates and habitats. The objective is to collect a single composite sample that is representative of the periphyton assemblage present in the reach. Sample all substrates (Table 6-1) and habitats (riffles, runs, shallow pools, nearshore areas) roughly in proportion to their areal coverage in the reach. Within a stream reach, light, depth, substrate, and current velocity can affect species composition of periphyton assemblages. Changes in species composition of algae among habitats are often evident as changes in color and texture of the periphyton. Small amounts (about 5 mL or less) of subsample from each habitat are usually sufficient. Pick specimens of macroalgae by hand in proportion to their relative abundance in the reach. Combine all samples into a common container.

Table 6-1. Summary of collection techniques for periphyton from wadeable streams (adapted from Kentucky DEP 1993, Bahls 1993).

Substrate Type	Collection Technique
Removable substrates (hard): gravel, pebbles, cobble, and woody debris	Remove representative substrates from water; brush or scrape representative area of algae from surface and rinse into sample jar.
Removable substrates (soft): mosses, macroalgae, vascular plants, root masses	Place a portion of the plant in a sample container with some water. Shake it vigorously and rub it gently to remove algae. Remove plant from sample container.
Large substrates (not removable): boulders, bedrock, logs, trees, roots	Place PVC pipe with a neoprene collar at one end on the substrate so that the collar is sealed against the substrate. Dislodge algae in the pipe with a toothbrush, nail brush, or scraper. Remove algae from pipe with pipette.
Loose sediments: sand, silt, fine particulate organic matter, clay	Invert petri dish over sediments. Trap sediments in petri dish by inserting spatula under dish. Remove sediments from stream and rinse into sampling container. Algal samples from depositional habitats can also be collected with spoons, forceps, or pipette.

4. Place all samples into a single water-tight, unbreakable, wide-mouth container. A composite sample measuring four ounces (ca. 125 ml) is sufficient (Bahls 1993). Add recommended amount of Lugol's (IKI) solution, "M3" fixative, buffered 4% formalin, 2% glutaraldehyde, or other preservative (APHA 1995).

5. Place a permanent label on the outside of the sample container with the following information: waterbody name, location, station number, date, name of collector, and type of preservative. Record this information and relevant ecological information in a field notebook or on the periphyton field data sheet (Appendix A-2, Form 1). Place another label with the same information inside the sample container. (Caution! Lugol's solution and other iodine-based preservatives will turn paper labels black.)

6. After sampling, review the recorded information on all labels and forms for accuracy and completeness.

7. Examine all brushing and scraping tools for residues. Rub them clean and rinse them in distilled water before sampling the next site and before putting them away.

8. Transport samples back to the laboratory in a cooler with ice (keep them cold and dark) and store preserved samples in the dark until they are processed. Be sure to stow samples in a way so that transport and shifting does not allow samples to leak. When preserved, check preservative every few weeks and replenish as necessary until taxonomic evaluation is completed.

9. Log in all incoming samples (Appendix A-2, Form 2). At a minimum, record sample identification code, date, stream name, sampling location, collector's name, sampling method, and area sampled (if it was determined).

6.1.1.2 Single Habitat Sampling

Variability due to differences in habitat between streams may be reduced by collecting periphyton from a single substrate/habitat combination that characterizes the study reach (Rosen 1995). For comparability of results, the same substrate/habitat combination should be sampled in all reference and test streams. Single habitat sampling should be used when biomass of periphyton will be assessed.

1. Define the sampling reach. The area sampled for single habitat sampling can be smaller than the area used for multihabitat sampling. Valuable results have been achieved in past projects by sampling just one riffle or pool.

2. Before sampling, complete the physical/chemical field sheet (see Chapter 5; Appendix A-1, Form 1) and the periphyton field data sheet

CHLOROPHYLL *a* SUBSAMPLING (OPTIONAL)

1. Chlorophyll *a* subsamples should be taken as soon as possible (< 12 hours after sampling). Generally, if chlorophyll subsamples can not be taken in the lab on the day of collection, subsample in the field.

2. Homogenize samples. In the field, shake vigorously. In the lab, use a tissue homogenizer.

3. Record the initial volume of sample on the periphyton sample log form.

4. Stir the sample on a magnetic stirrer and subsample. When subsampling, take at least two aliquots from the sample for each chlorophyll sample (two aliquots provides a more representative subsample than one). Record the subsample volume for chlorophyll *a* on the periphyton sample log form.

5. Concentrate the chlorophyll subsample on a glass fiber filter (e.g., Whatman® GFC or equivalent).

6. Fold the filter and wrap with aluminum to exclude light.

7. Store the filter in a cold cooler (not in water) and eventually in a freezer.

(Appendix A-2, Form 1). Complete habitat assessments as in multihabitat sampling so that the relative importance of the habitats sampled can be characterized.

3. The recommended substrate/habitat combination is cobble obtained from riffles and runs with current velocities of 10-50 cm/sec. Samples from this habitat are often easier to analyze than from slow current habitats because they contain less silt. These habitats are common in many streams. In low gradient streams where riffles are rare, algae on snags or in depositional habitats can be collected. Shifting sand is not recommended as a targeted substrate because the species composition on sand is limited due to the small size and unstable nature of the substratum. Phytoplankton should be considered as an alternative to periphyton in large, low gradient streams.

4. Collect several subsamples from the same substrate/habitat combination and composite them into a single container. Three or more subsamples should be collected from each reach or study stream.

5. The area sampled should always be determined if biomass (e.g., chlorophyll) per unit area is to be measured.

6. If you plan to assay samples for chlorophyll *a*, do not preserve samples until they have been subsampled (see textbox entitled "Chlorophyll *a* Subsampling").

7. Store, transport, process, and log in samples as in steps 4-9 in section 6.1.1.1.

6.1.2 Field Sampling Procedures: Artificial Substrates

Most monitoring groups prefer sampling natural substrates whenever possible to reduce field time and improve ecological applicability of information. However, periphyton can also be sampled by collecting from artificial substrates that are placed in aquatic habitats and colonized over a period of time. This procedure is particularly useful in non-wadeable streams, rivers with no riffle areas, wetlands, or the littoral zones of lentic habitats. Both natural and artificial substrates are useful in monitoring and assessing waterbody conditions, and have corresponding advantages and disadvantages (Stevenson and Lowe 1986, Aloi 1990). The methods summarized here are a composite of those specified by Kentucky (Kentucky DEP 1993), Florida (Florida DEP 1996), and Oklahoma (Oklahoma CC 1993).
Although glass microslides are preferred, a variety of artificial substrates have been used with success (see #2 below and textbox on p 6-6).

QUALITY CONTROL (QC) IN THE FIELD

1. Sample labels must be accurately and thoroughly completed, including the sample identification code, date, stream name, sampling location, and collector's name. The outside and any inside labels of the container should contain the same information. Chain of custody and sample log forms must include the same information as the sample container labels. **Caution!** Lugol's solution and iodine-based preservatives will turn paper labels black.

2. After sampling has been completed at a given site, all brushes, suction and scraping devices that have come in contact with the sample should be rubbed clean and rinsed thoroughly in distilled water. The equipment should be examined again prior to use at the next sampling site, and rinsed again if necessary.

3. After sampling, review the recorded information on all labels and forms for accuracy and completeness.

4. Collect and analyze one replicate sample from 10% of the sites to evaluate precision or repeatability of sampling technique, collection team, sample analysis, and taxonomy.

1. Microslides should be thoroughly cleaned before placing in periphytometers (e.g., Patrick et al. 1954). Rinse slides in acetone and clean with Kimwipes®.

2. Place surface (floating) or benthic (bottom) periphytometers fitted with glass slides, glass rods, clay tiles, plexiglass plates or similar substrates in the study area. Allow 2 to 4 weeks for periphyton recruitment and colonization.
3. Replicate a minimum of 3 periphytometers at each site to account for spatial variability. The total number should depend upon the study design and hypotheses tested. Samples can either be composited or analyzed individually.

4. Attach periphytometers to rebars pounded into the stream bottom or to other stable structures. Periphytometers should be hidden from view to minimize disturbance or vandalism. Avoid the main channel of floatable, recreational streams. Each periphytometer should be oriented with the shield directed upstream.

5. If flooding or a similar scouring event occurs during incubation, allow waterbody to equilibrate and reset periphytometers with clean slides.

6. After the incubation period (2-4 weeks), collect substrates. Remove algae using rubber spatulas, toothbrushes and razor blades. You can tell when all algae have been removed from substrates by a change from smooth, mucilaginous feel (even when no visible algae are present) to a non-slimy or rough texture.

7. Store, transport, process, and log in samples as in steps 4-9 in section 6.1.1.1.

8. One advantage of using artificial substrates is that containers (e.g., whirl-pack bags or sample jars) can be purchased that will hold the substrates so that substrates need not be scraped in the field. Different substrates can be designated for microscopic analysis and chlorophyll assay. Then algae and substrates can be placed in sampling containers and preserved for later processing and microscopic analysis or placed in a cooler on ice for later chlorophyll *a* analysis. Laboratory sample processing is preferred; so if travel and holding time are less than 12 hours, it is not necessary to split samples before returning to the lab.

FIELD EQUIPMENT/SUPPLIES NEEDED FOR PERIPHYTON SAMPLING-- ARTIFICIAL SUBSTRATES

- periphytometer (frame to hold artificial substrata)
- microslides or other suitable substratum (e.g., clay tiles, sanded Plexiglass® plates, or wooden or acrylic dowels)
- sledge hammer and rebars
- toothbrush, razor blade, or other scraping tools
- water bottle with distilled water
- white plastic or enamel pan
- aluminium foil
- sample containers
- sample container labels
- field notebook (waterproof)
- preservative [Lugol's solution, 4% buffered formalin, "M^3" fixative, or 2% glutaraldehyde (APHA 1995)]
- cooler with ice

6.1.3 Assessing Relative Abundances of Algal Taxa: Both "Soft" (Non-Diatom) Algae and Diatoms

The Methods summarized here are a modified version of those used by Kentucky (Kentucky DEP 1993), Florida (Florida DEP 1996), and Montana (Bahls 1993). For more detail or for alternative methods, see Standard Methods for the Examination of Water and Wastewater (APHA 1995).

Many algae are readily identifiable to species level by trained personnel who have a good library of literature on algal taxonomy (see section 6.3). All algae can not be identified to species because: the growth forms of some algal species are morphologically indistinguishable with the light microscope (e.g., zoospores of many green algae); the species has not been described previously; or the species is not in the laboratory's literature. Consistency in identifications within a laboratory and program is very important, because most bioassessment are based on contrasts between reference and test sites. Accuracy of identifications becomes most important when using autecological information from other studies. Quality assurance techniques are designed to ensure "internal consistency" and also improve comparisons with information in other algal assessment and monitoring programs.

6.1.3.1 "Soft" (Non-Diatom) Algae Relative Abundance and Taxa Richness

1. Homogenize algal samples with a tissue homogenizer or blender.

2. Thoroughly mix the homogenized sample and pipette into a Palmer counting cell (see textbox for alternative methods). Algal suspensions that produce between 10 and 20 cells in a field provide good densities for counting and identifying cells. Lower densities slow counting. Dilute samples if cells overlap too much for counting.

3. Fill in the top portion of the benchsheet for "soft" algae (Appendix A-2, Form 3) with enough information from the sample label and other sources to uniquely identify the sample.

4. Identify and count 300 algal "cell units" to the lowest possible taxonomic level at 400X magnification with the use of the references in Section 6.3.

    ! Distinguishing cells of coenocytic algae (e.g., *Vaucheria*) and small filaments of blue-green algae is a problem in cell counts. "Cell units" can be defined for these algae as 10mm sections of the thallus or filament.
    ! For diatoms, only count live diatoms and do not identify to lower taxonomic levels if a subsequent count of cleaned diatoms is to be undertaken (See section 6.1.3.2).
    ! Record numbers of cells or cell units observed for each taxon on a benchsheet.
    ! Make taxonomic notes and drawings on benchsheets of important specimens.

5. Optional - To better determine non-diatom taxa richness, continue counting until you have not observed any new taxa for 100 cell units or about three minutes of observation.

6.1.3.2 Diatom Relative Abundances and Taxa Richness

1. Subsample at least 5-10 mL of concentrated preserved sample while vigorously shaking the sample (or using magnetic stirrer). Oxidize (clean) samples for diatom analysis (APHA 1995, see textbox entitled "Oxidation Methods for Cleaning Diatoms").

2. Mount diatoms in Naphrax® or another high refractive index medium to make permanent slides. Label slides with same information as on the sample container label.

3. Fill in the top portion of the bench sheet for diatom counts (Appendix A-2, Form 4) with enough information from the sample label to uniquely identify the sample.

4. Identify and count diatom valves to the lowest possible taxonomic level, which should be species and perhaps variety level, under oil immersion at 1000X magnification with the use of the

references in Section 6.3. At minimum, count 600 valves (300 cells) and at least until 10 valves of 10 species have been observed. Be careful to distinguish and count both valves of intact frustules. The 10 valves of 10 species rule ensures relatively precise estimates of relative abundances of the dominant taxa when one or two taxa are highly dominant. Six hundred valve counts were chosen to conform with methods used in other national bioassessment programs (Porter et al. 1993). Record numbers of valves observed for each taxon on the bench sheet. Make taxonomic notes and drawings on benchsheets and record stage coordinates of important specimens.

5. Optional - To estimate total diatom taxa richness, continue counting until you have not observed any new species for 100 specimens or about three minutes of observation.

6.1.3.3 Calculating Species Relative Abundances and Taxa Richness

1. Relative abundances of "soft" algae are determined by dividing the number of cells (cell units) counted for each taxon by the total number of cells counted (e.g., 300). Enter this information on Appendix A-2, Form 3.

2. Relative abundances of diatoms have to be corrected for the number of live diatoms observed in the count of all algae. Therefore, determine the relative abundances of diatom species in the algal assemblage by dividing the number of valves counted for each species by the total number of valves counted (e.g., 600); then multiply the relative abundance of each diatom taxon in the diatom count by the relative abundance of live diatoms in the count of all algae. Enter this information on Appendix A-2, Form 4. Some analysts prefer to treat diatom and soft algal species composition separately. In this case, determine the relative abundances of diatom species in the algal assemblage by dividing the number of valves counted for each species by the total number of valves counted (e.g., 600).

3. Total taxa richness can be estimated by adding the number of "soft" algal taxa and diatom taxa.

6.1.3.4 Alternative Preparation Techniques

Palmer counting cells are excellent for identifying and counting soft-algae in most species assemblages. When samples have many very small blue-green algae or a few, relatively important large cells, other slide preparation techniques may be useful to increase magnification and sample size, respectively. Because accurate diatom identification is not possible in Palmer cells, we have recommended counting cleaned diatoms in special mounts. However, if the taxonomy of algae in samples is well known, preparation and counting time can be reduced by mounting algae in syrup. In syrup, both soft algae and diatoms can be identified, but resolution of morphological details of diatoms is not as great as in mounts of diatoms in resins (e.g., Naphrax®).

Assemblages with many small cells: We recommend a simple wet mount procedure when samples contain many small algae so samples can be observed at 1000X. A small volume of water under the coverglass prevents movement of cells when adjusting focus and using oil immersion. These preparations usually last several days if properly sealed (see below).

Wet mounts:

1. Clean coverglasses and place on flat surface.

2. Pipette 1.0 mL of algal suspension onto the coverglass.

3. Dry the algal suspension on the coverglass. For convenience, the evaporation of water can be increased on a slide-warmer or slowed by drying the sample in a vapor chamber (as simple as a cake pan or aluminum foil hood placed over samples).

4. As soon as the algal suspension dries, invert the coverglass into the 0.02 mL of distilled water on a microscope slide.

5. Seal the water under the microscope slide with fingernail polish or polyurethane varnish.

Assemblages with a few large cells: Sedgewick-Rafter counting chambers, which are large modified microscope slides with 1.0 mL wells, increase sample size. Counts in Sedgewick-Rafter counting cells should be done after counts in Palmer cells or wet mounts so that the relation between sample proportions with the two methods can be determined. While keeping track of the proportion of sample observed, identify and count large algae in transects at 200X or 100X magnification in the counting cell.

Syrup mounts:

1. Prepare Taft's syrup medium (TSM) by mixing 30 mL of clear corn syrup (e.g., Karo's® Corn Syrup) with 7 mL of formaldehyde and 63 mL of distilled water. Dilute a 10 mL proportion of this 100% TSM with 90 mL of distilled water to make 10% TSM.

2. Place 0.2 mL of 10% TSM on coverglass.

OXIDATION (CLEANING) METHODS FOR DIATOMS

Concentrated Acid Oxidation:

1. Place a 5-10 mL subsample of preserved algal sample in a beaker.

2. Under a fume hood, add enough concentrated nitric or sulfuric acid to produce a strong exothermic reaction. Usually equal parts of sample and acid will produce such a reaction.
(Caution! With some preservatives and samples from hard water, adding concentrated acid will produce a violent exothermic reaction. Use a fume hood, safety glasses, and protective clothing. Separate the sample beakers by a few inches to prevent cross-contamination of samples in the event of overflow.)

3. Allow the sample to oxidize overnight.

4. Fill the beaker with distilled water.

5. Wait 1 hour for each centimeter of water depth in the beaker.

6. Siphon off the supernatant and refill the beaker with distilled water. Siphon from the center of the water column to avoid siphoning light algae that have adsorbed onto the sides and surface of the water column.

7. Repeat steps 4 through 6 until all color is removed and the sample becomes clear or has a circumneutral pH.

Hydrogen Peroxide/Potassium Dichromate Oxidation:

1. Prepare samples as in step 1 above, but use 50% H_2O_2 instead of concentrated acid.

2. Allow the sample to oxidize overnight, then add a microspatula of potassium dichromate.
(Caution! This will cause a violent exothermic reaction. Use a fume hood, safety glasses, and protective clothing. Separate the sample beakers by a few inches to prevent cross-contamination in the event of overflow.)

3. When the sample color changes from purple to yellow and boiling stops, fill the beaker with distilled water.

4. Wait 4 hours, siphon off the supernatant, and refill the beaker with distilled water. Siphon from the center of

3. Place 1.0 mL of algal suspension on coverglass. Consider using several dilutions.

4. Let dry for 24 hours. Alternatively, dry on slide warmer on low setting. Do not overdry or cells will plasmolyze.
5. Place another ≈ 1.0 mL of 10% TSM on cover glass and dry (overnight or 4 hours on a slide warmer). Apply 10% TSM quickly to avoid patchy resuspension of the original layer of TSM and algae.

6. Invert coverglass onto microscope slide; place slide on hot plate to warm the slide and syrup. Do not boil, just warm. Press coverglass gently in place with forceps, being careful to keep all syrup under the coverglass. The syrup should spread under coverglass.

7. Remove the slide from the hotplate. Cooling should partially seal the coverglass to the slide.

8. More permanently seal the syrup under slides by painting fingernail polish around the edge of the cover glass and onto the microscope slide.

Note: Preserve color of chloroplasts by keeping samples in dark.

Special Note: If slides get too warm in storage, syrup will loose viscosity and become runny. Algae and medium may then escape containment under coverglass. Store slides in a horizontal position.

6.1.4 Metrics Based on Species Composition

The periphyton metrics presented here are used by several states and environmental assessment programs throughout the US and Europe (e.g., Kentucky DEP 1993, Bahls 1993, Florida DEP 1996, Whitton et al. 1991, Whitton and Kelly 1995). Each of these metrics should be tested for response to human alterations of streams in the region in which they are used (see Chapter 9, Biological Data Analysis). In many cases, diatom and soft algal metrics have been determined separately because changes in small abundant cyanobacteria (blue-green algae) can numerically overwhelm metrics based on relative abundance and because green algae with large cells (e.g., *Cladophora*) may not have appropriate weight. However, attempts should be made to integrate diatoms and soft algae in as many metrics as possible, especially in cases such as species and generic richness when great variability in relative abundance is not an issue.

Many metrics can be calculated based on presence/absence data or on relative abundances of taxa. For example, percent Pollution Tolerant Diatoms can be calculated as the sum of relative abundances of pollution tolerant taxa in an assemblage or as the number of species that are tolerant to pollution in an assemblage. Percent community similarity can be calculated as presented below, which quantifies the percent of organisms in two assemblages that are the same. Alternatively, it can be calculated as the percent of species that are the same by making all relative abundances greater than 0 equal to 1. The following metrics can also be calculated with presence/absence data instead of species relative abundances: % sensitive taxa, % motile taxa, % acidobiontic, % alkalibiontic, % halobiontic, % saprobiontic, % eutrophic, simple autecological indices, and change in inferred ecological conditions. Although we may find that metrics based on species relative abundances are more sensitive to environmental change, metrics based on presence/absence data may be more appropriate when developing metrics with multihabitat samples and proportional sampling of habitats is difficult. In the latter case, presence/absence of species should remain the same, even if relative abundance of taxa differs with biases in multihabitat sampling.

> **COSTS AND BENEFITS OF SIMPLER ANALYSES**
>
> - We recommend that all algae (soft and diatom) be identified and counted. Information may be lost if soft algae are not identified and counted because some impacts may selectively affect soft algae. Most of the species (and thus information) in a sample will be diatoms. Costs of both analyses are not that great.
> - Costs can be reduced by only counting diatoms or soft algae. Since diatoms are usually the most species-rich group of algae in samples and most metrics are based on differences in taxonomic composition, we recommend that diatoms be counted. In addition, permanently preserved and readily archived microslides of diatoms can serve as a historic reference of ecological conditions.
> - In general, identifying algae to species is recommended for two reasons: (1) to better characterize differences between assemblages that may occur at the species level and (2) because large differences in ecological preferences do exist among algal species within the same genus.
> - However, substantial information can be gained by identifying algae just to the genus level. Whereas identifying algae only to genus may loose valuable ecological information, costs of analyses can be reduced, especially for inexperienced analysts.
> - If implementing a new program and only an inexperienced analyst is available for the job, identifying diatom genera in assemblages can provide valuable characterizations of biotic integrity and environmental conditions.
> - As analysts get more experience counting, the taxonomic level of their analyses should improve. The cost of an experienced analyst counting and identifying algae to species is not much greater than analysis to genus.

The metrics have been divided into two groups which may be helpful in developing an Index of Biotic Integrity (IBI). Metrics in the first group are less diagnostic than the second group of metrics. Metrics in the first group (species and generic richness, Shannon diversity, etc.) generally characterize biotic integrity ("natural balance in flora and fauna…." as in Karr and Dudley 1981) without specifically diagnosing ecological conditions and causes of impairment. The second group of metrics more specifically diagnoses causes of impaired biotic integrity. Metrics from both groups could be included in an IBI to make a hierarchically diagnostic IBI. Alternatively, an IBI could be constructed from only metrics of biotic integrity so that inference of biotic integrity and diagnosis of impairment are independent (Stevenson and Pan 1999).

Autecological information about many algal species and genera has been reported in the literature. This information comes in several forms. In some cases, qualitative descriptions of the ecological conditions in which species were observed were reported in early studies of diatoms. Following the development of the saprobic index by Kolkwitz and Marsson (1908), several categorical classification systems (e.g., halobian spectrum, pH spectrum) were developed to describe the ecological preferences and tolerances of species (see Lowe 1974 for a review). Most recently, the ecological optima and tolerances of species for specific environmental conditions have been quantified by using weighted average regression approaches (see ter Braak and van Dam 1989 for a review). We have compiled a list of references for this information in Section 6.4. These references will be valuable for developing many of the metrics below.

Metrics of Biotic Integrity

1. **Species richness** is an estimate of the number of algal species (diatoms, soft algae, or both) in a sample. High species richness is assumed to indicate high biotic integrity because many species are adapted to the conditions present in the habitat. Species richness is predicted to decrease with increasing pollution because many species are stressed. However, many habitats may be naturally stressed by low nutrients, low light, or other factors. Slight increases in nutrient enrichment can increase species richness in headwater and naturally unproductive, nutrient-poor streams (Bahls et al. 1992).

2. **Total Number of Genera** (Generic richness) should be highest in reference sites and lowest in impacted sites where sensitive genera become stressed. Total number of genera (diatoms, soft algae, or both) may provide a more robust measure of diversity than species richness, because numerous closely related species are within some genera and may artificially inflate richness estimates.

3. **Total Number of Divisions** represented by all taxa should be highest in sites with good water quality and high biotic integrity.

4. **Shannon Diversity (for diatoms)**. The Shannon Index is a function of both the number of species in a sample and the distribution of individuals among those species (Klemm et al. 1990). Because species richness and evenness may vary independently and complexly with water pollution. Stevenson (1984) suggests that changes in species diversity, rather than the diversity value, may be useful indicators of changes in water quality. Species diversity, despite the controversy surrounding it, has historically been used with success as an indicator of organic (sewage) pollution (Wilhm and Dorris 1968, Weber 1973, Cooper and Wilhm 1975). Bahls et al. (1992) uses Shannon diversity because of its sensitivity to water quality changes. Under certain conditions Shannon diversity values may underestimate water quality e.g., when total number of taxa is less than 10. Assessments for low richness samples can be improved by comparing the assemblage Shannon Diversity to the Maximum Shannon Diversity value (David Beeson[1], personal communication).

5. **Percent Community Similarity (PS_c) of Diatoms**. The percent community similarity (PS_c) index, discussed by Whittaker (1952), was used by Whittaker and Fairbanks (1958) to compare planktonic copepod communities. It was chosen for use in algal bioassessment because it shows community similarities based on relative abundances, and in doing so, gives

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more weight to dominant taxa than rare ones. Percent similarity can be used to compare control and test sites, or average community of a group of control or reference sites with a test site. Percent community similarity values range from 0 (no similarity) to 100%.

The formula for calculating percent community similarity is:

$$PS_c = 100 - .5\Sigma_{i=1}^{s}|a_i - b_i| = \Sigma_{i=1}^{s}\min(a_i, b_i)$$

where:

a_i = percentage of species i in sample A
b_i = percentage of species i in sample B

6. **Pollution Tolerance Index for Diatoms.** The pollution tolerance index (PTI) for algae resembles the Hilsenhoff biotic index for macroinvertebrates (Hilsenhoff 1987). Lange-Bertalot (1979) distinguishes three categories of diatoms according to their tolerance to increased pollution, with species assigned a value of 1 for most tolerant taxa (e.g., *Nitzschia palea* or *Gomphonema parvulum*) to 3 for relatively sensitive species. Relative tolerance for taxa can be found in Lange-Bertalot (1979) and in many of the references listed in section 6.4. Thus, Lange-Bertalot's PTI varies from 1 for most polluted to 3 for least polluted waters when using the following equation:

$$PTI = \frac{\Sigma n_i t_i}{N}$$

where:

n_i = number of cells counted for species i
t_i = tolerance value of species i
N = total number of cells counted

In some cases, the range of values for tolerances has been increased, thereby producing a corresponding increase in the range of PTI values.

7. **Percent Sensitive Diatoms.** The percent sensitive diatoms metric is the sum of the relative abundances of all intolerant species. This metric is especially important in smaller-order streams where primary productivity may be naturally low, causing many other metrics to underestimate water quality.

8. **Percent *Achnanthes minutissima*.** This species is a cosmopolitan diatom that has a very broad ecological amplitude. It is an attached diatom and often the first species to pioneer a recently scoured site, sometimes to the exclusion of all other algae. *A. minutissima* is also frequently dominant in streams subjected to acid mine drainage (e.g., Silver Bow Creek, Montana) and to other chemical insults. The percent abundance of *A. minutissima* has been found to be directly proportional to the time that has elapsed since the last scouring flow or episode of toxic pollution. For use in bioassessment, the quartiles of this metric from a

population of sites has been used to establish judgment criteria, e.g., 0-25% = no disturbance, 25-50% = minor disturbance, 50-75% = moderate disturbance, and 75-100% = severe disturbance. Least-impaired streams in Montana may contain up to 50% *A. minutissima* (Bahls, unpublished data).

9. **Percent live diatoms** was proposed by Hill (1997) as a metric to indicate the health of the diatom assemblage. Low percent live diatoms could be due to heavy sedimentation and/or relatively old algal assemblages with high algal biomass on substrates.

Diagnostic Metrics that Infer Ecological Conditions

The ecological preferences of many diatoms and other algae have been recorded in the literature. Using relative abundances of algal species in the sample and their preferences for specific habitat conditions, metrics can be calculated to indicate the environment stressors in a habitat. These metrics can more specifically infer environmental stressors than the general pollution tolerance index.

10. **Percent Aberrant Diatoms** is the percent of diatoms in a sample that have anomalies in striae patterns or frustule shape (e.g, long cells that are bent or cells with indentations). This metric has been positively correlated to heavy metal contamination in streams (McFarland et al. 1997).

11. **Percent Motile Diatoms.** The percent motile diatoms is a siltation index, expressed as the relative abundance of *Navicula* + *Nitzschia* + *Surirella*. It has shown promise in Montana (Bahls et al. 1992). The three genera are able to crawl towards the surface if they are covered by silt; their abundance is thought to reflect the amount and frequency of siltation. Relative abundances of Gyrosigma, Cylindrotheca, and other motile diatoms may also be added to this metric.

12. **Simple Diagnostic Metrics** can infer the environmental stressor based on the autecology of individual species in the habitats. For example, if acid mine drainage was impairing stream conditions, then we would expect to find more acidobiontic taxa in samples. Calculate a simple diagnostic metric as the sum of the percent relative abundances (range 0-100%) of species that have environmental optima in extreme environmental conditions. For example (see Table 6-2):

    % acidobiontic + % acidophilic
    % alkalibiontic + % alkaliphilic
    % halophilic
    % mesosaprobic + % oligosaprobic + % saprophilic
    % eutrophic

13. **Inferred Ecological Conditions with Simple Autecological Indices (SAI)** - The ecological preferences for diatoms are commonly recorded in the literature. Using the standard ecological categories compiled by Lowe (1974, Table 6-2), the ecological preferences for different diatom species can be characterized along an environmental (stressor) gradient. For example, pH preferences for many taxa are known. These preferences (Θ_i) can be ranked from 1-5 (e.g., acidobiontic, acidophilic, indifferent, alkaliphilic, alkalibiontic, Table 6-2) and can be used in the following equation to infer environmental conditions (EC) and effect on the periphyton assemblage.

$$SAI_{EC} = \Sigma\, \Theta_i p_i$$

14. **Inferred Ecological Conditions with Weighted Average Indices** are based on the specific ecological optima (β_i) for algae, which are being reported more and more commonly in recent publications (see Pan and Stevenson 1996). Caution should be exercised, because we do not know how transferable these optima are among regions and habitats. Using the following equation, the ecological conditions (EC) in a habitat can be inferred more accurately by using the optimum environmental conditions (β_i) and relative abundances (ρ_i) for taxa in the habitat (ter Braak and van Dam 1989, Pan et al., 1996) than if only the ecological categorization were used (as above for the SAI). Optimum environmental conditions are those in which the highest relative abundances of a taxon are observed. These can be determined from the literature or from past surveys of taxa and environmental conditions in the study area (see ter Braak and van Dam 1989). In a pH example, the specific pH in a habitat can be inferred if we know the pH optima (H_i) of taxa in the habitat, and use the following general equation:

$$WAI_{EC} = \Sigma \beta_i p_i$$

and modify for inferring pH:

$$WAI_{pH} = \Sigma\, H_i p_i$$

15. **Impairment of Ecological Conditions** can be inferred with algal assemblages by calculating the deviation (Δ_{EC}) between inferred environmental conditions at a test site and at a reference site.

Compare inferred ecological conditions at the test site to the expected ecological conditions (EC_{ex}) of regional reference sites by using either simple autecological indices (SAI_{EC}) or weighted average indices (WAI_{EC}):

$$\Delta_{EC} = |SAI_{EC} - EC_{ex}|$$

$$\Delta_{EC} = |WAI_{EC} - EC_{ex}|$$

Table 6-2. Environmental definitions of autecological classification systems for algae (as modified or referenced by Lowe 1974). Definitions for classes are given if no subclass is indicated.

Classification System/ Ecological Parameter	Class	Subclass	Conditions of Highest Relative Abundances
pH Spectrum	Acidobiontic		Below 5.5 pH
	Acidophilic		Above 5.5 and below 7 pH
	Indifferent		Around 7 pH
	Alakaliphilic		Above 7 and below 8.5 pH
	Alkalibiontic		Above 8.5 pH
Nutrient Spectrum - based on P and N concentrations	Eutrophic		High nutrient conditions

Classification System/ Ecological Parameter	Class	Subclass	Conditions of Highest Relative Abundances
	Mesotrophic		Moderate nutrient conditions
	Oligotrophic		Low nutrient conditions
	Dystrophic		High humic (DOC) conditions
Halobion Spectrum - based on chloride concentrations or conductivity	Polyhalobous		Salt concentrations > 40,000 mg/L
	Euhalobous		Marine forms: 30,000-40,000 mg/L
	Mesohalobous	Alpha range	Brackish water forms: 10,000-30,000 mg/L
	Mesohalobous	Beta range	Brackish water forms: 500-10,000 mg/L
	Oligohalobous	Halophilous	Freshwater - stimulated by some salt
	Oligohalobous	Indifferent	Freshwater - tolerates some salt
	Oligohalobous	Halophobic	Freshwater - does not tolerate small amounts of salt
Saprobien System - based on organic pollution	Polysaprobic		Characteristic of zone of degradation and putrefication, oxygen usually absent or low in concentration
	Mesosaprobic	Alpha range	Zone of organic load oxidation — N as amino acids
		Beta range	Zone of organic load oxidation — N as ammonia
	Oligosaprobic		Zone in which oxidation of organics complete, but high nutrient concentrations persist
	Saprophilic		Usually in polluted waters, but also in clean waters
	Saproxenous		Usually in clean waters, but also found in polluted waters
	Saprophobic		Only found in unpolluted waters

6.1.5 Determining Periphyton Biomass

Measurement of periphyton biomass is common in many studies and may be especially important in studies that address nutrient enrichment or toxicity. In many cases, however, sampling benthic algae misses peak biomass, which may best indicate nutrient problems and potential for nuisance algal growths (Biggs 1996, Stevenson 1996).

Biomass measurements can be made with samples collected from natural or artificial substrates. To quantify algal biomass (chl *a*, ash-free dry mass, cell density, biovolume cm^{-2}), the area of the substrate sampled must be determined. Two national stream assessment programs sample and assess area-specific cell density and biovolume (USGS-NAWQA, Porter et al. 1993; and EMAP, Klemm and Lazorchak 1994). These programs estimate algal biomass in habitats and reaches by collecting composite samples separately from riffle and pool habitats.

Periphyton biomass can be estimated with chl *a*, ash-free dry mass (AFDM), cell densities, and biovolume, usually per cm^2 (Stevenson 1996). Each of these measures estimates a different component of periphyton biomass (see Stevenson 1996 for discussion).

LABORATORY EQUIPMENT FOR PERIPHYTON ANALYSIS

- compound microscope with 10X or 15X oculars and 20X, 40X and 100X (oil) objectives
- tally counter (for species proportional count)
- microscope slides and coverglasses
- immersion oil, lens paper and absorbent tissues
- tissue homogenizer or blender
- magnetic stirrer and stir bar
- forceps
- hot plate
- fume hood
- squeeze bottle with distilled water
- oxidation reagents (HNO_3, H_2SO_4, $K_2Cr_2O_7$, H_2O_2)
- 200-500 ml beakers
- safety glasses and protective clothing
- drying oven for AFDM
- muffle furnace for AFDM
- aluminum weighing pans for AFDM
- spectrophotometer or fluorometer for chl *a*
- centrifuge for chl *a*
- graduated test tubes for chl *a*
- acetone for chl *a*
- $MgCO_3$ for chl *a*

6.1.5.1 Chlorophyll *a*

Chlorophyll *a* ranges from 0.5 to 2% of total algal biomass (APHA 1995), and this ratio varies with taxonomy, light, and nutrients. A detailed description of chlorophyll *a* analysis is beyond the scope of this chapter. Standard methods (APHA 1995, USEPA 1992) are readily available. The analysis is relatively simple and involves:

1. extracting chlorophyll *a* in acetone;

2. measuring chlorophyll concentration in the extract with a spectrophotometer or fluorometer; and

3. calculating chlorophyll density on substrates by determining the proportion of original sample that was assessed for chlorophyll.

6.1.5.2 Ash-Free Dry Mass

Ash-free dry mass is a measurement of the organic matter in samples, and includes biomass of bacteria, fungi, small fauna, and detritus in samples. A detailed description of analysis is beyond the scope of this chapter, but standard methods (APHA 1995, USEPA 1995) are readily available. The analysis is relatively simple and measures the difference in mass of a sample after drying and after incinerating organic matter in the sample. We recommend using AFDM versus dry mass to measure periphyton biomass because silt can account for a substantial proportion of dry mass in some samples. Ash mass in samples can be used to infer the amount of silt or other inorganic matter in samples.

6.1.5.3 Area-Specific Cell Densities and Biovolumes

Cell densities (cells cm^{-2}) are determined by dividing the numbers of cells counted by the proportion of sample counted and the area from which samples were collected. Cell biovolumes (mm^3 biovolume cm^{-2}) are determined by summing the products of cell density and biovolume of each species counted (see Lowe and Pan 1996) and dividing that sum by the proportion of sample counted and the area from which samples were collected.

6.1.5.4 Biomass Metrics

High algal biomass can indicate eutrophication, but high algal biomass can also accumulate in less productive habitats after long periods of stable flow. Low algal biomass may be due to toxic conditions, but could be due to a recent storm event and spate or naturally heavy grazing. Thus, interpretation of biomass results is ambiguous and is the reason that major emphasis has not been placed on quantifying algal biomass for RBP. However, nuisance levels of algal biomass (e.g., > 10 μg chl *a* cm^{-2}, > 5 mg AFDM cm^{-2}, > 40% cover by macroalgae; see review by Biggs 1996) do indicate nutrient or organic enrichment. If repeated measurements of biomass can be made, then the mean and maximum benthic chl *a* could be used to define trophic status of streams. Dodds et al. (1998) have proposed guidelines in which the oligotrophic-mesotrophic boundary is a mean benthic chl *a* of 2 μg cm^{-2} or a maximum benthic chl *a* of 7 μg cm^{-2} and the mesotrophic-eutrophic boundary is a mean of 6 μg chl *a* cm^{-2} and a maximum of 20 μg chl *a* cm^{-2}.

QUALITY CONTROL IN THE LABORATORY

1. Upon delivery of samples to the laboratory, complete entries on periphyton sample log-in forms (Appendix 2, Form 2).

2. Maintain a voucher collection of all samples and diatom slides. They should be accurately and completely labeled, preserved, and stored in the laboratory for future reference. Specimens on diatom slides should be clearly circled with a diamond or ink marker to facilitate location. A record of the voucher specimens should be maintained. Photographs of specimens improve "in-house" QA.

3. For every QA/QC sample (replicate sample in every 10th stream), assess relative abundances and taxa richness in replicate wet mounts and a replicate diatom slide to assess variation in metrics due to variability in sampling within reaches (habitats), sample preparation, and analytical variability.

4. QA/QC samples should be counted by another taxonomist to assess taxonomic precision and bias, if possible.

5. Common algal taxa should be the same for the two wet mount replicates. The percent community similarity index (Whittaker 1952) (see Section 6.5.1) calculated from proportional counts of the two replicate diatom slides should exceed 75%.

6. If it is not possible to get another taxonomist in the lab to QA/QC samples, an outside taxonomist should be consulted on a periodic basis to spot-check and verify taxonomic identifications in wet mounts and diatom slides. All common genera in the wet mount and all major species on the diatom slide (>3% relative abundance) should be identified similarly by both analysts (synonyms are acceptable). Any differences in identification should be reconciled and bench sheets should be corrected.

7. A library of basic taxonomic literature is an essential aid in the identification of algae and should be maintained and updated as needed in the laboratory (see taxonomic references for periphyton in Section 6.5). Taxonomists should participate in periodic training to ensure accurate identifications

6.2 FIELD-BASED RAPID PERIPHYTON SURVEY

Semi-quantitative assessments of benthic algal biomass and taxonomic composition can be made rapidly with a viewing bucket marked with a grid and a biomass scoring system. The advantage of using this technique is that it enables rapid assessment of algal biomass over larger spatial scales than substrate sampling and laboratory analysis. Coarse-level taxonomic characterization of communities is also possible with this technique. This technique is a survey of the natural substrate and requires no laboratory proc essing, but hand picked samples can be returned to the laboratory to quickly verify identification. It is a technique developed by Stevenson and Rier[2].

FIELD EQUIPMENT FOR RAPID PERIPHYTON SURVEY

- viewing bucket with 50-dot grid [Make the viewing bucket by cutting a hole in bottom of large (≥0.5 m diameter) plastic bucket, but leave a small ridge around the edge. Attach a piece of clear acrylic sheet to the bottom of the bucket with small screws and silicon caulk. The latter makes water tight seal so that no water enters the bucket when it is partially submerged. Periphyton can be clearly viewed by looking down through the bucket when it is partially submerged in the stream. Mark 50 dots in a 7 x 7 grid on the top surface of the acrylic sheet with a waterproof black marker. Add another dot outside the 7 x 7 grid to make the 50 dot grid.]
- meter stick
- pencil
- Rapid Periphyton Survey Field Sheet

1. Fill in top of Rapid Periphyton Survey (RPS) Field Sheet, Appendix A-2, Form 5.
2. Establish at least 3 transects across the habitat being sampled (preferably riffles or runs in the reach in which benthic algal accumulation is readily observed and characterized).
3. Select 3 locations along each transect (e.g., stratified random locations on right, middle, and left bank).
4. Characterize algae in each selected location by immersing the bucket with 50-dot grid (7 x 7 + 1) in the water.
   ! First, characterize macroalgal biomass.
   - Observe the bottom of the stream through the bottom of the viewing bucket and count the number of dots that occur over macroalgae (e.g., Cladophora or Spirogyra) under which substrates cannot be seen. Record that number and the kind of macroalgae under the dots on RPS field sheet.
   - Measure and record the maximum length of the macroalgae.
   - If two or more types of macroalgae are present, count the dots, measure, and record information for each type of macroalgae separately.

   ! Second, characterize microalgal cover.
   - While viewing the same area, record the number of dots under which substrata occur that are suitable size for microalgal accumulation (gravel > 2 cm in size).
   - Determine the kind (usually diatoms and blue-green algae) and estimate the thickness (density) of microalgae under each dot using the following thickness scale:
     0 - substrate rough with no visual evidence of microalgae
     0.5 - substrate slimy, but no visual accumulation of microalgae is evident
     1 - a thin layer of microalgae is visually evident
     2 - accumulation of microalgal layer from 0.5-1 mm thick is evident
     3 - accumulation of microalgae layer from 1 mm to 5 mm thick is evident
     4 - accumulation of microalgal layer from 5 mm to 2 cm thick is evident
     5 - accumulation of microalgal layer greater than 2 cm thick is evident
     Mat thickness can be measured with a ruler.
   - Record the number of dots that are over each of the specific thickness ranks separately for diatoms, blue-green algae, or other microalgae.

[2] S.T. Rier is a graduate student at the University of Louisville.

5. Statistically characterize density of algae on substrate by determining:
   ! total number of grid points (dots) evaluated at the site (D_t);
   ! number of grid points (dots) over macroalgae (D_m)
   ! total number of grid points (dots) over suitable substrate for microalgae at the site (d_t);
   ! number of grid points over microalga of different thickness ranks for each type of microalga (d_i);
   ! average percent cover of the habitat by each type of macroalgae (i.e., 100X D_m/D_t);
   ! maximum length of each type of macroalgae;
   ! mean density (i.e., thickness rank) of each type of macroalgae on suitable substrate (i.e., $\Sigma d_i r_i/d_t$); maximum density of each type of microalgae on suitable substrate.

6. QA/QC between observers and calibration between algal biomass (chl *a*, AFDM, cell density and biovolume cm^{-2} and taxonomic composition) can be developed by collecting samples that have specific microalgal rankings and assaying the periphyton.

6.3 TAXONOMIC REFERENCES FOR PERIPHYTON

A great wealth of taxonomic literature is available for algae. Below is a subset of that literature. It is a list of taxonomic references that are useful for most of the United States and are either in English, are important because no English treatment of the group is adequate, or are valuable for the good illustrations.

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7 BENTHIC MACROINVERTEBRATE PROTOCOLS

Rapid bioassessment using the benthic macroinvertebrate assemblage has been the most popular set of protocols among the state water resource agencies since 1989 (Southerland and Stribling 1995). Most of the development of benthic Rapid Bioassessment Protocols (RBPs) has been oriented toward RBP III (described in Plafkin et al. 1989). As states have focused attention on regional specificity, which has included a wide variety of physical characteristics of streams, the methodology of conducting stream surveys of the benthic assemblage has advanced. Some states have preferred to retain more traditional methods such as the Surber or Hess samplers (e.g., Wyoming Department of Environmental Quality [DEQ]) over the kick net in cobble substrate. Other agencies have developed techniques for streams lacking cobble substrate, such as those streams in coastal plains. State water resource agencies composing the Mid-Atlantic Coastal Streams (MACS) Workgroup, i.e., New Jersey Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of Natural Resources (DNR) and Maryland Department of the Environment (MDE), Virginia DEQ, North Carolina Department of Environmental Management (DEM), and South Carolina Department of Health and Environmental Control (DHEC), and a workgroup within the Florida Department of Environmental Protection (DEP) were pioneers in this effort. These 2 groups (MACS and FLDEP) developed a multihabitat sampling procedure using a D-frame dip net. Testing of this procedure by these 2 groups indicates that this technique is scientifically valid for low-gradient streams. Research conducted by the U.S. Environmental Protection

STANDARD BENTHIC MACROINVERTEBRATE SAMPLING GEAR TYPES FOR STREAMS
(assumes standard mesh size of 500 μ nytex screen)

- **Kick net:** Dimensions of net are 1 meter (m) x 1 m attached to 2 poles and functions similarly to a fish kick seine. Is most efficient for sampling cobble substrate (i.e., riffles and runs) where velocity of water will transport dislodged organisms into net. Designed to sample 1 m^2 of substrate at a time and can be used in any depth from a few centimeters to just below 1m (Note -- Depths of 1m or greater will be difficult to sample with any gear).
- **D-frame dip net:** Dimensions of frame are 0.3 m width and 0.3 m height and shaped as a "D" where frame attaches to long pole. Net is cone or bag-shaped for capture of organisms. Can be used in a variety of habitat types and used as a kick net, or for "jabbing", "dipping", or "sweeping".
- **Rectangular dip net:** Dimensions of frame are 0.5 m width and 0.3 m height and attached to a long pole. Net is cone or bag-shaped. Sampling is conducted similarly to the D-frame.
- **Surber:** Dimensions of frame are 0.3 m x 0.3 m, which is horizontally placed on cobble substrate to delineate a 0.09 m^2 area. A vertical section of the frame has the net attached and captures the dislodged organisms from the sampling area. Is restricted to depths of less than 0.3 m.
- **Hess:** Dimensions of frame are a metal cylinder approximately 0.5 m in diameter and samples an area 0.8 m^2. Is an advanced design of the Surber and is intended to prevent escape of organisms and contamination from drift. Is restricted to depths of less than 0.5 m.

Agency (USEPA) for their Environmental Monitoring and Assessment Program (EMAP) program and the United States Geological Survey (USGS) for their National Water Quality Assessment Program (NAWQA) program have indicated that the rectangular dip net is a reasonable compromise between the traditional Surber or Hess samplers and the RBP kick net described the original RBPs.

From the testing and implementation efforts that have been conducted around the country since 1989, refinements have been made to the procedures while maintaining the original concept of the RBPs. Two separate procedures that are oriented toward a "single, most productive" habitat and a multihabitat approach represent the most rigorous benthic RBP and are essentially a replacement of the original RBP III. The primary differences between the original RBP II and III are the decision on field versus lab sorting and level of taxonomy. These differences are not considered sufficient reasons to warrant separate protocols. In addition, a third protocol has been developed as a more standardized biological reconnaissance or screening and replaces RBP I of the original document.

Kicknet

D-frame Dipnet

Rectangular Dipnet

Hess sampler

(Mary Kay Corazalla, Univ. of Minnesota)

7.1 SINGLE HABITAT APPROACH: 1 METER KICK NET

The original RBPs (Plafkin et al. 1989) emphasized the sampling of a single habitat, in particular riffles or runs, as a means to standardize assessments among streams having those habitats. This approach is still valid, because macroinvertebrate diversity and abundance are usually highest in cobble substrate (riffle/run) habitats. Where cobble substrate is the predominant habitat, this sampling approach provides a representative sample of the stream reach. However, some streams naturally lack the cobble substrate. In cases where the cobble substrate represents less than 30% of the sampling reach in reference streams (i.e., those streams that are representative of the region), alternate habitat(s) will need to be sampled (See Section 7.2). The appropriate sampling method should be selected based on the habitat availability of the reference condition and not of potentially impaired streams. For example, methods would not be altered for situations where the extent of cobble substrate in streams influenced by heavy sediment deposition may be substantially reduced from the amount of cobble substrate expected for the region.

7.1.1 Field Sampling Procedures for Single Habitat

1. A 100 m reach representative of the characteristics of the stream should be selected. Whenever possible, the area should be at least 100 meters upstream from any road or bridge crossing to minimize its effect on stream velocity, depth, and overall habitat quality. There should be no major tributaries discharging to the stream in the study area.

FIELD EQUIPMENT/SUPPLIES NEEDED FOR BENTHIC MACROINVERTEBRATE SAMPLING —SINGLE HABITAT APPROACH

- standard kick-net, 500 μ opening mesh, 1.0 meter width
- sieve bucket, with 500 μ opening mesh
- 95% ethanol
- sample containers, sample container labels
- forceps
- pencils, clipboard
- Benthic Macroinvertebrate Field Data Sheet*
- first aid kit
- waders (chest-high or hip boots)
- rubber gloves (arm-length)
- camera
- Global Positioning System (GPS) Unit

* It is helpful to copy fieldsheets onto water-resistant paper for use in wet weather conditions

2. Before sampling, complete the physical/chemical field sheet (see Chapter 5; Appendix A-1, Form 1) to document site description, weather conditions, and land use. After sampling, review this information for accuracy and completeness.

3. Draw a map of the sampling reach. This map should include in-stream attributes (e.g., riffles, falls, fallen trees, pools, bends, etc.) and important structures, plants, and attributes of the bank and near stream areas. Use an arrow to indicate the direction of flow. Indicate the areas that were sampled for macroinvertebrates on the map. Estimate "river mile" for sampling reach for probable use in data management of the water resource agency. If available, use hand-held Global Positioning System (GPS) for latitude and longitude determination taken at the furthest downstream point of the sampling reach.

4. All riffle and run areas within the 100-m reach are candidates for sampling macroinvertebrates. A composite sample is taken from individual sampling spots in the riffles and runs representing different velocities. Generally, a minimum of 2 m^2 composited area is sampled for RBP efforts.

5. Sampling begins at the downstream end of the reach and proceeds upstream. Using a 1 m kick net, 2 or 3 kicks are sampled at various velocities in the riffle or series of riffles. A *kick* is a stationary sampling accomplished by positioning the net and disturbing one square meter upstream of the net. Using the toe or heel of the boot, dislodge the upper layer of cobble or gravel and scrape the underlying bed. Larger substrate particles should be picked up and rubbed by hand to remove attached organisms. If different gear is used (e.g., a D-frame or rectangular net), a composite is obtained from numerous kicks (See Section 7.2).

ALTERNATIVES FOR STREAM REACH DESIGNATION

- **Fixed-distance designation**—A standard length of stream, such as a reach, is commonly used to obtain an estimate of natural variability. Conceptually, this approach should provide a mixture of habitats in the reach and provide, at a minimum, duplicate physical and structural elements such as a riffle/pool sequence.

- **Proportional-distance designation**—Alternatively, a standard number of stream "widths" is used to measure the stream distance, e.g., 40 times the stream width is defined by EMAP for sampling (Klemm and Lazorchak 1995). This approach allows variation in the length of the reach based on the size of the stream.

6. The jabs or kicks collected from different locations in the cobble substrate will be composited to obtain a single homogeneous sample. After every kick, wash the collected material by running clean stream water through the net 2 to 3 times. If clogging does occur, discard the material in the net and redo that portion of the sample in a different location. Remove large debris after rinsing and inspecting it for organisms; place any organisms found into the sample container. Do not spend time inspecting small debris in the field. [Note — an alternative is to keep the samples from different habitats separated as done in EMAP (Klemm and Lazorchak 1995).]

7. Transfer the sample from the net to sample container(s) and preserve in enough 95 percent ethanol to cover the sample. Forceps may be needed to remove organisms from the dip net. Place a label indicating the sample identification code or lot number, date, stream name, sampling location, and collector name into the sample container. The outside of the container should include the same information and the words "preservative: 95% ethanol". If more than one container is needed for a sample, each container label should contain all the information for the sample and should be numbered (e.g., 1 of 2, 2 of 2, etc.). This information will be recorded in the "Sample Log" at the biological laboratory (Appendix A-3, Form 2).

8. Complete the top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1), which duplicates the "header" information on the physical/chemical field sheet.

9. Record the percentage of each habitat type in the reach. Note the sampling gear used, and comment on conditions of the sampling, e.g., high flows, treacherous rocks, difficult access to stream, or anything that would indicate adverse sampling conditions.

10. Document observations of aquatic flora and fauna. Make qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling.

11. Perform habitat assessment (Appendix A-1, Form 2) after sampling has been completed; walking the reach helps ensure a more accurate assessment. Conduct the habitat assessment with another team member, if possible.

12. Return samples to laboratory and complete log-in form (Appendix A-3, Form 2).

QUALITY CONTROL (QC) IN THE FIELD

1. Sample labels must be properly completed, including the sample identification code, date, stream name, sampling location, and collector's name, and placed into the sample container. The outside of the container should be labeled with the same information. Chain-of-custody forms, if needed, must include the same information as the sample container labels.

2. After sampling has been completed at a given site, all nets, pans, etc. that have come in contact with the sample should be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found should be placed into the sample containers. The equipment should be examined again prior to use at the next sampling site.

3. Replicate (1 duplicate sample) 10% of the sites to evaluate precision or repeatability of the sampling technique or the collection team.

7.2 MULTIHABITAT APPROACH: D–FRAME DIP NET

Streams in many states vary from high gradient, cobble dominated to low gradient streams with sandy or silty sediments. Therefore, a method suitable to sampling a variety of habitat types is desired in these cases. The method that follows is based on Mid-Atlantic Coastal Streams Workgroup recommendations designed for use in streams with variable habitat structure (MACS 1996) and was used for statewide stream bioassessment programs by Florida DEP (1996) and Massachusetts DEP (1995). This method focuses on a multihabitat scheme designed to sample major habitats in proportional representation within a sampling reach. Benthic

FIELD EQUIPMENT/SUPPLIES NEEDED FOR BENTHIC MACROINVERTEBRATE SAMPLING —MULTI-HABITAT APPROACH

- standard D-frame dip net, 500 μ opening mesh, 0.3 m width (~ 1.0 ft frame width)
- sieve bucket, with 500 μ opening mesh
- 95% ethanol
- sample containers, sample container labels
- forceps
- pencils, clipboard
- Benthic Macroinvertebrate Field Data Sheet*
- first aid kit
- waders (chest-high or hip boots)
- rubber gloves (arm-length)
- camera
- Global Positioning System (GPS) Unit

* It is helpful to copy fieldsheets onto water-resistant paper for use in wet weather conditions

macroinvertebrates are collected systematically from all available instream habitats by kicking the substrate or jabbing with a D-frame dip net. A total of 20 jabs (or kicks) are taken from all major habitat types in the reach resulting in sampling of approximately 3.1 m^2 of habitat. For example, if the habitat in the sampling reach is 50% snags, then 50% or 10 jabs should be taken in that habitat. An organism-based subsample (usually 100, 200, 300, or 500 organisms) is sorted in the laboratory and identified to the lowest practical taxon, generally genus or species.

7.2.1 Habitat Types

The major stream habitat types listed here are in reference to those that are colonized by macroinvertebrates and generally support the diversity of the macroinvertebrate assemblage in stream ecosystems. Some combination of these habitats would be sampled in the multihabitat approach to benthic sampling.

Cobble (hard substrate) - Cobble will be prevalent in the riffles (and runs), which are a common feature throughout most mountain and piedmont streams. In many high-gradient streams, this habitat type will be dominant. However, riffles are not a common feature of most coastal or other low-gradient streams. Sample shallow areas with coarse (mixed gravel, cobble or larger) substrates by holding the bottom of the dip net against the substrate and dislodging organisms by kicking the substrate for 0.5 m upstream of the net.

Snags - Snags and other woody debris that have been submerged for a relatively long period (not recent deadfall) provide excellent colonization habitat. Sample submerged woody debris by jabbing in medium-sized snag material (sticks and branches). The snag habitat may be kicked first to help dislodge organisms, but only after placing the net downstream of the snag. Accumulated woody material in pool areas are considered snag habitat. Large logs should be avoided because they are generally difficult to sample adequately.

Vegetated banks - When lower banks are submerged and have roots and emergent plants associated with them, they are sampled in a fashion similar to snags. Submerged areas of undercut banks are good habitats to sample. Sample banks with protruding roots and plants by jabbing into the habitat. Bank habitat can be kicked first to help dislodge organisms, but only <u>after</u> placing the net downstream.

Submerged macrophytes - Submerged macrophytes are seasonal in their occurrence and may not be a common feature of many streams, particularly those that are high-gradient. Sample aquatic plants that are rooted on the bottom of the stream in deep water by drawing the net through the vegetation from the bottom to the surface of the water (maximum of 0.5 m each jab). In shallow water, sample by bumping or jabbing the net along the bottom in the rooted area, avoiding sediments where possible.

Sand (and other fine sediment) - Usually the least productive macroinvertebrate habitat in streams, this habitat may be the most prevalent in some streams. Sample banks of unvegetated or soft soil by bumping the net along the surface of the substrate rather than dragging the net through soft substrates; this reduces the amount of debris in the sample.

7.2.2 Field Sampling Procedures for Multihabitat

> **ALTERNATIVES FOR STREAM REACH DESIGNATION**
>
> - **Fixed-distance designation**—A standard length of stream, such as a reach, is commonly used to obtain an estimate of natural variability. Conceptually, this approach should provide a mixture of habitats in the reach and provide, at a minimum, duplicate physical and structural elements such as a riffle/pool sequence.
> - **Proportional-distance designation**—Alternatively, a standard number of stream "widths" is used to measure the stream distance, e.g., 40 times the stream width is defined by EMAP for sampling (Klemm and Lazorchak 1995). This approach allows variation in the length of the reach based on the size of the stream.

1. A 100 m reach that is representative of the characteristics of the stream should be selected. Whenever possible, the area should be at least 100 m upstream from any road or bridge crossing to minimize its effect on stream velocity, depth and overall habitat quality. There should be no major tributaries discharging to the stream in the study area.

2. Before sampling, complete the physical/chemical field sheet (see Chapter 5; Appendix A-1, Form 1) to document site description, weather conditions, and land use. After sampling, review this information for accuracy and completeness.

3. Draw a map of the sampling reach. This map should include in-stream attributes (e.g., riffles, falls, fallen trees, pools, bends, etc.) and important structures, plants, and attributes of the bank and near stream areas. Use an arrow to indicate the direction of flow. Indicate the areas that were sampled for macroinvertebrates on the map. Approximate "river mile" to sampling reach for probable use in data management of the water resource agency. If available, use hand-held GPS for latitude and longitude determination taken at the furthest downstream point of the sampling reach.

4. Different types of habitat are to be sampled in approximate proportion to their representation of surface area of the total macroinvertebrate habitat in the reach. For example, if snags comprise 50% of the habitat in a reach and riffles comprise 20%, then 10 jabs should be taken in snag material and 4 jabs should be take in riffle areas. The remainder of the jabs (6) would be taken in any remaining habitat type. Habitat types contributing less than 5% of the stable habitat in the stream reach should not be sampled. In this case, allocate the remaining jabs proportionately among the predominant substrates. The number of jabs taken in each habitat type should be recorded on the field data sheet.

5. Sampling begins at the downstream end of the reach and proceeds upstream. A total of 20 jabs or kicks will be taken over the length of the reach; a single *jab* consists of forcefully thrusting the net into a productive habitat for a linear distance of 0.5 m. A *kick* is a stationary sampling accomplished by positioning the net and disturbing the substrate for a distance of 0.5 m upstream of the net.

6. The jabs or kicks collected from the multiple habitats will be composited to obtain a single homogeneous sample. Every 3 jabs, more often if necessary, wash the collected material by running clean stream water through the net two to three times. If clogging does occur that may hinder obtaining an appropriate sample, discard the material in the net and redo that portion of

the sample in the same habitat type but in a different location. Remove large debris after rinsing and inspecting it for organisms; place any organisms found into the sample container. Do not spend time inspecting small debris in the field.

7. Transfer the sample from the net to sample container(s) and preserve in enough 95% ethanol to cover the sample. Forceps may be needed to remove organisms from the dip net. Place a label indicating the sample identification code or lot number, date, stream name, sampling location, and collector name into the sample container. The outside of the container should include the same information and the words "preservative: 95% ethanol". If more that one container is needed for a sample, each container label should contain all the information for the sample and should be numbered (e.g., 1 of 2, 2 of 2, etc.). This information will be recorded in the "Sample Log" at the biological laboratory (Appendix A-3, Form 2).

8. Complete the top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1), which duplicates the "header" information on the physical/chemical field sheet.

9. Record the percentage of each habitat type in the reach. Note the sampling gear used, and comment on conditions of the sampling, e.g., high flows, treacherous rocks, difficult access to stream, or anything that would indicate adverse sampling conditions.

10. Document observations of aquatic flora and fauna. Make qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling.

11. Perform habitat assessment (Appendix A-1, Form 3) after sampling has been completed. Having sampled the various microhabitats and walked the reach helps ensure a more accurate assessment. Conduct the habitat assessment with another team member, if possible.

12. Return samples to laboratory and complete log-in forms (Appendix A-3, Form 2).

QUALITY CONTROL (QC) IN THE FIELD

1. Sample labels must be properly completed, including the sample identification code, date, stream name, sampling location, and collector's name and placed into the sample container. The outside of the container should be labeled with the same information. Chain-of-custody forms, if needed, must include the same information as the sample container labels.

2. After sampling has been completed at a given site, all nets, pans, etc. that have come in contact with the sample should be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found should be placed into the sample containers. The equipment should be examined again prior to use at the next sampling site.

3. Replicate (1 duplicate sample) 10% of the sites to evaluate precision or repeatability of sampling technique or collection team.

7.3 LABORATORY PROCESSING FOR MACROINVERTEBRATE SAMPLES

Macroinvertebrate samples collected by either intensive method, i.e., single habitat or multihabitat, are best processed in the laboratory under controlled conditions. Aspects of laboratory processing include subsampling, sorting, and identification of organisms.

All samples should be dated and recorded in the "Sample Log" notebook or on sample log form (Appendix A-3, Form 2) upon receipt by laboratory personnel. All information from the sample container label should be included on the sample log sheet. If more than one container was used, the number of containers should be indicated as well. All samples should be sorted in a single laboratory to enhance quality control.

LABORATORY EQUIPMENT/SUPPLIES NEEDED FOR BENTHIC MACROINVERTEBRATE SAMPLE PROCESSING

- log-in sheet for samples
- standardized gridded pan (30 cm x 36 cm) with approximately 30 grids (6 cm x 6 cm)
- 500 micron sieve
- forceps
- white plastic or enamel pan (15 cm x 23 cm) for sorting
- specimen vials with caps or stoppers
- sample labels
- standard laboratory bench sheets for sorting and identification
- dissecting microscope for organism identification
- fiber optics light source
- compound microscope with phase contrast for identification of mounted organisms (e.g., midges)
- 70% ethanol for storage of specimens
- appropriate taxonomic keys

7.3.1 Subsampling and Sorting

Subsampling benthic samples is not a requirement, and in fact, is frowned upon by certain scientists. Courtemanch (1996) provides an argument against subsampling, or to use a volume-based procedure if samples are to be subsampled. Vinson and Hawkins (1996) and Barbour and Gerritsen (1996) provide arguments for a fixed-count method, which is the preferred subsampling technique for RBPs.

Subsampling reduces the effort required for the sorting and identification aspects of macroinvertebrate surveys and provides a more accurate estimate of time expenditure (Barbour and Gerritsen 1996). The RBPs use a fixed-count approach to subsampling and sorting the organisms from the sample matrix of detritus, sand, and mud. *The following protocol is based on a 200-organism subsample, but it could be used for any subsample size (100, 300, 500, etc.)*. The subsample is sorted and preserved separately from the remaining sample for quality control checks.

1. Prior to processing any samples in a lot (i.e., samples within a collection date, specific watershed, or project), complete the sample log-in sheet to verify that all samples have arrived at the laboratory, and are in proper condition for processing.

2. Thoroughly rinse sample in a 500 µm-mesh sieve to remove preservative and fine sediment. Large organic material (whole leaves, twigs, algal or macrophyte mats, etc.) not removed in the field should be rinsed, visually inspected, and discarded. If the samples have been preserved in alcohol, it will be necessary to soak the sample contents in water for about 15 minutes to hydrate the benthic organisms, which will prevent them from floating on the water surface during sorting. If the sample was stored in more than one container, the contents of all

containers for a given sample should be combined at this time. Gently mix the sample by hand while rinsing to make homogeneous.

SUBSAMPLE PROCEDURE MODIFICATIONS

Subsampling procedures developed by Hilsenhoff (1987) and modified by Plafkin et al. (1989) were used in the original RBP II and RBP III protocols. As an improvement to the mechanics of the technique, Caton (1991) designed a sorting tray consisting of two parts, a rectangular plastic or plexiglass pan (36 cm x 30 cm) with a rectangular sieve insert. The sample is placed on the sieve, in the pan and dispersed evenly.

When a random grid(s) is selected, the sieve is lifted to temporarily drain the water. A "cookie-cutter" like metal frame 6 cm x 6 cm is used to clearly define the selected grid; debris overhanging the grid may be cut with scissors. A 6 cm flat scoop is used to remove all debris and organisms from the grid. The contents are then transferred to a separate sorting pan with water for removal of macroinvertebrates.

These modifications have allowed for rapid isolation of organisms within the selected grids and easy removal of all organisms and debris within a grid while eliminating investigator bias.

3. After washing, spread the sample evenly across a pan marked with grids approximately 6 cm x 6 cm. On the laboratory bench sheet, note the presence of large or obviously abundant organisms; *do not remove them from the pan.* However, Vinson and Hawkins (1996) present an argument for including these large organisms in the count, because of the high probability that these organisms will be excluded from the targeted grids.

4. Use a random numbers table to select 4 numbers corresponding to squares (grids) within the gridded pan. Remove all material (organisms and debris) from the four grid squares, and place the material into a shallow white pan and add a small amount of water to facilitate sorting. If there appear (through a cursory count or observation) to be 200 organisms ± 20% (cumulative of 4 grids), then subsampling is complete.

Any organism that is lying over a line separating two grids is considered to be on the grid containing its head. In those instances where it may not be possible to determine the location of the head (worms for instance), the organism is considered to be in the grid containing most of its body.

If the density of organisms is high enough that many more than 200 organisms are contained in the 4 grids, transfer the contents of the 4 grids to a second gridded pan. Randomly select grids for this second level of sorting as was done for the first, sorting grids one at a time until 200 organisms ± 20% are found. If picking through the entire next grid is likely to result in a subsample of greater than 240 organisms, then that grid may be subsampled in the same manner as before to decrease the likelihood of exceeding 240 organisms. That is, spread the contents of the last grid into another gridded pan. Pick grids one at a time until the desired number is reached. The total number of grids for each subsorting level should be noted on the laboratory bench sheet.

TESTING OF SUBSAMPLING

Ferraro et al. (1989) describe a procedure for calculating the "power-cost efficiency" (PCE), which incorporates both the number of samples and the cost (i.e. time or money) for each alternative sampling scheme. With this analysis, the optimal subsampling size is that by which the costs of increased effort are offset by the lowest theoretical number of samples predicted from the power analysis to provide reliable resolution (Barbour and Gerritsen 1996).

There are 4 primary steps in assessing the PCE of a suite of alternative subsampling strategies:

Step 1: For each subsampling strategy (i.e., 100-, 200-, 300- organism level, or other) collect samples at several reference and impaired stations. The observed differences in each of the core metrics is defined to be the magnitude of the difference desired to be detected. The difference is the "effect size" and is equivalent to the inverse coefficient of variation (CV).

Step 2: Assess the "cost" (c_i), in time or money, of each subsampling scheme i at each site. The cost can include labor hours for subsampling, sorting, identification, and documentation. Total cost of each subsampling alternative is the product of cost per site and required sample size.

Step 3: Conduct statistical power analyses to determine the minimum number of replicate samples (n_i) needed to detect the effect size with an acceptable probability of Type I (α; the probability that the null hypothesis [e.g., "sites are good"] is true and it is rejected. Commonly termed the significance level.) and Type II (β; the probability that the null hypothesis is false and it is accepted) error. Typically, α and β are set at 0.05. This step may be deleted for those programs that already have an established number of replicate samples.

Step 4: Calculate the PCE for each sampling scheme by:

$$PCE_i = \frac{(n \mathrm{X} c)_{\min}}{(n_i \mathrm{X} c_i)}$$

where $(n \mathrm{X} c)_{\min}$ = minimum value of (n X c) among the i sampling schemes. The PCE formula is equivalent to the "power efficiency" ratio of the sample sizes attained by alternative tests under similar conditions (Ferraro et al. 1989) with the n's multiplied by the "cost" per replicate sample. Multiplying n by c puts efficiency on a total "cost" rather than on a sample size basis. The reciprocal of PCE_i is the factor by which the optimal subsampling scheme is more efficient than alternative scheme i. When PCE is determined for multiple metrics, the overall optimal subsampling scheme may be defined as that which ranks highest in PCE for most metrics of interest.

5. Save the sorted debris residue in a separate container. Add a label that includes the words "sorted residue" in addition to all prior sample label information and preserve in 95% ethanol. Save the remaining unsorted sample debris residue in a separate container labeled "sample residue"; this container should include the original sample label. Length of storage and archival is determined by the laboratory or benthic section supervisor.

6. Place the sorted 200-organism (± 20%) subsample into glass vials, and preserve in 70% ethanol. Label the vials inside with the sample identifier or lot number, date, stream name, sampling location and taxonomic group. If more than one vial is needed, each should be labeled separately and numbered (e.g., 1 of 2, 2 of 2). For convenience in reading the labels inside the

TESTING OF SUBSAMPLING

Ferraro et al. (1989) describe a procedure for calculating the "power-cost efficiency" (PCE), which incorporates both the number of samples and the cost (i.e. time or money) for each alternative sampling scheme. With this analysis, the optimal subsampling size is that by which the costs of increased effort are offset by the lowest theoretical number of samples predicted from the power analysis to provide reliable resolution (Barbour and Gerritsen 1996).

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Step 2: Assess the "cost" (c_i), in time or money, of each subsampling scheme *i* at each site. The cost can include labor hours for subsampling, sorting, identification, and documentation. Total cost of each subsampling alternative is the product of cost per site and required sample size.

Step 3: Conduct statistical power analyses to determine the minimum number of replicate samples (n_i) needed to detect the effect size with an acceptable probability of Type I (∝; the probability that the null hypothesis [e.g., "sites are good"] is true and it is rejected. Commonly termed the significance level.) and Type II (β; the probability that the null hypothesis is false and it is accepted) error. Typically, ∝ and β are set at 0.05. This step may be deleted for those programs that already have an established number of replicate samples.

Step 4: Calculate the PCE for each sampling scheme by:

$$PCE_i = \frac{(n \text{X} c)_{\min}}{(n_i \text{X} c_i)}$$

where $(n \text{ X } c)_{min}$ = minimum value of (n X c) among the *i* sampling schemes. The PCE formula is equivalent to the "power efficiency" ratio of the sample sizes attained by alternative tests under similar conditions (Ferraro et al. 1989) with the n's multiplied by the "cost" per replicate sample. Multiplying n by c puts efficiency on a total "cost" rather than on a sample size basis. The reciprocal of PCE_i is the factor by which the optimal subsampling scheme is more efficient than alternative scheme *i*. When PCE is determined for multiple metrics, the overall optimal subsampling scheme may be defined as that which ranks highest in PCE for most metrics of interest.

5. Save the sorted debris residue in a separate container. Add a label that includes the words "sorted residue" in addition to all prior sample label information and preserve in 95% ethanol. Save the remaining unsorted sample debris residue in a separate container labeled "sample residue"; this container should include the original sample label. Length of storage and archival is determined by the laboratory or benthic section supervisor.

6. Place the sorted 200-organism (± 20%) subsample into glass vials, and preserve in 70% ethanol. Label the vials inside with the sample identifier or lot number, date, stream name, sampling location and taxonomic group. If more than one vial is needed, each should be labeled separately and numbered (e.g., 1 of 2, 2 of 2). For convenience in reading the labels inside the

vials, insert the labels left-edge first. If identification is to occur immediately after sorting, a petri dish or watch glass can be used instead of vials.

7. Midge (Chironomidae) larvae and pupae should be mounted on slides in an appropriate medium (e.g., Euperal, CMC-9); slides should be labeled with the site identifier, date collected, and the first initial and last name of the collector. As with midges, worms (Oligochaeta) must also be mounted on slides and should be appropriately labeled.

8. Fill out header information on Laboratory Bench Sheet as in field sheets (see Chapter 5). Also check subsample target number. Complete back of sheet for subsampling/sorting information. Note number of grids picked, time expenditure, and number of organisms. If QC check was performed on a particular sample, person conducting QC should note findings on the back of the Laboratory Bench Sheet. Calculate sorting efficiency to determine whether sorting effort passes or fails.

9. Record date of sorting and slide monitoring, if applicable, on Log-In Sheet as documentation of progress and status of completion of sample lot.

QUALITY CONTROL (QC) FOR SORTING

1. Ten percent of the sorted samples in each lot should be examined by laboratory QC personnel or a qualified co-worker. (A lot is defined as a special study, basin study, entire index period, or individual sorter.) The QC worker will examine the grids chosen and tray used for sorting and will look for organisms missed by the sorter. Organisms found will be added to the sample vials. If the QC worker finds less than 10 organisms (or 10% in larger subsamples) remaining in the grids or sorting tray, the sample passes; if more than 10 (or 10%) are found, the sample fails. If the first 10% of the sample lot fails, a second 10% of the sample lot will be checked by the QC worker. Sorters in-training will have their samples 100% checked until the trainer decides that training is complete.

2. After laboratory processing is complete for a given sample, all sieves, pans, trays, etc., that have come in contact with the sample will be rinsed thoroughly, examined carefully, and picked free of organisms or debris; organisms found will be added to the sample residue.

7.3.2 Identification of Macroinvertebrates

Taxonomy can be at any level, but should be done consistently among samples. In the original RBPs, two levels of identification were suggested — family (RBP II) and genus/species (RBP III) (Plafkin et al. 1989). Genus/species provides more accurate information on ecological/ environmental relationships and sensitivity to impairment. Family level provides a higher degree of precision among samples and taxonomists, requires less expertise to perform, and accelerates assessment results. In either case, only those taxonomic keys that have been peer-reviewed and are available to other taxonomists should be used. Unnamed species (i.e., species A, B, 1, or 2) may be ecologically informative, but may be inconsistently handled among taxonomists and will, thus, contribute to variability when a statewide database is being developed.

1. Most organisms are identified to the lowest practical level (generally genus or species) by a qualified taxonomist using a dissecting microscope. Midges (Diptera: Chironomidae) are

mounted on slides in an appropriate medium and identified using a compound microscope. Each taxon found in a sample is recorded and enumerated in a laboratory bench notebook and then transcribed to the laboratory bench sheet for subsequent reports. Any difficulties encountered during identification (e.g., missing gills) are noted on these sheets.

2. Labels with specific taxa names (and the taxonomist's initials) are added to the vials of specimens by the taxonomist. (Note that individual specimens may be extracted from the sample to be included in a reference collection or to be verified by a second taxonomist.) Slides are initialed by the identifying taxonomist. A separate label may be added to slides to include the taxon (taxa) name(s) for use in a voucher or reference collection.

3. Record the identity and number of organisms on the Laboratory Bench Sheet (Appendix A-3, Form 3). Either a tally counter or "slash" marks on the bench sheet can be used to keep track of the cumulative count. Also, record the life stage of the organisms, the taxonomist's initials and the Taxonomic Certainty Rating (TCR) as a measure of confidence.

4. Use the back of the bench sheet to explain certain TCR ratings or condition of organisms. Other comments can be included to provide additional insights for data interpretation. If QC was performed, record on the back of the bench sheet.

5. For archiving samples, specimen vials, (grouped by station and date), are placed in jars with a small amount of denatured 70% ethanol and tightly capped. The ethanol level in these jars must be examined periodically and replenished as needed, before ethanol loss from the specimen vials takes place. A stick-on label is placed on the outside of the jar indicating sample identifier, date, and preservative (denatured 70% ethanol).

QUALITY CONTROL (QC) FOR TAXONOMY

1. A voucher collection of all samples and subsamples should be maintained. These specimens should be properly labeled, preserved, and stored in the laboratory for future reference. A taxonomist (the reviewer) not responsible for the original identifications should spot check samples corresponding to the identifications on the bench sheet.

2. The reference collection of each identified taxon should also be maintained and verified by a second taxonomist. The word "val." and the 1st initial and last name of the person validating the identification should be added to the vial label. Specimens sent out for taxonomic validations should be recorded in a "Taxonomy Validation Notebook" showing the label information and the date sent out. Upon return of the specimens, the date received and the finding should also be recorded in the notebook along with the name of the person who performed the validation.

3. Information on samples completed (through the identification process) will be recorded in the "sample log" notebook to track the progress of each sample within the sample lot. Tracking of each sample will be updated as each step is completed (i.e., subsampling and sorting, mounting of midges and worms, taxonomy).

4. A library of basic taxonomic literature is essential in aiding identification of specimens and should be maintained (and updated as needed) in the taxonomic laboratory (see attached list). Taxonomists should participate in periodic training on specific taxonomic groups to ensure accurate identifications.

7.4 BENTHIC METRICS

Benthic metrics have undergone evolutionary developments and are documented in the Invertebrate Community Index (ICI) (DeShon 1995), RBPs (Shackleford 1988, Plafkin et al. 1989, Barbour et al. 1992, 1995, 1996b, Hayslip 1993, Smith and Voshell 1997), and the benthic IBI (Kerans and Karr 1994, Fore et al. 1996). Metrics used in these indices evaluate aspects of both elements and processes within the macroinvertebrate assemblage. Although these indices have been regionally developed, they are typically appropriate over wide geographic areas with minor modification (Barbour et al. 1995).

The process for testing the efficacy and calibrating the metrics is described in Chapter 9. While the candidate metrics described here are ecologically sound, they may require testing on a regional basis. Those metrics that are most effective are those that have a response across a range of human influence (Fore et al. 1996, Karr and Chu 1999). Resh and Jackson (1993) tested the ability of 20 benthic metrics used in 30 different assessment protocols to discriminate between impaired and minimally impaired sites in California. The most effective measures, from their study, were the richness measures, 2 community indices (Margalef's and Hilsenhoff's family biotic index), and a functional feeding group metric (percent scrapers). Resh and Jackson emphasized that both the measures (metrics) and protocols need to be calibrated for different regions of the country, and, perhaps, for different impact types (stressors). In a study of 28 invertebrate metrics, Kerans and Karr (1994) demonstrated significant patterns for 18 metrics and used 13 in their final B-IBI (Benthic Index of Biotic Integrity). Richness measures were useful as were selected trophic and dominance metrics. One of the unique features of the fish IBI presently lacking in benthic indices is the ability to incorporate metrics on individual condition, although measures evaluating chironomid larvae deformities have recently been advocated (Lenat 1993).

Four studies that were published from 1995 through 1997 serve as a basis for the most appropriate candidates for metrics, because the metrics were tested in detail in these studies (DeShon 1995, Barbour et al. 1996b, Fore et al. 1996, Smith and Voshell 1997). These metrics have been evaluated for the ability to distinguish impairment and are recommended as the most likely to be useful in other regions of the country (Table 7-1). Other metrics that are currently in use in various states are listed in Table 7-2 and may be applicable for testing as alternatives or additions to the list in Table 7-1.

Taxa richness, or the number of distinct taxa, represents the diversity within a sample. Use of taxa richness as a key metric in a multimetric index include the ICI (DeShon 1995), the fish IBI (Karr et al. 1986), the benthic IBI (Kerans et al. 1992, Kerans and Karr, 1994), and RBP's (Plafkin et al. 1989, Barbour et al. 1996b). Taxa richness usually consists of species level identifications but can also be evaluated as designated groupings of taxa, often as higher taxonomic groups (i.e., genera, families, orders, etc.) in assessment of invertebrate assemblages. Richness measures reflect the diversity of the aquatic assemblage (Resh et al. 1995). The expected response to increasing perturbation is summarized, as an example, in Table 7-2. Increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat, and food source are adequate to support survival and propagation of many species. Number of taxa measures the overall variety of the macroinvertebrate assemblage. No identities of major taxonomic groups are derived from the total taxa metric, but the elimination of taxa from a naturally diverse system can be readily detected. Subsets of "total" taxa richness are also used to accentuate key indicator groupings of organisms. Diversity or variety of taxa within these groups are good indications of the ability of the ecosystem to support varied taxa. Certain indices that focus on a pair-wise site comparison are also included in this richness category.

Table 7-1. Definitions of best candidate benthic metrics and predicted direction of metric response to increasing perturbation (compiled from DeShon 1995, Barbour et al. 1996b, Fore et al. 1996, Smith and Voshell 1997).

Category	Metric	Definition	Predicted response to increasing perturbation
Richness measures	Total No. taxa	Measures the overall variety of the macroinvertebrate assemblage	Decrease
	No. EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Decrease
	No. Ephemeroptera Taxa	Number of mayfly taxa (usually genus or species level)	Decrease
	No. Plecoptera Taxa	Number of stonefly taxa (usually genus of species level)	Decrease
	No. Trichoptera Taxa	Number of caddisfly taxa (usually genus or species level)	Decrease
Composition measures	% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae	Decrease
	% Ephemeroptera	Percent of mayfly nymphs	Decrease
Tolerance/Intolerance measures	No. of Intolerant Taxa	Taxa richness of those organisms considered to be sensitive to perturbation	Decrease
	% Tolerant Organisms	Percent of macrobenthos considered to be tolerant of various types of perturbation	Increase
	% Dominant Taxon	Measures the dominance of the single most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa.	Increase
Feeding measures	% Filterers	Percent of the macrobenthos that filter FPOM from either the water column or sediment	Variable
	% Grazers and Scrapers	Percent of the macrobenthos that scrape or graze upon periphyton	Decrease
Habit measures	Number of Clinger Taxa	Number of taxa of insects	Decrease
	% Clingers	Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water.	Decrease

Composition measures can be characterized by several classes of information, i.e., the identity, key taxa, and relative abundance. Identity is the knowledge of individual taxa and associated ecological patterns and environmental requirements (Barbour et al. 1995). Key taxa (i.e., those that are of special interest or ecologically important) provide information that is important to the condition of the targeted assemblage. The presence of exotic or nuisance species may be an important aspect of biotic interactions that relate to both identity and sensitivity. Measures of composition (or relative abundance) provide information on the make-up of the assemblage and the relative contribution of the populations to the total fauna (Table 7-2). Relative, rather than absolute, abundance is used because the relative contribution of individuals to the total fauna (a reflection of interactive principles) is more informative than abundance data on populations without a knowledge of the interaction among taxa (Plafkin et al. 1989, Barbour et al. 1995). The premise is that a healthy and stable assemblage will be relatively consistent in its proportional representation, though individual abundances may vary in magnitude. Percentage of the dominant taxon is a simple measure of redundancy (Plafkin et al. 1989). A high level of redundancy is equated with the dominance of a pollution tolerant organism and a lowered diversity. Several diversity indices, which are measures of information content and incorporate both richness and evenness in their formulas, may function as viable metrics in some cases, but are usually redundant with taxa richness and % dominance (Barbour et al. 1996b).

Table 7-2. Definitions of additional potential benthic metrics and predicted direction of metric response to increasing perturbation.

Category	Metric	Definition	Predicted response to increasing perturbation	References
Richness measures	No. *Pteronarcys* species	The presence or absence of a long-lived stonefly genus (2-3 year life cycle)	Decrease	Fore et al. 1996
	No. Diptera taxa	Number of "true" fly taxa, which includes midges	Decrease	DeShon 1995
	No. Chironomidae taxa	Number of taxa of chironomid (midge) larvae	Decrease	Hayslip 1993, Barbour et al. 1996b
Composition measures	% Plecoptera	Percent of stonefly nymphs	Decrease	Barbour et al. 1994
	% Trichoptera	Percent of caddisfly larvae	Decrease	DeShon 1995
	% Diptera	Percent of all "true" fly larvae	Increase	Barbour et al. 1996b
	% Chironomidae	Percent of midge larvae	Increase	Barbour et al. 1994
	% Tribe Tanytarsini	Percent of Tanytarisinid midges to total fauna	Decrease	DeShon 1995
	% Other Diptera and noninsects	Composite of those organisms generally considered to be tolerant to a wide range of environmental conditions	Increase	DeShon 1995
	% *Corbicula*	Percent of asiatic clam in the benthic assemblage	Increase	Kerans and Karr 1994
	% Oligochaeta	Percent of aquatic worms	Variable	Kerans and Karr 1994
Tolerance/ Intolerance measures	No. Intol. Snail and Mussel species	Number of species of molluscs generally thought to be pollution intolerant	Decrease	Kerans and Karr 1994
	% Sediment Tolerant organisms	Percent of infaunal macrobenthos tolerant of perturbation	Increase	Fore et al. 1996

Table 7-2. Definitions of additional potential benthic metrics and predicted direction of metric response to increasing perturbation (continued).

Category	Metric	Definition	Predicted response to increasing perturbation	References
	Hilsenhoff Biotic Index	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution	Increase	Barbour et al. 1992, Hayslip 1993, Kerans and Karr 1994
Tolerance/ Intolerance measures (continued)	Florida Index	Weighted sum of intolerant taxa, which are classed as 1 (least tolerant) or 2 (intolerant). Florida Index = 2 X Class 1 taxa + Class 2 taxa	Decrease	Barbour et al. 1996b
	% Hydropsychidae to Trichoptera	Relative abundance of pollution tolerant caddisflies (metric could also be regarded as a composition measure)	Increase	Barbour et al. 1992, Hayslip 1993
Feeding measures	% Omnivores and Scavengers	Percent of generalists in feeding strategies	Increase	Kerans and Karr 1994
	% Ind. Gatherers and Filterers	Percent of collector feeders of CPOM and FPOM	Variable	Kerans and Karr 1994
	% Gatherers	Percent of the macrobenthos that "gather"	Variable	Barbour et al. 1996b
	% Predators	Percent of the predator functional feeding group. Can be made restrictive to exclude omnivores	Variable	Kerans and Karr 1994
	% Shredders	Percent of the macrobenthos that "shreds" leaf litter	Decrease	Barbour et al. 1992, Hayslip 1993
Life cycle measures	% Multivoltine	Percent of organisms having short (several per year) life cycle	Increase	Barbour et al. 1994
	% Univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years)	Decrease	Barbour et al. 1994

Tolerance/Intolerance measures are intended to be representative of relative sensitivity to perturbation and may include numbers of pollution tolerant and intolerant taxa or percent composition (Barbour et al. 1995). Tolerance is generally non-specific to the type of stressor. However, some metrics such as the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987, 1988) are oriented toward detection of organic pollution; the Biotic Condition Index (Winget and Mangum 1979) is useful for evaluating sedimentation. The Florida Index (Ross and Jones 1979) is a weighted sum of intolerant taxa (insects and crustaceans) found at a site (Beck 1965) and functions similarly to the HBI (Hilsenhoff 1987) used in other parts of the country. The tolerance/intolerance measures can be independent of taxonomy or can be specifically tailored to taxa that are associated with pollution tolerances. For example, both the percent of Hydropsychidae to total Trichoptera and percent Baetidae to total Ephemeroptera are estimates of evenness within these insect orders that generally are considered to be sensitive to pollution. As these families (i.e., Hydropsychidae and Baetidae) increase in relative abundance, effects of pollution (usually organic) also increase. Density (number of individuals per some unit of area) is a universal measure used in all kinds of biological studies. Density can be classified with the trophic measures because it is an element of production; however, it is difficult to interpret because it requires careful quantification and is not monotonic in its response (i.e., density can either decrease or increase in response to pollution) and is usually linked to tolerance measures.

Feeding measures or trophic dynamics encompass functional feeding groups and provide information on the balance of feeding strategies (food acquisition and morphology) in the benthic assemblage. Examples involve the feeding orientation of scrapers, shredders, gatherers, filterers, and predators. Trophic dynamics (food types) are also included here and include the relative abundance of herbivores, carnivores, omnivores, and detritivores. Without relatively stable food dynamics, an imbalance in functional feeding groups will result, reflecting stressed conditions. Trophic metrics are surrogates of complex processes such as trophic interaction, production, and food source availability (Karr et al. 1986, Cummins et al. 1989, Plafkin et al. 1989). Specialized feeders, such as scrapers, piercers, and shredders, are the more sensitive organisms and are thought to be well represented in healthy streams. Generalists, such as collectors and filterers, have a broader range of acceptable food materials than specialists (Cummins and Klug 1979), and thus are more tolerant to pollution that might alter availability of certain food. However, filter feeders are also thought to be sensitive in low-gradient streams (Wallace et al. 1977). The usefulness of functional feeding measures for benthic macroinvertebrates has not been well demonstrated. Difficulties with the proper assignment to functional feeding groups has contributed to the inability to consider these reliable metrics (Karr and Chu 1997).

Habit measures are those that denote the mode of existence among the benthic macroinvertebrates. Morphological adaptation among the macroinvertebrate distinguishes the various mechanisms for maintaining position and moving about in the aquatic environment (Merritt et al. 1996). Habit categories include movement and positioning mechanisms such as skaters, planktonic, divers, swimmers, clingers, sprawlers, climbers, burrowers. Merritt et al. (1996) provide an overview of the habit of aquatic insects, which are the primary organisms used in these measures. Habit measures have been found to be more robust than functional feeding groups in some instances (Fore et al. 1996).

7.5 BIOLOGICAL RECONNAISSANCE (BioRecon) OR PROBLEM IDENTIFICATION SURVEY

The use of biological survey techniques can serve as a screening tool for problem identification and/or prioritizing sites for further assessment, monitoring, or protection. The application of biological surveys in site reconnaissance is intended to be expedient, and, as such, requires an experienced and well-trained biologist. Expediency in

FIELD EQUIPMENT/SUPPLIES NEEDED FOR BENTHIC MACROINVERTEBRATE SAMPLING —BIORECON

- standard D-frame dip net, 500 μ opening mesh, 0.3 meter width (~ 1.0 ft frame width)
- sieve bucket, with 500 μ opening mesh
- 95% ethanol
- sample containers
- sample container labels
- forceps
- field data sheets*, pencils, clipboard
- first aid kit
- waders (chest-high or hip boots), rubber gloves (arm-length)
- camera
- Global Positioning System (GPS) Unit

* It is helpful to copy fieldsheets onto water-resistant paper for use in wet weather conditions

this technique is to minimize time spent in the laboratory and with analysis. The "turn-around" time from the biosurvey to an interpretation of findings is intended to be relatively short. The BioRecon is useful in discriminating obviously impaired and non-impaired areas from potentially affected areas requiring further investigation. Use of the BioRecon allows rapid screening of a large number of sites. Areas identified for further study can then either be evaluated using more rigorous bioassessment methods for benthic macroinvertebrates and/or other assemblages, or ambient toxicity methods.

Because the BioRecon involves limited data generation, its effectiveness depends largely on the experience of the professional biologist performing the assessment. The professional biologist should have assessment experience, a knowledge of aquatic ecology, and basic expertise in benthic macroinvertebrate taxonomy.

The BioRecon presented here is refined and standardized from the original RBP I (Plafkin et al. 1989), and is based on the technique developed by Florida DEP (1996), from which the approach derives its name. This biosurvey approach is based on a multihabitat approach similar to the more rigorous technique discussed in Section 7.2. The most productive habitats, i.e., those that contain the greatest diversity and abundance of macroinvertebrates, are sampled in the BioRecon. As a general rule, impairment is judged by richness measures, thereby emphasizing the presence or absence of indicator taxa. Biological attributes such as the relative abundance of certain taxa may be less useful than richness measures in the BioRecon approach, because samples are processed more quickly and in a less standardized manner.

7.5.1 Sampling, Processing, and Analysis Procedures

1. A 100 m reach representative of the characteristics of the stream should be selected. For the BioRecon, it is unlikely that the alternative reach designation approach (i.e., x times the stream width), will improve the resolution beyond a standard 100 m reach. Whenever possible, the area should be at least 100 meters upstream from any road or bridge crossing to minimize its effect on stream velocity, depth and overall habitat quality. There should be no major tributaries discharging to the stream in the study area.

2. Before sampling, complete the "Physical Characterization/Water Quality Field Data Sheet" (Appendix A-1, Form 1) to document site description, weather conditions, and land use. After sampling, review this information for accuracy and completeness.

3. The major habitat types (see 7.2.1 for habitat descriptions) represented in the reach are to be sampled for macroinvertebrates. A total of 4 jabs or kicks will be taken over the length of the reach. A minimum of 1 jab (or kick) is to be taken in each habitat. More than 1 jab may be desired in those habitats that are predominant. Habitat types contributing less than five percent of the stable habitat in the stream reach should not be sampled. Thus, allocate the remaining jabs proportionately among the predominant substrates. The number of jabs taken in each habitat type should be recorded on the field data sheet.

4. Sampling begins at the downstream end of the reach and proceeds upstream. A total of four jabs or kicks will be taken over the length of the reach; a single *jab* consists of forcefully thrusting the net into a productive habitat for a linear distance of 0.5 m. A *kick* is a stationary sampling accomplished by positioning the net and disturbing the substrate for a distance of 0.5 m upstream of the net.

5. The jabs or kicks collected from the multiple habitats will be composited into a sieve bucket to obtain a single homogeneous sample. If clogging occurs, discard the material in the net and redo that portion of the sample in the same habitat type but in a different location. Remove large debris after rinsing and inspecting it for organisms; place any organisms found into the sieve bucket.

6. Return to the bank with the sampled material for sorting and organism identifications. Alternatively, the material can be preserved in alcohol and returned to the laboratory for processing (see Step 7 in Section 7.1.1 for instructions).

7. Transfer the sample from the sieve bucket (or sample jar, if in laboratory) to a white enamel or plastic pan. A second, smaller, white pan may be used for the actual sorting. Place small aliquots of the detritus plus organisms in the smaller pan diluted with a minimal amount of site water (or tap water). Scan the detritus and water for organisms. When an organism is found, examine it with a hard lens, determine its identity to the lowest possible level (usually family or genus), and record it on the Preliminary Assessment Score Sheet (PASS) (Appendix A-3, Form 4) in the column labeled "tally." Place representatives of each taxon in a vial, properly labeled and containing alcohol.

QUALITY CONTROL (QC)

1. Sample labels must be properly completed, including the sample identification code date, stream name, sampling location, and collector's name and placed into the sample container. The outside of the container should be labeled with the same information. Chain-of-custody forms, if needed, must include the same information as the sample container labels.

2. After sampling has been completed at a given site, all nets, pans, etc. that have come in contact with the sample will be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found should be placed into the sample containers. The equipment should be examined again prior to use at the next sampling site.

3. A second biologist familiar with the recognition and taxonomy of the organisms should check the sample to ensure all taxa are encountered and documented.

8. If field identifications are conducted, verify in the lab and make appropriate changes for misidentifications.

9. Analysis is done by determining the value of each metric and comparing to a predetermined value for the associated stream class. These value thresholds should be sufficiently conservative so that "good" conditions or non-impairment is verified. Sites with metric values below the threshold(s) are considered "suspect" of impairment and may warrant further investigation. These simple calculations can be done directly on the PASS sheet.

7.6 TAXONOMIC REFERENCES FOR MACROINVERTEBRATES

The following references are provided as a list of taxonomic references currently being used around the United States for identification of benthic macroinvertebrates. Any of these references cited in the text of this document will also be found in Chapter 11 (Literature Cited).

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8 FISH PROTOCOLS

Monitoring of the fish assemblage is an integral component of many water quality management programs, and its importance is reflected in the aquatic life use-support designations of many states. Narrative expressions such as "maintaining coldwater fisheries", "fishable" or "fish propagation" are prevalent in state standards. Assessments of the fish assemblage must measure the overall structure and function of the ichthyofaunal community to adequately evaluate biological integrity and protect surface water resource quality. Fish bioassessment data quality and comparability are assured through the utilization of qualified fisheries professionals and consistent methods.

The Rapid Bioassessment Protocol (RBP) for fish presented in this document, is directly comparable to RBP V in Plafkin et al. (1989). The principal evaluation mechanism utilizes the technical framework of the Index of Biotic Integrity (IBI) — a fish assemblage assessment approach developed by Karr (1981). The IBI incorporates the zoogeographic, ecosystem, community and population aspects of the fish assemblage into a single ecologically-based index. Calculation and interpretation of the IBI involves a sequence of activities including: fish sample collection; data tabulation; and regional modification and calibration of metrics and expectation values. This concept has provided the overall multimetric index framework for rapid bioassessment in this document. A more detailed description of this approach for fish is presented in Karr et al. (1986) and Ohio EPA (1987). Regional modification and applications are described in Leonard and Orth (1986), Moyle et al. (1986), Hughes and Gammon (1987), Wade and Stalcup (1987), Miller et al. (1988), Steedman (1988), Simon (1991), Lyons (1992a), Simon and Lyons (1995), Lyons et al. (1996), and Simon (1999).

The RBP for fish involves careful, standardized field collection, species identification and enumeration, and analyses using aggregated biological attributes or quantification of the numbers (and in some cases biomass, see Section 8.3.3, Metric 13) of key species. The role of experienced fisheries scientists in the adaptation and application of the RBP and the taxonomic identification of fishes cannot be overemphasized. The fish RBP survey yields an objective discrete measure of the condition of the fish assemblage. Although the fish survey can usually be completed in the field by qualified fish biologists, difficult species identifications will require laboratory confirmation. Data provided by the fish RBP can serve to assess use attainment, develop biological criteria, prioritize sites for further evaluation, provide a reproducible impact assessment, and evaluate status and trends of the fish assemblage.

Fish collection procedures must focus on a multihabitat approach — sampling habitats in relative proportion to their local representation (as determined during site reconnaissance). Each sample reach should contain riffle, run and pool habitat, when available. Whenever possible, the reach should be sampled sufficiently upstream of any bridge or road crossing to minimize the hydrological effects on overall habitat quality. Wadeability and accessability may ultimately govern the exact placement of the sample reach. A habitat assessment is performed and physical/chemical parameters measured concurrently with fish sampling to document and characterize available habitat specifics within the sample reach (see Chapter 5: Habitat Assessment and Physicochemical Characterization).

8.1 FISH COLLECTION PROCEDURES: ELECTROFISHING

All fish sampling gear types are generally considered selective to some degree; however, electrofishing has proven to be the most comprehensive and effective *single* method for collecting stream fishes. Pulsed DC (direct current) electrofishing is the method of choice to obtain a representative sample of the fish assemblage at each sampling station. However, electrofishing in any form has been banned from certain salmonid spawning streams in the northwest. As with any fish sampling method, the proper scientific collection permit(s) must be obtained before commencement of any electrofishing activities. The accurate identification of each fish collected is essential, and species-level identification is required (including hybrids in some cases, see Section 8.3.3, Metric 11). Field identifications are acceptable; however, voucher specimens must be retained for laboratory verification, particularly if there is any doubt about the correct identity of the specimen (see Section 8.2). Because the collection methods used are not consistently effective for young-of-the-year fish and because their inclusion may seasonally skew bioassessment results, fish less than 20 millimeters total length will not be identified or included in standard samples.

ELECTROFISHING CONFIGURATION AND FIELD TEAM ORGANIZATION

All field team members must be trained in electrofishing safety precautions and unit operation procedures identified by the electrofishing unit manufacturer. Each team member must be insulated from the water and the electrodes; therefore, chest waders and rubber gloves are required. Electrode and dip net handles must be constructed of insulating materials (e.g., woods, fiberglass). Electrofishers/electrodes must be equipped with functional safety switches (as installed by virtually all electrofisher manufacturers). Field team members must not reach into the water unless the electrodes have been removed from the water or the electrofisher has been disengaged.

It is recommended that at least 2 fish collection team members be certified in CPR (cardiopulmonary resuscitation). *Many* options exist for electrofisher configuration and field team organization; however, procedures will always involve pulsed DC electrofishing and a minimum 2-person team for sampling streams and wadeable rivers. Examples include:

- Backpack electrofisher with 2 hand-held electrodes mounted on fiberglass poles, one positive (anode) and one negative (cathode). One crew member, identified as the electrofisher unit operator, carries the backpack unit and manipulates both the anode and cathode poles. The anode may be fitted with a net ring (and shallow net) to allow the unit operator to net specimens. The remaining 1 or 2 team members net fish with dip nets and are responsible for specimen transport and care in buckets or livewells.

- Backpack electrofisher with 1 hand-held anode pole and a trailing or floating cathode. The electrofisher unit operator manipulates the anode with one hand, and has a second hand free for use of a dip net. The remaining 1 or 2 team members also aid in the netting of specimens, and in addition are responsible for specimen transport in buckets or livewells.

- Tote barge (pramunit) electrofisher with 2 hand-held anode poles and a trailing/floating cathode (recommended for large streams and wadeable rivers). Two team members are each equipped with an anode pole and a dip net. Each is responsible for electrofishing and the netting of specimens. The remaining team member will follow, pushing or pulling the barge through the sample reach. A livewell is maintained within the barge and/or within the sampling reach but outside the area of electric current.

The safety of all personnel and the quality of the data is assured through the adequate education, training, and experience of all members of the fish collection team. At least 1 biologist with training and experience in electrofishing techniques and fish taxonomy *must* be involved in each sampling event. Laboratory analyses are conducted and/or supervised by a fisheries professional trained in fish taxonomy. Quality assurance and quality control must be a continuous process in fisheries monitoring and assessment, and must include all program aspects (i.e., field sampling, habitat measurement, laboratory processing, and data recording).


Tote barge (pram unit) Electrofishing

FIELD EQUIPMENT/SUPPLIES NEEDED FOR FISH SAMPLING—ELECTROFISHING

- appropriate scientific collection permit(s)
- backpack or tote barge-mounted electrofisher
- dip nets
- block nets (i.e., seines)
- elbow-length insulated waterproof gloves
- chest waders (equipped with wading cleats, when necessary)
- polarized sunglasses
- buckets/livewells
- jars for voucher/reference specimens
- waterproof jar labels
- 10% buffered formalin (formaldehyde solution)
- measuring board (500 mm minimum, with 1 mm increments)[a]
- balance (gram scale)[b]
- tape measure (100 m minimum)
- fish Sampling Field Data Sheet[c]
- applicable topographic maps
- copies of field protocols
- pencils, clipboard
- first aid kit
- Global Positioning System (GPS) Unit

[a] Needed only if program/study requires length frequency information
[b] Needed only if total biomass and/or the Index of Well-Being are included in the assessment process (see Section 8.3.3, Metric 13).
[c] It is helpful to copy fieldsheets onto water-resistant paper for use in wet weather conditions.

8.1.1 Field Sampling Procedures

1. A representative stream reach (see Alternatives for Stream Reach Designation, next page) is selected and measured such that primary physical habitat characteristics of the stream are included within the reach (e.g., riffle, run and pool habitats, when available). The sample reach should be located away from the influences of major tributaries and

bridge/road crossings (e.g., sufficiently upstream to decrease influences on overall habitat quality). The exact location (i.e., latitude and longitude) of the downstream limit of the reach must be recorded on each field data sheet. (If a Global Positioning System unit is used to provide location information, the accuracy or design confidence of the unit should be noted.) A habitat assessment and physical/ chemical characterization of water quality should be performed within the same sampling reach (see Chapter 5: Habitat Assessment and Physicochemical Characterization).

2. Collection via electrofishing begins at a shallow riffle, or other physical barrier at the downstream limit of the sample reach, and terminates at a similar barrier at the upstream end of the reach. In the absence of physical barriers, block nets should be set at the upstream and downstream ends of the reach prior to the initiation of any sampling activities.

ALTERNATIVES FOR STREAM REACH DESIGNATION

The collection of a representative sample of the fish assemblage is essential, and the appropriate sampling station length for obtaining that sample is best determined by conducting pilot studies (Lyons 1992b, Simonson et al. 1994, Simonson and Lyons 1995). Alternatives for the designation of stream sampling reaches include:

- **Fixed-distance designation**—A standard length of stream, e.g., a 150-200-meter reach (Ohio EPA 1987), 100-meter reach (Massachusetts DEP 1995) may be used to obtain a representative sample. Conceptually, this approach should provide a mixture of habitats in the reach and provide, at a minimum, duplicate physical and structural elements such as riffle/pool sequences.
- **Proportional-distance designation**— A standard number of stream channel "widths" may be used to measure the stream study reach, e.g., 40 times the stream width is defined by Environmental Monitoring & Assessment Program (EMAP) for sampling (Klemm and Lazorchak 1995). This approach allows variation in the length of the reach based on the size of the stream. Application of the proportional-distance approach in large streams or wadeable rivers may require the establishment of sampling program time and/or distance maxima (e.g., no more than 3 hours of electrofishing or 500-meter reach per sampling site, [Klemm et al. 1993]).

3. Fish collection procedures commence at the downstream barrier. A minimum 2-person fisheries crew proceeds to electrofish in an upstream direction using a side-to-side or bank-to-bank sweeping technique to maximize area coverage. All wadeable habitats within the reach are sampled via a single pass, which terminates at the upstream barrier. Fish are held in livewells (or buckets) for subsequent identification and enumeration.

4. Sampling efficiency is dependent, at least in part, on water clarity and the field team's ability to see and net the stunned fish. Therefore, each team member should wear polarized sunglasses, and sampling is conducted only during periods of optimal water clarity and flow.

5. All fish (greater than 20 millimeters total length) collected within the sample reach must be identified to species (or subspecies). Specimens that cannot be identified with certainty in the field are preserved in a 10% formalin solution and stored in labeled jars for subsequent laboratory identification (see Section 8.2). A representative voucher collection must be retained for unidentified specimens, very small specimens, new locality records, and/or a particular region. In addition to the unidentified specimen jar, a voucher collection of a

subsample of each species identified in the field should be preserved and labeled for subsequent laboratory verification, if necessary. Obviously, species of special concern (e.g., threatened, endangered) should be noted and released *immediately* on site. Labels should contain (at a minimum) location data (verbal description and coordinates), date, collectors' names, and sample identification code and/or station numbers for the particular sampling site. Young-of-the-year fish less than 20 millimeters (total length) are not identified or included in the sample, and are released on site. Specimens that can be identified in the field are counted, examined for external anomalies (i.e., deformities, eroded fins, lesions, and tumors), and recorded on field data sheets. An example of a "Fish Sampling Field Data Sheet" is provided in Appendix A-4, Form 1. Space is available for optional fish length and weight measurements, should a particular program/study require length frequency or biomass data. However, these data *are not required* for the standard multimetric assessment. Space is allotted on the field data sheets for the *optional* inclusion of measurements (nearest millimeter total length) and weights (nearest gram) for a subsample (to a maximum 25 specimens) of each species. Although fish length and weight measurements are optional, recording a range of lengths for species encountered may be a useful routine measure. Following the data recording phase of the procedure, specimens that have been identified and processed in the field are released on site to minimize mortality.

6. The data collection phase includes the completion of the top portion of the "Fish Sampling Field Data Sheet" (Appendix A-4, Form 1),

QUALITY CONTROL (QC) IN THE FIELD

1. Quality control must be a continuous process in fish bioassessment and should include all program aspects, from field collection and preservation to habitat assessment, sample processing, and data recording. Field validation should be conduced at selected sites and will involve the collection of a duplicate sample taken from an adjacent reach upstream of the initial sampling site. The adjacent reach should be similar to the initial site with respect to habitat and stressors. Sampling QC data should be evaluated following the first year of sampling in order to determine a level of acceptable variability and the appropriate duplication frequency.

2. Field identifications of fish *must* be conducted by qualified/trained fish taxonomists, familiar with local and regional ichthyofauna. Questionable records are prevented by: (a) requiring the presence of at least one experienced/trained fish taxonomist on every field effort, and (b) preserving selected specimens (e.g., Klemm and Lazorchak 1995 recommend a subsample of a maximum 25 voucher specimens of each species) and those that cannot by readily identified in the field for laboratory verification and/or examination by a second qualified fish taxonomist (see Section 8.2). Specimens must be properly preserved and labeled (refer to Section 8.1.1, number 5). When needed, chain-of-custody forms must be initiated following sample preservation, and must include the same information as the sample container labels.

3. All field equipment must be in good operating condition, and a plan for routine inspection, maintenance, and/or calibration must be developed to ensure consistency and quality of field data. Field data must be complete and legible, and should be entered on standardized field data forms and/or digital recorders. While in the field, the field team should possess sufficient copies of standardized field data forms and chains-of-custody for all anticipated sampling sites, as well as copies of all applicable Standard Operating Procedures (SOPs).

which duplicates selected information from the physical/chemical field sheet. Information regarding the sample collection procedures must also be recorded. This includes method of fish capture, start time, ending time, duration of sampling, maximum and mean stream widths. The percentage of each habitat type in the reach is estimated and documented on the data sheet. Comments should include sampling conditions, e.g., visibility, flow, difficult access to stream, or anything that may prove to be valuable information to consider for future sampling events or by personnel unfamiliar with the site.

8.2 LABORATORY IDENTIFICATION AND VERIFICATION

Fish records of questionable quality are prevented by preserving specimens (that cannot be readily identified in the field) for laboratory examination and/or a voucher collection for laboratory verification. Specimens must be properly preserved (e.g., 10% formalin for tissue fixing and 70% ethanol for long-term storage) and labeled (using museum-grade archival labels/paper, and formalin/alcohol-proof pen or pencil). Labels should contain (at a minimum) site location data (i.e., verbal description and site coordinates), collection date, collector's names, species identification (for fishes identified in the field), species totals, and sample identification code and/or station number. All samples received in the laboratory should be tracked using a sample log-in procedure (Appendix A-4, Form 2). Laboratory fisheries professionals *must* be capable of identifying fish to the lowest possible taxonomic level (i.e., species or subspecies) and should have access to suitable regional taxonomic references (see Section 8.4) to aid in the identification process. Laboratories that do not typically identify fish, or trained fisheries professionals that have difficulty identifying a particular specimen or group of fish, should contact a taxonomic specialist (i.e., a recognized authority for that particular taxonomic group). Taxonomic nomenclature *must* be kept consistent and current. Common and scientific names of fishes from the United States and Canada are listed in Robins et al. (1991).

QUALITY CONTROL (QC) FOR TAXONOMY

1. A representative voucher collection must be retained for unidentified specimens, small specimens, and new locality records. In addition, a second voucher jar should be retained for a subsample of each species identified in the field (e.g., Klemm and Lazorchak 1995 recommend a subsample of 25 voucher specimens of each species). The vouchers must be properly preserved, labeled, and stored in the laboratory for future reference (see Section 8.2).

2. Voucher collections should be verified by a second qualified fish taxonomist, i.e., a professional other than the taxonomist responsible for the original field identifications. The word "validated" and the name of the taxonomist that validated the identification should be added to each voucher label. Specimens sent from the laboratory to taxonomic specialists should be recorded in a "Taxonomy Validation Notebook" (see Chapter 7), noting the label information and date sent. Upon return of the specimens, the date received and findings should also be recorded in the notebook (and the voucher label), along with the name of the person who performed the validation.

3. Information on samples completed (through the identification/validation process) will be tracked in a "Sample Log" notebook, to track the progress of each sample (Appendix A-4, Form 2). Sample log entries will be updated as each step is completed (e.g., receipt, identification, validation, archive).

4. A library of taxonomic literature is essential for the aid and support of identification/verification activities, and must be maintained (and updated as needed) in the laboratory. A list of selected taxonomic references is provided in Section 8.4.

8.3 DESCRIPTION OF FISH METRICS

Through the IBI, Karr et al. (1986) provided a consistent theoretical framework for analyzing fish assemblage data. The IBI is an aggregation of 12 biological metrics that are based on the fish assemblage's taxonomic and trophic composition and the abundance and condition of fish. Such multiple-parameter indices are necessary for making objective evaluations of complex systems. The IBI was designed to evaluate the quality of small Midwestern warmwater streams but has been modified for use in many regions (e.g., eastern and western United States, Canada, France) and in different ecosystems (e.g., rivers, impoundments, lakes, and estuaries).

The metrics attempt to quantify a biologist's best professional judgment (BPJ) of the quality of the fish assemblage. The IBI utilizes professional judgment, but in a prescribed manner, and it includes quantitative standards for discriminating the condition of the fish assemblage (Figure 8-1). BPJ is involved in choosing both the most appropriate population or assemblage element that is representative of each metric and in setting the scoring criteria. This process can be easily and clearly modified, as opposed to judgments that occur after results are calculated. Each metric is scored against criteria based on expectations developed from appropriate regional reference sites. Metric values

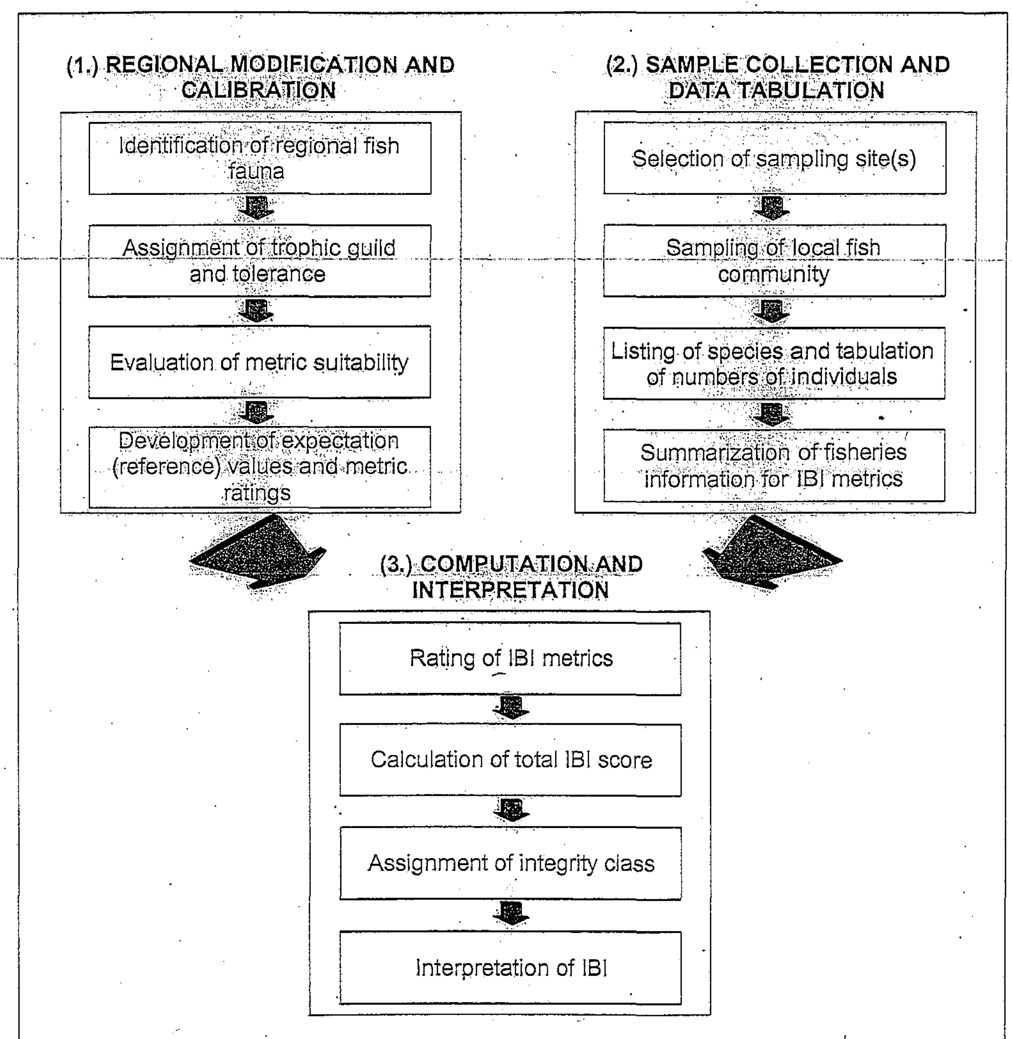

Figure 8-1. Sequence of activities involved in calculating and interpreting the Index of Biotic Integrity (adapted from Karr et al. 1986).

approximating, deviating slightly from, or deviating greatly from values occurring at the reference sites are scored as 5, 3, or 1, respectively. The scores of the 12 metrics are added for each station to give an IBI ranging from a maximum of 60 (excellent) to a minimum of 12 (very poor). Trophic and tolerance classifications of selected fish species are listed in Appendix C. Additional classifications can be derived from information in State and regional fish texts, by objectively assessing a large statewide database, or by contacting authors/originators of regional IBI programs or pilot studies. Use of the IBI by water resource agencies may result in further modifications. Many modifications have occurred (Miller et al. 1988) without changing the IBI's basic theoretical foundations.

The IBI serves as an integrated analysis because individual metrics may differ in their relative sensitivity to various levels of biological condition. A description and brief rationale for each of the 12 IBI metrics is outlined below. The original metrics described by Karr (1981) for Illinois streams are followed by substitutes used in or proposed for different geographic regions and stream sizes. Because of zoogeographic differences, different families or species are evaluated in different regions, with regional substitutes occupying the same general habitat or niche. The source for each substitute is footnoted below. Table 8-1 presents an overview of the IBI metric alternatives and their sources for various areas of the United States and Canada.

EXAMPLES OF SOURCES FOR METRIC ALTERNATIVES

Karr et al. (1986)
Leonard and Orth (1986)
Moyle et al. (1986)
Fausch and Schrader (1987)
Hughes and Gammon (1987)
Ohio EPA (1987)
Miller et al. (1988)
Steedman (1988)
Simon (1991)
Lyons (1992a)
Barbour et al. (1995)
Simon and Lyons (1995)
Hall et al. (1996)
Lyons et al. (1996)
Roth et al. (1997)
Simon (1999)

8.3.1 Species Richness and Composition Metrics

These metrics assess the species richness component of diversity and the health of resident taxonomic groupings and habitat guilds of fishes. Two of the metrics assess assemblage composition in terms of tolerant or intolerant species.

Metric 1. Total number of fish species Substitutes (Table 8-1): Total number of resident native fish species and salmonid age classes.

This number decreases with increased degradation; hybrids and introduced species are not included. In coldwater streams supporting few fish species, the age classes of the species found represent the suitability of the system for spawning and rearing. The number of species is strongly affected by stream size at most small warmwater stream sites, but not at large river sites (Karr et al. 1986, Ohio EPA 1987).

Metric 2. Number and identity of darter species Substitutes (Table 8-1): Number and identity of sculpin species, benthic insectivore species, salmonid juveniles (individuals); number of sculpins (individuals); percent round-bodied suckers, sculpin and darter species.

These species are sensitive to degradation resulting from siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats (Kuehne and Barbour 1983, Ohio EPA 1987). Many smaller species live within the rubble interstices, are weak swimmers, and spend their entire lives in an area of 100-400 m^2 (Matthews 1986, Hill and Grossman 1987). Darters are appropriate in most

Mississippi Basin streams; sculpins and yearling trout occupy the same niche in western streams. Benthic insectivores and sculpins or darters are used in small Atlantic slope streams that have few sculpins or darters, and round-bodied suckers are suitable in large midwestern rivers.

Metric 3. Number and identity of sunfish species. Substitutes (Table 8-1): Number and identity of cyprinid species, water column species, salmonid species, headwater species, and sunfish and trout species.

Table 8-1. Fish IBI metrics used in various regions of North America[a]

Alternative IBI Metrics	Midwestern United States	Central Appalachians	Sacramento-San Joaquin	Colorado Front Range	Western Oregon	Ohio	Ohio Headwater Sites	Northeastern United States	Ontario	Central Corn Belt Plain	Wisconsin-Warmwater	Wisconsin-Coldwater	Maryland Coastal Plain	Maryland Non-Tidal
1. Total Number of Species	X	X	X	X				X		X			X	X
#native fish species					X	X	X		X		X			
# salmonid age classes[b]				X	X									
2. Number of Darter Species	X	X		X		X				X	X			
# sculpin species					X									
# benthic insectivore species								X						
# darter and sculpin species							X							
# darter, sculpin, and madtom species											X			
# salmonid juveniles (individuals)[b]			X		X			X						
% round-bodied suckers						X[c]								
# sculpins (individuals)			X											
# benthic species													X	X
3. Number of Sunfish Species	X			X		X				X	X			
# cyprinid species					X									
# water column species								X						
# sunfish and trout species									X					
# salmonid species			X							X				
# headwater species							X							
% headwater species							X			X				
4. Number of Sucker Species	X				X	X		X		X	X			
# adult trout species[b]			X		X									
# minnow species				X			X			X				
# sucker and catfish species									X					
5. Number of Intolerant Species	X			X	X	X		X			X	X	X	X
# sensitive species							X			X				
# amphibian species			X											
presence of brook trout									X					
% stenothermal cool and cold water species												X		
% of salmonid ind. as brook trout												X		
6. % Green Sunfish	X													
% common carp					X									
% white sucker				X				X						
% tolerant species						X	X			X	X	X	X	X
% creek chub		X												
% dace species									X					
% eastern mudminnow													X	

Table 8-1. Fish IBI metrics used in various regions of North America.[a]

Alternative IBI Metrics	Midwestern United States	Central Appalachians	Sacramento-San Joaquin	Colorado Front Range	Western Oregon	Ohio	Ohio Headwater Sites	Northeastern United States	Ontario	Central Corn Belt Plain	Wisconsin-Warmwater	Wisconsin-Coldwater	Maryland Coastal Plain	Maryland Non-Tidal
7. % Omnivores	X			X		X	X	X	X	X	X			
% generalist feeders		X												
% generalists, omnivores, and invertivores														X
8. % Insectivorous Cyprinids	X												X	
% insectivores					X			X		X	X		X	X[e]
% specialized insectivores		X		X										
# juvenile trout			X											
% insectivorous species						X	X							
9. % Top Carnivores	X					X		X	X	X	X	X		
% catchable salmonids					X									
% catchable trout			X											
% pioneering species							X			X			X	
Density catchable wild trout			X											
10. Number of Individuals (or catch per effort)	X	X	X	X	X	X[d]	X[d]		X	X	X[d]		X	
Density of individuals								X						X
% abundance of dominant species													X	X
Biomass (per m²)														X[f]
11. % Hybrids	X							X						
% introduced species				X	X									
% simple lithophills						X				X	X			X
# simple lithophills species							X							
% native species			X											
% native wild individuals			X											
% silt-intolerant spawners													X	
12. % Diseased Individuals (deformities, eroded fins, lesions, and tumors)	X	X		X	X	X	X	X	X	X	X		X	X

Note: X = metric used in region. Many of these variations are applicable elsewhere.

a Taken from Karr et al. (1986), Leonard and Orth (1986), Moyle et al. (1986), Fausch and Schrader (1987), Hughes and Gammon (1987), Ohio EPA (1987), Miller et al. (1988), Steedman (1988), Simon (1991), Lyons (1992a), Barbour et al. (1995), Simon and Lyons (1995), Hall et al. (1996), Lyons et al. (1996), Roth et al. (1997).

b Metric suggested by Moyle et al. (1986) or Hughes and Gammon (1987) as a provisional replacement metric in small western salmonid streams.

c Boat sampling methods only (i.e., larger streams/rivers).

d Excluding individuals of tolerant species.

e Non-coastal Plain streams only.

f Coastal Plain streams only.

These pool species decrease with increased degradation of pools and instream cover (Gammon et al. 1981, Angermeier 1987, Platts et al. 1983). Most of these fishes feed on drifting and surface invertebrates and are active swimmers. The sunfishes and salmonids are important sport species. The sunfish metric works for most Mississippi Basin streams, but where sunfish are absent or rare, other groups are used. Cyprinid species are used in coolwater western streams; water column species occupy the same niche in northeastern streams; salmonids are suitable in coldwater streams; headwater species serve for midwestern headwater streams; and trout and sunfish species are used in southern Ontario streams. Karr et al. (1986) and Ohio EPA (1987) found the number of sunfish species to be dependent on stream size in small streams, but Ohio EPA (1987) found no relationship between stream size and sunfish species in medium to large streams, nor between stream size and headwater species in small streams.

Metric 4. Number and identity of sucker species. Substitutes (Table 8-1): Number of adult trout species, number of minnow species, and number of suckers and catfish.

These species are sensitive to physical and chemical habitat degradation and commonly comprise most of the fish biomass in streams. All but the minnows are longlived species and provide a multiyear integration of physicochemical conditions. Suckers are common in medium and large streams; minnows dominate small streams in the Mississippi Basin; and trout occupy the same niche in coldwater streams. The richness of these species is a function of stream size in small and medium sized streams, but not in large (e.g., non-wadeable) rivers.

Metric 5. Number and identity of intolerant species. Substitutes (Table 8-1): Number and identity of sensitive species, amphibian species, and presence of brook trout.

This metric distinguishes high and moderate quality sites using species that are intolerant of various chemical and physical perturbations. Intolerant species are typically the first species to disappear following a disturbance. Species classified as intolerant or sensitive should only represent the 5-10 percent most susceptible species, otherwise this becomes a less discriminating metric. Candidate species are determined by examining regional ichthyological books for species that were once widespread but have become restricted to only the highest quality streams. Ohio EPA (1987) uses number of sensitive species (which includes highly intolerant and moderately intolerant species) for headwater sites because highly intolerant species are generally not expected in such habitats. Moyle (1976) suggested using amphibians in northern California streams because of their sensitivity to silvicultural impacts. This also may be a promising metric in Appalachian streams which may naturally support few fish species. Steedman (1988) found that the presence of brook trout had the greatest correlation with IBI score in Ontario streams. The number of sensitive and intolerant species increases with stream size in small and medium sized streams but is unaffected by size of large (e.g., non-wadeable) rivers.

Metric 6. Proportion of individuals as green sunfish. Substitutes (Table 8-1): Proportion of individuals as common carp, white sucker, tolerant species, creek chub, and dace.

This metric is the reverse of Metric 5. It distinguishes low from moderate quality waters. These species show increased distribution or abundance despite the historical degradation of surface waters, and they shift from incidental to dominant in disturbed sites. Green sunfish are appropriate in small midwestern streams; creek chubs were suggested for central Appalachian streams; common carp were suitable for a coolwater Oregon river; white suckers were selected in the northeast and Colorado where green sunfish are rare to absent; and dace (*Rhinichthys* species) were used in southern Ontario. To avoid weighting the metric on a single species, Karr et al. (1986) and Ohio EPA (1987) suggest using a small number of highly tolerant species (e.g., alternative Metric 6— percent abundance of tolerant species).

8.3.2 Trophic Composition Metrics

These three metrics assess the quality of the energy base and trophic dynamics of the fish assemblage. Traditional process studies, such as community production and respiration, are time consuming to conduct and the results are equivocal; distinctly different situations can yield similar results. The trophic composition metrics offer a means to evaluate the shift toward more generalized foraging that typically occurs with increased degradation of the physicochemical habitat.

Metric 7. Proportion of individuals as omnivores. Substitutes (Table 8-1): Proportion of individuals as generalist feeders.

The percent of omnivores in the community increases as the physical and chemical habitat deteriorates. Omnivores are defined as species that consistently feed on substantial proportions of plant and animal material. Ohio EPA (1987) excludes sensitive filter feeding species such as paddlefish and lamprey ammocoetes and opportunistic feeders like channel catfish. In areas where few species fit the true definition of omnivore, the proportion of generalized feeders may be substituted (Leonard and Orth 1986).

Metric 8. Proportion of individuals as insectivorous cyprinids. Substitutes (Table 8-1): Proportion of individuals as insectivores, specialized insectivores, insectivorous species, and number of juvenile trout.

Invertivores, primarily insectivores, are the dominant trophic guild of most North American surface waters. As the invertebrate food source decreases in abundance and diversity due to habitat degradation (e.g., anthropogenic stressors), there is a shift from insectivorous to omnivorous fish species. Generalized insectivores and opportunistic species, such as blacknose dace and creek chub were excluded from this metric by Ohio EPA (1987). This metric evaluates the midrange of biological condition, i.e., low to moderate condition.

Metric 9. Proportion of individuals as top carnivores. Substitutes (Table 8-1): Proportion of individuals as catchable salmonids, catchable wild trout, and pioneering species.

The top carnivore metric discriminates between systems with high and moderate integrity. Top carnivores are species that feed, as adults, predominantly on fish, other vertebrates, or crayfish. Occasional piscivores, such as creek chub and channel catfish, are not included. In trout streams, where true piscivores are uncommon, the percent of large salmonids is substituted for percent piscivores. These species often represent popular sport fish such as bass, pike, walleye, and trout. Pioneering species are used by Ohio EPA (1987) in headwater streams typically lacking piscivores. Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation.

8.3.3 Fish Abundance and Condition Metrics

The last 3 metrics indirectly evaluate population recruitment, mortality, condition, and abundance. Typically, these parameters vary continuously and are time consuming to estimate accurately. Instead of such detailed population attributes or estimates, general population parameters are evaluated. Indirect estimation is less variable and much more rapidly determined.

Metric 10. Number of individuals in sample. Substitutes (Table 8-1): Density of individuals.

This metric evaluates population abundance and varies with region and stream size for small streams. It is expressed as catch per unit effort, either by area, distance, or time sampled. Generally sites with lower integrity support fewer individuals, but in some nutrient poor regions, enrichment increases the number of individuals. Steedman (1988) addressed this situation by scoring catch per minute of sampling greater than 25 as a 3, and less than 4 as a 1. Unusually low numbers generally indicate toxicity, making this metric most useful at the low end of the biological integrity scale. Hughes and Gammon (1987) suggest that in larger streams, where sizes of fish may vary in orders of magnitude, total fish biomass may be an appropriate substitute or additional metric.

THE INDEX OF WELL-BEING (IWB)

The Iwb (Gammon 1976, 1980, Hughes and Gammon 1987) incorporates two abundance and two diversity measures in an approximately equal fashion, thereby representing fish assemblage quality more realistically than a single diversity or abundance measure. The Iwb is calculated using the formula:

$$Iwb = 0.5 \ln N + 0.5 \ln B + \bar{H}_N + \bar{H}_B$$

where

N = number of individuals caught per unit distance sampled
B = biomass of individuals caught per unit distance
$\bar{H}$ = Shannon diversity index, calculated as:

$$\bar{H} = -\Sigma \frac{n_i}{N} \ln\left(\frac{n_i}{N}\right)$$

where

n_i = relative number or weight of the ith species
N = total number or weight of the sample

THE MODIFIED INDEX OF WELL-BEING (MIWB)

The MIwb (Ohio EPA 1987) retains the same formula as the Iwb; however, highly tolerant species, hybrids, and exotic species are eliminated from the abundance (i.e., number and biomass) components of the formula. This modification increases the sensitivity of the index to a wider array of environmental disturbances.

Metric 11. Proportion of individuals as hybrids. Substitutes (Table 8-1): Proportion of individuals as introduced species, simple lithophils, and number of simple lithophilic species.

This metric is an estimate of reproductive isolation or the suitability of the habitat for reproduction. Generally as environmental degradation increases the percent of hybrids and introduced species also increases, but the proportion of simple lithophils decreases. However, minnow hybrids are found in some high quality streams, hybrids are often absent from highly impacted sites, and hybridization is rare and difficult to detect. Thus, Ohio EPA (1987) substitutes simple lithophils for hybrids. Simple lithophils spawn where their eggs can develop in the interstices of sand, gravel, and cobble substrates without parental care. Hughes and Gammon (1987) and Miller et al. (1988) propose using percent introduced individuals. This metric is a direct measure of the loss of species segregation between midwestern and western fishes that existed before the introduction of midwestern species to western rivers.

Metric 12. Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

This metric depicts the health and condition of individual fish. These conditions occur infrequently or are absent from minimally impacted reference sites but occur frequently below point sources and in areas where toxic chemicals are concentrated. They are excellent measures of the subacute effects of chemical pollution and the aesthetic value of game and nongame fish.

Metric 13. Total fish biomass (optional).

Hughes and Gammon (1987) suggest that in larger (e.g., non-wadeable) rivers where sizes of fish may vary in orders of magnitude this additional metric may be appropriate. Gammon (1976, 1980) and Ohio EPA (1987) developed an Index of Well-Being (Iwb) and Modified Index of Well-Being (MIwb), respectively, based upon both fish abundance and biomass measures. The combination of diversity and biomass measures is a useful tool for assessing fish assemblages in larger rivers (Yoder and Rankin 1995b). Ohio EPA (1987) found that the additional collection of biomass data (i.e., in addition to abundance information needed for the IBI) required to calculate the MIwb does not represent a significant expenditure of time, providing that subsampling techniques are applied (see Field Sampling Procedures 8.1.1).

Because the IBI is an adaptable index, the choice of metrics and scoring criteria is best developed on a regional basis through use of available publications (Karr et al. 1986, Ohio EPA 1987, Miller et al. 1988, Steedman 1988; Simon 1991, Lyons 1992a, Simon and Lyons 1995, Hall et al. 1996, Lyons et al. 1996, Roth et al. 1997, Simon 1999). Several steps are common to all regions. The fish species must be listed and assigned to trophic and tolerance guilds. Scoring criteria are developed through use of high quality historical data and data from minimally-impaired regional reference sites. This has been done for much of the country, but continued refinements are expected as more ecological data become available for the fish community.

8.4 TAXONOMIC REFERENCES FOR FISH

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9 BIOLOGICAL DATA ANALYSIS

States are faced with the challenge of not only developing tools that are both appropriate and cost-effective (Barbour 1997), but also the ability to translate scientific data for making sound management decisions regarding the water resource. The approach to analysis of biological (and other ecological) data should be straightforward to facilitate a translation for management application. This is not meant to reduce the rigor of data analysis but to ensure its place in making crucial decisions regarding the protection, mitigation, and management of the nation's aquatic resources. In fact, biological monitoring should combine biological insight with statistical power (Karr 1987). Karr and Chu (1999) state that a knowledge of regional biology and natural history (not a search for statistical relationships and significance) should drive both sampling design and analytical protocol.

A framework for bioassessment can be either an *a priori* or *a posteriori* approach to classifying sites and establishing reference condition. To provide a broad comparison of the 2 approaches, it is assumed that candidate reference sites are available from a wide distribution of streams. In the first stage, data collection is conducted at a range of reference sites (and non-reference or test sites) regardless of the approach. The differentiation of site classes into more homogeneous groups or classes may be based initially on *a priori* physicochemical or biogeographical attributes, or solely on *a posteriori* analysis of biology (Stage 2 as illustrated in Figure 9-1). Analysts who use multimetric indices tend to use *a priori* classification; and analysts who use one of the multivariate approaches tend to use *a posteriori*, multivariate classification. However, there is no reason *a priori* classification could not be used with multivariate assessments, and vice-versa.

Two data analysis strategies have been debated in scientific circles (Norris 1995, Gerritsen 1995) over the past few years — the multimetric approach as implemented by most water resource agencies in the United States (Davis et al. 1996), and a multivariate approach advocated by several water resource agencies in Europe and Australia (Wright et al. 1993, Norris and Georges 1993). The contrast and similarity of these 2 approaches are illustrated by Figure 9-1 in a 5-stage generic process of bioassessment development. While there are many forms of multivariate analyses, the 2 most common multivariate approaches are the Benthic Assessment of Sediment (BEAST) used in parts of Canada, the River Invertebrate Prediction and Classification System (RIVPACS) used in parts of England and its derivation, the Australian River Assessment System (AusRivAS) used in Australia.

The development of the reference condition from the range of reference sites (Figure 9-1, Stage 4), is formulated by a suite of biological metrics in the multimetric approach whereas the species composition data are the basis for models used in the multivariate approach. However, both multivariate techniques differ in their probability models. Once the reference condition is established, which serves as a benchmark for assessment, the final stage becomes the basis for the assessment and monitoring program. In this fifth and final stage (Figure 9-1), the multimetric approach uses established percentiles of the population distribution of the reference sites for the metrics to discriminate between impaired and minimally impaired conditions. Where a dose/response relationship can be established from sites having a gradient of conditions (reference sites unknown), an upper percentile of the metric is used to partition metric values into condition ranges. The BEAST multivariate technique uses a probability model based on taxa ordination space

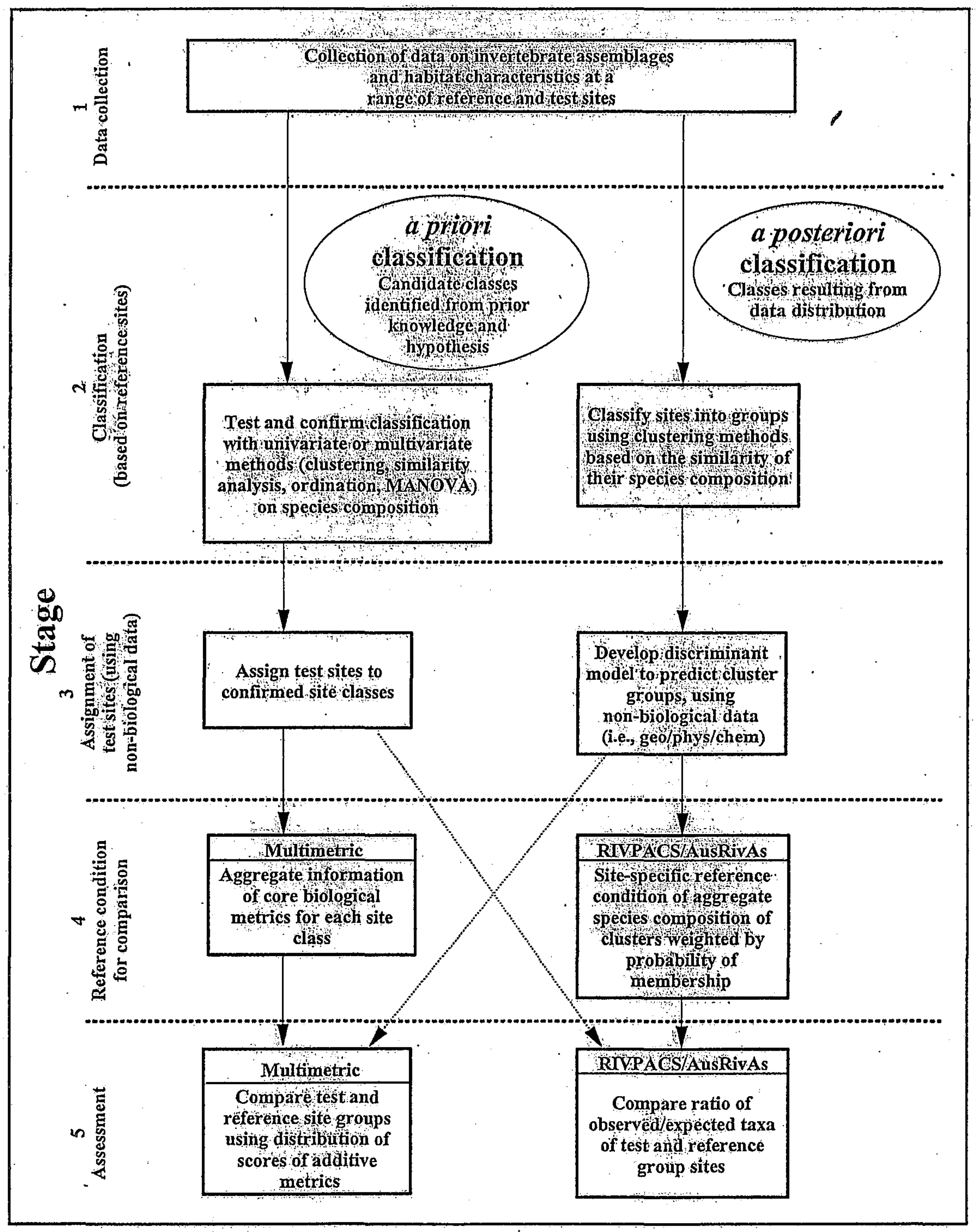

Figure 9-1. Comparison of the developmental process for the multimetric and multivariate approaches to biological data analysis (patterned after ideas based on Reynoldson, Rosenberg, and Resh, unpublished data).

and the "best fit" of the test site(s) to the probability ellipses constructed around the reference site classes (Reynoldson et al. 1995). The AusRivAS/RIVPACS model calculates the probability of expected taxa occurrence from the weighted reference site groups.

The bioassessment program in Maine is an example of a state that uses a multivariate analysis in the form of discriminant function models and applies these models to a variety of metrics. Decisions are made with regard to attainment (or non-attainment) of designated aquatic life uses. The approach used by Maine is based on characteristics of both the multivariate and multimetric approach. In this chapter, only the multimetric approach to biological data analysis is discussed in detail. Discussion of multivariate approaches is restricted to the overview of the discriminant function model used by Maine and the AusRivAS/RIVPACS technique.

9.1 THE MULTIMETRIC APPROACH

Performing data analysis for the Rapid Bioassessment Protocols (RBPs) or any other multimetric approach typically involves 2 phases: (1) Selection and calibration of the metrics and subsequent aggregation into an index according to homogenous site classes; and (2) assessment of biological condition at sites and judgment of impairment. The first phase is a developmental process and is only necessary as biological programs are being implemented. This process is essentially the characterizing of reference conditions that will form the basis for assessment. It is well-documented (Davis and Simon 1995, Gibson et al. 1996, Barbour et al. 1996b) and is summarized here. Developing the framework for reference conditions (i.e., background or natural conditions) is a process that is applicable to non-biological (i.e., physical and chemical) monitoring as well (Karr 1993, Barbour et al. 1996a).

The actual assessment of biological condition is ongoing and becomes cost-effective once Phase 1 has been completed, and the thresholds for determining attainment or non-attainment (impairment) have been established. The establishment of reference conditions (through actual sites or other means) is crucial to the determination of metric and index thresholds. These thresholds are essential elements in performing the assessment. It is possible that reference conditions (and resultant thresholds) will need to be established on a seasonal basis to accommodate year-round sampling and assessment. If data are available, a dose/response relationship between specific or cumulative stressors and biological condition will provide information on a gradient response, which can be a powerful means of determining impairment thresholds.

The 2 phases in data analysis for the multimetric approach are discussed separately in the following section. The reader is referred to supporting documentation cited throughout for more in-depth discussion of the concepts of multimetric assessment.

9.1.1 Metric Selection, Calibration, And Aggregation Into an Index

The development of biological indicators as part of a bioassessment program and as a framework for biocriteria is an iterative process where the site classification and metric selections are revisited at various stages of the analysis. However, once this process has been completed and the various technical issues have been addressed, continued monitoring becomes cost-effective. The conceptual process for proceeding from measurements to indicators to assessment of condition is illustrated in Figure 9-2 (Paulsen et al. 1991; Barbour et al., 1995; Gibson et al., 1996).

Index development outlined in this section requires a stream classification framework to partition natural variability and in which metrics are evaluated for scientific validity. The core metrics representing various attributes of the targeted aquatic assemblage can be either aggregated into an index or retained as individual measures.

Step 1. Classify the Stream Resource

> *Classification* is the partitioning of natural variability into groups or classes of stream sites that are relatively homogeneous with regard to physical, chemical, and biological attributes.

Site classification provides a framework for organizing and interpreting natural variability among streams; ecoregions are a principal example of a classification framework (Omernik 1995). However, classification variables can be at a coarser or finer scale than ecoregions or subecoregions, such as elevation and drainage area. Elevation was determined to be an important classification variable in montane regions of the country (Barbour et al. 1992, 1994, Spindler 1996). Spindler (1996) found that benthic data adhered more closely to elevation than to ecoregions. Ohio EPA (1987) found that stream size (or drainage area) was a covariate and not a determinant of stream classes. The number of fish species increased with stream size (Figure 9-3).

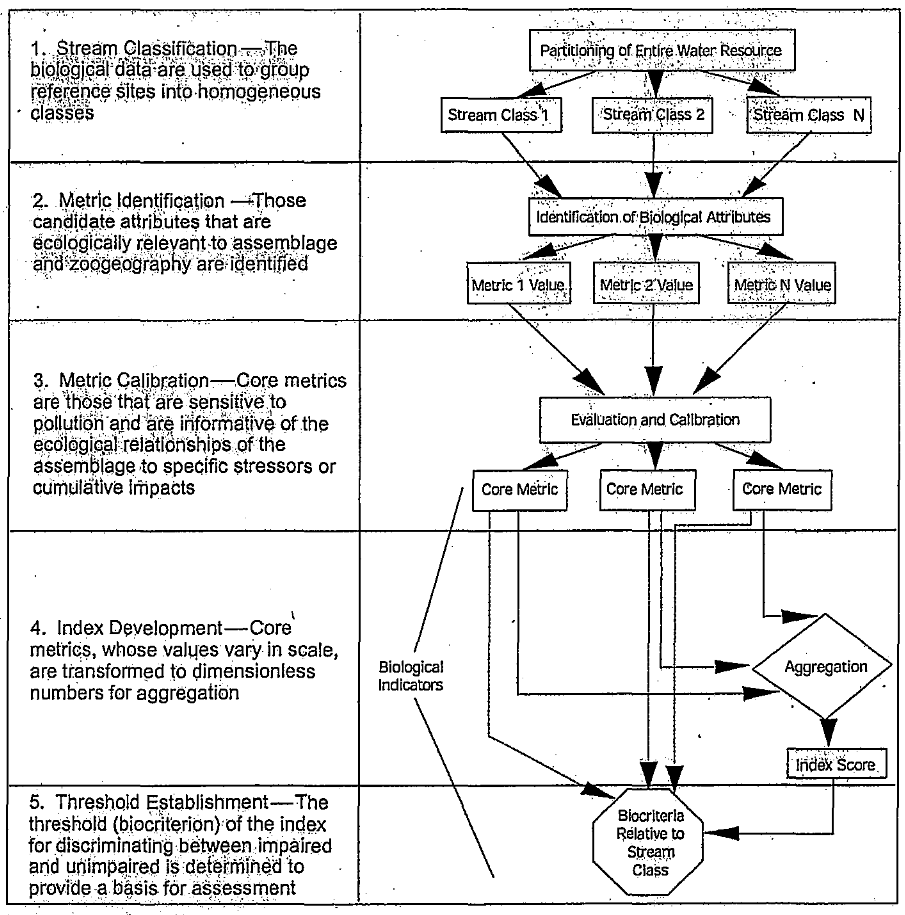

Figure 9-2. Process for developing assessment thresholds (modified from Paulsen et al. [1991] and Barbour et al. [1995]). Dotted lines indicate use of individual metric information to aid in the evaluation of biological condition and cause of impairment.

Classification is best accomplished with reference sites that reflect the most natural and representative condition of the region. Candidate reference sites that are based on minimally degraded physical habitat and water chemistry are used as the basis for stream classification. Quantitative criteria for reference sites aid in a consistent framework for selection. An example of quantitative criteria for identifying reference sites in a statewide study for Maryland (Roth et al., 1997) is presented below (a reference site must meet all 12 criteria):

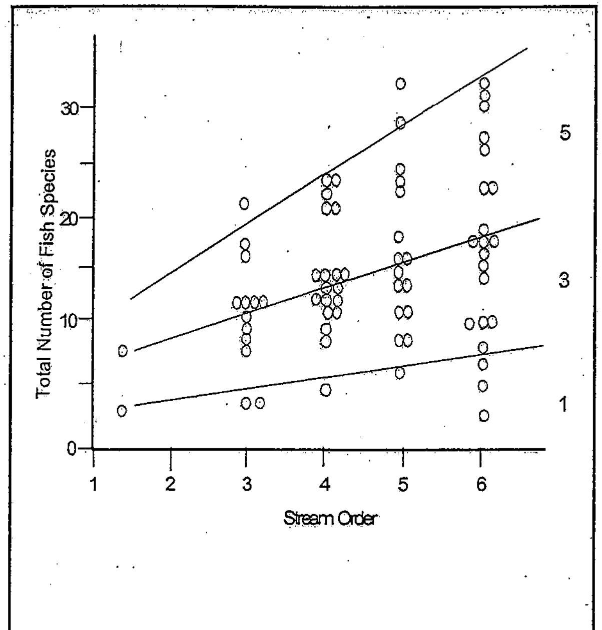

Figure 9-3. Species richness versus stream size (taken from Fausch et al. 1984).

1. pH ≥ 6; if blackwater stream, then pH < 6 and DOC ≥ 8 mg/l
2. ANC ≥ 50 µeq/l
3. DO ≥ 4 ppm
4. nitrate ≤ 300 µeq/l
5. urban land use ≤ 20% of catchment area
6. forest land use ≥ 25% of catchment area
7. remoteness rating: optimal or suboptimal
8. aesthetics rating: optimal or suboptimal
9. instream habitat rating: optimal or suboptimal
10. riparian buffer width ≥ 15 m
11. no channelization
12. no point source discharges

Sites are initially classified according to distinctive geographic, physical, or chemical attributes. Refinement and confirmation of the site classes is accomplished using the biological data (Figure 9-4). Classification is used to determine whether the sampled sites should be placed into specific groups that will minimize variance *within* groups and maximize variance *among* groups. As an example, 3 ecoregionally based delineations (bioregions) were effective at partitioning the variability among reference sites in Florida (Figure 9-5).

Components of Step 1 include:

- Identify classification alternatives. Use physical and chemical parameters that are minimally influenced by human activity to identify classes for testing.

- Identify candidate reference sites that meet the criteria of most "natural" conditions of region.

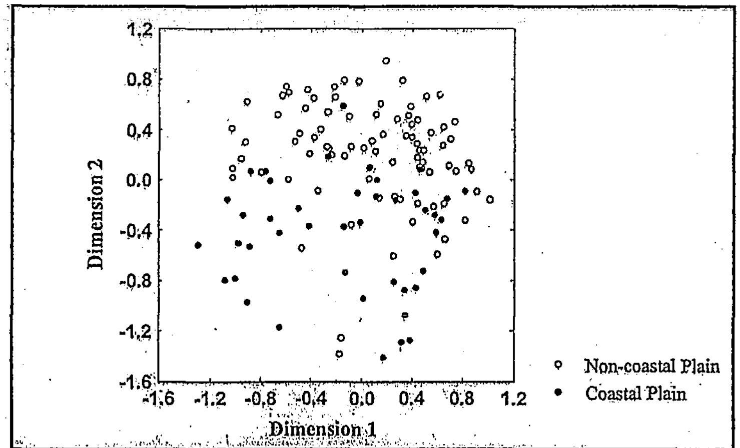

Figure 9-4. Results of multivariate ordination on benthic macroinvertebrate data from "least impaired" streams from Maryland, using nonmetric multidimensional scaling (NMDS) of Bray-Curtis dissimilarity coefficients.

- Test alternative classification schemes of subecoregion, stream type, elevation, etc., using multiple metric and non-metric biological characteristics including measures such as species composition and EPT taxa (Figure 9-5). Several multivariate classification and ordination methods, and univariate descriptions and tests, can assist in this process (Reckhow and Warren-Hicks 1996, Gerritsen 1995, 1996, Barbour et al. 1996b).

- Evaluate classification alternatives and determine best distinction into groups or classes using biological data. By confirming resource classification based on biological data, site classes are identified that adequately partition variability.

Step 2. Identify Potential Measures For Each Assemblage

> A *metric* is a characteristic of the biota that changes in some predictable way with increased human influence.

Metrics allow the investigator to use meaningful indicator attributes in assessing the status of assemblages and communities in response to perturbation. The definition of a metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1995). For a metric to be useful, it must have the following technical attributes: (1) ecologically relevant to the biological assemblage or community under study and to the specified program objectives; (2) sensitive to stressors and provides a response that can be discriminated from natural variation. The purpose of using multiple metrics to assess biological condition is to aggregate and convey the information available regarding the elements and processes of aquatic communities.

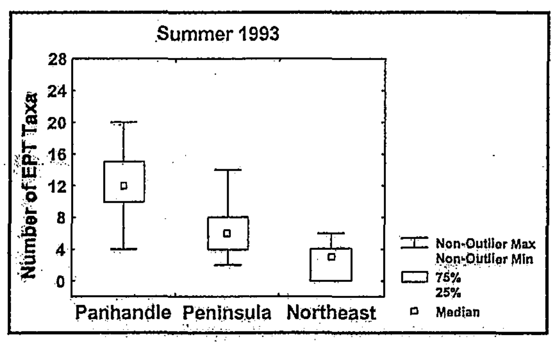

Figure 9-5. An example of a metric that illustrates classification of reference stream sites in Florida into bioregions.

All metrics that have ecological relevance to the assemblage under study and that respond to the targeted stressors are potential metrics for testing.

From this "universe" of metrics, some will be eliminated because of insufficient data or because the range of values is not sufficient for discrimination between natural variability and anthropogenic effects. This step is to identify the candidate metrics that are most informative, and therefore, warrant further analysis.

The potential measures that are relevant to the ecology of streams within the region or state should be selected to ensure that various aspects of the elements and processes of the aquatic assemblage are addressed. Representative metrics should be selected from each of 4 primary categories: (1) richness measures for diversity or variety of the assemblage; (2) composition measures for identity and dominance; (3) tolerance measures that represent sensitivity to perturbation; and (4) trophic or habit measures for information on feeding strategies and guilds. Karr and Chu (1999) suggest that measures of individual health be used to supplement other metrics. Karr has expanded this concept to include metrics that are reflective of landscape level attributes, thus providing a more comprehensive multimetric approach to ecological assessment (Karr et al. 1987). See Table 9-1 for potential metrics that have been useful for periphyton, benthic macroinvertebrates, and fish are summarized in Chapters 6, 7, and 8, respectively.

Components of Step 2 include:

! Review value ranges of potential metrics, and eliminate those that have too many zero values in the population of reference sites to calculate the metric at a large enough proportion of sites.

! Use descriptive statistics (central tendency, range, distribution, outliers) to characterize metric performance within the population of reference sites of each site class.

! Eliminate metrics that have too high variability in the reference site population that they can not discriminate among sites of different condition. The potential for each measure is based on possessing enough information and a specific range of variability to discriminate among site classes and biological condition.

Step 3. Select Robust Measures

Core metrics are those that will discriminate between good and poor quality ecological conditions. It is important to understand the effects of various stressors on the behavior of specific metrics. Metrics that are responsive to specific pollutants or stressors, where the response is well-characterized, are most useful as a diagnostic tool. Core metrics are those that represent diverse aspects of structure, composition, individual health, or processes of the aquatic biota. Together they form the foundation for a sound, integrated analysis of the biotic condition to judge attainment of biological criteria.

> The ability of a biological metric to *discriminate* between "known" reference conditions and "known" stressed conditions (defined by physical and chemical characteristics) is crucial in the selection of *core metrics* for future assessments.

Discriminatory ability of biological metrics can be evaluated by comparing the distribution of each metric at a set of reference sites with the distribution of metrics from a set of "known" stressed sites (defined by physical and chemical characteristics) within each site class. If there is minimal or no overlap between the distributions, then the metric can be considered to be a strong discriminator between reference and impaired conditions (Figure 9-6).

As was done with candidate reference sites (see Step 1), criteria are established to identify a population of "known" stressed sites based on physical and chemical measures of degradation. An example set of criteria established for Maryland streams for which failure indicated a stressed site for testing discriminatory power (Roth et al. 1997) is as follows:

- pH ≤ 5 and ANC ≤ 0 μeq/l (except for blackwater streams, DOC ≥ 8 mg/l)
- DO ≤ 2 ppm
- nitrate > 500 μM/l and DO < 3 ppm
- instream habitat rating poor and urban land use > 50% of catchment area
- instream habitat rating poor and bank stability rating poor
- instream habitat rating poor and channel alteration rating poor

Table 9-1. Some potential metrics for periphyton, benthic macroinvertebrates, and fish that could be considered for streams. Redundancy can be evaluated during the calibration phase to eliminate overlapping metrics.

	Richness Measures	Composition Measures	Tolerance Measures	Trophic/Habit Measures
Periphyton	• Total no. of taxa • No. of common nondiatom taxa • No. of diatom taxa	• % community similarity • % live diatoms • Diatom (Shannon) diversity index	• % tolerant diatoms • % sensitive taxa • % aberrant diatoms • % acidobiontic • % alkalibiontic • % halobiontic	• % motile taxa • Chlorophyll a • % saprobiontic • % eutrophic
Benthic Macroinvertebrate	• No. Total taxa • No. EPT taxa • No. Ephemeroptera taxa • No. Plecoptera taxa • No. Trichoptera taxa	• % EPT • % Ephemeroptera • % Chironomidae	• No. Intolerant Taxa • % Tolerant Organisms • Hilsenhoff Biotic Index (HBI) • % Dominant Taxon	• No. Clinger taxa • % Clingers • % Filterers • % Scrapers
Fish	• Total no. of native fish species • No. and identity of darter species • No. and identity of sunfish species • No. and identity of sucker species	• % pioneering species • Number of fish per unit of sampling effort related to drainage area	• No. and identity of intolerant species • % of individuals as tolerant species • % of individuals as hybrids • % of individuals with disease, tumors, fin damage, and skeletal anomalies	• % omnivores • % insectivores • % top carnivores

Step 3 can be separated into 2 elements that correspond to discrimination of core metrics (element 1) and determination of biological/physicochemical associations (element 2). Components of these elements include:

Element 1 *Select core measures that are best for discriminating degraded condition*

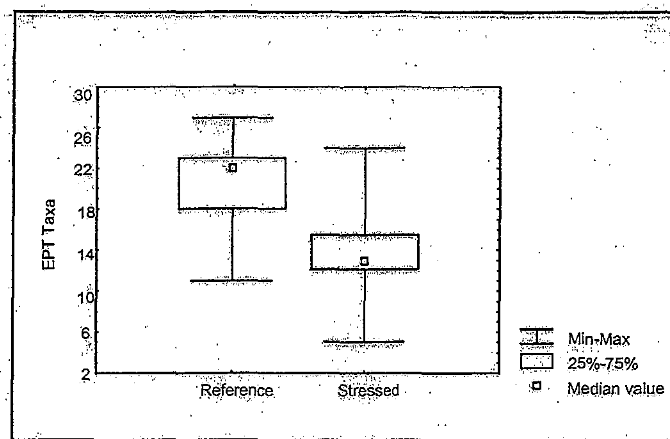

Figure 9-6. Example of discrimination, using the EPT index, between reference and stressed sites in Rocky Mountain streams, Wyoming.

! Good (reference) designations of stream sites should be based on land use, physical and chemical quality, and habitat quality.

! Poor (stressed) designations of stream sites for testing impairment discriminations are also based on judgement criteria involving land use, physical and chemical and quality, and habitat quality.

! Determine which biological metrics best discriminate between the reference sites and sites with identified anthropogenic stressors.

! Those metrics having the strongest discriminatory power will provide the most confidence in assessing biological condition of unknown sites.

Element 2 *Determine the associations/linkages between candidate biological and physicochemical measures*

! Plot relationship of metric values against various stressor categories, e.g., chemical concentrations, habitat condition and other measured stressors.

! If desired, multivariate ordination models may be used to elucidate gradients of response of metrics to stressors.

! Monotonic relationships between metrics and stressors allow the use of extreme values (highest or lowest) as reference condition.

! Some metrics may not always be monotonic. For example, total biomass and taxa richness values may exceed the reference at intermediate levels of nutrient enrichment.

! Multiple metrics should be selected to provide a strong and predictable relationship with stream condition.

> An *index* provides a means of integrating information from a composite of the various measures of biological attributes.

Step 4. Determine the best aggregation of core measures for indicating status and change in condition

The purpose of an index is to provide a means of integrating information from the various measures of biological attributes (or metrics). Metrics vary in their scale—they are integers, percentages, or dimensionless numbers. Prior to developing an integrated index for assessing biological condition, it is necessary to standardize core metrics via transformation to unitless scores. The standardization assumes that each metric has the same value and importance (i.e., they are weighted the same), and that a 50% change in one metric is of equal value to assessment as a 50% change in another.

Where possible, the scoring criterion for each metric is based on the distribution of values in the population of sites, which include reference streams; for example, the 95th percentile of the data distribution is commonly used (Figure 9-7) to eliminate extreme outliers. From this upper percentile, the range of the metric values can be standardized as a percentage of the 95th percentile value, or other (e.g., trisected or quadrisected), to provide a range of scores. Those values that are closest to the 95th percentile would receive higher scores, and those having a greater deviation from this percentile would have lower scores. For those metrics whose values *increase* in response to perturbation (see Table 7-2 for examples of "reverse" metrics for benthic macroinvertebrates) the 5th percentile is used to remove outliers and to form a basis for scoring.

Alternative methods for scoring metrics, as illustrated in Figure 9-7, are currently in use in various parts of the US for multimetric indexes. A "trisection" of the scoring range has been well-documented (Karr et al. 1986, Ohio EPA 1987, Fore et al. 1996, Barbour et al. 1996b). A "quadrisection" of the range has been found to be useful for benthic assemblages (DeShon 1995, Maxted et al. in press). More recent studies are finding that a standardization of all metrics as percentages of the 95th percentile value yields the most sensitive index, because information of the component metrics is retained (Hughes et al. 1998). Unpublished data from statewide databases for Idaho, Wyoming, Arizona, and West Virginia, are supportive of this third alternative for scoring metrics. Ideally, a composite of all sites representing a gradient of conditions is used. This situation is analogous to a determination of a dose/response relationship and depends on the ability of incorporating both reference and non-reference sites.

Aggregation of metric scores simplifies management and decision making so that a single index value is used to determine whether action is needed. Biological condition of waterbodies is judged based on the summed index value (Karr et al. 1986). If the index value is above a criterion, then the stream is judged as "optimal" or "excellent" in condition. The exact nature of the action needed (e.g., restoration, mitigation, pollution enforcement) is not determined by the index value, but by analyses of the component metrics, in addition to the raw data and integrated with other ecological information. Therefore, the index is not the sole determinant of impairment and diagnostics, but when used in concert with the component information, strengthens the assessment (Barbour et al. 1996a).

Components of Step 4 include:

! Determine scoring criteria for each metric (within each site class) from the appropriate percentile of the data distribution (Figure 9-7). If the metric is associated with a significant covariate such as watershed size, a

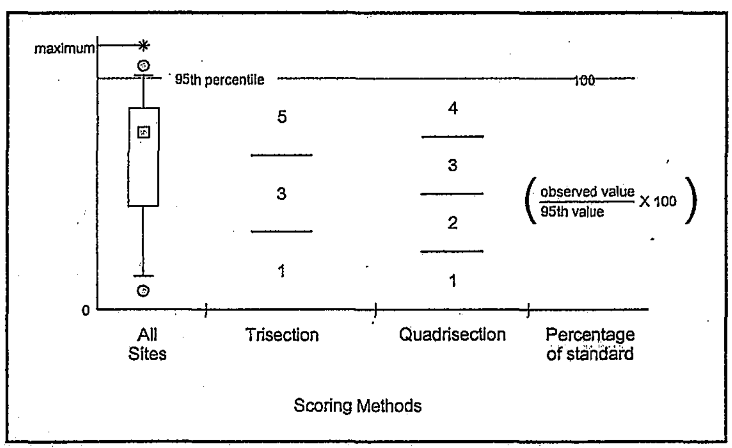

Figure 9-7. Basis of metric scores using the 95th percentile as a standard.

scatterplot of the metric and covariate (Figure 9-3) and a moving estimate of the appropriate percentile, are used to determine scoring criteria as a function of the covariate (e.g., Fausch et al. 1984, Plafkin et al. 1989).

! Test the ability of the final index to discriminate between populations of reference and anthropogenically affected (stressed) sites (Figure 9-8). Generally, indices (aggregate of metrics) discriminate better than individual metrics (e.g., total taxa is generally a weak metric because of inconsistency in taxonomic resolution). Those sites that are misclassified with regard to "reference" and "stressed" can be identified and evaluated for reassignment.

Step 5. Index thresholds for assessment and biocriteria

The multimetric index value for a site is a summation of the scores of the metrics and has a finite range within each stream class and index period depending on the maximum possible scores of the metrics (Barbour et al. 1996c). This range can be subdivided into any number of categories corresponding to various levels of impairment. Because the metrics are normalized to reference conditions and expectations for the stream classes, any decision on subdivision should reflect the distribution of the scores for the reference sites. For example, division of the Wyoming benthic IBI range (aggregation of metric scores) within each stream class provides 5 ordinal rating categories for assessment of impairment (Stribling et al. 1999, Figure 9-8).

> Biocriteria are based on *thresholds* determined to differentiate impaired from non-impaired conditions. While these thresholds may be subjective, the performance of the *a priori* selected reference sites will ultimately verify the appropriateness of the threshold.

The 5 rating categories are used to assess the condition of both reference and non-reference sites. Most of the reference sites should be rated as *good* or *very good* in biological condition, which would be as expected. However, a few reference sites may be given the rating as *poor* sporadically among the collection dates. If a "reference" site consistently receives a fair or poor rating, then the site should be re-evaluated as to its proper assignment. Putative reference sites may be rated "poor" for several reasons:

- **Natural variability** — owing to seasonal, spatial, and random biological events, any reference site may score below the reference population 10th percentile. If due to natural variability, a low score should occur 10% of the time or less.

- **Impairment** — stressors that were not detected in previous sampling or surveys may occur at a

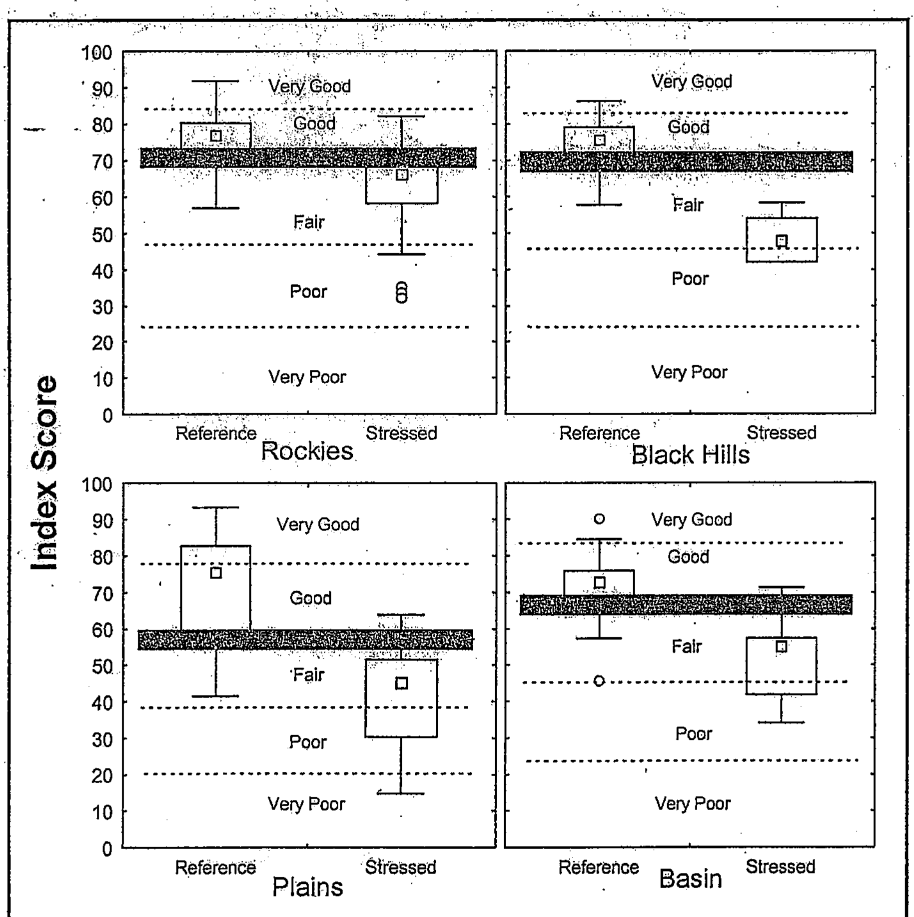

Figure 9-8. Discriminatory power analysis of the Wyoming Benthic Index of Biotic Integrity. The population of stressed sites was determined *a priori*. The 25th percentile of the reference distribution determined the threshold, or separation between "good" and "fair" condition ratings. All other condition ratings resulted from equidistant sectioning of the remaining index range. The shaded region represents the 90% confidence limits around a single observation (no replication) falling near the critical threshold.

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"reference" site; for example, episodic non-point-source pollution or historical contamination may be present at a site.

- **Non-representative site** — reference sites are intended to be representative of their class. If there are no anthropogenic stressors, yet a "reference" site consistently scores outside the range of the rest of the reference population the site may be a special or unique case, or it may have been misclassified and actually belong to another class of streams.

An understanding of variability is necessary to ensure that sites that are near the threshold are rated with known precision (discussed in more detail in Chapter 4). To account for variance associated with measurement error in an assessment, replication is required. The first step is to estimate the standard deviation of repeated measures of streams. The standard deviation is calculated as the root mean square error (RMSE) of an analysis of variance (ANOVA), where the sites are treatments in the ANOVA.

As an example, the question of precision was tested for the Wyoming Benthic IBI scores in the stream classes. This study showed that the 95% confidence interval (CI) around a single sample is ±8 points, on a scale of 100 (Table 9-2). What if a single site was sampled with no replication and found to be points below the biocriterion? The rightmost column (Table 9-2) shows that a triplicate sample is required for a 95% CI less than 5 points. These conclusions make 3 assumptions:

- measurement error is normally distributed,
- measurement error is not affected by subecoregion or impairment, and
- the sample standard deviation of repeated measures is an unbiased and precise estimate of population measurement error.

Components of Step 5 include:

- The range in possible scores for each stream class is the minimum number of metrics (if a score of 1 is assigned to greatest level of degradation) to the maximum aggregate of scores. Pentasect, quadrisect, or trisect this range, depending on how many biological condition categories are desired.
- Evaluate the validity of these biological condition categories by comparing the index scores of the reference and known stressed sites to those categories. If reference sites are not rated as good or very good, then some adjustment in either the biological condition designations or the listing of reference sites may be necessary.
- Test for confidence in multimetric analysis to determine biological condition for sites that fall within close proximity to threshold. Calculate precision and sensitivity values to determine repeatability and detectable differences that will be important in the confidence level of the assessment.

Table 9-2. Statistics of repeated samples in Wyoming and the detectable difference (effect size) at 0.10 significance level. The index is on a 100 point scale (taken from Stribling et al. 1999).

Metric	Standard Deviation for Repeated Measures	Approx. Mean[a]	Approx. Coefficient of Variation (%)	Detectable Differences (p = 0.10)		
				Single Sample	Duplicate Samples	Triplicate Samples
Total Taxa	4.1	35.9	11.5	7 taxa	5 taxa	5 taxa
Ephemeroptera taxa	0.9	6.8	13.3	2 taxa	1 taxa	1 taxa
Plecoptera taxa	1.0	4.8	21.2	2 taxa	1 taxa	1 taxa
Trichoptera taxa	1.1	6.9	15.3	2 taxa	1 taxa	1 taxa
% non-insects	3.8	8.9	42.9	6.3 %	4.4 %	4.3 %
% diptera (non-chironomid)	1.3	5.1	25.0	2.1 %	1.5 %	1.4 %
HBI	0.27	3.43	7.85	0.44 units	0.31 units	0.26 units
% 5 dominant taxa	4.3	64.2	6.7	7.1 %	5.0 %	4.1 %
% scrapers	4.8	25.5	18.9	7.9 %	5.6 %	4.6 %
Index	2.0	70.0	2.9	3.3 units	2.3 units	1.9 units

a: Mean of 25 replicated sites; population means may differ.

9.1.2 Assessment of Biological Condition

Once the framework for bioassessment is in place, conducting bioassessments becomes relatively straightforward. Either a targeted design that focuses on site-specific problems or a probability-based design, which has a component of randomness and is appropriate for 305(b), area-wide, and watershed monitoring, can be done efficiently. Routine monitoring of reference sites should be based on a random selection procedure, which will allow cost efficiencies in sampling while monitoring the status of the reference condition of a state's streams. Potential reference sites of each stream class would be randomly selected for sampling, so that an unbiased estimate of reference condition can be developed. A randomized subset of reference sites can be resampled at some regular interval (e.g., a 4 year cycle) to provide information on trends in reference sites.

A reduced effort in monitoring reference sites allows more investment of time into assessing other stream reaches and problem sites. Through use of Geographical Information System (GIS) and station location codes, assessment sites throughout the state can be randomly selected for sampling as is being done for the reference sites. This procedure will provide a statistically valid means of estimating attainment of aquatic life use for the state's 305(b) reporting. In addition, the multimetric index will be helpful for targeted sampling at specific problem areas and judging biological condition with a procedure that has been calibrated regionally (Barbour et al. 1996c). To evaluate possible influences on the biological condition of sites, relationships among total bioassessment scores and physicochemical variables can be investigated. These relationships may indicate the influence of particular categories of stressors on the biological condition of individual sites. For example, a strong negative correlation between total bioassessment score and embeddedness would suggest that siltation from nonpoint sources could be affecting the biological condition at a site. Considerations relevant to assessment and diagnostics of biological condition are as follows:

! Evaluate the relationship of biological response signatures such as functional attributes (reproduction, feeding group responses, etc.) to specific stressors.

- Hold physical habitat relationships constant and look for associations with other physical stressors (e.g., hydrologic modification, streambed stability), chemical stressors (e.g., point-source discharges or pesticide application to cropland), biological stressors (i.e., exotics), and landscape measures (e.g., impervious surface, Thematic mapper land use classes, human population census information, landscape ecology parameter of dominance, contagion, fractal dimension).

- Explore the relationship between historical change in biota and change in landscape (e.g., use available historical data from the state or region).

9.2 DISCRIMINANT MODEL INDEX

Discriminant analysis may be used to develop a model that will divide, or discriminate, observations among two or more predetermined classes. Output of discriminant analysis is a function that is a linear combination of the input variables, and that obtains the maximum separation (discrimination) among the defined classes. The model may then be used to determine class membership of new observations. Thus, given a set of unaffected reference sites, and a set of degraded sites (due to toxicity, low DO, or habitat degradation), a discriminant function model can identify variables that will discriminate reference from degraded sites.

Developing biocriteria with a discriminant model requires a training data set to develop the discriminant model, and a confirmation data set to test the model. The training and confirmation data may be from the same biosurvey, randomly divided into two, or they may be two consecutive years of survey data, etc. All sites in each data set are identified by degradation class (e.g., reference vs stressed) or by designated aquatic life use class. To avoid circularity, identification of reference and stressed, or of designated use classes, should be made from non-biological information such as quality of the riparian zone and other habitat features; presence of known discharges and nonpoint sources, extent of impervious surface in the watershed, extent of land use practices, etc.

One or more discriminant function models are developed from the training set, to predict class membership from biological data. After development, the model is applied to the confirmation data set to determine its performance: The test determines how well the model can assign sites to classes, using independent data that were not used to develop the model. More information on discriminant analysis is in any textbook on multivariate statistics (e.g., Ludwig and Reynolds 1988, Jongman et al. 1987, Johnson and Wichern 1992).

An example of this approach is the hierarchical decision-making technique used by Maine DEP. It begins with statistical models (linear discriminant analysis) to make an initial prediction of the classification of an unknown sample by comparing it to characteristics of each class identified in the baseline database (Davies et al. 1993). The output from analysis by the primary statistical model is a list of probabilities of membership for each of four groups designated as classes A, B, C, and nonattainment (NA) of Class C (Table 9-3). Subsequent models are designed to distinguish between a given class and any higher classes as one group, and any lower classes as a second group.

One or more discriminant models to predict class membership are developed from the training set. The purpose of the discriminant analysis here is not to test the classification (the classification is administrative rather than scientific), but to assign test sites to one of the classes.

Stream biologists from Maine DEP assigned a training set of streams to four life use classes. In operational assessment, sites are evaluated with the two-step hierarchical models. The first stage linear discriminant model is applied to estimate the probability of membership of sites into one of the four classes (A, B, C, or NA). Second, the series of two-way models are applied to distinguish the membership between a given class and any higher classes, as one group. The model uses 31 quantitative measures of community structure, including the Hilsenhoff Biotic Index, Generic Species Richness, EPT, and EP values. Monitored test sites are then assigned to one of the four classes based on the probability of that result, and uncertainty is expressed for intermediate sites. The classification can be the basis for management action if a site has gone down in class, or for reclassification to a higher class if the site has improved.

Table 9-3. Maine's water quality classification system for rivers and streams, with associated biological standards (taken from Davies et al. 1993).

Aquatic Life Use Class	Management	Biological Standard	Discriminant Class
AA	High quality water for recreation and ecological interests. No discharges or impoundments permitted.	Habitat natural and free flowing. Aquatic life as naturally occurs.	A
A	High quality water with limited human interference. Discharges restricted to noncontact process water or highly treated wastewater equal to or better than the receiving water. Impoundments allowed.	Habitat natural. Aquatic life as naturally occurs.	A and AA are indistinguish-able because biota are "as naturally occurs."
B	Good quality water. Discharge of well treated effluent with ample dilution permitted.	Habitat minimally impaired. Ambient water quality sufficient to support life stages of all indigenous aquatic species. Only nondetrimental changes in community composition allowed.	B
C	Lowest water quality. Maintains the interim goals of the Federal Water Quality Act (fishable/swimmable). Discharge of well-treated effluent permitted.	Ambient water quality sufficient to support life stages of all indigenous fish species. Change in community composition may occur but structure and function of the community must be maintained.	C
NA			Not attaining Class C

Maine biocriteria thus establish a direct relationship between management objectives (the three aquatic life use classes and nonattainment) and biological measurements. The relationship is immediately viable for management and enforcement as long as the aquatic life use classes remain the same. If the classes are redefined, a complete reassignment of streams and a review of the calibration procedure would be necessary. This approach is detailed by Davies et al. (1993).

See Maine DEP's website for more information
http://www.state.me.us/dep/blwq/biohompg.htm

9.3 RIVER INVERTEBRATE PREDICTION AND CLASSIFICATION SCHEME (RIVPACS)

RIVPACS and its derivative, AusRivAS (Australian Rivers Assessment System) are empirical (statistical) models that predict the aquatic macroinvertebrate fauna that would be expected to occur at a site in the absence of environmental stress (Simpson et al. 1996). The AusRivAS models predict the invertebrate communities that would be expected to occur at test sites in the absence of impact. A comparison of the invertebrates predicted to occur at the test sites with those actually collected provides a measure of biological impairment at the tested sites. The predicted taxa list also provides a "target" invertebrate community to measure the success of any remediation measures taken to rectify identified impacts. The type of taxa predicted by the AusRivAS models may also provide clues as to the type of impact a test site is experiencing. This information can be used to facilitate further investigations e.g., the absence of predicted Leptophlebiidae may indicate an impact on a stream from trace metal input.

These models are the primary ecological assessment analysis techniques for Great Britain (Wright et al. 1993) and Australia (Norris 1995). The models are based on a stepwise progression of multivariate and univariate analyses and have been developed for several regions and various habitat types found in lotic systems. Regional applications of the AusRivAS model, in particular, have been developed for the Australian states and territories (Simpson et al. 1996), and for streams in the Sierra and Cascade mountain ranges in California (Hawkins and Norris 1997). Users of these models claim rapid turn around of results is possible and output can be tailored for a range of users including community groups, managers, and ecologists. These attributes make RIVPACS and AusRivAS likely candidate analysis techniques for rapid bioassessment programs.

Although the same procedures are used to build all AusRivAS models, each model is tailored to specific regions (or states) to provide the most accurate predictions for the season and habitat sampled. The stream habitats for which these models have been applied include the edge/backwater, main channel, riffle, pool, and macrophyte stands. The multihabitat sampling techniques used in many RBP programs have not yet been tested with a RIVPACS model. The models can be constructed for a single season, or data from several seasons may be combined to provide more robust predictions. To date the RIVPACS/AusRivAs models have only been developed for the benthic assemblage. Discussion of RIVPACS and AusRivAS is taken from the *Australian River Assessment System National River Health Program Predictive Model Manual* by Simpson et al. (1996). As is the case with the multimetric approach, a more thorough treatment of the RIVPACS/AusRivAS models can be obtained by referring to the citations of the supporting documentation provided in this discussion.

> The reader is directed to the AusRivAS website for more specific information and guidance regarding these multivariate techniques.
> **http://ausrivas.canberra.edu.au/ausrivas**

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10 DATA INTEGRATION AND REPORTING

Human impacts on the biological integrity of water resources are complex and cumulative (Karr 1998). Karr (1998) states that human actions jeopardize the biological integrity of water resources by altering one or more of five principal factors — physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical quality of the water. These factors can be addressed in environmental management by shifting our focus from technology-based to water resource-based management strategies. This change in focus requires a commensurate shift from the measurement of pollutant loadings to a measurement of ecosystem health. Biological assessment addresses ecosystem health and cumulative impacts by concentrating on population and community level response rather than on discharger performance (Courtemanch 1995).

The translation of biological data into a report that adequately conveys the message of the assessment is a critical process. It is important to identify the intended audience(s) for the report and to bear in mind that users of the report will likely include groups (i. e. managers, elected officials, communities) who are not biologists. Reports must be coherent and easily understood in order for people to make informed decisions regarding the water resource. First, the data must be summarized and integrated, then clearly explained and presented. The use of a multimetric index provides a convenient, yet technically sound method for summarizing complex biological data for each assemblage (Karr et al. 1986, Plafkin et al. 1989). The procedures for developing the Multimetric Index for each assemblage is described in Chapter 9. The index itself is only an aggregation of contributory biological information and should not be used exclusive of its component metrics and data (Yoder 1991, Barbour et al. 1996a). However, the index and its component metrics serve as effective tools to communicate biological status of a water resource.

10.1 DATA INTEGRATION

Once indices and values are obtained for each assemblage, the question becomes how to interpret all of the results, particularly if the findings are varied and suggest a contradiction in assessment among the assemblages? Also, how are habitat data used to evaluate relationships with the biological data? These questions are among the most important that will be addressed in this chapter. The integration of chemical and toxicological data with biological data is not treated in depth here. It is briefly described in Chapter 3 and discussed in more detail elsewhere (Jackson 1992, USEPA 1997c).

10.1.1 Data Integration of Assemblages

USEPA advises incorporating more than 1 assemblage into biocriteria programs whenever practical. Surveying multiple assemblages provides a more complete assessment of biological condition since the various assemblages respond differently to certain stressors and restoration activities. For instance, Ohio EPA found, in a study of the Scioto River, that fish responded (recovered) more quickly than did benthos to restoration activities aimed at reducing the effects of cumulative impacts (i.e., impoundments, combined sewer overflows, wastewater treatment plants, urbanization) (Yoder and Rankin 1995a). Although significant improvement was observed in the condition of both assemblages in the river from 1980 to 1991, the benthic assemblage was still impaired in several reaches of the river; whereas, the fish assemblage met Ohio's warm water habitat criterion in 1991 for many of the same reaches. The use of both assemblages enhanced the agency's assessment of trend analysis for the Scioto River.

In addition, using more than 1 assemblage allows programs to more fully assess the occurrence of multiple stressors and seasonal variation in the intensity of the stressors (Gibson et al. 1996). Mount et al. (1984) found that benthic and fish assemblages responded differently to the same inputs in the Ottawa River in Ohio. Benthic diversity and abundance responded negatively to organic loading from a wastewater treatment plant and exhibited no observable response to chemical input from industrial effluent. Fish exhibited no response to the organic inputs and a negative response to metal concentrations in the water.

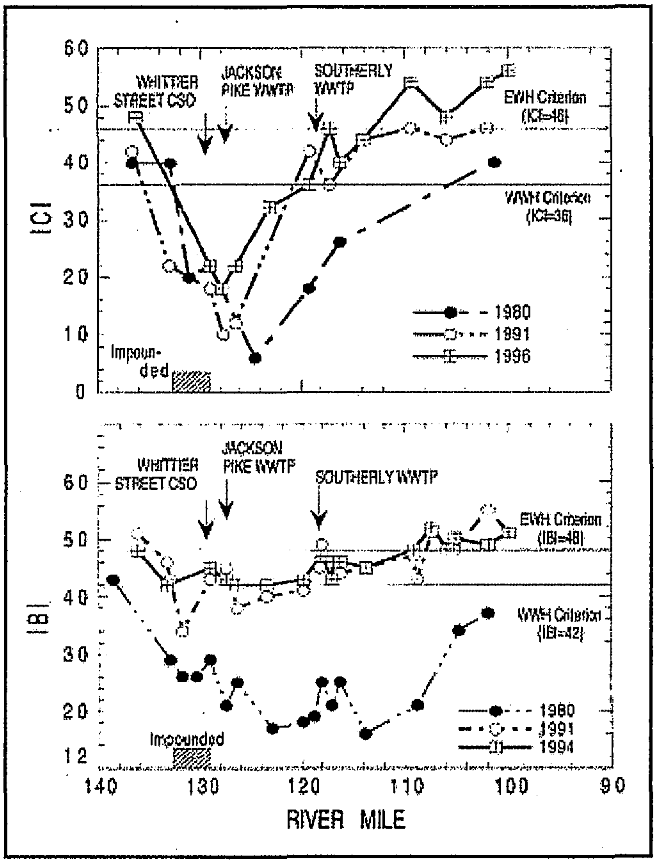


Figure 10-1. Cumulative frequency diagrams (CFD) for the IBI (upper) and the ICI (lower) comparing the pre-1988 and post-1988 status on a statewide basis from Ohio. In each case, estimated attainable level of future performance is indicated. The Warm Water Habitat (WWH) and Exceptional Warm Water Habitat (EWH) biological thresholds are given for each index.

Integration of information from each assemblage should be done such that the results complement and supplement the assessment of the site. Trend analysis (monitoring changes over time) is useful to illustrate differences in response of the assemblages (Figure 10-1). In this example of the Scioto River (Figure 10-1), the improvement in the fish Index of Biotic Integrity (IBI) and the benthic macroinvertebrate Index of Community Integrity (ICI) assemblages can be seen over time (1980 and 1991) and over a length of the river (River Mile [RM] 140 to 90) (Yoder 1995a).

Biological attributes and indices can also be illustrated side-by-side to highlight differences and similarities in the results. Oftentimes, differences in the results are useful for diagnosing cause-and-effect.

10.1.2 Relationship Between Habitat and Biological Condition

Historically, non-chemical impacts to biotic systems have not been a major focus of the nation's water quality agencies. Yet there is clear evidence that habitat alteration is a primary cause of degraded aquatic resources (USEPA 1997c). Habitat degradation occurs as a result of hydrological flow modification, alteration of the system's energy base, or direct impact on the physical habitat structure. Preservation of an ecosystem's natural physical habitat is a fundamental requirement in maintaining diverse, functional aquatic communities in surface waters (Rankin 1995). Habitat quality is an essential measurement in any biological survey because aquatic fauna often have very specific habitat requirements independent of water-quality composition (Barbour et al. 1996a). Diagnostic evaluations are enhanced when assessment of the habitat, flow regime, and energy base are incorporated into the interpretation of the biological condition (USEPA 1990b).

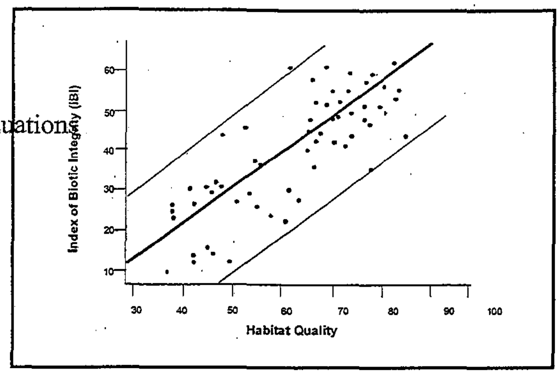


Figure 10-2. Relationship between the condition of the biological community and physical habitat.

The relationship between habitat quality (as defined by site-specific factors, riparian quality, and upstream land use) and biological condition can be graphed, as illustrated in Figure 10-2 to enhance data interpretation. On the X-axis, habitat is shown to vary in quality from 30 points, which is poor (nonsupporting of an acceptable biological condition) to 85 points, which is good (comparable to the reference condition). Biological condition, represented by the fish IBI on the Y-axis, varies from 10 points (severely impaired) to 60 points (excellent). Interpretation of the relationship between habitat and biology as depicted by Figure 10-2 can be summarized by 4 points relating to specific areas of the graph.

1. The upper right-hand corner of the curve is the ideal situation where optimal habitat quality and biological condition occur.

2. The decrease in biological condition is proportional to a decrease in habitat quality.

3. Perhaps the most important area of the graph is the lower right-hand corner where degraded biological condition can be attributed to something other than habitat quality (Barbour et al. 1996a).

4. The upper left-hand corner is where optimal biological condition is not possible in a severely degraded habitat (Barbour et al. 1996a).

A relationship between biology and habitat should be substantiated with a large database sufficient to develop confidence intervals around a regression line. Rankin (1995) found that Ohio's visual-based habitat assessment approach, called the Qualitative Habitat Evaluation Index (QHEI), explained most of the variation in the IBI for the fish assemblage. However, Rankin also pointed out that covariate relationships between aggregate riparian quality and land use of certain subbasins could be used to partition natural variability. In one example, Rankin illustrated how high-quality patches of habitat structure in otherwise habitat-degraded stream reaches may harbor sensitive species, thus masking the effects of habitat alteration.

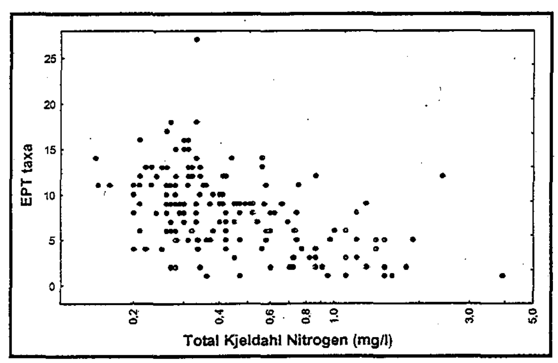


Figure 10-3. Data from a study of streams in Florida's Panhandle.

An informative approach to evaluating affects from specific or cumulative stressors is to ascertain a gradient response of the aquatic community using a bivariate scatter plot. In one example provided by Florida DEP, a gradient response of the EPT taxa indicated a strong relationship to nitrogen in the stream (Figure 10-3).

When multiple data types (i.e., habitat, biological, chemical, etc.) are available, sun ray plots may be used to display the assessment results. As an example, the assessments of habitat, macroinvertebrates and fish are integrated for evaluating of the condition of individual stream sites in a Pennsylvania watershed (Snyder et al. 1998). The assessment scores for each of the triad data types are presented as a percentage of reference condition (Figure 10-4). The area enclosed by each sun ray plot can be measured to provide a comparison of the biological and habitat condition among the sites of interest (Snyder et al. 1998). This technique helps determine the extent of impairment and also which ecological components are most affected.

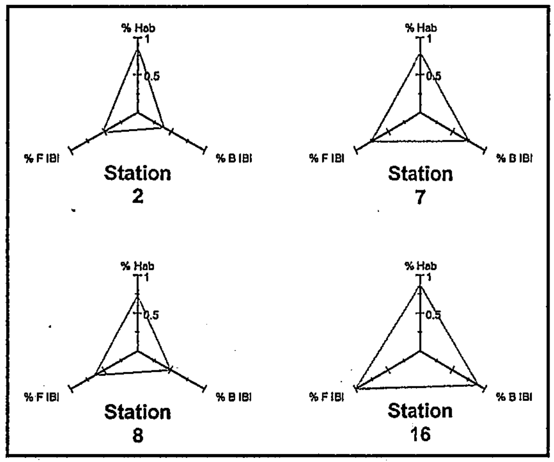


Figure 10-4. Comparison of integrated assessment (habitat, fish, and benthos) among stream sites in Pennsylvania. Station 16 is a reference site. (Taken from Snyder et al. 1998).

10.2 REPORTING

Historically, reports containing assessment results and recommendations for further action have been designed to address objectives and data uses relevant to the specific monitoring program. Increasingly, however, assessment reports are designed to reach a broader, non-scientific audience including water resource managers and the environmentally conscious public. Communicating the condition of biological systems, and the impact of human activities on those systems, is the ultimate purpose of biological monitoring (Karr and Chu 1999). Reporting style and format has become an important component in effectively communicating the findings of ecological assessments to diverse audiences. As pointed out by Karr and Chu (1999), effective communication can transform biological monitoring from a scientific exercise into a powerful tool for environmental decision making.

10.2.1 Graphical Display

Graphical displays are a fundamental tool for illustrating scientific information. Graphs reveal—more effectively than do strictly statistical tools—patterns of biological response. Patterns include "outliers," which may convey unique information that can help diagnose particular problems or reveal specific traits of a site (Karr and Chu 1999). Examples of some of the most useful graphical techniques are presented for specific biological program objectives:

1. Stream classification — a graph should illustrate the distinction between and among site classes or groups. Two common graphical displays are bivariate scatter plots (used in non-metric multidimensional scaling) and cluster dendrograms.

Bivariate scatter plots—used for comparing the scatter or clustering of points given 2 dimensions. Can be used to develop regression lines or to incorporate 3 factors (3-dimensional) (Figure 10-5).

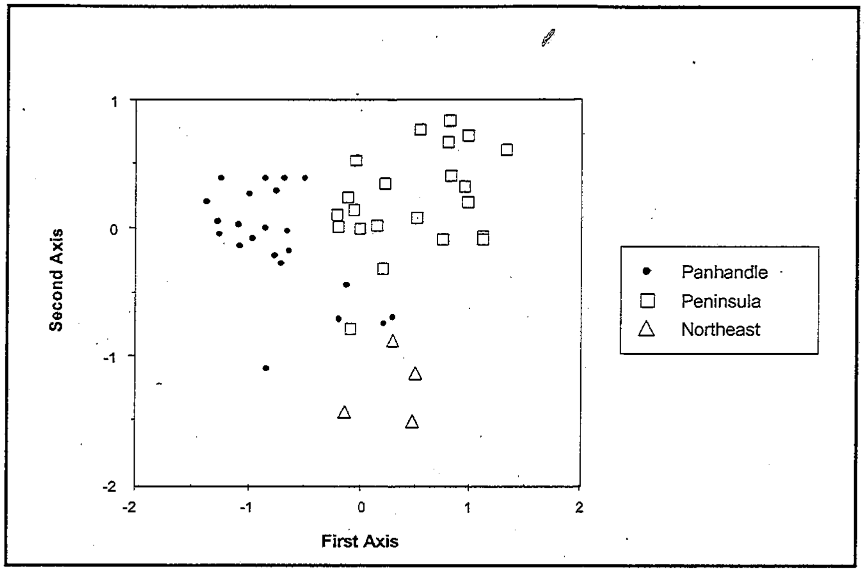


Figure 10-5. Use of multidimensional scaling on benthic data to ascertain stream classification. The first and second axes refer to the dimensions of combinations of data used to measure similarity (Taken from Barbour et al. 1996b).

Cluster dendrogram—used to illustrate the similarities and dissimilarities of sites in support of classes (Figure 10-6).

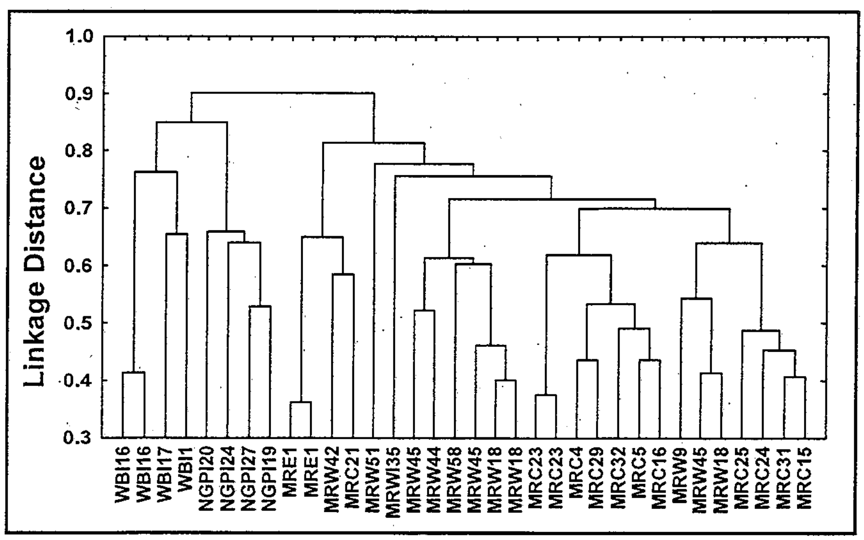


Figure 10-6. Example of a cluster dendrogram, illustrating similarities and clustering of sites (x-axis) using biological data.

2. Problem Identification and Status of Water Resource — The status of the condition of water resources requires consolidating information from many samples and can be illustrated in several ways.

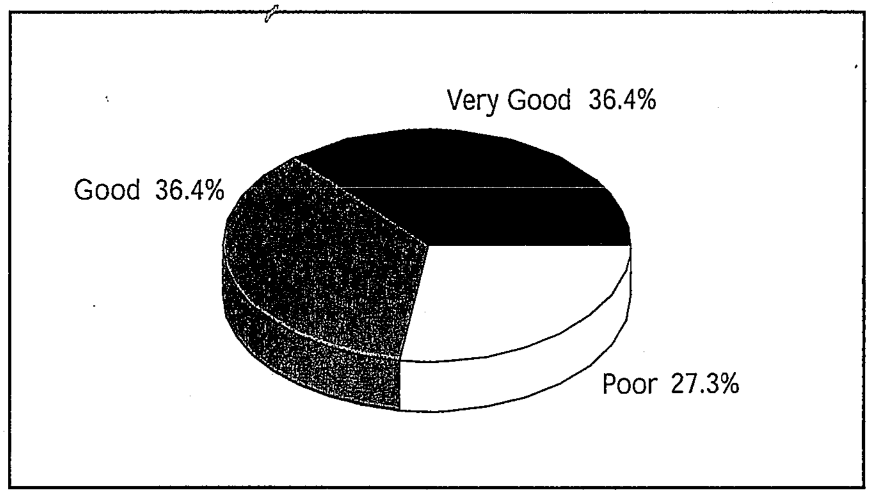


Figure 10-7. Results of the benthic assessment of streams in the Mattaponi Creek watershed of southern Prince George's County, Maryland. Percent of streams in each ecological condition category. (Taken from Stribling et al. 1996b).

Pie charts—used to illustrate proportional representation of the whole by its component parts. Can be sized according to magnitude or density (Figure 10-7)

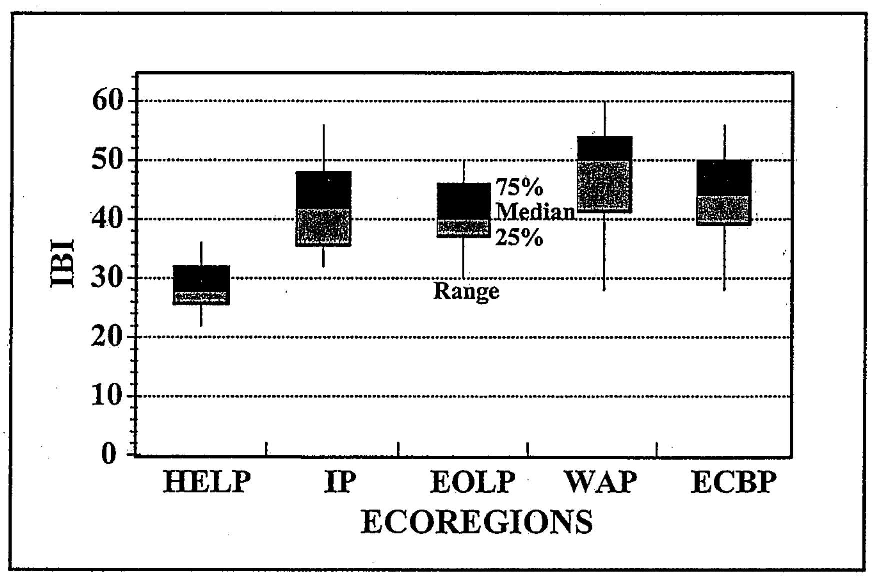


Figure 10-8. The population of values of the IBI in reference sites within each of the ecoregions of Ohio. (Contributed by Ohio EPA).

Box-and-whisker plots— used to illustrate population attributes (via percentile distribution) and provides some sense of variability (Figure 10-8).

3. Trend monitoring and assessment — Monitoring over a temporal or spatial scale requires a graphical display depicting trends, which may show improvement, degradation, or no change.

Line graphs—used to illustrate temporal or spatial trends that are contiguous. Assumes that linkage between points is linear (Figure 10-9).

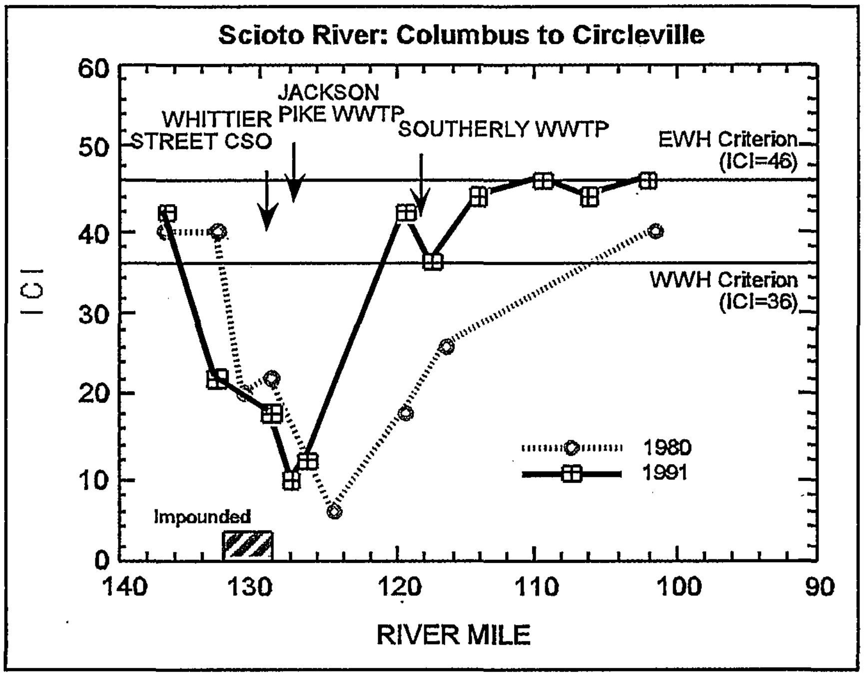


Figure 10-9. Spatial and temporal trend of Ohio's Invertebrate Community Index. The Scioto River - Columbus to Circleville. (Contributed by Ohio EPA).

Cumulative frequency diagram—illustrates an ordered accumulation of observations from lowest to highest value that allows one to determine status of resource at any given level (Figure 10-10).

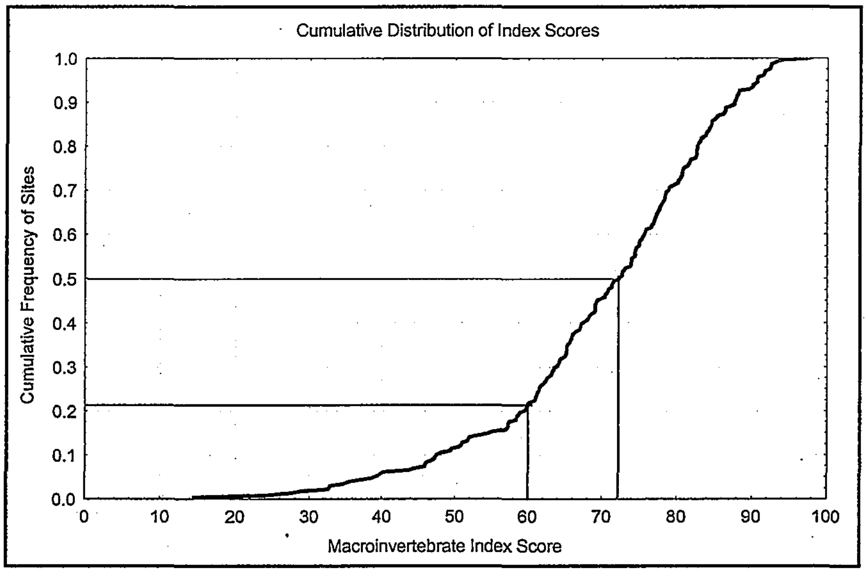


Figure 10-10. Cumulative distribution of macroinvertebrate index scores. 21% of sites scored at or below 60. The median index score is 75, where the cumulative frequency is 50%.

4. A determination of cause-and-effect — illustrating the source of impairment may not be a straightforward process. However, certain graphs lend themselves to showing comparative results in diagnosing problems.

Bar charts — used to display magnitude of values for discrete entities. Can be used to illustrate deviation from a value of central tendency (Figure 10-11).

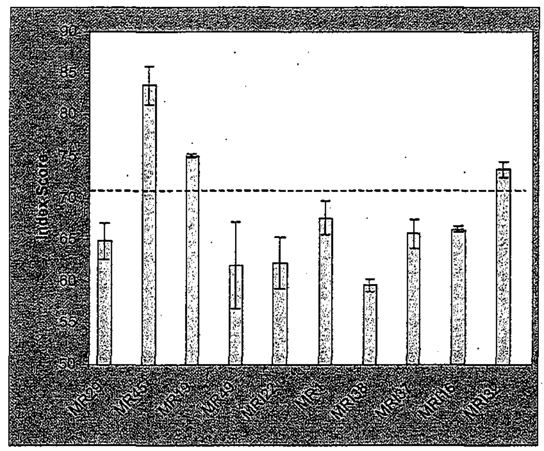


Figure 10-11. Biological assessment of sites in the Middle Rockies, showing mean and standard deviation of repeated measures and the assessment threshold (dashed line).

Sun Ray plots — used to compare more than 2 endpoints or data types. Most effective when reference condition is incorporated into axes or comparison (Figure 10-12).

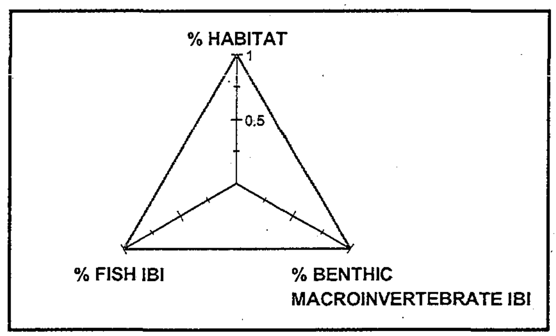


Figure 10-12. Integration of data from habitat, fish, and benthic assemblages.

Box-and-whisker plots— used to illustrate population attributes (via percentile distribution). Distinction among plots illustrates degree of similarity/differences (Figure 10-13).

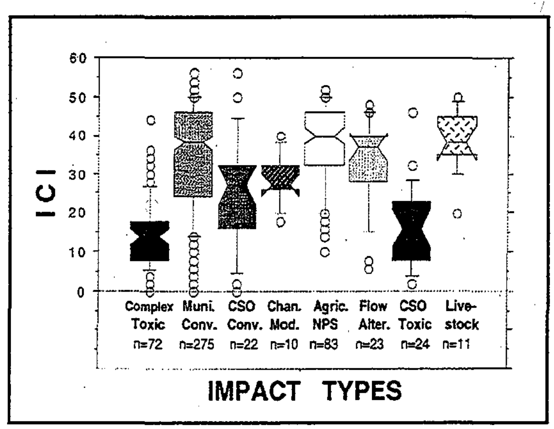


Figure 10-13. The response of the benthic macroinvertebrate assemblage (ICI) to various types of impacts (provided by Ohio EPA).

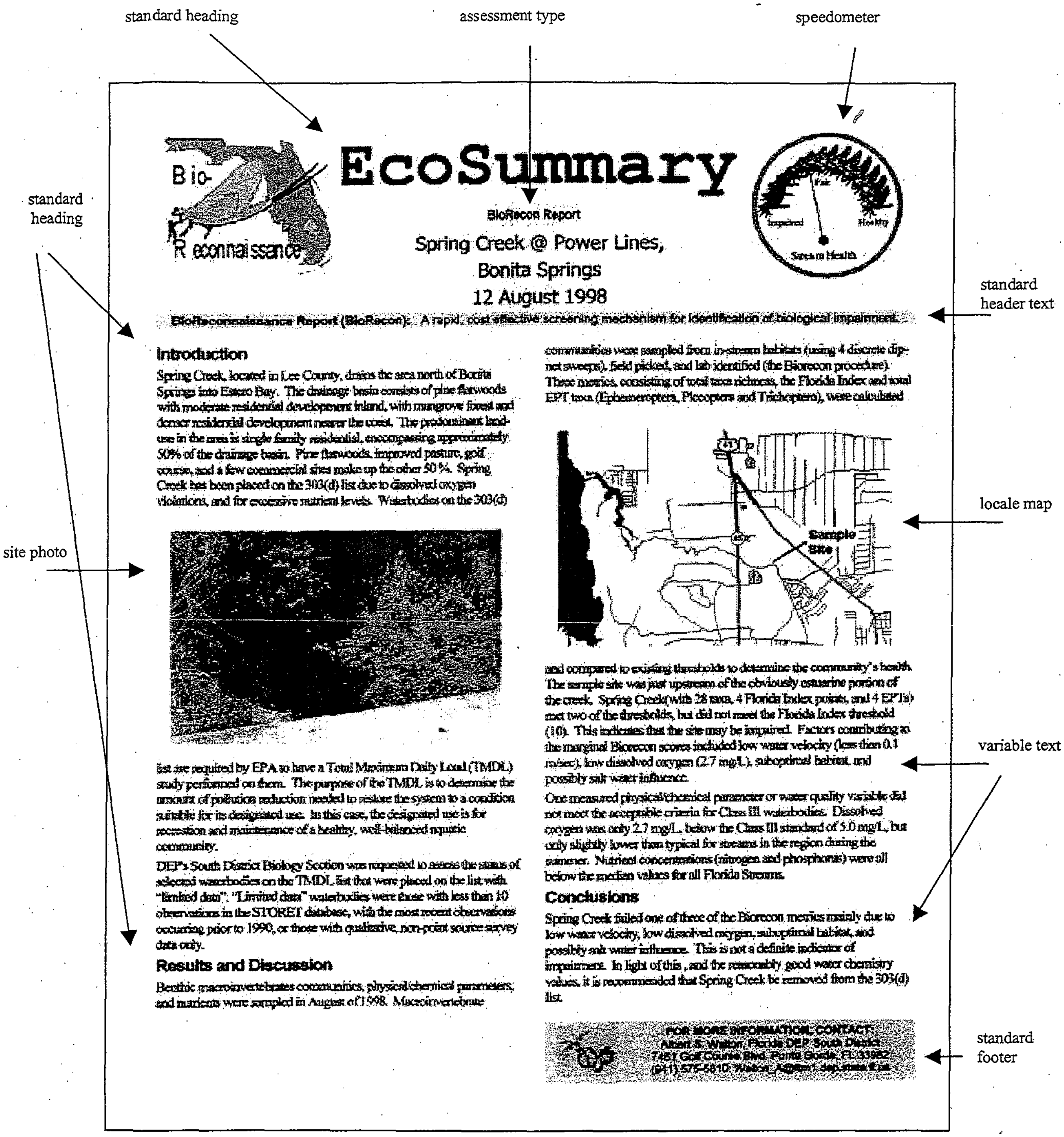
10.2.2 Report Format

Two basic formats are recommended for reporting ecological assessments. Each of these formats is intended to highlight the scientific process, focus on study objectives, and judge the condition of the assessed sites. The first format is a summary report, targeted for use by managers in making decisions regarding the resource. This report format can also be an invaluable public information tool. The second report format is patterned after that of peer-reviewed journals and is primarily designed for informing a more technical audience.

The *Ecosummary* is an example of the first report format. It has an uncomplicated style and conveys various information including study results. The simplicity of this format quickly and effectively documents results and assists a non-technical audience in making informed decisions. An executive summary format is appropriate. An executive summary format is appropriate to present the "bottom line" assessment for the Ecosummary, which will be read by agency managers and decision-makers. Technical appendices or supplemental documentation should either accompany the report or be available to support the scientific integrity of the study.

These Ecosummaries are generally between 1-4 pages in length and lend themselves to quick and easy dissemination. Color graphics may be added to enhance the presentation or findings. An example of an Ecosummary format used by Florida Department of Environmental Protection (DEP) is illustrated in Figure 10-14. This 1-page report highlights the purpose of the study as well as the results and significance of the findings. A summary of the ecological data in the form of bar charts and tables may be provided on subsequent pages. Because this study follows prescribed methods and procedures, all of this documentation is not included in the report but is included in agency Standard Operating Procedures (SOPs).

The second format for reporting is a *scientific report*, which is structured similarly to a peer-reviewed journal. The report should be peer-reviewed by non-agency scientists to validate its scientific credibility. An abstract or executive summary should be prepared to highlight the essential findings. As in a peer-reviewed journal article, the methods and results are presented succinctly and clearly. The introductory text should outline the objectives and purpose of the study. A discussion of the results should include supporting literature to add credence to the findings, particularly if there is a discussion of suspected cause of impairment. Preparation of a report using this format will require more time than the Ecosummary. However, this report format is more inclusive of supportive information and will be more important in litigious situations.



EcoSummary

BioRecon Report

Spring Creek @ Power Lines,
Bonita Springs
12 August 1998

BioReconnaissance Report (BioRecon): A rapid, cost effective screening mechanism for identification of biological impairment.

Introduction

Spring Creek, located in Lee County, drains the area north of Bonita Springs into Estero Bay. The drainage basin consists of pine flatwoods with moderate residential development inland, with mangrove forest and denser residential development nearer the coast. The predominant land-use in the area is single family residential, encompassing approximately 50% of the drainage basin. Pine flatwoods, improved pasture, golf course, and a few commercial sites make up the other 50 %. Spring Creek has been placed on the 303(d) list due to dissolved oxygen violations, and for excessive nutrient levels. Waterbodies on the 303(d) list are required by EPA to have a Total Maximum Daily Load (TMDL) study performed on them. The purpose of the TMDL is to determine the amount of pollution reduction needed to restore the system to a condition suitable for its designated use. In this case, the designated use is for recreation and maintenance of a healthy, well-balanced aquatic community.

DEP's South District Biology Section was requested to assess the status of selected waterbodies on the TMDL list that were placed on the list with "limited data". "Limited data" waterbodies were those with less than 10 observations in the STORET database, with the most recent observations occurring prior to 1990, or those with qualitative, non-point source survey data only.

Results and Discussion

Benthic macroinvertebrates communities, physical/chemical parameters, and nutrients were sampled in August of 1998. Macroinvertebrate communities were sampled from in-stream habitats (using 4 discrete dip-net sweeps), field picked, and lab identified (the Biorecon procedure). Three metrics, consisting of total taxa richness, the Florida Index and total EPT taxa (Ephemeroptera, Plecoptera and Trichoptera), were calculated and compared to existing thresholds to determine the community's health. The sample site was just upstream of the obviously estuarine portion of the creek. Spring Creek(with 28 taxa, 4 Florida Index points, and 4 EPTs) met two of the thresholds, but did not meet the Florida Index threshold (10). This indicates that the site may be impaired. Factors contributing to the marginal Biorecon scores included low water velocity (less than 0.1 m/sec), low dissolved oxygen (2.7 mg/L), suboptimal habitat, and possibly salt water influence.

One measured physical/chemical parameter or water quality variable did not meet the acceptable criteria for Class III waterbodies. Dissolved oxygen was only 2.7 mg/L, below the Class III standard of 5.0 mg/L, but only slightly lower than typical for streams in the region during the summer. Nutrient concentrations (nitrogen and phosphorus) were all below the median values for all Florida Streams.

Conclusions

Spring Creek failed one of three of the Biorecon metrics mainly due to low water velocity, low dissolved oxygen, suboptimal habitat, and possibly salt water influence. This is not a definite indicator of impairment. In light of this , and the reasonably good water chemistry values, it is recommended that Spring Creek be removed from the 303(d) list.

FOR MORE INFORMATION CONTACT:
Albert S. Walton, Florida DEP South District
7481 Golf Course Blvd. Punta Gorda, FL 33982
(941) 575-5810

Figure 10-14. Guidance for Florida Ecosummary — A one-page bioassessment report. (Contributed by Florida DEP).

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APPENDIX A:

SAMPLE DATA FORMS FOR THE PROTOCOLS

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APPENDIX A-1:

Habitat Assessment and Physicochemical Characterization Field Data Sheets

Form 1: Physical Characterization/Water Quality Field Data Sheet
Form 2: Habitat Assessment Field Data Sheet - High Gradient Streams
Form 3: Habitat Assessment Field Data Sheet - Low Gradient Streams

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PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT____________ LONG____________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE________ TIME________ AM PM
REASON FOR SURVEY	

WEATHER CONDITIONS	Now / Past 24 hours: ❑ storm (heavy rain) ❑ ❑ rain (steady rain) ❑ ❑ showers (intermittent) ❑ ____%❑ %cloud cover ❑____% ❑ clear/sunny ❑ **Has there been a heavy rain in the last 7 days?** ❑ Yes ❑ No **Air Temperature**_____ ^{0} C **Other**____________________
SITE LOCATION/MAP	**Draw a map of the site and indicate the areas sampled (or attach a photograph)**
STREAM CHARACTERIZATION	**Stream Subsystem** ❑ Perennial ❑ Intermittent ❑ Tidal **Stream Type** ❑ Coldwater ❑ Warmwater **Stream Origin** ❑ Glacial ❑ Spring-fed ❑ Non-glacial montane ❑ Mixture of origins ❑ Swamp and bog ❑ Other__________ **Catchment Area**__________km^2

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES	**Predominant Surrounding Landuse** ❑ Forest ❑ Commercial ❑ Field/Pasture ❑ Industrial ❑ Agricultural ❑ Other ________ ❑ Residential **Local Watershed NPS Pollution** ❑ No evidence ❑ Some potential sources ❑ Obvious sources **Local Watershed Erosion** ❑ None ❑ Moderate ❑ Heavy
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ❑ Trees ❑ Shrubs ❑ Grasses ❑ Herbaceous **dominant species present** ________________
INSTREAM FEATURES	**Estimated Reach Length** _______m **Estimated Stream Width** _______m **Sampling Reach Area** _______m² **Area in km² (m²x1000)** _______km² **Estimated Stream Depth** _______m **Surface Velocity (at thalweg)** _______m/sec **Canopy Cover** ❑ Partly open ❑ Partly shaded ❑ Shaded **High Water Mark** _______m **Proportion of Reach Represented by Stream Morphology Types** ❑ Riffle _______% ❑ Run _______% ❑ Pool _______% **Channelized** ❑ Yes ❑ No **Dam Present** ❑ Yes ❑ No
LARGE WOODY DEBRIS	**LWD** _______m² **Density of LWD** _______m²/km² (LWD/ reach area)
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ❑ Rooted emergent ❑ Rooted submergent ❑ Rooted floating ❑ Free floating ❑ Floating Algae ❑ Attached Algae **dominant species present** ________________ **Portion of the reach with aquatic vegetation** _____%
WATER QUALITY	**Temperature** _______ °C **Specific Conductance** ________ **Dissolved Oxygen** ________ **pH** ________ **Turbidity** ________ **WQ Instrument Used** ______________ **Water Odors** ❑ Normal/None ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Fishy ❑ Other ________ **Water Surface Oils** ❑ Slick ❑ Sheen ❑ Globs ❑ Flecks ❑ None ❑ Other ________ **Turbidity (if not measured)** ❑ Clear ❑ Slightly turbid ❑ Turbid ❑ Opaque ❑ Stained ❑ Other ________
SEDIMENT/ SUBSTRATE	**Odors** ❑ Normal ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Anaerobic ❑ None ❑ Other ________ **Oils** ❑ Absent ❑ Slight ❑ Moderate ❑ Profuse **Deposits** ❑ Sludge ❑ Sawdust ❑ Paper fiber ❑ Sand ❑ Relict shells ❑ Other ________ **Looking at stones which are not deeply embedded, are the undersides black in color?** ❑ Yes ❑ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION # ______ RIVERMILE ______	STREAM CLASS	
LAT ______ LONG ______	RIVER BASIN	
STOREt #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE ______ TIME ______ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Condition Category: Suboptimal	Condition Category: Marginal	Condition Category: Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score __________

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION # ________ RIVERMILE ________	STREAM CLASS	
LAT ________ LONG ________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE ________ TIME ________ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE ___	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score ________

APPENDIX A-2:

Periphyton Field and Laboratory Data Sheets

Form 1: Periphyton Field Data Sheet
Form 2: Periphyton Sample Log-In Sheet
Form 3: Periphyton Soft Algae Laboratory Bench Sheet (front and back)
Form 4: Periphyton Diatom Laboratory Bench Sheet (front and back)
Form 5: Rapid Periphyton Survey Field Sheet

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PERIPHYTON FIELD DATA SHEET

STREAM NAME	LOCATION
STATION # ______ RIVERMILE	STREAM CLASS
LAT ______ LONG	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	LOT NUMBER
FORM COMPLETED BY	DATE ______ TIME ______ AM PM
	REASON FOR SURVEY

HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Sand-Silt-Mud-Muck____% ❑ Gravel-Cobble____% ❑ Bedrock_____% ❑ Small Woody Debris____% ❑ Large Woody Debris____% ❑ Plants, Roots_____% ❑ Riffle____% ❑ Run____% ❑ Pool_____% ❑ Canopy____%
SAMPLE COLLECTION	**Gear used** ❑ suction device ❑ bar clamp sample ❑ scraping ❑ Other ____________ **How were the samples collected?** ❑ wading ❑ from bank ❑ from boat **If natural habitat collections, indicate the number of samples taken in each habitat type.** ❑ Sand-Silt-Mud-Muck____% ❑ Gravel-Cobble____% ❑ Bedrock____% ❑ Small Woody Debris____% ❑ Large Woody Debris____% ❑ Plants, Roots____%
GENERAL COMMENTS	

QUALITATIVE LISTING OF AQUATIC BIOTA

Indicate estimated abundance: **0 = Absent/Not Observed, 1 = Rare (<5%), 2 = Common (5% - 30%), 3= Abundant (30% - 70%), 4 = Dominant (>70%)**

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

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page ___ of ___

PERIPHYTON SAMPLE LOG-IN SHEET

Date Collected	Collected By	Number of Containers	Preservation	Station #	Stream Name and Location	Date Received by Lab	Lot Number	Date of Completion		
								sorting	mounting	identification

Serial Code Example: P0754001(1)
P = Periphyton (B = Benthos, F = Fish)# 0754 = project number # 001 = sample number # (1) = lot number (e.g., winter 1996 =1; summer 1996 = 2)

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PERIPHYTON SOFT ALGAE LABORATORY BENCH SHEET (FRONT)

page _____ of _____

STREAM NAME	LOCATION
STATION # RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET # LOT #	AGENCY
COLLECTORS INITIALS DATE	TAXONOMISTS INITIALS DATE
SUBSAMPLE TARGET FOR SOFT ALGAE ☐ 300 ☐ 400 ☐ 500 ☐ Other ____	

TAXA NAME	TALLY	CODE	# OF CELLS	TCR

Taxonomic certainty ratings (TCR) can be determined for each taxa or for the laboratory as a whole. The TCR scale is 1-5, with: 1 = most certain and 5 = least certain. If rating is 3-5, give reason. The number of cells for filamentous algae is an estimate of relative biomass.

Total No. Algal cells ____________ **Total No. Taxa** ____________

PERIPHYTON SOFT ALGAE LABORATORY BENCH SHEET (BACK)

STREAM IDENTIFICATION CODE	DATE COUNTED
COUNTED TRANSECT LENGTH	COUNTED TRANSECT WIDTH
SIZE OF COVERGLASS	TOTAL SAMPLE VOLUME
VOLUME OF SAMPLE ON COVERGLASS	SAMPLE DILUTION FACTOR
PROPORTION OF SAMPLE COUNTED	AREA OF SUBSTRATE SAMPLED
TOTAL NUMBER OF CELLS COUNTED	TOTAL ASSEMBLAGE CELL DENSITY

TAXONOMY ID ____________ Date ____________	Explain TCR ratings of 3-5: Other Comments (e.g. condition of algae): QC: ❑ YES ❑ NO **QC Checker** ____________ Algal recognition ❑ pass ❑ fail Verification complete ❑ YES ❑ NO

General Comments (use this space to add additional comments):

A010260

PERIPHYTON DIATOM LABORATORY BENCH SHEET (FRONT)

page ____ of ____

STREAM NAME	LOCATION
STATION # RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET # LOT #	AGENCY
COLLECTORS INITIALS DATE	TAXONOMISTS INITIALS DATE
SUBSAMPLE TARGET FOR DIATOM ☐ 300 ☐ 400 ☐ 600 ☐ Other ___	

TAXA NAME	TALLY (# of valves)	CODE	# OF CELLS	TCR

Taxonomic certainty ratings (TCR) can be determined for each taxa or for the laboratory as a whole. The TCR scale is 1-5, with: 1 = most certain and 5 = least certain. If rating is 3-5, give reason. The number of cells for filamentous algae is an estimate of relative biomass.

Total No. Algal cells ____________ **Total No. Taxa** ____________

PERIPHYTON DIATOM LABORATORY BENCH SHEET (BACK)

TAXONOMY ID ________ Date ________	Explain TCR ratings of 3-5: Other Comments (e.g. condition of algae): QC: ☐ YES ☐ NO QC Checker ________ Algal recognition ☐ pass ☐ fail Verification complete ☐ YES ☐ NO

General Comments (use this space to add additional comments):

RAPID PERIPHYTON SURVEY FIELD SHEET

STREAM NAME	LOCATION
STATION # RIVERMILE	STREAM CLASS
LAT LONG	RIVER BASIN
STORET # LOT #	AGENCY
COLLECTORS INITIALS DATE	TAXONOMISTS INITIALS DATE

ASSESSED BY	
GRID AREA	
ID MACROALGA #1	
ID MACROALGA #2	
ID MICROALGA #1	
ID MICROALGA #2	

Macroalga #1 Maximum Length ______________________

Macroalga #2 Maximum Length ______________________

TRANSECT/ VIEW #	# DOTS IN GRID AREA	MACROALGA #1 DOTS COVERED	MACROALGA #2 DOTS COVERED	# DOTS MICROALGA SUBSTRATE	MICROALGA #1 DOTS COVERED BY THICKNESS RANK							MICROALGA #2 DOTS COVERED BY THICKNESS RANK						
					0	0.5	1	2	3	4	5	0	0.5	1	2	3	4	5
TOTAL # DOTS AT SITE																		

General Comments:

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APPENDIX A-3:

Benthic Macroinvertebrate Field and Laboratory Data Sheets

Form 1: Benthic Macroinvertebrate Field Data Sheet
Form 2: Benthic Macroinvertebrate Sample Log-In Sheet
Form 3: Benthic Macroinvertebrate Laboratory Bench Sheet
Form 4: Preliminary Assessment Score Sheet (Pass)

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BENTHIC MACROINVERTEBRATE FIELD DATA SHEET

STREAM NAME	LOCATION	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT ____________ LONG ____________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		LOT NUMBER
FORM COMPLETED BY	DATE ______ TIME ______ AM PM	REASON FOR SURVEY

HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Cobble_____% ❑ Snags_____% ❑ Vegetated Banks_____% ❑ Sand_____% ❑ Submerged Macrophytes_____% ❑ Other ( )_____%
SAMPLE COLLECTION	**Gear used** ❑ D-frame ❑ kick-net ❑ Other ______________________ **How were the samples collected?** ❑ wading ❑ from bank ❑ from boat **Indicate the number of jabs/kicks taken in each habitat type.** ❑ Cobble_____ ❑ Snags_____ ❑ Vegetated Banks_____ ❑ Sand_____ ❑ Submerged Macrophytes_____ ❑ Other ( )_____
GENERAL COMMENTS	

QUALITATIVE LISTING OF AQUATIC BIOTA
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare, 2 = Common, 3= Abundant, 4 = Dominant

Periphyton	0	1	2	3	4	Slimes	0	1	2	3	4
Filamentous Algae	0	1	2	3	4	Macroinvertebrates	0	1	2	3	4
Macrophytes	0	1	2	3	4	Fish	0	1	2	3	4

FIELD OBSERVATIONS OF MACROBENTHOS
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms), 3= Abundant (>10 organisms), 4 = Dominant (>50 organisms)

Porifera	0	1	2	3	4	Anisoptera	0	1	2	3	4	Chironomidae	0	1	2	3	4
Hydrozoa	0	1	2	3	4	Zygoptera	0	1	2	3	4	Ephemeroptera	0	1	2	3	4
Platyhelminthes	0	1	2	3	4	Hemiptera	0	1	2	3	4	Trichoptera	0	1	2	3	4
Turbellaria	0	1	2	3	4	Coleoptera	0	1	2	3	4	Other	0	1	2	3	4
Hirudinea	0	1	2	3	4	Lepidoptera	0	1	2	3	4						
Oligochaeta	0	1	2	3	4	Sialidae	0	1	2	3	4						
Isopoda	0	1	2	3	4	Corydalidae	0	1	2	3	4						
Amphipoda	0	1	2	3	4	Tipulidae	0	1	2	3	4						
Decapoda	0	1	2	3	4	Empididae	0	1	2	3	4						
Gastropoda	0	1	2	3	4	Simuliidae	0	1	2	3	4						
Bivalvia	0	1	2	3	4	Tabinidae	0	1	2	3	4						
						Culcidae	0	1	2	3	4						

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page __ of __

BENTHIC MACROINVERTEBRATE SAMPLE LOG-IN SHEET

Date Collected	Collected By	Number of Containers	Preservation	Station #	Stream Name and Location	Date Received by Lab	Lot Number	Date of Completion		
								sorting	mounting	identification

Serial Code Example: B0754001(1)
B = Benthos (F = Fish; P = Periphyton)# 0754 = project number # 001 = sample number # (1) = lot number (e.g., winter 1996 =1; summer 1996 = 2)

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BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (FRONT)

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
COLLECTED BY DATE________	LOT #
TAXONOMIST DATE________	SUBSAMPLE TARGET ☐ 100 ☐ 200 ☐ 300 ☐ Other ____

Enter Family and/or Genus and Species name on blank line.

Organisms		No.	LS	TI	TCR	Organisms		No.	LS	TI	TCR
Oligochaeta						Megaloptera					
Hirudinea						Coleoptera					
Isopoda											
Amphipoda						Diptera					
Decapoda											
Ephemeroptera											
						Gastropoda					
						Pelecypoda					
Plecoptera											
						Other					
Trichoptera											
Hemiptera											

Taxonomic certainty rating (TCR) 1-5:1=most certain, 5=least certain. If rating is 3-5, give reason (e.g., missing gills). LS= life stage: I = immature; P = pupa; A = adult TI = Taxonomists initials

Total No. Organisms ____________ **Total No. Taxa** ____________

BENTHIC MACROINVERTEBRATE LABORATORY BENCH SHEET (BACK)

SUBSAMPLING/SORTING INFORMATION

Sorter ______________

Date ______________

Number of grids picked: ________

Time expenditure ________ No. of organisms ________

Indicate the presence of large or obviously abundant organisms:

QC: ❑ YES ❑ NO **QC Checker** ______________

organisms originally sorted [ ] ÷ (# organisms recovered by checker [ ] + # organisms originally sorted [ ]) = % sorting efficiency [ ]

≥90%, sample passes ________

<90%, sample fails, action taken ______________

TAXONOMY

ID ______________

Date ______________

Explain TCR ratings of 3-5:

Other Comments (e.g. condition of specimens):

QC: ❑ YES ❑ NO **QC Checker** ______________

Organism recognition ❑ pass ❑ fail

Verification complete ❑ YES ❑ NO

PRELIMINARY ASSESSMENT SCORE SHEET
(PASS)

page ____ of ____

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
COLLECTED BY DATE________	LOT # ______ NUMBER OF SWEEPS ________
HABITATS: ☐ COBBLE ☐ SHOREZONE ☐ SNAGS ☐ VEGETATION	

Enter Family and/or Genus and Species name on blank line.

Organisms		No.	LS	TI	TCR	Organisms		No.	LS	TI	TCR
Oligochaeta						Megaloptera					
Hirudinea						Coleoptera					
Isopoda											
Amphipoda						Diptera					
Decapoda											
Ephemeroptera											
						Gastropoda					
						Pelecypoda					
Plecoptera											
						Other					
Trichoptera											
Hemiptera											

Taxonomic certainty rating (TCR) 1-5:1=most certain, 5=least certain. If rating is 3-5, give reason (e.g., missing gills). LS= life stage: I = immature; P = pupa; A = adult TI = Taxonomists initials

	Site Value	Target Threshold	
Total No. Taxa			If 2 or more metrics are ≥ target threshold, site is **HEALTHY**
EPT Taxa			If less than 2 metrics are within target range, site is **SUSPECTED IMPAIRED**
Tolerance Index			

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APPENDIX A-4:

Fish Field and Laboratory Data Sheets

Form 1: Fish Sampling Field Data Sheet
Form 2: Fish Sample Log-In Sheet

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FISH SAMPLING FIELD DATA SHEET (FRONT)

page _____ of _____

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
GEAR	INVESTIGATORS
FORM COMPLETED BY	DATE ______ TIME ______ AM PM / REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ❑ back pack ❑ tote barge ❑ other ______________ **Block nets used?** ❑ YES ❑ NO **Sampling Duration** Start time ________ End time ________ Duration ________ **Stream width (in meters)** Max________ Mean________
HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Riffles____% ❑ Pools____% ❑ Runs____% ❑ Snags____% ❑ Submerged Macrophytes____% ❑ Other ( )____%
GENERAL COMMENTS	

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMEN MAX SUBSAMPLE)					ANOMALIES*							
							D	E	F	L	M	S	T	Z

FISH SAMPLING FIELD DATA SHEET (BACK)

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMEN MAX SUBSAMPLE)					ANOMALIES*							
							D	E	F	L	M	S	T	Z

* **ANOMALY CODES:** D = deformities; E = eroded fins; F = fungus; L = lesions; M = multiple DELT anomalies; S = emaciated; Z = other

FISH SAMPLE LOG-IN SHEET

Date Collected	Collected By	Number of Containers	Preservation	Station #	Stream Name and Location	Date Received by Lab	Lot Number	Date of Completion		
								sorting	mounting	identification

Serial Code Example: F0754001(1)
F = Fish (B = Benthos; P = Periphyton)# 0754 = project number # 001 = sample number # (1) = lot number (e.g., winter 1996 =1; summer 1996 = 2)

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APPENDIX B:

REGIONAL TOLERANCE VALUES, FUNCTIONAL FEEDING GROUPS AND HABIT/BEHAVIOR ASSIGNMENTS FOR BENTHIC MACROINVERTEBRATES

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APPENDIX B

Appendix B is a list of selected benthic macroinvertebrates of the United States in phylogenetic order. Included are the Taxonomic Serial Number (TSN) and the Parent Taxonomic Serial Number for each of the taxa listed according to the Integrated Taxonomic Information System (ITIS). The ITIS generates a national taxonomic list that is constantly updated and currently posted on the World Wide Web at <www.itis.usda.gov>. If you are viewing this document electronically, this page is linked to the ITIS web site.

This Appendix displays regional tolerance values, primary and secondary functional feeding group information, and primary and secondary habit designations for selected benthic macroinvertebrates. In an effort to provide regionally accurate tolerance information, lists included in this Appendix were taken from the following states (and workgroup): Idaho (Northwest), Ohio[1] (Midwest), North Carolina (Southeast), Wisconsin (Upper Midwest), and the MACS workgroup (Mid-Atlantic Coastal Streams). Tolerance values are on a 0 to 10 scale, 0 representing the tolerance value of an extremely sensitive organism and 10 for a tolerant organism. For functional feeding group and habit/behavior assignments, primary and secondary designations are listed, if both are known. Each characterization is based on the organisms' larval qualities, except a group of beetles (listed as 'adult') that are aquatic as adults. The following are lists of the abbreviations used in this appendix.

FUNCTIONAL FEEDING DESIGNATIONS

PA=parasite
PR=predator
OM=omnivore
GC=gatherer/collector
FC=filter/collector
SC=scraper
SH=shredder
PI=piercer

HABIT/BEHAVIOR DESIGNATIONS

cn=clinger
cb=climber
sp=sprawler
bu=burrower
sw=swimmer
dv=diver
sk=skater

Sources For Benthic Tolerance, Functional Feeding Group, and Habit/Behavior Designations [(a)]

ID= Idaho DEP (Northwest)

OH= Ohio EPA (Midwest)

NC = North Carolina DEM (Southeast)

WI = Wisconsin DNR (Upper Midwest)

MACS= Mid-Atlantic Coastal Streams Workgroup (NJ DEP, DE DNREC, MD DNR, VA DEC, NC DEM, SC DHES)

[(a)] Habit/Behavior information is primarily based on Merritt and Cummins (1996) and pertains to insect larval forms (except for Dryopidae adults) and is mostly at genus level.

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[1] Ohio traditionally uses an inverted 60-point scale compared to the other states in this list. In order to be comparable to the other listed states, the Ohio values were converted to a 0-10 scale as discussed above.

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Regional Tolerance Values, Functional Feeding Groups, and Habit/Behavior Assignments for Benthic Macroinvertebrates

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
202423	59490	Nematoda				5		PA			
202423	64183	Nematomorpha						PA			
202423	57411	Nemertea				8		PR			
	57412	Rhynchocoela									
57577	57578	Prostoma graecense	6.6					PR			
57577	193496	Prostoma rubrum									
202423	53963	Platyhelminthes									
53963	53964	Turbellaria				4		PR			
53965	54468	Tricladida				4		GC			
54552	54553	Cura									
54468	54502	Planariidae				1		OM			
54502	54503	Dugesia				4		OM			
54503	54504	Dugesia tigrina	7.5					PR			
54502	54510	Polycelis				6		GC			
54510	54512	Polycelis coronata				1		OM			
202423	46861	Porifera						FC			
47690	47691	Spongillidae						FC			
47691	47692	Spongilla						FC			
47692	47696	Spongilla aspinosa						FC			
	155470	Ectoprocta									
156691	156692	Plumatella repens									
174619	174662	Hydrobates									
202423	48738	Cnidaria									
50844	50845	Hydra				5		PR			
50845	50846	Hydra americana									
156753	156754	Urnatella gracilis									
69458	79118	Bivalvia						FC			
	79119	Pelecypoda				8		FC			
79517	79519	Brachidontes exustus						FC			
79912	79913	Unionidae				8		FC			
79913	79930	Anodonta				8		FC			
79930	79946	Anodonta couperiana						FC			
		Anodonta nuttalliana idahoensis				8		FC			
79913	79951	Elliptio						FC			
79951	79975	Elliptio buckleyi						FC			
79951	79952	Elliptio complanata	5.4								
79951	79964	Elliptio lanceolata	1.9								
79913	80032	Gonidea				4		FC			
80032	80033	Gonidea angulata				8		FC			
79986	80006	Lampsilis teres						FC			
79913	80370	Margaritifera				4		FC			
80370	80371	Margaritifera margaritifera				8		FC			
80059	80067	Quadrula cylindrica						FC			
81381	81385	Corbicula						FC			
81385	81387	Corbicula fluminea	6.3		3.2			FC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
81385	81386	Corbicula manilensis						FC			
81333	81335	Mytilopsis leucophaeata						FC			
80384	81388	Pisidiidae				8		GC			
	81389	Sphaeriidae				8	8	FC			
81388	81436	Eupera									
	205642	Byssanodonta cubensis (= Eupera)						FC			
81436	81438	Eupera cubensis						FC			
81388	81427	Musculium					5	FC			
81427	81430	Musculium lacustre					5	FC			
		Byssanodonta (= Eupera)						FC			
81427	81434	Musculium securis					5	FC			
81427	81428	Musculium transversum									
81388	81400	Pisidium	6.8		4.6	8	8	FC			
81400	81405	Pisidium casertanum				8		SC			
81400		Pisidium lilljborgi					8	FC			
81400	81406	Pisidium compressum				8		FC			
81400	81402	Pisidium dubium						FC			
81400	81408	Pisidium fallax				8		FC			
81400	81403	Pisidium idahoense				8		FC			
81400	81424	Pisidium punctatum				8		FC			
81400	81425	Pisidium punctiferum						FC			
81400	81420	Pisidium walkeri				8		FC			
81388	81391	Sphaerium	7.7		4.7	6		GC	FC		
81391	81395	Sphaerium patella				8		FC			
81391	81398	Sphaerium striatinum						FC			
69458	69459	Gastropoda				7		SC			
76437	76568	Ancylidae				6		SC			
76568	76569	Ferrissia	6.9		5.2	6	7	SC			
76569	76573	Ferrissia hendersoni						SC			
76569	76572	Ferrissia rivularis						SC			
76569	76575	Ferrissia walkeri					7	SC			
76585	76586	Hebetancylus excentricus						SC			
76568	76576	Laevapex						SC			
76576	76578	Laevapex diaphanus						SC			
76576	76577	Laevapex fuscus	7.3		6.7			SC			
76576	76579	Laevapex peninsulae						SC			
76476	76477	Lanx				6		GC			
76437	76483	Lymnaeidae			6.9	6	6	SC			
76483	76497	Fossaria			2.6	8		SC			
76483	76484	Lymnaea				8		SC			
76483	76528	Pseudosuccinea						SC			
76528	76529	Pseudosuccinea columella	7.2					SC			
76483	76525	Radix									
76483	76534	Stagnicola	8			10	7	SC			
76437	76676	Physidae				8		SC			
76676	76677	Physa				8		SC			
76676	76698	Physella	9.1		7.6	8	8	SC			
76698	76707	Physella cubensis						SC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
76698	76724	Physella hendersoni						SC			
76698	76736	Physella heterostropha						SC			
76437	76591	Planorbidae				7		SC			
76591	76592	Gyraulus				8		SC			
76592	76593	Gyraulus circumstriatus					7	SC			
76592	76595	Gyraulus parvus			5.5			SC			
76591	76599	Helisoma						SC			
76599	76600	Helisoma anceps	6.5		6		7	SC			
76591	76626	Menetus									
76626	205210	Menetus dilatatus	8.4		8.1			SC			
76591	76643	Micromenetus						SC			
76643	76648	Micromenetus dilatatus						SC			
76643	76646	Micromenetus floridensis						SC			
76591	76654	Planorbella				6		SC			
76654	76662	Planorbella duryi						SC			
76654	76667	Planorbella pilsbryi			7.4						
76654	76668	Planorbella scalaris						SC			
76671	205212	Planorbella trivolvis			9.5			SC			
76591	76621	Promenetus						GC			
76591	76673	Vorticifex				8		SC			
76673		Vorticifex effusa				6		SC			
77064	77300	Limacidae									
70160	70163	Neritina reclivata						SC			
70745	70747	Amnicola	4.8			5		SC			
70747	70764	Amnicola dalli						SC			
70747		Amnicola grana					8	SC			
70764	205008	Amnicola dalli johnsoni						SC			
70747	70748	Amnicola limosa					8	SC			
70745	70778	Fluminicola				5		SC			
70778	70782	Fluminicola hindsi				5		SC			
	71549	Pleurocera			3.7						
70298	70493	Hydrobiidae			7			SC			
		Pyrgulopsis idahoensis				8		SC			
70493	70509	Cincinnatia						SC			
70509	70513	Cincinnatia floridana						SC			
70493	70643	Fontelicella				8		SC			
70493	70527	Littoridinops						SC			
70527	70530	Littoridinops monroensis						SC			
70633	70634	Notogillia wetherbyi						SC			
70493	205005	Potamopyrgus				10		SC			
205005	205006	Potamopyrgus antipodarum				8		SC			
70699	70700	Pyrgophorus platyrachis						SC			
70712	70713	Rhapinema dacryon						SC			
	70548	Somatogyrus	6.5								
70548	70582	Somatogyrus walkerianus						SC			
70493	70702	Spilochlamys						SC			
70702	70703	Spilochlamys conica						SC			
71541	71654	Elimia	2.5		3.6		2	SC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
71654	71858	Elimia athearni						SC			
71654	71746	Elimia curvicostata						SC			
71654	71761	Elimia floridensis						SC			
71541	71542	Goniobasis									
71541	71570	Juga				7		SC			
71541	71601	Leptoxis	1.6								
70298	71531	Thiaridae						SC			
71531	71532	Melanoides						SC			
71532	71533	Melanoides tuberculata						SC			
70298	70345	Valvatidae						SC			
70345	70346	Valvata				8		SC			
73194	73195	Marisa cornuarietis									
70342	70343	Pomacea paludosa						SC			
331584	70304	Viviparidae				6		SC			
331600	70311	Campeloma						SC			
70311	70312	Campeloma decisum	6.7			6		SC			
70311	70322	Campeloma floridense						SC			
70311	70315	Campeloma geniculum						SC			
70311	70317	Campeloma limum						SC			
70333	70336	Lioplax pilsbryi						SC			
331585	70305	Viviparus						SC			
70305	70307	Viviparus georgianus						SC			
202423	64357	Annelida						GC			
64357	68422	Oligochaeta				5		GC			
68498	69069	Lumbricina				8		GC			
68422	69168	Branchiobdellida									
69168	69169	Branchiobdellidae				6		GC			
69069	69080	Glossoscolecidae					10	GC			
69069	69165	Lumbricidae					10	GC			
68498	68499	Sparganophilidae									
68509	68510	Enchytraeidae	10			10	10	GC			
68509	68854	Naididae						GC			
68423	68424	Aeolosoma									
68854	68967	Allonais						GC			
68967	68971	Allonais inequalis						GC			
68854	69021	Bratislavia						GC			
69021	69022	Bratislavia bilongata						GC			
69021	69023	Bratislavia unidentata						GC			
68934	68935	Chaetogaster diaphanus									
68854	68898	Dero	10				10	GC			
68898	555636	Dero botrytis						GC			
68898	68904	Dero digitata						GC			
68898	68902	Dero flabelliger						GC			
68898	68912	Dero furcata						GC			
68898	68924	Dero lodeni						GC			
68898	68900	Dero nivea						GC			
68898	68907	Dero obtusa						GC			
68898	68923	Dero pectinata						GC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
68898	68903	Dero trifida						GC			
68898	68915	Dero vaga						GC			
69003	69004	Haemonais waldvogeli						GC			
	68946	Nais	9.1								
68946	68949	Nais behningi						GC			
68946	68950	Nais communis						GC			
68946	68952	Nais elinguis						GC			
68946	68954	Nais pardalis						GC			
68946	68956	Nais pseudobtusa						GC			
68946	68957	Nais simplex						GC			
68946	68959	Nais variabilis						GC			
68862	68863	Paranais litoralis						GC			
68854	68876	Pristina	9.9					GC			
68876	68879	Pristina aequiseta						GC			
68876	68880	Pristina breviseta						GC			
68876	68881	Pristina foreli						GC			
68876	68894	Pristina leidyi						GC			
68876	68893	Pristina longisoma						GC			
68876	68887	Pristina osborni						GC			
68876	68891	Pristina plumaseta						GC			
68876	68878	Pristina sima						GC			
68876	68895	Pristina synclites						GC			
68854	69024	Pristinella						GC			
69024	69030	Pristinella jenkinae						GC			
69024	69025	Pristinella longisoma						GC			
69024	69026	Pristinella osborni						GC			
68854	68855	Slavina						GC			
68855	68856	Slavina appendiculata	7.1					GC			
68984	68985	Specaria josinae						GC			
69017	69018	Stephensoniana trivandrana						GC			
68871	68873	Stylaria fossularis					8	GC			
68871	68872	Stylaria lacustris	8.5					GC			
68854	69009	Vejdovskyella						GC			
69009	69010	Vejdovskyella comata						GC			
68509	69041	Opistocystidae									
68509	68585	Tubificidae				10	10	GC			
	68588	Peloscolex	8.8								
68679	68683	Aulodrilus americanus						GC			
68679	68682	Aulodrilus limnobius	5.2					GC			
68679	68680	Aulodrilus pigueti	4.7					GC			
68679	68684	Aulodrilus pluriseta					8	GC			
68619	68621	Branchiura sowerbyi	8.4					GC			
68585	68745	Haber									
68745	68746	Haber speciosus	2.8								
68660	68662	Ilyodrilus templetoni	9.4					GC			
68808	68809	Isochaetides curvisetosus	7.2					GC			
68808	68810	Isochaetides freyi	7.6								
68585	68638	Limnodrilus	9.6					GC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
68638	68653	Limnodrilus angustipenis						GC			
68638	68652	Limnodrilus cervix	10								
68638	68639	Limnodrilus hoffmeisteri	9.8					GC			
68638	68649	Limnodrilus profundicola						GC			
68638	68644	Limnodrilus udekemianus	9.7					GC			
68780	68610	Spirosperma ferox						GC			
68780	68781	Spirosperma nikolskyi	7.7								
68585	68751	Psammoryctides									
68751	68752	Psammoryctides convolutus						GC			
68793	68794	Quistradrilus multisetosus					10	GC			
68839	68844	Rhyacodrilus sodalis				10		GC			
68585	68780	Spirosperma						GC			
68780	68782	Spirosperma carolinensis					10	GC			
68585	68622	Tubifex				10		GC			
68622	68623	Tubifex tubifex	10					GC			
68439	68440	Lumbriculidae	7.3			8		GC			
68440	68473	Eclipidrilus					8				
68473	68476	Eclipidrilus palustris						GC			
68440	68441	Lumbriculus						GC			
68441	68447	Lumbriculus inconstans						GC			
68441	68444	Lumbriculus variegata						GC			
68422	69290	Hirudinea				10		PR			
69406	69407	Hirudinidae				7		PR			
69407	69408	Haemopsis				10		PR			
69408	69412	Haemopsis marmorata						PR			
69418	69421	Macrobdella ditetra									
69407	69430	Percymoorensis				10		PR			
69407	69423	Philobdella									
69437	69438	Erpobdellidae				8		PR			
69438	69439	Dina				8		PR			
69438	69449	Mooreobdella	7.8					PR			
69449	69454	Mooreobdella tetragon	9.7					PR			
69455	69456	Nephelopsis obscura						PR			
69295	69357	Glossiphoniidae				8		PR			
69388	69389	Alboglossiphonia heteroclita						PR			
69380	69390	Glossiphonia heteroclita									
69357	69358	Batracobdella						PA			
69358	69359	Batracobdella paludosa						PA			
69357	69380	Glossiphonia						PR			
555637	555638	Desserobdella phalera						PR			
69380	69381	Glossiphonia complanata						PR			
69357	69396	Helobdella				6		PA	PR		
	204822	Gloiobdella elongata						PR			
69396	69397	Helobdella elongata	9.9					PR			
69396	69401	Helobdella fusca						PA			
69396	69398	Helobdella stagnalis	6.7					PR			
69396	69399	Helobdella triserialis	8.9					PA			
69357	69363	Placobdella				6		PR			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
69363	69367	Placobdella multilineata						PR			
69363	69364	Placobdella papillifera	9					PA			
69363	69365	Placobdella parasitica	6.6					PA			
	69374	Batracobdella phalera	7.1								
69363	69372	Placobdella translucens						PA			
69357	69375	Theromyzon				10		PR			
69315	69316	Myzobdella lugubris						PR			
69296	69304	Piscicola				10		PR			
69304	69309	Piscicola salmositica				7		PR			
		Acari						PR			
		Acariformes						PR			
		Corticacarus delicatus				8		PR			
83538	83544	Oribatei									
		Parasitengona									
		Protzia californensis				8		PR			
82754	82769	Trombidiformes									
82862	82864	Arrenurus						PR			
82864	82907	Arrenurus apetiolatus						PR			
82864	82953	Arrenurus bicaudatus						PR			
82864	205790	Arrenurus hovus						PR			
82864	205791	Arrenurus problecornis						PR			
82864	205792	Arrenurus zapus						PR			
83434	83435	Albia						PR			
83176	83177	Clathrosperchon						PR			
82770	82771	Halacaridae									
82770	83122	Hydrachnidae									
83122	83123	Hydrachna						PR			
83224	83225	Hydrodroma						PR			
82770	83281	Hygrobatidae				8		PR			
83281	83282	Atractides						PR			
83281	83297	Hygrobates						PR			
83297	83310	Hygrobates occidentalis				8		PR			
83499	83500	Geayia									
83499	83502	Krendowskia									
82770	83033	Lebertiidae				8		PR			
83033	83034	Lebertia				8		PR			
83050	205794	Centrolimnesia						PR			
83050	83051	Limnesia						PR			
83145	83146	Limnochares						PR			
83476	83479	Mideopsis						PR			
83239	83240	Frontipoda						PR			
83239	83244	Oxus						PR			
82770	83159	Piersigiidae				8		PR			
83330	83350	Piona						PR			
83164	83172	Wandesia									
82770	83005	Sperchonidae				8		PR			
83005	83006	Sperchon						PR			
83006		Sperchon pseudoplumifer				8		PR			

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
83005	83029	Sperchonopsis						PR			
83249	83254	Torrenticola						PR			
83072	83093	Koenikea									
83093	205798	Koenikea angulata									
83093	193512	Koenikea aphrasta									
83093	193513	Koenikea elaphra									
83099	205797	Koenikea spinipes carella									
83072	83103	Neumania						PR			
83103	83106	Neumania distincta						PR			
83072	83073	Unionicola						PR			
82697	83677	Crustacea				8		GC			
95495	95599	Decapoda				8		SH			
98789	98790	Rhithropanopeus harrisii									
97250	97251	Potimirim potimirim									
96106	96213	Palaemonidae									
96213	96220	Macrobrachium									
96220	96225	Macrobrachium acanthurus									
96220	96221	Macrobrachium ohione									
96213	96383	Palaemonetes									
96383	96396	Palaemonetes kadiakensis					4	OM			
96383	96385	Palaemonetes paludosus					4				
97306	97324	Astacidae	7.2			8		SC			
97324	97325	Pacifastacus				6		OM			
97325		Pacifastacus cambilii				6		SH			
97325	97328	Pacifastacus connectens				6		SH			
97325	97326	Pacifastacus leniusculus				6		SH			
97306	97336	Cambaridae					6	GC			
97336	97337	Cambarus	8.1								
97336	97421	Orconectes	2.7								
97421	97423	Orconectes limosus					6	SH			
97336	97490	Procambarus	9.5								
97490	97492	Procambarus acutus					9	SH			
97490	97498	Procambarus alleni									
97490	97514	Procambarus fallax									
97490	97555	Procambarus pygmaeus									
97490	97566	Procambarus spiculifer									
89802	93294	Amphipoda				4		GC			
93584	93589	Corophium						FC			
93589	93594	Corophium lacustre						FC			
93641	93642	Grandidierella bonnieroides						GC			
95080	95081	Crangonyx	8				4	GC			
95081	95088	Crangonyx richmondensis						OM			
95081	193517	Crangonyx serratus	8.1					GC			
93295	93745	Gammaridae						GC			
93745	93747	Anisogammarus				4		GC			
	97160	Argis	8.7	8							
93745	93773	Gammarus				4		OM			
93773	93780	Gammarus fasciatus	6.9				6	GC			

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
93773	93789	Gammarus lacustris						OM			
93773	93781	Gammarus tigrinus						GC			
	93862	Stygonectes									
93947	93949	Synurella chamberlaini						GC			
94022	94025	Hyalella				8		GC			
94025	94026	Hyalella azteca	7.9	8			8	GC			
93295	95032	Talitridae				8		GC			
89802	92120	Isopoda				8		GC			
92148	92149	Cyathura polita						GC			
92650	92657	Asellidae						GC			
92657	92658	Asellus	9.4	8		8		GC			
92658	92659	Asellus occidentalis				8		GC			
92657	92686	Caecidotea				8	6	GC			
92686		Caecidotea attenuatus					6				
92686		Caecidotea communis				6		GC			
92686	92701	Caecidotea forbesi					6				
92686	92692	Caecidotea racovitzai					6				
92692	92695	Caecidotea racovitzai australis						GC			
92657	92666	Lirceus	7.7				8	GC			
	92977	Munna reynoldsi						GC			
92973	92976	Uromunna reynoldsi						GC			
93207	93209	Probopyris floridensis						GC			
93132	93133	Probopyus pandalicola						GC			
92224	92225	Cirolanidae						GC			
92225	541967	Anopsilana						GC			
92345	92348	Cassidinidea ovalis						GC			
92283	92301	Exosphaeroma						GC			
92283	92337	Sphaeroma						GC			
92337	92338	Sphaeroma destructor						GC			
92337	92342	Sphaeroma terebrans						GC			
206378	206379	Oniscus asellus									
92623	92624	Edotea montosa						GC			
92564	92588	Idotea						GC			
89802	89807	Mysidacea									
89856	90138	Mysidopsis						FC			
89856	90041	Mysis									
90275	90277	Taphromysis bowmani						FC			
89802	91061	Tanaidacea						FG			
	92068	Hargeria rapax						FC			
92026	92067	Leptochelia rapax									
	91502	Tanais cavolinii (part)									
	91396	Tanais cavolinii (part)									
	91400	Tanais cavolinii (part)									
	91519	Tanais cavolinii (part)									
83677	85257	Copepoda				8		GC			
83677	84195	Ostracoda				8		GC			
83767	83832	Cladocera				8		FC			
83872	83873	Daphnia				8		FC			

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89599	89600	Balanus						FC			
89600	89621	Balanus eburneus						FC			
85780	85801	Diaptomus pribilofensis									
85257	88530	Cyclopoida				8		FC			
84409	84763	Entocytheridae									
82697	99208	Insecta									
99209	99237	Collembola				10		GC			
99239	99240	Podura						GC			
99240	99241	Podura aquatica									
99917	99918	Hypogastrura						GC			
99238	99245	Isotomidae						OM			
99245	99246	Isotomurus						GC			
99246	99247	Isotomurus palustris						GC			
99238	99643	Entomobryidae						GC			
100257	100258	Sminthuridae									
100258	100402	Bourletiella						GC			
100402	100436	Bourletiella spinata									
100500	100502	Ephemeroptera						GC			
		Polymitarcidae				2		GC			
101569	101570	Ephoron				2		GC		bu	
101570	101572	Ephoron leukon	1.5	2							
101459	101467	Caenidae				7		GC			
101467	101468	Brachycercus	3.5	3				GC			
101468	101475	Brachycercus maculatus						GC			
101468	101477	Brachycercus prudens				3		GC			
101467	101478	Caenis	7.6	7	3.1	7	7	GC		sp	cb
101478	101480	Caenis amica						OM			
101478	101488	Caenis latipennis				7		GC	SC		
101478		Caenis macafferti					7	GC			
101478	101483	Caenis diminuta						OM			
101478	101486	Caenis hilaris						OM			
101478	101489	Caenis punctata					7	GC			
101508	101525	Ephemeridae				4		GC			
101525	101526	Ephemera	2.2	1	3.1	4		GC		bu	
101526		Ephemera guttalata	0								
101525	101537	Hexagenia	4.7	6	3.6	6	6	GC		bu	
101537	101538	Hexagenia bilineata						GC			
101537	101552	Hexagenia limbata			2.6			GC			
101540	101549	Hexagenia munda orlando						GC			
101566	101567	Litobrancha recurvata	0	6							
100503	100755	Baetidae				4	4	GC			
	100801	Acentrella				4	4	GC		sw	cn
100801		Acentrella amplus	3.6								
100801		Acentrella insignificans				4		GC			
100801		Acentrella turbida				4		GC			
		Acerpenna					4	SH		sw	cn
		Acerpenna macdunnoughi			1.1		4	SH			
	206620	Acerpenna pygmaeus	3.7	4	2.3			OM			

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100755	100800	Baetis			3.1.	5	6	GC		sw	cb
100800		Baetis diphetorhageni									
100800	206621	Baetis alachua						OM			
100800	100803	Baetis alius				1		GC	SC		
100800	100821	Baetis australis						OM			
100800	100823	Baetis bicaudatus						GC			
100800	100833	Baetis ephippiatus	3.9					OM			
100800	100835	Baetis flavistriga	7.2	4	2.9	4		GC			
100800	100838	Baetis frondalis	8	5				OM			
100800	100807	Baetis insignificans						GC			
100800	100808	Baetis intercalaris	5.8	6	2.7	5	6	OM	GC		
100800	100810	Baetis intermedius						GC			
100800		Baetis notos				4		GC	SC		
100800	100858	Baetis pluto	4.8								
100800	100860	Baetis propinquus	6.2	6				OM			
100800	100861	Baetis pygmaeus						OM			
100800	100817	Baetis tricaudatus	1.8					GC			
100800	206618	Baetis armillatus			1.5			OM			
100800	206619	Baetis punctiventris						OM			
		Barbaetis						GC		sw	cn
		Plauditus									
		Plauditus cestus					4	GC			
100755	100903	Callibaetis	9.3	9	5.6	9	9	GC		sw	cn
100903	100919	Callibaetis floridanus						GC			
100903	100928	Callibaetis pretiosus						GC			
		Camelobaetidius								sw	cn
100755	100873	Centroptilum	6.3	2	2.7	2	2	GC			
100873	100884	Centroptilum hobbsi						OM			
100873	100897	Centroptilum viridocularis						OM			
100755	100756	Cloeon	7.4	4	3.5			OM		sw	cn
100756	100758	Cloeon rubropictum						OM			
		Diphetor				5		GC		sw	cn
		Diphetor hageni			2.3	5		GC			
		Fallceon quilleri						GC			
	100794	Heterocloeon	3.6					SC		sw	cn
		Labiobaetis				6		GC		sw	cn
		Labiobaetis frondalis									
		Labiobaetis propinquus				6		GC			
	100899	Paracloeodes	8.7					SC			
	206622	Procloeon						OM	GC	sw	cn
206622	206617	Procloeon rubropictum						OM			
206622	206623	Procloeon viridocularis						OM			
100755	100771	Pseudocloeon	4.4	4	1.7	4		SC			
100771	100776	Pseudocloeon bimaculatum						OM			
100771	100783	Pseudocloeon parvulum						OM			
100771	100784	Pseudocloeon punctiventris						OM			
		Ametropodidae									
101073	101074	Ametropus						GC		bu	

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100503	100504	Heptageniidae				4		SC			
100504	100598	Cinygma				4		SC		cn	
100598	100600	Cinygma integrum						SC			
100504	100557	Cinygmula				4		SC		cn	
100557	100570	Cinygmula subaequalis	0								
100504	100626	Epeorus	1.2	0		0		SC		cn	
100626		Epeorus iron				0		SC			
100626		Epeorus ironopis				1		SC			
100626	100629	Epeorus albertae				0		SC			
100626	100632	Epeorus deceptivus				0		SC			
100626	100651	Epeorus dispar	1								
100626	100635	Epeorus grandis				0		SC			
100626	100637	Epeorus longimanus				0		SC			
100626	100642	Epeorus pleuralis	2								
100626	100645	Epeorus rubidus	1.4								
100627	100636	Ironopsis grandis				3		SC			
100504	100602	Heptagenia	2.8	3		4		SC		cn	sw
100602	100694	Heptagenia criddlei						SC			
100602	100608	Heptagenia diabasia			1.9						
100602	100604	Heptagenia elegantula				4		SC			
100602	100610	Heptagenia flavescens						OM			
100602	100612	Heptagenia julia	0.5								
100602	100616	Heptagenia marginalis	2.5								
100602	100619	Heptagenia pulla	2.3								
100602	100620	Heptagenia simpliciodes						SC			
100504	100666	Ironodes				4		SC		cn	
100504	100676	Leucrocuta	0	1	2.4	1		SC	GC	cn	
100676		Leucrocuta aphrodite	2.5	1							
100676	100677	Leucrocuta hebe			2.7						
100676	100679	Leucrocuta maculipennis			2.1						
100504	100692	Nixe				4		SC	GC	cn	
100692		Nixe simplicioides				2		SH			
100692	100693	Nixe criddlei				2		SH			
100692	100705	Nixe perfida			5.1						
100504	100572	Rhithrogena	0.4	0		0		SC		cn	
100572	100577	Rhithrogena amica	0								
100572	100579	Rhithrogena exilis	0								
100572	100595	Rhithrogena fuscifrons	0								
100572	100583	Rhithrogena hageni						GC			
100572	100575	Rhithrogena morrisoni						SC			
100572	100589	Rhithrogena robusta						GC			
100504	100713	Stenacron			3.1		4	SC		cn	
100713	100735	Stenacron carolina	1.7								
100713	100739	Stenacron floridense						OM			
100713	100714	Stenacron interpunctatum	7.1	7				OM			
100713	100736	Stenacron pallidum	2.9								
100504	100507	Stenonema				2	4	SC		cn	
100507	100513	Stenonema carlsoni	2.1								

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
100507	100514	Stenonema exiguum			1.9			OM			
100507	100516	Stenonema femoratum	7.5	5	3.1						
100507	100521	Stenonema integrum	5.5	4				OM			
100507	100527	Stenonema ithaca	4.1								
100507		Stenonema lenati	2.3								
100507	100530	Stenonema mediopunctatum	1.7	3	1.9						
100507	100531	Stenonema meririvulanum	0.3								
100507	206616	Stenonema mexicanum integrum			2.6			OM			
100507	100532	Stenonema modestum	5.8	1				SC			
100507	100536	Stenonema pudicum	2.1								
100507	100509	Stenonema pulchellum			2.3						
100507	100541	Stenonema smithae						OM			
100507	100542	Stenonema terminatum	4.5	4	2.3						
100507	100548	Stenonema vicarium	1	2	2.3						
100503	100951	Siphlonuridae				7		GC			
	100953	Siphlonurus	2.6	7		7		GC		sw	cb
100953	100955	Siphlonurus occidentalis				7		GC	SC		
		Acanthametropodidae									
100951	100996	Ameletus				0		GC		sw	cb
100996	101019	Ameletus celer				0		GC	SC		
100996	101009	Ameletus lineatus	2.1	0							
100996	101012	Ameletus similior						GC			
100996	101005	Ameletus connectus						GC			
100996	101006	Ameletus cooki				0		GC			
100996	101013	Ameletus sparsatus						GC			
100996	101002	Ameletus validus						GC			
100996	101003	Ameletus velox				0		GC			
101094	101232	Ephemerellidae				1		GC			
101232	101338	Attenella				3		GC			
101338	101340	Attenella attenuata	2.6	3							
101338	101345	Attenella delantala				3		GC			
101338	101343	Attenella margarita						GC			
101232	101347	Caudatella				1		GC		cn	
101347		Caudatella cascadia				1		GC			
101347		Caudatella edmundsi						SC			
101347	101351	Caudatella heterocaudata						GC			
101347	101348	Caudatella hystrix						SC			
		Caurinella				0		GC			
		Caurinella idahoensis				0		GC			
101232	101365	Drunella				0		PR		cn	sp
101365		Drunella allegheniensis	1.3								
101365	101389	Drunella coloradensis						PR			
101365		Drunella conestee	0								
101365	101366	Drunella cornutella	0								
101365	101368	Drunella doddsi						SC			
101365	101392	Drunella flavilinea						SC			
101365	101370	Drunella grandis						GC			
101365	185972	Drunella lata	0.1								

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
101365		Drunella pelosa						SC			
101365	101385	Drunella spinifera						PR			
101365	185974	Drunella tuberculata	0.2								
101365	185973	Drunella walkeri	1								
101365		Drunella wayah	0								
101232	101233	Ephemerella			2.9	1		GC		cn	sw
101233	101251	Ephemerella alleni						GC			
101233	101255	Ephemerella aurivillii						GC			
101233	101259	Ephemerella berneri	0								
101233	101262	Ephemerella catawba	4	1							
101233	101280	Ephemerella hispida	0.6								
101233	101239	Ephemerella inermis						SH			
101233	101240	Ephemerella infrequens						GC			
101233	101282	Ephemerella invaria	2.2	1							
101233	101285	Ephemerella lacustris				1		GC			
101233	101291	Ephemerella needhami	0	2							
101233	101296	Ephemerella rotunda	2.8					OM			
101233	101299	Ephemerella septentrionalis	2								
101233	101305	Ephemerella trilineata						OM			
101232	101324	Eurylophella			2.1		4	SC		cn	sp
101324	101334	Eurylophella bicolor	5.1	1							
101324		Eurylophella coxalis	2.6								
101324		Eurylophella doris						GC			
101324	101332	Eurylophella funeralis	2.3								
101324	101326	Eurylophella temporalis	4.6	5				GC			
101324	193519	Eurylophella trilineata						GC			
101324		Eurylophella verisimilis	0.3								
101232	101395	Serratella			0.6	2	2	GC		cn	
101395		Serratella carolina	0								
101395	101396	Serratella deficiens	2.7	2	2.1		2				
101395		Serratella micheneri				1		GC			
101395	185976	Serratella serrata	2.7			1		GC			
101395	185975	Serratella serratoides	1.5								
101395		Serratella teresa						GC			
101395	101399	Serratella tibialis						GC			
	101317	Timpanoga				7		GC			
101317	101318	Timpanoga hecuba				7		GC			
101360	101361	Dannella lita	0	4							
101360	101363	Dannella simplex	3.9	2	1.2						
101094	101095	Leptophlebiidae				2		GC			
101095	101108	Choroterpes			4			GC		cn	sp
101108	101114	Choroterpes hubbelli						OM			
101095	101183	Habrophlebia								sw	cn
101183	101184	Habrophlebia vibrans	0					OM			
101095	101122	Habrophlebiodes								sw	cn
101122	101124	Habrophlebiodes brunneipennis									
101095	101148	Leptophlebia	6.4	4		2		GC		sw	cn
101148		Leptophlebia bradleyi						OM			

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
101148	101161	Leptophlebia intermedia						OM			
101095	101187	Paraleptophlebia	1.2	1	2.8	1	1	GC		sw	cn
101187	101206	Paraleptophlebia bicornuta				4		GC			
101187	101193	Paraleptophlebia debilis						GC			
101187	101195	Paraleptophlebia gregalis				4		GC			
101187	101212	Paraleptophlebia heteronea				2		GC			
101187	101214	Paraleptophlebia memorialis				4		GC			
101187	101227	Paraleptophlebia vaciva				4		GC			
101187	101199	Paraleptophlebia volitans						OM			
101094	101404	Tricorythidae				4		GC			
101404	101405	Tricorythodes	5.4	4	2.7	5	4	GC		sp	cn
101405	101406	Tricorythodes albilineatus						GC			
101405	101413	Tricorythodes minutus				4		GC			
	101429	Leptohyphes	2							cn	
101429	101432	Leptohyphes dolani									
		Baetiscidae									
101493	101494	Baetisca					4	GC		sp	
101494	101497	Baetisca becki						OM			
101494		Baetisca berneri	0.6								
101494	101499	Baetisca carolina	3.6	5							
101494	101503	Baetisca gibbera	1.4								
101494	101495	Baetisca obesa						OM			
101494	101506	Baetisca rogersi						OM			
		Metretopodidae									
		Siphloplectron	3.1	2			2	PR		sw	cn
		Isonychiidae									
101029	101041	Isonychia	3.8	2	1.9		2	FC		sw	cn
101041	101069	Isonychia arida									
101041	101060	Isonychia sayi									
101041	101062	Isonychia sicca									
		Neoephemeridae									
101460	101461	Neoephemera						GC		sp	cn
101461	101463	Neoephemera compressa						GC			
101461	101464	Neoephemera purpurea	2.1								
101461	101465	Neoephemera youngi						GC			
101523	101524	Dolania americana								bu	
		Anthopotamus			3.2						
	101510	Potamanthus	1.6	4							
109215	109216	Coleoptera						PR			
111952	111953	Amphizoa				1		PR		cn	
109226	109234	Carabidae				4		PR			
109234	111436	Chlaenius									
109226	111963	Dytiscidae				5		PR			
112072	112073	Agabetes acuductus						PR			
111963	111966	Agabus				8	5	PR		sw	dv
111963	112319	Bidessonotus								sw	cb
111963	112322	Bidessus									
111963	112362	Brachyvatus								sw	cb

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
111963	112136	Celina					5	PR		sw	dv
112136	112142	Celina contiger						PR			
	112379	Colymbetes				5		PR		sw	dv
111963	112561	Copelatus	9.1				5	PR		sw	dv
112561	112567	Copelatus caelatipennis						PR			
111963	112371	Coptotomus	9					PR		sw	dv
112371	112375	Coptotomus interrogatus						PR			
111963	112364	Cybister						PR		sw	dv
111963	112153	Deronectes				5		PR		sw	
112153		Deronectes striatellus						PR			
111963	112159	Derovatellus								sw	cb
111963	112145	Desmopachria				5		PR		sw	cb
	112118	Dytiscus				5		PR		sw	dv
111963	112172	Hydaticus				5		PR		sw	dv
111963	112390	Hydroporus	8.9		4.1	5	5	PR		sw	cb
112390	112423	Hydroporus mellitus	1.8								
112390	112418	Hydroporus pilatei						PR			
111963	112257	Hydrovatus						PR			
112257	112259	Hydrovatus pustulatus						PR			
112257	112259	Hydrovatus pustulatus						PR			
112259	112261	Hydrovatus pustulatus compressus						PR		sw	cb
111963	112200	Hygrotus						PR		sw	dv
111963	112181	Ilybius					5	PR			
111963	112268	Laccodytes						PR		sw	dv
111963	112278	Laccophilus	10		7.9	5	5	PR			
112278	112281	Laccophilus fasciatus						PR			
112281	112283	Laccophilus fasciatus rufus						PR			
112278	112299	Laccophilus gentilis						PR			
112278	112285	Laccophilus proximus						PR			
112278	112298	Laccophilus schwarzi						PR			
112270	112276	Laccornis difformis								sw	cb
111963	112580	Liodessus						PR		sw	cb
111963	112595	Neoclypeodytes						PR		sw	cb
111963	112314	Oreodytes				5		PR			
112314		Oreodytes congruus				5		PR		sw	dv
111963	112086	Rhantus									
112109	112113	Thermonectus basillaris						PR		sw	cb
111963	112575	Uvarus									
109226	112653	Gyrinidae				5		PR		sw	dv
112653	112711	Dineutus	5.5		3.7	4	4	PR			
112711	112718	Dineutus carolinus									
112711	112715	Dineutus ciliatus									
112711	112713	Dineutus discolor									
112711	112727	Dineutus emarginatus									
112711	112719	Dineutus nigrior					4	PR			
112711	112717	Dineutus serrulatus								sw	dv
112653	112706	Cyretes									
112706	112707	Cyretes iricolor								sw	dv

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112653	112654	Gyrinus	6.3		3.6	5	4	PR			
112654	112661	Gyrinus aeneolus					4	PR			
112654	112704	Gyrinus lugens									
112654	112701	Gyrinus pachysomus									
109226	111857	Haliplidae				7				cn	
111857	111947	Brychius						SC			
111947	111948	Brychius hornii								cb	
111857	111858	Haliplus									
111858	111872	Haliplus fasciatus					5	SH		cb	cn
111857	111923	Peltodytes	8.5		7		5	SH			
111923	111926	Peltodytes duodecimpuntatus									
111923	111927	Peltodytes floridensis									
111923	111928	Peltodytes lengi									
111923	111929	Peltodytes muticus									
111923	111930	Peltodytes oppositus									
111923	111932	Peltodytes sexmaculatus									
109226	112606	Noteridae						PR		cb	
112606	112623	Hydrocanthus	6.9								
112623	112626	Hydrocanthus iricolor						OM			
112623	112624	Hydrocanthus oblongus						OM		bu	
112606	112621	Notomicrus									
112636	193587	Suphis inflatus								cb	
112606	112607	Suphisellus						OM			
112607	112614	Suphisellus floridanus						OM			
112607	112613	Suphisellus gibbulus									
112607	193586	Suphisellus insularis						OM			
112607	112610	Suphisellus puncticollis						OM			
	112745	Hydroscapha				7		SC			
112736	112737	Sphaeriidae				8	8	FC			
114496	114509	Chrysomelidae						SH		cn	
114509	114613	Agasicles									
114613	114614	Agasicles hygrophila						SH		cn	
114509	114615	Disonycha						SH		cn	
114509	114510	Donacia						SH		cn	
114509	114546	Pyrrhalta									
113844	113869	Melyridae						PR			
114654	114666	Curculionidae						SH		cn	cb
114666	114667	Anchytarsus						SH			
114667	114668	Anchytarsus bicolor	3.8					SH		sp	cn
	114037	Lutrochus									
114037	114038	Lutrochus laticeps			2.9					cn	
114666	114779	Bagous						SH			
114779		Bagous carinatus						SH		cn	cb
114666	114676	Phytobius						SH			
	114679	Stenopelmus						SH			
206639	206640	Tyloderma capitale									
113918	113923	Helodidae (= Scirtidae)									
	113924	Scirtidae								cb	

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
113923	113948	Cyphon					7	SC		cb	sp
113923	113969	Elodes								cb	sp
113923	113925	Prionocyphon								cb	
113923	113929	Scirtes									
113998	114278	Chelonariidae									
114278	114279	Chelonarium lecontei									
113998	113999	Dryopidae (adult)						SH		cb	
113999	114025	Dryops (adult)								cn	
113999	114006	Helichus (adult)	5.4	5	3.2		5	SH			
114006	114011	Helichus basalis (adult)									
114006	114013	Helichus fastigiatus (adult)									
114006	114009	Helichus lithophilus (adult)									
114006	114017	Helichus striatus (adult)				5		SH			
114017	114019	Helichus striatus foveatus (adult)				5		SH		cb	
113999	114001	Pelonomus (adult)									
114001	114004	Pelonomus obscurus (adult)									
113998	114093	Elmidae				4		GC		cn	bu
	114196	Ampumixis				4		GC	SC	cn	bu
114196	114197	Ampumixis dispar				4		GC		cn	sp
114093	114193	Ancyronyx						OM			
114193	114194	Ancyronyx variegatus	6.9	6	4			OM		cn	
114093	114251	Atractelmis				4		GC		cn	
114093	114164	Cleptelmis				4		GC			
114164	114166	Cleptelmis addenda				4		GC	SC	cn	
114164	114165	Cleptelmis ornata				4		GC		cn	
114093	114208	Cylloepus				4		GC	SC	cn	cb
114093	114126	Dubiraphia	6.4	6	4.7	4	6	GC	SC		
114126	114129	Dubiraphia bivittata			3.1			OM			
114126		Dubiraphia giullianii				6		SC			
114126	114130	Dubiraphia quadrinotata			3.2			OM			
114126	114131	Dubiraphia vittata						OM		cn	cb
114093	114216	Gonielmis				5		GC			
114216	114217	Gonielmis dietrichi						OM		cn	
114093	114237	Heterelmis				4		GC		cn	
114093	114167	Heterlimnius				4		GC			
114167	114169	Heterlimnius corpulentus				4		GC		cn	bu
114167	114168	Heterlimnius koebelei				4		GC	SC	cn	
114093	114137	Lara				4		SH			
114137	114139	Lara avara				4		SH		cn	
114093	114212	Macronychus						OM			
114212	114213	Macronychus glabratus	4.7	4	2.9			OM		cn	cb
114093	114146	Microcylloepus				4		GC	SC		
114146	114147	Microcylloepus pusillus	2.1	3		2		GC			
114147	114151	Microcylloepus pusillus lodingi						OM			
114146	114160	Microcylloepus similis				2		GC		cn	
114093	114142	Narpus				4		GC			
114142	114144	Narpus concolor				4		GC		cn	
114093	114177	Optioservus	2.7	4	3.6	4	4	SC			

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114177	193732	Optioservus castanipennis				4		SC			
114177	114178	Optioservus divergens				4		SC			
114177	114190	Optioservus fastiditus			1.9	4	4	SC			
114177	114180	Optioservus quadrimaculatus				4		SC			
114177	114181	Optioservus seriatus				4		SC		cn	
114093	114235	Ordobrevia				4					
114235		Ordobrevia nubrifera				4		GC		cn	
114093	114244	Oulimnius				4		SC			
114244	114245	Oulimnius latiusculus	1.8							cn	
114093	114229	Promoresia					2	SC			
114229	114230	Promoresia elegans	2.2					OM			
114229	114231	Promoresia tardella	0				2	SC		cn	
114093	114198	Rhizelmis				1		SC		cn	
114093	114095	Stenelmis	5.4	5	3	7	5	SC			
114095	114117	Stenelmis antennalis						OM			
114095	114118	Stenelmis convexula						OM			
114095	114102	Stenelmis crenata						OM			
114095	114104	Stenelmis decorata					5	SC			
114095	114121	Stenelmis fuscata						OM			
114095	114105	Stenelmis humerosa						OM			
114095	114106	Stenelmis hungerfordi						SC			
114095	114108	Stenelmis markeli					5	SC			
114095	114114	Stenelmis sinuata						OM			
114095	114115	Stenelmis vittipennis						OM		cn	
114093	114205	Zaitzevia				4		GC			
114205	114207	Zaitzevia milleri				4		GC			
114205		Zaitzevia parvula				4		GC			
113998	114069	Psephenidae				4		SC		cn	
114069	114087	Ectopria				4	5	SC			
114087	114088	Ectopria nervosa	4.3	5	4			SC		cn	
114069	114085	Eubrianax				4		SC			
114085	114086	Eubrianax edwardsi				4		SC		cn	
114069	114070	Psephenus				4		SC			
114070	114074	Psephenus falli				4		SC		bu	
114070	114072	Psephenus herricki	2.5	4	3.5						
114265	114266	Anchycteis									
114266	114267	Anchycteis velutina									
114265	114273	Ptilodactyla					5	SH			
112752	112756	Hydraenidae				5		PR		cn	cb
112756	112757	Hydraena				5		PR			
112757	112758	Hydraena pennsylvanica								cn	
112756	112777	Ochthebius									
112777	112793	Ochthebius sculptus				5		PR			
112752	112811	Hydrophilidae				5		PR		sw	dv
	112890	Ametor				5					
112811	112812	Berosus	8.6		6.7	5		PR	PI		
112812	112824	Berosus peregrinus									
112812	112821	Berosus striatus								cb	

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
112811	112845	Chaetarthria				5				bu	
112811	113220	Crenitis				5		PR		bu	
112811	113017	Cymbiodyta								sw	dv
112811	113087	Derallus						OM			
113087	113088	Derallus altus						OM			
113085	113086	Dibolocelus ovatus								bu	sp
112811	112973	Enochrus	8.5			5		GC			
112973	112990	Enochrus ochraceus									
112811	113162	Helobata						OM			
113162	113165	Helobata striata						OM			
112811	113150	Helochares						OM			
112811	113106	Helophorus	7.9					SH		sw	dv
112811	113244	Hydrobiomorpha									
113244	113245	Hydrobiomorpha castus								cb	cn
112811	113196	Hydrobius				8		PR			
113196	113200	Hydrobius tumidus						OM		cb	
112811	113166	Hydrochus						SH		sw	dv
112811	113204	Hydrophilus									
112811	112858	Laccobius	8		1.9			PR			
112811	112909	Paracymus				5		PR	OM	cn	
112811	112931	Sperchopsis				5	5	PR	CG		
112931	112932	Sperchopsis tessellatus	6.5					OM		cb	
112811	112938	Tropisternus	9.8			5	10	PR			
112938	112951	Tropisternus blatchleyi									
112938	112944	Tropisternus lateralis									
112944	112946	Tropisternus lateralis nimbatus									
112938	193660	Tropisternus striolatus									
113264	113805	Ptiliidae									
113264	113265	Staphylinidae				8		PR		cn	
113265	113304	Bledius						PR		sk	
113265	113576	Stenus								bu	
113265	113440	Thinopinus									
114413	114429	Salpingidae									
109215	152741	Hymenoptera				8		PA			
109215	117232	Lepidoptera				6		SH	SC		
117294	117318	Noctuidae						SH		bu	
117915	117952	Pyroderces				5					
117639	117641	Pyralidae				5		SH		cb	
117641	117741	Acentria				1		SH		cb	
117641	117672	Munroessa						SH			
117672	117677	Munroessa gyralis						SH		cb	
117641	117756	Neargyractis						SH		cb	sw
117641	117642	Paraponyx					5	SH		cn	
117641	117682	Petrophila			2.7	5		SC		cb	sw
117654	117656	Synclita obliteralis						SH			
117906	117909	Prionoxystus				5					
117854	117856	Tortricidae									
109215	115000	Megaloptera									

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115000	115023	Corydalidae				0		PR		cn	cb
115023	115024	Chauliodes						PR			
115024	115027	Chauliodes pectinicornis						PR			
115024	115025	Chauliodes rastricornis						PR		cn	cb
115023	115033	Corydalus						PR			
115033	115034	Corydalus cornutus	5.6	6	2.4			PR		cn	cb
115023	115048	Neohermes								cn	cb
115023	115028	Nigronia						PR			
115028	115029	Nigronia fasciatus	6.2		1.8			PR			
115028	115031	Nigronia serricornis	5.5	0	3.6			PR		cn	cb
115023	115044	Orohermes				0		PR		cb	cn
115085	115086	Climacia									
115086	115087	Climacia areolaris	6.5								
115085	115090	Sisyra						PI			
115000	115001	Sialidae								bu	cb
115001	115002	Sialis	7.4	4	4.9	4	4	PR			
115002	193739	Sialis americana						PR			
115002	115017	Sialis iola						PR			
115002	115010	Sialis mohri						PR			
109215	115095	Trichoptera								sp	
		Beraeidae									
116489	116490	Beraea									
115095	116905	Brachycentridae				1		FC		cn	cb
116905	116933	Amiocentrus				1		GC			
116933	116934	Amiocentrus aspilus				2		GC		cn	
116905	116906	Brachycentrus	2.2			1		FC			
116906	116912	Brachycentrus americanus				1		FC			
116906	116921	Brachycentrus appalachia	1.1								
116906	116922	Brachycentrus chelatus	0								
116906	116914	Brachycentrus lateralis	0.4	1							
116906	116916	Brachycentrus nigrosoma	2.2								
116906	116910	Brachycentrus numerosus	1.8	1							
116906	116918	Brachycentrus occidentalis				1		FC		cn	sp
116906	116924	Brachycentrus spinae	0								
116905	116958	Micrasema				1	2		SH		
116958	116967	Micrasema bactro				1					
116958		Micrasema bennetti	0								
116958	116966	Micrasema burksi	0								
116958	116959	Micrasema charonis	0.3								
116958		Micrasema rickeri	0								
116958	116961	Micrasema rusticum	0					OM			
116958	116960	Micrasema wataga	3.2	2				OM		cn	
116905	116973	Oligoplectrum				1		GC			
115095	116529	Calamoceratidae								sp	
116529	116530	Anisocentropus						SH			
116530	116531	Anisocentropus pyraloides	0.8					SH		sp	
116537	553090	Heteroplectron americanum	2.9				3	SH			
116537	116538	Heteroplectron californicum				1		SH			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
		Uenoidae				0		SC			
115933	116331	Farula						SC			
115933	116046	Neophylax	1.6	3		3		SC			
116046	116047	Neophlax concinnus	1.2								
116046	116050	Neophlax mitchelli	0								
116046	116065	Neophylax occidentalis				3		SC			
116046	116057	Neophlax oligius	2.6								
116046	116052	Neophlax ornatus	1.6								
116046	116054	Neophylax rickeri				3		SC		cn	
116046	116063	Neophylax splendens				3		SC			
115933	116388	Neothremma				0		SC		cn	
116388	116389	Neothremma alicia				0		SC		sp	
115933	116039	Oligophlebodes				1		SC			
		Sericostriata				0		SC			
		Sericostriata surdickae				0		SC			
115095	117120	Glossosomatidae				0		SC		cn	
117120	117121	Agapetus	0			0		SC			
117120	117154	Anagapetus				0		SC		cn	
115236	115238	Culoptila cantha				0		SC		cn	
117120	117159	Glossosoma	1.5			0		SC			
117159	117165	Glossosoma penitus						SC			
117159	117167	Glossosoma alascense						SC			
117159	117162	Glossosoma intermedium				0		SC			
117159	117160	Glossosoma montana						SC			
117159	117202	Glossosoma oregonense						SC			
117159	117220	Glossosoma wenatchee						SC			
115246	115247	Matrioptila jeanae	0								
115096	115221	Protoptila	2.8	1		1		SC			
115221	183768	Protoptila coloma				1		SC			
115221	115232	Protoptila tenebrosa				1		SC		sp	
115095	117015	Helicopsychidae				3		SC		cn	
117015	117016	Helicopsyche				3		SC			
117016	117020	Helicopsyche borealis	0	3	1.8	3		SC			
115095	115398	Hydropsychidae				4	4	FC			
		Hydropsychidae									
		Arctopsychinae				2		FC		cn	
115398	115529	Arctopsyche				1		FC			
115529	115538	Arctopsyche californica				2		FC	OM		
115529	115530	Arctopsyche grandis				2		FC		cn	
115529	115533	Arctopsyche irrorata	0								
		Hydropsychinae						FC			
115398	115570	Ceratopsyche						FC		cn	
115570	115596	Ceratopsyche alhedra	0	3							
115570		Ceratopsyche bifida	1								
115570	115577	Ceratopsyche bronta	2.7	5							
115570		Ceratopsyche macleodi	0.9								
115570	115580	Ceratopsyche morosa	3.2	2	1.8						
115570	115586	Ceratopsyche slossonae	0	4	2						

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
115570	115589	Ceratopsyche sparna	3.2	1	3.2						
115570		Ceratopsyche ventura	0								
115398	115408	Cheumatopsyche	6.6	5	2.9	5	5	FC			
115408	115409	Cheumatopsyche campyla				6		FC			
115408	115441	Cheumatopsyche enonis				6		FC			
115408	115426	Cheumatopsyche pettiti				6		FC		cn	
115398	115399	Diplectrona				0		FC			
115399	115402	Diplectrona modesta	2.2					FC		cn	
115398	115618	Homoplectra								cn	
115398	115453	Hydropsyche				4	4	FC			
115453	115456	Hydropsyche aerata			2.6						
115453	115454	Hydropsyche betteni	8.1	6			4	FC			
115453	115458	Hydropsyche bidens			2.5						
115453	115455	Hydropsyche californica				4		FC			
115453	115462	Hydropsyche decalda	4.1					FC			
115453	115463	Hydropsyche demora	1.8								
115453	115465	Hydropsyche dicantha			3.5						
115453	115488	Hydropsyche elissoma						FC			
115453	115468	Hydropsyche frisoni			1.8						
115453	115469	Hydropsyche hageni	0								
115453	115471	Hydropsyche incommoda	5	7							
115453	115474	Hydropsyche mississippiensis						FC			
115453	115513	Hydropsyche occidentalis				4		FC			
115453	115485	Hydropsyche orris			2.6						
115453	115490	Hydropsyche oslari				4		FC			
115453	115477	Hydropsyche phalerata	3.7	1							
115453	206641	Hydropsyche rossi	4.9								
115453	115480	Hydropsyche scalaris	3	2							
115453	115481	Hydropsyche simulans			2.4						
115453	115527	Hydropsyche sparna					4	FC		cn	
115453	115484	Hydropsyche venularis	5.3		2.9						
115453	115482	Hydropsyche valanis			3						
115398	115603	Macrostemum	3.6	3			3	FC			
115603	115608	Macrostemum carolina						FC		cn	
115603	115606	Macrostemum zebratum			1.8						
115398	115556	Parapsyche				1		PR			
115556	115563	Parapsyche almota				3		PR			
115556	115559	Parapsyche cardis	0								
115556	115560	Parapsyche elsis				1		PR		cn	
115398	115551	Potamyia						FC			
115551	115552	Potamyia flava			2.5			FC			
115095	115629	Hydroptilidae				4				cb	
115629	115635	Agraylea			5.7	8				cn	
115629	115826	Dibusa								cn	
115826	115827	Dibusa angata			2.6						
115629	115641	Hydroptila	6.2	6	3.2	6	6	SC	PR		
115641	115643	Hydroptila ajax				6		SC			
115641	115695	Hydroptila arctia				6		SC			

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
115641	115696	Hydroptila argosa				6		SC		cn	
115629	115630	Leucotrichia				6		SC		cn	
115630	115631	Leucotrichia pictipes	4.3	2							
115629	115811	Mayatrichia				6		SC			
115811	115812	Mayatrichia ayama						SC		cn	
115629	115833	Neotrichia			3.6			SC			
115833		Neotrichia halia				4		SH		cn	
115629	115714	Ochrotrichia	7.2			4		GC		cn	
115629	115714	Ochrotrichia				4		GC		cb	
115629	115828	Orthotrichia				6		SC		cn	
115629	115779	Oxyethira			5.2						
115629	115817	Stactobiella				2		SH		cb	sp
		Limnephiloidea									
115095	116793	Lepidostomatidae				3		SH			
116793	116794	Lepidostoma	1	1		1	1	SH			
116794	116888	Lepidostoma cinereum				3		SH			
116794	116870	Lepidostoma quercinum				1		SH		sp	cb
115095	116547	Leptoceridae				4		GC		cb	sw
116547	116684	Ceraclea			2.6	5	3	GC		cn	sp
116684	116696	Ceraclea ancylus	2.5	3							
116684		Ceraclea flava	0								
116684	116725	Ceraclea maculata	6.4		3.6						
116684		Ceraclea transversa	2.7								
116547	116598	Mystacides				4	4	GC			
116598	116599	Mystacides sepulchralis	3.5	4							
116547	116651	Nectopsyche			2.4	3	3	SH			
116651	116661	Nectopsyche candida	3.8					OM			
116651	116663	Nectopsyche diarina			3.2						
116651	116659	Nectopsyche exquisita	4.2	3				OM			
116651	116662	Nectopsyche gracilis				3		SC			
116651	116660	Nectopsyche pavida	4.2		2.1			OM			
116651		Nectopsyche halia				3		SC			
116651		Nectopsyche lahontanensis				3		SC		sp	cb
116651		Nectopsyche stigmatica				3		SC		sp	cb
116547	116607	Oecetis	5.7	8	3	8	8	PR			
116607		Oecetis parva									
116607	116608	Oecetis avara									
116607	116609	Oecetis cinerascens									
116607	116643	Oecetis georgia					8				
116607	116613	Oecetis inconspicua					8				
116607	116631	Oecetis nocturna								sp	cn
116607	116636	Oecetis persimilis					8			sw	cb
116547	116548	Setodes	0.9	2				OM			
116547	116565	Triaenodes				6	6				
116565	206642	Triaenodes abus	4.3					SH			
116565	116569	Triaenodes flavescens						SH			
116565	206643	Triaenodes florida						SH			
116565	116571	Triaenodes ignitus						SH			

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
116565	116574	Triaenodes injusta	2.2								
116565	116575	Triaenodes marginatus				6	6	sh			
116565	116577	Triaenodes ochraceus						SH			
116565	206644	Triaenodes perna						SH			
116565	116580	Triaenodes tardus	4.7	6				SH			
115095	115933	Limnephilidae				4	4	SH			
115969	115970	Allocosmoecus partitus				0		SC		cn	cb
115867	115907	Cryptochia				0		SH			
	116438	Allomyia				0		SC			
115933	116253	Amphicosmoecus						SH		sp	
	115956	Anabolia						SH			
115933	115935	Apatania	0.6			1		SC			
		Apataniinae				1		SC			
	116247	Arctopora									
115933	116017	Chyranda				1		SH		sp	
116017	116018	Chyranda centralis				1		SH		sp	bu
115933	116013	Clostoeca						SH		sp	
115933	.116023	Desmona				1		SH			
		Dicosmoecinae				1		SC			
115933	116265	Dicosmoecus				1		SH			
116265	116266	Dicosmoecus atripes				1		PR		bu	
116265	116268	Dicosmoecus gilvipes				2		SC		cn	
116340	116342	Ecclisocosmoecus scylla				0		SH			
115933	116025	Ecclisomyia				2		GC			
		Eocosmoecus						SH		sp	
		Eocosmoecus schmidi						SH			
115933	116030	Glyphopsyche				1				cn	
115933	116309	Grammotaulius				4		SH		sp	
115933	116295	Grensia				6		SH			
115933	116001	Hesperophylax				5		SH		sp	cb
115933	116286	Homophylax				0		SH			
115933	115995	Hydatophylax				1		SH			
115995	115997	Hydatophylax argus	2.3	2				SH		sp	
115933	116381	Imania						SC		cb	sp
115933	116382	Ironoquia								cn	
116382	116385	Ironoquia punctatissima	7.3	3							
		Limnephilinae				4		SH		sp	
115933	116069	Limnephilus				5		SH		sp	
115933	116344	Manophylax						SC		cn	
115933	116379	Moselyana				4		GC		cn	
115933	116315	Onocosmoecus				1		SH			
116315	116318	Onocosmoecus unicolor				2		SH		cb	
115972	115973	Pedomoecus sierra				0		SC		sp	
115933	116407	Platycentropus									
	115989	Pseudostenophylax				1		SH			
115933	115974	Psychoglypha				1		GC			
115974	115977	Psychoglypha bella				2		GC		sp	cb
115974	115981	Psychoglypha subborealis				2		GC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
115933	116409	Pycnopsyche	2.3	4	3.3		4	SH			
116409	116413	Pycnopsyche gentilis	0.8								
116409	116414	Pycnopsyche guttifer	2.7					SH		sp	cn
116409	116416	Pycnopsyche lepida	2.5								
116409	116417	Pycnopsyche scabripennis	4					SH			
	116473	Molannidae									
116473	116474	Molanna					6	SC		sp	
116474	116478	Molanna blenda	3.9		4						
116474	116479	Molanna tryphena								sp	
	116496	Odontoceridae									
116496	116520	Namamyia				0		OM	GC		
116496	116522	Nerophilus				0		OM		sp	
116522	116523	Nerophilus californicus				0		OM		sp	
116496	116527	Pseudogoera				0		OM	PR		
116496	116497	Psilotreta	0	0			0	SC			
116497	116498	Psilotreta frontalis								cn	
115095	115257	Philopotamidae				3	3	FC		cn	
115257	115273	Chimarra	2.8	4			4	FC		cn	
	115278	Chimarra aterrima			1.9						
	115276	Chimarra obscura			3.4						
115257	115319	Dolophilodes	1			1		GC			
115257	115258	Wormaldia	0.4			3		FC			
115258	115261	Wormaldia gabriella						SC			
115095	115867	Phryganeidae						SH		cb	
	115892	Phryganea				4		OM			
115867	115868	Ptilostomis	6.7	5			5	SH		cn	
		Goerinae				1		SC			
115933	116423	Goera	0.3							sn	
116423	116431	Goera archaon				1		SC		sb	
115933	116298	Goeracea				0		SC		sp	
		Goereilla						SH			
115095	117043	Polycentropodidae						FC		cn	
115334	115373	Cernotina						PR		cn	
115373	115375	Cernotina spicata						PR			
117043	117091	Cyrnellus						FC		cn	
117091	117092	Cyrnellus fraternus	7.4	8	4			FC			
117043	117095	Neureclipsis	4.4	7	2.7		7	FC		cn	
117095	117098	Neureclipsis crepuscularis									
117043	117104	Nyctiophylax	0.9	5	2.5	5		FC		cn	
	117112	Nyctiophylax moestus	2.6			5	5	PR			
		Paranyctiophylax									
117043	117044	Polycentropus	3.5	6	3.4	6	5	PR	FC	cn	
115334	115361	Phylocentropus	5.6	4			5	FC		cn	
115334	115395	Polyplectropus									
115095	115334	Psychomyiidae						GC			
115334	115391	Lype						SC		bu	
115391	115392	Lype diversa	4.3	2	2.8			SC			
115334	115335	Psychomyia				2		SC			

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115335	115341	Psychomyia flavida	3.3	2	1.9						
115335	115346	Psychomyia lumina				2		SC			
115335	115344	Psychomyia nomada	2								
115334	115350	Tinodes				2		SC			
115095	115096	Rhyacophilidae				0		PR		cn	
115096	115243	Himalopsyche						PR			
115096	115097	Rhyacophila				0		PR			
115097	115098	Rhyacophila acropedes				1		PR			
115097	115160	Rhyacophila acutiloba	0								
115097	115163	Rhyacophila alberta						PR			
115097	115099	Rhyacophila angelita						PR			
115097	115165	Rhyacophila arnaudi						PR			
115097	115146	Rhyacophila atrata	0								
115097	115101	Rhyacophila betteni						PR			
115097	115102	Rhyacophila bifila						PR			
115097	115153	Rhyacophila blarina						PR			
115097	115151	Rhyacophila brunnea						PR			
115097	115131	Rhyacophila carolina	0								
115097	115156	Rhyacophila coloradensis						PR			
115097	115133	Rhyacophila fuscula	2	0							
115097	115105	Rhyacophila grandis				1		PR			
115097	115159	Rhyacophila hyalinata						PR			
115097	115177	Rhyacophila iranda				0		PR			
115097	115134	Rhyacophila ledra	3.4								
115097	115147	Rhyacophila minor	0								
115097	115155	Rhyacophila narvae						PR			
115097	115111	Rhyacophila nevadensis				1		PR			
115097	115138	Rhyacophila nigrita	0								
115097	115208	Rhyacophila oreia						PR			
115097	115114	Rhyacophila pellisa				0		PR			
115097	115116	Rhyacophila rayneri				0		PR			
115097	115187	Rhyacophila robusta									
115097	115117	Rhyacophila rotunda						PR			
115097		Rhyacophila sibirica				0		PR			
115097	115144	Rhyacophila torva	1.8								
115097		Rhyacophila trissemani				1		PR			
115097	115189	Rhyacophila tucula									
115097	115120	Rhyacophila vaccua						PR			
115097	115191	Rhyacophila vaefes				1		PR			
115097		Rhyacophila vaeter				1		PR			
115097	115152	Rhyacophila vagrita						PR			
115097	115121	Rhyacophila valuma				1		PR			
115097	115123	Rhyacophila velora				1		PR			
115097	115124	Rhyacophila vepulsa									
115097	115125	Rhyacophila verrula									
115097	115195	Rhyacophila visor				1		PR		cn	
115097	115197	Rhyacophila vofixa				0		PR			
115097	115148	Rhyacophila vuphipes	0								

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115095	116982	Sericostomatidae						SH			
116982	116983	Agarodes								sp	
116983	116991	Agarodes libalis	0	3							
117012	117013	Fattigia pele	1.1								
116982	117003	Gumaga				3		SH			
100900	103358	Hemiptera						PR		cb	sw
103358	103683	Belostomatidae						PR			
103683	103717	Abedus						PR		cb	sw
103717	103739	Abedus immaculatus						PR			
103683	103684	Belostoma	9.8					PR			
103684	103689	Belostoma flumineum						PR			
103684	103687	Belostoma lutarium						PR		cb	sw
103684	103688	Belostoma testaceum						PR			
103683	103699	Lethocerus						PR		sw	
103358	103364	Corixidae	9			10	5	PR		sw	
103364	103514	Callicorixa						PR			
103364	103501	Cenocorixa						PR		sw	
103501	103504	Cenocorixa bifida				8		PR		sw	
103364	103484	Corisella						PR		sw	
103364	103525	Cymatia				8		PI		sw	cb
103364	103547	Graptocorixa						PR		sw	
103364	103444	Hesperocorixa								sw	
103364	103491	Palmacorixa					5	PR		sw	cb
103364	103365	Ramphocorixa									
103364	103369	Sigara					9	PR			
103369	103370	Sigara alternata								sw	
103369	103398	Sigara washingtonensis				8		GC		sw	cb
103364	181192	Tenagobia				8					
103364	103423	Trichocorixa					5	PR			
103423	103424	Trichocorixa calva									
103423	103429	Trichocorixa sexcincta								sp	
103358	103768	Gelastocoridae						PR			
103768	103769	Gelastocoris						PR		sk	
103358	103801	Gerridae				5		PR			
103801	103829	Gerris						PR			
103829	103842	Gerris buenoi				5		PR		sk	
103829	103841	Gerris remigis				5		PR		sk	
103801	103872	Limnoporus						PR			
103801	103857	Metrobates						PR		sk	
103857	103859	Metrobates hesperius						PR			
103801	103881	Neogerris						PR		sk	
103881	103882	Neogerris hesione						PR			
103801	103802	Rheumatobates						PR			
103802	103807	Rheumatobates palosi								sk	
103802	103804	Rheumatobates tenuipes									
103801	103811	Trepobates				10		PR		cb	bu
103811	103815	Trepobates pictus						PR		cb	bu
103964	103965	Hebrus						PR		sk	cb

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
103964	103986	Lipogomphus						PR			
103964	103983	Merragata						PR			
103983	103984	Merragata brunnea						PR		sk	
103983	103985	Merragata hebroides						PR			
103938	103939	Hydrometra						PR			
103939	103944	Hydrometra wileyae						PR		sk	cb
103358	103953	Mesoveliidae						PR			
103953	103954	Mesovelia						PR			
103954	103955	Mesovelia cryptophila						PR			
103954	103956	Mesovelia mulsanti						PR		cn	sw
103358	103613	Naucoridae				5		PR		cb	sw
103613	103614	Ambrysus						PR			
103613	103665	Pelocoris					7	PR			
103665	103667	Pelocoris femoratus						PR		cb	
103358	103747	Nepidae						PR			
103747	103748	Ranatra	7.5					PR			
103748	103749	Ranatra australis						PR			
103748	103750	Ranatra buenoi						PR			
103748	103761	Ranatra drakei						PR			
103748	103755	Ranatra fusca						PR			
103748	103751	Ranatra kirkaldyi						PR			
103748	103754	Ranatra nigra						PR		sw	cb
103358	103557	Notonectidae						PR			
103557	103558	Notonecta						PR			
103558	103573	Notonecta irrorata						PR			
103558	103575	Notonecta uhleri						PR		sw	cb
103358	103602	Pleidae						PR			
103602	103603	Neoplea						PI			
103603	103604	Neoplea striola						PI		cb	
103358	104063	Saldidae				10		PR			
104063	104069	Pentacora						PR			
104063	104140	Saldula				10		PR		sk	
103358	103885	Veliidae									
103885	103900	Microvelia					6	PR			
103900	103908	Microvelia hinei						PR			
103900	103910	Microvelia pulchella						PR			
103885	103923	Paravelia						PR		sk	
103923	103924	Paravelia brachialis						PR			
103885	103886	Rhagovelia					6	PR			
103886	103894	Rhagovelia choreutes						PR			
103886	103895	Rhagovelia disticta						PR		sk	
103886	103887	Rhagovelia obesa						PR			
	103935	Trochopus						PR			
100500	102467	Plecoptera						PR		cn	
102468	102643	Capniidae				1	1	SH		sp	cn
102643	102644	Allocapnia	2.8	3			3	SH		sp	cn
102643	102688	Capnia				1		SH			
102785	102786	Eucapnopsis brevicauda				1		SH		sp	cn

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
102788	102804	Paracapnia				1		SH		sp	cn
102804	102805	Paracapnia angulata	0.2	1							
102468	102840	Leuctridae				0		SH			
102840	102841	Despaxia				0		SH		cn	
102841	102842	Despaxia augusta				0		SH		sp	cn
102840	102844	Leuctra	0.7				0	SH		sp	cn
102840	102877	Megaleuctra				0		SH		sp	cn
102909	102910	Moselia infuscata				0		SH			
102840	102887	Paraleuctra				0		SH		sp	cn
102887	102890	Paraleuctra occidentalis				0		SH			
103202	103239	Perlomyia				0		SH		sp	cn
102468	102517	Nemouridae				2		SH			
102517	102540	Amphinemura	3.4	3		2		SH			
102540	102541	Amphinemura delosa								sp	cn
102540	102542	Amphinemura nigritta								sp	cn
102517	102567	Malenka				2		SH		sp	cn
102517	102526	Nemoura								sp	cn
102517	102632	Ostrocera								sp	cn
102517	102622	Ostrocerca								sp	cn
102517	102605	Podmosta				2		SH			
102517	102584	Prostoia	6.1	2		2		SH		sp	cn
102584	102585	Prostoia besametsa				2		SH		sp	cn
102517	102640	Shipsa								sp	cn
102640	102641	Shipsa rotunda	0.3	2							
102517	102556	Soyedina				2		SH			
102517	102614	Visoka						SC		sp	cn
102614	102615	Visoka cataractae				1		SH			
102517	102591	Zapada				2		SH			
102591	102594	Zapada cinctipes				2		SH			
102591	102596	Zapada columbiana				2		SH			
102591	102601	Zapada frigida				2		SH			
102591	102597	Zapada oregonensis				2		SH		cn	sp
102468	102488	Peltoperlidae				2		SH		cn	sp
102488	102489	Peltoperla								cn	sp
102994	103142	Soliperla				2		SH			
102488	102500	Tallaperla	1.4							cn	sp
102500	102505	Tallaperla cornelia									
102488	102510	Yoraperla				2		SH			
102510		Yoraperla mariana				2		SH			
102510	102512	Yoraperla brevis				2		SH		cn	sp
102468	102470	Pteronarcidae						SH			
102470	102485	Pteronarcella				0		SH			
102485	102486	Pteronarcella badia				0		SH		cn	sp
102485	102487	Pteronarcella regularis				0		SH			
102470	102471	Pteronarcys	1.7		2.2	0		SH			
102471	102473	Pteronarcys californica				0		SH			
102471	102478	Pteronarcys dorsata	1.8					SH			
102471	102484	Pteronarcys princeps				0		SH		sp	cn

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
102468	102788	Taeniopterygidae				2		SH		sp	cn
102838	102839	Doddsia occidentalis				2		SC		sp	cn
102788	102830	Oemopteryx								sp	cn
102788	102808	Strophopteryx	2.5	3							
102788	102816	Taenionema				2		SC		sp	cn
102816	102827	Taenionema pallidum				2		SC			
102788	102789	Taeniopteryx	6.3	2			2	SH			
102789	102791	Taeniopteryx burksi	5.8					OM			
102789	102792	Taeniopteryx lita						OM		cn	
102789	102795	Taeniopteryx metequi	1.4								
102912	103202	Chloroperlidae				1		PR		cn	
	103236	Kathroperla				0		PR			
103236	103237	Kathroperla perdita				1		GC		cn	
		Chloroperlinae				1		PR			
103202	103203	Alloperla	1.4			1		PR		cn	
103202	103260	Haploperla								cn	
103260	103263	Haploperla brevis	1.3	1							
103202	103303	Neaviperla						PR		cn	
103303	103304	Neaviperla forcipata				1		PR		cn	
103202	103233	Paraperla				1		PR		cn	
103233	103234	Paraperla frontalis						PR			
103202	103305	Plumiperla						PR		cn	
103202	103254	Suwallia	0			1		PR		cn	
103202	103273	Sweltsa	0			1		PR			
103202	103308	Triznaka				1		PR		cn	
102912	102914	Perlidae				1	1	PR			
102914	102917	Acroneuria					0	PR			
102917	102919	Acroneuria abnormis	2.2	0				PR			
102917	102920	Acroneuria arenosa	2.2					PR			
102917	102922	Acroneuria carolinensis	0		2.3						
102917	102923	Acroneuria evoluta			2.8						
102917	102925	Acroneuria internata			2.2						
102917	102918	Acroneuria lycorias	1.5		2.4			PR			
102917	102926	Acroneuria mela	0.9					PR		cn	
102917	102927	Acroneuria perplexa						PR		cn	
102914	102975	Agnetina			1.8		2	PR		cn	
102975	102983	Agnetina annulipes	0				2			cn	
102975	102979	Agnetina capitata						PR		cn	
102975	102984	Agnetina flavescens	0								
102954	102955	Attaneuria ruralis						PR		cn	
102914	102934	Beloneuria	0			3		PR		cn	
102914	102985	Calineuria				3		PR		cn	
102985	102986	Calineuria californica				1		PR		cn	
102994	103121	Doroneuria				1		PR		cn	
103121	103123	Doroneuria baumanni				1		PR		cn	
103121	103122	Doroneuria theodora				1		PR		cn	
102914	102930	Claassenia				3		PR		cn	
102930	102932	Claassenia sabulosa				3		PR		cn	

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
102914	102939	Eccoptura								cn	
102939	102940	Eccoptura xanthenes	4.1							cn	
102914	102971	Hesperoperla						PR		cn	
102971	102972	Hesperoperla pacifica				1		PR		cn	
102914	102942	Neoperla	1.6	1	3.1			PR		cn	
102942	102944	Neoperla clymene						PR			
102914	102962	Paragnetina						PR			
102962	102965	Paragnetina fumosa	3.5					PR			
102962	102970	Paragnetina ichusa	0								
102962	102966	Paragnetina immarginata	1.7								
102962	102967	Paragnetina kansensis	2					PR		cn	sp
102962	102968	Paragnetina media			2.1						
103202	103251	Perlesta	0		4.5	5		PR		cn	
103251	103253	Perlesta placida	4.9	5				OM			
103202	103244	Perlinella						PR			
103244	103246	Perlinella drymo	0	1				PR		cn	
103244	103248	Perlinella ephyre						PR		cn	
102912	102994	Perlodidae				2	2	PR		cn	sp
102994	103155	Calliperla				2		PR		cn	sp
102994	103157	Cascadoperla				2		PR			
102994	103118	Clioperla								cn	
103118	103119	Clioperla clio	4.8	1						cn	
102994	103137	Cultus				2		PR		cn	
103137	103139	Cultus decisus	1.6								
102994	103166	Diploperla	2							cn	
103166	103167	Diploperla duplicata	2.7								
103166	103169	Diploperla morgani	1.5								
	103094	Diura				2		PR			
103094	103096	Diura knowltoni				2		SC		cn	
103171	103172	Frisonia picticeps				2		PR		cn	
102994	103084	Helopicus								cn	
103084	103087	Helopicus bogaloosa	0							cn	
103084	103085	Helopicus subvarians	0.8								
	103124	Isogenoides				2		PR			
103124		Isogenoides hansoni	0								
102994	103070	Isogenus				2		PR			
102994	102995	Isoperla				2	2	PR			
102995	103012	Isoperla bilineata	5.5								
102995	103021	Isoperla dicala	2.2	2							
102995	103004	Isoperla fulva				2		PR			
102995	103029	Isoperla fusca				2		PR			
102995	103020	Isoperla holochlora	0								
102995	103007	Isoperla mormona				2		PR			
102995	103017	Isoperla namata	1.8								
102995	103018	Isoperla orata	0					OM			
102995	103009	Isoperla pinta				2		PR			
102995	103019	Isoperla similis	0.7								
102995	103035	Isoperla slossonae	2.6								

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
102995	103036	Isoperla transmarina	5.6								
102994	103149	Kogotus				2		PR		cn	
103174	103175	Malirekus hastatus	1.4								
102994	103110	Megarcys				2		PR		cn	
102994	103180	Oroperla				2		PR		cn	
102994	103134	Perlinodes						PR		cn	
103134	103135	Perlinodes aureus				2		PR		cn	
102994	103186	Pictetiella				2		PR		cn	
103186	103188	Pictetiella expansa				2		PR		cn	
103099	103100	Remenus bilobatus	0.3								
102994	103189	Rickera						PR		cn	
103189	103190	Rickera sorpta				2		PR		cn	
102994	103193	Setvena				2		PR		cn	
103193	103194	Setvena bradleyi				2		PR		cn	
102994	103102	Skwala				2		PR			
102994	103197	Yugus				2		PR		cn	sp
103197	103200	Yugus arinus	0								
103197	103198	Yugus bulbosus	0								
100500	101593	Odonata						PR		cb	
101595	101596	Aeshnidae				3		PR			
	101602	Aeshna				5		PR			
101596	101597	Anax				8	5	PR			
101597	101598	Anax junius						PR		cb	sp
101597	101599	Anax longipes						PR		cb	sp
101596	101648	Basiaeschna								cb	sp
101648	101649	Basiaeschna janata	7.7	6				PR			
101596	101645	Boyeria						PR		cb	
101645	101646	Boyeria grafiana	6.3								
101645	101647	Boyeria vinosa	6.3	2	3.5			PR		cb	sp
101639	101640	Coryphaeschna ingens						PR		cb	cn
101637	101638	Epiaeschna heros						PR		cb	cn
101634	101635	Gomphaeschna furcillata						PR			
101653	101654	Nasiaeschna pentacantha	8					PR		bu	
101595	101664	Gomphidae				1		PR		bu	
101715	101716	Aphylla williamsoni						PR			
101664	101770	Arigomphus								bu	
101770	101771	Arigomphus pallidus						PR			
101664	101730	Dromogomphus	6.3					PR			
101730	101731	Dromogomphus armatus						PR			
101730	101732	Dromogomphus spinosus						PR		bu	
	101725	Erpetogomphus				4		PR			
101777	101780	Gomphurus dilatatus	6.2	5	2.5			PR			
101664	101665	Gomphus					5	PR			
101665	101677	Gomphus dilatatus						PR			
101665	101668	Gomphus geminatus						PR			
101665	101685	Gomphus lividus					5	PR			
101665	101686	Gomphus minutus						PR			
101665	101689	Gomphus pallidus						PR		sp	

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
101665	101694	Gomphus spiniceps	4.9								
101734	101735	Hagenius brevistylus	4	1				PR		bu	
101791	206625	Hylogomphus geminatus						PR		bu	
101664	101766	Lanthus	2.7							bu	
101664	101736	Octogomphus				1		PR		bu	
101664	101738	Ophiogomphus	6.2	1		1		PR		bu	
101664	101718	Progomphus						PR		bu	
101718	101720	Progomphus obscurus	8.7					PR		bu	
101664	101761	Stylogomphus								bu	
101761	101762	Stylogomphus albistylus	4.8								
101664	206626	Stylurus						PR		sp	
206626	206627	Stylurus ivae						PR			
	101594	Anisoptera						PR			
101659	101660	Tachopteryx				10		PR		bu	
102025	102026	Cordulegastridae						PR		bu	
102026	102027	Cordulegaster	6.1	3		0	3	PR			
102027	102031	Cordulegaster maculata						PR		sp	
101796	102020	Corduliidae				2	5	PR		cb	sp
101851	101852	Didymops transversa						PR		cb	sp
	101862	Epicordulia	5.6								
101862	101863	Epicordulia princeps						PR		sp	
101862	101864	Epicordulia regina						PR		sp	
101797	101918	Macromia	6.7	2			2	PR		sp	
101918	101920	Macromia georgiana						PR		sp	
101918	101924	Macromia georgina						PR		cb	cn
101918	101922	Macromia taeniolata						PR			
101797	101934	Neurocordulia	5.8					PR			
101934	101938	Neurocordulia alabamensis						PR			
101934	101936	Neurocordulia molesta	3.3	5				PR			
101934	101939	Neurocordulia obsoleta	5.4	0				PR		sp	
101934	101935	Neurocordulia virginiensis	1.6					PR		sp	
101797	101947	Somatochlora	8.9	1		9	1	PR		cb	sp
101947	101949	Somatochlora linearis						PR			
102026	102035	Epitheca					4	PR			
102035	206629	Epitheca princeps						PR			
102035		Epitheca sepia						PR			
206629	206631	Epitheca princeps regina						PR		cb	sp
102035	185986	Epitheca cynosura						PR			
101797	101994	Tetragoneuria	8.5					PR			
101994	101996	Tetragoneuria cynosura						PR		sp	
101796	101797	Libellulidae				9	9	PR		sp	
101830	101831	Brachymesia gravida						PR		sp	
101797	101865	Erythemis						PR		cb	
101865	101866	Erythemis simplicicollis	7.7					PR		cb	
101797	101870	Erythrodiplax						PR		cb	
101870	101872	Erythrodiplax minuscula						PR		sp	
101797	101885	Leucorrhinia									
101797	101893	Libellula	9.8	9		9	8	PR			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
101893	101901	Libellula auripennis						PR			
101893	101900	Libellula incesta						PR			
101893	101903	Libellula semifasciata						PR		sp	
101893	101904	Libellula vibrans						PR		sp	cb
102009	102010	Miathyria marcella						PR		sp	
101932	101933	Nannothemis bella						PR		sp	
101797	101945	Orthemis						PR		sp	
101945	101946	Orthemis ferruginea						PR		sp	
101798	101799	Pachydiplax longipennis	9.6					PR		sp	
101797	101803	Perithemis	10				4	PR		sp	
101803	101805	Perithemis seminola						PR		sp	
101803	101804	Perithemis tenera						PR		sp	cb
101808	101809	Plathemis lydia	10	8	8.2			PR			
101797	101976	Sympetrum	7.3	10			4	PR		sp	
101976	101977	Sympetrum ambiguum						PR			
101818	101820	Tramea carolina						PR			
100500	102042	Zygoptera						PR		cb	
102042	102043	Calopterygidae					5	PR		cb	
102043	102052	Calopteryx	8.3	5	3.7	6	6	PR		cb	
102052	102054	Calopteryx dimidiata						PR		cb	cn
102052	102055	Calopteryx maculata						PR			
102043	102048	Hetaerina	6.2	6	2.8			PR			
102048	102050	Hetaerina americana						PR			
102048	102049	Hetaerina titia						PR		cb	sw
102042	102077	Coenagrionidae			6.1	9	9	PR		cb	
102077	102093	Amphiagrion				5		PR		cn	cb
102077	102139	Argia			5.1	7	6	PR			
102139	102140	Argia apicalis						PR			
102139	102143	Argia fumipennis						PR			
102139	102146	Argia moesta						PR			
102139	102147	Argia sedula						PR			
102139	102148	Argia tibialis						PR		cb	
102139	102154	Argia violacea						PR		cb	
102077	102133	Chromagrion				6		PR		cb	
102077	102102	Enallagma	9	9		9	8	PR		cb	
102102	102103	Enallagma antennuatus						PR		cb	
102102	102104	Enallagma cardenium						PR		cb	
102102	102106	Enallagma daecki						PR		cb	
102102	102108	Enallagma divagans						PR		cb	
102102	102110	Enallagma dubium						PR		cb	
102102	181184	Enallagma pallidum						PR		cb	
102102	102114	Enallagma pollutum						PR		cb	
102102	102115	Enallagma signatum						PR		cb	
102102	102119	Enallagma vesperum						PR		cb	
102102	102120	Enallagma weewa						PR		cb	
102077	102078	Ischnura	9.4	9		9	9	PR		cb	
102078	206632	Ischnura hastata						PR			
102078	102082	Ischnura posita						PR		cb	

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
102078	102084	Ischnura ramburi						PR		cb	
102077	102135	Nehalennia						PR		cb	
102135	102136	Nehalennia intergricollis						PR		cb	
102096	102099	Telebasis byersi						PR			
102077	102100	Zoniagrion				9		PR			
102058	102061	Lestes				9		PR		cb	
109215	118831	Diptera				7					
121226	121227	Blephariceridae				0		SC			
121229	121230	Agathon				0		SC		cn	
121229	121250	Bibiocephala				0		SC			
121229	121255	Blepharicera	0.2	0		0		SC		sp	bu
121229	121278	Philorus				0		SC		sp	cb
125808	127076	Ceratopogonidae			5.7	6		PR			
127277	127278	Dasyhelea						GC		sp	cn
127076	127112	Forcipomyiinae				6		PR	GC	sp	
127112	127113	Atrichopogon	6.8		4.5	6		PR	GC		
127113	127150	Atrichopogon websteri			4.4						
127112	127152	Forcipomyia				6		SC	PR	bu	
127076	127338	Ceratopogoninae				6		PR		bu	
127526	127533	Alluaudomyia						PR			
127774	127778	Bezzia				6	6	GC	PR	bu	
127526	127564	Ceratopogon					6	PR		bu	
127339	127340	Culicoides	6.5	10			10	PR	GC	bu	
127683	127720	Nilobezzia						PR			
127774	127859	Palpomyia				6		PR	GC	bu	
127859	127905	Palpomyia tibialis								bu	
127683	127729	Probezzia					6	PR		bu	
127526	127614	Serromyia					6	PR		bu	
127683	127761	Sphaeromias						PR	GC		
127526	127619	Stilobezzia						PR		sp	sw
125808	125886	Chaoboridae						PR			
125892	125904	Chaoborus						PR			
125904	125923	Chaoborus punctipennis	8.5	8				PR			
125887	125888	Eucorethra				7		PR			
125808	127917	Chironomidae				6		GC		bu	
127917	127994	Tanypodinae				7		PR		bu	
127995	127996	Clinotanypus					8	PR			
127996	127998	Clinotanypus pinguis	9.8	8	7.5						
127995	128010	Coelotanypus	6.2					PR			
128010	128012	Coelotanypus concinnus	7.7					PR			
128010	128016	Coelotanypus scapularis						PR		bu	
128010	128018	Coelotanypus tricolor						PR		bu	
	128020	Macropelopiini						PR			
127995	206646	Alotanypus									
128020	128021	Apsectrotanypus						PR		bu	
128021	128024	Apsectrotanypus johnsoni	0					PR			
128020	128026	Brundiniella				6		PR		sp	
128026	128028	Brundiniella eumorpha	3.8								

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206647	206648	Fittkauimyia serta								sp	bu
128020	128034	Macropelopia				6		PR			
128020	128048	Psectrotanypus			8.1	10	10	PR		sp	
128048	128056	Psectrotanypus dyari	10	10	8.6						
128270	128271	Djalmabatista						PR		sp	
128271	128272	Djalmabatista pulcher						PR			
128270	128277	Procladius	9.3	9	6.5	9	9	PR	GC	sp	
128277	128285	Procladius bellus						PR			
128069	128070	Natarsia	10	8	5.9		8	PR		sp	
128070	128071	Natarsia baltimoreus			5.6						
127994	128078	Pentaneurini				6		PR			
128078	128079	Ablabesmyia			5.2		8	GC	PR		
128079	128081	Ablabesmyia annulata			4.1			OM			
128079	128083	Ablabesmyia aspera						OM			
128079	128087	Ablabesmyia cinctipes						OM			
128079	128089	Ablabesmyia hauberi						OM			
128079	128090	Ablabesmyia idei						OM			
128079	128093	Ablabesmyia janta	7.1		4.9			OM			
128079	128097	Ablabesmyia mallochi	7.6	8	5			OM			
128079	128113	Ablabesmyia peleensis	4.6					OM		sp	
128079	128121	Ablabesmyia rhamphe						OM			
128078	128130	Conchapelopia	8.7	6	4.3	6	6	PR			
		Denopelopia atria									
128161	128162	Guttipelopia guttipennis						PR			
	128237	Hayesomyia						PR		sp	
128237	128249	Hayesomyia senata			4.6						
	128131	Helopelopia			3.9		6	PR		sp	
128078	128167	Hudsonimyia						PR			
128078	128170	Krenopelopia						PR		sp	
128170	128171	Krenopelopia hudsoni						PR			
128078	128173	Labrundinia			3.8			PR			
128173	128174	Labrundinia becki						PR			
128173	128175	Labrundinia johannseni						PR			
128173	128176	Labrundinia maculata						PR			
128173	128177	Labrundinia neopilosella					7	PR			
128173	128178	Labrundinia pilosella	6	7	3.1			PR		sp	
128173	128182	Labrundinia virescens	4.5					PR			
128078	128183	Larsia	8.3	6	4.3	6	6	PR			
128183	128184	Larsia berneri						PR			
128183	128186	Larsia decolorata						PR			
128183	128189	Larsia indistincta						PR		sp	
	128132	Meropelopia			2.7		7				
128078	128199	Monopelopia				6		PR		sp	
128199	128200	Monopelopia boliekae						PR			
128078	128202	Nilotanypus	4	6		6		PR		sp	
128202	128203	Nilotanypus fimbriatus			2.8			PR			
128078	128207	Paramerina	2.8			6	4	PR		sp	
128207	128208	Paramerina anomala									

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128207	128209	Paramerina fragilis			4.7						
128078	128215	Pentaneura	4.6	6		6		PR	GC		
128215	128216	Pentaneura inconspicua			4.9			PR		sp	
128215	128218	Pentaneura inculta						PR		sp	
128078	128226	Rheopelopia						PR		sp	
128226	128229	Rheopelopia paramaculipennis			2.9						
	128234	Telopelopia okoboji			4						
128078	128236	Thienemannimyia				6	6	PR		sp	
128078	128251	Trissopelopia						PR			
128078	128259	Zavrelimyia	9.3	8	4.1	8	8	PR		sp	
128259	128262	Zavrelimyia sinuosa						PR			
128323	128324	Tanypus	9.6	10	8.8		10	PR	GC		
128324	128329	Tanypus neopunctipennis			7.5			OM			
128324	128335	Tanypus carinatus						OM			
128324	128333	Tanypus punctipennis						OM		sp	
128324	128336	Tanypus stellatus						OM			
127953	127954	Boreochlus				6		GC	SC		
127917	128341	Diamesinae						GC		sp	
128342	128343	Boreoheptagyia				6		GC			
	128351	Diamesini				2		GC			
128351	128355	Diamesa	7.7	8		5		GC	SC	sp	
128351	128401	Pagastia	2.2	1		1		GC			
128351	128408	Potthastia				2		OM	GC		
128408	128409	Potthastia gaedii	2			6		GC		sp	
128408	128412	Potthastia longimana	7.4			2		GC		sp	
128351	128416	Pseudodiamesa				6		GC		sp	
128351	128426	Sympotthastia	5.7	2		2		GC	SC	sp	
128437	128440	Monodiamesa				7		GC		bu	sp
128437	128446	Odontomesa				4		GC			
128446	128447	Odontomesa fulva	5.9	4							
128437	128452	Prodiamesa				3		GC		sp	
128452	128454	Prodiamesa olivacea	7.9	3							
125808	128457	Orthocladiinae				5		GC		bu	
128457	128563	Corynoneura	6.2	7	3.5	7	7	GC			
128563	128565	Corynoneura celeripes			2.3			GC		sp	
128563	128567	Corynoneura lobata			3.3						
128563	128570	Corynoneura taris						GC			
128457	129182	Thienemanniella	6	6	3.7	6	6	GC			
129182	129193	Thienemanniella fusca						GC			
129182	129189	Thienemanniella similis			2.4			GC			
129182	129190	Thienemanniella xena			3.6			GC			
		Orthocladiini				6		GC			
128457	128460	Acamptocladius						GC		bu	sp
128457	128470	Antillocladius									
128457	128477	Brillia	5.2	5		5	5	SH	GC		
128477	128478	Brillia flavifrons				5		SH			
128477	128487	Brillia par								bu	cn
128477	128482	Brillia retifinis				5		SH		sp	

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			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
128457	128511	Cardiocladius	6.2	5		5		PR		cn	bu
128511	128515	Cardiocladius obscurus			2.2						
128457	128520	Chaetocladius				6		GC			
128457	128575	Cricotopus		7	4.3	7	7	SH	GC		
128575	128583	Cricotopus bicinctus	8.7		6.7		7	OM			
128575	128594	Cricotopus festivellus				7		SH			
128575	128610	Cricotopus infuscatus	9								
128575		Cricotopus Isocladius				7		SH			
128575		Cricotopus Nostococladius				7		SH			
128575	128640	Cricotopus politus						OM			
128575		Cricotopus sylvestris	10					OM			
128575	128651	Cricotopus tremulus				7	7	SH		sp	
128575	128659	Cricotopus trifascia				7		OM			
128575	128664	Cricotopus varipes	8.1								
128575	128666	Cricotopus vierriensis	4.8		4.2						
128457	128670	Diplocladius						GC		sp	
128670	128671	Diplocladius cultriger	7.7	8				GC			
128680	128681	Doncricotopus bicaudatus			4.8						
128457	128689	Eukiefferiella				8		GC	SC		
128689	128704	Eukiefferiella brehmi	3.7			8		GC			
128689	128703	Eukiefferiella brevicalcar	1.7			8		GC			
128689	128693	Eukiefferiella claripennis	5.7	8		8		GC			
128689	128695	Eukiefferiella devonica	2.6			8		GC			
128689	128705	Eukiefferiella gracei	2.7			8		GC			
128689	128706	Eukiefferiella pseudomontana				8		GC		sp	
128457	128712	Georthocladius								sp	
128457	128718	Gymnometriocnemus					7	GC		sp	bu
128457	128730	Heleniella	0			6		GC			
128457	128737	Heterotrissocladius	5.4	0		4		GC	SC	sp	
128737	128746	Heterotrissocladius subpilosus				0		GC		sp	
128457	128750	Hydrobaenus	9.6	8		8	8	SC	GC	sp	
	128771	Krenosmittia				1		GC			
128457	128776	Limnophyes			3.1	8	8	GC			
128457	128811	Lopescladius	2.2	4		6		GC		bu	sp
128457	128818	Mesosmittia								sp	
128457	128821	Metriocnemus						OM	GC		
128457	128844	Nanocladius	7.2	3	5.3	3	3	GC			
128844	128852	Nanocladius crassicornus			4.3		3	GC			
128844	128853	Nanocladius distinctus			6.1			GC			
128844	128855	Nanocladius downesi	2.6								
128844	128859	Nanocladius minimus			4.5						
128844	128860	Nanocladius rectinervis						GC		sp	bu
128844	128862	Nanocladius spiniplenus			3.5						
128457	128867	Oliveridia				6		GC			
128457	128874	Orthocladius		6	3.9			GC			
128874		Orthocladius Eudactylocladius				6		GC			
128874		Orthocladius Euorthocladius	6.3			6		GC			
128874		Orthocladius Pogonocladius				6		GC			

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128874	128878	Orthocladius annectens						GC		sp	
128874	128882	Orthocladius carlatus			2						
128874	128885	Orthocladius clarkei	5.8								
128874	128898	Orthocladius dorenus	6.7								
128874	128913	Orthocladius lignicola						GC		sp	
128874	128920	Orthocladius nigritus	0.9								
128874	128923	Orthocladius obumbratus	8.8								
128874	128929	Orthocladius robacki	7.2								
128457	128951	Parachaetocladius	0			6	2	GC		sp	
128457	128968	Parakiefferiella	5.9		4.8	6	4	GC			
128457	128978	Parametriocnemus			2.8	5	5	GC		sp	
128978	128982	Parametriocnemus lundbecki	3.7	5				GC		sp	
128457	128989	Paraphaenocladius				5	4	GC		sp	
128457	129005	Paratrichocladius			2	6		GC		sp	bu
128457	129011	Parorthocladius				6		GC			
128457	129018	Psectrocladius	3.8	8	5.7	8	8	GC	SH		
129018	129027	Psectrocladius elatus						OM			
129018	129031	Psectrocladius limbatellus				8		GC		sp	
129018	129051	Psectrocladius sordidellus				8		GC			
128457	129052	Pseudorthocladius	0	0		0	0	GC		sp	
128457	129071	Pseudosmittia						GC		sp	
128457	129083	Psilometriocnemus						GC			
128457	129086	Rheocricotopus			4.9	6	6	GC	SH		
129086	129101	Rheocricotopus pauciseta					6	GC			
129086	129102	Rheocricotopus robacki	7.7	6	3.8						
129086	129105	Rheocricotopus tuberculatus	6.8							bu	
128457	129107	Rheosmittia						GC			
128457	129110	Smittia						GC			
128457	129152	Stilocladius						GC		sp	
128457	129156	Symbiocladius				6		PA			
	128877	Symposiocladius								sp	
128877	128915	Symposiocladius lignicola	5.4								
128457	129161	Synorthocladius	4.7	2		2		GC	SC		
129161	129162	Synorthocladius semivirens			2.5						
128457	129197	Tvetenia		5		5	5	GC			
129197	129205	Tvetenia bavarica	4			5		GC			
129197	189327	Tvetenia discoloripes	3.9			5		GC			
128457	129206	Unniella					4	GC		bu	
129206	129207	Unniella multivirga	0					GC			
128457	129208	Xylotopus	6.6	2						bu	
129208	129209	Xylotopus par					2				
128457	129213	Zalutschia					7	SH			
128457	129228	Chironominae				6		GC			
129228	129229	Chironomini				6		GC			
	206655	Apedilum									
206655	129618	Apedilum elachista								sp	bu
129231	129234	Asheum beckae						GC			
129229	129236	Axarus						GC			

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129229	206657	Beardius								bu	
206657	206658	Beardius truncatus									
129229	129254	Chironomus	9.8	10	8.1	10	10	GC	SH		
129254	129280	Chironomus decorus						OM			
129254	129313	Chironomus riparius						OM		bu	
129254	129322	Chironomus stigmaterus						OM		sp	bu
129229	129350	Cladopelma	2.5	9			7	GC			
129229	129368	Cryptochironomus			4.9	8	8	PR		sp	
129368	129370	Cryptochironomus blarina	8	8							
129368	129376	Cryptochironomus fulvus	6.7	8				PR		bu	
129229	129394	Cryptotendipes	6.1	6	4.2		6	GC		bu	
129229	129421	Demicryptochironomus	2.1				8	GC			
129229	129428	Dicrotendipes	7.9		5.6	8	8	GC	FC		
129428	129436	Dicrotendipes fumidus			5.8						
129428	129441	Dicrotendipes leucoscelis						FG			
129428	129445	Dicrotendipes lobus						FG			
129428	129458	Dicrotendipes lucifer			6.3						
129428	129448	Dicrotendipes modestus	9.2	5	5.9			FG			
129428	129450	Dicrotendipes neomodestus	8.3		4.5			FG			
129428	129452	Dicrotendipes nervosus	10					FG			
129428	193743	Dicrotendipes simpsoni	10		7.4			FG			
129428	206649	Dicrotendipes thanatogratus						FG		bu	
129428	183774	Dicrotendipes tritomus						FG			
129229	129459	Einfeldia				8		GC			
129459	129460	Einfeldia austini						GC		cn	
129459	129463	Einfeldia natchitocheae						GC			
129229	129470	Endochironomus			5.6	10	10	SH	GC		
129470	129471	Endochironomus nigricans	7.5	8	5.3						
129470	129474	Endochironomus subtendens									
128457	130046	Endotribelos						GC		bu	cn
130046	130047	Endotribelos hesperium						GC			
129229	129483	Glyptotendipes	8.5	10	6.2		10	FC	GC		
129483	129484	Glyptotendipes amplus			3.2						
129483	129485	Glyptotendipes barbipes					10	FC			
129483	129493	Glyptotendipes meridionalis									
129483	129494	Glyptotendipes paripes								bu	
129483	129496	Glyptotendipes seminole									
129229	129506	Goeldichironomus					8	GC			
129506	206650	Goeldichironomus amazonicus						GC			
129506	129508	Goeldichironomus carus						GC			
129506	206651	Goeldichironomus fluctuans						GC			
129506	129512	Goeldichironomus holoprasinus	10					GC		cb	cn
129506	206652	Goeldichironomus natans						GC		bu	
129229	129516	Harnischia	7.5	8				GC	SC		
129516	129517	Harnischia curtilamellata			3.5						
129229	129522	Kiefferulus					10	GC			
129522	129523	Kiefferulus dux	10	10	5.2			GC		cn	
129525	129526	Lauterborniella agrayloides						GC			

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129229	129535	Microtendipes	6.2	7		6		FC	GC		
129535	129540	Microtendipes caelum			2.7						
129535	129541	Microtendipes pedellus						FG			
129535	129547	Microtendipes rydalensis			2			FG			
129229	129548	Nilothauma	5.5	2	3.1		2				
129548	129551	Nilothauma bicorne						GC			
129229	129561	Pagastiella						GC		sp	
129561	206654	Pagastiella orophila						GC			
129561	129562	Pagastiella ostansa	2.6								
129229	129564	Parachironomus	9.2	10	4.1			PR	GC		
129564	129565	Parachironomus abortivus			8						
129564	129569	Parachironomus carinatus			5.3						
129564	129573	Parachironomus directus			7.9						
129564	129579	Parachironomus frequens			3.8						
129564	129595	Parachironomus hirtalatus									
129564	129581	Parachironomus monochromus	7.9								
129564	129583	Parachironomus pectinatellae			3.7						
129564	129587	Parachironomus schneideri								sp	
129564	129588	Parachironomus sublettei									
129229	129597	Paracladopelma	6.4	7				GC			
129597	129608	Paracladopelma nereis	1.8					GC		cn	
129597	129612	Paracladopelma undine	5.2					GC			
129229	129616	Paralauterborniella					8	GC		bu	
129616	129619	Paralauterborniella nigrohalterale									
129229	129623	Paratendipes	5.3	8	5.7	8	8	GC			
129623	129624	Paratendipes albimanus			4.3			GC		cn	
129623	129632	Paratendipes subaequalis						GC			
129229	129637	Phaenopsectra	6.8	7		7	7	SC	GC		
129637	129642	Phaenopsectra flavipes	8.5		5.7						
129637	129647	Phaenopsectra obediens						OM		cb	cn
129637	129652	Phaenopsectra punctipes			3.5			SC			
129229	129657	Polypedilum				6	6	SH	GC		
129657		Polypedilum Pentapedilum				6		SH			
129657	129725	Polypedilum angulum	5.6								
129657	129666	Polypedilum aviceps	4		1.9						
129657	129726	Polypedilum bergi					6	SH			
129657	129671	Polypedilum convictum	5.3		3.6						
129657	129676	Polypedilum fallax	6.7								
129657	129684	Polypedilum halterale	7.2								
129657	129686	Polypedilum illinoense	9.2		6.9						
129657	129692	Polypedilum laetum									
129657	129698	Polypedilum ontario			2.6						
129657	129708	Polypedilum scalaenum	8.7								
129657	129718	Polypedilum trigonum								bu	
129657	129719	Polypedilum tritum									
129229	129730	Robackia						GC			
129730	129731	Robackia claviger	2.4					GC		bu	
129730	129733	Robackia demeijerei	4.3			7		GC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values					Functional Feeding Group		Habit/ Behavior	
			Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	primary	secondary	primary	secondary
129229	129735	Saetheria						GC		wood	
129735	129736	Saetheria hirta						GC			
129735	129737	Saetheria tylus	8.1	4							
129229	129743	Stelechomyia					7	GC		bu	
129743	129744	Stelechomyia perpulchra	4.6					GC		bu	
129229	129746	Stenochironomus	6.4	5	3.6		5	SH	GC		
129229	129785	Stictochironomus	6.7	9	4			OM	GC	bu	
129785	129790	Stictochironomus devinctus						OM			
129229	129820	Tribelos	6.6	5			5	GC			
129820	206656	Tribelos atrum						GC			
129820	129823	Tribelos fuscicorne			5.1			GC		bu	
129820	129827	Tribelos jucundus			5.6			GC			
129229	129837	Xenochironomus						PR			
129837	129838	Xenochironomus xenolabis	7	0				PR			
129229	129842	Xestochironomus						OM			
129842	129844	Xestochironomus subletti						OM			
129872	130040	Zavreliella								bu	
130040	189328	Zavreliella marmorata									
129850	129851	Pseudochironomus	4.2	5	4.7	5		GC			
129228	129872	Tanytarsini				6		FC			
129872	129873	Cladotanytarsus	3.7	7	4.4	7	7	GC	FC	cb	sp
129872	129884	Constempellina				6		GC			
129872	129890	Micropsectra	1.4	7	3.5	7	7	GC			
129872	129932	Nimbocera				6		FC		sp	
129932	206659	Nimbocera limnetica						FG			
129872	129935	Paratanytarsus	7.7	6	4.2	6	6	GC		cn	
129935		Paratanytarsus inopterus					6	GC			
129872	129952	Rheotanytarsus	6.4	6	3.3	6	6	FC			
129952	129955	Rheotanytarsus distinctissimus						FC		cb	sp
129952	129955	Rheotanytarsus distinctissimus						FC		cb	sp
129952	129957	Rheotanytarsus exiguus						FC			
129872	129962	Stempellina	2	2		2		GC		cb	cn
129872	129969	Stempellinella	5.3	4	2.6	4	4	GC			
129872	129975	Sublettea				6		FC			
129975	129976	Sublettea coffmani	1.7		2.2						
129872	129978	Tanytarsus	6.7	6	3.5	6	6	FC	GC		
129978	130030	Tanytarsus glabrescens						FG		cb	sp
129978	129997	Tanytarsus guerlus						FG			
		Thienemanniola				6		GC			
129872	130038	Zavrelia	2.7			8		GC		sw	
125875	125877	Corethrella								sw	
125808	125930	Culicidae				8		GC		sw	
126233	126234	Aedes					8	FC			
125955	125956	Anopheles	9.1				6	FC			
126233	126455	Culex	10				8	FC			
126233	126518	Deinocerites						FC			
125931	125932	Toxorhynchites						PR			
121226	121286	Deuterophlebiidae						SC			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
121286	121287	Deuterophlebia				0		SC		sw	cb
121287	121290	Deuterophlebia nielsoni						SC			
125808	125809	Dixidae				1	1	GC			
125809	125810	Dixa	2.8			1		GC			
125809	125854	Dixella						GC			
125809	125873	Meringodixa				2		GC		bu	
125350	125351	Psychodidae				10		GC			
125391	125392	Maruina				1		SC			
125391	125514	Pericoma			5.6	4	4	GC			
125391	125468	Psychoda	9.9		3.7	10		GC			
125468	125469	Psychoda alternata						GC		bu	
125399	125400	Telmatoscopus albipunctatus									
125762	125763	Ptychopteridae				7		GC			
125764	125765	Bittacomorpha									
125785	125786	Ptychoptera				7		GC			
125808	126640	Simuliidae				6		FC		cn	
	126658	Cnephia mutata	4		5						
126648	126674	Gymnopais						SC		cn	
126648	126687	Metacnephia				6		FC			
	126642	Parasimulium						FC			
126648	126703	Prosimulium	2.6			3		FC			
126703	126736	Prosimulium mixtum	3.3	3							
126773	126774	Simulium	4.4		4.8	6	6	FC			
126774	126790	Simulium bivittatum				6		FC			
126774	126832	Simulium jenningsi					6	FC			
126774	126834	Simulium jonesi					6	FC			
126774	126841	Simulium meridionale				6		FC			
126774	126870	Simulium rivuli					6	FC			
126774	126873	Simulium slossonae						FC			
126774	126883	Simulium tuberosum					6	FC		cn	
126774	126892	Simulium venustum	7.4	5			6	FC			
126774	126903	Simulium vittatum	8.7	7		6	6	FC			
126648	126761	Stegopterna									
126648	126767	Twinnia				6		FC			
125762	125799	Tanyderidae									
	125802	Protanyderus				1				sp	bu
125799	125800	Protoplasa				5		GC			
125800	125801	Protoplasa fitchii	5								
125808	126624	Thaumaleidae						OM			
126624	126629	Thaumalea						OM			
126629	126631	Thaumalea elnora						OM			
126629	126632	Thaumalea fusca						OM			
118839	118840	Tipulidae				3		SH		bu	
118841	118905	Megistocera									
118841	119008	Prionocera				4		SH		cn	
118841	119037	Tipula	7.7	4	7.2	4	4	SH			
119037	119041	Tipula abdominalis			4						
119037		Tipula ormosia				4		OM			

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
119655	119656	Antocha	4.6	3	2.2	3		GC			
119656	119660	Antocha monticola				3		GC			
	120488	Cryptolabis						SH	GC	bu	
121026	121027	Dicranota	0	3		3		PR			
120030	120076	Elephantomyia						SH		sp	bu
120397	120503	Erioptera				3		GC			
120397	120640	Gonomyia						GC		bu	sp
119655	119690	Helius					4	GC		bu	sp
120397	120732	Hesperoconopa				1		GC		bu	
120030	120094	Hexatoma	4.7	2	2.3	2	2	PR		bu	sp
	120095	Eriocera						PR		bu	sp
120030	120164	Limnophila				4		PR		bu	
119655	119704	Limonia	10	6		6		SH		bu	
	119706	Geranomyia					3	SH			
120397	120758	Molophilus				4		SH		bu	
120397	120830	Ormosia	6.5			3		GC		bu	
121026	121118	Pedicia				6		PR		bu	
120030	120335	Pilaria				7	7	PR			
120030	120365	Pseudolimnophila	7.3	2			2	PR			
120397	120968	Rhabdomastix				8		PR		sp	bu
120968	120977	Rhabdomastix fascigera				3		GC		bu	
120968	120995	Rhabdomastix setigera				3		GC		bu	
120030	120387	Ulomorpha									
118831	130052	Brachycera									
130928	130929	Atherix				2	2	PR			
130929	130930	Atherix lantha	2.1	2	3.1			PR			
130929	130932	Atherix variegata				2		PR			
130741	130914	Pelecorhynchidae				3		PR			
130914	130915	Glutops				3		PR			
131750	136824	Dolichopodidae	9.7	4		4		PR			
137952	137953	Dolichopus								cn	
131750	135830	Empididae	8.1	6	3.5	6		PR		sp	bu
136304	136305	Chelifera				6		GC			
135844	135849	Clinocera				6		PR			
136304	136327	Hemerodromia				6	6	PR			
136361	136377	Oreogeton				5		PA			
135844	135881	Oreothalia				6		PR			
135930	136123	Rhamphomyia				6		PR		sp	bu
135844	135920	Wiedemannia				6		PR			
130130	130150	Stratiomyidae				8		GC			
130155	130160	Allognosta				7		GC			
130408	130409	Caloparyphus				7		GC		sp	
130408	130436	Euparyphus						GC			
130685	130694	Nemotelus								sp	bu
130483	130573	Odontomyia					7	GC			
130408	130461	Oxycera								sp	bu
130483	130627	Stratiomys						FG			
130741	130934	Tabanidae				8		PR		sp	bu

Parent TSN	TSN	Scientific Name	Regional Tolerance Values: Southeast (NC)	Upper Midwest (WI)	Midwest (OH)	Northwest (ID)	Mid-Atlantic (MACS)	Functional Feeding Group: primary	secondary	Habit/ Behavior: primary	secondary
131061	131078	Chrysops	7.3	6	4.6		7	GC	PR		
131061	131062	Silvius						PR			
131318	131527	Tabanus	9.7	5		5	5	PR			
131750	148316	Canaceidae						SC		bu	
131750	146893	Ephydridae				6		GC			
131750	150025	Muscidae				6		PR			
150729	150730	Limnophora	7					PR			
138933	139013	Dohrniphora									
131750	144653	Sciomyzidae				6		PR		bu	
144770	144898	Sepedon						PR			
131750	139621	Syrphidae				10		GC			
141029	141049	Chrysogaster									
	140904	Eristalis	10		0			GC		bu	

APPENDIX C:

TOLERANCE AND TROPHIC GUILDS OF SELECTED FISH SPECIES

Appendix C

Appendix C is a list of selected fishes of the United States in phylogenetic order. Included are the Taxonomic Serial Number (TSN) and the Parent Taxonomic Serial Number for each of the species listed according to the Integrated Taxonomic Information System (ITIS). The ITIS generates a national taxonomic list that is constantly updated and currently posted on the World Wide Web at <www.itis.usda.gov>. If you are viewing this document electronically, this page is linked to the ITIS web site.

Additionally, this Appendix details trophic and tolerance designations for selected fishes of the United States. To generate this list, we compiled a consensus rating for each taxon from the literature sources listed below. Exceptions are listed for each source that does not agree with the consensus of other cited literature. Exceptions are noted by first listing the designation then the literature source code in parentheses. The following is a list of the designations and literature sources used in this Appendix.

Trophic Designations

P=Piscivore
H=Herbivore
O=Omnivore
I=Insectivore (including specialized insectivores)
F=Filter feeder
G=Generalist feeder
V=Invertivore

Notes on Trophic Designations
Piscivore—although some investigators separate certain species into subcategories such as parasitic (e.g., sea lamprey) or top carnivore (e.g., walleye), we have grouped these together as piscivores for this list.

Tolerance Designations (relevant to non-specific stressors)

I = Intolerant
M = Intermediate
T = Tolerant

Notes on Tolerance Designations
Intolerant—although some investigators separate certain species into subcategories such as rare intolerant, special intolerant or common intolerant, we have grouped these together as intolerant for this list.

Literature Sources For Trophic/Tolerance Designations

(A) = Midwestern United States (Karr et al. 1986)

(B) = Ohio (Ohio EPA 1987)

(C) = Midwestern United States (Plafkin et al. 1989)

(D) = Central Corn Belt Plain (Simon 1991)

(E) = Wisconsin Warmwater (Lyons 1992)

(F) = Maryland Coastal Plain (Hall et al. 1996)

(G) = Northeastern United States (Halliwell et al. 1999)

APPENDIX D:

SURVEY APPROACH FOR COMPILATION OF HISTORICAL DATA

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QUESTIONNAIRE SURVEY FOR EXISTING BIOSURVEY DATA AND BIOASSESSMENT INFORMATION

Ecological expertise and knowledge of the aquatic ecosystems of a state can reside in agencies and academic institutions other than the water resource agency. This expertise and historical knowledge can be valuable in problem screening, identifying sensitive areas, and prioritizing watershed-based investigations. Much of this expertise is derived from biological survey data bases that are generally available for specific surface waters in a state. A systematic method to compile and summarize this information is valuable to a state water resource agency.

The questionnaire survey approach presented here is modified from the methods outlined in the original RBP IV (Plafkin et al. 1989) and is applicable to various types of biological data. The purpose of this questionnaire survey is to compile and document historical/existing knowledge of stream physical habitat characteristics and information on the periphyton, macroinvertebrate, and fish assemblages.

The template questionnaire is divided into 2 major sections: the first portion is modeled after RBP IV and serves as a screening assessment; the second portion is designed to query state program managers, technical experts, and researchers regarding existing biosurvey and/or bioassessment data. This approach can provide a low cost qualitative screening assessment (Section 1) of a large number of waterbodies in a relative short period. The questionnaire can also prevent a duplication of effort (e.g., investigating a waterbody that has already been adequately characterized) by polling the applicable experts for available existing information (Section 2).

The quality of the information obtained from this approach depends on survey design (e.g., number and location of waterbodies), the questions presented, and the knowledge and cooperation of the respondents. The potential respondent (e.g., agency chief, program manager, professor) should be contacted initially by telephone to specifically identify appropriate respondents. To ensure maximum response, the questionnaire should be sent at times other than the peak of the field season and/or the beginning or end of the fiscal year. The inclusion of a self-addressed, stamped envelope should also increase the response rate. A personalized cover letter (including official stationary, titles, and signatures) should accompany each questionnaire. As a follow-up to mailings, telephone contact may be necessary.

Historical data may be limited in coverage and varied in content on a statewide basis, but be more comprehensive in coverage and content for specific watersheds. A clearly stated purpose of the survey will greatly facilitate evaluation of data from reaches that are dissimilar in characteristics. The identification of data gaps will be critical in either case. Regardless of the purpose, minimally impaired reference reaches may be selected to serve as benchmarks for comparison. The definition of minimal impairment varies from region to region. However, it includes those waters that are generally free of point source discharges, channel modifications, and/or diversions, and have diverse habitats, complex substrates, considerable instream cover and a wide buffer of riparian vegetation. Selection of specific reaches for consideration (e.g., range and extent) in the questionnaire survey is ultimately dependent on program objectives and is at the discretion of the surveyor. The questionnaire approach and the following template form allows considerable flexibility. Results can be reported as histograms, pie graphs, or box plots.

Questionnaire design and responses should address, when possible, the:

- extent of waterbody or watershed surveyed
- condition of the periphyton, macroinvertebrate and/or fish assemblage
- quality of available physical habitat
- frequency of occurrence of particular factors/causes limiting the biological condition
- effect of waterbody type and size on the spatial and temporal trends, if known
- likelihood of improvement or degradation based on known land use patterns or mitigation efforts

BIOASSESSMENT/BIOSURVEY QUESTIONNAIRE

Date of Questionnaire Survey ____________

This questionnaire is part of an effort to assess the biological condition or health of the flowing waters of this state. Our principle focus is on the biotic health of the designated waterbody as indicated by its periphyton, macroinvertebrate and/or fish community. You were selected to participate in this survey because of your expertise in periphyton, macroinvertebrate, and/or fish biology and your knowledge of the waterbody identified in this questionnaire.

Please examine the entire questionnaire form. If you feel that you cannot complete the form, check here [ ] and return it. If you are unable to complete the questionnaire but are aware of someone who is familiar with the waterbody and/or related bioassessments, please identify that person's name, address, and telephone number in the space provided below:

Contact: Name______________________________
Address______________________________
Agency/Institution______________________
Phone______________Fax______________
Email______________________________

This questionnaire is divided into two major sections. Section 1 serves as a screening assessment and Section 2 is a request for existing biosurvey data and/or bioassessment results.

This form addresses the following waterbody:

____
Waterbody

State:____________ County:____________ Lat./Long.:__________ Waterbody code:________

Ecoregion:__________ Subecoregion:________ Description of site/reach:____________________

Drainage size:__________ Flow: <1cfs; 1-10cfs; >10cfs ______________

Description of data set (i.e., years, seasons, type of data, purpose of survey)____________________

SECTION 1. SCREENING ASSESSMENT

Using the scale of biological conditions found in the following text box, please circle the rank that best describes your impression of the condition of the waterbody.

SCALE OF CONDITIONS

5	Species composition, age classes, and trophic structure comparable to non (or minimally) impaired waterbodies of similar size in that ecoregion or watershed.
4	Species richness somewhat reduced by loss of some intolerant species; less than optimal abundances, age distributions, and trophic structure for waterbody size and ecoregion.
3	Intolerant species absent; considerably fewer species and individuals than expected for that waterbody size and ecoregion; trophic structure skewed toward omnivory.
2	Dominated by highly tolerant species, omnivores, and habitat generalists; top carnivores rare or absent; older age classes of all but tolerant species rare; diseased fish and anomalies relatively common for that waterbody size and ecoregion.
1	Few individuals and species present; mostly tolerant species; diseased fish and anomalies abundant compared to other similar-sized waterbodies in the ecoregion.
0	No fish, depauperate macroinvertebrate and/or periphyton assemblages.

(Circle one number using the scale above.)

1. Rank the current conditions of the reach

   5 4 3 2 1 0

If impairment noted (i.e., scale of 1-3 given), complete each subsection below by **checking off** the most appropriate limiting factor(s) and probable cause(s). Clarify if reference is to past or current conditions.

PHYSICOCHEMICAL

(a.) WATER QUALITY

Limiting Factor	Probable Cause
☐ Temperature too high ☐ Temperature too low ☐ Turbidity ☐ Salinity ☐ Dissolved oxygen ☐ Gas supersaturation ☐ pH too acidic ☐ pH too basic ☐ Nutrient deficiency ☐ Nutrient surplus ☐ Toxic substances ☐ Other (specify below) ________________ ☐ Not limiting	☐ Primarily upstream ☐ Within reach Point source discharge ☐ Industrial ☐ Municipal ☐ Combined sewer ☐ Mining ☐ Dam release Nonpoint source discharge ☐ Individual sewage ☐ Urban runoff ☐ Landfill leachate ☐ Construction ☐ Agriculture ☐ Feedlot ☐ Grazing ☐ Silviculture ☐ Mining ☐ Natural ☐ Unknown ☐ Other (specify below) ________________

(b.) WATER QUANTITY

Limiting Factor	Probable Cause
☐ Below optimum flows ☐ Above optimum flows ☐ Loss of flushing flows ☐ Excessive flow fluctuation ☐ Other (specify below) ________________ ☐ Not limiting	☐ Dam ☐ Diversion Watershed conversion ☐ Agriculture ☐ Silviculture ☐ Grazing ☐ Urbanization ☐ Mining ☐ Natural ☐ Unknown ☐ Other (specify below) ________________

BIOLOGICAL/HABITAT

(Check the appropriate categories)

(a.) Limiting Factor	HABI	PERI	MACR	FISH
Insufficient instream structure				
Insufficient cover				
Insufficient sinuosity				
Loss of riparian vegetation				
Bank failure				
Excessive siltation				
Insufficient organic detritus				
Insufficient woody debris for organic detritus				
Frequent scouring flows				
Insufficient hard surfaces				
Embeddedness				
Insufficient light penetration				
Toxicity				
High water temperature				
Altered flow				
Overharvest				
Underharvest				
Fish stocking				
Non-native species				
Migration barrier				
Other (specify) ______________________				
Not limiting				

Key:

HABI - Habitat
PERI - Periphyton
MACR - Macroinvertebrates
FISH - Fish

(b.) Probable Cause	HABI	PERI	MACR	FISH
Agriculture				
Silviculture				
Mining				
Grazing				
Dam				
Diversion				
Channelization				
Urban encroachment				
Snagging				
Other channel modifications				
Urbanization/impervious surfaces				
Land use changes				
Bank failure				
Point source discharges				
Riparian disturbances				
Clear cutting				
Mining runoff				
Stormwater				
Fishermen				
Aquarists				
Agency				
Natural				
Unknown				
Other (specify) ________________				

Key:

HABI - Habitat	PERI - Periphyton
MACR - Macroinvertebrates	FISH - Fish

SUMMARY: ASPECT OF PHYSICOCHEMICAL OR BIOLOGICAL CONDITION AFFECTED
☐ Water quality ☐ Water quantity ☐ Habitat structure ☐ Periphyton assemblage ☐ Macroinvertebrate assemblage ☐ Fish assemblage ☐ Other (specify) ________________

SECTION 2. AVAILABILITY OF DATA

Please complete this section with applicable response(s) and fill in the blanks with appropriate information based on your knowledge of available biosurvey and bioassessment information.

Reach characterized by:

- ☐ Stream habitat surveys
- ☐ Periphyton surveys — assemblage ☐ — key species ☐
- ☐ Macroinvertebrate surveys — assemblage ☐ — key species ☐
- ☐ Fish surveys — assemblage ☐ — key species ☐

Sampling gear(s) or methods

____
____
____
____

Sampling frequency (spatial and temporal)

____
____
____
____

Data analysis/interpretation based on:

- Tabulated data ☐
- Graphical data ☐
- Multivariate analyses. ☐
- Multimetric approach. ☐

Electronic file available:

Format ______________________________
____
____

Statistical routines include:

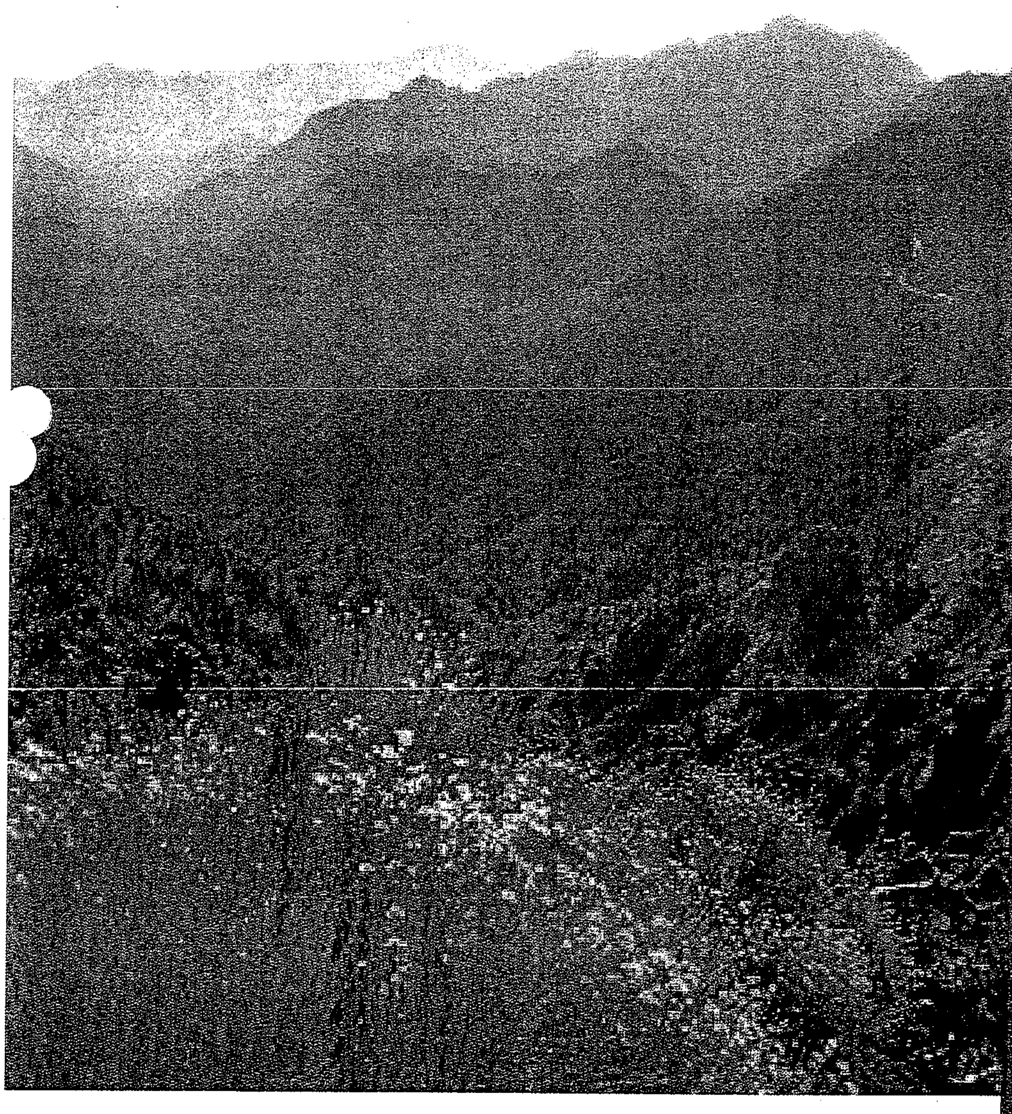
____
____
____
____

Metrics include:

____
____
____
____

REGIONAL MONITORING OF SOUTHERN CALIFORNIA'S COASTAL WATERSHEDS

Stormwater Monitoring Coalition
Bioassessment Working Group



Southern California Coastal Water Research Project

Technical Report 539 - December 2007

REGIONAL MONITORING OF SOUTHERN CALIFORNIA'S COASTAL WATERSHEDS

Stormwater Monitoring Coalition Bioassessment Working Group

December, 2007

Technical Report 539

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A010349

INTRODUCTION

Watersheds in the coastal range of southern California are a valuable aquatic resource. Comprising over 5,000 stream miles, both humans and wildlife use these watershed resources for fish habitat and fishing, drinking water, swimming and other recreational uses, water augmentation and groundwater recharge, agriculture, and many others.

Despite the many beneficial uses derived from the rivers and streams, southern California's burgeoning population also places a large number of potential stressors on its coastal watersheds. Habitat alteration, hydromodification through increased imperviousness, flood control, water augmentation and diversion, discharge of treated and industrial wastewaters, and contributions from urban runoff can all result in impairments to aquatic life in the region's rivers and streams.

At this point in time, the regional health of southern California's rivers and streams cannot be determined. One reason the regional health cannot be determined is because so little of the region's streams and rivers are monitored. Based on existing monitoring effort, only 29% the stream miles in southern California are monitored on an ongoing basis. Some watersheds, such as the San Gabriel River have many sampling locations and are well-monitored, but the status of other watersheds like Calleguas Creek remain virtually unmonitored. The reason for this uneven level of effort is due mostly to the presence of instream discharges, where monitoring is mandated. Otherwise, monitoring is typically not conducted. As a result, the most monitoring occurs in locations where impacts are expected to occur and the potential for a biased picture of aquatic health is likely.

Even if expansive monitoring programs of aquatic health were conducted, the monitoring is currently conducted by over a dozen different organizations. Each of these organizations has disparate programs that vary in design, frequency, and indicators selected for measurement. Even where designs are similar, often the field techniques, laboratory methods, and quality assurance requirements are not comparable, so cumulative assessments are infeasible. Finally, assuming all programs were of comparable design and quality, there is no overarching information management system, so sharing data is extremely labor intensive if not entirely impracticable.

The goal of this document is to describe a large-scale, regional monitoring program of southern California's coastal streams and rivers. The objective is to create a comprehensive monitoring design that integrates many elements of the individualized monitoring programs that currently exist within the region. As part of this design, a necessary component will facilitate comparability in the field and the laboratory, set performance-based QA guidelines, and initiate an information management system for sharing data. Data analysis elements will be described for creating assessment endpoints of stream health. This integrated regional monitoring program is designed to be collaborative, so that each individual program can assess their local geography, then contribute their portion to the whole of the region to address large-scale management needs and provide answers to the public about the health of southern California's streams and rivers.

The motivation behind the integrated regional watershed monitoring is the Stormwater Monitoring Coalition (SMC) and the Surface Water Ambient Monitoring Program (SWAMP).

The SMC is a coalition of stormwater management agencies and Regional Water Quality Control Boards (RWQCBs) from Ventura to San Diego (Table 1). Unlike any other organization in the United States, the SMC's mission is to cooperatively answer the technical questions that enable better environmental decision-making regarding stormwater management. The SWAMP is a statewide receiving water monitoring program administered by the Sate Water Resources Control Board (SWRCB). The two programs effectively cross paths in the area of wadeable streams in southern California with the parallel objective of assess health of the region's aquatic resources. As such, the two programs have joined forces to create the regional watershed monitoring program described herein.

MONITORING QUESTIONS AND GENERAL APPROACH

The Regional Watershed Monitoring Program addresses three questions of importance to regulated agencies, regulatory organizations, and public:

1. What is the condition of streams in Southern California?
2. What are the major stressors to aquatic life?
3. Are conditions in locations of special interest getting better or worse?

Each of these questions is answered by a different component of the monitoring program. Together, these components determine the spatial and temporal extent of impacts, their magnitude, and potential causes.

The first question addresses the magnitude and spatial extent of impacts of all streams in the region using a probabilistic sampling design. The goal will be to achieve an estimate of impacted stream miles at varying severity of impairment. In addition, the spatial extent of impact will be compared among watersheds and land uses. Therefore, stratification of the probabilistic design will occur across 15 different watershed areas that are defined by management units (hereafter referred to as "watersheds"). Stratification will also occur across three different land uses defined as urban, agricultural, and open. At each site, multiple indicators will be used to assess the ecological health of the stream, including water chemistry, aquatic toxicity, benthic macroinvertebrate community structure, periphyton community structure and biomass, and physical and riparian habitat. Impacts will be defined by thresholds for each indicator, such as comparison with established benchmarks or standards for water quality. Macroinvertebrate communities will be evaluated by calculating the Southern California Index of Biotic Integrity (IBI, Ode et al. 2005) and by multivariate tools, such as the RIVPACS ratio of observed to expected taxa (O/E, Hawkins et al. 2000). A periphyton index of biotic integrity for southern California is currently under development, with a draft IBI expected in 2010. Riparian condition will be evaluated by the California Rapid Assessment Method (CRAM) index (Collins et al. 2007).

The second question addresses the stressors that affect the health of streams in Southern California. The goal of this component is to build upon the stressor and response data collected in the first component to develop a relative risk index (Van Sickle et al. 2006). The response variables will focus on ecological health endpoints such as biological metrics or indices (e.g., IBI or O/E). Example stressors will include elevated nutrients, trace metals, degraded physical habitat, and increased toxicity. The relative risk of each stressor will be calculated by comparing the ecological health response variables at sites where the stressor is above or below thresholds of concern. This component requires no sampling effort beyond that required by the first component, but rather a more thorough analysis of the data.

The third question addresses the temporal changes in stream health at locations of primary interest to managers. The goal is to assess if stream health is improving, degrading, or remaining static over time. A targeted monitoring design that focuses on watershed sites that integrate upstream inputs is preferred. To answer this question, we will set up a network of long-term monitoring sites across the region. All coastal watersheds will have at least one long-term monitoring site located at the bottom of the watershed. Additional sites may be located in the interior below major tributaries and other regions of interest. At each site, water chemistry and toxicity will be evaluated at least once per year during dry weather. Ideally, these sites will be co-located at existing sites so that historical data can be used to help assess trends.

SPECIFIC APPROACH

The specific approach to the regional monitoring design is broken into two sections according to design. The first section addresses the first and second questions and is focused on spatial extent and stressor identification. The next section addresses the third question and is focused on trends.

Spatial Extent and Stressor Identification

The questions regarding spatial extent has several study design characteristics including sampling frame, sample size, frequency, indicators, and methods.

Sampling Frame

Sample sites were selected using a probabilistic approach weighting by watershed, land use, and stream order (Stevens and Olsen 2004). The sampling frame includes 15 watershed units located from Ventura to San Diego and as far east as San Bernardino and Riverside Counties (Figure 1). These watersheds equate to combinations of management units utilized by the RWQCBs or SMC member agencies. Altogether, these 15 watershed units are comprised of roughly 28,051 km^2 (Table 2). The streamlines used to define the sampling frame were derived from the National Hydrography Dataset (NHD Plus) (US EPA and USGS 2007). Altogether, there are 9,492 stream miles of Strahler order 2 and greater in the sampling frame. Land use was defined as either urban, agriculture, or open based on CCAP remote imaging algorithms (National Oceanic and Atmospheric Administration 1995) (Figure 2). CCAP defines 35 different land use classes that have been aggregated into the three categories for this study (i.e., open, agriculture, urban, and water) (Table 3). The dominant land use within a 500-m buffer was assigned to each stream reach. Individual watersheds are described in Appendix 1.

Sample Size

Sample size was defined based on the relative effort to obtain estimates of spatial extent with known estimates of precision. These estimates are defined by a power curve from a binomial distribution (Figure 3). In this case, a sample of 30 provides an estimate of spatial extent $\pm$ 12%, which was considered sufficient by managers in this region for making decisions. So, if each watershed requires 30 samples, and there are 15 watersheds, the total sample size for the spatial extent question will be 450 samples (Table 4). Because there are only three land use strata, there will be more than 30 sites in each land use (Table 4). The number of sites representing each land use type reflects the abundance of the land use type within the entire region. Figure 4 shows the distribution of sites in the sample draw, according to watershed and land use.

Frequency

Each site shall be sampled only once during an index period beginning 4 weeks following the last significant rainfall and no more than 12 weeks following the last rainfall. Significant rainfall is defined as precipitation that produces sufficient scouring to disrupt benthic communities. In addition, no sampling shall occur within 72 hours of any measurable rainfall. Based on historical rainfall records, the wet season in southern California ends April 15th (Figure 5). Without a priori knowledge of rainfall, the default index period will occur from May 15 to July 15.

Although all sampling must occur within the index period, not all sites need to be collected during the same year (Table 4). In fact, it is better to collect the sites across multiple years to incorporate the effects of differences in rainfall and subsequent hydrology. What was important to the SMC and SWAMP was to get an answer to the first monitoring question after five years (i.e., one NPDES permit cycle). Therefore, one-fifth of the samples will be collected each year. This equates to six sites per watershed or 90 sites per year total. After five years, a rolling five-year window can be used to assess trends in spatial extent.

Indicators

There are six different types of indicators used answer the question about spatial extent. All of these indicators will be measured in a manner comparable to SWAMP to ensure integration with statewide data sets. The first indicator is water chemistry. Water chemistry shall include conventional water quality, nutrients, trace metals, and pyrethroid pesticides (Table 5). The water chemistry variables shall be collected and analyzed according to Puckett (2002) and Ode (2007). The second indicator is aquatic toxicity to the water flea, *Ceriodaphnia dubia*. Chronic toxicity shall be measured as a 7-day exposure with effects endpoints of lethality and reproduction according to US EPA (1993). The freshwater amphipod, *Hyalella azteca,* in a water phase text, can be used as a back up species if conductivity is too high (i.e., > 2,500 μS/cm) for *Ceriodaphnia* control survival. The third indicator is physical habitat that includes several types of measures of stream condition including flow, channel morphology, riparian cover, substrate, and human alterations. Measurements shall be collected according to Ode (2007). The fourth indicator is benthic macroinvertebrates. Benthos shall be collected using the multi-habitat method described in the SWAMP protocol (Ode 2007). Identifications will be done according to the Standard Taxonomic Effort Level 2 for California benthic macroinvertebrates, as described in Richards and Rogers (2007). The fifth indicator is wetland status. Wetland status shall be measured using the California Rapid Assessment Method (CRAM). CRAM is a cost effective diagnostic tool that is part of a comprehensive statewide program to monitor the health of wetlands and riparian habitats throughout California (Collins et al., 2007). The sixth indicator is periphyton. Periphyton, or attached algae, shall be measured in two ways; biomass and taxonomic identification. Periphyton is sensitive to water chemistry alteration and nutrient enrichment. SWAMP is currently developing standardized methodology for periphyton. In an effort to maintain comparability, the regional monitoring program shall adopt these same methods.

Trends

The question regarding temporal trends has several study design characteristics including sample sites, frequency, indicators and methods.

Sampling Sites

Sample sites were selected using a targeted approach. The criteria for site selection included: 1) location near the terminus of the stream or river so that it integrates all discharges upstream of the site; and 2) previous monitoring efforts (where possible) so prior data collection can be utilized. One site per watershed (two in the San Gabriel watershed) examined in the spatial extent design was selected for a total of 16 sites (Figure 1, Table 6). Additional sites may be selected as desired.

Frequency

Sampling frequency is a function of data variability, amount of change to detect, and time to detect change. These three factors are best evaluated using power analysis at each site for each indicator. Based on power analysis from a subset of sites, a minimum of 1 sample per year shall be collected during a dry weather index period from each site (Figure 6). Additional samples may be collected to increase the power to detect trends on a site-by-site basis. The index period shall match the index period used for the spatial extent question.

Indicators

There are two different types of indicators used answer the question about trends: water chemistry and aquatic toxicity. Both of these indicators will be measured in a manner comparable to SWAMP to ensure integration with statewide data sets. Water chemistry shall include conventional water quality, nutrients, trace metals, PAHs, and pyrethroid pesticides (Table 5). The water chemistry variables shall be collected and analyzed according to Puckett (2002) and Ode (2005). The second indicator is aquatic toxicity to the water flea, *Ceriodaphnia dubia*. Chronic toxicity shall be measured as a 7-day exposure with effects endpoints of lethality and reproduction according to US EPA (1993).

PRODUCTS

There will be four types of products generated for the regional monitoring program: a field manual, a quality assurance manual, an information management manual, and an assessment report. The field manual will document all of the recommended methods for field activities including necessary equipment, sampling protocols, training requirements, field data sheets, and sample site assignments. As part of the field manual, there will be a meeting of all of the field team leaders to ensure consistency and comparability among agencies conducting sampling. One such training and intercalibration occurred in February 2004 and a second in May 2006.

The second product from the regional monitoring program will be a quality assurance manual. The quality assurance manual will document the recommended data quality objectives (DQOs) for field and laboratory activities. The DQOs set minimum standards for sensitivity, accuracy, precision, and representativeness. Only with this level of quality control can data be made comparable enough for compilation. The SMC has already undergone two laboratory intercalibrations and created a laboratory guidance manual for many of the water chemistry constituents required for this workplan.

The third product from the regional monitoring program will be an Information Management (IM) Manual. The IM Manual will be the key document that enables the various agencies share data. The IM Manual will consist of standardized data formats (SDTFs). SDTFs detail the data types and formats (i.e., order of variables) enabling laboratories to deliver complete data sets in any software format, including delimited ASCII code. No new software, hardware, or extensive personnel training is required for SDTFs. The SMC has already created and shared SDTFs for most of the data types being collected in the Regional Monitoring Program (Cooper et al. 2004).

The fourth product from the regional monitoring program will be an assessment report. The assessment report will be a synopsis of the findings of the survey that addresses the three questions. While there are a large number of potential data products from this type of a survey, a few examples are listed here. To answer the first question, an assessment of stream-miles impacted will be conducted (Figure 7). This will provide a statistically valid answer to the question of overall health of streams regionally. This assessment will include the percent of stream-miles for southern California as a whole and by individual watersheds. A similar data product can be developed, but replacing watersheds with different land uses along the x-axis.

To answer the second question, the relative risk of various stressors will be evaluated by dividing the extent of stream-miles impacted by that stressor by the extent of impacted stream-miles not impacted by that same stressor (Figure 8). Quotients near unity represent limited or no increased risk to aquatic life for that stressor. Quotients greater than one represent an increased risk for that stressor. The greater the quotient, the greater the relative risk (Van Sickle et al., 2006). These data can be used to assess the potential risk in future site-specific applications, help to determine sources of impact at individual sites, or to help assess important factors in remediation/restoration projects.

To answer the third question, the temporal trends of stream health indicators will be plotted over time to determine if resources are improving, degrading, or remaining unchanged (Figure 9).

These plots will be useful at the watershed specific level to determine if site-specific management has been successful at improving or maintaining water quality. This analysis will also be useful at the regional level to determine if large-scale changes may be influencing local or site specific trends. That is, decreases (or increase) in stream health may be a reflection of large-scale phenomenon such as global warming, nonindigenous species, or other events, rather than watershed-specific activities.

SCHEDULE

The regional monitoring program will be a five-year process (Figure 10). Sample preparation, including field and QA manuals will occur prior to the first year of sampling. Sampling will be completed by July and Laboratory analysis should take approximately 6 months. Compiling data, examining results, and making our first year assessments should require approximately three months (March). This will provide sufficient time to use what lessons were learned during year 1 and improve the program for year 2. An oral report of results from the first year will be presented by March, and a written first year report should be completed by June. This process is then repeated each year.

TABLES

Table 1. List of member agencies in the Stormwater Monitoring Coalition.

California Regional Water Quality Control Board, Los Angeles Region
California Regional Water Quality Control Board, San Diego Region
California Regional Water Quality Control Board, Santa Ana Region
California Department of Fish and Game
City of Long Beach
City of Los Angeles, Watershed Protection Division
County of Orange, Public Facilities and Resources Dept.
County of San Diego Stormwater Management Program
Los Angeles County Department of Public Works
Riverside County Flood Control and Water Conservation District
San Bernardino County Flood Control District
Southern California Coastal Water Research Project
State Water Resources Control Board
US Environmental Protection Agency, Office of Research and Development
Ventura County Watershed Protection District

Table 2. Management units included in the monitoring program.

Watersheds	Area (km²)	Stream order (max)	Total stream length (km)	Land use by area (proportion)			
				Open	Agricultural	Urban	Water
Ventura	642	6	264	0.88	0.05	0.05	0.03
Santa Clara	4,327	7	1,763	0.85	0.07	0.05	0.03
Calleguas	891	5	391	0.46	0.31	0.21	0.03
Santa Monica Bay	1,171	4	260	0.59	0.03	0.37	0.06
Los Angeles	2,160	5	626	0.44	0.02	0.53	0.06
San Gabriel	1,758	5	586	0.49	0.02	0.47	0.05
Santa Ana River	7,092	6	2,202	0.58	0.10	0.29	0.04
--Lower Santa Ana	1,253	6	349	0.35	0.06	0.54	0.07
--Middle Santa Ana	2,135	6	622	0.43	0.13	0.41	0.04
--Upper Santa Ana	1,721	5	654	0.78	0.04	0.15	0.03
--San Jacinto	1,984	4	576	0.71	0.14	0.12	0.02
San Juan	1,019	4	400	0.75	0.03	0.19	0.03
Northern San Diego	3,640	6	1,299	0.80	0.12	0.06	0.02
Central San Diego	1,725	5	513	0.57	0.08	0.32	0.04
Mission Bay and San Diego River	1,270	5	390	0.71	0.03	0.23	0.04
Southern San Diego	2,355	5	798	0.78	0.04	0.15	0.04
Entire region	28,051	7	9,492	0.66	0.08	0.23	0.03

Table 3: Derivation of SMC land-use classes from CCAP classes.

SMC class	CCAP class
Agriculture	Cultivated Land
Agriculture	Managed Grassland
Agriculture	Orchards
Agriculture	Pasture
Agriculture	Row Crop
Open	Bare Land
Open	Chaparral
Open	Deciduous Forest
Open	Estuarine Emergent Wetland
Open	Estuarine Forested Wetland
Open	Estuarine Scrub/Shrub Wetland
Open	Evergreen Forest
Open	Golf Courses
Open	Mixed Forest
Open	Palustrine Emergent Wetland
Open	Palustrine Forested Wetland
Open	Palustrine Scrub/Shrub Wetland
Open	Parks / Lawns
Open	Rangeland
Open	Sage
Open	Scrub/Shrub
Open	Unmanaged Grassland
Urban	Commercial/Industrial
Urban	High Intensity Developed
Urban	High Intensity Urban Residential
Urban	Low Intensity Developed
Urban	Rural Residential
Urban	Suburban Residential
Urban	Urban Residential
Excluded	Background
Excluded	Estuarine Aquatic Bed
Excluded	Palustrine Aquatic Bed
Excluded	Unclassified
Excluded	Unconsolidated Shore
Excluded	Water

Table 4. Projected number of samples by year.

Year	Number of samples in all watersheds	Number of samples in each watershed	Number of samples by land use		
			Open	Agriculture	Urban
2009	90	6	40	15	35
2010	90	6	28	21	41
2011	90	6	36	21	33
2012	90	6	28	32	30
2013	90	6	30	28	32
Total after five years	450	30	162	117	171

Table 5. **Variables measured at each site in the. P = variables measured at sites included in the probabilistic components of the project (i.e., questions 1 and 2). T = variables measured at sites included in the network of long-term trends sites. SRM: Standard Reference Material; CI: Confidence Interval; MS: Matrix Spike; MSD: Matrix Spike Duplicate; RPD: Relative Percent Difference; NA: Not applicable.**

Variable	P/T	Method	Accuracy	Precision	Reporting Limit
Biological					
Benthic macroinvertebrates	P	Ode 2007	Re-sort frequency: 100% Re-sort accuracy: ≥95% Lab ID frequency: 10% Lab ID accuracy: ≥95%	Field duplicates: 10%	SAFIT Level 2
Periphyton:				Field duplicates: 10%	
Chlorophyll a	P		±20% of SRM.		10 µg/cm2
Ash-free dry mass	P		NA		1 mg/ cm2
Taxonomy	P	Expected 2008	Diatoms and soft algae: Re-sort frequency: 100% Re-sort accuracy: ≥95% Lab ID frequency: 10% Lab ID Accuracy: ≥95%		NA
Riparian condition (CRAM)	P	Collins 2007	NA	NA	NA
Toxicity					
Ceriodaphnia dubia assays	P,T	EPA 1993	NA	Lab duplicates 10%	NA
Hyallela azteca assays	P,T	EPA 1993	NA	Lab duplicates 10%	NA
Water Chemistry					
Conventional water chemistry	P,T				
Temperature		Probe	NA	± 0.5 C	NA
pH		Probe	± 0.5 units of SRM	± 0.5 units	0 - 14 pH units
Conductivity		Probe	±5% of SRM	±5%	2.5 mS/cm
Dissolved oxygen		Probe	±0.5 mg/L of SRM	±0.5 mg/L	0.5 mg/L
Alkalinity			±10% of SRM	±10%	10 mg/L
Hardness					
Nutrients	P,T		Within 80% to 120% of true value	Field replicate, laboratory duplicate 10%, or MS/MSD + 25% RPD. Laboratory duplicate minimum.	
Ammonia					0.1 mg/L
Nitrite					0.01 mg/L
Nitrate					0.1 mg/L

Table 5. Continued.

Total nitrogen					0.1 mg/L
Orthophosphate					0.01 mg/L
Total phosphorous					0.1 mg/L
Major ions	P,T		Within 80% to 120% of true value	Field replicate, laboratory duplicate 10%, or MS/MSD + 25% RPD. Laboratory duplicate minimum.	
Calcium					0.05 mg/L
Sulfate					0.25 mg/L
Metals (dissolved and total)	P,T	EPA 200.8	Within 80% to 120% of true value	Field replicate, laboratory duplicate, or MS/MSD + 20% RPD. Laboratory duplicate minimum.	
Arsenic					1.0 µg/L
Cadmium					0.5 µg/L
Chromium					1.0 µg/L
Copper					1.0 µg/L
Iron					10 µg/L
Lead					1.0 µg/L
Nickel					1.0 µg/L
Zinc					1.0 µg/L
Organic constituents			50% to 150% of true value.	Field replicate or MS/MSD + 25% RPD. Field replicate minimum.	
Pyrethroid pesticides	P,T				1.0 ng/L
Organophosphate pesticides	T				1.0 ng/L
PCBs	T	8081/82			1.0 ng/L
PAHs	T	EPA 8270			0.5 – 1.0 ng/L
Physical habitat	P				
Location (latitude and longitude)		Ode 2007	NA	NA	10^{-5} degrees
Channel dimensions					
Channel substrate					1 cm
Embeddedness					1 mm
Gradient and sinuosity					NA
Human influence					NA
Riparian vegetation					NA
Instream habitat complexity					NA
Flow habitats					NA
Discharge					
Rapid bioassessment scores					NA
Additional habitat characterization					NA

Table 6. List of trend monitoring sites.

Watershed	Stream	Location
Ventura	Ventura River	at Foster Park
Santa Clara	Santa Clara River	Freeman Diversion
Calleguas	Calleguas Creek	at University Drive
Santa Monica Bay	Ballona Creek	at Sawtelle
Los Angeles	Los Angeles River	at Willow
San Gabriel	San Gabriel River	R9W
San Gabriel	San Gabriel River	R9E
Lower Santa Ana	San Diego Creek	at Campus Drive
Middle Santa Ana	Santa Ana River	at River Road
Upper Santa Ana	Santa Ana River	MWD Crossing
San Jacinto	San Jacinto River	at Goetz/TMDL site
San Juan	San Juan Creek	at Novia
Northern San Diego	Santa Margarita	at Basilone
Central San Diego	Escondido Creek	at Mass Emissions Site
Mission Bay and San Diego River	San Diego River	at Fashion Valley Rd
Southern San Diego	Tijuana River	at Hollister Rd

FIGURES

Figure 1. Map of watersheds included in the regional watershed monitoring program.

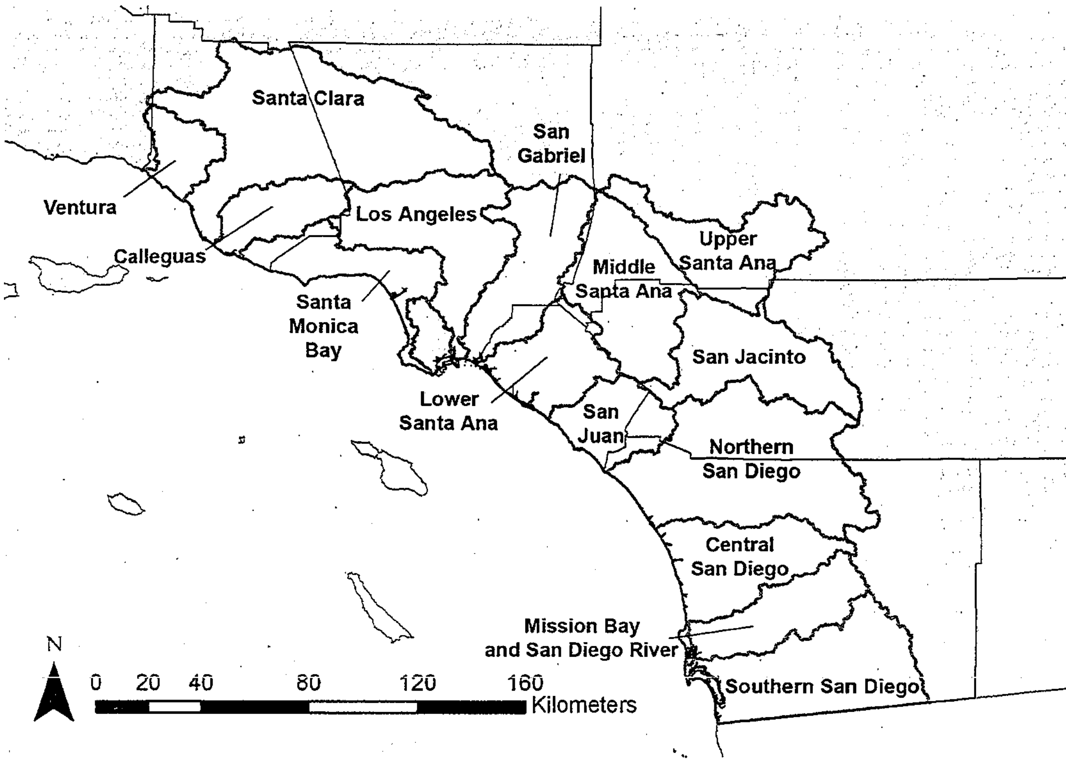
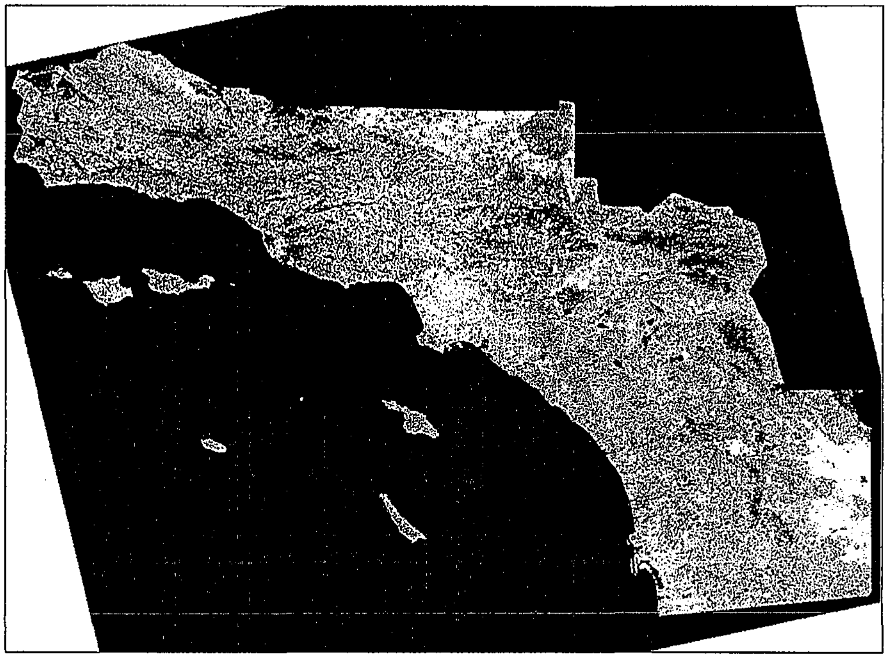


Figure 2. CCAP remote imaging of land use in the southern California region (A). Land use assignments for the watersheds included in the study (B).

A)



B)

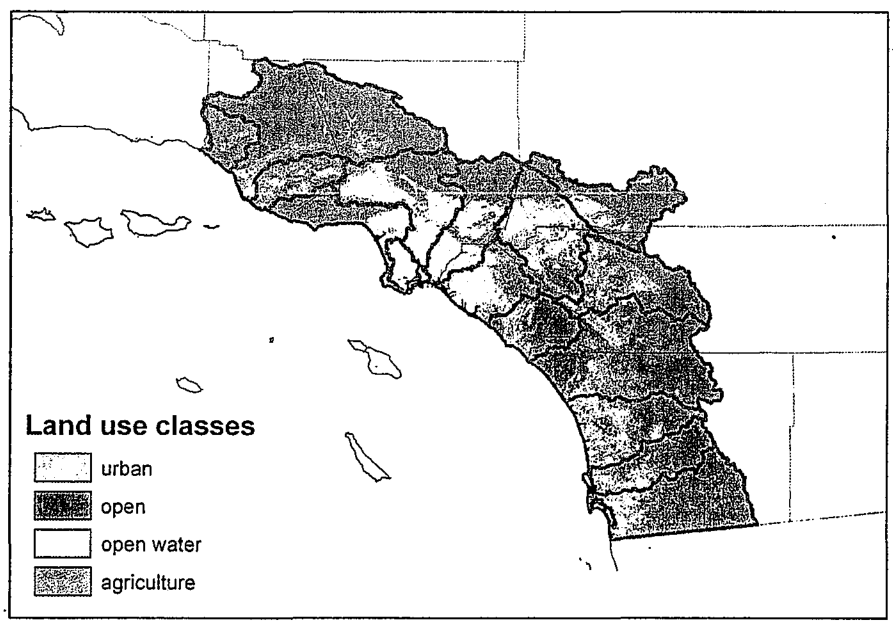


Figure 3. Size of confidence intervals about areal estimates (i.e., percent stream-miles) for different sample sizes.

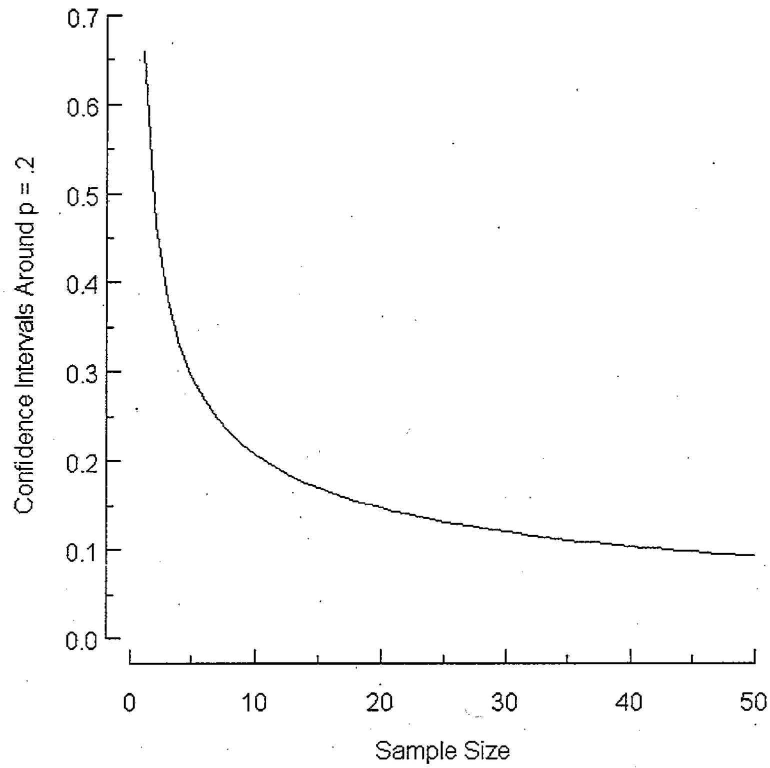


Figure 4. Locations of sample sites for the SMC regional watershed monitoring program.

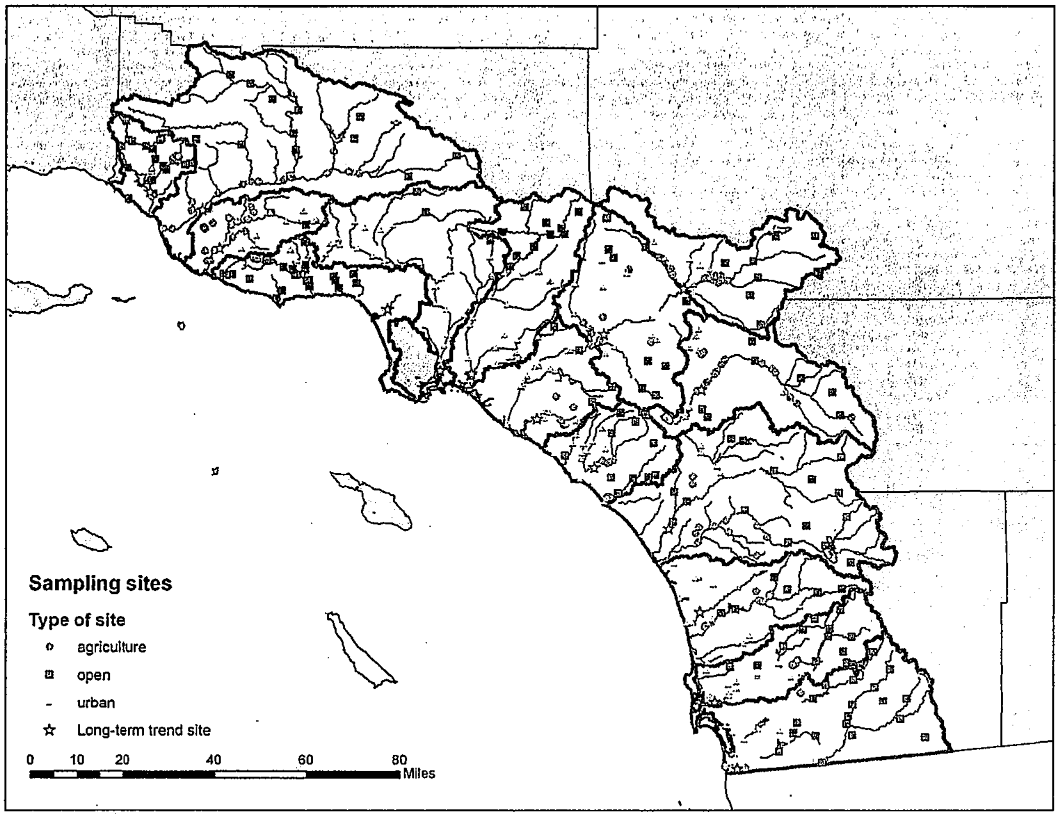


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Figure 5. Average monthly rainfall quantities at Lindbergh Field, San Diego from 1905 to 2006.

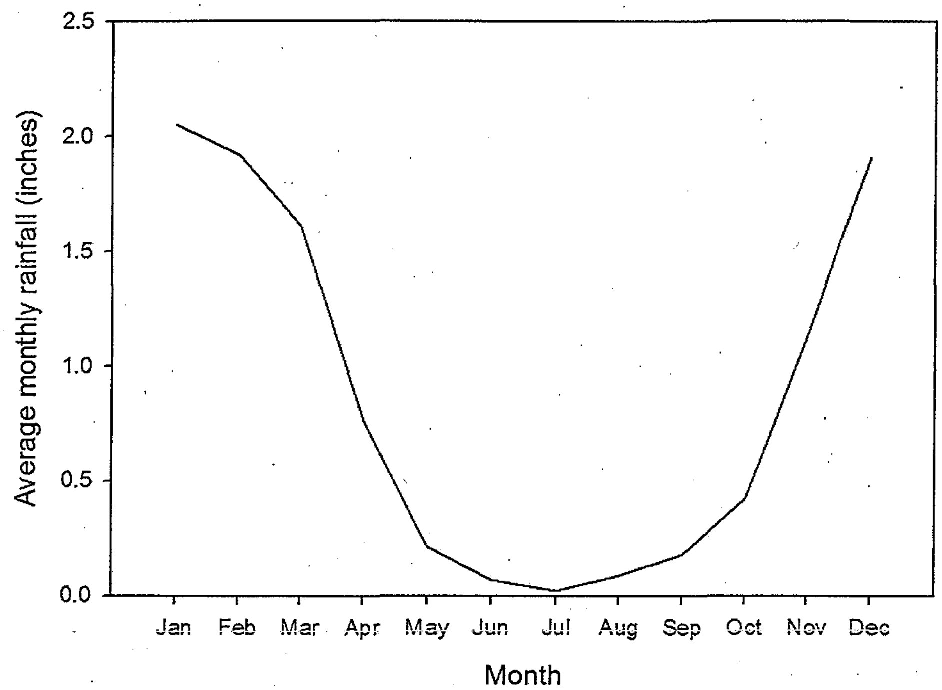

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Figure 6. Power curves to detect changes in a constituent at a long-term monitoring site (Hemet NPDES site in Riverside County). The right-most solid line represents power of one sample per year; from left to right, the remaining samples represent 2, 3, and 4 samples per year.

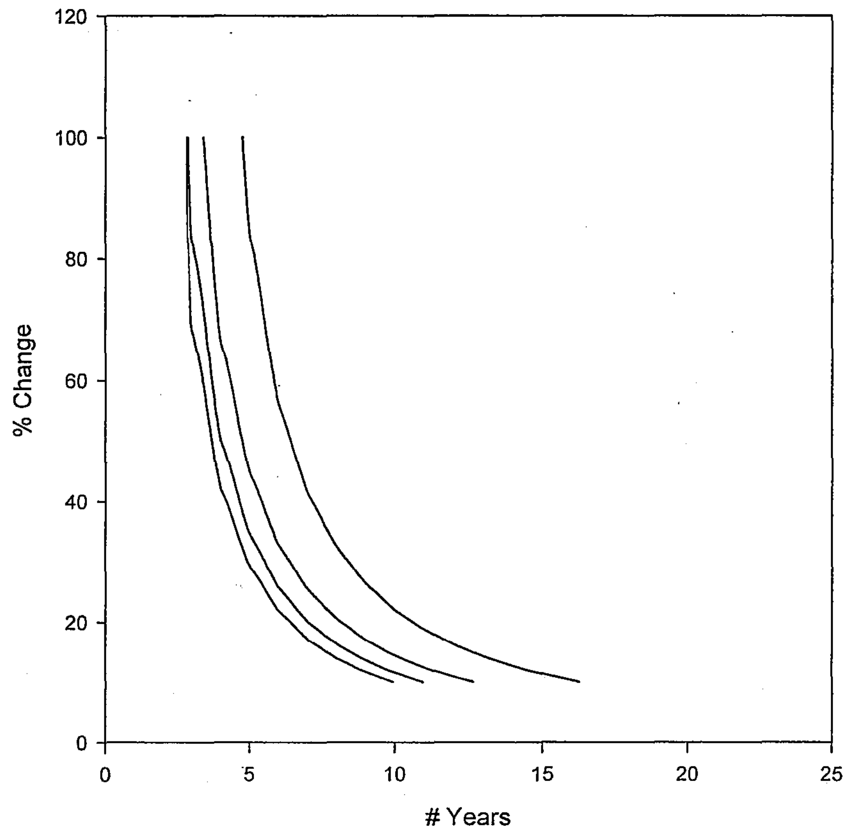

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Figure 7. Hypothetical distribution of degraded stream miles among different watersheds.

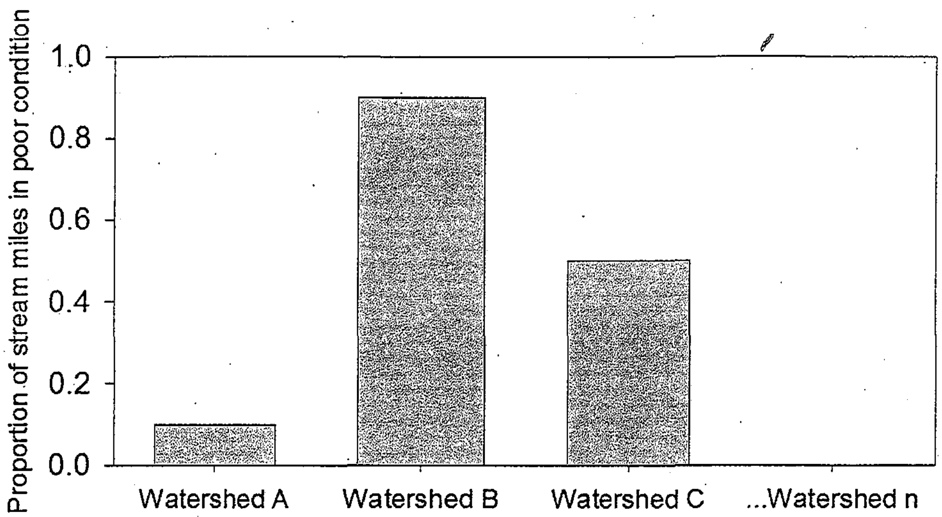

Figure 8. Hypothetical relative risks for stressors to an indicator. Relative risk is the quotient of extent (as %) of stream miles impaired by stressor x in an anthropogenic stratum and the extent of stream miles (as %) of stream miles impaired by stressor x in open (or reference) stratum.

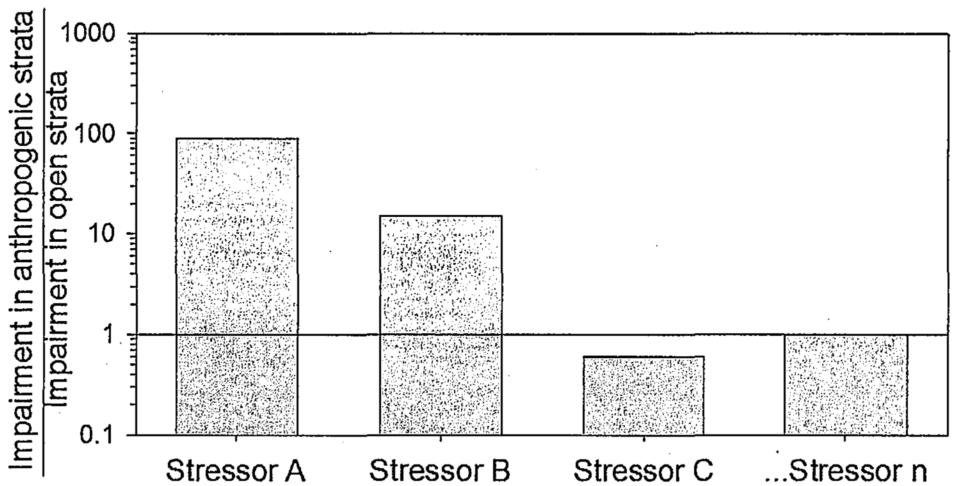

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Figure 9. Hypothetical trends in a constituent measured at a trends site. Points reflect differences in values relative to Year 1 values at an integrator site.

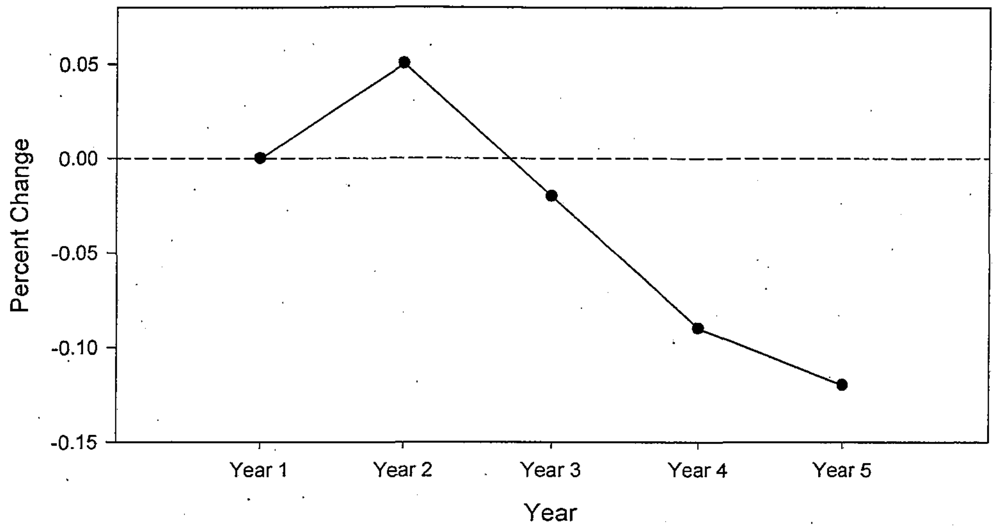
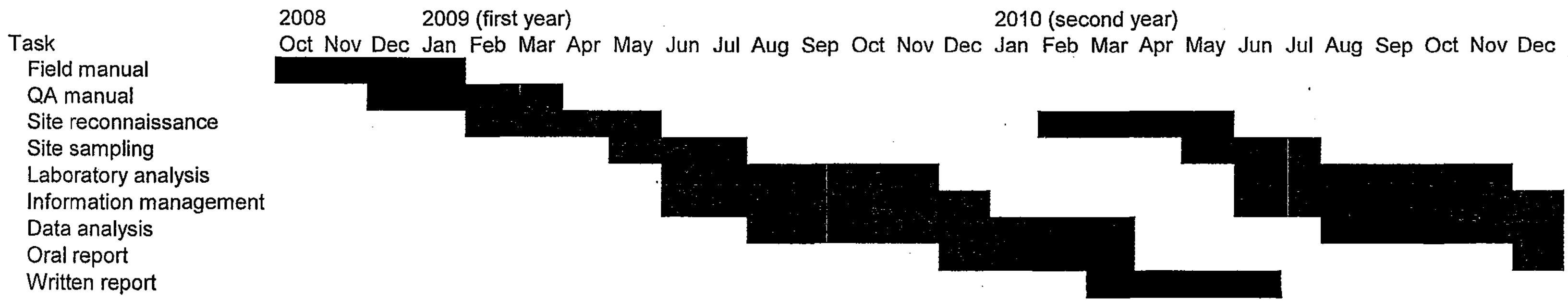


Figure 10. Timeline of activities through the first two years.



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IBI Scores - Ventura River Watershed

Year	Sites 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2001 - SD IBI	N/A	VG	Good	Good	Good	VG	dry	VG	VG	VG	VG	VG	Good	Fair	VG	Good
2002 - SD IBI	Fair	Good	dry	VG	VG	dry	dry	dry	VG	VG	Good	VG	Fair	Good	dry	VG
2003 - SD IBI	**Poor**	N/A	dry	dry	Fair	dry	dry	dry	VG	VG	Good	VG	VG	Good	Good	Good
2004 - So CA IBI	**Poor**	N/A	dry	dry	Fair	dry	dry	dry	Fair	Fair	Fair	Good	Fair	**Poor**	dry	Fair
2005 - So CA IBI	**Poor**	N/A	Fair	Fair	Fair	Fair	dry	**Poor**	Fair	Fair	Fair	Fair	Fair	Fair	Fair	**Poor**

SD IBI - San Diego Index of Biological Integrity
So CA IBI - Southern California Index of Biological Integrity

VG - Very Good

Ventura River Main Stem - 0, 1, 4, 6 & 12
Canada Larga Creek - 2 & 3
Matilija Creek - 10, 11, 13 & 14
San Antonio Creek - 5, 7, 8, 9 & 15

California Stream Bioassessment Protocol (CSBP)

IBI Scores - Ventura River Watershed

	Sites															
	Main Stem					Canada Larga		Matilija				San Antonio				
Year	**0**	**1**	**4**	**6**	**12**	**2**	**3**	**10**	**11**	**13**	**14**	**5**	**7**	**8**	**9**	**15**
2001 - SD IBI	N/A	VG	Good	dry	Good	Good	Good	VG	VG	Fair	VG	VG	VG	VG	VG	Good
2002 - SD IBI	Fair	Good	VG	dry	Fair	dry	VG	Good	VG	Good	dry	dry	dry	VG	VG	VG
2003 - SD IBI	**Poor**	N/A	Fair	dry	VG	dry	dry	Good	VG	Good	Good	dry	dry	VG	VG	Good
2004 - So CA IBI	**Poor**	N/A	Fair	dry	Fair	dry	dry	Fair	Good	**Poor**	dry	dry	dry	Fair	Fair	Fair
2005 - So CA IBI	**Poor**	N/A	Fair	dry	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	**Poor**	Fair	Fair	**Poor**

SD IBI - San Diego Index of Biological Integrity
So CA IBI - Southern California Index of Biological Integrity

VG - Very Good

Ventura River Main Stem - 0, 1, 4, 6 & 12
Canada Larga Creek - 2 & 3
Matilija Creek - 10, 11, 13 & 14
San Antonio Creek - 5, 7, 8, 9 & 15

California Stream Bioassessment Protocol (CSBP)

Physical / Habitat Scores - Ventura River Watershed

Year	Sites 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2001	N/A	**marginal**	**marginal**	sub	sub	sub	dry	sub	sub	optimal	optimal	optimal	optimal	sub	optimal	sub
2002	sub	sub	dry	sub	optimal	dry	dry	dry	sub	sub	optimal	optimal	optimal	optimal	dry	sub
2003	sub	N/A	dry	dry	sub	dry	dry	dry	sub	sub	sub	sub	optimal	sub	optimal	sub
2004	optimal	N/A	dry	dry	sub	dry	dry	dry	sub	optimal	optimal	optimal	optimal	optimal	dry	sub
2005	**marginal**	N/A	**marginal**	**marginal**	sub	sub	dry	sub	sub	sub	sub	sub	optimal	sub	sub	sub

Sub = suboptimal

tura River Main Stem - 0, 1, 4, 6 & 12
ada Larga Creek - 2 & 3
lija Creek - 10, 11, 13 & 14
Antonio Creek - 5, 7, 8, 9 & 15

ornia Stream Bioassessment Protocol (CSBP)

Physical / Habitat Scores - Ventura River Watershed

	Sites															
	Main Stem					Canada Larga		Matilija				San Antonio				
Year	0	1	4	6	12	2	3	10	11	13	14	5	7	8	9	15
2001	N/A	**marginal**	sub	dry	optimal	**marginal**	sub	optimal	optimal	sub	optimal	sub	sub	sub	optimal	sub
2002	sub	sub	optimal	dry	optimal	dry	sub	optimal	optimal	optimal	dry	dry	dry	sub	sub	sub
2003	sub	N/A	sub	dry	optimal	dry	dry	sub	sub	sub	optimal	dry	dry	sub	sub	sub
2004	optimal	N/A	sub	dry	optimal	dry	dry	optimal	optimal	optimal	dry	dry	dry	sub	optimal	sub
2005	**marginal**	N/A	sub	dry	optimal	**marginal**	**marginal**	sub	sub	sub	sub	sub	sub	sub	sub	sub

) = suboptimal

ıtura River Main Stem - 0, 1, 4, 6 & 12
ıada Larga Creek - 2 & 3
ilija Creek - 10, 11, 13 & 14
ı Antonio Creek - 5, 7, 8, 9 & 15

'ornia Stream Bioassessment Protocol (CSBP)

Ventura River Watershed Biological and Physical/Habitat Assessment Report

September 24-26, 2001

A010384

Ventura River Watershed
Biological and Physical/Habitat Assessment
Ventura County, California

September 24-26, 2001

Ventura Countywide Stormwater Quality Management Program

Ventura County Flood Control District
Water Quality Division
In conjunction with
Sustainable Land Stewardship Institute

Executive Summary

- On September 24-26, 2001, VFCD assisted by the Sustainable Land Stewardship Institute (SLSI) conducted the first year sampling event at 14 stream reaches within the Ventura river watershed. The California Stream Bioassessment Procedure (CSBP), a standardized sampling, laboratory and quality assurance procedure was used to describe the BMI community and the physical/habitat condition of the stream reaches.

- Using a newly developed San Diego IBI, the majority of the sites in the Ventura River watershed were rated as Very Good and Good. The San Diego IBI was used because the San Diego region is much more similar in terms of climate, precipitations, geology and general ecosystem to Ventura County.

- The overall assessment of the sites sampled from the Ventura River watershed indicates a healthy aquatic system.

- Physical/Habitat scores for the 14 sites ranged from 73 to 180, which relates to marginal to optimal conditions. The best habitat scores tended to be in the upper parts of the watershed and the worst in the lower parts.

- There was evidence to suggest that the human community is having some impact on Matilija Creek. These problem areas were identified through the bioassessment data and need to be verified and investigated further.

- There were evidence that Matilija Dam is impacting the downstream biologic condition. These problem areas were identified through the bioassessment data and need to be verified and investigated further.

- There was evidence to suggest that cattle grazing is having some effect on the biological condition of the Canada Larga creek. These problem areas were identified through the bioassessment data and need to be verified and investigated further.

Biological and Physical/Habitat Assessment of Selected Sites Within the Ventura River Watershed, Ventura County, California

Sustainable Land Stewardship Institute

BACKGROUND

Streams and rivers throughout the world face a number of problems, primarily associated with modification of in-stream and riparian structure, inputs of contaminated water and increases in the size and frequency of floods due to the increase in impervious surfaces. There have been many studies and reports showing the deleterious effects of land-use activities to macroinvertebrate and fish communities (Jones and Clark 1987; Lenat and Crawford 1994; Weaver and Garman 1994; Karr 1998). Preventing some of these problems and restoring streams to a healthier condition is being attempted throughout the world (Karr et al. 2000).

Direct measurements of ambient biological communities including plants, invertebrates, fish, and microbial life have been used for the past 150 years as indicators of sanitation, potable water supplies and the health of water for fisheries and recreation. In addition to these water quality implications, biological assessments (bioassessments) can be used as a watershed management tool for surveillance and compliance of land-use best management practices. Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term trend monitoring of watershed condition (Davis and Simon 1996).

Biological assessments of water resources integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality and provide the public with more familiar expressions of ecological health than the results of chemical and toxicity tests (Gibson 1996). Furthermore, biological assessments when integrated with physical and chemical assessments better define the effects of point-source discharges of contaminates and provide a more appropriate means for evaluating discharges of non-chemical substances (e.g. nutrients, sedimentation and habitat destruction).

Water resource monitoring using benthic macroinvertebrates (BMI) is by far the most popular method used throughout the world. BMIs are ubiquitous, relatively stationary and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of evolutionary, ecological and biogeographical information (Erman 1996).

While there are many potential methods for evaluating biotic condition from community data, most approaches in the United States use a combination of multimetric and multivariate techniques. In multimetric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kerans and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (Harrington 1999). As the Russian River IBI was being developed, the Department of Fish and Game (DFG) began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. During 1997 through 2000, data was collected from 93 locations distributed throughout the San Diego region. In 2001, a new set of sites were chosen and sampled to further establish reference conditions in the San Diego region. The results of this sampling event were combined with the results of earlier sampling events to establish a preliminary Index of Biological Integrity (IBI) for the San Diego region. In July 2002, a final report was presented as a working IBI for the San Diego region.

This newly developed San Diego IBI is currently the best tool to analyze macroinvertebrate data from Southern California in general, and Ventura County in this particular instance. The San Diego region is much more similar in terms of climate, precipitations, geology and general ecosystem, than is the Russian River area.

INTRODUCTION

NPDES permit CAS004002 required the Ventura Flood Control District (VFCD) to implement a countywide monitoring plan which included the development of an instream bioassessment monitoring program (this work plan), and the implementation of the monitoring program.

In spring 2001, VFCD's staff, with the assistance of the Sustainable Land Stewardship Institute (SLSI), developed a biological and physical/habitat assessment program within Ventura river watershed. On September 24-26, 2001, VFCD and SLSI conducted the first year sampling event. The goal of the program is to:

1) Provide base line information on the macroinvertebrate assemblages within Ventura River watershed;
2) Evaluate the biological and physical/habitat condition of various sampling sites within the Ventura River watershed using the preliminary Index of Biological Integrity (IBI) for the San Diego region;
3) Examine the effects of various land-use activities, including urban runoff, impacts on the macroinvetebrate community structure throughout the Ventura River watershed, and
4) Provide recommendations and strategies for continued monitoring.

Materials and Methods

Sampling Site Descriptions

The 14 Ventura River watershed sites sampled on September 24-26, 2001 are listed in Table 1 and in Figure 1. Sites' photographs are displayed in Table 2.

Table 1. BMI sampling location information for 16 reaches selected for the biological monitoring plan and sampled* September 24-26, 2001 in Ventura River watershed.

Sta.ID	Name	Description and Comments	Latitude	Longitude	Elev.
0	Ventura River – Main Street Bridge	Mainstem Ventura River, first site above estuary with fresh water. ***Not sampled**	34 16 54.23	119 18 24.09	19
1	Ventura River - Shell Road	Mainstem Ventura River. Area similar to site #0. ¼ to ½ mile downstream from wastewater and treatment plant.	34 18 59.6	119 17 41.3	195
2	Canada Larga Creek	Canada Larga Creek, d/s of grazing	34 20 31.7	119 17 08.2	293
3	Canada Larga Creek	Canada Larga Creek, above main area of grazing impact	34 22 23.3	119 14 8.8	334
4	Ventura River - Foster Park	Mainstem Ventura River. Closest downstream site to monitor impacts of San Antonio Creek. Station is also site is also mass emission station. Bioassessment u/s from Foster Park Bridge.	34 21 07.9	119 18 23.7	571
5	San Antonio Creek - near Ventura River	San Antonio Creek, first upstream site from confluence with Ventura River.	34 22 50.9	119 18 23.9	347
6	Ventura River - Santa Ana Rd.	Mainstem Ventura River ***Dry due in part to casitas diversion - not sampled**			
7	Lion Canyon Creek – u/s conf. San Antonio Creek	Lion Canyon Creek (tributary to San Antonio Creek) First u/s location from confluence. Impacted by nearby stables and grazing. Heavy sediment load.	34 25 19.3	119 15 46.8	623
8	Stewart Canyon Creek – u/s conf. San Antonio Creek	Stuart Creek (tributary to San Antonio Creek) First u/s location from confluence. Impacted by the city of Ojai and less densely developed residential lots.	34 26 07.1	119 14 49.3	685
9	San Antonio Creek near Stewart Canyon Creek	San Antonio Creek. Impacted by the City of Ojai and less densely developed residential lots.	34 26 1.8	119 14 52.7	650
10	North Fork Matilija Creek- u/s Ventura River conf.	North Fork Matilija Creek. No dam influence. Below quarry.	34 29 06.0	119 17 59.4	978
11	North Fork Matilija Creek- at gauging station	North Fork Matilija Creek. No dam influence. Above quarry	34 29 35.1	119 18 18.6	1,360
12	Ventura River - below Matilija Dam	Matilija Creek First station below Matilija dam and first existing station above urban influence. Because of dam influence, suggest not using as reference site for urban impact.	34 29 2.4	119 18 1.7	1020
13	Matilija Creek - below community	Matilija Creek. Above dam and below community Monitoring station to evaluate effects of community as excessive amount of algae was found immediately downstream from community.	34 30 04.5	119 20 51.7	1,355
14	Matilija Creek - @ gate at end of road	Matilija Creek. Above dam. Monitoring station to evaluate effects of dam and as possible reference conditions.	34 30 16.9	119 22 26.3	1,553
15	San Antonio Creek above Lion Creek	San Antonio Creek above Lion Creek	34 25 19.3	119 15 46.8	623

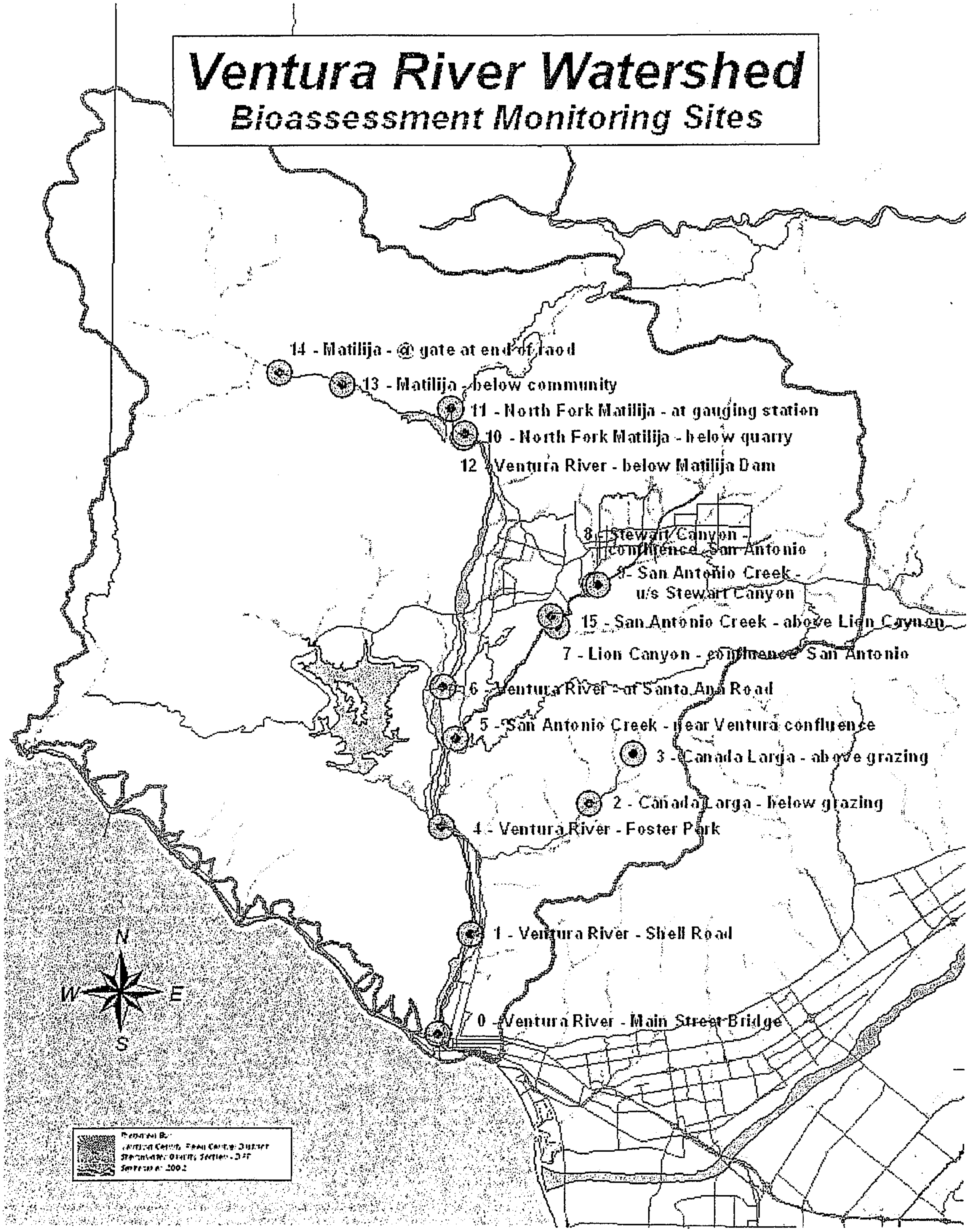
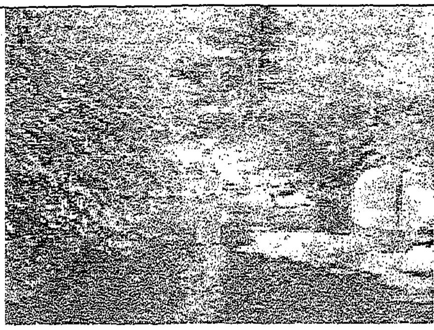
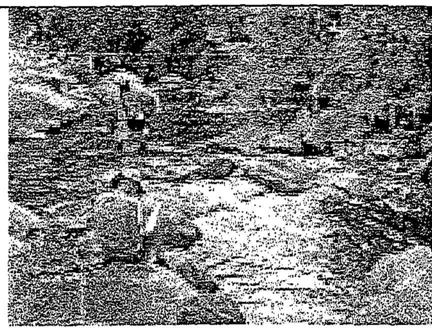
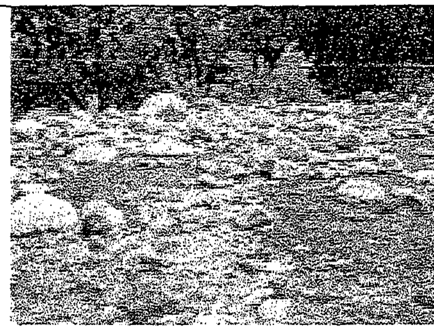
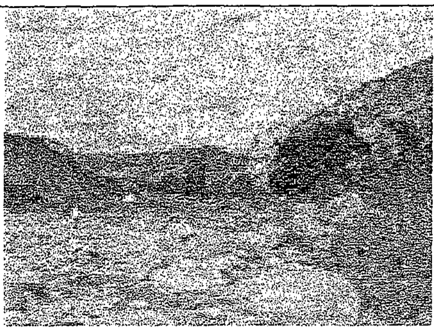
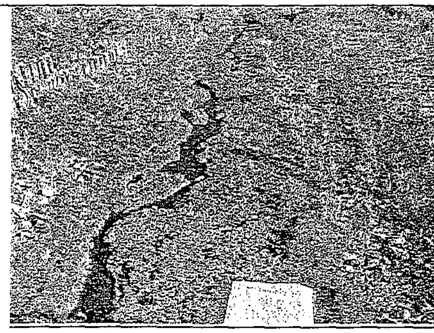


Figure 1. BMI sampling location of the 16 reaches selected for the biological monitoring plan

Table 2: BMI sampling location photos of the 16 reaches selected for the biological monitoring plan.

 site 11: North Fork Matilija Creek- at gauging station	 site 12: Ventura River - below Matilija Dam	 site 13: Matilija Creek below community
 site 14: Matilija Creek - @ gate at end of road	 site 15: San Antonio Creek above Lion Creek	 site 0: Ventura River - Main Street Bridge

BMI Sampling

Based on the workplan developed in the spring 2001, it was determined that Fall might be the most appropriate sampling index for the Ventura watershed. Waiting until the Fall to sample allow for the maximum development and establishment of macroinvertebrate communities. The downside of Fall sampling would be if too many reaches dry out. It was suggested to initiate the sampling during the Fall, and adjust later if necessary.

The California Stream Bioassessment Procedure (CSBP) was used to describe the BMI community and the biotic condition of 14 stream reaches ranging from fairly pristine to very impacted. The DFG (Harrington 1996) developed the CSBP as standardized and cost-effective sampling, laboratory and quality assurance procedures for the State's bioassessment programs (**Appendix A**). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al. 1999) and has been used in various parts of the world to measure biological integrity of aquatic systems (Davis et al. 1996).

Riffle length was measured for each of the three riffles, and a random number table was used to randomly establish a point along the upstream third of each riffle at which a transect was established perpendicular to stream flow. Starting with the riffle transect furthest downstream, the benthos within a 2 ft^2 area was sampled upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net, followed by "kicking" the upper layers of substrate to dislodge any remaining invertebrates . The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrate that required rubbing by hand; more and larger substrates required more time to process. Three locations representing any habitat diversity along each transect were sampled and combined into a composite sample, representing a 6 ft^2 area for each transect and 18 ft^2 for the entire reach. Each composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol. This technique was repeated for each of three riffles in each reach.

BMI Laboratory Analysis

Initial laboratory analysis was performed by Aquatic Bioassay and Consultant laboratory, in Ventura. At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All sample material was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs collected on September 24-26, 2001, were then identified to a standard taxonomic level, typically genus level for insects and order or class for non-insects. All samples were QAQC'd by DFG and the Sustainable Land Stewardship Institute Laboratories, using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Kathman and Brinkhurst 1998, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Data Analysis

A taxonomic list of all aquatic macroinvertebrates identified from the samples was entered into a Microsoft Excel7 spreadsheet program. Excel7 was used to generate a stand alone taxonomic list, and to calculate and summarize the aquatic macroinvertebrate community based metric values. The biological metrics are listed in Table 3 and have been categorized into the following types:

Richness Measures - These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat and food sources are adequate to support survival and propagation of a variety of species.

Composition Measures - These metrics reflect the relative contribution of the population of individual taxa to the total fauna. Choice of a relevant taxon is based on knowledge of the individual taxa and their associated ecological patterns and environmental requirements such as those that are environmentally sensitive or a nuisance species.

Tolerance/intolerance Measures - These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant and intolerant, but are generally nonspecific to the type of stressors. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increases. Tolerance values have been assigned to North American taxa, but are lacking for taxa found exclusively in Central America. In cases where these values were not available, we either used the North American value for the family if that family was represented in the North American or the closest estimate based on like taxa with North American values.

Functional Feeding Groups - These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a surrogate for complex processes of trophic interaction, production and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

Table 3. Bioassessment metrics used to describe characteristics of the BMI community information for 14 selected reaches sampled September 24-26, 2001 in Ventura River watershed.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Ephemeroptera Taxa	Number of taxa in the insect order Ephemeroptera (mayflies)	decrease
Plecoptera Taxa	Number of taxa in the insect order Plecoptera (stoneflies)	decrease
Trichoptera Taxa	Number of taxa in the insect order Trichoptera (caddisflies)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the mayfly family Baetidae	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

Index of Biological Integrity (IBI)

The IBI used to evaluate the monitoring sites in this report was developed for the San Diego region. The scoring values derived from Ode et al. (2000) are listed in Table 4.

Table 4. Scoring ranges for the seven metrics included in the San Diego IBI and the IBI values.

	Metric Scoring Ranges for San Diego IBI						
Score	Cumulative Taxa	Dominant Taxon	Sensitive EPT Index	Cumulative EPT Taxa	Shannon Diversity	Intolerant Taxa	Percent Grazers
0	0-16	>56	0-0.6	0-1	0-1.31	0-.5	0-0.6
1	17-19	54-56	0.7-1.3	2	1.31-1.4	0.6-1.0	0.7-1.3
2	20-21	51-53	1.4-2.0	3	1.41-1.49	1.1-1.6	1.4-2.0
3	22-23	49-50	2.1-2.7	4	1.5-1.58	1.7-2.1	2.1-2.7
4	24-25	47-48	2.8-3.3	5	1.59-1.67	2.2-2.7	2.8-3.4
5	26-27	45-46	3.4-4	6	1.68-1.76	2.8-3.2	3.5-4.1
6	28-29	42-44	4.1-4.6	7	1.77-1.84	3.3-3.8	4.2-4.8
7	30-31	40-41	4.7-5.3	8	1.85-1.93	3.9-4.3	4.9-5.5
8	32-33	37-39	5.4-6	9	1.94-2.02	4.4-4.9	5.6-6.2
9	34-35	34-36	6.1-6.9	10	2.03-2.11	5.0-5.4	6.3-7
10	>35	0-33	>6.9	11	>2.11	>5.4	>7

IBI Scores	Very Poor 0-12	Poor 13-25	Fair 26-37	Good 38-54	Very Good 55-70

PHYSICAL HABITAT QUALITY

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al. 1999). Habitat quality assessments were recorded for each monitoring reach during each macroinvertebrate sampling events within riffle/ run habitats. Description of reach scale habitat parameters used to document local habitat conditions along stream corridors is shown in **Appendix B.**

RESULTS

The BMIs identified from the samples collected on September 24-26, 2001 from the 14 sites are listed in the Species Sheet of attached Excel Spreadsheet. The means and coefficients of variation (CV) for biological metrics calculated from BMI samples are listed in Means and Metrics Sheets of attached Excel Spreadsheet. Forms containing chemical and physical/habitat characteristic scores and field notes are on file at the Ventura County Public Works Agency office in Ventura, and copies are on file at the SLSI office in Sacramento.

BMI Community Structure

One hundred and twelve taxa of BMIs were identified in the 32 samples collected at the 14 sampling sites in the Ventura River watershed. **Appendix C** contains a list of the five most common taxa found at the 14 sites. Although all the biological metrics listed in Table 2 were calculated for the Ventura River watershed sites, only seven (Cumulative Taxa, % Dominant Taxon, Sensitive EPT Index, Cumulative EPT Taxa, Shannon Diversity, % Intolerant Taxa, and % Grazers) were used in the IBI and described in graphic form in this report. These biological metrics seemed to give the best overall sensitivity and discriminatory power to describe biological condition (Ode et al. 2002).

Richness Measures: There were two biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Cumulative Taxa values ranged from 24 to 52 for the 14 monitoring sites and are displayed in Figure 1. Cumulative EPT Taxa ranged from 8 to 25 for the 14 monitoring sites and are displayed in Figure 2.

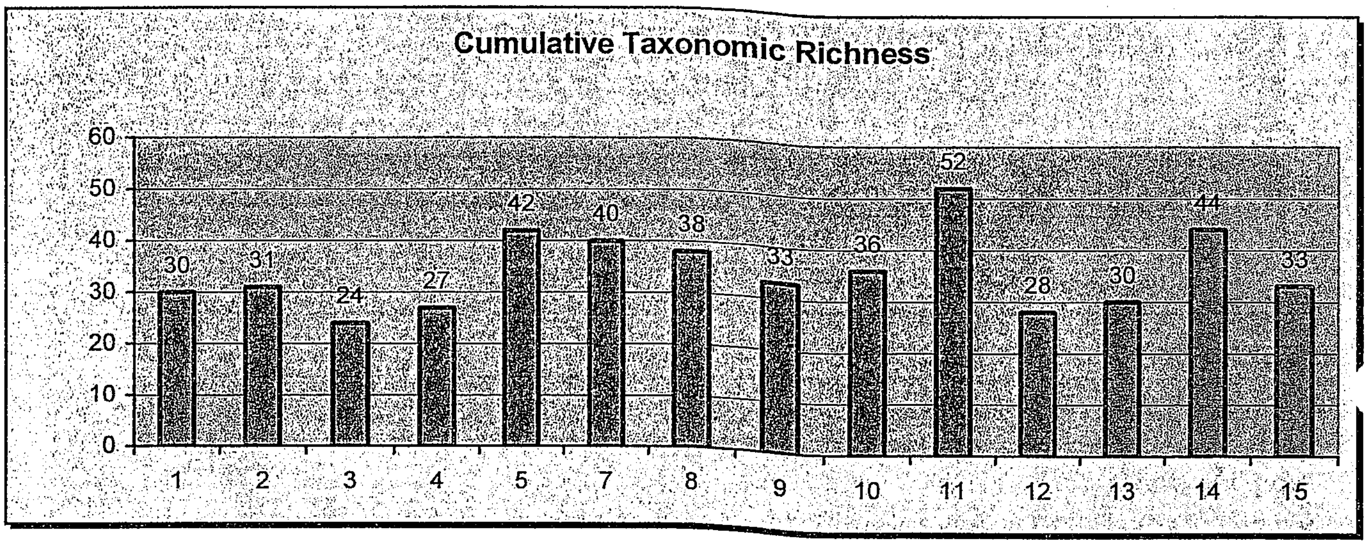


Figure 1. Mean Taxonomic Richness for BMIs collected on September 24-26, 2001 in Ventura River watershed, California.

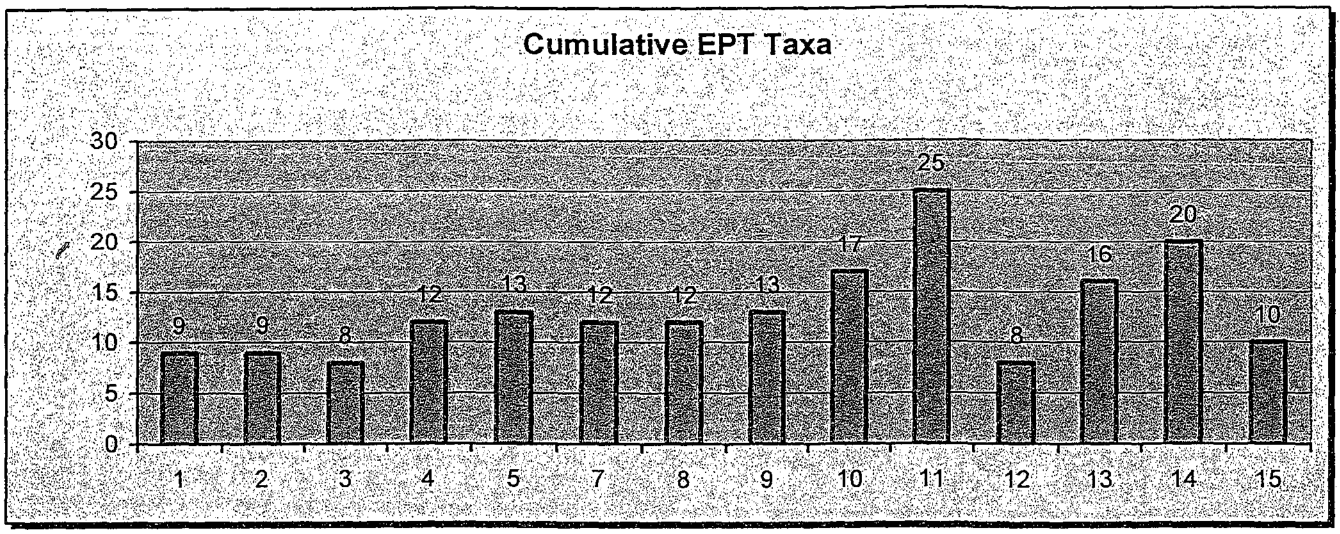


Figure 2. Cumulative EPT Taxa for BMIs collected on September 24-26, 2001 in Ventura River watershed, California.

Composition Measures: There were three biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Mean Sensitive EPT Index values ranged from 0% to 41% for the 14 monitoring sites and are displayed in Figure 3. Mean Shannon Diversity values ranged from 1.4 to 3.0 for the 14 monitoring sites and are displayed in Figure 4. Mean Percent Dominant Taxon values ranged from 14 to 62 for the 14 monitoring sites and are displayed in Figure 5.

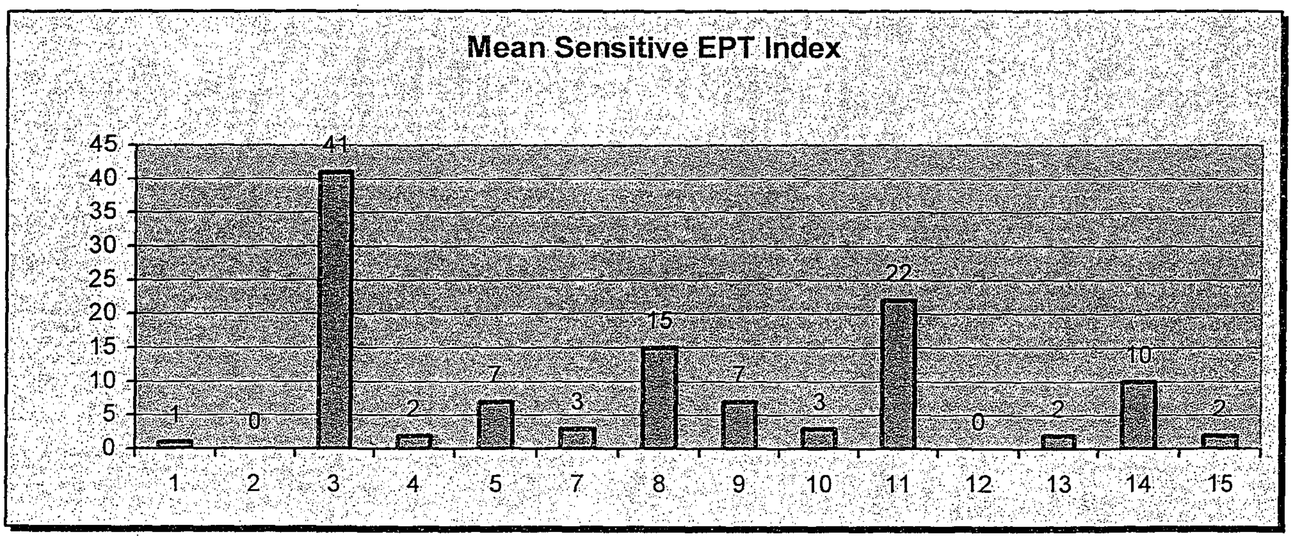


Figure 3. Mean Sensitive EPT Index for BMIs collected on September 24-26, 2001, in Ventura River watershed, California.

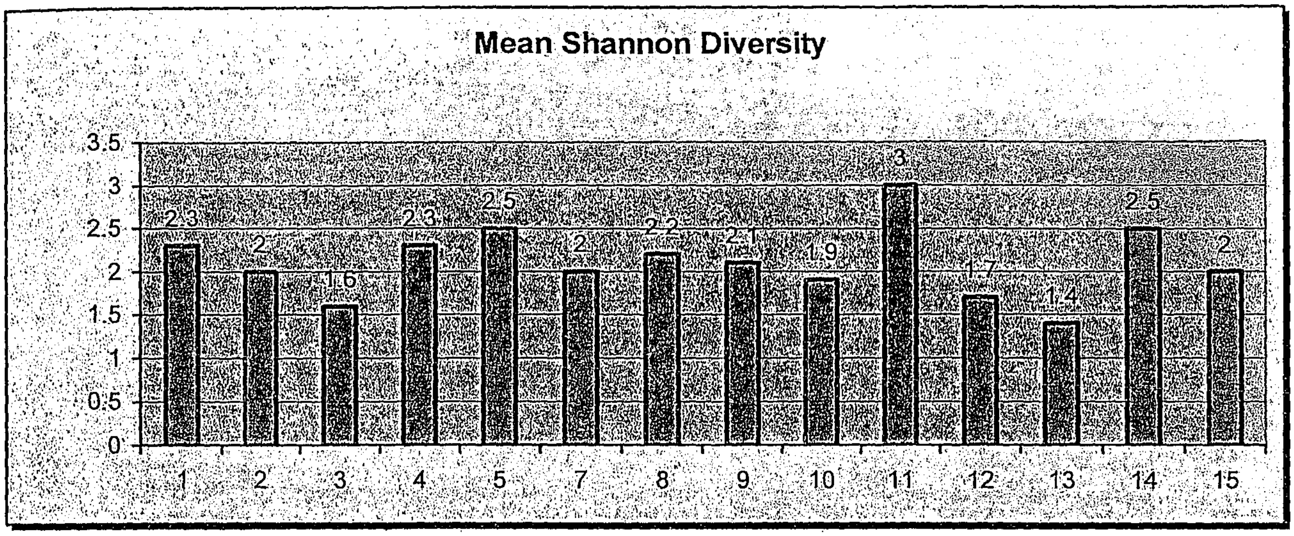


Figure 4. Mean Shannon Diversity for BMIs collected on September 24-26, 2001 in Ventura River watershed, California.

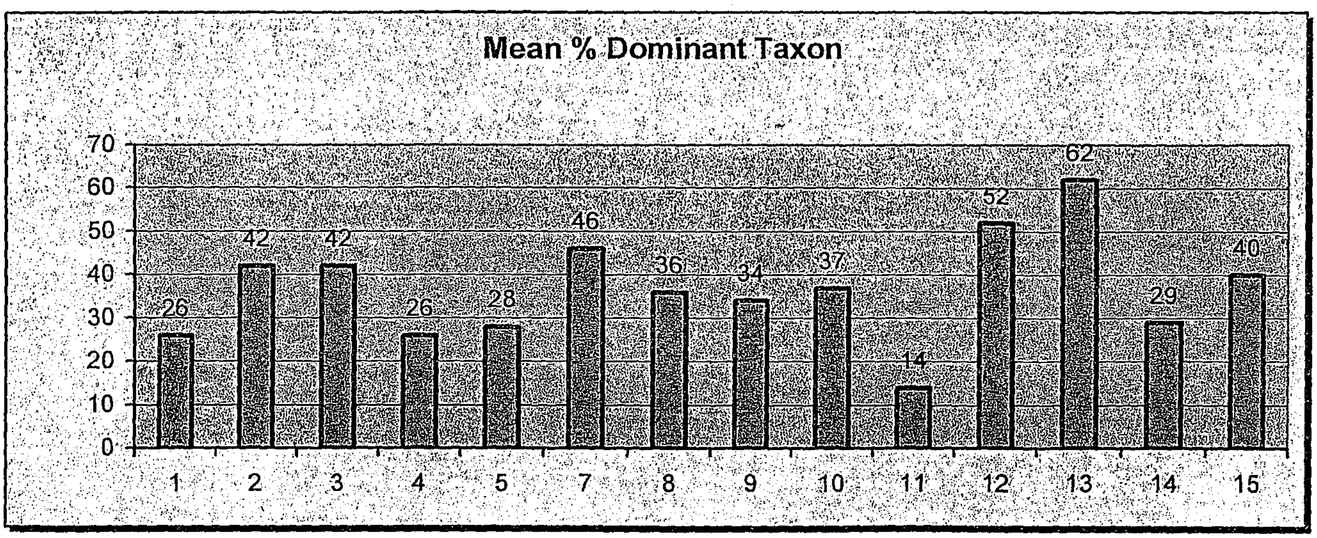


Figure 5. Mean Percent Dominant Taxon for BMIs collected on September 24-26, 2001 in Ventura River watershed, California.

Tolerance Measures: There was one biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Mean Intolerant Taxa values ranged from 0 to 43 for the 14 monitoring sites and are displayed in Figure 6.

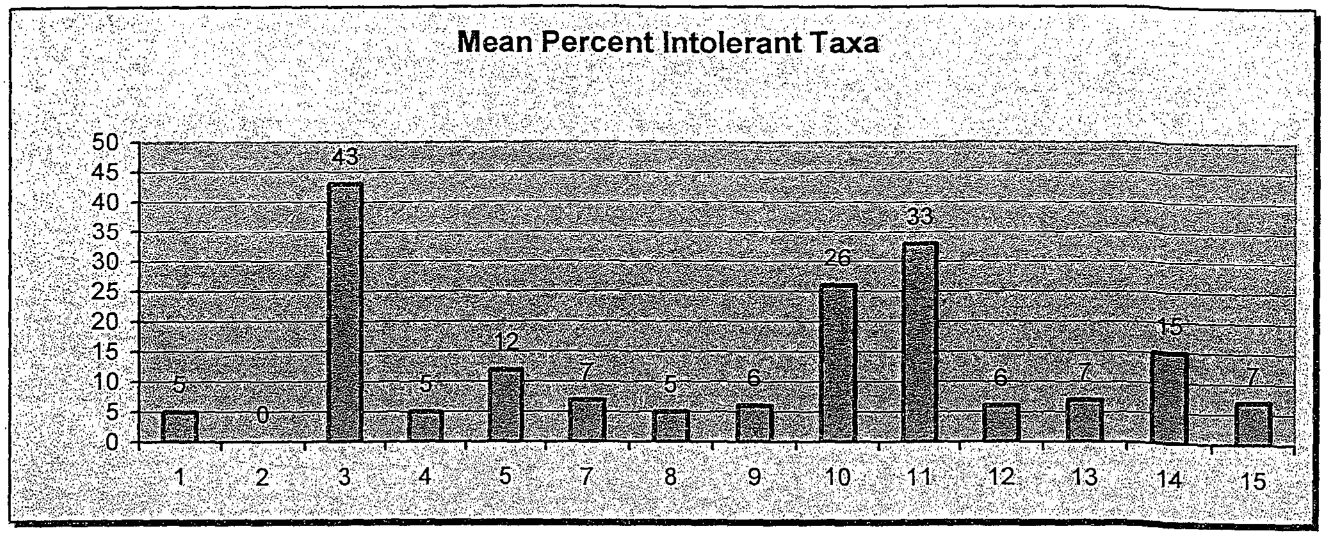


Figure 6. Mean Percent Intolerant taxa for BMIs collected on September 24-26, 2001 in Ventura River watershed, California.

Functional Feeding Groups: There was one biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Mean Percent Grazers values ranged from 1% to 32% for the 14 monitoring sites and are displayed in Figure 7.

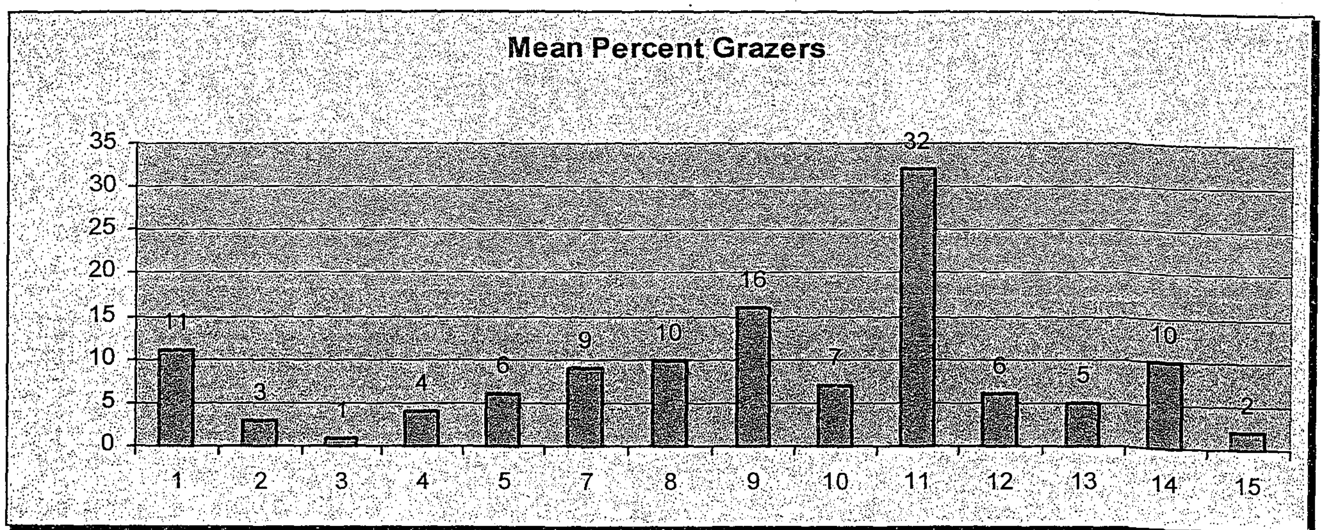


Figure 7. Mean Percent Grazers collected on September 24-26, 2001 in Ventura River watershed, California.

IBI Scores

The IBI scores calculated for the 14 Ventura River watershed sites and their corresponding condition rating are listed in Table 5.

Table 5. IBI scores and rating for sites sampled in the Ventura River watershed, fall 2001.

Site #	1	2	3	4	5	7	8	9	10	11	12	13	14	15
Cummulative Taxa	7	7	4	5	10	10	10	8	10	10	6	7	10	8
Dominant Taxon	10	6	6	10	10	5	9	9	8	10	2	0	10	7
Sensitive EPT Index	1	0	10	2	10	4	10	10	4	10	0	2	10	2
Cummulative EPT Taxa	8	8	7	10	10	10	10	10	10	10	7	10	10	9
Shannon Diversity	10	8	4	10	10	8	10	10	7	10	5	1	10	8
Intolerant Taxa	9	9	10	9	10	10	9	10	10	10	10	10	10	10
Percent Grazers	10	5	1	5	8	10	10	10	10	10	8	7	10	2
Total	55	43	42	51	68	57	68	67	59	70	38	37	70	46
Rating	Very Good	Good	Good	Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Good	Fair	Very Good	Good

Physical/Habitat Scores

Physical/Habitat scores for the 14 sites ranged from 73 to 180, which relates to marginal to optimal conditions (Table 6). The best sites were tended to be in the upper parts of the watershed and the worst in the lower parts.

Table 6. Habitat parameters for fourteen selected reaches sampled September 24-26, 2001 in Ventura River watershed, California

Habitat Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Instream Cover	8	2	9	14	8	DRY	15	17	17	18	17	18	16	13	13
2. Embeddedness	8	7	11	15	13		19	13	13	14	16	18	18	18	10
3. Velocity/Depth Regime	18	5	10	19	9		17	9	14	19	16	18	17	14	12
4. Sediment Deposition	8	3	6	13	12		16	8	10	18	15	18	17	17	11
5. Channel Flow	7	6	14	15	10		10	8	14	10	10	18	10	10	15
6. Channel Alteration	6	10	15	13	11		15	11	16	14	15	18	13	19	16
7. Riffle Frequency	16	2	17	17	16		15	16	18	18	18	17	18	18	15
8. Bank Stability	4	10	4	16	13		7	10	16	16	15	18	12	12	10
9. Vegetative Protection	4	12	4	12	11		3	11	18	18	18	18	12	16	14
10. Riparian Vegetative Zone Width	4	16	12	16	14		2	10	18	13	12	19	12	16	16
Reach Total	**83**	**73**	**102**	**150**	**117**		**119**	**113**	**154**	**158**	**152**	**180**	**145**	**153**	**132**
Condition Category	**margi nal**	**margi nal**	**subop timal**	Subop timal	Subop timal		Subop timal	Subop timal	**optim al**	**optim al**	**optim al**	**optim al**	Sub-opt	**optim al**	Sub-opt
Other Reach Descriptions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vegetative Canopy Cover Estimate (%)	**5%**	**45%**	**85%**	**0**	**14%**		**0**	**88%**	**30%**	**13%**	**73%**	**7%**	**0**	**0**	**20%**
pH	**8.64**	**8.33**	**7.9**	**8.23**	**8.1**		**7.81**	**8.0**	**7.9**	**8.24**	**8.13**	**8.31**	**8.43**	**8.31**	**8.25**
D.O (mg/L)	**11.76**	**8.25**	**6.48**	**11.89**	**8.39**		**7.5**	**5.85**	**7.83**	**7.62**	**8.43**	**8.39**	**9.86**	**9.41**	**9.44**
Water Temperature (°C)	**25.1**	**28.6**	**20.2**	**20.0**	**20.6**		**16.6**	**18.4**	**17.9**	**20.8**	**20.3**	**23.4**	**20.8**	**17.2**	**16.8**
Specific Conductance (µS/cm at 25°C)	**1320**	**2858**	**2168**	**822**	**1070**		**1512**	**1310**	**978**	**755**	**871**	**831**	**745**	**706**	**969**
Comments						**Dry due to casita s divers ion**									

Discussion of Bioassement Results

The overall assessment of the sites sampled from the Ventura River watershed indicates a healthy aquatic system. The following potential problems were indicated through the bioassessment data and need to be verified and investigated further for cause.

Indication of Human Impacts: There were two sites above the dam on the main stem of Matilija Creek (#14 and #13). Site #14 has little, if any human impacts. Site #13 was on the same area of Matilija creek, just below a small community. Both had similar habitat scores (153 for Site #14 and 145 for Site #13). The proximity to each other and similar habitat scores would suggest that the macroinvertebrate communities and resulting IBI scores would be somewhat similar. However, site #14 scored 70 in the IBI and was tied for the best score with North Matilija Creek, while site #13 scored only 37, making it the worst site. Numerous pollution intolerant macroinvertebrates found in site #14 were missing from #13. Notably, the mayfly *Serratella*, the stonefly *Calineuria californica*, the caddisflies *Rhyacophila* and *Micrasema*, and the dobsonfly *Corydalus*. This site was also dominated the pollution tolerant taxa *Baetis* and *Microcylloepus*, and the filter feeders *Hydropsyche* and *Simulium*. These four taxa represented 84% of the total abundance. There was also a large bloom of filamentous algae just below the community in Site 13. This evidence might suggest that the human community is having some impact on Matilija Creek and further investigation might be warranted.

Effects of Matilija Dam: Site #12 was on Matilija Creek just below the dam. This site was the second most impacted site, with an IBI rating of 38. Four of the five most dominant taxa (*Baetis*, *Simulium*, *Fallceon quilleri*, and *Microcylloepus*) were pollution tolerant taxa and accounted for approximately 70% of the total abundance. Also, a number of intolerant taxa (*Calineuria californica*, *Rhyacophila*, and *Micrasema*) which were observed at Site #14 were at Site 12. This evidence makes strong suggestions that Matilija Dam is impacting the downstream biologic condition.

Effects of Cattle Grazing: There were two sites located on Canada Larga creek (#2 and #3). There was a large cattle grazing operation between the two sites. Although these sites had almost identical IBI ratings, (42 and 43, respectively) there was one conspicuous difference in the macroinvertebrate data. The shredding stonefly *Malenka* was dominant above the grazing impact (40.6%) and completely absent below. Sites #2 and #3 were dominated by the *Hydropsyche* and the mayfly *Tricorythodes* (54.7% combined). *Tricorythodes* is tolerant of fine sediment and Hydropsyche is tolerant of fine particulate organic matter associated with nutrient enrichment. This evidence suggests that cattle grazing is having some effect on the biological condition of the stream.

Site #4 on the Ventura River and site #15 on San Antonio Creek above Lion Canyon were both rated as good. The Ventura River site which was a lower river stretch, was dominated by *Hydropsyche* and *Tricorythodes* (approximately 39% combined). *Hydropsyche* and the dipertan larvae from the family Stratiomyiidae dominated at site #15 (approximately 47%). Although these were relatively tolerant taxa, the biological condition of the sites were good enough to support diverse BMI communities (27 and 33 cumulative taxa, respectively), and intolerant taxa such as the caddisfly *Marilia.*

The remaining 8 sites were all rated as Very Good. Of special interest was Site #1, the Ventura River at Shell Road. Although, it just barely fell within the Very Good range with an IBI score of 55, it was the lowest site in the watershed. Typical of lower elevation sites which can naturally have less diverse communities, Site #1 was populated by relatively tolerant non-insect taxa (physid snails, water mites, ostracods, and amhipods). However, the top five taxa in abundance at this site were all insect taxa and the most dominant taxon only accounts for approximately 14% of the total abundance.

Recommendations

The observation of biological condition for the monitoring sites in the Ventura River watershed was based on general knowledge of the BMI community and the IBI that was developed for the San Diego region. We are confident with the assessment results discussed in this report and will continue biological monitoring at these sites to verify the observations. If the 2002 sampling data confirms this year's findings, we may be able to reduce the number of sampling sites close in proximity and where the data is very similar.

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of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kerans and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (Harrington 1999). As the Russian River IBI was being developed, the Department of Fish and Game (DFG) began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. During 1997 through 2000, data was collected from 93 locations distributed throughout the San Diego region. In 2001, a new set of sites were chosen and sampled to further establish reference conditions in the San Diego region. The results of this sampling event were combined with the results of earlier sampling events to establish a preliminary Index of Biological Integrity (IBI) for the San Diego region. In July 2002, a final report was presented as a working IBI for the San Diego region.

This newly developed San Diego IBI is currently the best tool to analyze macroinvertebrate data from Southern California in general and Ventura County in this particular instance. The San Diego region is much more similar in terms of climate, precipitations, geology and general ecosystem, than is the Russian River area.

10.1.4.2 Bioassessment Introduction

NPDES permit CAS004002 required the Ventura County Watershed Protection District (VCWPD) to implement a countywide monitoring plan which included the development of an instream bioassessment monitoring program (this work plan), and the implementation of the monitoring program.

In spring 2001, VCWPD's staff, with the assistance of the Sustainable Land Stewardship Institute (SLSI), developed a biological and physical/habitat assessment program within Ventura River watershed. On September 18 and 19, 2002, VCWPD and SLSI conducted the second year sampling event. The goal of the program was to:

1) Provide base line information on the macroinvertebrate assemblages within Ventura River watershed;

2) Evaluate the biological and physical/habitat condition of various sampling sites within the Ventura River watershed using the preliminary Index of Biological Integrity (IBI) for the San Diego region;

3) Examine the effects of various land-use activities, including urban runoff, impacts on the macroinvetebrate community structure throughout the Ventura River watershed, and

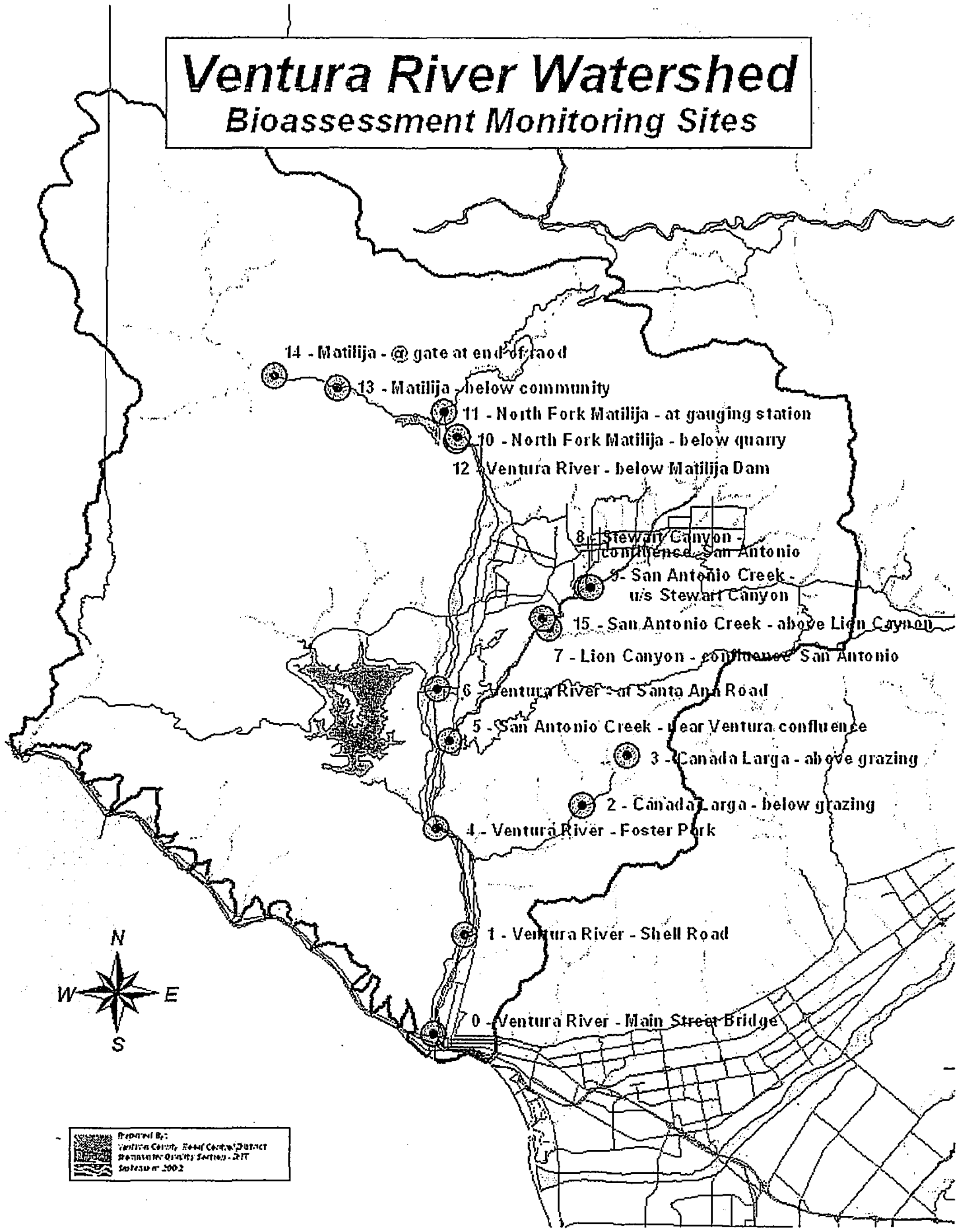
4) Provide recommendations and strategies for continued monitoring.

10.1.4.3 Materials and Methods

10.1.4.3.1 Sampling Site Descriptions

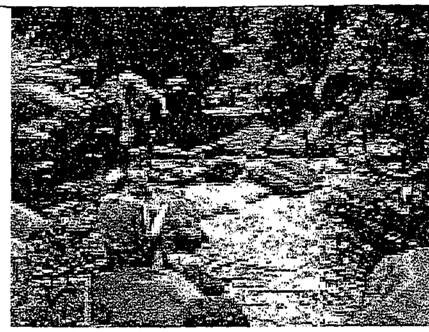
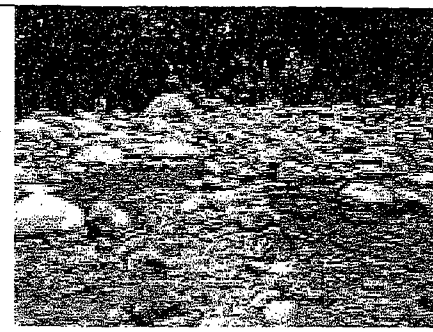
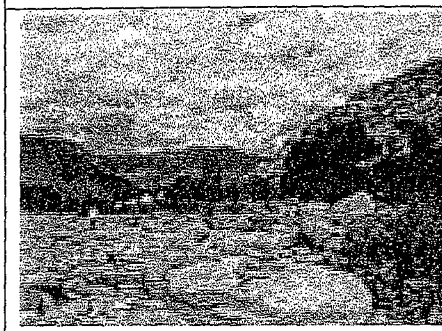
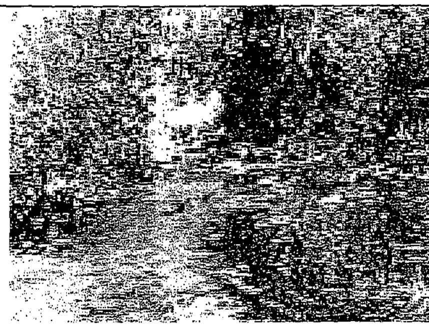
• Table 10-1. 11 Ventura River watershed sites sampled on September 18 and 19, 2002

Sta.ID	Name	Description and Comments	Latitude	Longitude	Elev.
0	Ventura River – Main Street Bridge	Mainstem Ventura River, first site above estuary with fresh water.	34 16 54.23	119 18 24.09	19
1	Ventura River - Shell Road	Mainstem Ventura River. Area similar to site #0. ¼ to ½ mile downstream from wastewater and treatment plant.	34 18 59.6	119 17 41.3	195
2	Canada Larga Creek	Canada Larga Creek, d/s of grazing ***Dry - not sampled**	34 20 31.7	119 17 08.2	293
3	Canada Larga Creek	Canada Larga Creek, above main area of grazing impact	34 22 23.3	119 14 8.8	334
4	Ventura River - Foster Park	Mainstem Ventura River. Closest downstream site to monitor impacts of San Antonio Creek. Station is also site is also mass emission station. Bioassessment u/s from Foster Park Bridge.	34 21 07.9	119 18 23.7	571
5	San Antonio Creek - near Ventura River	San Antonio Creek, first upstream site from confluence with Ventura River. ***Dry - not sampled**	34 22 50.9	119 18 23.9	347
6	Ventura River - Santa Ana Rd.	Mainstem Ventura River ***Dry - not sampled**			
7	Lion Canyon Creek – u/s conf. San Antonio Creek	Lion Canyon Creek (tributary to San Antonio Creek) First u/s location from confluence. Impacted by nearby stables and grazing. Heavy sediment load. ***Dry - not sampled**	34 25 19.3	119 15 46.8	623
8	Stewart Canyon Creek – u/s conf. San Antonio Creek	Stuart Creek (tributary to San Antonio Creek) First u/s location from confluence. Impacted by the city of Ojai and less densely developed residential lots.	34 26 07.1	119 14 49.3	685
9	San Antonio Creek near Stewart Canyon Creek	San Antonio Creek. Impacted by the City of Ojai and less densely developed residential lots.	34 26 1.8	119 14 52.7	650
10	North Fork Matilija Creek- u/s Ventura River conf.	North Fork Matilija Creek. No dam influence. Below quarry.	34 29 06.0	119 17 59.4	978
11	North Fork Matilija Creek- at gauging station	North Fork Matilija Creek. No dam influence. Above quarry	34 29 35.1	119 18 18.6	1,360
12	Ventura River - below Matilija Dam	Matilija Creek First station below Matilija dam and first existing station above urban influence. Because of dam influence, suggest not using as reference site for urban impact.	34 29 2.4	119 18 1.7	1020
13	Matilija Creek - below community	Matilija Creek. Above dam and below community Monitoring station to evaluate effects of community as excessive amount of algae was found immediately downstream from community.	34 30 04.5	119 20 51.7	1,355
14	Matilija Creek - @ gate at end of road	Matilija Creek. Above dam. Monitoring station to evaluate effects of dam and as possible reference conditions. ***Dry - not sampled**	34 30 16.9	119 22 26.3	1,553
15	San Antonio Creek above Lion Creek	San Antonio Creek above Lion Creek	34 25 19.3	119 15 46.8	623



• Figure 10-1. BMI sampling location of the 16 reaches selected for the biological monitoring plan

• Table 10-3. BMI sampling location photos of the 16 reaches selected for the biological monitoring plan (continued).

 site 11: North Fork Matilija Creek- at gauging station	 site 12: Ventura River - below Matilija Dam	 site 13: Matilija Creek below community
 site 14: Matilija Creek - @ gate at end of road	 site 15: San Antonio Creek above Lion Creek	

BMI Sampling

Based on the workplan developed in the spring 2001, it was determined that Fall might be the most appropriate sampling index for the Ventura watershed. Waiting until the Fall to sample allow for the maximum development and establishment of macroinvertebrate communities. The downside of Fall sampling would be if too many reaches are dry. It was suggested to initiate the sampling during the Fall, and adjust later if necessary.

The California Stream Bioassessment Procedure (CSBP) was used to describe the BMI community and the biotic condition of 11 stream reaches ranging from fairly pristine to very impacted. The DFG (Harrington 1996) developed the CSBP as standardized and cost-effective sampling, laboratory and quality assurance procedures for the State's bioassessment programs (Appendix A). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al. 1999) and has been used in various parts of the world to measure biological integrity of aquatic systems (Davis et al. 1996).

Riffle length was measured for each of the three riffles, and a random number table was used to randomly establish a point along the upstream third of each riffle at which a transect was established perpendicular to stream flow. Starting with the riffle transect furthest downstream, the benthos within a 2 ft^2 area was sampled upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net, followed by "kicking" the upper layers of substrate to dislodge any remaining invertebrates . The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrate that required rubbing by hand; more and larger substrates required more time to process. Three locations representing any habitat diversity along each transect were sampled and combined into a composite sample, representing a 6 ft^2 area for each transect and 18 ft^2 for the entire reach. Each composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol. This technique was repeated for each of three riffles in each reach.

10.1.4.3.2 BMI Laboratory Analysis

Laboratory analysis was performed by Aquatic Bioassay and Consultant Laboratory, in Ventura. At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All sample material was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs collected on September 18 and 19 2002, were then identified to a standard taxonomic level, typically genus level for insects and order or class for non-insects. All samples were QA/QC'd by DFG and the Sustainable Land Stewardship Institute Laboratories, using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Kathman and Brinkhurst 1998, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Data Analysis

A taxonomic list of all aquatic macroinvertebrates identified from the samples was entered into a Microsoft Excel7 spreadsheet program. Excel7 was used to generate a stand alone taxonomic list, and to calculate and summarize the aquatic macroinvertebrate community based metric values. The biological metrics are listed in Table 10-4 and Table 10-5 and have been categorized into the following types:

Richness Measures - These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat and food sources are adequate to support survival and propagation of a variety of species.

Composition Measures - These metrics reflect the relative contribution of the population of individual taxa to the total fauna. Choice of a relevant taxon is based on knowledge of the individual taxa and their associated ecological patterns and environmental requirements such as those that are environmentally sensitive or a nuisance species.

Tolerance/intolerance Measures - These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant and intolerant, but are generally nonspecific to the type of stressors. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increases. Tolerance values have been assigned to North American taxa, but are lacking for taxa found exclusively in Central America. In cases where these values were not available, we either used the North American value for the family if that family was represented in the North American or the closest estimate based on like taxa with North American values.

Functional Feeding Groups - These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a surrogate for complex processes of trophic interaction, production and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

• Table 10-4. Bioassessment metrics used to describe characteristics of the BMI community information for 14 selected reaches sampled September 24-26, 2001 in Ventura River watershed.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Ephemeroptera Taxa	Number of taxa in the insect order Ephemeroptera (mayflies)	decrease
Plecoptera Taxa	Number of taxa in the insect order Plecoptera (stoneflies)	decrease
Trichoptera Taxa	Number of taxa in the insect order Trichoptera (caddisflies)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the mayfly family Baetidae	increase

• Table 10-5. Bioassessment metrics used to describe characteristics of the BMI community information for 14 selected reaches sampled September 24-26, 2001 in Ventura River watershed. (continued)

BMI Metric	Description	Response to Impairment
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

Index of Biological Integrity (IBI)

The IBI used to evaluate the monitoring sites in this report was developed for the San Diego region. The scoring values derived from Ode et al. (2000) are listed in Table 10-6.

• Table 10-6. Scoring ranges for the seven metrics included in the San Diego IBI and the IBI values.

	Metric Scoring Ranges for San Diego IBI						
Score	Cumulative Taxa	Dominant Taxon	Sensitive EPT Index	Cumulative EPT Taxa	Shannon Diversity	Intolerant Taxa	Percent Grazers
0	0-16	>56	0-0.6	0-1	0-1.31	0-.5	0-0.6
1	17-19	54-56	0.7-1.3	2	1.31-1.4	0.6-1.0	0.7-1.3
2	20-21	51-53	1.4-2.0	3	1.41-1.49	1.1-1.6	1.4-2.0
3	22-23	49-50	2.1-2.7	4	1.5-1.58	1.7-2.1	2.1-2.7
4	24-25	47-48	2.8-3.3	5	1.59-1.67	2.2-2.7	2.8-3.4
5	26-27	45-46	3.4-4	6	1.68-1.76	2.8-3.2	3.5-4.1
6	28-29	42-44	4.1-4.6	7	1.77-1.84	3.3-3.8	4.2-4.8
7	30-31	40-41	4.7-5.3	8	1.85-1.93	3.9-4.3	4.9-5.5
8	32-33	37-39	5.4-6	9	1.94-2.02	4.4-4.9	5.6-6.2
9	34-35	34-36	6.1-6.9	10	2.03-2.11	5.0-5.4	6.3-7
10	>35	0-33	>6.9	11	>2.11	>5.4	>7

IBI Scores	Very Poor	Poor	Fair	Good	Very Good
	0-12	13-25	26-37	38-54	55-70

10.1.4.4 Physical Habitat Quality

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al. 1999). Habitat quality assessments were recorded for each monitoring reach during each macroinvertebrate sampling events within riffle/ run habitats. Description of reach scale habitat parameters used to document local habitat conditions along stream corridors is shown in Appendix B.

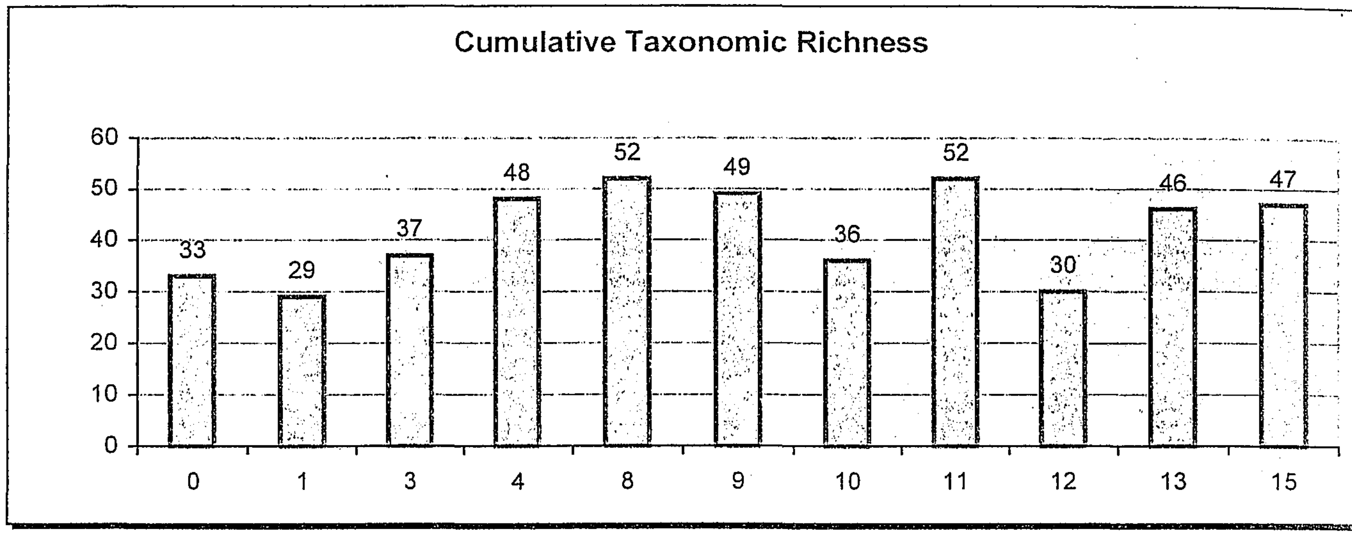
10.1.4.5 Results

The BMIs identified from the samples collected on September 18-19, 2002 from the 11 sites are listed in the Species Sheet of attached Excel Spreadsheet. The means and coefficients of variation (CV) for biological metrics calculated from BMI samples are listed in Means and Metrics Sheets of attached Excel Spreadsheet. Forms containing chemical and physical/habitat characteristic scores and field notes are on file at the Ventura County Public Works Agency office in Ventura, and copies are on file at the SLSI office in Sacramento.

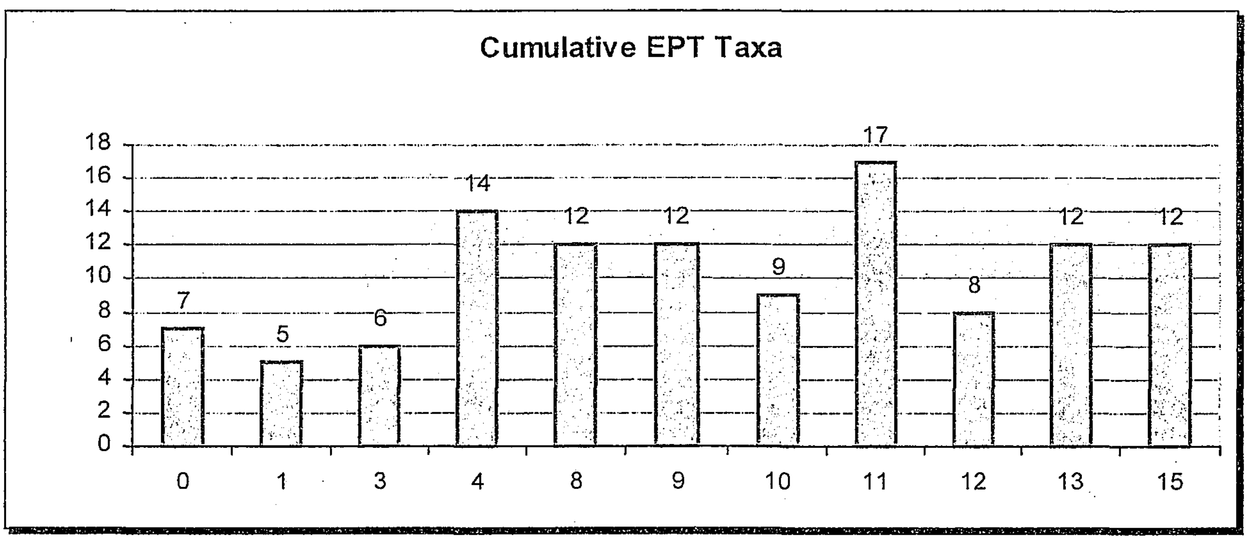
10.1.5 BMI Community Structure

One hundred and forty three taxa of BMIs were identified in the 33 samples collected at the 11 sampling sites in the Ventura River watershed (Appendix C). The data also contains a list of the five most common taxa found at the 11 sites. Although all the biological metrics listed in Table 10-4 and Table 10-5 were calculated for the Ventura River watershed sites, only seven (Cumulative Taxa, % Dominant Taxon, Sensitive EPT Index, Cumulative EPT Taxa, Shannon Diversity, % Intolerant Taxa, and % Grazers) were used in the IBI and described in graphic form in this report. These biological metrics seemed to give the best overall sensitivity and discriminatory power to describe biological condition (Ode et al. 2002).

Richness Measures: There were two biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Cumulative Taxa values ranged from 29 to 52 for the 11 monitoring sites and are displayed in . Cumulative EPT Taxa ranged from 5 to 17 for the 11 monitoring sites and are displayed in . .

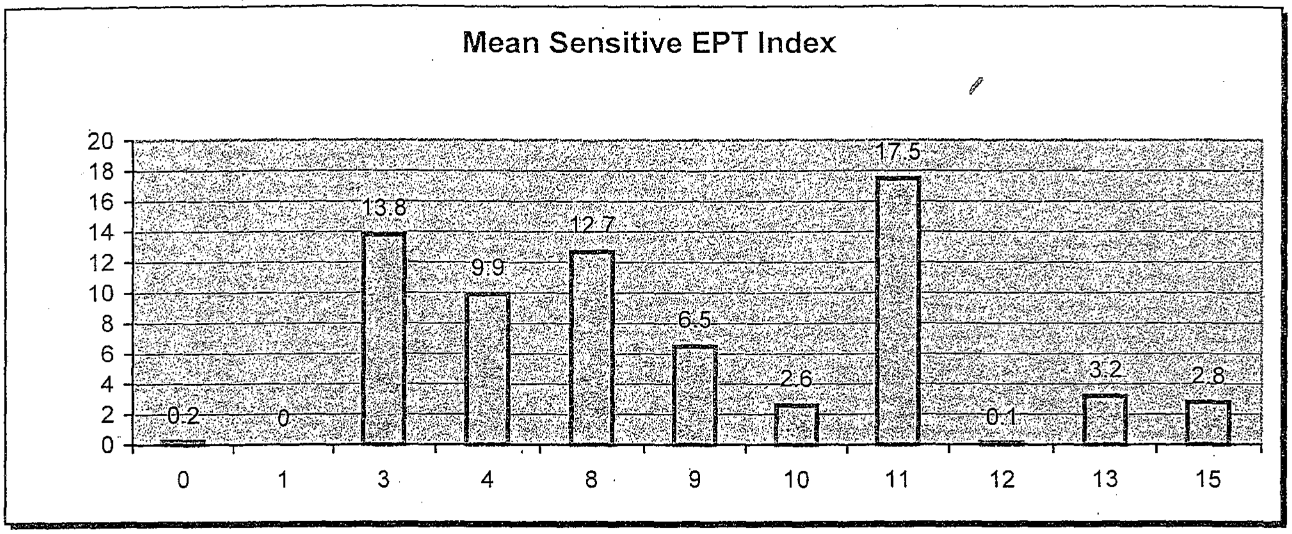


• Figure 10-2. Cumulative Taxonomic Richness for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.

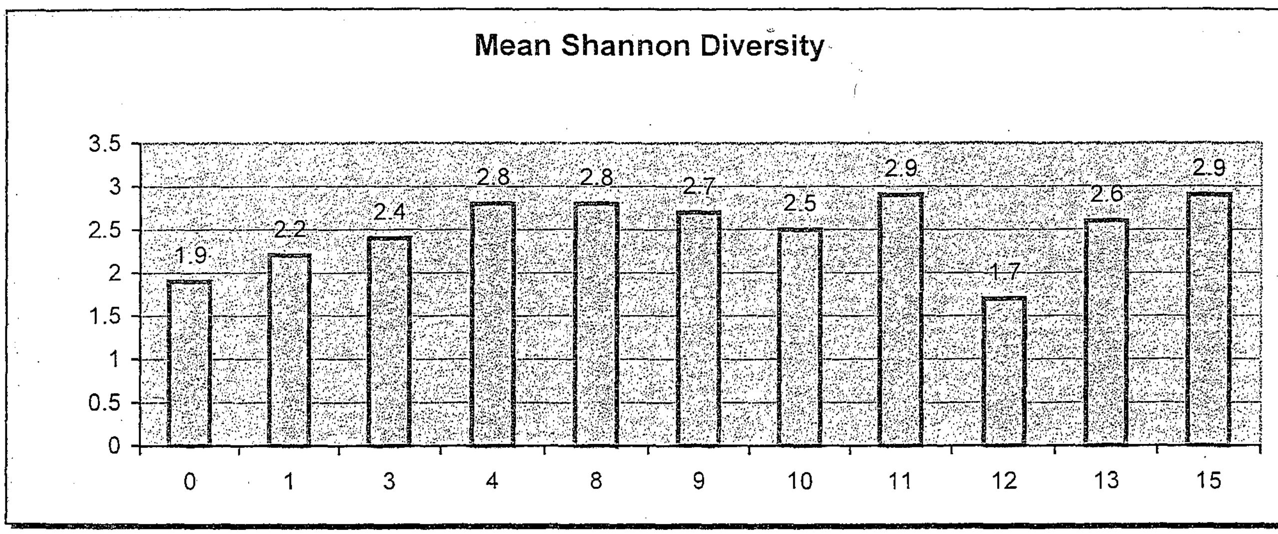


• Figure 10-3. Cumulative EPT Taxa for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.

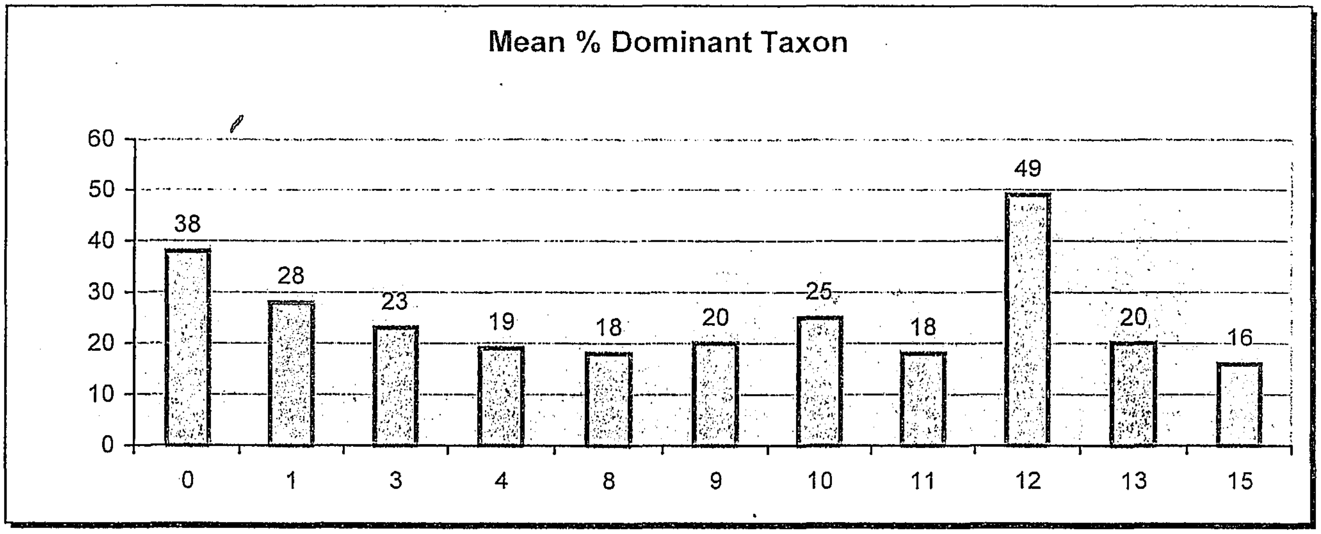
Composition Measures: There were three biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the composition of the BMI community. Mean Sensitive EPT Index values ranged from 0% to 17.5% for the 11 monitoring sites and are displayed in Figure 10-4. Mean Shannon Diversity values ranged from 1.7 to 2.9 for the 11 monitoring sites and are displayed in Figure 10-5. Mean Percent Dominant Taxon values ranged from 16 to 49 for the 11 monitoring sites and are displayed in Figure 10-6.



• Figure 10-4. Mean Sensitive EPT Index for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.

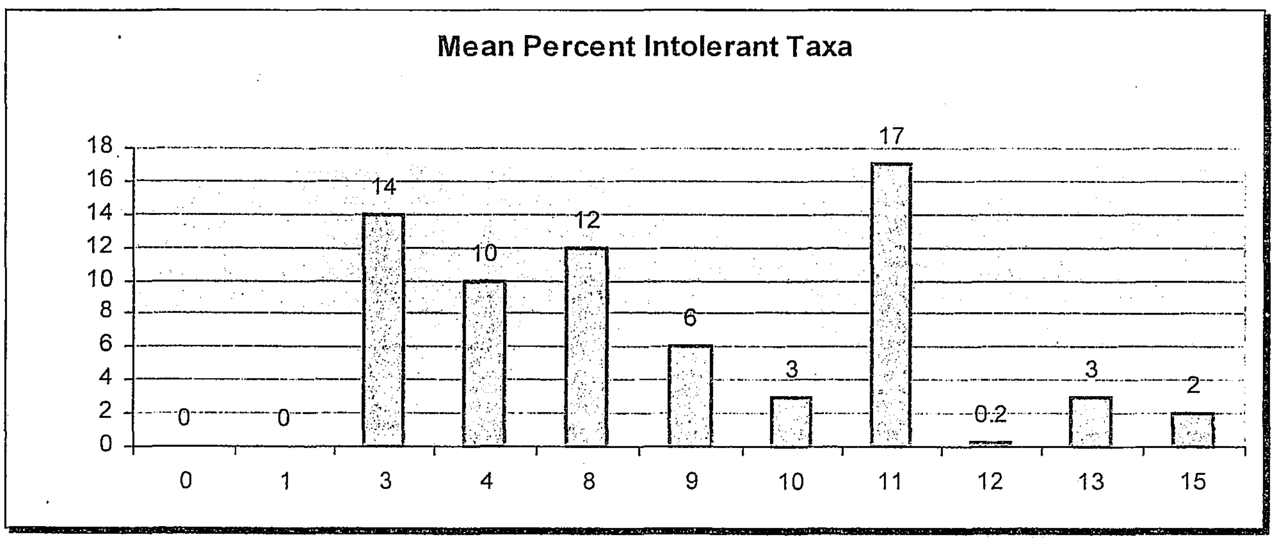


• Figure 10-5. Mean Shannon Diversity for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.



• Figure 10-6. Mean Percent Dominant Taxon for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.

Tolerance Measures: There was one biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the tolerance of the BMI community. Mean Intolerant Taxa values ranged from 0 to 17 for the 11 monitoring sites and are displayed in Figure 10-7.



• Figure 10-7. Mean Percent Intolerant taxa for BMIs collected on September 18 and 19, 2002 in Ventura River watershed, California.

Functional Feeding Groups: There was one biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure partial feeding guild composition of the BMI community. Mean Percent Grazers values ranged from 2% to 35% for the 11 monitoring sites and are displayed in Figure 10-8.

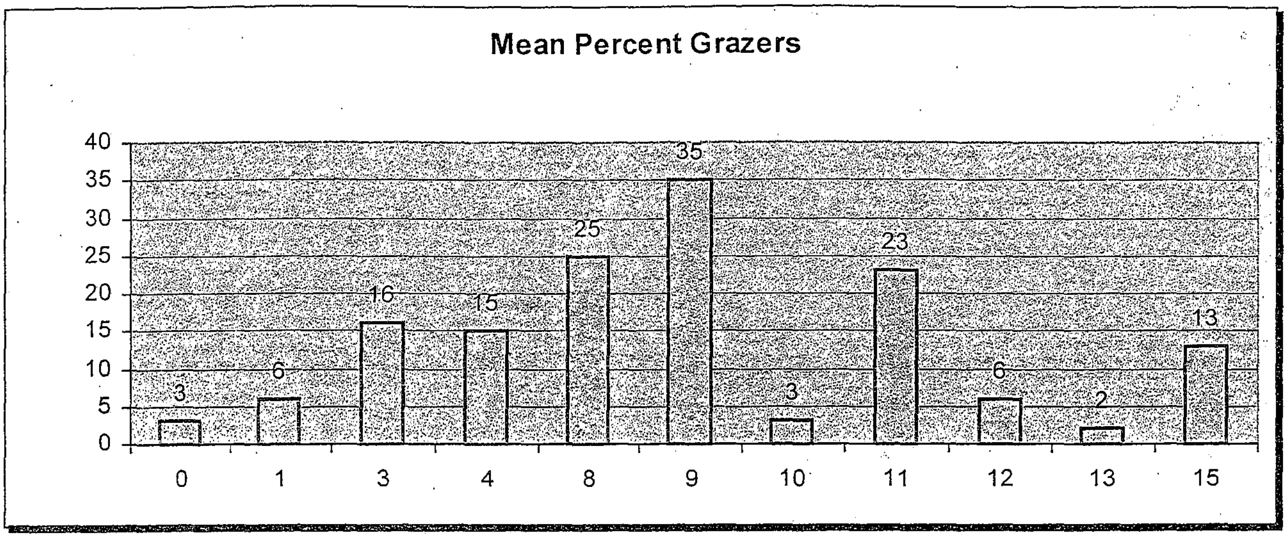


Figure 10-8. Mean Percent Grazers collected on September 18 and 19, 2002 in Ventura River watershed, California.

IBI Scores

The IBI scores calculated for the 11 Ventura River watershed sites and their corresponding condition rating are listed in Table 10-7.

Table 10-7. IBI scores and rating for sites sampled in the Ventura River watershed, Fall 2001.

Site #	0	1	3	4	8	9	10	11	12	13	15
Cummulative Taxa	8	6	10	10	10	10	10	10	7	10	10
Dominant Taxon	8	10	10	10	10	10	10	10	4	10	10
Sensitive EPT Index	0	0	10	10	10	9	3	10	0	4	4
Cummulative EPT Taxa	6	4	5	10	10	10	8	10	7	10	10
Shannon Diversity	7	10	10	10	10	10	10	10	5	10	10
Intolerant Taxa	0	0	10	10	10	10	4	10	0	5	3
Percent Grazers	4	9	10	10	10	10	4	10	8	2	10
Total	**33**	**39**	**65**	**70**	**70**	**69**	**49**	**70**	**31**	**51**	**57**
Rating	**Fair**	**Good**	**Very Good**	**Very Good**	**Very Good**	**Very Good**	**Good**	**Very Good**	**Fair**	**Good**	**Very Good**

Physical/Habitat Scores

Physical/Habitat scores for the 11 sites ranged from 73 to 180, which relates to marginal to optimal conditions (Table 10-8 and Table 10-9). The best sites tended to be in the upper parts of the watershed and the worst in the lower parts.

Table 10-8. Habitat parameters for 11 selected reaches sampled September 18 and 19, 2002 in Ventura River watershed, California.

Habitat Parameter	0	1	3	4	8	9	10	11	12	13	15
1. Instream Cover	17	12	12	18	14	13	16	19	11	15	16
2. Embeddedness	17	12	14	16	16	13	16	17	18	16	18
3. Velocity/Depth Regime	16	17	10	14	8	11	16	16	16	16	17
4. Sediment Deposition	14	14	9	15	16	13	16	14	18	16	11
5. Channel Flow	6	7	5	8	11	10	10	11	8	8	12
6. Channel Alteration	15	10	20	15	11	18	13	19	15	18	19
7. Riffle Frequency	10	7	16	14	13	10	15	14	16	15	18
8. Bank Stability	16	14	4	18	13	16	18	17	18	16	8
9. Vegetative Protection	16	8	10	18	16	18	18	18	20	17	16
10. Riparian Vegetative Zone Width	14	8	14	18	13	20	16	19	20	19	14
Reach Total	**141**	**102**	**114**	**154**	**131**	**142**	**154**	**164**	**160**	**156**	**149**
Condition Category	**Suboptimal**	**Suboptimal**	**Suboptimal**	**Optimal**	**Suboptimal**	**Suboptimal**	**Optimal**	**Optimal**	**Optimal**	**Optimal**	**Suboptimal**

• Table 10-9. Habitat parameters for 11 selected reaches sampled September 18 and 19, 2002 in Ventura River watershed, California. (continued)

Other Reach Descriptions	0	1	3	4	8	9	10	11	12	13	15
Vegetative Canopy Cover Estimate (%)	20	30	90	13	78	38	43	86	34	8	77
pH	7.8	8.0	7.8	7.6	7.9	7.9				8.0	8.3
D.O (mg/L)	6.1	8.9	5.7	9.3	8.0	8.2				9.1	11.0
Water Temperature (B C)	19.0	20.1	15.0	18.5	19.0	22.2				19.2	21.5
Specific Conductance (ΦS/cm at 25EC)	158.9	133.5	160.0	125.8	130.0	120.0				76.4	128.9
Comments											

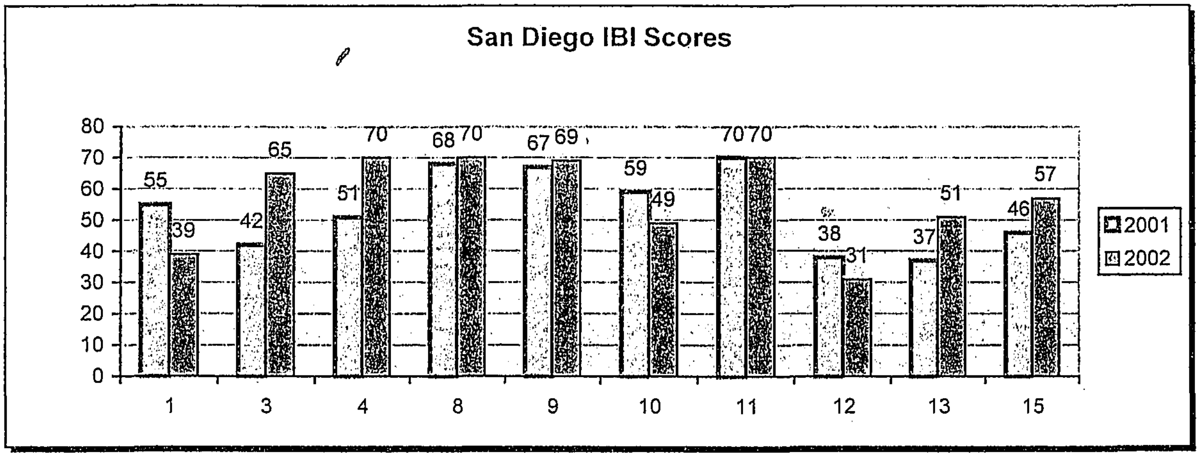
10.1.5.1 Discussion of Bioassessment Results

The assessment of the sites sampled from the Ventura River watershed in 2002 indicates an overall healthy aquatic system. Six of the 11 sites (Site numbers 3, 4, 8, 9, 11 and 15) were rated as very good using the San Diego IBI. All 11 Ventura River watershed sites had physical/habitat quality ratings of optimal or suboptimal.

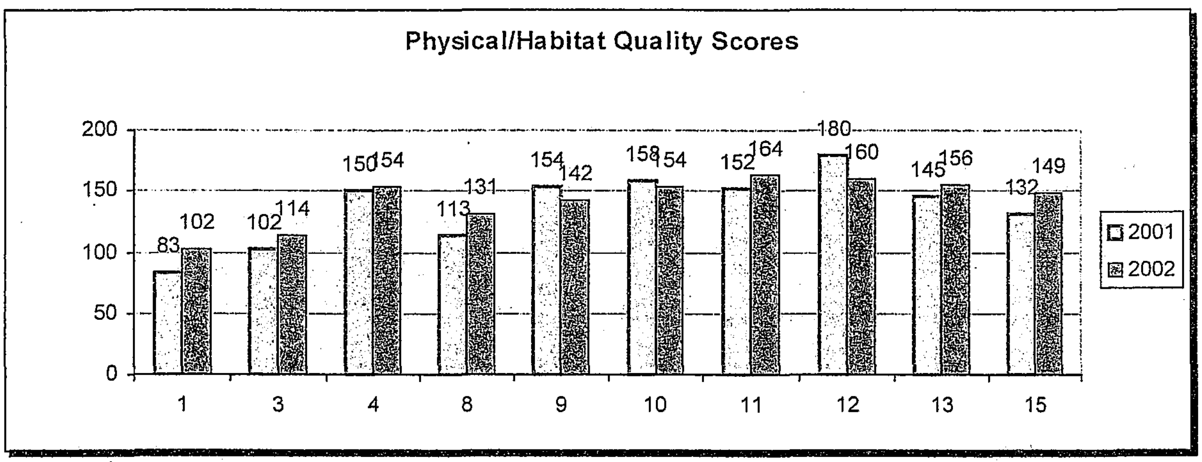
The sites that scored the lowest were the Ventura River sites 0, 1 and 12. Site 0 and 1 are the two lower most sites in the watershed. These two sites were similarly low in diversity and dominated by a few taxa (*Microcylloepus sp.*, Planariidae, *Hyalella sp.*, *Baetis sp. and Fallceon sp.*). Lower diversity is typical of lower elevation sites and sites in the lowermost portion of larger watersheds. Although the dominant taxa at these sites were moderately tolerant species, the assemblage was not indicative of unhealthy sites. The mayflies, *Baetis sp. and Fallceon sp* are tolerant of marginal habitat and sedimentation, but would be absent under toxic conditions. Site #12 was on Matilija Creek just below the dam. This site was the most impacted site, with an IBI rating of 31. Three of the five most dominant taxa (*Baetis*, *Simulium*, and *Microcylloepus sp.*) were tolerant taxa and accounted for 71% of the total abundance. The 2001 biotic condition at site #12 was somewhat higher with an IBI rating of 38, but still of lower quality compared to other sites.

There were two sites (#13 and #10) that had IBI scores of 51 and 49, respectively. These scores equated to a biotic condition rating of good. Site #13 was above the dam on the main stem of Matilija Creek just below a small community. In 2001, this site was the worst of the 14 sites tested having an IBI score of 37. In 2001, there was also a large bloom of filamentous algae just below the community in site #13 and four taxa, (*Baetis* and *Microcylloepus*, and the filter feeders *Hydropsyche* and *Simulium*) represented 84% of the total abundance. In 2002, the taxa composition changed and, although dominated by moderately tolerant taxa (*Fallceon sp. Tricorythodes sp. Dasythelea sp. and Microcylloepussp.*), they only represented 57% of the total abundance. Site #10 was scored as very good in 2001 with a score of 59. The 2002 IBI score was 10 points lower and primarily a result of fewer pollution intolerant species and grazer taxa being part of the invertebrate community that year.

The 2002 San Diego IBI scores determined for sites also sampled in 2001, were higher at six sites, lower at three sites and identical at one (Figure 10-9). Although the sites with the highest and lowest ratings remained the same in both years, the differences resulted in a change of rating designation in six of the 11 sites. Since the difference in the two years was not informally higher or lower, the discrepancy could be a result of sampling difficulty related to flow change. Five of the intended sampling sites could not be sampled in 2002 due to no flow conditions. Differences in physical/habitat condition were less evident but also were influence by low flow conditions (Figure 10-10). Regardless of the difference in score value, the trend of higher and lower physical/habitat quality was similar in both years.



• Figure 10-9. San Diego IBI Scores for sites that were sampled both in Fall 2001 and 2002 in Ventura River watershed, California.



• Figure 10-10. Physical/Habitat Quality Scores for sites that were sampled both in Fall 2001 and 2002 in Ventura River watershed, California.

Recommendations

The observation of biological condition for the monitoring sites in the Ventura River watershed was based on general knowledge of the BMI community and the IBI that was developed for the San Diego region. An IBI developed from test and reference sites from Monterey Bay to the Mexico border is close to completing and will be available for the 2003 data analysis. This new SoCal IBI will be more appropriate for use with Ventura River watershed sites and may or may not produce changes in biotic condition ratings. We recommend that next year's report have a recalculation of biotic condition scores for all three years.

For this bioassessment analysis, benthic macroinvertebrates (BMIs) were identified to a taxonomic level of Species, but the California Stream Bioassessment Procedure (CBSP) requires a BMI identification to a taxonomic level of Family. Although identification of BMIs to a Species level could provide more detail, the San Diego Region IBI used for this analysis was designed for Family level identification. In the near future, another Bioassessment report using BMI identification to the taxonomic level of Family will be produced and sent to the Regional Water Quality Control Board.

Receiving water monitoring at these sites was first implemented during the 1997-98 season and captures stormwater runoff from the Revolon Slough sub basin.

9.1.3 Mass Emission Monitoring

The purpose of mass emission monitoring is to identify pollutant loads to the ocean, identify long term trends in pollutant concentrations, and characterize surface water quality in major receiving waters. Mass Emission sites are located in the lower reaches of major watersheds. Through these sites, the Stormwater Monitoring Program can evaluate the cumulative effects of stormwater runoff and other surface water discharges on beneficial uses in the watershed prior to discharge to the ocean. Both Mass Emission stations and Receiving Water stations measure water quality concentrations in a surface water body, rather than a discharge to a water body like the Land Use monitoring stations. Mass Emission monitoring stations measure water quality concentrations resulting from discharges and stormwater runoff throughout an entire watershed. The Mass Emission drainage area is much larger than the drainage area for the Receiving Water sites and includes other sources of discharge, such as wastewater treatment plants and groundwater discharges.

Mass Emission stations are located in the three major Ventura County watersheds: Calleguas Creek (ME-CC), Ventura River (ME-VR), and Santa Clara River (ME-SCR). Each Mass Emission station was monitored this season. During the 2003-2004 monitoring season, water quality samples from three wet weather and three dry weather events were collected for water chemistry and toxicity at the Mass Emission sites. Monitoring at two of these stations, ME-CC and ME-VR, was initiated during the 2000/01 monitoring season, while monitoring at the ME-SCR was initiated during the 2001/02 monitoring season.

9.1.4 Bioassessment Monitoring

The Ventura County Stormwater Monitoring Program also includes the Bioassessment Monitoring Program. A work plan for in-stream bioassessment monitoring in the Ventura River watershed was developed and submitted in January 2001 to the Regional Water Quality Control Board (RWQCB) as part of the revised Stormwater Management Plan. For three years, starting in 2001, bioassessment monitoring has been conducted once a year in the fall to establish baseline data. The bioassessment monitoring for this reporting period occurred in September, 2003, and included 15 monitoring locations, including main streams and tributaries. Three of the 15 monitoring locations were dry, resulting in no monitoring at those locations. Bioassessment monitoring is conducted during the fall because it is the time period during which flows are most consistent and benthic macroinvertebrates are most productive and diverse. The fall season provides a consistent, stable environment for sampling that allows for benthic macroinvertebrate comparability from year to year. The results and a discussion of the fall 2003 bioassessment monitoring are provided in Section 9.2 of this Report. Pictures showing the bioassessment monitoring conducted during the fall of 2003 are provided below.

Monitoring Program's Land Use (Events 1 and 2), Receiving Water (Event 1), and Mass Emission (all events) sites, as well as three dry weather events monitored at each of the Mass Emission stations.

This monitoring report is organized into 9 sections. The first section, Section 9.1 provides the background and purpose of the Stormwater Monitoring Program. Section 9.2 provides the results and a discussion of the fall 2003 bioassessment monitoring. Section 9.3 includes a description of the monitoring sites. Section 9.4 discusses precipitation and flow conditions at the monitoring sites. Section 9.5 gives an overview of sample collection procedures and Section 9.6 provides tabular results of the sample analyses. Section 9.7 describes the quality assurance and control procedures employed by the Stormwater Monitoring Program. Section 9.8 discusses the water quality results and Section 9.9 summarizes mass loadings and data analysis.

9.2 Ventura River Watershed Macroinvertebrate Bioassessment and Physical/Habitat Assessment

9.2.1 Background

Streams and rivers throughout the world face a number of problems, primarily associated with modification of in-stream and riparian structure, inputs of contaminated water and increases in the size and frequency of floods due to the increase in impervious surfaces. There have been many studies and reports showing the deleterious effects of land-use activities to macroinvertebrate and fish communities (Jones and Clark 1987; Lenat and Crawford 1994; Weaver and Garman 1994; Karr 1998). Preventing some of these problems and restoring streams to a healthier condition is being attempted throughout the world (Karr et al. 2000).

Direct measurements of ambient biological communities including plants, invertebrates, fish, and microbial life have been used for the past 150 years as indicators of sanitation, potable water supplies, and the health of water for fisheries and recreation. In addition to these water quality implications, biological assessments (bioassessments) can be used as a watershed management tool for surveillance and compliance of land-use best management practices. Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term biological trend monitoring of watershed condition (Davis and Simon 1996).

Biological assessments of water resources integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality, and provide the public with more familiar expressions of ecological health than the results of chemical and toxicity tests (Gibson 1996). Furthermore, biological assessments when integrated with physical and chemical assessments better define the effects of point-source discharges of contaminates and provide a more appropriate means for evaluating discharges of non-chemical substances (e.g. nutrients, sedimentation and habitat destruction).

Water resource monitoring using benthic macroinvertebrates (BMI) is by far the most popular method used throughout the world. BMIs are ubiquitous, relatively stationary, and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment, and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of evolutionary, ecological and biogeographical information (Erman 1996).

While there are many potential methods for evaluating biotic condition from community data, most approaches in the United States use a combination of multi-metric and multivariate techniques. In multi-metric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair", and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kerans and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (Harrington 1999). As the Russian River IBI was being developed, the California Department of Fish and Game (CDFG) began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted CDFG to help them incorporate bioassessment into their ambient water quality monitoring program. During 1997 through 2000, data were collected from 93 locations distributed throughout the San Diego region. In 2001, a new set of sites were chosen and sampled to further establish reference conditions in the San Diego region. The results of this sampling event were combined with the results of earlier sampling events to establish a preliminary Index of Biological Integrity (IBI) for the San Diego region. In July 2002, a final report was presented as a working IBI for the San Diego region.

Since the distribution of the San Diego IBI, work has been completed on an IBI that can be used for the entire Southern California coastal area (Ode et al. 2004). Although the new IBI is complete and will eventually replace the San Diego version, the methodology is not yet included in permits or part of the Surface Water Ambient Monitoring Program (SWAMP). At the time of this report, the San Diego IBI is currently the best tool to analyze macroinvertebrate data from Southern California in general and Ventura County in this particular instance. The San Diego region is much more similar in terms of climate, precipitations, geology, and general ecosystem characteristics than is the Russian River area.

9.2.2 Introduction

NPDES permit CAS004002 required the Ventura County Watershed Protection District (VCWPD) to implement a countywide monitoring plan which included the development of an in-stream bioassessment monitoring program (this work plan), and the implementation of the monitoring program.

In spring 2001, VCWPD staff, with the assistance of the Sustainable Land Stewardship Institute (SLSI), developed a biological and physical/habitat assessment program within Ventura River watershed. On September 24 – 26, 2003, VCWPD and SLSI conducted the second year sampling event. The goal of the program was to:

1. Provide baseline information on the macroinvertebrate assemblages within Ventura River watershed;
2. Evaluate the biological and physical/habitat condition of various sampling sites within the Ventura River watershed using the preliminary Index of Biological Integrity (IBI) for the San Diego region;
3. Examine the effects of various land-use activities, including urban runoff, on the macroinvetebrate community structure throughout the Ventura River watershed; and
4. Provide recommendations and strategies for continued monitoring.

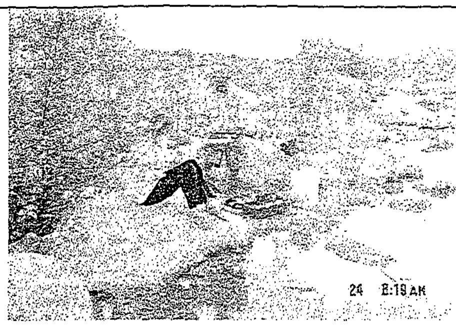
9.2.3 Materials and Methods

Sampling Site Descriptions

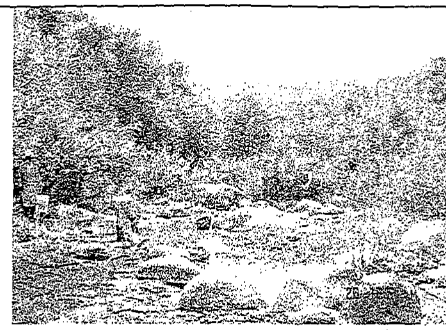
The 15 established sampling sites in the Ventura River watershed are listed in Table 1 (shown on page 9-9) and shown in Figure 9–1 (shown on page 9-10). Ten sites had flowing water in 2003 and were sampled on September 24 – 26. Photographs of these 10 sites are displayed in Figure 9–2 (shown on pages 9-11 and 9-12).

Table 9-1: BMI sampling location information for 15 reaches selected for the biological monitoring plan and the 10 sites sampled (5 sites were dry) on September 24 – 26, 2003, in the Ventura River Watershed

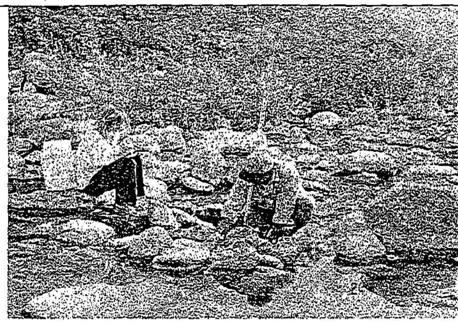
Sta.ID	Name	Description and Comments	Latitude	Longitude	Elev.
0	Ventura River – Main Street Bridge	Mainstem Ventura River, first site above estuary with fresh water.	34 16 54.23	119 18 24.09	19
2	Canada Larga Creek	Canada Larga Creek, d/s of grazing ***Dry - not sampled**	34 20 31.7	119 17 08.2	293
3	Canada Larga Creek	Canada Larga Creek, above main area of grazing impact ***Dry - not sampled**	34 22 23.3	119 14 8.8	334
4	Ventura River - Foster Park	Mainstem Ventura River. Closest downstream site to confluence with San Antonio Creek. Station is also mass emission station. Bioassessment d/s from Foster Park Bridge.	34 21 07.9	119 18 23.7	571
5	San Antonio Creek - near Ventura River	San Antonio Creek, first upstream site from confluence with Ventura River. ***Dry - not sampled**	34 22 50.9	119 18 23.9	347
6	Ventura River - Santa Ana Rd.	Mainstem Ventura River ***Dry - not sampled**			
7	Lion Canyon Creek – u/s conf. San Antonio Creek	Lion Canyon Creek (tributary to San Antonio Creek) First u/s location from confluence. Site with heavy sediment load and influenced by nearby stables and grazing. ***Dry - not sampled**	34 25 19.3	119 15 46.8	623
8	Stewart Canyon Creek – u/s conf. San Antonio Creek	Stuart Creek (tributary to San Antonio Creek) First u/s location from confluence. Within close proximity to the city of Ojai and less densely developed residential lots.	34 26 07.1	119 14 49.3	685
9	San Antonio Creek near Stewart Canyon Creek	San Antonio Creek. Within close proximity to the City of Ojai and less densely developed residential lots.	34 26 1.8	119 14 52.7	650
10	North Fork Matilija Creek- u/s Ventura River conf.	North Fork Matilija Creek. No dam influence. Below quarry.	34 29 06.0	119 17 59.4	978
11	North Fork Matilija Creek- at gauging station	North Fork Matilija Creek. No dam influence. Above quarry	34 29 35.1	119 18 18.6	1,360
12	Ventura River - below Matilija Dam	Matilija Creek First station below Matilija dam and first existing station above urban influence.	34 29 2.4	119 18 1.7	1020
13	Matilija Creek - below community	Matilija Creek. Above dam and below community. Site has excessive amount of algae.	34 30 04.5	119 20 51.7	1,355
14	Matilija Creek - @ gate at end of road	Matilija Creek. Above dam. Monitoring station to evaluate effects of dam and as possible reference conditions.	34 30 16.9	119 22 26.3	1,553
15	San Antonio Creek above Lion Creek	San Antonio Creek above Lion Creek	34 25 19.3	119 15 46.8	623



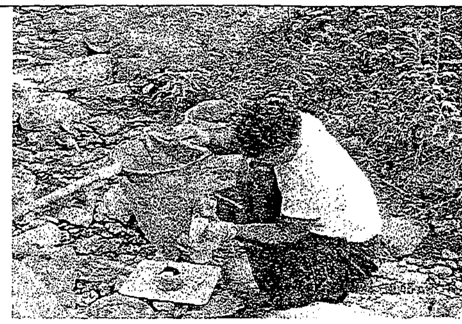
Site 14: Matilija Creek - @ gate at end of road



Site 15 San Antonio Creek above Lion Creek



Biological sampling techniques



Biological sampling techniques

Figure 9-2 (Continued): BMI sampling location photos of the 10 reaches sampled in 2003 for the Ventura River Watershed Biological Monitoring Program

9.2.4 BMI Sampling

Based on the work plan developed in spring 2001, the fall season was determined to be the most appropriate sampling index for the Ventura River watershed. The fall represents the most critical time for water quality and the highest stress on biotic communities. The problem with sampling in the fall is that some sites can be dry, especially in years experiencing drought conditions.

The California Stream Bioassessment Procedure (CSBP) was used to describe the BMI community and the biotic condition of 10 stream reaches sampled in 2003. The CDFG (Harrington 1996) developed the CSBP as standardized and cost-effective sampling, laboratory, and quality assurance procedures for the State's bioassessment programs (see Appendix 3 for additional information). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al. 1999) and has been used in various parts of the world to measure biological integrity of aquatic systems (Davis et al. 1996).

Riffle length was measured for each of the three riffles, and a random number table was used to randomly establish a point along the upstream third of each riffle at which a transect was established perpendicular to stream flow. Starting with the riffle transect furthest downstream, the benthos within a 2 ft^2 area was sampled upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net, followed by "kicking" the upper layers of substrate to dislodge any remaining invertebrates. The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrate that required rubbing by hand; more and larger substrates required more time to process. Three locations representing any habitat diversity along each transect were sampled and combined into a composite sample, representing a 6 ft^2 area for each transect and 18 ft^2 for the entire reach. Each composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol. This technique was repeated for each of three riffles in each reach.

9.2.5 BMI Laboratory Analysis

Laboratory analysis was performed by Aquatic Bioassay and Consulting Laboratories, Inc. in Ventura. At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All sample material was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs collected on September 24 - 26, 2003, were then identified to a standard taxonomic level, typically genus level for insects and order or class for non-insects. All samples were QA/QC'd by CDFG and the Sustainable Land Stewardship Institute Laboratories using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Kathman and Brinkhurst 1998, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

9.2.6 Data Analysis

A taxonomic list of all aquatic macroinvertebrates identified from the samples was entered into a Microsoft Excel 7 spreadsheet program. Excel 7 was used to generate a stand alone taxonomic list, and to calculate and summarize the aquatic macroinvertebrate community based metric values. The biological metrics are listed in Table 9-2 (shown on page 9-15) and have been categorized into the following types:

Richness Measures - These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat, and food sources are adequate to support survival and propagation of a variety of species.

Composition Measures - These metrics reflect the relative contribution of the population of individual taxa to the total fauna. Choice of a relevant taxon is based on knowledge of the individual taxa and their associated ecological patterns and environmental requirements such as those that are environmentally sensitive or a nuisance species.

Tolerance/intolerance Measures - These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant and intolerant, but are generally nonspecific to the type of stressors. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increases.

Functional Feeding Groups - These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a surrogate for complex processes of trophic interaction, production, and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

Table 9–2: Bioassessment metrics used to describe characteristics of the BMI community at the 10 selected reaches sampled September 24 – 26, 2003, in the Ventura River Watershed

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Ephemeroptera Taxa	Number of taxa in the insect order Ephemeroptera (mayflies)	decrease
Plecoptera Taxa	Number of taxa in the insect order Plecoptera (stoneflies)	decrease
Trichoptera Taxa	Number of taxa in the insect order Trichoptera (caddisflies)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the mayfly family Baetidae	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

9.2.7 Index of Biological Integrity (IBI)

The IBI used to evaluate the monitoring sites in this report was developed for the San Diego region. The scoring values derived from Ode et al. (2002) are listed in Table 9-3 (shown below).

Table 9-3: Scoring ranges for the seven metrics included in the San Diego IBI and the IBI values

	Metric Scoring Ranges for San Diego IBI						
Score	Cumulative Taxa	Dominant Taxon	Sensitive EPT Index	Cumulative EPT Taxa	Shannon Diversity	Intolerant Taxa	Percent Grazers
0	0-16	>56	0-0.6	0-1	0-1.31	0-.5	0-0.6
1	17-19	54-56	0.7-1.3	2	1.31-1.4	0.6-1.0	0.7-1.3
2	20-21	51-53	1.4-2.0	3	1.41-1.49	1.1-1.6	1.4-2.0
3	22-23	49-50	2.1-2.7	4	1.5-1.58	1.7-2.1	2.1-2.7
4	24-25	47-48	2.8-3.3	5	1.59-1.67	2.2-2.7	2.8-3.4
5	26-27	45-46	3.4-4	6	1.68-1.76	2.8-3.2	3.5-4.1
6	28-29	42-44	4.1-4.6	7	1.77-1.84	3.3-3.8	4.2-4.8
7	30-31	40-41	4.7-5.3	8	1.85-1.93	3.9-4.3	4.9-5.5
8	32-33	37-39	5.4-6	9	1.94-2.02	4.4-4.9	5.6-6.2
9	34-35	34-36	6.1-6.9	10	2.03-2.11	5.0-5.4	6.3-7
10	>35	0-33	>6.9	11	>2.11	>5.4	>7

IBI Scores	Very Poor	Poor	Fair	Good	Very Good
	0-12	13-25	26-37	38-54	55-70

9.2.8 Physical Habitat Quality

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al. 1999). Habitat quality assessments were recorded for each monitoring reach during each macroinvertebrate sampling event within riffle/ run habitats. A description of reach scale habitat parameters used to document local habitat conditions along stream corridors is provided in Appendix 4.

9.2.9 Results

The BMIs identified from the samples collected on September 24 – 26, 2003, from the 10 sites are listed in the Species Sheet included in Appendix 5. The means and coefficients of variation (CV) for biological metrics calculated from BMI samples are listed in the Detailed Metrics Sheet included in Appendix 5. Forms containing chemical and physical/habitat characteristic scores and field notes are on file at the VCWPD office in Ventura, and copies are on file at the SLSI office in Sacramento.

In September 2004, three (10% of total) BMI samples were submitted to the CDFG Aquatic Bioassessment Laboratory in Sacramento for Taxonomic Quality Assurance Testing. Only small taxonomic and numeric discrepancies were found, none of which would affect the biological metric values cited in this report.

9.2.10 BMI Community Structure

One hundred and thirty-three taxa of BMIs were identified in the 30 samples collected at the 10 sampling sites in the Ventura River watershed. Appendix 5 contains a list of the five most common taxa found at the 10 sites. Although all the biological metrics listed in Table 9–2 (shown on page 9-15) were calculated for the Ventura River watershed sites, only seven (Cumulative Taxa, % Dominant Taxon, Sensitive EPT Index, Cumulative EPT Taxa, Shannon Diversity, % Intolerant Taxa, and % Grazers) were used in the IBI and described in graphic form in this report. These biological metrics seemed to give the best overall sensitivity and discriminatory power to describe biological condition (Ode et al. 2002).

Richness Measures: There were two biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the richness of the BMI community. Cumulative Taxa values ranged from 26 to 50 for the 10 monitoring sites and are displayed in Figure 9–3: Cumulative Taxonomic Richness BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California. Cumulative EPT Taxa ranged from 5 to 18 for the 10 monitoring sites and are displayed in Figure 9–4 (shown on page 9-18).

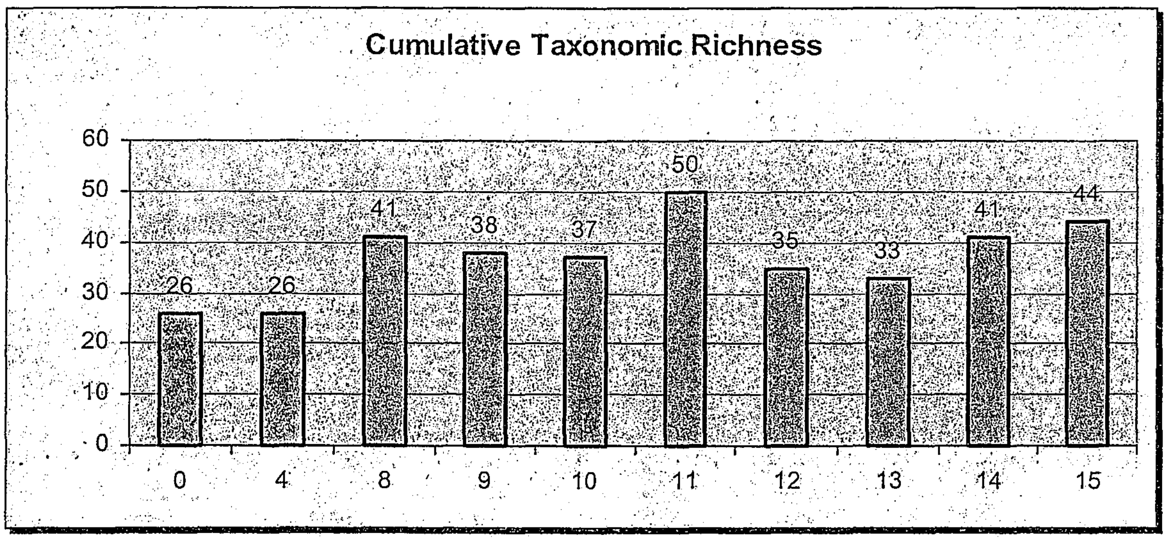


Figure 9–3: Cumulative Taxonomic Richness BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California

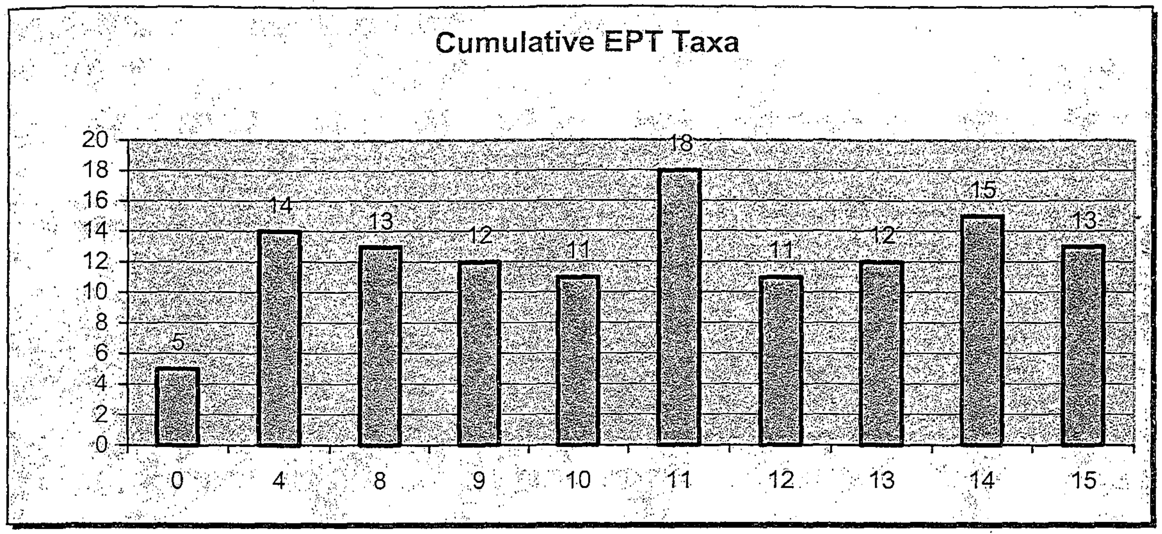


Figure 9–4: Cumulative EPT Taxa for BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California

Composition Measures: There were three biological metrics used to evaluate the biological condition of the Ventura River watershed sites that measure the composition of the BMI community. Mean Sensitive EPT Index values ranged from 0% to 22.8% for the 10 monitoring sites and are displayed in Figure 9–5 (shown below). Mean Shannon Diversity values ranged from 1.8 to 2.7 for the 10 monitoring sites and are displayed in Figure 9–6 (shown on page 19). Mean Percent Dominant Taxon values ranged from 20 to 44 for the 10 monitoring sites and are displayed in Figure 9–7 (shown on page 19).

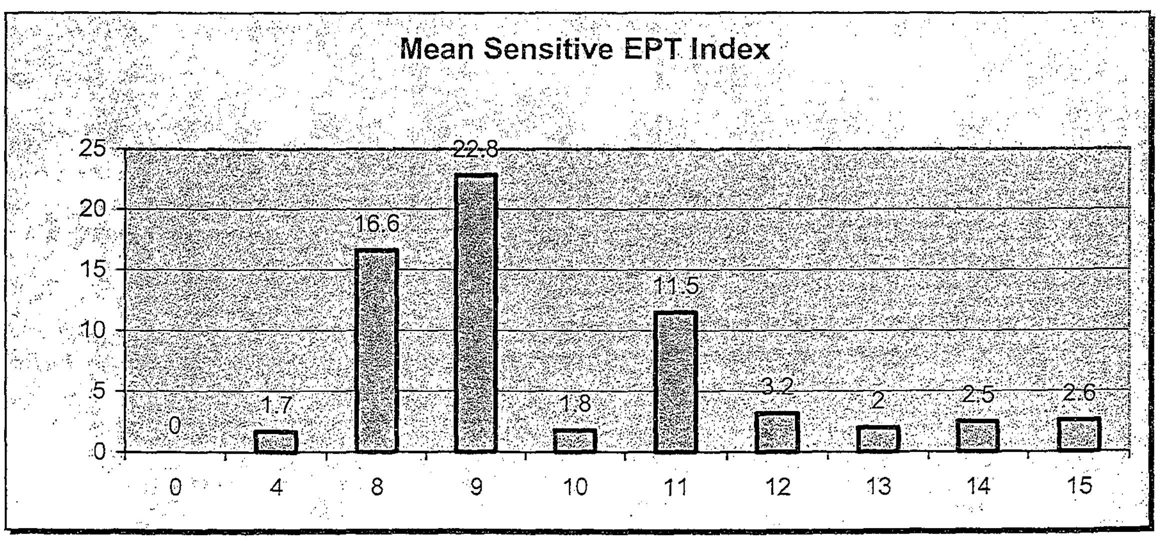


Figure 9–5: Mean Sensitive EPT Index for BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California

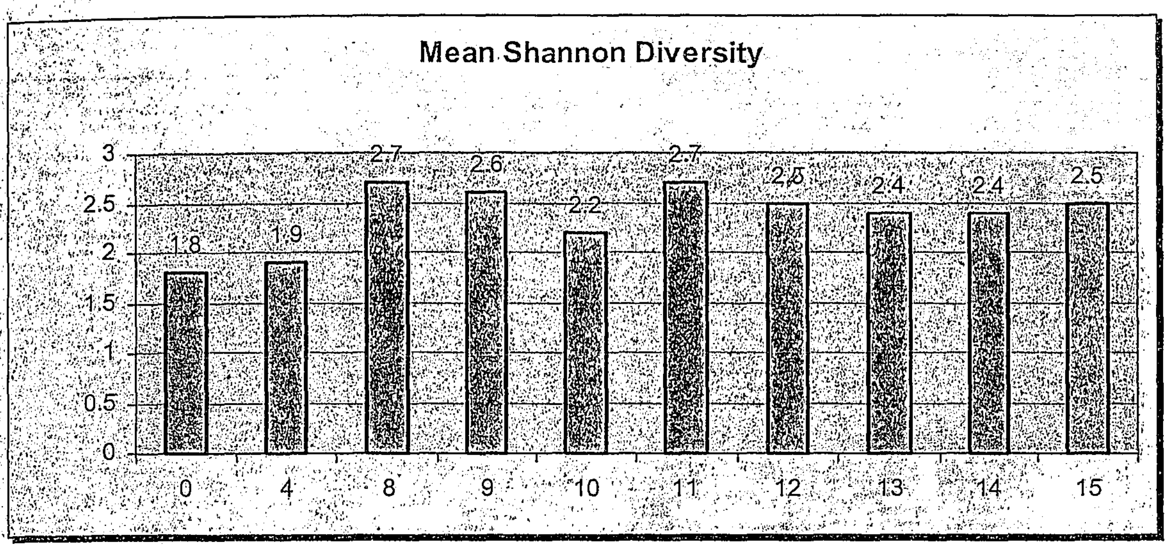


Figure 9–6: Mean Shannon Diversity for BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California

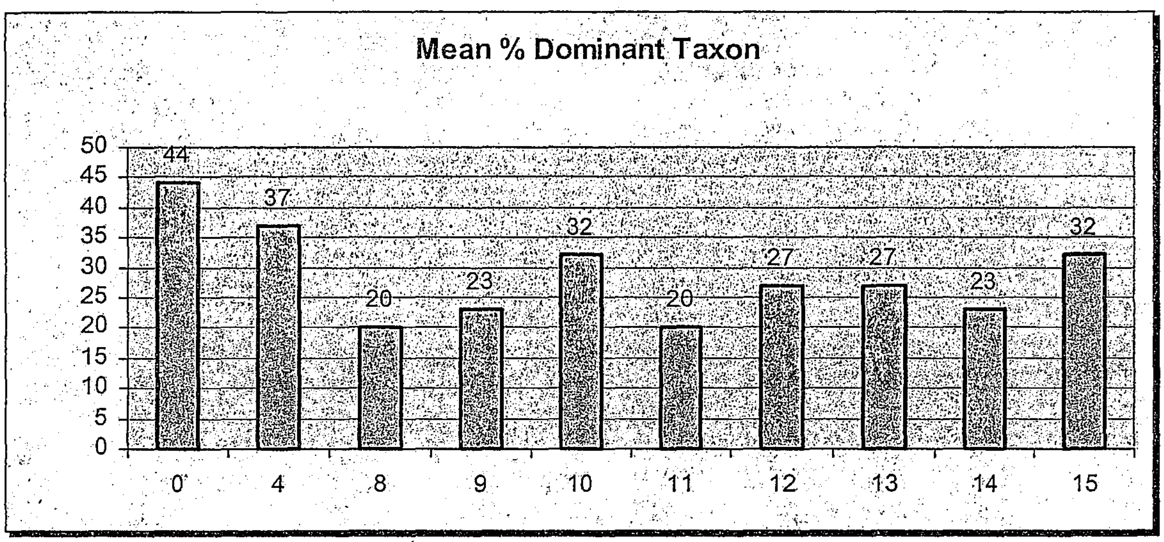


Figure 9–7: Mean Percent Dominant Taxon for BMIs collected on September 24 – 26, 2003, in the Ventura River Watershed, California

Tolerance Measures: There was one biological metric used to evaluate the biological condition of the Ventura River watershed sites that measure the tolerance of the BMI community. Mean Intolerant Taxa values ranged from 0.1 to 22 for the 10 monitoring sites and are displayed in Figure 9–8 (shown on page 9-20).

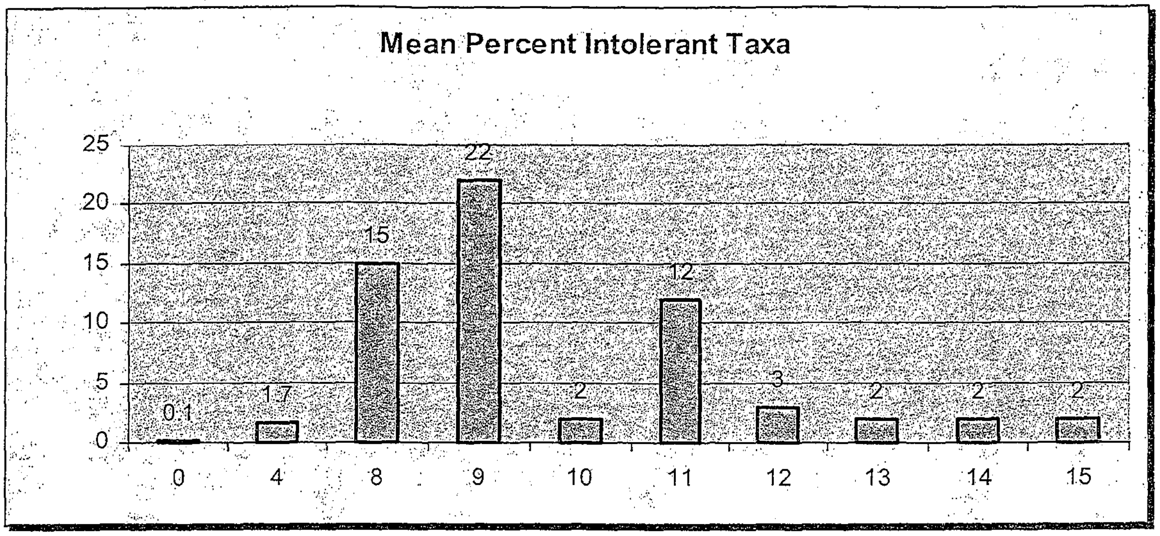


Figure 9-8: Mean Percent Intolerant Taxa for BMIs collected on September 24 - 26, 2003, in the Ventura River Watershed, California

Functional Feeding Groups: There was one biological metric used to evaluate the biological condition of the Ventura River watershed sites that measure partial feeding guild composition of the BMI community. Mean Percent Grazers values ranged from 1% to 26% for the 10 monitoring sites and are displayed in Figure 9-9 (shown below).

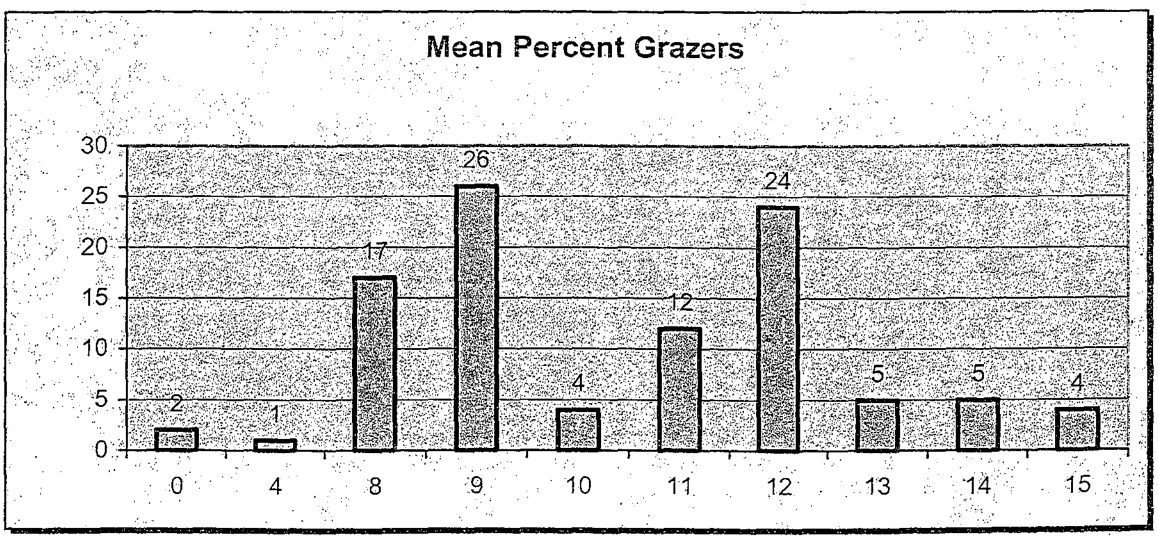


Figure 9-9: Mean Percent Grazers collected on September 24 - 26, 2003, in the Ventura River Watershed, California

9.2.11 IBI Scores

The IBI scores calculated for the 10 Ventura River watershed sites and their corresponding condition rating are listed in Table 9-4 (shown on page 9-21).

Table 9-4: IBI scores and rating for sites sampled in the Ventura River Watershed, fall 2003

Site #	0	4	8	9	10	11	12	13	14	15
Cummulative Taxa	6	8	10	10	10	10	10	10	10	10
Dominant Taxon	5	5	10	10	10	10	9	8	10	10
Sensitive EPT Index	0	2	10	10	2	10	4	2	3	3
Cummulative EPT Taxa	4	7	10	10	10	10	10	10	10	10
Shannon Diversity	6	7	10	10	10	10	10	10	10	10
Intolerant Taxa	0	3	10	10	3	10	5	3	2	2
Percent Grazers	2	0	10	10	5	10	10	6	6	5
Total	23	32	70	70	50	70	58	49	51	50
Rating	Poor	Fair	Very Good	Very Good	Good	Very Good	Very Good	Good	Good	Good

9.2.12 Physical/Habitat Scores

Physical/Habitat scores for the 10 sites ranged from 102 to 176 as shown in Table 9-5 (shown on page 9-22), which relates to marginal to optimal conditions. The best sites tended to be in the upper reaches of the watershed and the worst in the lower reaches.

Table 9-5: Habitat parameters for 10 selected reaches sampled September 24 – 26, 2003, in the Ventura River Watershed, California

Habitat Parameter	0	4	8	9	10	11	12	13	14	15
1. Instream Cover	14	15	15	16	18	18	17	16	12	12
2. Embeddedness	15	10	12	12	16	16	17	16	17	15
3. Velocity/Depth Regime	18	16	11	10	17	17	18	17	12	14
4. Sediment Deposition	8	10	9	10	17	13	18	16	16	4
5. Channel Flow	6	10	7	10	12	13	16	10	11	9
6. Channel Alteration	8	11	11	16	13	14	18	15	20	13
7. Riffle Frequency	10	13	11	10	16	18	17	17	17	13
8. Bank Stability	11	16	10	16	16	14	17	13	13	6
9. Vegetative Protection	6	12	11	18	18	16	19	16	18	10
10. Riparian Vegetative Zone Width	6	14	10	18	11	14	19	12	16	10
Reach Total	**102**	**127**	**107**	**136**	**138**	**139**	**176**	**148**	**152**	**106**
Condition Category	**Sub-optimal**	**Sub-optimal**	**Sub-optimal**	**Sub-optimal**	**Sub-optimal**	**Sub-optimal**	**optimal**	**Sub-optimal**	**optimal**	**Sub-optimal**
Other Reach Descriptions										
Vegetative Canopy Cover Estimate (%)	40	0	85	50	15	75	15	5	5	10
pH	8.0	7.7	7.9	7.7	8.1	7.9	8.2	8.0	7.9	8.1
D.O (mg/L)	7.8	7.5	9.4	8.0	8.6	7.6	8.7	8.7	9.1	8.5
Water Temperature (ºC)	19.0	18.2	18.9	20.4	20.1	18.1	20.4	18.5	15.6	18.3
Specific Conductance (ΦS/cm at 25EC)	1480	970	1563	1350	1004	1068	963	893	836	1320
Comments										

9.2.13 Discussion of Bioassessment Results

The assessment of the sites sampled from the Ventura River watershed in 2003 indicates an overall healthy aquatic system. Four of the 10 sites (Site numbers 8, 9, 11 and12) were rated as very good using the San Diego IBI. All 10 Ventura River watershed sites had physical/habitat quality ratings of optimal or suboptimal.

The sites that had the overall lowest San Diego IBI scores were the Ventura River Sites 0 and 4. Site 0 is the lower most site in the watershed sampled in 2003. This site was low in diversity and dominated by a few taxa (*Baetis sp., Simulium sp. and Hydropsyche sp.*) of filtering and gathering collectors. Lower diversity is typical of lower elevation sites and sites in the lowermost portion of larger watersheds. Although the dominant taxa at this site were moderately tolerant species, the assemblage was not indicative of an unhealthy site. The mayfly, *Baetis sp.* is tolerant of marginal habitat and sedimentation, but would be absent under toxic conditions.

There were two sites (#13 and #10) that had IBI scores of 50 and 49, respectively in 2003 and 51 and 49, respectively in 2002. These scores were remarkably similar over the two years and equated to a biotic condition rating of "good". Site #13 was above the dam on the main stem of Matilija Creek just below a small community. In 2001, this site was the worst of the 14 sites tested that year having an IBI score of 37. In 2001, there was also a large bloom of filamentous algae just below the community in site #13 and four taxa, (*Baetis* and *Microcylloepus*, and the filter feeders *Hydropsyche* and *Simulium*) represented 84% of the total abundance. In 2002 and again in 2003, the taxa composition changed and although dominated by moderately tolerant taxa, they only represented 57% and 54%, respectively of the total abundance. Site #10 was scored as "very good" in 2001 with a score of 59. The 2002 and 2003 San Diego IBI scores were approximately 10 points lower and primarily a result of fewer pollution intolerant species and grazer taxa being part of the invertebrate community that year.

The San Diego IBI scores for the 10 sites sampled in 2003 had minimal, but predominantly lower scores compared with those determined in 2001 and 2002 as shown in Figure 9-10 (shown on page 9-24). Three sites (site # 8, 9, and 11) had a "very-good" rating all three years and three other sites (site # 10, 13 and 15) fluctuated slightly between the three years, but with no discernable pattern. Site #0 was lowered from a "fair" rating in 2002 to a "poor" rating in 2003. This might be related to lower habitat quality since the physical/habitat scores were lower in 2003. Site # 4 showed the largest decrease in the San Diego IBI scores changing from a "good" rating in 2001 and "very-good" in 2002 to a "fair" rating in 2003. The physical/habitat scores for this site did not change much for the three years, but there was a much higher percentage (33%) of *Simulium sp.* collected in 2003 that were not dominant in the other two years. *Simulium sp.*, a tolerant, filtering aquatic fly, also played a role in the unusual increase in the San Diego IBI scores for site #12. This organism and the tolerant mayfly, *Baetis sp.* dominated at site #12 in 2001 and 2002, but not in 2003. Site #14 which was not sampled in 2002 because the channel was dry, changed from a rating of "very good" in 2001 to "good" in 2003. This change was probably related to the dry conditions experienced at the site.

Differences in physical/habitat condition at most sites were slight enough to be a product of subjective error in assessing the sites. However, there was a consistent decrease in physical/habitat scores in 2003 compared with the other two years as shown in Figure 9–11 (shown on page 9-24).

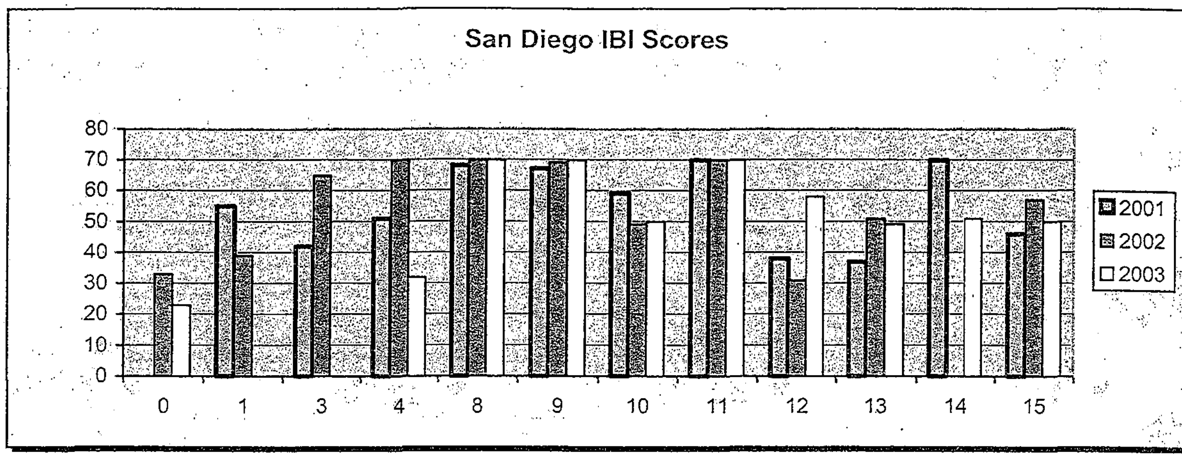


Figure 9-10: San Diego IBI Scores for sites that were sampled in Fall 2001, 2002, and 2003 in the Ventura River Watershed, California

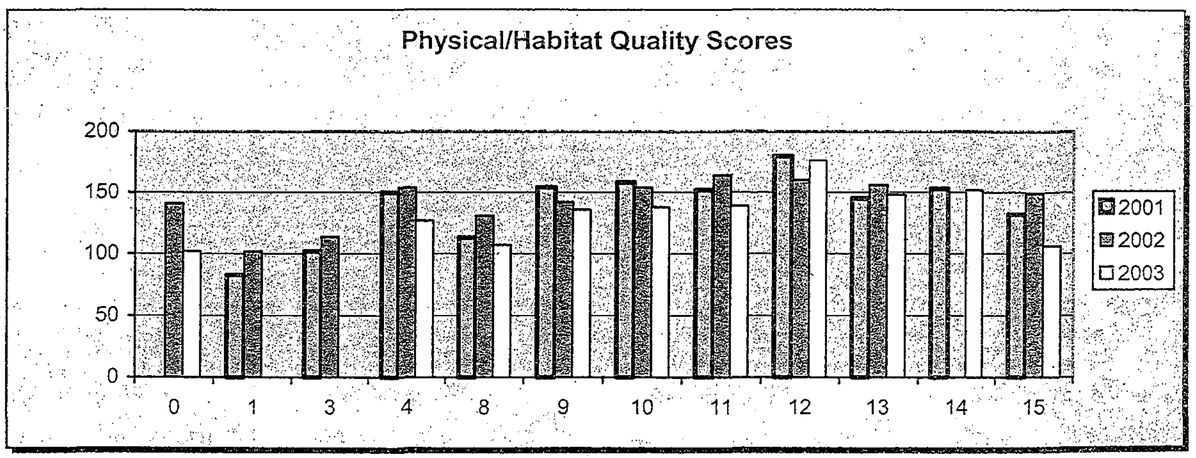


Figure 9–11: Physical/Habitat Quality Scores for sites that were sampled in Fall 2001, 2002, and 2003 in the Ventura River Watershed, California

9.2.14 Recommendations

1. The observation of biological condition for the monitoring sites in the Ventura River watershed was based on general knowledge of the BMI community and the IBI that was developed for the San Diego region. An IBI developed from test and reference sites from Monterey Bay to the Mexico border was completed in 2004 and is currently in press (Ode et al. 2004). This new SoCal IBI will be more appropriate for use with Ventura River watershed sites and may or may not produce changes in biotic condition ratings. We recommend converting to the SoCal IBI as soon as practicable and to have all past data converted.

2. This monitoring program is establishing baseline conditions for the Ventura River watershed and will allow for trend monitoring of biologic and physical/habitat condition. We recommend continued sampling of biological and physical/habitat condition in the Ventura River watershed so that a significant database can be generated to help in identifying regional biotic trends.

3. Collecting benthic invertebrate samples in the fall is optimal for detecting lowest water quality conditions. Sampling in the spring is also an option in the Southern California region since some streams may stand a better chance of having flowing water. We recommend evaluating spring conditions to determine if spring would be a better index period for sampling in the Ventura River watershed.

9.2.15 Literature Cited

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9.3 Ventura River Watershed 2004 Bioassessment Monitoring Report

9.3.1 Executive Summary

The 2004 bioassessment survey of the Ventura River watershed was conducted by staff members from the Ventura County Watershed Protection District, the Ojai Valley Sanitation District and Aquatic Bioassay and Consulting Laboratories on September 15th, 16th and 17th, 2004. Staff members from the California Department of Fish and Game (CDFG) and/or the Sustainable Land Stewardship Institute (SLSI) have been present during each of the four survey years to audit all sample collection activities and to provide data analysis and reporting services (CDFG = Jim Harrington, SLSI = Monique Born).

Fifteen benthic macroinvertebrate (BMI) sampling locations were visited during the survey, with nine sites having sufficient flow for sample collection. Physical/habitat observations, flow and water quality samples were also collected at each site. The taxonomic identification of BMI organisms, data analysis and report generation was conducted by Aquatic Bioassay and Consulting Laboratories in Ventura, CA. All of the QC guidelines for collection, sorting and identification of BMI organisms specified in the California Stream Bioassessment Protocol (2003) were met.

The physical habitat quality of the survey stations ranged from suboptimal to optimal. Stations located on the main stem of the Ventura River (Stations 0, 4 and 12) the upper portion of San Antonio Creek (Station 9) and on the Matilija Creek system (10, 11, and 13) scored at or just below the optimal range. These sites were characterized by relatively high substrate complexity, were composed of high percentages of cobble and boulders, had good bank stability, had little evidence of sedimentation due to upstream erosion and had good vegetative protection. The lowest physical habitat scores were measured at Station 15 on San Antonio Creek and Station 8 on Stewart Canyon Creek. These sites were characterized by having less instream cover and, especially in the case of Station 15, increased amounts of sedimentation and embeddedness (a measure of the amount of space surrounding cobble and gravel in the streambed). The increased sedimentation is most likely the result of erosion due to upstream grazing, poor bank stability, poor vegetative cover and stable operations. Water quality (pH, dissolved oxygen, temperature, specific conductance) was similar at all sites during the survey.

The aquatic health of the Ventura River watershed was assessed using the Southern California Index of Biological Integrity (So CA IBI). Based on this index, BMI communities that are ranked as poor can be considered to be impaired. The IBI rankings for the nine stations sampled for BMIs in 2004 ranged from good (1 station) to fair (6 stations) to poor (2 stations). The two stations that were rated as poor were located at the Main St. bridge near where the Ventura River discharges into the Pacific Ocean (Station 0) and Station 13 located downstream of a small residential community on Matilija Creek in the upper watershed. Station 11 in the North Fork of Matilija Creek received an IBI score of good, indicating that the BMI community found there is comparable to other reference site locations in southern California. Stations located on San Antonio Creek, at Foster Park on the Ventura River and below the Matilija Dam all scored in the fair range.

An historical analysis was conducted which included all the BMI data collected from 2001 through 2004. This analysis showed that the BMI communities were delineated more by their location in the watershed, than by survey year. The composition of the BMI community was mostly similar throughout the watershed both spatially and temporally. Most of the community changes during the four year period included only subtle shifts in the relative abundances of species. These results indicated that water quality in the watershed remained relatively stable during this four year period.

9.3.2 Introduction

9.3.2.1 Ventura River Watershed

The 228 square mile Ventura River watershed includes rugged mountains, a coastal chaparral ecosystem and valleys that lead to the Pacific Ocean. Almost half of the watershed is in the Los Padres National Forest. The Ventura River is the main watercourse within the watershed, with several major tributaries that includes Matilija Creek, San Antonio Creek and Cañada Larga Creek (Figure 9-1). Matilija Creek drains the mountainous northern most portion of the watershed and can be divided into the main stem of the Creek above Matilija Dam and the North Fork of Matilija Creek which discharges into the main stem below the dam. San Antonio Creek drains the northeastern portion of the watershed and has two main tributaries, Lions Canyon Creek and Stewart Canyon Creek. Cañada Larga Creek drains the eastern portion of the watershed.

The land use patterns within the watershed vary, but for the most part is undeveloped land and open space (89%). There are urbanized areas (1.5%) that include the cities of Ojai and San Buenaventura (southeast side), and unincorporated communities including Oak View, Matilija Canyon, Live Oak Acres, Meiners Oaks and Casitas Springs. The approximate human population of these communities is 20,000. The land use designations in the developed areas vary widely from rural to residential to industrial. Human impacted areas include activities related to grazing and livestock, agriculture, oil production and recreation.

9.3.2.2 Bioassessment Monitoring

Major issues facing streams and rivers in California include modification of in-stream and riparian structure, contaminated water and increases in impervious surfaces, which has led to the increased frequency of flooding. There have been many studies and reports showing the deleterious effects of land-use activities to macroinvertebrate and fish communities (Jones and Clark 1987; Lenat and Crawford 1994; Weaver and Garman 1994; and Karr 1998). A major focus of freshwater scientists has been the prevention of further degradation and restoration of streams to their more pristine conditions (Karr et al. 2000).

During the past 150 years direct measurements of biological communities including plants, invertebrates, fish, and microbial life have been used as indicators of degraded water quality. In addition, biological assessments (bioassessments) can be used as a watershed management tool for surveillance and compliance of land-use best management practices. Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term trend monitoring of watershed conditions (Davis and Simons 1995).

Biological communities act to integrate the effects of water quality conditions in a stream by responding with changes in their population abundances and species composition over time. These populations are sensitive to multiple aspects of water and habitat quality and provide the public with more familiar expressions of ecological health than the results of chemical and toxicity tests (Gibson 1996). Furthermore, biological assessments when integrated with physical and chemical assessments, better define the effects of point-source discharges of contaminates and provide a more appropriate means for evaluating discharges of non-chemical substances (e.g. nutrients and sediment).

Water resource monitoring using benthic macroinvertebrates (BMI) is by far the most popular method used throughout the world. BMIs are ubiquitous, relatively stationary and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of ecological and bio-geographical information (Erman 1996).

In the United States the evaluation of biotic conditions from community data uses a multi-metric technique. In multi-metric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981) but was subsequently adapted for BMI communities (Kerans and Karr 1994).

The first demonstration of a California regional IBI was applied to the Russian River watershed in 1999 (DFG 1998). As the Russian River IBI was being developed, the Department of Fish and Game (DFG) began a much larger project for the San Diego Regional Board. After a pilot project conducted on the San Diego River in 1995 and 1996, the San Diego Regional Board contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. During 1997 through 2000, data was collected from 93 locations distributed throughout the San Diego region. Finally, between 2000 and 2003, bioassessment data were collected from the Mexican border to the south, Monterey County to the north and to the eastern extent of the coastal mountain range. These data were used to create an IBI that is applicable to southern California and is applied to the data in this report (Ode 2005).

In fulfillment of the District's NPDES storm water permit requirement, the goal of this report was to assess the aquatic health of the Ventura River and its main tributaries based on the results of the physical habitat and BMI community data collected at nine sites in September 2004. In addition, these data were compared and contrasted to the previous three years of data to look for any spatial or temporal water quality trends.

9.3.3 Materials and Methods

9.3.3.1 <u>Sampling Site Descriptions</u>

Fifteen BMI sampling locations were visited in the Ventura River watershed from September 15th to 17th, 2004 (Figure 9-1, Table 9-1). Photographs of each site are displayed in Figure 9-2. The 15 sites can be grouped into four geographic areas: Stations 0, 4, 6 and 12 located in the main stem of the Ventura River; Stations 2 and 3 located in Cañada Larga Creek; the upper watershed which includes Stations 10, 11, 13 and 14 in Matilija Creek and the North Fork of Matilija Creek; and Stations 5, 7, 8, 9 and 15 located in San Antonio Creek and its tributaries, Lions Canyon Creek and Stewart Canyon Creek.

Ventura River Watershed (Stations 0, 4, 6 and 12)

The stations located on the main stem of the Ventura River range in elevation from 19 ft. at Station 0 near the ocean to 1020 ft. at Station 12 below the Matilija Dam. The Ventura River is the main drainage for the entire watershed and receives runoff from three main tributary systems: the Matilija Creek system above the dam; the San Antonio Creek system; and the Cañada Larga Creek system.

Station 0 is located upstream of the Main St. bridge just above where the Ventura River discharges into the Pacific Ocean. It is the first site in the Ventura River that is not influenced by salinity changes caused by tidal flushing. The river bed at Station 0 is heavily influenced by a large transient human population which lives there. The banks on each side of the river are stabilized by rock levees designed to protect the City of San Buenaventura from flooding.

The Ojai Valley Sanitation Plant is located 2.5 miles upstream of Station 0 and discharges 2.0 million gallons per day (MGD) of tertiary treated effluent, a process that includes nitrogen and phosphorus removal.

Station 4 is located at Foster Park, 1.85 miles downstream of the confluence of the San Antonio Creek with the Ventura River. This reach is located downstream of a traffic bridge, has small levees stabilizing both banks. The river bottom is composed of boulders and cobble. During the dry season filamentous algae is prevalent.

Station 6 is located upstream of the traffic bridge at Santa Ana Road. The channel at this site is concrete reinforced and covered with cobble on the sides and bottom. The river has historically flowed underground from a point upstream of Station 6 and then reverted to surface flow at a point downstream of the station. This site has been dry during September for the last four years. The site was selected in the event that sufficient precipitation would fall in the subwatershed to produce flow at this site.

Station 12 is located at the base of the Matilija Dam. The dam, which is fed by Matilija Creek, is filled with sediment and no longer serves as a flood control structure and is scheduled for future removal. The habitat at Station 12 is composed of boulders and natural vegetation.

Cañada Larga Creek (Stations 2 and 3)

Stations 2 and 3 are located on Cañada Larga Creek, the first major tributary to the Ventura River upstream of the ocean. The Cañada Larga drains a rural area composed of ranch land and open space. Station 3 is located near its headwaters and above areas of heavy grazing. Station 2 is located just upstream of the Cañada Larga's confluence with the Ventura River and downstream of the heavily grazed portion of the watershed. Both of these sites were dry during the September 2004 sampling event. Additionally, Station 2 lost its hydrological connection to Cañada Larga Creek during the high flows of January and February, 2005, when the creek's channel was redirected, thus bypassing Station 2.

Matilija Creek, Upper Watershed (Stations 10, 11, 13 and 14)

Each of the stations in the upper watershed is located above the influence of the Matilija Dam, at elevations near or above 1,000 ft. The Matilija Creek system drains a small portion of the Los Padres National Forest and is composed of mostly rural and recreational lands. Each of the monitoring sites is located in relatively pristine areas and is composed of high gradient, bolder and cobble habitats. Stations 10 and 11 are located on the North Fork of Matilija Creek, above (Station 11) and below (Station 10) an active rock quarry. Stations 13 and 14 are located on the main stem of Matilija Creek, above (Station 14) and below (Station 13) a small residential community that uses septic tanks as its means of sanitation. In previous years excessive algal growth had been present at Station 13, leading to concerns that the community could be contributing nutrients to the Creek. Station 14 was dry during the September 2004 sampling event.

San Antonio Creek (Stations 5, 7, 8, 9 and 15)

Stations 5, 7, 8, 9 and 15 are located in the San Antonio Creek system and include sites on San Antonio Creek (Stations 5, 9 and 15), as well as its main tributaries, Lions Canyon Creek (Station 7) and Stewart Canyon Creek (Station 8). Station 5 is located upstream of the bike path on San Antonio Creek just above its confluence with the Ventura River. The streambed is predominantly cobble with dense bank vegetation. Station 7 is located in Lions Canyon Creek above its confluence with San Antonio Creek in an area with stables, heavy grazing and sedimentation. Station 15 is located in San Antonio Creek upstream of Lions Canyon Creek and is composed of boulders, cobble and sand. Station 8 is located in Stewart Canyon Creek

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above the confluence with the San Antonio Creek and has a streambed composed of cobble, gravel and sand. Station 9 is located in San Antonio Creek upstream of Stewart Canyon Creek and is composed of cobble, gravel and sand with heavy vegetation on both banks. Both Stewart Canyon and San Antonio Creek at Stations 8 and 9 drain the City of Ojai's downtown and residential areas. Of these sites, Stations 5 and 7 were dry during the September 2004 sampling event.

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Table 9-1: Sampling location descriptions for 15 locations in the Ventura River Watershed (key: u/s = upstream; d/s = downstream)

Sta.ID	Name	Description and Comments	Latitude	Longitude	Elev.
0	Ventura River – Main Street Bridge	Mainstem Ventura River, first site above estuary with fresh water.	34 16 54.23	119 18 24.09	19
4	Ventura River - Foster Park	Mainstem Ventura River. Closest downstream site to confluence with San Antonio Creek. Station is also mass emission station. Bioassessment d/s from Foster Park Bridge.	34 21 07.9	119 18 23.7	200
6	Ventura River -Santa Ana Rd.	Mainstem Ventura River **Dry - not sampled**	34 23 59.1	119 18 29.7	403
12	Ventura River - below Matilija Dam	Matilija Creek. First station below Matilija dam and first existing station above urban influence.	34 29 2.4	119 18 1.7	1020
2	Canada Larga Creek	Canada Larga Creek, d/s of grazing **Dry - not sampled**	34 20 31.7	119 17 08.2	293
3	Canada Larga Creek	Canada Larga Creek, above main area of grazing impact. **Dry - not sampled**	34 22 23.3	119 14 8.8	334
5	San Antonio Creek - near Ventura River	San Antonio Creek, first upstream site from confluence with Ventura River. **Dry - not sampled**	34 22 50.9	119 18 23.9	347
7	Lion Canyon Creek – u/s conf. San Antonio Creek	Lion Canyon Creek (tributary to San Antonio Creek) First u/s location from confluence. Site with heavy sediment load and influenced by nearby stables and grazing. **Dry - not sampled**	34 25 19.3	119 15 46.8	623
15	San Antonio Creek above Lion Creek	San Antonio Creek above Lion Creek	34 25 19.3	119 15 46.8	623
8	Stewart Canyon Creek – u/s conf. San Antonio Creek	Stewart Creek (tributary to San Antonio Creek) First u/s location from confluence. Within close proximity to the City of Ojai and less densely developed residential lots.	34 26 07.1	119 14 49.3	685
9	San Antonio Creek near Stewart Canyon Creek	San Antonio Creek. Within close proximity to the City of Ojai and less densely developed residential lots.	34 26 1.8	119 14 52.7	650
10	North Fork Matilija Creek- u/s Ventura River conf.	North Fork Matilija Creek above influence of Matilija Dam and below rock quarry.	34 29 06.0	119 17 59.4	978
11	North Fork Matilija Creek- at gauging station	North Fork Matilija Creek above influence of Matilija Dam and above rock quarry.	34 29 35.1	119 18 18.6	1,360
13	Matilija Creek - below community	Matilija Creek. Above dam and below community. Site has excessive amount of algae.	34 30 04.5	119 20 51.7	1,355
14	Matilija Creek - at gate at end of road	Matilija Creek. Above dam and above community. **Dry - Not Sampled**	34 30 16.9	119 22 26.3	1,553

9.3.3.2 Collection of Benthic Macroinvertebrates

September was chosen for sampling the BMI communities in the Ventura watershed since fall represents the time when the water quality conditions are the most stressful for biotic communities. However, the Ventura River and its tributaries can be dry during the late summer and fall months as is typical of most southern California river systems. In addition, average rainfall during the 2003 – 2004 rainy season was below normal. As a result, only nine of the 15 sites had sufficient water for BMI sampling during September 2004.

Sampling and laboratory procedures for this survey followed the California Stream Bioassessment Procedure (CSBP 2003). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al. 1999) and has been used in various parts of the world to measure biological integrity of aquatic systems (Davis et al. 1996). Sampling procedures were audited by Jim Harrington of the California Department of Fish and Game.

Benthic macroinvertebrate (BMI) samples were collected in strict adherence to the CSBP in terms of both sampling methodology and QC procedures. At each station, a 100 m reach was measured and 3 riffles were randomly selected from all the possible riffles that were present within the reach. When access to the full 100 m reach was not possible due to obstacles (i.e. heavy vegetation), riffles were chosen from the portion of the reach where access was possible. Riffles were defined as areas in the reach where the velocity of flow was greatest due to shallow water coupled with a high relief bottom. At each site the California Bioassessment Worksheet (CBW) was used to collect all of the necessary station information.

Once three riffles were randomly identified, the most downstream riffle was occupied and the length of the riffle was measured. A random number table was used to randomly establish three points along the riffle where transects were established perpendicular to stream flow. Starting with the downstream riffle, the benthos within a 2 ft^2 area was sampled upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net, followed by "kicking" the upper layers of substrate to dislodge any remaining invertebrates. The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrate that required rubbing by hand; more and larger substrates required more time to process.

Three locations along each transect that were representative of habitat diversity were sampled and combined into a composite sample. Each composite sample was transferred into a 1 gallon wide-mouth plastic jar containing approximately 300 ml of 95% ethanol. This technique was repeated for each of three riffles in each reach, thus, three composite samples were collected for each site. Chain of Custody (COC) sheets were completed for samples as each station was completed.

9.3.3.3 Physical/Habitat Quality Assessment and Chemical Measurements

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al. 1999). The team collected the physical/habitat measurements at each station and recorded the information on the CBW. These measurements are summarized as follows:

1. Water temperature, specific conductance, and dissolved oxygen were measured using a hand held YSI 85 water quality meter that was pre-calibrated in the field. Similarly, a field-calibrated Beckman Model 225 meter was used to measure pH.

2. Riffle length, width and depth in meters were recorded. Width measures were averages taken at each transect and depth measures were averages taken along each transect.

3. A hand held Marsh McBirney Flo-Mate 2000 velocity meter was used to measure current velocity. Three measures were collected along each transect and then averaged together. Flow was calculated using the cross sectional flow measurement method.

4. A densitometer was used to measure % canopy cover.

5. Substrate complexity, embeddedness, consolidation and categories (fines, gravel, cobble, boulder, and bedrock) were estimated using the CSBP Physical/Habitat Quality Form.

6. Stream gradient was estimated using an inclinometer.

7. Nutrient samples for nitrate and nitrite nitrogen, and phosphate phosphorus were collected and analyzed by the Ojai Valley Sanitation District laboratory.

8. Aquatic bioassay and Consulting Laboratories analyzed all bacterial samples. Samples were collected in sterile 250 mL plastic containers and analyzed according to Standard Methods for the Examination of Water and Wastewater, APHA, 19th Edition, methods 9222 (total and fecal coliforms) and 9230 (*enterococcus* bacteria).

9.3.3.4 Sample Analysis/Taxonomic Identification of Benthic Macroinvertebrate (BMIs)

Sample sorting and taxonomy were conducted by Aquatic Bioassay and Consulting Laboratories. Sorting was conducted in the Aquatic Bioassay laboratory in Ventura, CA and taxonomic identifications were conducted by Dr. Kim Kratz in Lake Oswego, OR. Identifications were made using standard taxonomic keys (Literature Cited, Taxonomic References). In most cases taxa for this study were identified to the species level. In adherence with Taxonomic Effort Level 1 specified in the CSBP, identifications were rolled up to the appropriate taxonomic level for the calculation of biological metrics and the Southern California IBI. Samples entering the lab were processed as follows:

A maximum number of 300 organisms were sub-sampled from the composite sample using a divided tray, and then sorted into major taxonomic groups. All remnants were stored for future reference. The 300 organisms were identified to the genus level for most insects and order or class for non-insects. As new species to the survey area were identified, examples of each were added to the voucher collection. The voucher collection includes at least one individual of each species collected and ensures that naming conventions can be maintained and changed as necessary into the future.

The taxonomic quality control (QC) procedures followed for this survey included:

- Sorting efficiencies were checked on all samples. The leftover material from each sample was inspected by the laboratory supervisor. Minimum required sorting efficiency was 95%, i.e. no more than 5% of the total number of organisms sorted from the grids could be left in the remnants. Sorting efficiency results were documented on each station's sample tracking sheet.

- Once identification work was completed, 10% of all samples were sent to the Department of Fish and Game (DF&G) offices in Rancho Cordova for a QC check. Samples were sorted by species into individual vials that included an internal label. Any discrepancies in counts or identification found by the DF&G taxonomists were discussed, and then resolved. All data sheets were corrected and, when necessary, bioassessment metrics were updated.

9.3.3.5 Data Development and Analysis

Multi-metric Analysis

As species were identified, they were included in an Excel data sheet that, once complete, automatically calculated the bioassessment metrics used to assess the spatial and temporal BMI community changes in the watershed or necessary to calculate the southern California IBI (Ode 2004). The following metrics were calculated and their responses to impaired conditions are listed in Table 9-2:

1. Richness measures: taxa richness, cumulative taxa, EPT taxa, cumulative EPT taxa, Coleopteran taxa.

2. Composition measures: EPT index, sensitive EPT index, Shannon diversity.

3. Tolerance/intolerance measures: mean tolerance value, intolerant organisms (%), tolerant organisms (%), dominant taxa (%), Chironomidae (%), non-insect taxa (%).

4. Functional feeding groups: collectors (%), filterers (%), grazers (%), predators (%), shredders (%).

Southern California IBI

The seven biological metric values used to compute the Southern California Index of Biological Integrity (So CA IBI) are presented in Table 9-3 (Ode et al. 2005). The So CA IBI is based on the calculation of biological metrics from a group of 500 organisms from a composite sample collected at each stream reach. The sampling design for the Ventura Watershed for each of the last four sampling events (2001 through 2004) included a total of 900 organisms per reach (three replicate samples, 300 organisms each). As a result, before the So CA IBI could be computed for each station, 500 individual organisms were randomly selected from the list of 900 organisms at each station. These 500 organisms were used to compute the seven biological metrics used in the IBI computation. Ode et al. (2005) showed that this adjustment does not affect the outcome of the IBI. This adjustment was also applied to the data for the prior three years, so that historical trends could be elucidated.

San Diego IBI

The seven biological metric values used to compute the San Diego Index of Biological Integrity (SD IBI) are presented in Table 9-4 (Ode et. al. 2002). The SD IBI was developed solely for the San Diego region, but has been applied to the BMI data collected from the Ventura watershed during the past three years for lack of a more appropriate assessment tool.

Table 9-3: Scoring ranges for the seven metrics included in the Southern California IBI and the cumulative IBI score ranks

Metric Scoring Ranges for the Southern California IBI										
Metric Score	Coleoptera Taxa	EPT Taxa		Predator Taxa	% Collector Individuals		% Intolerant Individuals		% Non-Insect Taxa	% Tolerant Taxa
	All Sites	6	8	All Sites	6	8	6	8	All Sites	All Sites
10	>5	>17	>18	>12	0-59	0-39	25-100	42-100	0-8	0-4
9		16-17	17-18	12	60-63	40-46	23-24	37-41	9-12	5-8
8	5	15	16	11	64-67	47-52	21-22	32-36	13-17	9-12
7	4	13-14	14-15	10	68-71	53-58	19-20	27-31	18-21	13-16
6		11-12	13	9	72-75	59-64	16-18	23-26	22-25	17-19
5	3	9-10	11-12	8	76-80	65-70	13-15	19-22	26-29	20-22
4	2	7-8	10	7	81-84	71-76	10-12	14-18	30-34	23-25
3		5-6	8-9	6	85-88	77-82	7-9	10-13	35-38	26-29
2	1	4	7	5	89-92	83-88	4-6	6-9	39-42	30-33
1		2-3	5-6	4	93-96	89-94	1-3	2-5	43-46	34-37
0	0	0-1	0-4	0-3	97-100	95-100	0	0-1	47-100	38-100

Cumulative IBI Scores				
Very Poor	Poor	Fair	Good	Very Good
0-19	20-39	40-59	60-79	80-100

Table 9-4: Scoring ranges for the seven metrics included in the San Diego IBI and the cumulative IBI score ranks

Metric Scoring Ranges for the San Diego IBI							
Score	Cumulative Taxa	Dominant Taxon	Sensitive EPT Index	Cumulative EPT Taxa	Shannon Diversity	Intolerant Taxa	Percent Grazers
0	0-16	>56	0-0.6	0-1	0-1.31	0-.5	0-0.6
1	17-19	54-56	0.7-1.3	2	1.31-1.4	0.6-1.0	0.7-1.3
2	20-21	51-53	1.4-2.0	3	1.41-1.49	1.1-1.6	1.4-2.0
3	22-23	49-50	2.1-2.7	4	1.5-1.58	1.7-2.1	2.1-2.7
4	24-25	47-48	2.8-3.3	5	1.59-1.67	2.2-2.7	2.8-3.4
5	26-27	45-46	3.4-4	6	1.68-1.76	2.8-3.2	3.5-4.1
6	28-29	42-44	4.1-4.6	7	1.77-1.84	3.3-3.8	4.2-4.8
7	30-31	40-41	4.7-5.3	8	1.85-1.93	3.9-4.3	4.9-5.5
8	32-33	37-39	5.4-6	9	1.94-2.02	4.4-4.9	5.6-6.2
9	34-35	34-36	6.1-6.9	10	2.03-2.11	5.0-5.4	6.3-7
10	>35	0-33	>6.9	11	>2.11	>5.4	>7
		Very Poor 0-12	Poor 13-25	Fair 26-37	Good 38-54	Very Good 55-70	

Historical Analysis

An historical data analysis was performed using all of the BMI, physical habitat and water quality data collected during the past four sampling surveys (2001 through 2004). The goal of this analysis was to determine if any spatial or temporal trends in the BMI community could be detected and, if changes had occurred, what their cause(s) might be.

Historical IBI Scores

Data from 2001 through 2004 were used to compute the So CA IBI. For the So CA IBI, data from each year were converted from 900 count species abundances to 500 using the randomization process described above. The historic San Diego IBI data presented in previous reports (SLSI 2001, 2002, 2003) were used and for 2004 were computed using the 900 species count as specified in the protocol (Ode et. al. 2002).

Cluster Analysis

The spatial and temporal patterns of the BMI communities in the Ventura River watershed were defined using cluster analyses that were based on Bray-Curtis dissimilarities for pairs of stations. Species with relatively high abundances within a station group characterize the unique species composition of the group. Symbols on the two-way coincidence tables indicate relative abundance by the size of the symbol. Cluster analysis considers relative abundance of each tested taxa across the stations it occupies and is not weighted towards dominant species and therefore provides a more complete assessment of community structure.

9.3.4 Results

Results for the 2004 BMI are presented in the section below, followed by a historical analysis of the combined data from 2001 through 2004.

9.3.4.1 2004

9.3.4.1.1 Rainfall

Rainfall measured at the Stewart Creek gauging station during the 2003 to 2004 rain year (12.6 inches) was 8.5 inches below normal (21.2 inches) (Figure 9-3). Only the 2001 to 2002 rain year had less rain (7.2 inches) during the four years that the Ventura River watershed BMI survey has been conducted. The greatest amount of rain fell during eh 2000 to 2001 rain year (27.1 inches), followed by the 2002 to 2003 rain year (21.7 inches). Typical of southern California, the rain season started in the fall (October or November) and ended in either May or June. Peak months for rain were November through March. In 2004, the last measurable rain fell in April. Therefore, BMI sampling in September followed five months of dry weather and lead to the absence of water at six of the fifteen sampling locations.

9.3.4.1.2 Physical Habitat Characteristics

9.3.4.1.2.1 Velocity and Flow

The physical characteristics of the riffles sampled in the Ventura River watershed during September 2004 are presented in Table 9-5. Riffle velocities ranged from 0.4 ft/sec at Stations 8 (Stewart Canyon Creek) and 10 (North Fork Matilija Creek) to 1.85 ft/sec at Station 13 on Matilija Creek. Flow in the watershed was greatest at Station 0 (2.29 cfs). This flow measurement was taken in one of several channels found in this reach and is therefore an underestimate of the flow that was present across the entire reach. The next greatest flow was measured at Station 13 (1.81 cfs), below the residential community in Matilija Creek. Lowest flows were measured at Station 8 in Stewart Canyon (0.08 cfs) and Station 9 in San Antonio Creek (0.05 cfs).

9.3.4.1.2.2 Canopy Cover and Substrate

Vegetative canopy cover ranged from 4% at Station 10 on the North Fork of Matilija Creek to 68% at Station 11 which is located just upstream of Station 10. Substrate complexity was relatively good at most sites and ranged from 13 at Station 15 (Lions Canyon Creek) to 18 at Station 0 (Main St. bridge). The exceptions to this were low scores (7) at both Stations 8 and 9 located in San Antonio Creek and Stewart Canyon Creeks, respectively. Streambed substrates in the lower watershed (Stations 0, 4, 12, 15, 8, and 9) were, for the most part, composed of similar percentages of fines, gravel, cobble, and boulders. The exceptions to this were Station 12 located under the Matilija Dam where boulders predominated and Station 8 in Stewart's Canyon where cobble predominated. Each of the highest elevation, upper watershed Stations (10, 11 and 14) were composed predominately of boulders. All of the sites were high gradient streams ($\geq$2%), except Station 8 in Stewart Canyon where the gradient was 1%.

9.3.4.1.3 Water Quality, Nutrients and Bacteria

The range for pH measurements was narrow among all sites and ranged from 7.4 at Station 8 to 8.2 at Stations 15 and 12 (Table 9-5). Dissolved oxygen concentrations ranged from 5.03 mg/L at Station 13 to 9.28 mg/L at Station 4 on the main stem of the Ventura River. Dissolved oxygen concentrations can vary widely at the same site throughout the day due to changes in water temperature and, based on the amount of available sunlight, the photosynthetic rate of oxygen producing algae. Water temperatures were typical of summer conditions and ranged from 18.1 °C to 22.5 °C. Specific conductance ranged from 575 S/cm at Station 9 in Stewart Canyon to 1621 S/cm at Station 0.

Nitrate nitrogen was greatest at Stations 8 (1.1 mg/L) and 9 (2.5 mg/L), was just above the detection limit at Station 0 (0.2 mg/L), and was below detection at all other sites. Nitrite nitrogen was below detection at all sites. Phosphate phosphorus was greatest at Station 0 (0.9 mg/L), above detection at Station 8 (0.2 mg/L) and below detection at all other sites.

Total coliform bacteria concentrations were elevated throughout the watershed and were greatest at Station 8 (3500 MPN/100 mL) and lowest at Station 13 below the community on Matilija Creek (900 MPN/100 mL). Fecal coliform concentrations were greatest at Stations 15 (3000 MPN/100 mL), 8 (1100 MPN/100 mL) and 9 (2400 MPN/100 mL) all in the San Antonio Creek system. When the ratio between total and fecal coliform bacteria approaches one, the likelihood that the source of contamination is of either human or animal origin increases. Fecal coliform concentrations at all other sites were much lower. Enterococcus bacteria concentrations were also greatest at stations in San Antonio Creek (Station 8 = 1100, Station 9 = 500).

9.3.4.1.4 Physical/Habitat Scores

Assessment of the physical/habitat conditions of a stream reach is necessary for two reasons: one is to assess the overall quality of a stream reach and another is to assess the physical/habitat of the bioassessment site. In many cases organisms may not be exposed to chemical contaminants, yet their populations indicate that impairment has occurred. These population shifts can be due to degradation of the streambed and bank habitats. Excess sediment, caused by bank erosion due to human activities, is the leading pollutant in streams and rivers of the United States (Harrington and Born 2000). Sediments fill pools and interstitial areas of the stream substrate where fish spawn and invertebrates live, causing their populations to decline or to be altered. Physical/habitat characterization of the site is also important to help ensure that habitats are uniform between riffles so that population differences can be accurately assessed.

Out of a total possible score of 200, physical/habitat scores ranged from 108 at Station 15 at Lions Canyon Creek to 169 at Station 12 below the Matilija Dam (Table 9-5, Figure 9-4). Of the nine sites where samples were collected in 2004, six scored in the optimal range (Stations 0, 12, 9, 10, 11 and 13) and the other three sites (Stations 4, 15, and 8) scored in the suboptimal range. Of note were the following findings:

Instream cover is a measure of the amount of suitable BMI habitat in a reach and includes cobble, tree fall, undercut banks, etc. It was best at Station 0 (18) near the Main St. Bridge and worst at Station 8 (12) in Stewart Canyon.

Embeddedness is a measure of the amount of empty space (interstitial space) surrounding the rocks and cobble in a streambed. The higher the embeddedness score, the more interstitial space there is surrounding the streambed cobble, and the more available habitat there is for BMI's. Excessive upstream erosion and sedimentation can lead to low embeddedness at a site. The embeddedness score (11) was lowest at Station 15 in Lions Canyon, which is downstream of stables and grazing. Additionally, Station 15 had the most sediment deposition (score of 3) of all sites in the watershed. Sediment deposition at all other sites ranged from 12 (Station 8, Stewart Canyon) to 19 (Station 9, San Antonio Creek).

Channel flows were low at most stations due to the low rainfall conditions that preceded this sampling event. Exceptions to this were below the Matilija Dam (Station 12) and on the North Fork of the Matilija (Stations 10 and 11) where stream flow was close to normal. Bank stability scores ranged from 12 at Station 15 to 20 at Station 4. Vegetative protection was highest at Stations 0 and 4 on the main stem of the Ventura River and Station 11 on the North

Fork of the Matilija. The lowest score for vegetative protection was at Station 15 in Lions County.

9.3.4.1.5 BMI Community Structure

The complete taxa list including raw abundances by site and replicate are presented in Appendix A, Table A-1. The ranked abundance of the top 75% of the BMIs identified is illustrated in Table 9-6. The biological metrics calculated for this survey were grouped into the four categories described in Table 9-3 and presented in Figure 9-5 through Figure 9-8: richness measures, composition measures, tolerance/intolerance measures and functional feeding groups. The So CA IBI scores for each station are shown in Table 9-7 and illustrated in Figure 9-9. The biological metrics are presented for each replicate and then averaged by site in Appendix A (Tables A-2 and A-3, respectively).

9.3.4.1.5.1 Species Composition

A combined total of 8,425 BMIs, represented by 102 taxa, were identified from the 27 samples collected at the nine sampling sites during the September 2004 survey (Appendix A, Table A-1). Based on this figure, the projected total abundance for all sites combined would be 87,523 individuals (Figure 9-5 and Appendix A, Table A-1). Stations 0, 4 and 12, located on the main stem of the Ventura River, shared two relatively abundant species in common, Baetid mayflies (*Baetis sp.*) and chrionomids (Orthocladiinae) (Table 9-6). Baetid mayflies were either first or second most abundant at these sites and dominated the total abundance at Station 0, contributing 31% of the total population. At Station 4 the trichopteran, *Hydrophyche sp.*, was most abundant while the black fly (*Simulium sp.*) was most abundant at Station 12, below the Matilija Dam.

Stations located in the San Antonio Creek system (Stations 15, 8 and 9) shared three relatively abundant species in common: flies of the *Euparyphus/Caloparyphus* complex, which were dominant at Station 15, *Hydropsyche sp.*, which was dominant at Station 9 and Orthocladiinid flies. The gastropod, *Physa/Physella sp.* was most abundant at Station 8. The trichopteran, *Micrasema sp.*, was second in abundance at both Stations 8 and 9. This species has a tolerance value of 1, indicating that it is very sensitive to disturbances.

The three Stations in the upper watershed on the Matilija Creek system (Stations 10, 11 and 13), shared four species in common: the beetle, *Microcylloepus sp.*, which was most abundant at Stations 10 and 13; both Simulium sp. and Orthocladiinid flies, and Baetid mayflies (*Baetis sp.*). Station 13, on Matilija Creek below the human residential community, was almost exclusively comprised of these four species. The trichopteran, *Micrasema sp.*, was most abundant at Station 11, located on the North Fork of Matilija Creek.

9.3.4.1.5.2 Biological Metrics

The biological metrics listed in Table 9-3, above, were calculated for this survey and are presented by group in Figure 9-5 through Figure 9-8 and Appendix A, Table A-3.

Richness Measures: Taxa richness is a measure of the total number of species found at a site. This relatively simple index can provide much information about the integrity of the community. Few taxa at a site indicate that some species are being excluded, while a large number of species indicate a more healthy community. Cumulative taxa is a simultaneous count of all of the taxa from each of the three replicate samples taken at a station. Cumulative EPT taxa is the simultaneous count of all of the mayflies (Ephemeroptera), caddisflies (Trichoptera), and stoneflies (Plecoptera) present at a location. These families are generally sensitive to impairment and, when present, are usually indicative of a healthy community. Both Coleopteran and Predator taxa are included since they are used to calculate the So CA IBI.

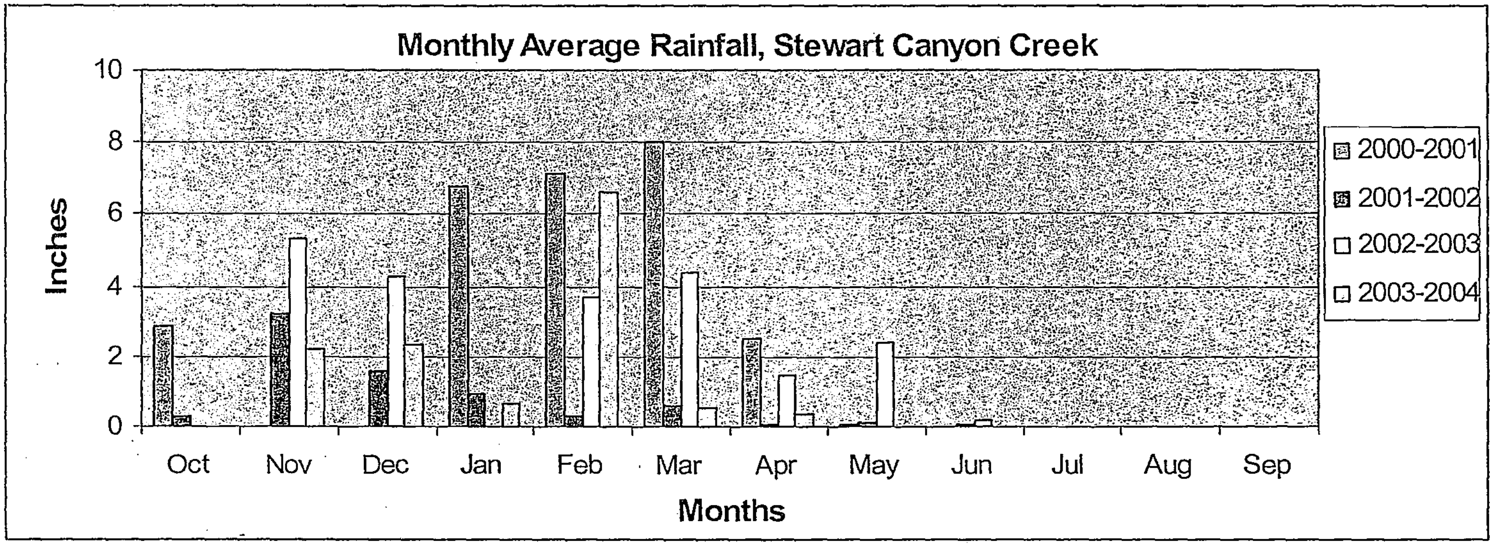


Figure 9-3: Monthly average rainfall (inches) at Stewart Canyon Creek for the 2001-2002 through 2003-2004 rain years

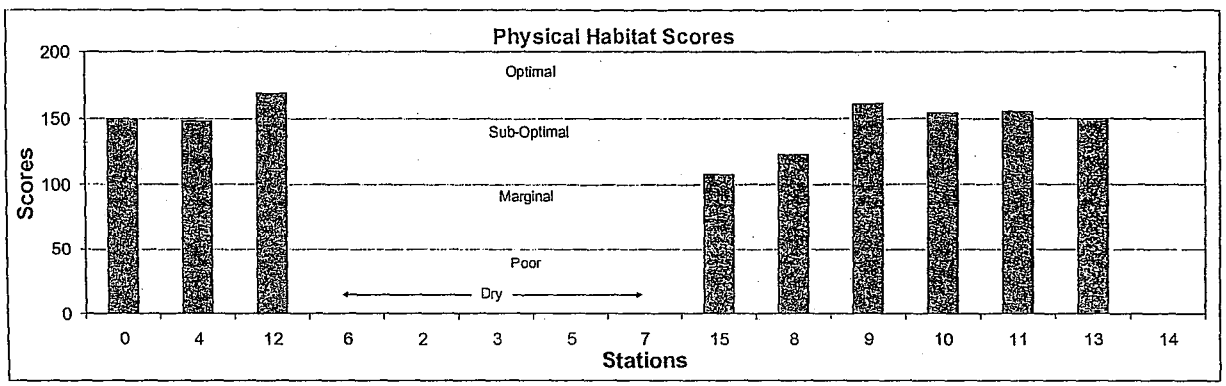


Figure 9-4: Physical habitat scores for reaches in the Ventura River Watershed

Table 9-5: Physical habitat scores and characteristics for reaches in the Ventura River Watershed (CDFG 2004)

	Ventura River				Canada Larga		San Antonio Creek					North Fork Matilija Creek		Matilija Creek	
	Main Street Bridge	Foster Park	Below Matilija Dam	@Santa Ana Rd.	Below Grazing	Above Grazing	u/s Ventura River Confluence	Lion Canyon u/s San Antonio	u/s Lion Canyon	Stewart Canyon u/s San Antonio	u/s Stewart Canyon Creek	u/s Ventura River Confluence	At gauging station	Below community	Above Community
Station	0	4	12	6 Dry	2 Dry	3 Dry	5 Dry	7 Dry	15	8	9	10	11	13	14 Dry
Physical Habitat Parameter															
1. Instream Cover	18	14	16						13	12	16	17	17	15	
2. Embeddedness	16	14	19						11	16	17	17	16	17	
3. Velocity/Depth Regime	10	10	17						14	9	10	18	17	15	
4. Sediment Deposition	16	18	18						3	12	19	16	14	16	
5. Channel Flow	7	4	15						9	8	9	13	14	10	
6. Channel Alteration	12	16	18						13	9	18	13	15	16	
7. Riffle Frequency	19	18	17						13	19	19	16	17	18	
8. Bank Stability	18	20	18						12	15	18	17	16	14	
9. Vegetative Protection	18	18	14						10	13	16	17	18	15	
10. Riparian Vegetative Zone	16	16	17						10	10	19	10	11	14	
Reach Total	150	148	169						108	123	161	154	155	150	
Condition Category	Optimal	Sub-optimal	Optimal						Sub-optimal	Sub-optimal	Optimal	Optimal	Optimal	Optimal	
Physical Habitat Characteristics															
Average Riffle Length (ft)	15	11	14						37	24	11	25	24	20	
Average Riffle Width (ft)	7	4	11						3	4	3	12	7	12	
Average Riffle Depth (in)	7	5	4						6	3	3	8	2	6	
Average Riffle Velocity (ft/sec)	1.2	0.63	1.6						0.73	0.4	0.57	0.4	0.85	1.85	
Flow (cf/sec)	2.29	0.2	0.52						0.55	0.08	0.05	0.21	0.65	1.81	
Vegetative Canopy Cover (%)	50	10	33						37	60	60	4	68	18	
Average Substrate Complexity	18	14	16						13	7	7	17	17	15	
Average Embeddedness	16	14	18						11	16	17	17	16	17	
Substrate Composition (%)															
Fines (<0.1 in.)	5	5	10						23	5	25	2	2	5	
Gravel ((0.1 -2 in.)	20	25	10						23	10	25	0	5	0	
Cobble (2-10 in)	57	40	13						22	80	35	28	42	42	
Boulder (>10 in.)	18	30	70						25	5	15	70	53	53	
Bedrock (solid)	0	0	0						7	0	0	0	0	0	
Substrate Consolidation	High	Mod	High						Mod	High	High	High	High	High	
Percent Gradient (%)	2	2	2						2	1	3	3	3	2	
Chemical Characteristics															
pH	7.82	7.6	8.2						8.16	7.4	7.5	7.9	7.7	7.6	
D.O (mg/L)	6.95	9.28	8.6						7.86	5.83	6.67	8	6.59	5.03	
Water Temperature (C°)	20.3	20.0	22.5						20.3	18.1	18.3	20.3	18.2	18.3	
Specific Conductance (S/cm at 25EC)	1621	1046	778						1425	1135	575	950	1014	812	
Nitrate Nitrogen (mg/L)	0.2	ND	ND						ND	1.1	2.5	ND	ND	ND	
Nitrite Nitrogen (mg/L)	ND	ND	ND						ND	ND	ND	ND	ND	ND	
Phosphate-Phosphorus (mg/L)	0.9	ND	ND						ND	0.2	ND	ND	ND	ND	
Indicator Bacteria															
Total Coliforms (MPN/100 mL	3000	2400	1600						3000	3500	2400	3000	3000	900	
Fecal Coliforms (MPN/100 mL	50	80	2						3000	1100	2400	50	5	8	
Enterococcus (MPN/100 mL)	70	50	<2						50	1100	500	59	17	110	

ND = non-detected, <0.1 mg/L

Taxa richness, both cumulative and individual EPT taxa and Predator taxa each followed a similar trend across sites, with the largest number of taxa found at Station 4 in the lower watershed, Stations 15, 8 and 9 in San Antonio Creek, and Stations 10 and 11 on the North Fork of Matilija Creek (Figure 9-5). Lower numbers were found at Station 0 near the ocean, Station 12 below the Matilija Dam and Station 13 below the small human residential community on the upper Matilija Creek. The numbers of Coleopteran taxa were similar across sites and were greatest at Stations 11 and 15, and least at Station 8 on Stewart Creek.

***Composition Measures*:** The percent EPT taxa, sensitive EPT, percent non-insects and the Shannon Diversity index are all measures of community composition. Species diversity indices are similar to numbers of species; however they contain an evenness component as well. For example, two samples may have the same numbers of species and the same numbers of individuals. However, one station may have most of its numbers concentrated into only a few species while a second station may have its numbers evenly distributed among its species. The diversity index would be higher for the latter station. Percent EPT taxa are the proportion of the abundance at a site that is comprised of mayflies, stoneflies and caddisflies. Percent Sensitive EPT taxa is similar except it includes only those EPT taxa whose tolerance values range from 0 to 3. These taxa are very sensitive to impairment and, when present, can be indicative of more natural conditions. Percent non-insect taxa are used in the calculation of the So CA IBI.

The percentage of EPT ranged from 40 to 60% at Stations 0, 4 and 12 on the main stem of the Ventura River and from 20 to 40% at Stations 15, 8, 10, 11 and 13 on both San Antonio Creek and Matilija Creek (Figure 9-6). Station 9, on San Antonio Creek, exceeded 60% EPT taxa and was an exception to this trend. The percentage of Sensitive EPT taxa was lowest in the lower watershed and highest in San Antonio Creek (Stations 8 and 9) and the North Fork of Matilija Creek (Station 11). Therefore, although large numbers of EPT taxa were present at Stations 0, 4 and 12, most were not sensitive species. The same was true for Stations 15, 10 and 13. Shannon Diversity was similar across all stations. Non-insect species composition was elevated at Stations 15 and 8 in San Antonio Creek.

***Tolerance Measures*:** The Southern California IBI uses both the percent intolerant and tolerant organisms to evaluate the overall sensitivity of organisms to pollution and habitat impairment. Each species is assigned a tolerance value from 0 (highly intolerant) to 10 (highly tolerant). The percent Intolerance Value for a site is calculated by multiplying the tolerance value of each species with a tolerance value ranging from 0 to 2, by its abundance, then dividing by the total abundance for the site. The percent Tolerant Value is similar except that only species with tolerance values ranging from 8 to 10 are included. A site with many tolerant organisms present is considered to be less pristine or more impacted by human disturbance than one that has few tolerant species. The tolerance values for each species were developed in different parts of the United States and can therefore be region specific. Also, different organisms can be tolerant to one type of disturbance, but highly sensitive to another. For example, an organism that is highly sensitive to sediment deposition may be very insensitive to organic pollution. With these drawbacks in mind, the Tolerance measures generally depict disturbances in a stream that, when coupled with other metrics, can provide good information regarding a stream reach.

Percent dominance reflects the proportion of the total abundance at a site represented by the most abundant species. For example, if 100 organisms are collected at a site and species A is the most abundant with 30 individuals, the percent dominance index score for the site is 30%. The benthic environment tends to be healthier when the dominance index is low, which indicates that more than just a few taxa make up the majority of the community.

The percent Hydropsychidae (caddisflies) and Baetidae (mayflies) present in a stream reach can indicate stressed habitat conditions when they are found in high abundance. They will not be present in highly polluted streams, but can be found in moderately polluted streams, especially when nutrients are high or there is a large amount of sedimentation.

Mean Tolerance Values were similar across sites and ranged from 4.1 at Station 11 to 5.5 at Station 15 (Figure 9-7). There were low percentages of intolerant organisms present at most sites, except at Stations 8 (23.2%), 9 (18.3%) and 11 (26.1%). The highest percentages of tolerant organisms were found at Stations 15 (24%) and 8 (24%). Percent Dominance exceeded 25% at Stations 0, 12, 9, 11 and 13. Hydropsychid caddisflies were present in large numbers at Station 9 (34%). Baetid mayflies were present in large numbers at Station 0 (37%) and 12 (33%).

Functional Feeding Groups: These indices provide information regarding the balance of feeding strategies represented in an aquatic assemblage. The combined feeding strategies of the organisms in a reach provide information regarding the form and transfer of energy in the habitat. When the feeding strategy of a stream system is out of balance it can be inferred that the habitat is stressed. For the purposes of this study, species were grouped by feeding strategy as percent collector-gatherers, collector-filterers, grazers, predators and shredders. The Southern California IBI uses the numbers of predators and percent collectors (gatherers + filterers) at a site to calculate the index.

Collecting was the predominant feeding strategy used by organisms in the watershed (Figure 9-8). Collectors exceeded 75% of the population at Stations 0, 4, 8, 10, 11 and 13. The percentage of filterers ranged from 10.7% at Station 11 to 37.3% at Station 9. Grazers were highest at San Antonio and Matilija Creek Stations 8 (27.3%), 9 (18.6%) and 11 (31.8%). Predators ranged from 4.1% at Station 12 below the Matilija Dam to 18.6% at Station 8 at Stewart Canyon Creek. Shredders were absent or present in low numbers at all sites.

9.3.4.1.5.3 IBI Scores

Work conducted in the 1990's by the San Diego Regional Board and the California Department of Fish and Game, established an Index of Biotic Integrity (IBI) for the San Diego region and its watersheds (Ode and Harrington 2002). The index has recently been expanded to include all of southern California (Ode et. al. 2005) and is used in this section. In previous reports (2001 to 2003), the San Diego IBI was applied to the BMI data collected for the Ventura watershed. A comparison of the So CA IBI and SD IBI scores for each of the four years of survey data is presented in the historical analysis section below.

The IBI is a multi-metric technique that employs seven biological metrics that were each found to respond to a habitat and/or water quality impairment. Each of the seven biological metrics measured at a site are converted to an IBI score then summed. These cumulative scores can then be ranked according to very good (80-100), good (60-79), fair (40-59), poor (20-39) and very poor (0-19) habitat conditions. The threshold limit for this scoring index is 39. Despite the fact that rankings can be identified as "fair", sites with scores above 39 are within two standard deviations of the mean reference site conditions in southern California and are not considered to be impaired. Sites with scores below 39 are considered to have impaired conditions. The metric scoring ranges established for the Southern California IBI survey are listed in Table 9-3 and were used to classify the Ventura watershed sites for the 2004 survey.

The IBI scores for six of the nine sites were in the fair range and included Stations 4 and 12 in the Ventura River, 15, 8 and 9 in the San Antonio Creek system, and Station 10 in the North Fork of Matilija Creek (Table 9-7, Figure 9-9). Two stations scored at or below the impairment threshold of 39 in the poor range: Station 0 at the Main St. Bridge and Station 13 on Matilija Creek below the community. Station 11, on the North Fork of Matilija Creek, scored in the good range.

9.3.4.2 Historical Results (2001 to 2004)

Physical habitat and IBI scores for the first four years of the Ventura watershed BMI monitoring program were combined and are presented graphically by site in Figure 9-10 and Figure 9-11. Since the San Diego IBI was applied to the BMI data in past reports (2001 to 2003), it was computed for the 2004 survey data, and then combined with the previous three years so that the SD IBI scores could be compared to the So CA IBI (Figure 9-12).

9.3.4.2.1 Physical Habitat Scores

Most sites varied from optimal to sub-optimal between years, with the majority of the scores for all sites and years in the sub-optimal range (Figure 9-10). Marginal scores were only reported at Station 1 on the Ventura River below the waste treatment facility in 2001 and Station 2 on Cañada Larga Creek. Station 1 improved to sub-optimal in 2002, while Station 2 was dry during the next three years. Station 12 was the only site to score in the optimal range for each of the four years. Differences in physical habitat scores between years for each site were not large, except at Station 15 where the score dropped from the high end of the sub-optimal range in 2001 and 2002, to the low end in 2003 and 2004. This change was not the result of a large decrease in one or two physical habitat parameters in these latter years, but rather an incremental decrease across each of the 10 parameters.

9.3.4.2.2 IBI Scores

So CA IBI: There was an upward trend in IBI scores for Stations 0, 12, 15, 8, 9, and 13 during the four year period (Figure 9-11). There were not large changes between years for any of these sites, but the scores for Stations 15, 8 and 9 on the San Antonio Creek system increased from Poor to Fair ratings during this period. The 2001 IBI score for Station 5, located on San Antonio Creek above its confluence with the Ventura River, was greater than all other upstream sites on the San Antonio during the same year. This indicates that the water quality and/or habitat conditions lowering the IBI scores at the upstream sites were not fully influencing the downstream portions of this Creek system.

Stations 0 and 1, located on the main stem of the Ventura River, had the lowest IBI scores during the four year period. Station 0 is heavily used by a large transient human population. Both sites are also located downstream of a waste treatment facility. Station 12, located below the Matilija Dam, scored in the Poor range for each of the four years. The physical habitat scores for this site were the highest measured in the watershed during the four year period, indicating that the lower IBI scores measured here were probably due to water quality conditions.

Station 11, located above the rock quarry on the North Fork of Matilija Creek, was the only station that scored in the Good range and did so during three of the four years. Station 10 located downstream of Station 11, scored in the poor to fair range during the same time period indicating the possible effects from the quarry. Additionally, Station 10 is heavily used as a swimming hole by Valley residence. Stations 13 and 14 are located downstream and upstream, respectively, of a small human residential community located on the banks of Matilija Creek. Since both sites scored in the Poor range during the years when samples were taken at each, it appears that the water quality impairment found at these sites was due to more widespread sources than just the influence of the residential community.

So CA IBI Compared to the SD IBI: The So CA IBI scores for each site across the four sampling years were uniformly lower than the scores computed using the SD IBI (Figure 9-12). The SD IBI ranked most stations as either Good or Very Good, while the So CA IBI ranked most in the Poor to Fair range. Only Station 0 during 2003 ranked in the Poor range when using the SD IBI. The general trends between sites were similar between the So CA IBI and the SD IBI with lowest scores measured at Station 0 and highest scores in San Antonio Creek system and Matilija Creek.

9.3.4.2.3 Cluster Analysis

The spatial and temporal patterns of the BMI communities in the Ventura River watershed were defined using cluster analyses that were based on Bray-Curtis dissimilarities for pairs of stations. The station and species dendograms summarizing the cluster analyses are presented in Appendix A, Figures A-1 and A-2. A two-way coincidence table that summarizes species abundances in each station and species cluster group is presented in Figure 9-13. Species with relatively high abundances within a station group characterize the unique species composition of the group. Symbols on the two-way coincidence table indicate relative abundance by the size of the symbol. Cluster analysis considers relative abundance of each tested taxa across the stations it occupies and is not weighted towards dominant species and therefore provides a more complete assessment of community structure. Table 9-8 presents the ten most common species averaged for each station over time, for each cluster group. A detailed description of the methods used for these analyses are presented in Appendix B.

Seven Station (1 thru 7) and five Species (A thru E) Groups were identified by cluster analysis (Figure 9-13). The seven Station Groups were delineated more by their location in the watershed, than by survey year. For the five Species Groups, there were no clearly defined distribution patterns across stations and years. Most of the changes were subtle shifts in the relative abundances of a group of species that were common throughout the watershed. These results indicate that water quality in the watershed remained relatively stable during this four year period.

Station Group 1 was comprised of stations on the Ventura River located either at the base of the Matilija Dam (Station 12) or by stations in the lower watershed (Stations 0 and 4). The top ten species common to this group included two Baetid mayflies (*Baetis sp.* and *Fallceon quilleri*), four genera of true flies, two caddisflys (including *Hydropsyche sp.*), a beetle (*Microcylloepus sp.*) and a gastropod mollusk (Table 9-8).

Station Group 2 was comprised of Stations 0 and 1 in 2002. The most abundant species at these sites included *Microcylloepus sp.*, as well as large numbers of non-insects (Planariidae, *Hyalella sp.* and Cyprididae). Station Group 3 included Station 3 in the Upper Cañada Larga Creek during 2001 and 2002, the only years when it was flowing. The most common species to this group included *Malenka sp.* (a pollution intolerant stonefly), *Hydropsyche sp.* and the dragonfly, *Argia sp.* Station Group 4 was composed of sites on Matilija Creek (Stations 13 and 14) and the North Fork of the Matilija Creek (Station 10). Among all taxa, *Microcylloepus sp.*, *Hydropsyche sp.*, five genera of true flies, and three mayflies were most abundant.

Station Groups 5 was comprised of sites on San Antonio Creek (Stations 15 and 7) and the lower Ventura River (Station 4). This group was dominated by the true fly, *Euparyphus/Caloparyphus sp.* Station Group 6 included sites from the 2001 survey in the San Antonio Creek and the lower Ventura River. Species composition for this group was dominated by *Hydropsyche sp.*, *Euparyphus/Caloparyphus sp.* and the mayfly, *Tricorythodes sp.* Station Group 7 was composed of Station 11 located on the North Fork of Matilija Creek, Station 8 on Stewart Canyon Creek and Station 9 on San Antonio Creek. The composition of species for this group was similar to other sites except that an extremely intolerant species of caddisfly (*Micrasema sp.*) was relatively abundant through the four year period.

9.3.5 Discussion

The 2004 So CA IBI results indicated that the aquatic health of the Ventura watershed ranged from poor to good. Stations 0 and 13 each scored in the poor range, indicating that these habitats were impaired. Station 0 is located just upstream of where the Ventura River discharges into the Pacific Ocean. During the previous two years the IBI score for this site has been very poor and poor (based on the So CA IBI). Conversely, the physical habitat score at this site has been either suboptimal or optimal as a result of the good instream cover, vegetative protection, bank stability, and the low amounts sedimentation. The explanation for the low IBI scores could be related to several factors including the reinforced levees present on each bank which protect the City of Ventura from flooding, the large transient human population that use the streambed for shelter and possibly the sites location 2.5 miles downstream of the Ojai Valley Sanitation Plant. This site supported few sensitive BMI species and the greatest number of Baetid mayflies found at any site in the watershed. Baetid mayflies are indicative of moderately disturbed conditions that could be the result of either elevated nutrient loading or sedimentation.

Station 13 is located downstream of a small human residential community on Matilija Creek, which is located in the upper watershed in what appears to be good stream habitat. The physical habitat scores during the past four years were either at the top end of the suboptimal range or optimal and have varied little during that time. The So CA IBI scores for this site during the same four years have been in the poor range. In 2004 the low IBI score was due to the absence of sensitive species and elevated numbers of collector species that included mostly Baetid mayflies and caddisflies, (*Hydropsyche sp.*). During 2004, Station 14 located upstream of Station 13 was dry. However, during 2001 and 2003 when the Creek was flowing at Station 14, its So CA IBI score was in the poor range. This indicates that the low score at Station 13 in 2004 may not have been due to some influence from the residential community.

Station 12 is located below the Matilija Dam at a site that had the highest physical habitat scores (optimal) in the entire watershed during each of the last four years. The So CA IBI scores at this site have been in the poor range during the same time period, except in 2004 when the score improved to fair. From 2001 to 2002 the lower IBI scores were the result of the near absence of sensitive species, large numbers of collector species (*Simulium sp.* and *Baetis sp.*), and few predator species. In 2003 and 2004 the IBI rank increased to fair due to an increase in the numbers of predator taxa which included caddisflies, *Ochrotrichia sp.*, dragonflies (*Argia sp.*), gastropods (*Sperchon sp.*), and flatworms (Planariidae).

Station 11 is located on the North Fork of the Matilija at an elevation of just over 1,300 ft and was the only site to score in the good range for the So CA IBI during 2001, 2002 and 2004. In 2003 the score dropped into the fair range. High IBI scores at Station 11 indicate that it is comparable in species composition to reference site locations throughout southern California. The physical habitat score at this site was in the optimal (2001, 2002 and 2004) to suboptimal (2003) range.

Station 10 is located below Station 11 and an active rock quarry. During the past four years the IBI scores for this site have been lower than at Station 11 in the poor to fair range. Two factors that could be influencing the aquatic health at Station 10 are the upstream rock quarry or its use as a swimming hole by local residents. In past years the BMI population at this site has been dominated by black flies (*Simulium sp.*).

IBI scores for each of the three San Antonio Creek system stations (15, 8 and 9) steadily increased from fair to poor since 2001. One would expect these sites to receive low IBI scores since the upper San Antonio drains downtown Ojai and the east end of the Ojai Valley, which is agricultural. Also, the physical habitat scores for these sites were mostly suboptimal during the four years. The reason for the improved BMI communities at these sites is unclear.

The SD IBI scores consistently ranked the aquatic health of the Ventura watershed sites as very good or good at nearly all sites during the 2001 to 2004 survey period. In contrast, the computed So CA IBI scores for the same data sets ranked them as poor to fair, with only one site receiving a rank of good. These results show that the use of IBI scores outside of the region where they were developed can be misleading. Since the development of the So CA IBI included reference sites from throughout the entire southern California area (coastal Monterey to the Mexican boarder), it is a more comparative index for use in the Ventura watershed.

Based on the results of the 2004 bioassessment survey, the sites chosen for BMI analysis in the Ventura watershed can be characterized as providing optimal to suboptimal habitat conditions. The best habitat conditions occurred at sites in the upper watershed and also on the main stem of the Ventura River, where there is high instream cover and complexity, low sedimentation, high bank stability and good vegetative protection. Less optimal habitat conditions exist in San Antonio Creek above its confluence with Lion's Canyon Creek and Stewart Canyon Creek where there was increased evidence of sedimentation.

The data collection technique for physical habitat assessment relies on the subjective opinion of the field crew regarding the habitat conditions found at each site. As a result, the scores for a given site can vary between years as a result of sampling bias. Therefore, minor changes between years at a site do not necessarily imply that a habitat change has occurred. The sampling team strove to eliminate bias by ensuring that staff members were well trained, collaborated on the scoring of each site, and by ensuring that experienced field people were always involved in the collection of these data.

An example of the subjectivity of this sampling technique is provided by the decrease in physical habitat scores at Station 15 in San Antonio Creek between 2002 and 2003. This site is located on private land and is visited by appointment. In the first two years of the program the entire sampling team (four people) participated in the collection of the physical habitat data. Due to the land owner's sensitivity to access, in 2002 and 2003 it was decided that is was more appropriate for only two team members to participate in sampling at this site. Since the habitat at this site did not change dramatically during this time period, it is probable that the decreased physical habitat score was the result of a personnel change.

Results of the historical cluster analysis, which included all the BMI data collected from 2001 through 2004, delineated seven Station and five Species Groups. The station groups were delineated more by their location in the watershed, than by survey year. For the five Species Groups, there were few distribution patterns across stations and years. Most of the changes were subtle shifts in the relative abundances of groups of species that were common throughout the watershed. These results indicated that water quality in the watershed remained relatively stable during this four year period.

9.3.6 Recommendations

1. It is recommended that the new Southern California Index of Biological Integrity (So CA IBI) developed by the California Department of Fish and Game be used to assess the aquatic health conditions of the Ventura River watershed, since it appears to be more sensitive to benthic macroinvertebrate (BMI) community disturbances than the San Diego Index of Biological Integrity (SD IBI).

2. It is recommended that the BMI sampling and taxonomic procedures for this program be modified to follow the new methods developed by the California Department of Fish and Game. This new protocol specifies that the BMI samples collected at a reach be taken along three transects then composited into a single sample, from which 500 organisms are identified for analysis.

3. It is recommended that the Ventura Watershed Protection District continue to work with the Southern California Coastal Water Research Project (SCCWRP) to assist in the development of improved BMI sampling design, sampling protocols, taxonomic identification and analysis techniques.

Table 9-6: Ranked % abundance for species comprising the top 75% of organisms at each site in the Ventura Watershed 2004
Hierarchical taxa codes (Grp): E = Emphemeroptera, T = Trichoptera, D = Diptera, NI = non-insects, C = Coleoptera, O = Odonata

Station 0 Ventura River Main Street Bridge	Grp	Tol	FFG	%
Baetis sp.	E	5	cg	31
Hydropsyche sp.	T	4	cf	14
Chironominae	D	6	cg	13
Simulium sp.	D	6	cf	10
Orthocladiinae	D	5	cg	9
% of Total				77

Station 4 Ventura River Foster Park	Grp	Tol	FFG	%
Hydropsyche sp.	T	4	cf	13
Baetis sp.	E	5	cg	10
Tricorythodes sp.	E	5	cg	10
Chironominae	D	6	cg	10
Ochrotrichia sp.	T	4	cg	8
Tinodes sp.	T	2	cg	6
Euparyphus/Caloparyphus	D	8	cg	6
Oligochaeta	NI	5	cg	5
Orthocladiinae	D	5	cg	5
Fallceon quilleri	E	4	cg	3
% of Total				75

Station 12 Ventura River below Matilija Dam	Grp	Tol	FFG	%
Simulium sp.	D	6	cf	25
Baetis sp.	E	5	cg	18
Fallceon quilleri	E	4	cg	15
Microcylloepus sp.	C	4	cg	12
Orthocladiinae	D	5	cg	7
% of Total				77

Station 15 San Antonio Creek above Lion Canyon	Grp	Tol	FFG	%
Euparyphus/Caloparyphus	D	8	cg	10
Hydropsyche sp.	T	4	cf	9
Fallceon quilleri	E	4	cg	8
Microcylloepus sp.	C	4	cg	8
Cyprididae	NI	8	cg	6
Orthocladiinae	D	5	cg	5
Simulium sp.	D	6	cf	5
Oligochaeta	NI	5	cg	5
Hyalella sp.	NI	8	cg	5
Argia sp.	O	7	p	5
Baetis sp.	E	5	cg	4
Oxyethira sp.	T	3	cg	4
% of Total				73

Station 8 Stewart Canyon Creek u/s conf. San Antonio Creek	Grp	Tol	FFG	%
Physa/Physella sp.	NI	8	sc	14
Micrasema sp.	T	1	sc	12
Hydropsyche sp.	T	4	cf	12
Tinodes sp.	T	2	cg	10
Argia sp.	O	7	p	8
Simulium sp.	D	6	cf	7
Orthocladiinae	D	5	cg	6
Sperchon sp.	NI	8	p	5
Euparyphus/Caloparyphus	D	8	cg	3
% of Total				78

Station 9 San Antonio Creek near Stewart Canyon Creek	Grp	Tol	FFG	%
Hydropsyche sp.	T	4	cf	35
Micrasema sp.	T	1	sc	13
Orthocladiinae	D	5	cg	7
Tricorythodes sp.	E	5	cg	6
Euparyphus/Caloparyphus	D	8	cg	6
Tinodes sp.	T	2	cg	5
Argia sp.	O	7	p	4
% of Total				76

Station 10 North Fork Matilija Creek u/s conf. Ventura River	Grp	Tol	FFG	%
Microcylloepus sp.	C	4	cg	17
Hydropsyche sp.	T	4	cf	13
Dasyhelea sp.	D	6	cg	9
Simulium sp.	D	6	cf	8
Chironominae	D	6	cg	7
Orthocladiinae	D	5	cg	7
Baetis sp.	E	5	cg	5
Ochrotrichia sp.	T	4	cg	5
Tinodes sp.	T	2	cg	4
% of Total				76

Station 11 North Fork Matilija Creek at gauging station	Grp	Tol	FFG	%
Micrasema sp.	T	1	sc	22
Orthocladiinae	D	5	cg	21
Microcylloepus sp.	C	4	cg	9
Hydropsyche sp.	T	4	cf	7
Chironominae	D	6	cg	5
Simulium sp.	D	6	cf	4
Baetis sp.	E	5	cg	4
Euparyphus/Caloparyphus	D	8	cg	4
Maruina lanceolata	D	2	sc	2
% of Total				77

Station 13 Matilija Creek below community	Grp	Tol	FFG	%
Microcylloepus sp.	C	4	cg	30
Simulium sp.	D	6	cf	23
Orthocladiinae	D	5	cg	14
Baetis sp.	E	5	cg	7
Fallceon quilleri	E	4	cg	6
% of Total				80

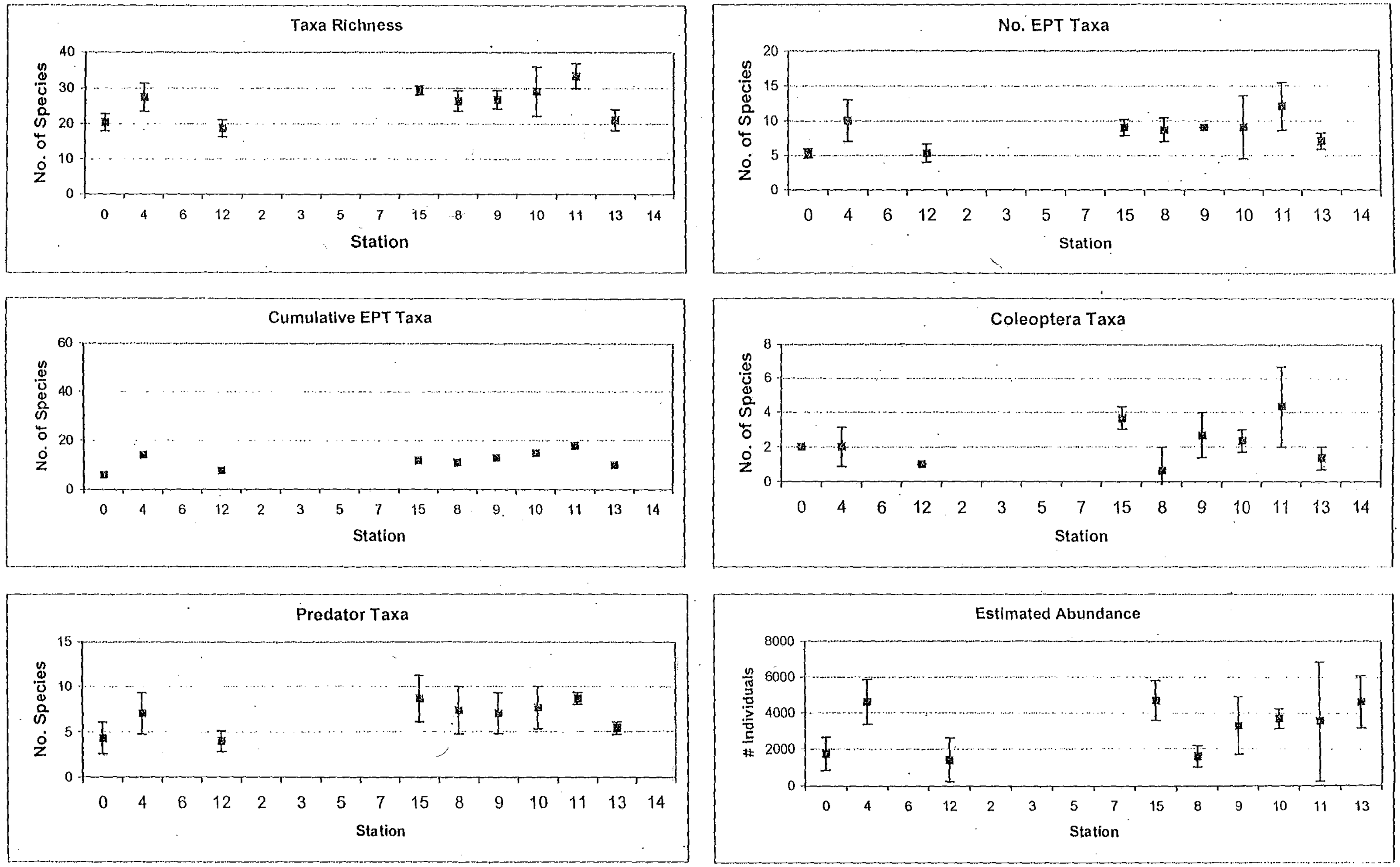


Figure 9-5: Richness measures: average (n=3) for each biological metric (± 95% CI) by site in the Ventura Watershed, 2004

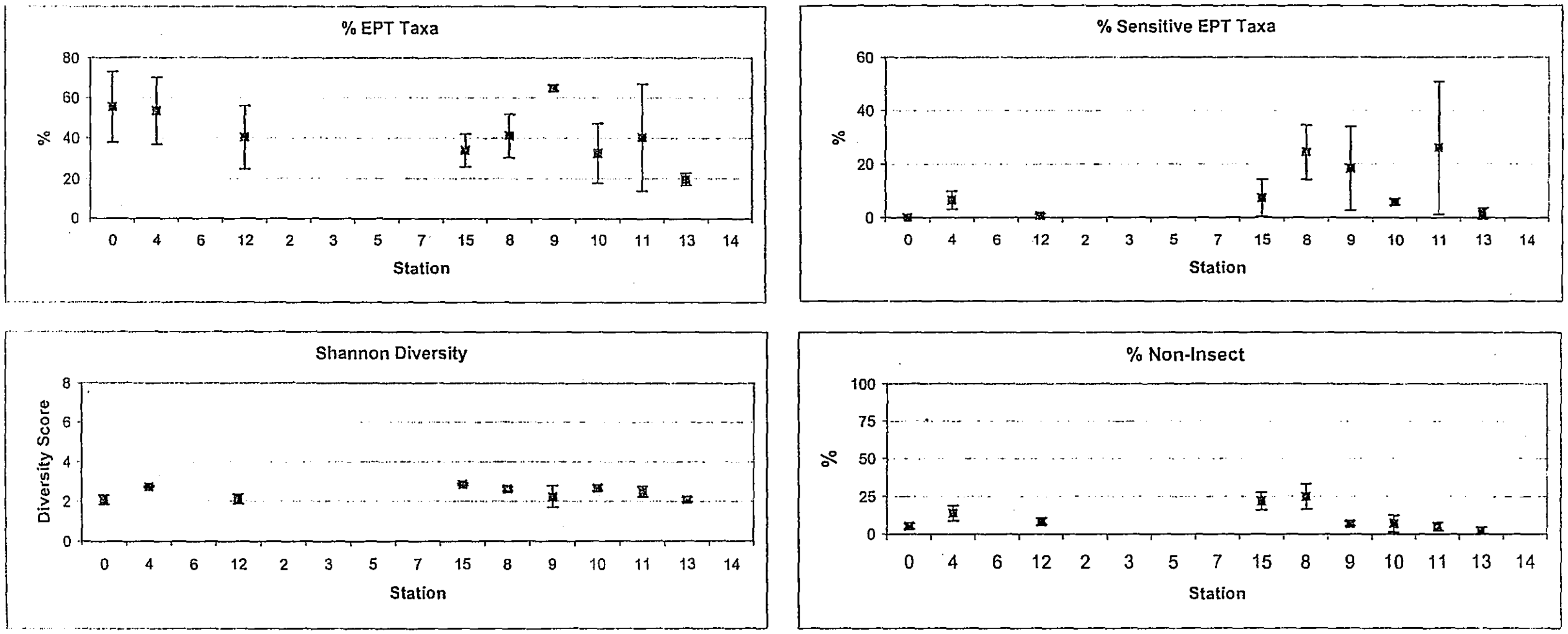


Figure 9-6: Composition measures: average (n=3) for each biological metric (± 95% CI) by site in the Ventura Watershed, 2004

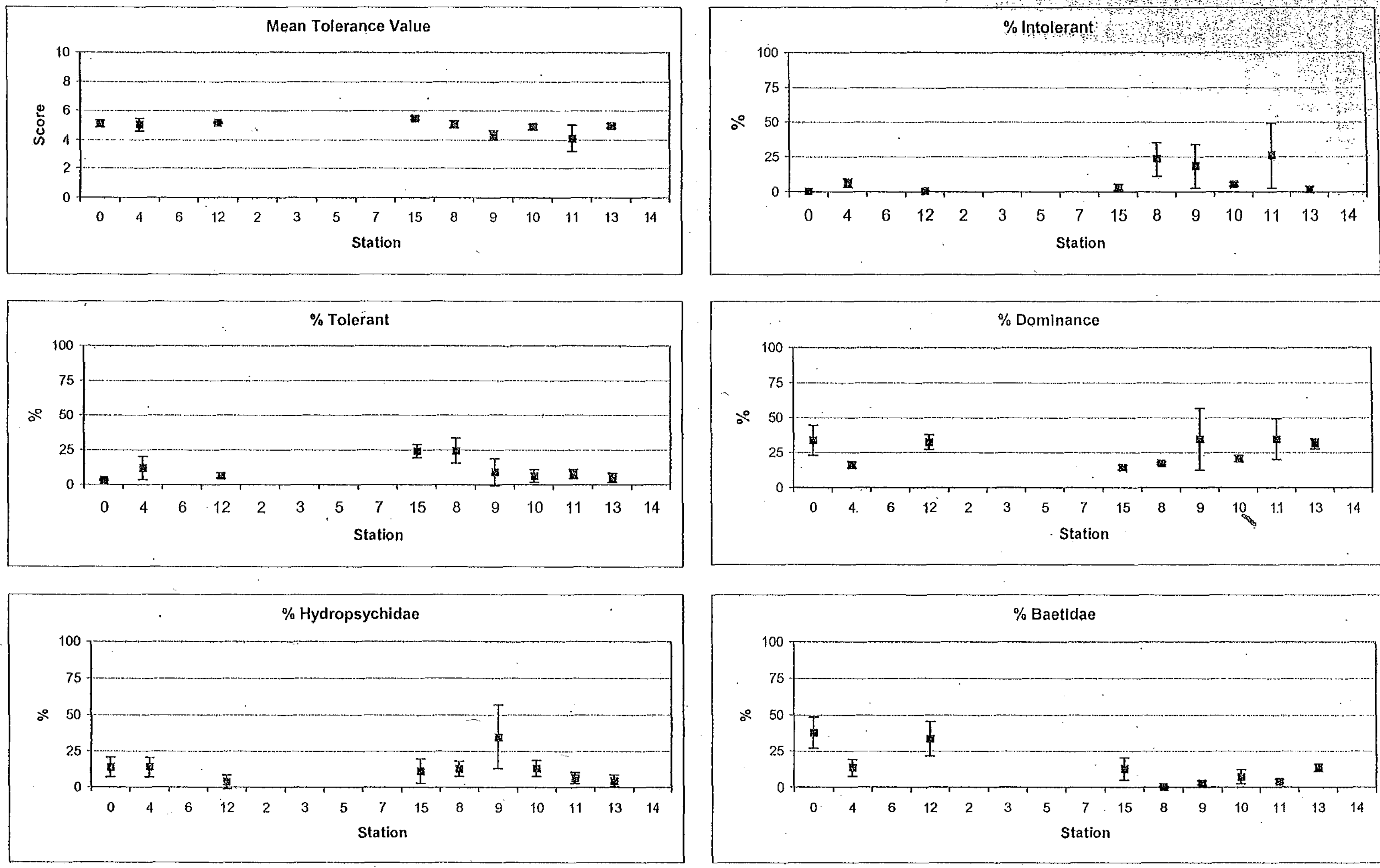


Figure 9-7: Tolerance/Intolerance measures: average (n=3) for each biological metric (± 95% CI) by site in the Ventura Watershed, 2004

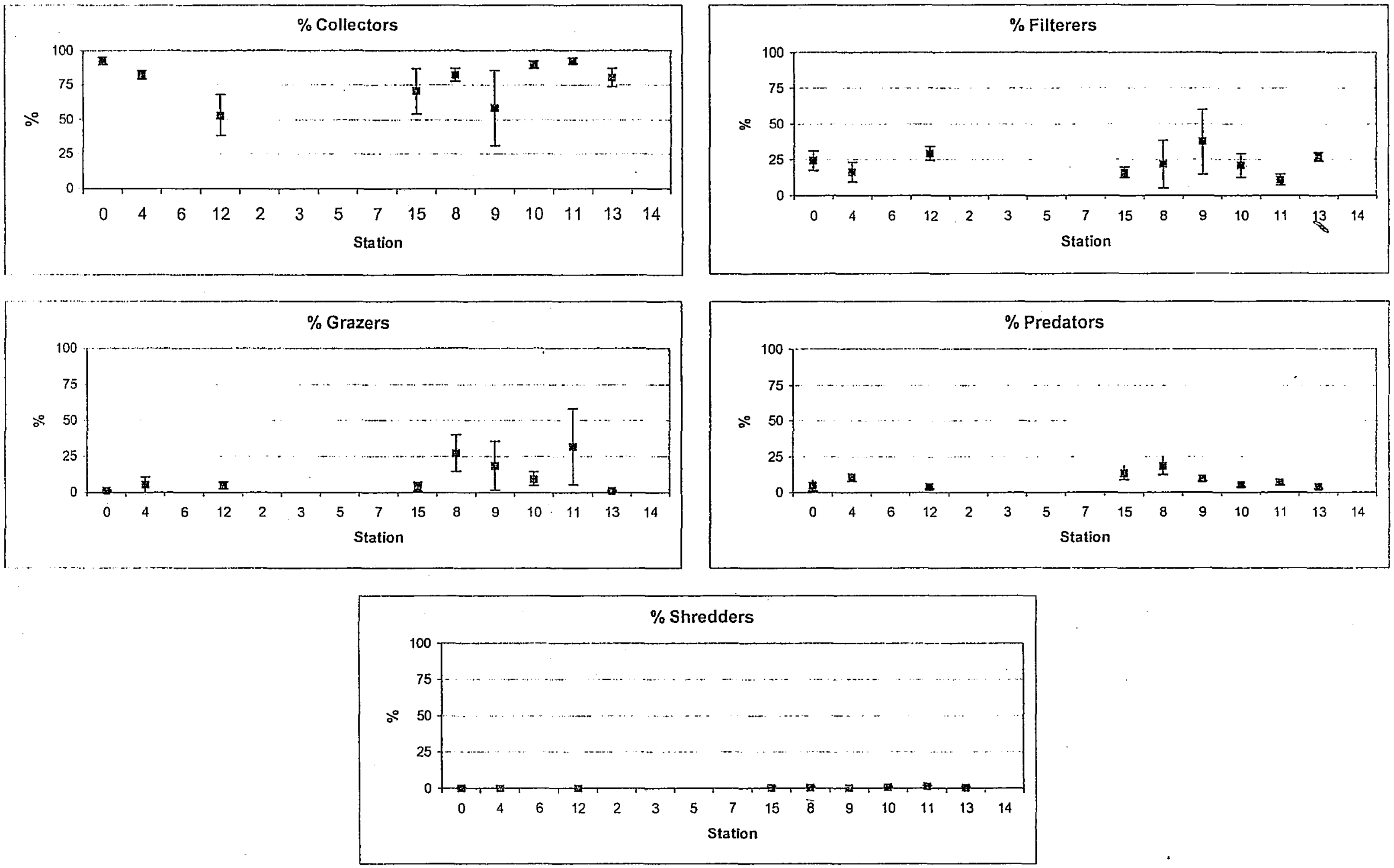


Figure 9-8: Functional Feeding Group measures: average (n=3) for each biological metric (± 95% CI) by site in the Ventura Watershed, 2004

Table 9-7: Southern California IBI scores and ratings for sites sampled in the Ventura Watershed

River/Stream System	Ventura River				Canada Larga		San Antonio Creek					North Fork Matilija Creek		Matilija Creek	
Station Description	Main Street Bridge	Foster Park	Below Matilija Dam	@Santa Ana Rd.	Below Grazing	Above Grazing	u/s Ventura River Confluence	Lion Canyon u/s San Antonio	u/s Lion Canyon	Stewart Canyon u/s San Antonio	u/s Stewart Canyon Creek	u/s Ventura River Confluence	At gauging station	Below community	Above Community
Biological Metric	0	4	12	6	2	3	5	7	15	8	9	10	11	13	14
Coleopteran Taxa	4	7	5						10	5	7	8	10	5	
EPT Taxa	3	7	5						6	6	5	7	6	5	
Predator Taxa	3	9	8						10	10	8	10	9	6	
% Collectors (cg + cf)	1	4	3						5	10	7	4	10	2	
% Intolerant	0	2	0						1	9	7	2	10	1	
% Non-Insect Taxa	10	10	10						8	10	10	10	10	10	
% Tolerant	10	8	9						5	4	9	9	9	10	
Total	31	47	40	Dry	Dry	Dry	Dry	Dry	45	54	53	50	64	39	Dry
So. Cal. IBI Rating	Poor	Fair	Fair						Fair	Fair	Fair	Fair	Good	Poor	

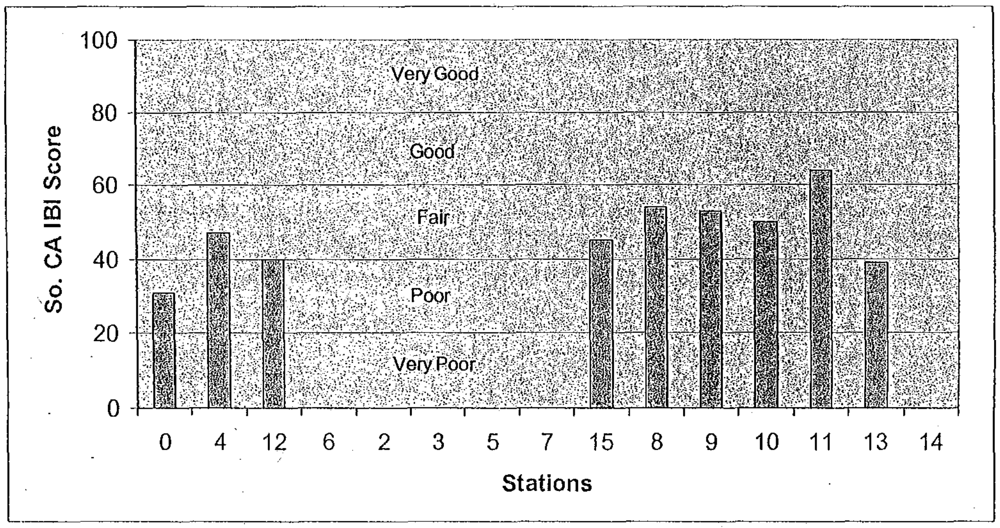


Figure 9-9: Southern California IBI scores for sites in the Ventura Watershed, 2004

Figure 9-10: Physical habitat scores for sites in the Ventura Watershed, 2001 to 2004

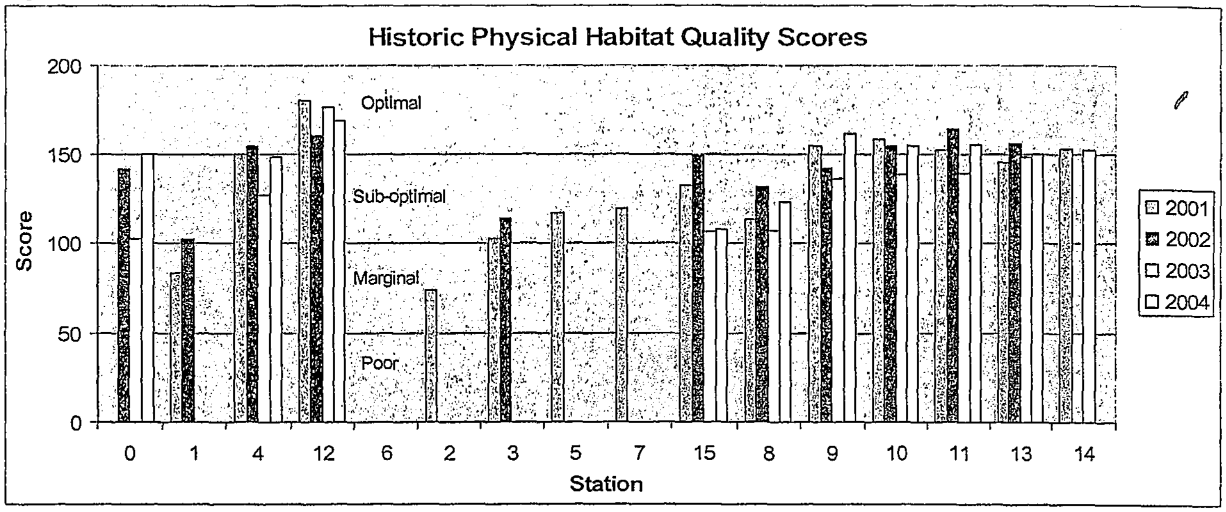


Figure 9-11: So CA IBI scores for sites in the Ventura Watershed, 2001 to 2004

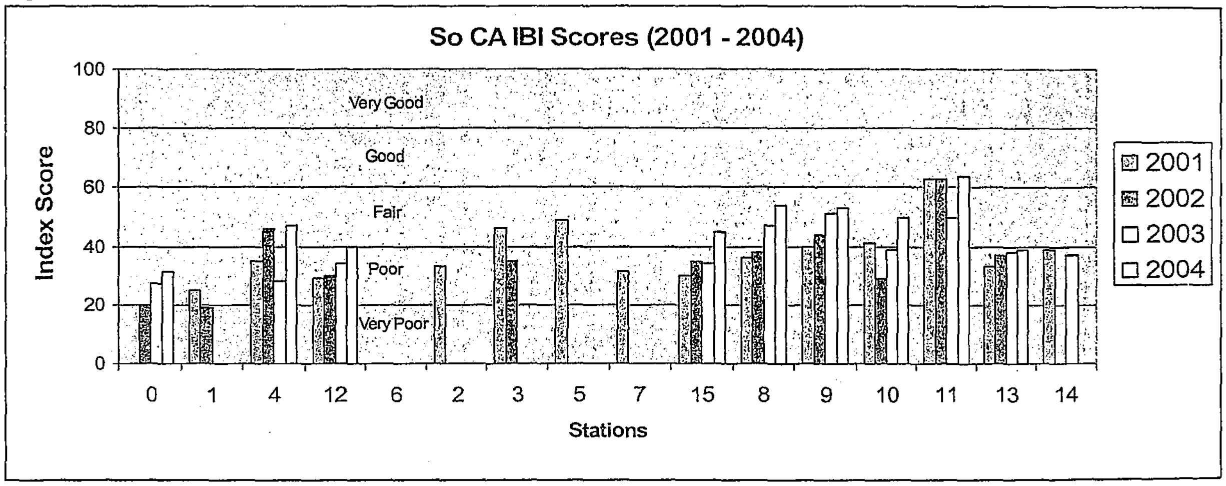
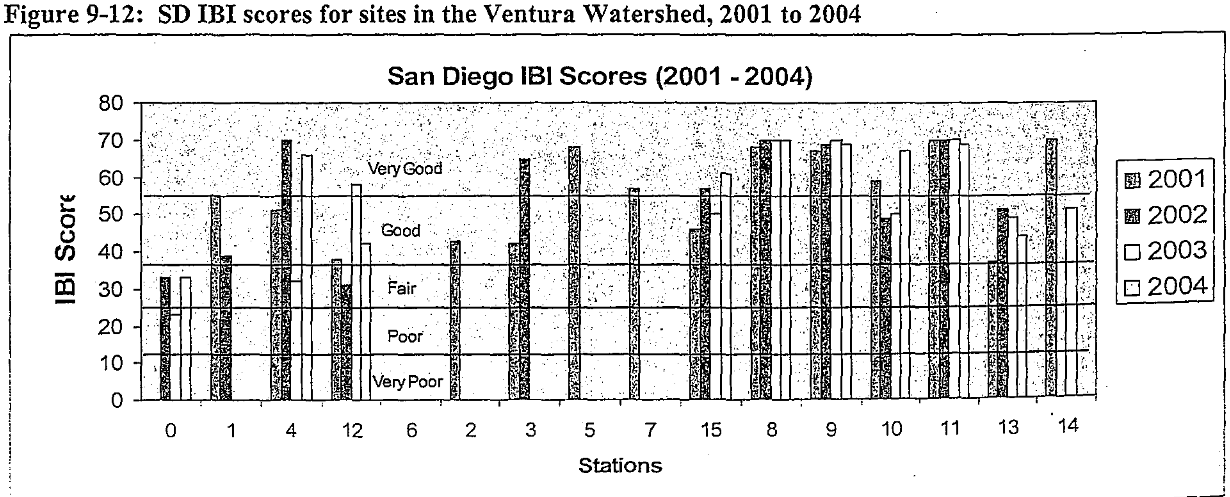


Figure 9-12: SD IBI scores for sites in the Ventura Watershed, 2001 to 2004



2004/2005

Figure 9-13: Two-way coincidence table of historical species groups (left) vs. stations (top) as resolved by cluster analysis using the Bray-Curtis dissimilarity metric
(Data square root-transformed; symbols represent relative abundance of each species at a station)

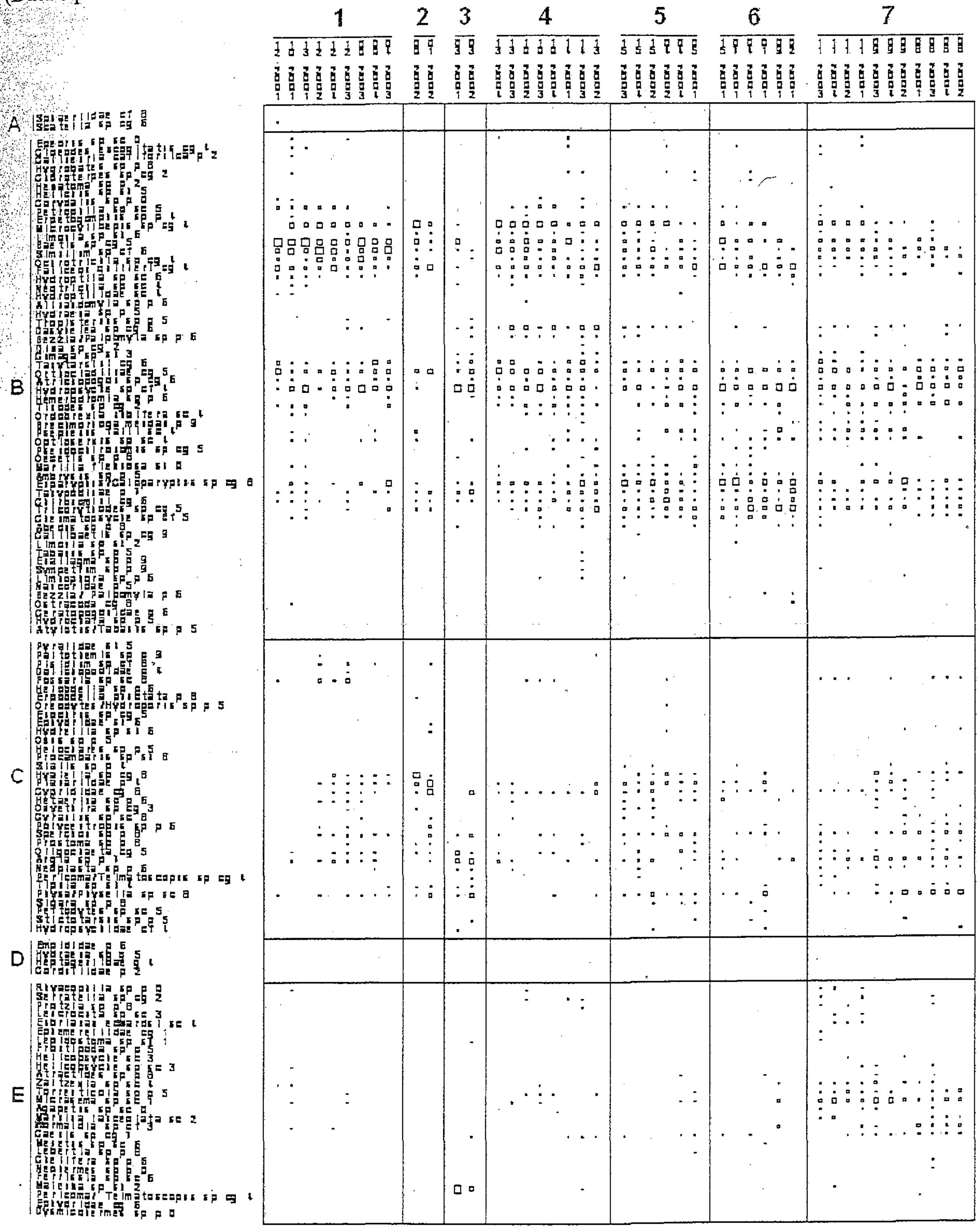


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Table 9-8: Top 10 species averaged across each station by species cluster group (2001-2004)
Grp = taxa groups: E = Ephemeroptera; D = Dipterans; T = Trichopterans; C = Coleopterans; M = Mollusks; NI = non-insects; P = Plecopterans; O = Odonata. Tol = tolerance groups. FFG = functional feeding groups: cg = collector gatherers; cf = collector filterers; p = predators; sc = scrapers.

Cluster Grp 1 – Ventura River/Matilija Dam

	Grp	Tol	FFG	Avg
Baetis sp	E	5	cg	280
Simulium sp	D	6	cf	153
Hydropsyche sp	T	4	cf	89
Microcylloepus sp	C	4	cg	59
Orthocladiinae	D	5	cg	51
Fallceon quilleri	E	4	cg	49
Ochrotrichia sp	T	4	cg	40
Fossaria sp	M	8	sc	25
Tanytarsini	D	6	cg	23
Euparyphus/Caloparyphus sp	D	8	cg	19

Cluster Grp 2 – Lower Watershed 2002

	Grp	Tol	FFG	Avg
Microcylloepus sp	C	4	cg	174
Planariidae	NI	4	p	137
Hyalella sp	NI	8	cg	114
Cyprididae	NI	8	cg	103
Fallceon quilleri	E	4	cg	94
Baetis sp	E	5	cg	75
Orthocladiinae	D	5	cg	58
Physa/Physella sp	M	8	sc	26
Tanypodinae	D	7	p	15
Simulium sp	D	6	cf	12

Cluster Grp 3 – Canada Larga Creek

	Grp	Tol	FFG	Avg
Malenka sp	P	2	sh	246
Hydropsyche sp	T	4	cf	217
Argia sp	O	7	p	107
Physa/Physella sp	M	8	sc	76
Baetis sp	E	5	cg	41
Orthocladiinae	D	5	cg	40
Tanypodinae	D	7	p	37
Cyprididae	NI	8	cg	31
Oligochaeta	NI	5	cg	24
Tanytarsini	D	6	cg	19

Cluster Grp 4 – Matilija Creek

	Grp	Tol	FFG	Avg
Microcylloepus sp	C	4	cg	169
Hydropsyche sp	T	4	cf	96
Orthocladiinae	D	5	cg	81
Baetis sp	E	5	cg	75
Simulium sp	D	6	cf	62
Dasyhelea sp	D	6	cg	59
Fallceon quilleri	E	4	cg	56
Euparyphus/Caloparyphus sp	D	8	cg	54
Tricorythodes sp	E	5	cg	32
Tanytarsini	D	6	cg	29

Cluster Grp 5 – San Antonio Creek

	Grp	Tol	FFG	Avg
Euparyphus/Caloparyphus sp	D	8	cg	105
Fallceon quilleri	E	4	cg	82
Microcylloepus sp	C	4	cg	75
Hydropsyche sp	T	4	cf	67
Orthocladiinae	D	5	cg	52
Chironomini	D	6	cg	46
Simulium sp	D	6	cf	42
Planariidae	NI	4	p	39
Tricorythodes sp	E	5	cg	35
Tinodes sp	T	2	cg	29

Cluster Grp 6 – San Antonio Creek/Ventura River

	Grp	Tol	FFG	Avg
Hydropsyche sp	T	4	cf	195
Euparyphus/Caloparyphus sp	D	8	cg	150
Tricorythodes sp	E	5	cg	106
Fallceon quilleri	E	4	cg	85
Orthocladiinae	D	5	cg	45
Chironomini	D	6	cg	45
Baetis sp	E	5	cg	44
Tanypodinae	D	7	p	23
Cheumatopsyche sp	T	5	cf	19
Microcylloepus sp	C	4	cg	18

Cluster Grp 7 – North Fork Matilija Creek/Upper San Antonio Creek

	Grp	Tol	FFG	Avg
Hydropsyche sp	T	4	cf	140
Orthocladiinae	D	5	cg	96
Micrasema sp	T	1	sc	84
Physa/Physella sp	M	8	sc	52
Euparyphus/Caloparyphus sp	D	8	cg	46
Simulium sp	D	6	cf	44
Tinodes sp	T	2	cg	42
Microcylloepus sp	C	4	cg	34
Argia sp	O	7	p	33
Ochrotrichia sp	T	4	cg	30

2. Ventura River Watershed 2005 Bioassessment Monitoring

BMI Survey

The Ventura County Stormwater Monitoring Program also includes the Bioassessment Monitoring Program. Biological assessments (bioassessments) of water resources integrate the effects of water quality over time and are capable of simultaneously evaluating multiple aspects of water and habitat quality. When integrated with physical and chemical assessments, bioassessments help to further define the effects of point and non-point source discharges of pollutants and provide a more appropriate means for evaluating impacts of non-chemical substances, such as sedimentation and habitat alteration. A work plan for in-stream bioassessment monitoring in the Ventura River Watershed was developed and submitted in January 2001 to the Regional Water Quality Control Board (RWQCB) as part of the revised Stormwater Management Plan. For five years, starting in 2001, bioassessment monitoring has been conducted once a year in the fall to compile a baseline data set.

Fifteen benthic macroinvertebrate (BMI) sampling locations were visited during the 2005 bioassessment survey. The survey was conducted by staff members from the Ventura County Watershed Protection District, the Ojai Valley Sanitation District, and Aquatic Bioassay and Consulting Laboratories. Samples were collected on September 13th, 14th, and 15th of 2005 for BMI organisms, physical and habitat observations, flow, and water quality at each location. All of the quality control guidelines for collection, sorting, and identification of BMI organisms specified in the California Bioassessment Protocol (2003) were met. Staff members from the California Department of Fish and Game (CDFG) and /or the Sustainable Land Stewardship Institute (SLSI) audited sample collection activities during each of the four survey years and provided data analysis and reporting services.

The September 2005 BMI survey was preceded by winter storms in December, January and February that dropped a combined total of 44.5 inches of rain (23.3 inches above normal) and represented the greatest amount of rain measured during the last five years since BMI sampling began. These storms produced widespread flooding, erosion, and sedimentation throughout the watershed. As a result of the unusually large amount of rain, 14 of the 15 BMI sampling locations had sufficient flow for sample collection (as compared to nine sites during the 2004 BMI survey possessing sufficient flow to allow sample collection). The 15 locations are described in Table 1. Station 6 was not sampled in 2005 due to lack of flow.

Table 1: BMI Monitoring Stations and Locations

Station	Waterbody	Location
0	Ventura River	1st above estuary
4	Ventura River	Main stem, closest to San Antonio Creek
6	Ventura River	Main stem
12	Ventura River	1st above urban influence
2	Canada Larga Creek	Downstream of grazing
3	Canada Larga Creek	Above grazing impact
5	San Antonio Creek	1st above Ventura River confluence
7	Lion Canyon Creek	1st above San Antonio Creek confluence
15	San Antonio Creek	Above Lion Canyon Creek
8	Stewart Canyon Creek	1st above San Antonio Creek confluence
9	San Antonio Creek	Close to City of Ojai
10	North Fork Matilija Creek	Above influence of Matilija Dam, below quarry
11	North Fork Matilija Creek	Above influence of Matilija Dam, above quarry
13	Matilija Creek	Above dam, below community
14	Matilija Creek	Above dam, above community

2005 Results

Physical habitat conditions at the 14 sampling sites ranged from marginal to optimal, as shown in Figure 1. The best (highest) habitat scores were at locations on the upper main stem of the Ventura River, upper San Antonio Creek and Matilija Creek. The worst (lowest) scores were at locations on the lower Ventura River and Canada Larga Creek. Habitat conditions were scored out of a total possible score of 200.

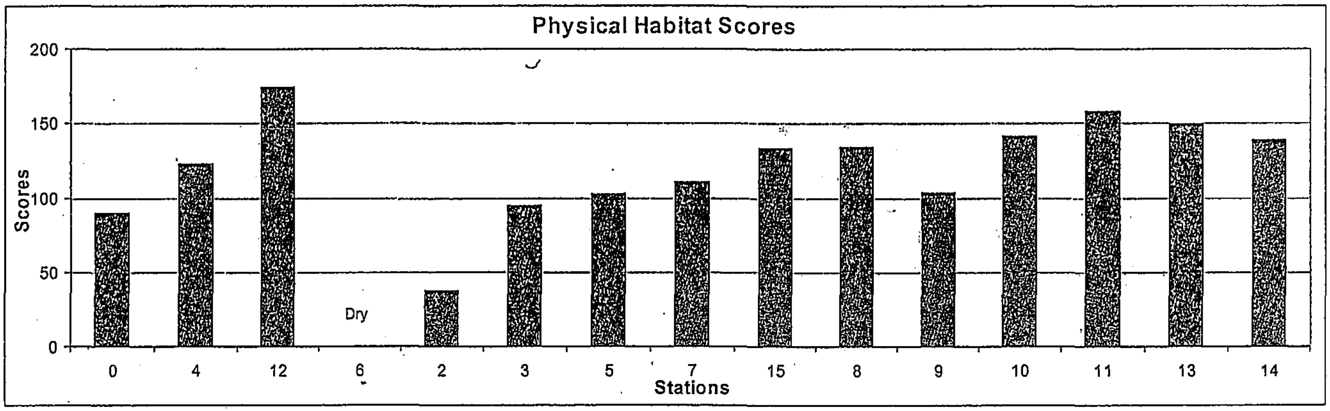

Figure 1: Physical Habitat Scores for Reaches in the Ventura River Watershed, 2005

Based on the Southern California Index of Biological Integrity (So CA IBI), the aquatic health of the Ventura Watershed during 2005 ranged from poor to fair, as shown in Figure 2 (histogram bars are divided by the proportion that each biological metric contributed to the total score). One site each on the Ventura River and San Antonio Creek ranked in the poor range and the other twelve sites in the watershed ranked in the fair range. The sites that ranked in the poor range were located in areas of the watershed that were impacted by either a large transient human population on the Ventura River or was located downstream of an erosion control project in the vicinity of grazing and stables.

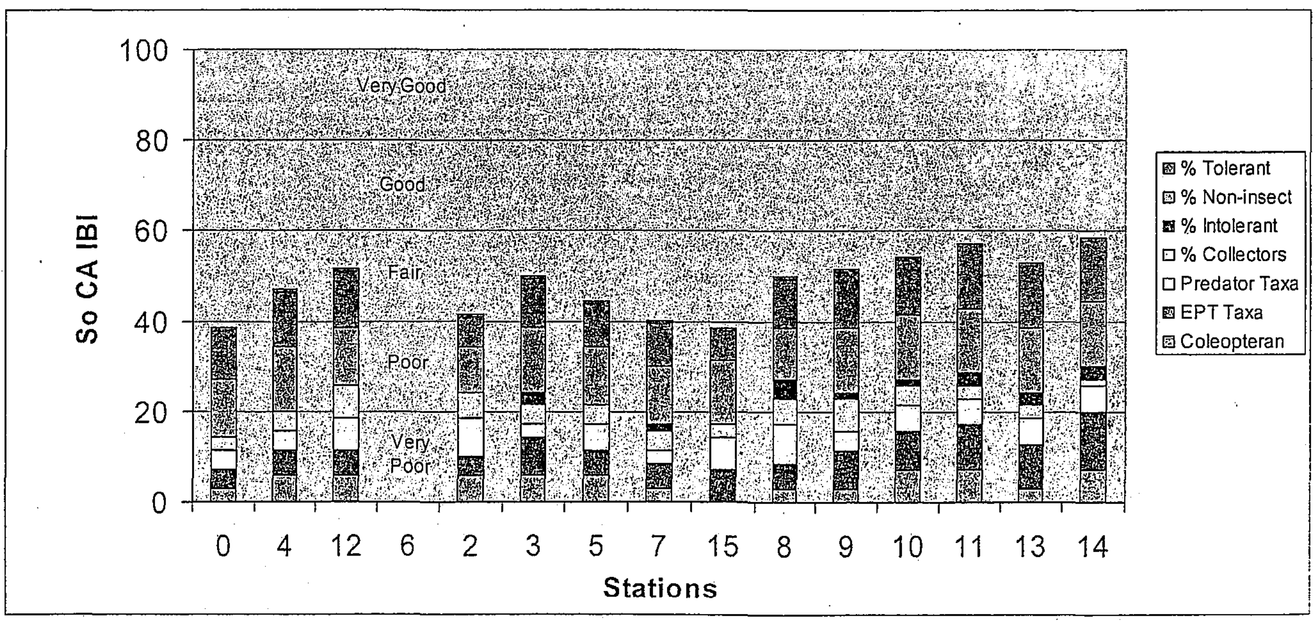

Figure 2: Southern California IBI Scores for sites in the Ventura River Watershed, 2005

The highly invasive New Zealand Mud Snail (*Potamopyrgus antipodarum*) that has infested a number of California waterbodies in recent years was not found in the Ventura River Watershed during the 2005 BMI survey. VCWPD staff takes great precaution to avoid the introduction of the snail into the waterbodies monitored by the Stormwater Monitoring Program.

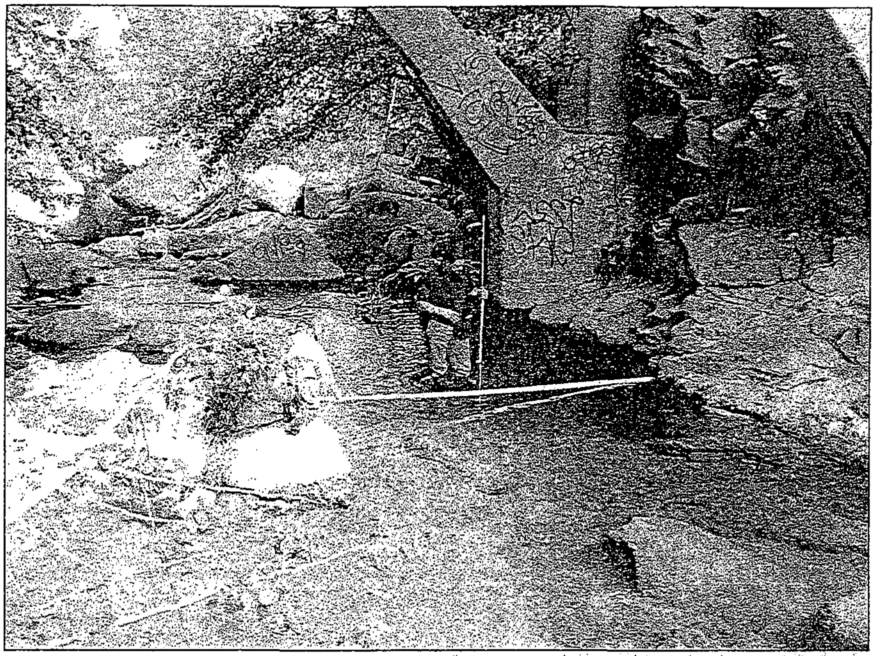

Figure 3: Benthic Macroinvertebrate Sampling at the North Fork of Matilija Creek (BMI Station 10)

Historical Results (2001-2005)

The best habitat conditions during the five year period from 2001 to 2005 were measured at Station 12 below the Matilija Dam and the worst occurred on Canada Larga Creek above its confluence with the main stem of the Ventura River. Physical habitat scores increased as elevation in the watershed increased, becoming progressively greater on the Ventura River main stem from Station 0 near the ocean to Station 12 below Matilija Dam, and from Canada Larga Creek (Stations 2 and 3) to the North Fork of Matilija Creek (Stations 10 to 14). The greatest variation in physical/habitat scores during the five year period were found at Stations 0 and 2. Station 0 is located just above the confluence of the Ventura River with the ocean and Station 2 is located just above the confluence of Canada Larga Creek with the Ventura River in the lower watershed. The habitats at each of these sites are strongly influenced by the severity of the storm season preceding sampling. During large storms the stream beds are scoured of vegetation and upstream sediments are deposited, which decreases the amount of instream cover present for BMIs. During relatively mild storm seasons, the vegetative and instream cover at these sites remain unchanged. In contrast, the upper watershed (Stations 10, 11, 12 and 13) is characterized as much more stable, owing to a streambed composed mostly of boulder, cobble and gravel, with banks mostly covered with dense stands of vegetation.

During the five year period from 2001 to 2005, the average IBI scores for all sites, except Stations 0 and 1, were in the fair to very good range. The average scores for Stations 0 and 1, each located above the Main Street Bridge, were below the impairment threshold of 39. IBI scores increased with elevation on the Ventura River, Canada Larga Creek (Stations 2 and 3), and San Antonio Creek (Stations 5, 7, 15, 8 and 9). The greatest average IBI score during the five year period was at Station 11 on the North Fork of Matilija Creek. Based on the findings of the 2005 BMI monitoring, it is recommended that the Ventura County Watershed Protection District continue to work with the Southern California Coastal Water Research Project (SCCWRP) to assist in the development of improved BMI sampling design, sampling protocols, taxonomic identification, and analysis techniques.

The complete Ventura County Stormwater Monitoring Program Ventura River Watershed 2005 Bioassessment Monitoring Report prepared by Aquatic Bioassay & Consulting Laboratories is presented in Appendix O.