Flow Science Incorporated
723 E. Green Street, Pasadena CA 91101
(626) 304-1134 • Fax (626) 304-9427

FLOW SCIENCE®

GENERAL CONSTRUCTION PERMIT: ACTION LEVELS AND NUMERIC EFFLUENT LIMITS ANALYSIS

RECOMMENDATION OF ALTERNATIVES

Prepared for
California Building Industry Association (CBIA)
1215 K Street, Ste. 1200
Sacramento CA, 95814

REGISTERED PROFESSIONAL ENGINEER
SUSAN C. PAULSEN
No. 66554
Exp: 6/30/08
CIVIL
STATE OF CALIFORNIA
Susan C. Paulsen

REGISTERED PROFESSIONAL ENGINEER
E. JOHN LIST
No. 36791
Exp: 6/30/08
CIVIL
STATE OF CALIFORNIA
John List

Prepared By	Prepared By	Reviewed By
Vada K. Yoon, DEnv	Susan C. Paulsen, Ph.D., P.E.	E. John List, Ph.D., P.E.
Project Scientist	Vice President, Senior Scientist	Principal Consultant

FSI 077026.1
Date March 31, 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The State Water Resources Control Board (SWRCB) is in the process of adopting a new permit for discharges of storm water from construction sites (Construction General Permit). A Preliminary Draft Permit was issued in March 2007 and contained both action levels (ALs) and numeric effluent limits (NELs) for turbidity, pH, total petroleum hydrocarbons (TPH), and toxicity. Since the Preliminary Draft Permit was issued, the SWRCB has received comments from numerous parties concerned about the application of numeric limits. Some environmental organizations have advocated that numeric limits should be included in permits, claiming that they will make assessing compliance easier. Other organizations have asserted that numeric limits are inappropriate at this time. Flow Science was retained by the California Building Industry Association (CBIA) to assess available information and data related to the application of ALs and/or NELs to discharges of storm water from construction sites, and this report presents the results of that analysis.

Key conclusions from the report are summarized below.

Several options are available for regulating storm flows. As shown in Figure ES-1, there are four basic alternatives for regulating storm flows:

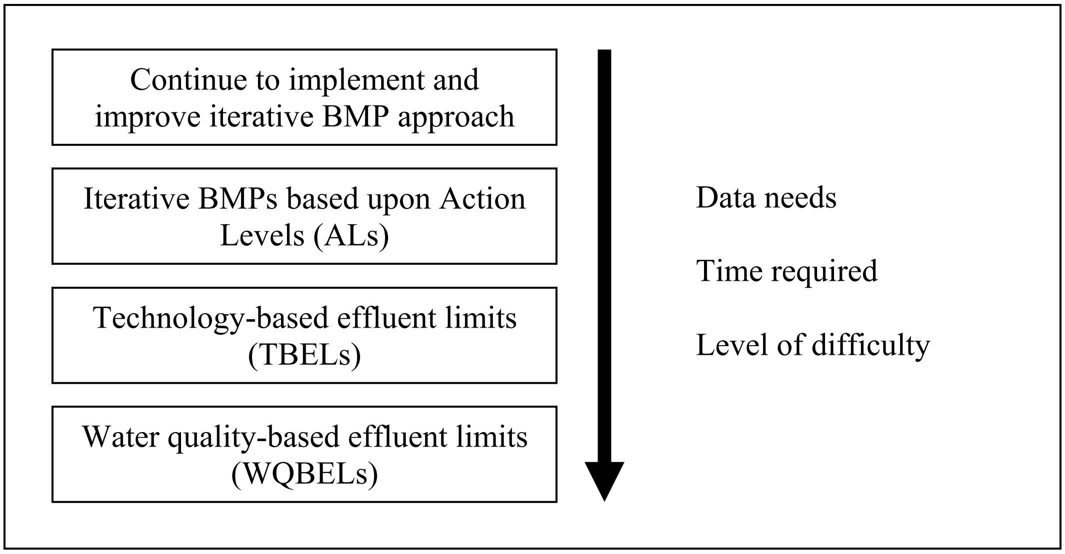


Figure ES-1. Options for regulation of storm water discharges.

- Iterative BMP approach. The current construction permit uses an iterative BMP approach and protection of water quality is dependent upon the design and implementation of appropriate and effective BMPs. Improvements to this approach could include specifying better methods for BMP selection, design, maintenance, and stepped-up inspection frequencies and inspection protocols.

- Action levels (ALs). ALs would serve to identify those discharges or sites with a propensity, based on monitoring data, to contribute disproportionately to high concentrations of constituents. Exceedance of an AL would trigger an iterative management approach and would require immediate action to evaluate and/or address the exceedance but would not constitute a permit violation. ALs could be developed based upon the treatment efficiency of BMPs ("technology-based action levels," or TBALs) or upon water quality goals within the receiving waters ("water quality-based action levels," or WQBALs), or upon a combination of the two.

- Technology-Based Effluent Limits (TBELs). TBELs are numeric limits based upon available technologies and the treatment efficiency of those technologies. For storm flows, TBELs would need to be developed in consideration of the volume or flow rate to be treated, the efficiency of the treatment process, and the quality of storm flow influent to the treatment process. TBELs should be developed based on USEPA guidance.

- Water Quality-Based Effluent Limits (WQBELs). WQBELs are numeric limits based upon the goal of meeting water quality standards in the receiving water. Current methodologies for developing WQBELs are not appropriate for storm flows and thus new methodologies must be created.

As indicated in Figure ES-1, the data needs, amount of time required, and level of effort would be greater for NELs than for ALs. Our data review indicates that current data may be sufficient to support the development of ALs for discharges from construction sites for pH, but additional data and methodology should be developed prior to establishing ALs for other constituents and prior to establishing NELs for discharges from most construction sites. There are insufficient data for catchments in California, and no accepted methodology exists to establish a single NEL for discharges from construction sites in California. It does appear appropriate to develop NELs for discharges from Active Treatment Systems, which may be economically feasible for larger sites with a designated design storm.

Characterizing and regulating storm flows will require new methodology. Storm water discharges are intermittent and highly variable, both in terms of flow rates/volumes and constituent concentrations. Storm water constituent concentrations are highly variable and tend to fit "heavy-tailed" or "extreme value" probability distributions. For this reason, statistical approaches known as "semi-parametric methods," which do not assume particular parametric formulas for the probability distributions of underlying data, are likely the most promising methods for developing either ALs or NELs for storm water discharges from construction sites.

Careful data collection will be required to properly establish ALs or NELs. Because of systematic and widespread differences in these characteristics from facility to facility, from storm to storm, and from sample to sample, it is necessary to carry out a well-designed data collection effort at a representative set of facilities over a period of years. One or two years of data cannot represent the range of variability in number and severity of storms from year to year. Nor can data accumulated haphazardly from a variety of sites be used to provide the necessary consideration of what the Blue Ribbon Panel referred to as site-to-site variability. For example, basic statistical analyses demonstrate that the Caltrans dataset used by SWRCB Staff cannot be regarded as a sample from a single distribution, but must be treated as a mixture of distributions (see Section 1.4).

A "design storm" or other hydrologic design condition(s) should be prescribed. The Blue Ribbon Panel recognized that "Numeric Limits and Action Levels [should] not apply to storms of unusual event size and/or pattern" and that "it may be unreasonable to expect all events to be below a numeric value." A design storm provides a recognition that it is more feasible to treat smaller or moderate sized storm conditions, and that the water quality improvement achieved from treating ever larger events comes at significant expense. A design storm is necessary both to handle "outliers" in concentration or flow volume that may result from extreme events and to provide criteria to which BMPs and other site control measures may be designed.

ALs or NELs for sediment must consider ambient, local background conditions. Sediment is an essential, integral, and dynamic part of river and coastal systems. It is important for habitat and provides a major nutrient source for organisms. Natural background conditions vary greatly throughout the state, and sediment concentrations in storm water runoff from natural, undeveloped watersheds may range as high as 100,000 mg/l total suspended solids (TSS) or thousands of turbidity units (NTU). In such highly erosive environments, BMPs may not result in reductions in sediment concentrations that could meet the SWRCB's proposed turbidity AL. In some environments, such as the Delta, native aquatic life is adapted to high levels of turbidity, and sediment is also important to stream stability and beach replenishment. Introducing discharges with sediment concentrations below natural levels into these environments can cause channel erosion and hydromodification and can have adverse impacts on the aquatic ecosystem. In other environments, such as salmon spawning streams, clearer waters are necessary to support beneficial uses, and it is important that sediment discharges be maintained at lower levels for such environments. For these reasons, ALs or NELs established for sediment must be site- or watershed-specific, and must consider natural conditions.

ALs or NELs for pH should also consider ambient, local background conditions. The potential for storm water discharges to alter pH is significant primarily when certain materials and/or activities are occurring at the site, and ALs or NELs for pH should be considered for use only when those activities are occurring on a site. The pH of storm water can vary significantly depending upon local conditions. The pH of rain water, for example, can range as low as 4.5, and pH values as high as 9.3 have been observed in some of the state's receiving waters. Additionally, the chemistry of receiving waters can vary significantly, and most receiving waters have relatively large buffering capacities. pH values measured in receiving waters occur within a relatively small range (generally 6-9) and exhibit less variability than sediment in storm water runoff. Thus, there may be sufficient data to establish an AL for pH for runoff from construction sites, but development of an enforceable NEL should involve additional data analysis, including a review of receiving water pH to ensure that NELs are consistent with receiving water quality and an evaluation of BMP effectiveness in adjusting pH.

NELs should be used for discharges from Advanced Treatment Systems (ATS). In specific circumstances, particularly upstream of sensitive receiving waters that have naturally low levels of sediment, it may be advisable to employ ATS to reduce sediment concentrations in construction site discharges to very low levels. However, ATS generally employ chemical addition and have the potential to cause receiving water toxicity and alter the chemistry (especially pH) of discharges. For this reason, it appears appropriate to require NELs for discharges from ATS. NELs for ATS would be classified as TBELs, and thus must be analyzed based on best available technology (BAT) and best conventional technology (BCT) standards. Available data indicate that turbidity levels of properly operated ATS systems may range from near 0 to about 45 NTU, and these data should be used to characterize system performance for the purpose of establishing NELs. Finally, residual tests should be used in lieu of bioassay toxicity tests whenever possible. Residual tests would be appropriate when residual concentrations of added chemicals can be detected below levels that may cause toxicity to aquatic life. Because bioassay toxicity tests have long turnaround times, test results would not be available prior to discharge from the ATS.

Program recommendations. If ALs are to be developed in the future for storm water discharges from construction sites, a well-designed and implemented program of site monitoring and data collection needs to be developed. That program should chart a clear direction for the program, and should collect data to support the development of a methodology to calculate ALs and/or NELs.

Based on the information we have reviewed to date, we believe that the calculation of ALs should consider (a) "natural background" receiving water concentrations; (b) the condition and configuration of the receiving water (e.g., hardened channels v. natural channels); (c) BMP treatment efficiencies and anticipated effluent sediment and/or turbidity, considering site-specific conditions; and (d) a "design storm" or other hydrologic condition, to which the ALs would apply. Consistent with the Blue Ribbon Panel report (Blue Ribbon Report), we recommend that the State Board consider developing future ALs sequentially, focusing first on "high risk" construction sites (where risk is determined in consideration of receiving water conditions). Further the Board should consider whether ALs would apply at all times an under all conditions, or only during certain construction phases (e.g., open, active grading), seasons (e.g., dry v. wet season), or only when necessary to protect sensitive receiving waters. These decisions may guide the data collection process, allowing monitoring and resources to be expended for higher priority areas before moving to all construction sites generally.

INTRODUCTION

The Federal Water Pollution Control Act (the Clean Water Act, CWA) was amended in 1972 to prohibit the discharge of pollutants to waters of the United States from any point source that was not covered by a National Pollution Discharge Elimination System (NPDES) permit. In 1987, Section 402(p) was added to the CWA to regulate municipal and industrial storm water discharges under the NPDES Program. Final regulations that establish storm water permit application requirements for Construction Activities and other categories of industrial activities were adopted by the U.S. Environmental Protection Agency (USEPA) on November 16, 1990. The 1990 regulations required NPDES permits for discharges of storm water to waters of the United States from construction sites that encompassed five (5) or more acres of soil disturbance. Final regulations published on December 8, 1999, expanded the existing NPDES program to address storm water discharges from construction sites that disturb land equal to or greater than one (1) acre and less than five (5) acres (small construction activity).

The California State Water Resources Control Board (SWRCB) elected to adopt a statewide General Permit for Discharges of Storm Water Associated with Construction Activity (General Permit) that applies to most storm water discharges associated with construction activity.[1] The current General Permit (Water Quality Order No. 99-08-DWQ, adopted on August 19, 1999) requires "dischargers where construction activity disturbs one acre or more to: 1) develop and implement a Storm Water Pollution Prevention Plan (SWPPP) which specifies Best Management Practices (BMPs) that will prevent all construction pollutants from contacting storm water and with the intent of keeping all products of erosion from moving off site into receiving waters; 2) eliminate or reduce nonstorm water discharges to storm sewer systems and other waters of the nation; and 3) perform inspections of all BMPs." (Fact Sheet for WQO 99-08-DWG at p. 1-2)

In 1999, when the current General Permit was adopted, the SWRCB stated that "It is not feasible at this time …to establish numeric effluent limitations." The reasons why it is not feasible to establish numeric effluent limitations are discussed in detail in SWRCB Order Nos. WQ 91-03 and WQ 91-04. Therefore, the effluent limitations contained in this General Permit are narrative and include the requirement to implement appropriate BMPs."(Fact Sheet for WQO 99-08-DWG at p. 4) Among other things,

---

[1] The General Permit does not apply to construction activities on Tribal Lands, in the Lake Tahoe Hydrologic Unit, or those performed by the California Department of Transportation (Caltrans).

SWRCB Order Nos. WQ 91-03 and WQ 91-04 addressed issues regarding the inclusion of numeric effluent limits for toxic pollutants in municipal separate storm sewer systems (MS4s) storm water permits.

In 2004, the SWRCB conducted a public hearing on a draft General Industrial Storm Water Permit. The first draft of the proposed permit did not contain numeric effluent limits, while a later draft included benchmarks contained in the USEPA multi-sector general permit. The hearings on the draft General Industrial Permit raised the issue of whether numeric limits should be applied to discharges of storm water. The environmental community has generally asserted that the current permit system is too complicated, and that numeric effluent limits would make it easier to measure compliance. In contrast, the regulated community argued that due to the unique nature of storm events and storm water discharges, any numeric limit that is placed in a storm water permit must take into consideration the episodic and unique nature of storm events. The adoption of the General Industrial Permit was effectively put on hold at that point.

In September 2005, the SWRCB staff convened a panel of nationally recognized storm water experts (Blue Ribbon Panel) to examine the feasibility of developing numeric effluent limits for storm water discharges. These experts were tasked with answering the following questions, as they pertain to industrial, construction, and municipal permits: "1) is it technically feasible to establish numeric effluent limitations, or some other quantifiable limit, for inclusion in storm water permits?; and 2) how would such limitations or criteria be established, and what information and data would be required?" The Panel was also asked to address "both technology-based limitations or criteria and water quality-based limitations or criteria. In evaluating establishment of any objective criteria, the panel should address all of the following: 1) the ability of the Water Board to establish appropriate objective limitations or criteria; 2) how compliance determinations would be made; 3) the ability of dischargers and inspectors to monitor for compliance; and 4) the technical and financial ability of dischargers to comply with the limitations or criteria." (Blue Ribbon Report)

In June of 2006, the Blue Ribbon Panel issued a final report entitled "*The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial, and Construction Activities*" (Blue Ribbon Report) ("Blue Ribbon Report"). In this report, the Blue Ribbon Panel suggested that "Action Levels" (ALs) might be feasible for storm water discharges, and could be set in a number of different ways. For discharges from construction sites, the Panel concluded that Numeric Effluent Limits (NELs) are likely "not feasible" if chemical addition is not permitted. The Blue Ribbon Panel also listed a number of factors that should be considered before NELs or ALs are established for storm runoff from construction sites, including natural background receiving water quality, the need for a "design storm," and the need to consider site-specific factors in establishing ALs or NELs.

In early 2007, the Board published a Preliminary Draft General Construction Permit (Preliminary Draft), and adoption of the General Construction Permit will precede adoption of the General Industrial Permit. The General Construction Permit, when adopted, will supersede the current General Permit (Order 99-08-DWQ). The Preliminary Draft included both action levels (ALs) and numeric effluent limits (NELs). The ALs and NELs included in the draft permit would be imposed uniformly statewide, and as such were developed without consideration of local water quality issues, or differences in soil types, within individual regions or watersheds. Further, the SWRCB did not consider information regarding background water quality.

The U.S. Environmental Protection Agency (EPA) is currently developing effluent limitation guidelines for the Construction and Development industry pursuant to a judicial order in Natural Resources Defense Council et al v. EPA et al (C.D. Cal. 2006, Case No. CV-04-8307 GHK). The order calls for EPA to publish a proposed rule by December 2008 and a final rule by December 2009 (USEPA, 2007). The development of guidelines is summarized in Section 3 of this document.

In response to the Preliminary Draft, and following workshops on the draft and discussions with SWRCB staff, the California Building Industry Association (CBIA) retained Flow Science to analyze the ALs and NELs proposed by the SWRCB, to review existing data that describe background water quality across the State, and to make recommendations for the regulation of storm water from construction sites. This report contains the results of this study effort and is organized in the following manner:

- Section 1: Action levels and numeric effluent limits and the information and methodology required to develop appropriate limits
- Section 2: Review of limits proposed by State Board in preliminary construction general permit
- Section 3: Inventory of available data on existing water quality and natural background water quality
- Section 4: Summarizing existing data and information on the concentrations and variability of water quality constituents in storm flow
- Section 5: Assessing existing data for several selected watersheds and impact of land use and storm size on sediment levels
- Section 6: The ecological role of suspended sediment
- Section 7: Conclusions and recommendations

1 ACTION LEVELS AND NUMERIC EFFLUENT LIMITS AND THE INFORMATION AND METHODOLOGY REQUIRED TO DEVELOP APPROPRIATE LIMITS

1.1 Storm Flow Characteristics

Storm flows are quite different from many other types of discharges, particularly in the arid west. Most notably, storm flows exhibit highly variable flow rates, flow volumes, and constituent concentrations. Storm flow water quality is a complex function of watershed size, slope, soils, vegetation types, rainfall (storm size and intensity), antecedent conditions (a function of the time since last rainfall), land use, and climate. Available data demonstrate that storm flow constituent concentrations can vary by an order of magnitude or more on timescales of an hour or less (FSI, 2005; Stein and Yoon, 2007). Constituent concentrations can also vary just as widely between storm events, and at any given time between relatively closely located sites. Also, as discussed in Section 5, receiving water flow rates and constituent concentrations may also vary by an order of magnitude or more during storm events.

Analysis of existing data demonstrates that storm flow constituent concentrations frequently do not follow a neat, "lognormal" statistical model. The procedures the State and Regional Boards currently employ to develop numeric limits for non-storm flow discharges rely upon the assumption that data are lognormally distributed. For storm flow data, this assumption is incorrect, so that new methodologies will be needed to develop numeric limits (especially Water Quality Based Effluent Limits (WQBELs), as discussed below). These methodologies will need to account for extreme events (e.g., high rainfall intensities, changed site conditions) that can result in measured storm water concentrations that fall significantly outside of the "normal" range of observations.

Constituents enter storm flows from a variety of sources, including both natural sources (site soils, airborne dust, wildfire ash, and combustion products) and manmade sources (atmospheric deposition of anthropogenic origin: automobile exhaust and wear products, road dust, building materials, site activities and practices, and application of pesticides). At construction sites, local parameters, such as soil type, rainfall intensity, and slope, will be important in determining concentrations of water quality constituents in site runoff.

Strategies available to improve storm water quality range from best management practices (BMPs) to storage and treatment approaches. All approaches are challenged by the high volumes and flow rates of storm flows and by highly variable rainfall intensities, which necessitate hydrologic design criteria, such as a "design storm" or other hydrologic specifications. As noted by the Blue Ribbon Panel, exceedances of limits can be expected to occur several or more times per year, based largely on hydrologic considerations alone (Blue Ribbon Report p. 13).

1.2 Options for Regulating Storm Water Runoff

The various options for regulating storm water runoff have been discussed by the SWRCB, the regulated community, and the environmental community at length in the past. The Blue Ribbon Report addresses the feasibility of developing numeric limits for storm flows. Subsequent hearings on the report and on options for regulating storm water discharges pursuant to the State's General Industrial permit highlighted four major approaches to regulating storm flows, as shown in Figure 1. Each of these options is discussed below.

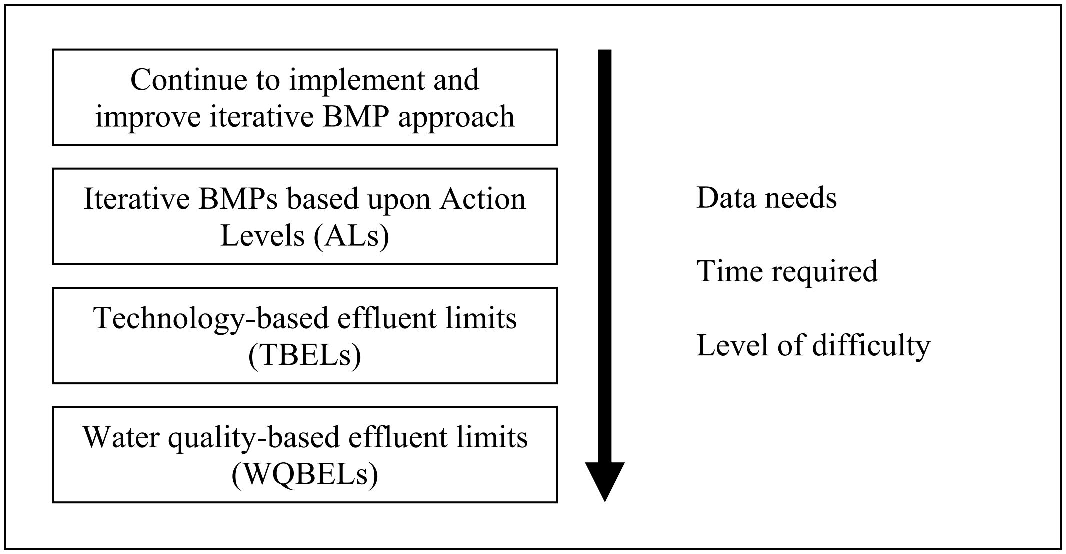


Figure 1. Options for regulation of storm water discharges.

1.2.1 Option 1: Continue to Implement and Improve the Iterative BMP Approach

The first option is to continue to implement and improve the existing approaches to managing storm flows using an iterative BMP process. As noted by the Panel, improvements can be made in this process, including utilizing BMP performance data and knowledge about the impairments or constituents of concern in a receiving water to select better and more efficient BMPs. With this option, compliance and enforcement would be based upon selection of appropriate BMPs, then continued implementation and maintenance of the selected option(s). Examples of additional data and information that could be collected to improve the iterative BMP approach include:

- Development of a list of BMP options
- Data collection and research into BMP unit design and efficiency

- BMP design criteria (a "design storm" or other hydrologic design criteria)
- Information on gross receiving water quality (identification of constituents of concern and flow characteristics, etc.)
- Detailed analysis of maintenance and enforcement options

Implementation of Option 1 could begin immediately, as it would be an extension of the regulatory approach contained in the current General Construction Permit. In effect, under this approach, the program itself could be iterative, with improvements made pursuant to a coordinated, well-designed program of data collection and subsequent development of program guidance, likely at the direction of the SWRCB.

1.2.2 Option 2: Iterative BMPs with "Action Levels" (ALs)

ALs would serve to identify those discharges or sites with a propensity, based on monitoring data, to contribute disproportionately to high concentrations of constituents in receiving waters. ALs would trigger an iterative management approach. An exceedance of an AL would not constitute a permit violation, but would trigger specific actions to be undertaken on a construction site to evaluate and/or address the exceedance. ALs could be developed based upon the treatment efficiency of BMPs (i.e., "technology-based action levels," or TBALs), upon water quality goals within receiving waters (i.e., "water quality based action levels, or WQBALs), or upon a combination of the two.

To proceed with implementation of ALs, Flow Science recommends that the SWRCB identify both the methodology to be used to establish ALs and to clarify how measurements would be compared to ALs and the actions that would be triggered. As discussed below, existing receiving water data may be sufficient to establish ALs for pH, again depending upon the way in which ALs are to be used. While the SWRCB's Preliminary Draft also included ALs for turbidity and TPH, it does not appear from our analysis that available data are sufficient to support AL development for these constituents at this time. Examples of additional data that would be required to develop and implement ALs for additional constituents are:

- Development of a list of BMP options.
- Data collection and research into BMP unit design and efficiency.
- BMP design criteria (a "design storm" or other hydrologic design criteria).
- Information on gross receiving water quality (identification of constituents of concern, constituent concentrations, and receiving water flow characteristics.)
- Process and procedures for establishing ALs.
- Actions required when ALs are exceeded at a certain frequency.
- Data on effluent constituent concentrations for those constituents that will have ALs.

1.2.3 Option 3: Technology-Based Effluent Limits (TBELs)

TBELs are numeric effluent limits based upon available technologies and the treatment efficiency of those technologies. For storm flows, TBELs would need to be developed in consideration of the volume or flow rate to be treated, the efficiency of the treatment process, and the quality of storm flow influent to the treatment process. The USEPA has provided guidance on the development of TBELs (Federal Register, 2006), which specifies the factors that must be considered in developing TBELs. In addition, the effects of implementing a particular TBEL on the environment and beneficial uses of receiving waters should be considered. Our review of available data indicates that the data required to develop TBELs for storm water discharges (Federal Register, 2006) from construction sites do not currently exist, with the potential exception of TBELs for discharges from ATSs (see Section 3).

As shown in Figure 2, the final effluent stream will be a mixture of treated effluent and untreated effluent (i.e., effluent beyond the hydraulic design capacity of the treatment system). Data and other requirements for TBELs may include:

- Detailed characterization of influent (raw) water quality.
- BMP and treatment system performance data, which would be required for a range of influent concentrations and under field, not laboratory, conditions.
- A process for setting TBELs that would recognize the variability of storm water flow rates/volumes and constituent concentrations.
- Monitoring and compliance options (e.g., grab v. composite samples, sampling frequency, etc.).

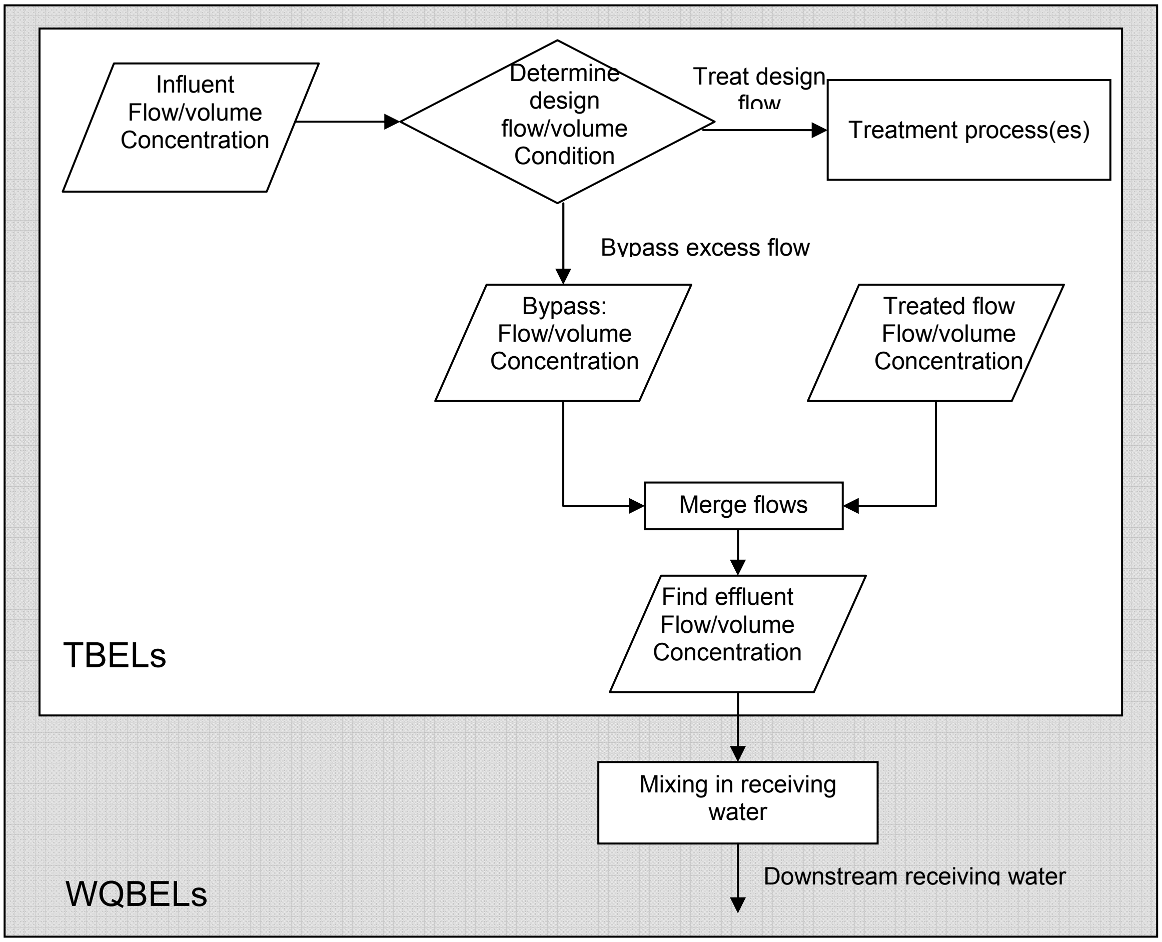


Figure 2. Considerations in the Development of TBELs and WQBELs.

1.2.4 Option 4: Water Quality-Based Effluent Limits (WQBELs)

WQBELs are numeric effluent limits based upon the goal of meeting water quality standards in the receiving water. To date, WQBELs have been developed using relatively simple, idealized data distributions (generally log-normal distributions). These data often do not incorporate the real distribution of storm hydrographs, which are often considered to be "heavy-tailed" or "extreme value" distributions. Therefore, a new basis for WQBELs must be developed for storm water if WQBELs are to be incorporated into the General Construction Permit. Either dynamic modeling or statistical approaches could be considered to incorporate these considerations into limit calculation procedures, as described briefly in EPA's Technical Support Document (USEPA, 1991). These considerations are also discussed in greater detail below. Further, WQBEL development will necessarily be very data intensive, requiring information on BMP or treatment system influent water quality, hydrologic design capacity, and receiving water quality. The time step for such data must correspond with the water quality objectives to be implemented. For example, development of WQBELs for metals would require data on an hourly or sub-hourly time step, as acute metals criteria are specified in the California Toxic Rule (CTR) as one-hour averages.[2] For pollutants such as sediment and pH, no specified averaging periods are available, but values of these constituents will also vary significantly over time, and similar considerations apply. For example, if compliance is to be assessed using grab samples, the variability of sediment or pH values over the course of a storm should be characterized. Available data are insufficient to support the development of WQBELs for storm water discharges from construction sites at this time and unless a very extensive monitoring and evaluation program is undertaken.

1.3 Summary of Blue Ribbon Report Recommendations

In June 2006, the Blue Ribbon Panel published a report (Blue Ribbon Report) examining the feasibility of establishing numeric limits for storm water discharges from facilities regulated by the State's General Permits, including the Construction General Permit. In this report, the Panel's recommendations for construction sites were as follows:

1. *The active treatment systems have generally been employed on sites five acres or larger. While the systems are technically feasible for sites of any size, including sites or drainages as small as an acre or less, the cost may be prohibitive. The cost-effectiveness of active treatment systems is greatly enhanced for large drainage areas, at which construction occurs for an extended period of time, over one or more wet season. There is also a more "passive" active system that is employed in New Zealand that uses captured rainfall to release the chemical into flows entering a detention system that requires less instrumentation and flow measurement infrastructure. Even more passive systems such as the use of polymer logs and filter bags are currently under development for small sites. Regardless, the Panel recommends that the Board give particular attention to improving the application of cost-effective source controls to small construction sites.*

2. *In considering widespread use of active treatment systems, full consideration must be given to whether issues related to toxicity or other environmental effects of the use of chemicals has been fully answered. Consideration should*

---

[2] 40 CFR 131, Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule, 65FR31682.

be given to longer-term effects of chemical use, including operational and equipment failures or other accidental excess releases.

3. *Consideration should be given to the seasonality of applying Numerical Limits. There may be sites where summer only construction that complies with Action Levels may be preferred to year-round that sites that include winter construction that complies with Numeric Limits. In such cases, applying Numeric Limits to summer construction may be a disincentive to winter construction that complies with Numeric Limits. In such cases, applying Numeric Limits to summer construction may be a disincentive to scheduling active grading during dry periods. Allowing summer only construction sites to comply with action levels would discourage winter construction activities.*

4. *Consideration should be given to whether Numeric Limits would apply to all construction sites or only those with significant disturbed soil areas (e.g. active grading, un-vegetated and/or un-stabilized soils). A site could meet certain conditions to be considered "Stabilized" for the runoff season.*

5. *Where Numeric Limits are not feasible or where they would not apply during designated seasons or site conditions, the Panel recommended that the Board consider the concept of Action Levels for sites where only traditional erosion and sediment controls are applied or construction sites that are considered "stabilized" for the runoff season. An Action Level indicates a failure of BMPs (within some storm size limits).*

6. *The Board should consider Numeric Limits or Action Levels for other pollutants of relevance to construction sites, but in particular pH. It is of particular concern where fresh concrete or wash water from cement mixers/equipment is exposed to storm water.*

7. *The Board should consider the phased implementation of Numeric Limits and Action Levels, commensurate with the capacity of the dischargers and support industry to respond.*

8. *The Panel recommends that a Numeric Limit or Action Level should be compared to the average discharge concentration. The minimum number of individual samples required to represent the average discharge concentration for a storm will need to be defined.*

9. *The Board should set different Action Levels that consider the site's climate region, soil condition, and slopes, and natural background conditions (e.g. vegetative cover) as appropriate " and as data is available." With active treatment systems, discharge quality is relatively independent of these*

conditions. In fact, active treatment systems could result in turbidity and TSS levels well below natural levels, which can also be a problem for receiving waters

10. *The Board should consider whether the Numeric Limits or Action Levels should differ between receiving waters that are water quality limited with respect to turbidity, sediment or other pollutants associated with construction, from those water bodies that are not water quality limited.*

11. *The Panel recommends that Numeric Limits and Action Levels not apply to storms of unusual event size and/or pattern (e.g. flood events). The determination of Water Quality Capture Volume should consider the differing climate regions to specify these events.*

12. *The Board should set Numeric Limits and Action Levels to encourage loading reductions as appropriate as opposed to only numeric concentrations. Examples include phased construction (e.g. limited exposed soil areas or their duration), infiltration, and spraying captured runoff in vegetated areas as means to reduce loading.*

13. *The Panel is concerned that the monitoring of discharges to meet either the Action Levels or Numeric Limits may be costly. The Panel recommends that the Board consider this aspect.*

In the section of the Blue Ribbon Report that discusses municipalities, the Panel stated that three different approaches could be used for developing ALs (Blue Ribbon Report pp.8-10). These included:

1) Consensus Based Approach. In this approach, all parties would agree upon effluent concentrations that all parties feel are not acceptable. For example, most parties would likely agree that an average concentration of dissolved copper above 100 μg/l from an urban catchment would not be acceptable. This would be an Action Level value that would trigger an appropriate management response. This approach may not directly address the issue of establishing numeric effluent criteria and achieving desired effluent quality, but the consensus-based approach would ensure that the "bad actor" watersheds received needed attention.

2) Ranked Percentile Distributions. The ranked percentile approach (also a statistical approach) relies on the average cumulative distribution of water quality data for each constituent developed from many water quality samples taken for many events at many locations. The AL would then be defined as those concentrations that consistently exceed some percentage of all water quality events (i.e., the 90th percentile). In this case, action would be required at those *locations that were consistently in the outer limit (i.e., uppermost 10th percentile) of the distribution of observed effluent qualities from urban runoff.*

3) Statistically-Based Population. In this approach, parameters would once again rely on the average distribution of measured water quality values developed from many water quality samples taken for many events at many locations. In this case, however, the Action Level would be defined by the central tendency and variance estimates from the population of data. For example, the AL could be set as two standard deviations above the mean, i.e., if measured concentrations are consistently higher than two standard deviations above the mean, an Action situation would be triggered. Other population based estimators of central tendency could be used (i.e., geomean, median, etc.) or estimates of variance (i.e. prediction intervals, etc.). Regardless of which population-based estimators are used (or percentile from above), the idea would be to identify the statistically derived point at which managers feel concentrations are significantly beyond the norm.

The recommendations of the Blue Ribbon Panel have formed the basis for many of the recommendations contained in this report.

1.4 Statistical and Data Collection Considerations for Establishing Numeric Limits or Action Levels for Storm Water Effluents[3]

Experts of the Blue Ribbon Panel repeatedly acknowledge the need to recognize that storm water flows are extremely variable and are dramatically affected by unusual events. They point out that '…there is wide variation in storm water quality from place to place, facility to facility, and storm to storm' (Blue Ribbon Report p.6), that '…it may be unreasonable to expect all events to be below a numeric value' (Ibid. at p.6), and that "Storm water agencies should not be held accountable for pollutant removal from storms beyond the size for which a BMP is designed" (Ibid. at p.10).

As a matter of statistical methodology, the State of California's *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (known as the "SIP") relies heavily on the lognormal distribution, using confidence intervals for extreme values—i.e., high percentiles—of a data distribution that are based upon the lognormal assumption. To date, the NELs implemented in individual NPDES permits throughout the State have relied upon the methodology and calculation procedures of the SIP. In testimony before

---

[3] The section 1.4 was prepared by Dr. Gary Lorden at California Institute of Technology on behalf of FSI.

SWRCB (December 13, 2006), a staff statistician cited as scientific support for this assumption a paper of Shumway *et al.* (2002), in which the authors state on the first page

> *Most methodology recognizes that it is unlikely that the underlying water quality data will be either normal or log-normally distributed and entertains various procedures for protecting against distributional departures.*

The Shumway et al. (2002) paper includes some calculations using Caltrans storm water data, but only to compare two ways of estimating the mean of the storm water distributions. Nowhere do they assess the adequacy of the lognormal model in fitting the data, except in the quotation cited. In fact, our analyses of a variety of water quality datasets, including storm water datasets such as the dataset presented below, indicates that the lognormal model is not at all a good fit. Specifically, the estimation of the two parameters of the lognormal model from the sample moments (mean and standard deviation)—upon which all estimates and confidence bounds are based—leads to gross underestimates of the upper tail of storm water data distributions. For example, the maximum value in a dataset is typically much larger than would be expected from fitting a lognormal model. This tendency to underestimate the maximum—and accordingly to underestimate the probabilities of large values—makes the lognormal approach unreliable and typically over-optimistic in estimating the frequencies of exceedance of numeric limits, which are often the basis for determining numeric limits from historical data.

Better fits to particular datasets have been obtained by other distribution models—for instance, so-called "extreme value distributions", such as the Gumbel distribution (Gumbel, 1960). But these fits are *ad hoc,* and it is unreasonable to expect that any fixed "shape" of distribution will provide an adequate model to rely on for statistical analysis, particularly when the goal is to use datasets to estimate the upper tail of a distribution, as is required for numerical limit-setting. There are standard nonparametric statistical methods for such analyses, but they require exceptionally large sample sizes to be of any practical use. Consider, for example, the problem of calculating a 95% confidence upper bound on the 99th percentile of a data distribution, where a sample of 300, would yield on average only 3 measurements that exceed the 99th percentile.

The most promising approaches are what statisticians called 'semiparametric methods' that do not assume particular parametric formulas for the probability distributions involved, but instead rely on estimating structural properties of the distributions. Where the upper tail is key, as it is in setting numeric limits, a useful property of a distribution is its so-called 'tail index', defined as a positive number γ such that the probability of exceeding x goes to zero as x goes to infinity roughly like 1/x to the power γ. The Hill estimator (Hill, 1975) provides a natural and easily computed estimate of γ, based on the largest k data values in a sample of n—the k largest of the so-called ‘order statistics’. Note that without strong assumptions about precise formulas, like the lognormal fitting all datasets, there is no virtue in using general-purpose summary statistics such as means, medians, and standard deviations to estimate the upper-tail percentiles of a data distribution, and therefore the semiparametric methods, like the nonparametric ones, always use a relevant number of the largest values in a dataset to estimate upper-tail percentiles.

The following table shows the results of two semiparametric analyses of storm water grab-sample data from outfalls in California (Table 1). Note that these data were taken from storm water runoff from industrial locations that are predominantly open space, rather than from a construction site, as there is no comparable or sufficient dataset available for construction site runoff. Nonetheless, there is no reason to believe that construction site runoff will be any less variable than runoff from this type of industrial site.

Table 1. Semiparametric analyses of storm water grab-sample data from outfalls in California.

	TSS	Copper
Sample size (n)	236	259
Number of order statistics used (k)	6	7
Estimated tail index (γ)	1.12	2.41
Estimated 99th percentile	1543 mg/l	33.2 ug/l
95% confidence upper bound	2703 mg/l	42.9 ug/l

The estimates shown are maximum likelihood estimates, and the 95% upper confidence bounds were calculated using a method recently proposed by Peng and Qi (2006), justified by a rigorous mathematical analysis similar in concept to the standard justification of approximate confidence intervals associated with maximum likelihood estimates of parameter values in the standard context of parametric statistical models.

Application of this kind of semiparametric method does not require the very large sample sizes necessary for nonparametric methods, but the statistical requirements for well-justified numerical limits are substantial for other reasons. Because of the systematic and widespread differences in these characteristics from site to site, storm to storm, and sample to sample, it is necessary to carry out an extensive and well-designed data collection effort at a representative set of sites over a period of years. One or two years of data cannot represent the range of variability in number and severity of storms from year to year. Nor can haphazardly accumulated data from a variety of sites be used to provide the necessary consideration of what the Blue Ribbon Panel referred to as site to site variability (Blue Ribbon Report p. 15).

An instructive example of the importance of adequate planning of data collection and careful analysis of place-variability in setting numeric limits is provided by the Caltrans data set (Kayhanian et al., 2002). For example, the 49 grab-sample measurements of turbidity come from 10 sites, and the number of samples collected at each site ranged from 1 to 13. Half of the sites have 7 or 8 data values, and the other half have 1 to 4 data values. Even a cursory examination of the numbers quickly reveals that the sites yield data on considerably different scales of magnitude. The two largest of the 49 measurements—3390 NTU and 2500 NTU—come from the same site, the next two largest—1870 NTU and 1730 NTU—come from another site, and the 10 smallest measurements—ranging from 17 NTU to 72 NTU—comprise all of the data from two of the sites. It is statistically unsupportable to regard this combined dataset as a sample from a single distribution. Rather, it must be treated as what is called a mixture of distributions. Analyzing a mixture of distributions at different sites for the purpose of setting numeric limits requires careful data collection over a sufficient period of time (at least several years) and selection of sites according to a design scheme that insures reasonably faithful representation of the range of sites to which the numerical limits will be applied. In particular, one cannot take (as in the Caltrans dataset) whatever sample sizes happen to be available from different locations and lump them into one large dataset as though they all represent samples from the same distribution. To set numeric limits or action levels to be applied to a large collection of sites, it is necessary to use weighted statistical calculations on data from a representative set of sites to account for the necessarily haphazard sample sizes and to incorporate properly the variability of scales of data from site to site.

Most of the available data on storm flow quality, both from individual sites and in receiving waters, are in the form of a single grab sample per storm event, and generally for a relatively limited number of constituents. Thus, with the current data, it has not been possible to develop relationships between parameters that affect storm flow quality (such as rainfall amount and intensity, antecedent conditions, site conditions) or to predict or explain the full range of variability observed in storm flows. Very few data are available to describe variations in concentrations during a storm or in the form of event mean concentrations (EMCs, or composite samples). As discussed above, the degree to which the variability of storm flows must be characterized will depend upon the type of limit to be adopted, and the actions triggered by observed exceedances of those limits. For this reason, fewer data would be required to establish ALs than for Technology Based Effluent Limits (TBELs), and fewer data would be required for TBELs than for WQBELs. In any case, a broad, controlled program of data collection is needed to support a comparison of water quality concentrations between regions, or in different soil types.

As described in this report, existing data may be sufficient to establish ALs in limited cases, but establishing additional ALs or NELs will require significant additional planning, data collection, and analysis. The type and quantity of data to be collected are dependent upon the type of limit to be developed, the methodology to be used to compute ALs or NELs, and the monitoring and compliance strategies to be used after limits are established. For example, if compliance with NELs is to be determined using grab samples, then the data collection effort necessary to develop limits would likely be more data-intensive, so that those grab samples can be related to variations in concentration within a storm or to EMCs (flow-weighted composite concentrations).

Finally, the Blue Ribbon Panel recommended “that Numeric Limits and Action Levels not apply to storms of unusual event size and/or pattern (e.g., flood events)” (Blue Ribbon Report p. 18). The statistical considerations discussed herein also indicate the need for a hydrologic design condition, above which the NELs and/or ALs would not apply for enforcement purposes but could serve to trigger site actions, such as maintenance of BMPs, deployment of additional BMPs, or consideration of off-site impacts.

1.5 USEPA Efforts to Develop Effluent Guidelines for Storm Flows from Construction Sites

The U.S. Environmental Protection Agency (EPA) is developing effluent limitation guidelines for the Construction and Development industry pursuant to a judicial order in *Natural Resources Defense Council et al v. EPA et al* (C.D. Cal. 2006, Case No. CV-04-8307 GHK). The order calls for EPA to publish a proposed rule by December 2008 and a final rule by December 2009 (USEPA, 2007). The guidelines will apply to discharges of storm water during the active phase of construction as well as long-term storm water discharges from newly developed land areas. A number of regulatory options for storm water discharges from construction sites are being developed, and data are being collected to complete technical, economic and environmental analyses. EPA appears to be considering four major options for this rule (communication to Eric Strecker from Jesse Pritts, September 10, 2007), which are described briefly below.

1.5.1 Option 1 - Codify Requirement to Prepare a SWPPP

This option would require permittees to prepare a storm water pollution prevention plan to comply with applicable federal, state, and local requirements. This option would essentially continue the current permit scheme.

1.5.2 Option 2 - BMP Standard

Option 2 would establish minimum sizing criteria for BMPs, such as sediment basins and sediment traps, used at construction sites and would establish minimum standards for soil stabilization. Under this option, the costs and pollutant removal efficiency of various size sediment basins, or other BMP options, could be evaluated.

This option could also evaluate the use of advanced sediment basins designs, such as requiring the use of skimmers for sediment basin outlets and requiring baffles in sediment basins, and enhanced sedimentation using polymers such as polyacrylamide. Under Option 2, requirements for stabilizing exposed soils within a certain time period could be considered, as could limits on the extent of clearing and grading.

1.5.3 Option 3 – Design Particle Size Standard

This option would establish a numeric standard for designing sediment basins and sediment traps to remove a specified particle size fraction of sediment contained in storm water runoff, similar to the California Stormwater Quality Association's (CASQA) Construction BMP Handbook (http://www.cabmphandbooks.com/Construction.asp) contains an option for designing sediment basins. Sediment in construction site storm water runoff frequently consists of a range of particle sizes, which affect the efficiency of particle removal basins and traps. An effluent guideline could establish specific soil testing requirements using ASTM or other standards, which could then form the basis for sediment basin sizing requirements based on site-specific soil grain sizes. Cost and economic achievability of these options could be considered.

1.5.4 Option 4 - Numeric Discharge Standard

A fourth option would be to establish "numeric discharge limits or action levels" for pollutants such as turbidity or total suspended solids in discharges from construction sites and associated monitoring requirements. An effluent guideline could include numeric discharge standards based on the performance of specific technologies (i.e., TBELs). The states of Oregon, Washington, and Georgia currently have numeric discharge standards, monitoring requirements, or numeric action levels, and effluent guidelines could be modeled off these existing approaches.

2 REVIEW OF LIMITS PROPOSED BY STATE BOARD IN PRELIMINARY CONSTRUCTION GENERAL PERMIT

In early 2007, the SWRCB issued a Preliminary Draft Construction General Permit (Preliminary Draft) that contained provisions to regulate storm flow discharges from construction sites. The Preliminary Draft permit contained both action levels (ALs) and numeric effluent limits (NELs), as follows:

- For high and medium risk sites, the Preliminary Draft proposed the following limits:
    - AL for pH of 6.5-8.5, to apply for the first 18 months after permit adoption
    - AL for turbidity of 500 NTU
    - AL for total petroleum hydrocarbons (TPH) of 15 mg/l
    - NEL for pH of 5.8-9.0, to apply 18 months after permit adoption
- For discharges from Active Treatment Systems (ATS), the Preliminary Draft proposed the following:
    - NEL for pH of 6.5-8.5
    - NEL for turbidity of 10 NTU
    - NEL for acute toxicity (required to be similar to a control)
    - NEL for chronic toxicity (required to be 1.0TUc or less, where 1 TUc=100/NOEC)

The Preliminary Draft permit did not specify a “design storm” or other hydrologic condition to which BMPs should be designed, or above which the ALs and NELs would not apply. Flow Science has reviewed the Preliminary Draft permit citations and the methods and data used to develop the proposed ALs and NELs. In this Section, the proposed ALs and NELs from the Preliminary Draft for pH, turbidity, TPH, and toxicity are discussed.

2.1 Action Levels for pH

The Preliminary Draft contains ALs for pH with a value range between 6.5 and 8.5 pH units. These ALs would apply to discharges from medium and high risk sites. This range was derived by calculating one standard deviation above and below the mean pH of runoff from highway constructions sites in California (Fact Sheet p. 35).

The Blue Ribbon Report recommended that in establishing ALs for discharges from construction sites, the SWRCB should consider “the site’s climate region, soil condition, and slopes, and natural background conditions (e.g., vegetative cover) as appropriate and as data is [sic] available.”(Blue Ribbon Report p. 17) The Panel also recommended that an AL should be established to indicate an “upset value, which is clearly above the normal observed variability.”(Blue Ribbon Report p. 17)

Flow Science has several concerns with this proposed AL. First, an AL at plus or minus one standard deviation from the mean is not an appropriate metric. This method for establishing the AL assumes that the available pH data are normally distributed. This assumption should be tested prior to using this method, and it appears that the SWRCB did not test the data against the assumed normal distribution. If data are normally distributed, a range of plus or minus one standard deviation would include 68.2% of the data in the dataset that were used to calculate the AL. This would mean that, of all available data, about 31.8% would trigger an AL exceedance and require subsequent action. Clearly, this is not congruent with the concept of an upset value, in that a large portion of the dataset used to derive the AL is within the normal observed variability. Additionally, the Caltrans data used to establish the ALs for pH were taken from six of the eleven Caltrans Districts (CALTRANS, 2002) and may not be representative of conditions throughout the State.

Finally, data collected by the U.S. Geological Survey (USGS) indicate that rain in California has a long-term average pH that varies between 5.3 and 6.0, depending upon location (see http://water.usgs.gov/nwc/NWC/pH/html/ph.html). For individual storms, pH values as low as 4.5 have been observed (see, e.g., http://nadp.sws.uiuc.edu/ads/2003/CA45.pdf). If storm water runoff includes water that has not had significant contact time with soil or earth, it is possible for runoff pH values to be low and outside the range of the ALs. In addition, some areas of the State include alkaline soils, and pH in runoff from these soil types may be higher than average values. In some streams, natural receiving water pH ranges as high as 8.9 (e.g., see Trinity River data discussed in Section 4). These data should be taken into account in establishing any ALs for pH.

2.2 Action Levels for Turbidity

For turbidity, the AL proposed in the Preliminary Draft Permit is 500 NTU. The turbidity AL of 500 NTU was developed by Staff using the Modified Universal Soil Loss Equation (MUSLE) (Fact sheet p. 36). The MUSLE equation is as follows.

$$T = 95\,(Q_p * V)^{0.56}(K)(LS)(C)(P)$$

Where
T = Sediment yield for specific storm event (tons)
Q_p = Peak flow for specific storm event (cubic feet per second)
V = Volume of specific storm event (acre-feet)
K = soil erodibility factor
LS = length-slope factor
C = cover factor
P = management operations and support practices

The MUSLE is derived from the Revised Universal Soil Loss Equation (RUSLE) in order to estimate a sediment yield for a specific storm. The RUSLE estimates average annual sediment yield (ton/acre • year). The RUSLE equation is as follows.

$$A = (R)(K)(LS)(C)(P)$$

Where: A = the rate of sheet and rill erosion (tons per acre per year)
R = rainfall-runoff erosivity factor
K = soil erodibility factor
LS = length-slope factor
C = cover factor (erosion controls)
P = management operations and support practices (sediment controls)

The factors of K, LS, C, and P common to both equations were assessed by USEPA for three slope/slope length combinations (3% slope/200 foot slope length, 7% slope/140 foot slope length, and 12% slope/100 foot slope length) and the dominant soil textures in each ecoregion by USEPA (Fact Sheet p. 35). SWRCB Staff chose a 2-year, 24-hour storm event for the sediment yield per storm event. SWRCB Staff also assumed a 1:1 relationship between turbidity (NTU) and suspended sediment concentration (mg/l) (Fact sheet p. 36) in order to convert a suspended sediment concentration to a turbidity level.

Even with the information provided in the Preliminary Draft Fact Sheet, it is unclear how the value of 500 NTU was calculated. No information was provided to explain how the storm-event-specific sediment yield, which is expressed in mass (tons), was converted to suspended solids, which is expressed as a concentration in water (mg/l). In addition, no rationale has been provided for assuming the entire sediment yield contributes only to suspended sediment and not to bedload.

Flow Science is concerned with the use of MUSLE in these calculations. While the MUSLE equation has been widely applied, it should be used with caution in California as it was developed empirically, based on limited data for Texas and the southwestern United States. The document entitled "Guidelines For The Use Of The Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands," (Galetovic et al., 1998) (Guidelines) addresses primary limitations in applying RUSLE to construction sites. The limitations are not only applied to RUSLE but also to MUSLE because the parameters of K, LS, C, and P are common to both equations, and because MUSLE is the modification of RUSLE for a specific storm event. The limitations are summarized below (Galetovic et al., 1998).

- RUSLE provides soil-loss estimates rather than absolute soil-loss data,
- the soil-loss estimates are long-term average rates rather than precipitation-event-

specific estimates,

- estimates for hillslope-length factor (L) and hillslope-gradient factor (S) are accurate within a certain ranges of hill slopes and hill gradients,
- RUSLE does not produce watershed-scale sediment yields and it is inappropriate to input average watershed values for the computation of the RUSLE factors, and
- using RUSLE in geographic areas beyond its verification does not necessarily constitute a misuse, but caution is certainly warranted.

The AL of 500 NTU in the Preliminary Draft would be used as the criterion against which storm water runoff data would be compared for each individual rain event. However, this value was computed using MUSLE, which provides a long-term average rate, not an event-specific rate. In addition, the Guidelines clearly advise that the soil loss estimation should not be conducted as a watershed-wide scale, and that average parameter values over a watershed should not be used. Despite these cautions, Staff applied RUSLE to each broad ecoregion in California, i.e., at a scale much larger than a watershed, and used average parameter values calculated over large areas. Thus, the AL of 500 NTU represents long-term average values, may not be accurate at the scale of large ecoregions, and does not incorporate and accurately reflect the variability of storm flow sediment concentrations at an event-scale.

Additionally, the K values that were used in the equation to calculate the state-wide AL of 500 NTU may vary widely and usually are not available for the disturbed soils or mined lands, construction sites, or reclaimed lands. For soils at individual sites, a K value can be estimated using the soil-erodibility nomograph program in RUSLE, based on data obtained from soil samples and field observations by qualified soil scientists or engineers who have experience in the area. However, the statewide AL did not examine sensitivity to K values that may vary at any given site.

It appears that the SWRCB Staff adopted USEPA's three combinations of slope/slope length (3% slope/200 foot slope length, 7% slope/140 foot slope length, and 12% slope/100 foot slope length) for the LS factor (Fact Sheet, p. 35). It is unclear how these combinations were selected and how representative they are for construction sites within each ecoregion. Again, additional information as to how these slope/slope lengths are representative of construction sites is needed from Staff to justify use of the equation to calculate a statewide AL.

It is not clear whether Staff conducted areal weighting in calculating the average sediment load. According to the Guidelines, the LS value is used to describe a single hillslope profile within a landscape and does not apply to an overall landscape, nor does it apply to entire watersheds. Three-dimensional effects of hollows that concentrate overland flow, and spur-ends which disperse overland flow, require special consideration within RUSLE. If the average watershed soil loss is required, several representative combinations of RUSLE factors (including LS) should be used to estimate soil loss. Then, an areally-weighted average soil loss should be calculated outside of RUSLE based on the proportion of the watershed that each factor combination represents. In addition to the most appropriate values for slope and slope length, the most appropriate land use should be determined in the computation of accurate LS values by the RUSLE program (Galetovic et al., 1998). Staff should provide information on whether land use factor was considered and if so what land use type was used.

Flow Science also requests clarification for why 2-year, 24-hour storm event were used as a model storm for the estimation of sediment load (Fact Sheet at p. 36), and whether these data are appropriate for calculating a representative sediment yield from a construction site in California.

As noted above, SWRCB staff assumed a 1:1 relationship between TSS and turbidity (i.e., assumed that 1 mg/l TSS was equivalent to 1 NTU). Although several authors have attempted to correlate turbidity measurements with gravimetric measurements of TSS (Schroeder et al., 1981; Schubel et al., 1978; Schubel et al., 1979), a consistent relationship has not been established. Correlations are generally site-specific and may change over the course of a year, although not in a consistent fashion (Manka, 2005). The suspended sediment-turbidity relationship shifts between the rising and falling limbs of the hydrograph (Knighton, 1998). Variability in the TSS-NTU correlations can be attributed to differences in size, composition, and refractive index of particles (Earhart, 1984). For dilute solutions, there appears to be a linear relationship between the amount of light scattered and the amount of suspended material, but when TSS levels are high, light cannot penetrate the sample and will distort the turbidity reading (Schubel et al., 1978). Data presented in these references indicate that the TSS:NTU relationship can vary from 0.03:1 to 71:1, indicating that the assumption that a 1:1 relationship exists between turbidity and TSS is suspect and represents a serious oversimplification.

The use of "dominant soil textures in each ecoregion" appears to be a rational way to determine particle size distribution, but many construction sites are typically comprised of disturbed soils with varying textures from all horizons within the soil profile. Further, there is high variability within a single region and between regions, such that RUSLE calculations can vary widely between two sites both within a single ecoregion and between ecoregions.

The Panel expressed the following concern in developing an AL for turbidity, stating that *"... it is important to consider natural background levels of turbidity or TSS* [Total Suspended Solids] *in setting Numerical Limits or Action Levels for construction activities. The difficulty in determining natural background concentrations/levels for all areas of the state could make the setting of Numeric Limits or Action Levels impractical from an agency resource perspective."*(Blue Ribbon Report p. 16).

The proposed AL does not appear to consider natural background conditions. Natural background turbidity and/or TSS levels in storm water runoff vary considerably both within different areas of the state and in response to different storm conditions (e.g., rainfall intensity, rainfall amount, and antecedent conditions) (see Section 5). Thus, it makes little sense to adopt a single AL for turbidity that is applied uniformly throughout the State. Caltrans monitoring data for turbidity show that "typical construction site runoff" in California ranges from 15 NTU to 16,000 NTU (CALTRANS, 2002). The USEPA also estimated sediment loads as part of their effluent limitation guidelines for construction activities, and these estimates ranged from approximately 500 NTU to 15,000 NTU (Preliminary Draft at p. 30). These data support the premise that ALs for turbidity should be site-specific and established after consideration of receiving water conditions.

In summary, it is unclear how the 500 NTU for turbidity AL was computed, although it appears that many broad and general assumptions were made in the calculation. Because conditions may vary significantly within a region, and from one individual storm event to another, Flow Science recommends that if ALs are to be developed for sediment, they should be calculated for smaller areas than an ecoregion and should incorporate various environmental characteristics found throughout California and at individual construction sites.

2.3 Action Levels for TPH

The Preliminary Draft also provides an AL for total petroleum hydrocarbons (TPH), calculated for carbon range C_{12} through C_{28}, of 15 mg/l. This AL is based on a City of Tacoma 2003 Surface Water Manual (Tacoma Manual), which states that typical oil water separators (one BMP available to treat diesel-contaminated runoff) should be designed and maintained to reduce effluent concentrations to 15 mg/l (Fact Sheet at p. 37).

The Tacoma Manual specifies that the 15 mg/l performance goal applies to *facilities* (emphasis added) at high-use sites that generate high concentrations of oil. High-use sites include the following:

- *An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;*
- *An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil;*

- *An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);*
- *A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements.*

Construction sites are unlikely to be high-use sites as defined above. Therefore, it is not defensible to require the same Best Management Practice (BMPs) and performance goal as high-use sites for construction sites where neither constant high traffic nor high oil handling occurs.

Samples collected for TPH analysis must be collected by trained personnel using clean sampling techniques and shipped to a laboratory for analysis, with a typical turnaround time of five days (based on contact with analytical laboratories). TPH samples collected from stored/contained storm water will not be representative of discharge conditions as TPH may volatilize from water.

Because of these considerations, visual observations of sheen are generally a better indicator of the presence of hydrocarbons in storm water. We recommend that the permit be modified to require specific observations for sheen instead of laboratory testing.

2.4 Numeric Effluent Limits (NELs) and Receiving Water Limitations for pH

2.4.1 NELs for pH.

In the Preliminary Draft, dischargers at medium and high risk sites where active treatment systems (ATS) are not used must maintain a numeric effluent limit for pH within a range of 5.8-9.0 units, which would become enforceable 18 months after the adoption of the General Permit (Fact Sheet p. 37).

Staff derived the pH NEL values by "*calculating two standard deviations above and below the mean pH of runoff from highway construction sites in California*."(Fact Sheet p. 37). The Fact Sheet for the Preliminary Draft also states that "*proper implementation of BMPs should result in discharges that are within the range of 5.8 to 9.0 pH units*" and references SWRCB Staff's reliance on best professional judgment (BPJ) equivalent to Best Available Technology (BAT) and Best Conventional Pollutant Control Technology (BCT) (Fact Sheet p. 37). SWRCB staff assumed that the data in the dataset used to derive the NELs for pH are normally distributed; however, this assumption should be tested. If normally distributed, 95.4% of the data points in the dataset would fall within the pH limits specified by the Preliminary Draft, and 4.6%

would fall outside those limits. As noted in Section 1.4, the pH of rainfall is below the lower limit of the pH NEL. The pH in runoff from construction sites is likely to differ from natural pH conditions only when practices that may alter pH are employed at the site, and thus monitoring should be triggered only when a visual inspection during site monitoring indicates site contamination and where pH altering practices have occurred.

More importantly, the proposed NELs were developed without consideration of receiving water quality. The requirements of the Preliminary Draft may require effluent from construction sites to be treated to a level that is different from the receiving water, and pH values outside the range of the proposed NELs may occur naturally (see Section 4).

2.4.2 Receiving Water Limitations for pH.

The Preliminary Draft Permit also includes receiving water limitations that specify that storm water and non-storm water discharges from high and medium risk construction sites shall not be more than 0.2 standard units higher or lower than the pH of the receiving waters. The NELs would be applied in both wet and dry seasons.

This requirement appears to conflict with provisions for pH that are contained in many of the state's Water Quality Control Plans (Basin Plans). For example, the Basin Plan for the Los Angeles Region requires that "*the pH of inland surface waters shall not be depressed below 6.5 or raised above 8.5 as a result of waste discharges. Ambient pH levels shall not be changed by more than 0.5 units from natural conditions as a result of waste discharge.*"[4]

Because of considerations related to mixing and receiving water buffering capacity, a discharge would have to have a pH difference from the receiving water far greater than 0.2 pH units to induce a change of 0.2 pH units within the receiving water itself. The current requirement in the Preliminary Draft is more stringent than applicable water quality objectives and improperly applied to effluent, rather than being evaluated within the receiving water. Meeting this requirement would require receiving water monitoring for pH for all storms, regardless of whether or not an AL or NEL had been exceeded.

---

[4] "Water Quality Control Plan: Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties," California Regional Water Quality Control Board, Los Angeles Region, 1994, at p.3-15.

2.5 NELs for discharges from Active Treatment Systems (ATS)

The Preliminary Draft permit would require the use of Active Treatment Systems (ATS) at all construction sites where the graded area would exceed five (5) acres, and where site soils consist of 10% or greater fines (i.e., 0.02 um, a medium silt). As discussed in CBIA and CICWQ' comments submitted on the Preliminary Draft Construction Permit (2007), the requirement would effectively require ATS to be used at most construction sites throughout the state.

ATS are systems that capture storm water runoff and treat that runoff to reduce sediment loads prior to release to the receiving water. Most ATS systems employ polymer coagulation, although electrocoagulation may also be an option for ATS. The polymers typically used in ATS have the potential to cause toxicity to aquatic life, and can result in changes to the pH of the storm water to be discharged. To protect against toxicity, the SWRCB in the Preliminary Draft proposed the inclusion of toxicity NELs for ATS discharges. The Preliminary Draft also contained NELs for turbidity and pH for ATS discharges. The limits proposed by SWRCB Staff in the Preliminary Draft are discussed below.

2.5.1 Turbidity NELs for ATS discharges

For sites where Active Treatment Systems (ATS) are used, the Preliminary Draft included a proposed NEL for turbidity of 10 NTU, which would apply in both wet and dry seasons. The Blue Ribbon Panel concluded that use of ATS could make NELs for construction site discharges feasible, but the Panel noted that *"[t]he SWRCB should take into account the long-term effects of chemical use, operational and equipment failures or accidental releases.*"(Blue Ribbon Report p. 15) The Panel also noted the difficulties associated with establishing ALs or NELs for turbidity, stating "… *it is important to consider natural background levels of turbidity or TSS in setting Numerical Limits or Action Levels for construction activities. The difficulty in determining natural background concentrations/levels for all areas of the state could make the setting of Numeric Limits or Action Levels impractical from an agency resource perspective."* (Blue Ribbon Report p. 15) Finally, the panel noted that *"active treatment systems could result in turbidity and TSS levels well below natural levels, which can also be a problem for receiving waters.*" (Blue Ribbon Report p. 17)

The Blue Ribbon Panel's findings concerned ATS that used polymer coagulation. The Preliminary Draft permit also asserted that electrocoagulation types of ATS could consistently provide effluent meeting the permit requirements, but this assertion was unsupported by scientific or technical evidence. Geosyntec Consultants have conducted a detailed review of ATS as applied to construction site runoff (Geosyntec, 2007). Geosyntec's review of ATS performance measures for multiple construction sites found that reported influent turbidity ranged between 2 NTU and 22,000 NTU, while reported ATS treated effluent turbidities ranged from <1 NTU to 45 NTU. While these values show that ATS systems can reduce the turbidity of construction runoff to below 10 NTU, they also show that effluent turbidity does exceed 10 NTU at times, even when the ATS system is operated appropriately. Thus, available evidence indicates that ATS would not consistently achieve the proposed NEL of 10 NTU.

The Blue Ribbon Panel also stated that "*it is important to consider natural background levels of turbidity or TSS in setting [NELs] or [ALs] for construction activities*." (Blue Ribbon Report p. 16) The Panel noted that turbidity in some areas of the state is naturally very high, particularly in arid or semi-arid regions. Requiring effluent turbidity that is "too low" (i.e., far lower than natural turbidity levels) can cause downstream erosion in natural channels. This effect would be especially pronounced where the construction site discharge is a large fraction of the water flow in the stream. When turbidity or TSS is too low in a discharge, downstream scouring of stream channels will occur, increasing stream hydromodification. Turbidity levels that are too low can also cause ecological concerns (see Section 6). A turbidity value of 10 NTU is very low, and is significantly lower than observed storm event turbidity levels in all streams for which data have been reviewed (see Section 4). The SWRCB should exercise great care in establishing NELs for turbidity, and should not require effluent to be treated to levels that are "cleaner" than natural background levels during storm events.

2.5.2 pH NELs for ATS discharges

The Preliminary Draft also proposes an NEL for pH for discharges from ATS. The Preliminary Draft would require these discharges to have a pH between 6.5 and 8.5. As noted in Geosyntec (2007), chemical addition may be required to achieve this NEL, and the storage and use of chemicals on-site itself poses some measure of risk to water quality.

The Preliminary Draft also contains a receiving water limitation for pH from ATS discharges. As with discharges from medium and high risk sites, the Preliminary Draft specifies that discharges from ATS shall not be more than 0.2 standard units higher or lower than the pH of the receiving waters. As noted above, this requirement appears to conflict with provisions for pH that are contained in many of the state's Water Quality Control Plans (Basin Plans), and improperly applies receiving water limits directly to the discharge itself (i.e., as effluent limits). Further, it may not be possible to achieve both this limit and the requirement that pH be between 6.5 and 8.5, as the pH of some of the state's receiving waters may lie outside the 6.5 to 8.5 range (see Section 4).

2.5.3 Acute and Chronic Toxicity Testing

The proposed language in the Preliminary Draft states that acute and chronic toxicity tests must be performed on all discharges from an ATS (Preliminary Draft p. 11).

The Preliminary Draft requires that acute toxicity tests be performed on all ATS discharges, and specifies that the discharges shall have no significant difference, at the

95% confidence level, between a control discharge and 100% effluent. Since the test methodology for acute toxicity is a 96-hour test, results would not be available before discharge. Flow Science is also concerned about the laboratory capacity to run a large quantity of tests at the same time (e.g., when several contractors submit samples from the same storm event). For toxicity tests, the control sample is to be collected from an alternate storm water discharge location on site where an ATS is not being used. If site soils meet the Preliminary Draft's fines requirements, it is our understanding that the entire site would be required to use ATS. Thus, it is not clear that an alternate storm water discharge location would exist.

In addition, the Preliminary Draft requires a chronic toxicity test for discharges of treated storm water from an ATS. It appears that this requirement may be inappropriate and unnecessary. Chronic testing assesses the effects of long-term (chronic) exposures to toxic substances. By definition, ATS discharges are short-term, storm-driven events, so that discharges from ATS will not last long enough to cause a chronic exposure. Thus, the chronic toxicity test appears to be irrelevant for ATS discharges. The test methodology for chronic toxicity is a 7-day test (Test Method 1002.0), so that results would not be available before discharge.

2.6 Statistical considerations related to Acute Toxicity Testing[5]

The Preliminary Draft requires an acute toxicity test to be conducted on discharges from an ATS. The Preliminary Draft specifies that the test data should indicate no significant difference between a control discharge and 100% effluent at the 95% confidence level (Preliminary Draft at p. 11):

> *Acute toxicity of ATS discharges shall have no significant difference, at the 95% confidence level, between the control discharge and 100 percent effluent (a t-test), applied as a monthly median of pass-fail tests (p11).*

If the data used for this comparison are survival counts for fish placed in tanks with effluent samples and controls, then there are several statistical considerations worth noting: the standard "Student-t test for comparing two populations" should not be used for count data, since that test assumes not only that the data follow normal (Gaussian) distributions, at least approximately, but also that the sample means and sample variances, which are used in the t-test formula, are independent random variables. This is typically not true for count data.

---

[5] The section 2.6 was prepared by Dr. Gary Lorden at California Institute of Technology on behalf of FSI.

- A more reasonable statistical analysis of "counts" comparing fish survival is the Binomial model[6], which stipulates that *given* the total number of fish deaths—say, n—in one or more such comparison tests, the number that occur in the 100% effluent—say, x— follows a Binomial distribution with parameters n and p, the latter denoting the probability that a fish death, known to have occurred in one tank or the other, occurred in the tank containing 100% effluent. (It is assumed that the same numbers of fish are tested for survival in each tank.) This is the approach taken in the State's current 303(d) listing policy (State Water Resources Control Board, 2004).

- A correct use of a 95% confidence level for summarizing the effluent/control comparison is, then, to calculate a 95% confidence interval for p. If this interval contains the point p=1/2, then the data do not rule out the hypothesis that the survival rates are identical. For example, if a series of comparison tests yield a total of 25 fish deaths and 15 of those occurred in the 100% effluent tanks, then with 95% confidence it can be inferred that p lies in the interval [.39 .79], whereas if 18 of the 25 deaths occurred in the effluent, the 95% confidence interval for p is [.51 .88], thus ruling out p=.5 and indicating that the 100% effluent causes significantly more fish deaths than the control.

---

[6] The binomial distribution is defined as: $f(x) = [n!/(x! *(n-x)!)] * p^x * q^{n-x}$ where *p* is the probability of success at each trial, *q* is equal to 1-p, and n is the number of independent trial (Yule, 1911).

3 INVENTORY OF AVAILABLE DATA ON EXISTING WATER QUALITY AND NATURAL BACKGROUND WATER QUALITY

A number of data sources were reviewed to assess existing data for water quality for pH, turbidity (NTU), and suspended solids. Flow Science first conducted a review to determine data availability, then compiled and reviewed the data identified in the inventory (see Section 4). Databases reviewed by Flow Science include:

1) California Data Exchange Center (CDEC),
2) Bay Delta and Tributaries Project (BDAT),
3) Southern California Coastal Water Research Project's (SCCWRP's) Natural Loadings study (Stein and Yoon, 2007),
4) Environmental Monitoring and Assessment Program (EMAP),
5) Various storm water quality monitoring programs of Sacramento, Los Angeles, Orange, San Diego, and Ventura Counties , and
6) U.S. Geological Survey National Stream Water-Quality Monitoring Networks (USGS NASQAN and HBN).

In general, two types of data were available for review. The datasets from northern California consist mainly of continuous data records for turbidity and pH, especially in the Delta area and for rivers or streams that flow to the Delta. These records do not distinguish between dry and wet weather flows but rather include both conditions. Most northern California data are available at the CDEC web site (http://cdec.water.ca.gov/). In southern California and in Sacramento County, most available data are from event-based sampling, and continuous records are not available. Event-based sampling data include measurements of turbidity, total suspended solids (TSS), and pH. Land use types for the watersheds upstream of each sampling station are not readily available. However, based on the location of stations and satellite images of stations, it appears that most sampling locations are in developed watersheds that have significant areas of undeveloped land.

Data from the Natural Loadings study (Stein and Yoon, 2007) are the only data available from undeveloped watersheds. Although these data were collected during a limited period of time (i.e., two years), they provide important information on natural background water quality in southern California.

Although additional datasets were evaluated, not all databases provided additional useful information and not all databases are included in this inventory and analyses. San Diego County data were not available in an electronic form and were not included in our data review. Most data available from BDAT overlap with data from CDEC, and duplicate data were not included. USGS NASQAN and HBN data were also excluded because they were from one-time sampling and thus not indicative of the variability of water quality data, or of the range of likely water quality values. In summary, our data review includes continuous record data obtained from CDEC, storm event water quality monitoring data from the Counties of Sacramento[7], Los Angeles, Orange, and Ventura, and storm event water quality monitoring data from the Natural Loadings study data. These datasets are summarized in greater detail below.

3.1 California Data Exchange Center, CDEC

The California Data Exchange Center (CDEC) collects, stores, disseminates, and exchanges hydrometeorological data and related information. CDEC data can be found at http://cdec.water.ca.gov. Hourly turbidity (NTU), pH, and flow data are available for 45 stations in California (Tables 2.a, b and 3.a, b). Daily-mean data are also available for a limited number of stations. No solids (i.e. total suspended solids, suspended solids) data are available from CDEC. Only one station contains both turbidity and rainfall data. For other stations, the nearest rain gauging stations are listed in the station information table (Table 2).

3.2 Los Angeles County Storm Water Monitoring

Turbidity, TSS, pH, flow, and rainfall data are available from the monitoring conducted by Los Angeles County Department of Public Works (LACDPW) to fulfill the requirements of the Monitoring and Reporting Program (MRP) under Order No. 01-182, National Pollutant Discharge Elimination System (NPDES). Metals (Cu, Pb, and Zn), and bacteria (total coliform, fecal coliform, fecal streptococcus, and fecal enterococcous) data are also available. A total of thirteen stations[8] contain up to eleven samples per year from 1999 to 2006. Samples are event-based, i.e., collected during storm events (Tables 4 and 5). For every monitoring station, a minimum of one automatic tipping bucket (intensity measuring) rain gauge was located nearby or within the tributary watershed. Large watersheds may require multiple rain gauges to accurately characterize the rainfall, and the LACDPW operates various automatic rain gauges throughout the county. Existing gauges near the monitored watersheds were also utilized in calculating storm water runoff. More detailed description of the monitoring is provided in Integrated Receiving Water Impacts (IRWI) Report Final Report - August 2005 **(**http://ladpw.org/wmd/NPDES/1994-05_report/contents.html**).**

---

[7] Data of Sacramento County are from both receiving waters and MS4 (storm drain) while data of other counties are only from receiving waters. Data are also combined from grab and composite samples.

[8] Stations are located in the Los Angeles River, San Gabriel River, Malibu Creek, and Santa Clara River watersheds.

3.3 Orange County NPDES Monitoring

pH, TSS, flow, and rainfall data at mass emission sites are available from the NPDES monitoring conducted by Orange County. Metals (Cu, Pb, and Zn), and bacteria (total coliform, fecal coliform, and enterococcous) data are also available. Wet season turbidity data are not available, but data are available from bioassessment studies that were conducted during dry seasons. Samples are storm event-based, i.e., collected during storm events, from 1992 to 2006. The data set also contain sample concentrations, event mean concentrations, and loads for TSS. Data are collected in Westminster, Newport Bay, and Santa Ana River watersheds. Summaries of water quality data are in unified annual reports at http://www.ocwatersheds.com/StormWater/documents_damp_pea.asp**.** Station information and data availability are provided in Tables 6 and 7.

3.4 Storm Water Monitoring Data from Mass Emission Stations in Ventura County

Event-based storm water data were available from 17 stations[9] in Ventura County for Water Years 1995 through 2006. Data for pH, turbidity (NTU), TSS (mg/l), metals (both dissolved and total concentrations), nutrients (mg/l), and indicator bacteria (*E. coli,* enterococcus, fecal coliform, fecal streptococcus, and total coliform; MPN/100mL) are available. Rainfall data are available from a rain gauging station nearby. Station information and data availability are provided in Tables 8 and 9.

3.5 Storm Water Monitoring Data from Stations in Sacramento County

Event-based storm water data were obtained for 10 stations[10] in Sacramento County from Water Year 1990 to 2005. Data for pH, turbidity (NTU), TSS (mg/l), metals (both dissolved and total concentrations), nutrients (mg/l), and indicator bacteria (*E. coli,* enterococcus, fecal coliform, fecal streptococcus, and total coliform, all in MPN/100mL) are available. Station information and data availability are provided in Tables 10 and 11.

---

[9] A-1(Wood Road), C-1 (Via Del Norte), I-1(Via Pescador), I-2 (Ortega Street), LC-1 (Lindero Canyon), LV-1 (Las Virgenes Canyon), MC-1 (Medea Canyon), ME-CC (Calleguas Creek at University Drive), ME-SCR (Santa Clara River at Freeman Diversion), ME-VR (Ventura River at Foster Park), ME-VR2 (Ventura River at Ojai Valley Sanitation), R-1 (Swan Street), R-2 (Lawrence Way), W-1 (Heywood Street), W-2 (Alamo Street), W-3 (La Vista Drain), and W-4 (Revolon Slough)

[10] Sacramento River and San Joaquin River watersheds

3.6 Natural Loadings Study

This study measured surface water quality at 22 natural open-space sites[11] spread across southern California's coastal watersheds. Sites were selected to represent a range of conditions and were located across six counties and twelve different watersheds: Arroyo Sequit, Los Angeles River, San Gabriel River, Malibu Creek, San Mateo Creek, San Juan Creek, Santa Ana River, San Luis Rey River, Santa Clara River, Ventura River, and Calleguas Creek watersheds (Table 12). Data were collected from a total of 30 storm sampling-events during two wet seasons between December 2004 and April 2006, with each site being sampled during two to three storms (Table 13). pH, TSS, flow, and rainfall during storm events were measured.

---

[11] >95% natural and undeveloped

4 SUMMARY OF EXISTING DATA AND INFORMATION ON THE CONCENTRATIONS AND VARIABILITY OF WATER QUALITY CONSTITUENTS IN STORM FLOWS

The data identified in the data inventory, described in Section 3, were collected, compiled, and analyzed. Descriptive statistics were developed for these datasets to describe concentrations and variability of turbidity, TSS, pH, metals (copper, zinc, and lead), and indicator bacteria. The data are presented in Tables 13 through 30. The distribution of data was examined before statistical analysis to determine the distribution type. The analyses and resulting data statistics are presented below.

4.1 Data Distribution and Descriptive Statistics by Data Source

Data from multiple stations were first combined and categorized by data source. The distribution of data was then tested for normal or log-normal distribution using Kolmogorov-Smirnov Goodness-of-Fit Test[12] (Chakravarti et al., 1967). The results of the normality tests are presented in summary tables 13 through 15.

This data analysis demonstrated that most storm runoff TSS and turbidity data from the various sources are neither normally nor log-normally distributed with several exceptions. TSS data from Sacramento County (Figure 3), turbidity data from Orange County (Figure 4), and turbidity data from Ventura County were determined to be log-normally distributed.

In general, data are skewed toward the lowest value; the lowest values in the dataset were lower than would be predicted by either a normal or a lognormal population (i.e., the data are “heavy-tailed” or would more likely fit “extreme value distributions.”). For instance, turbidity data from CDEC and Orange County show a significant number of individual data points above 500 NTU (Figure 5). In both data sets, turbidity levels even over 1000 NTU are observed. For TSS data from Ventura County, very high values above 5000 mg/l were observed (Figure 6). Areas upstream of the Ventura County sampling stations contain considerable areas of open land[13], which may have contributed to high concentrations of TSS during storm events. Impact of land use type will be discussed further in the next section.

---

[12] The Kolmogorov-Smirnov test is used to decide if a sample comes from a population with a specific distribution (normal/log normal distribution in our study).

[13] Ventura County Resource Management Agency (2007), transmitted by Jose M. Moreno, GIS department supervisor, August 31, 2007.

pH data are generally distributed around 7 for all stations. *E coli* data from Sacramento County from Ventura County are log-normally distributed. Raw data for TSS and pH from the Natural Loadings study were also tested and found to be neither normally nor log-normally distributed.

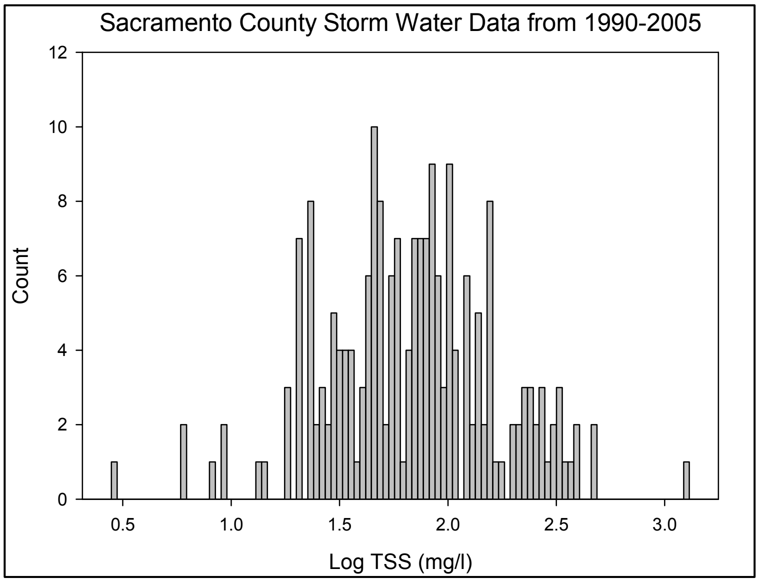


Figure 3. Log-normal distribution of TSS data from Sacramento County storm water program; data from multiple stations were combined for each data source; N= 203.

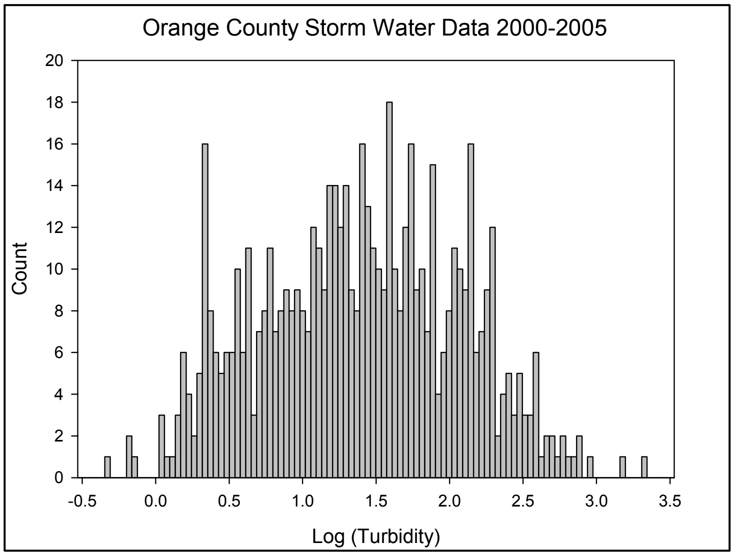


Figure 4. Log-normal distribution of turbidity data (NTU) from Orange County storm water program; data from multiple stations were combined for each data source; N=601.

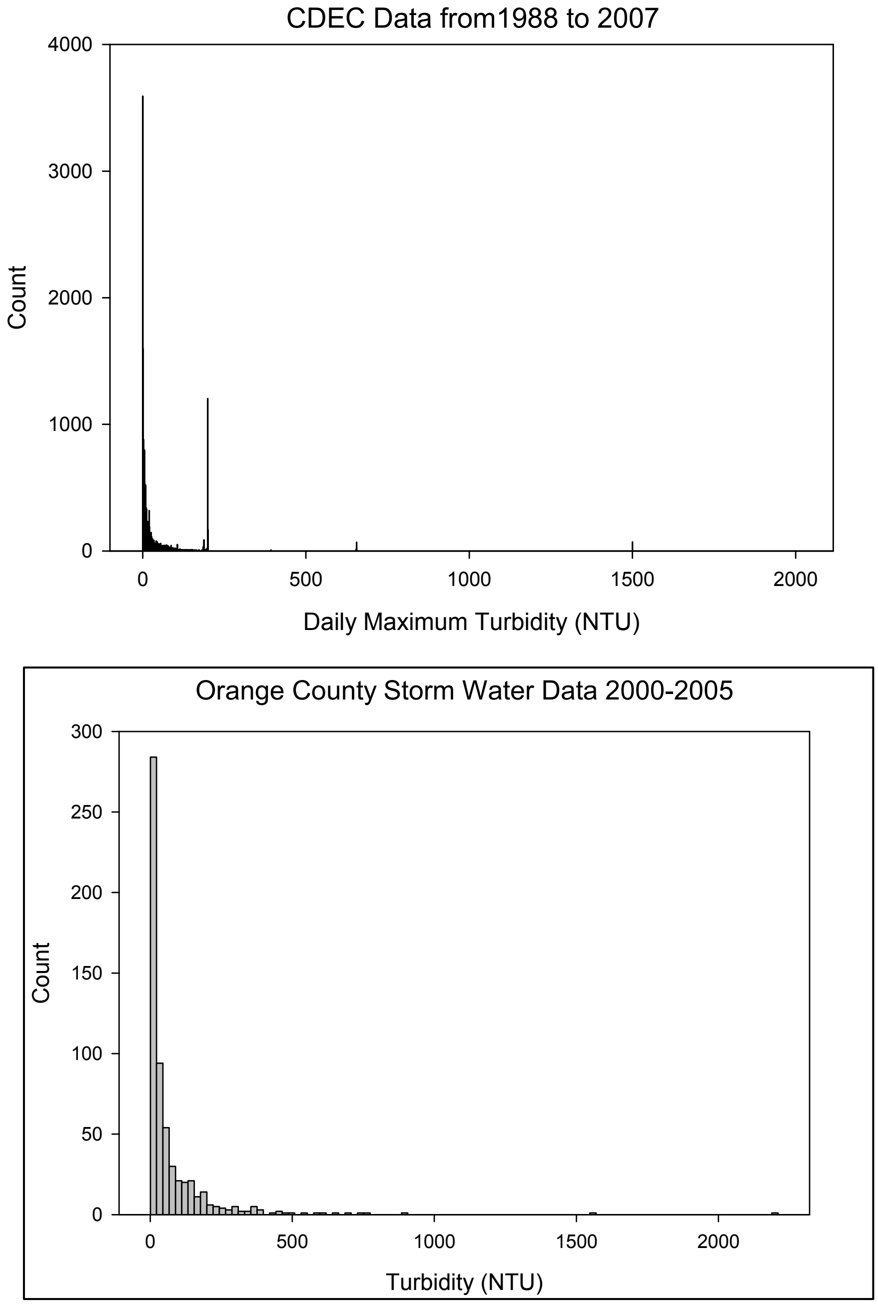


Figure 5. Distribution of turbidity data from CDEC (N=51515) and Orange County (N=599); data from multiple stations were combined for each data source.

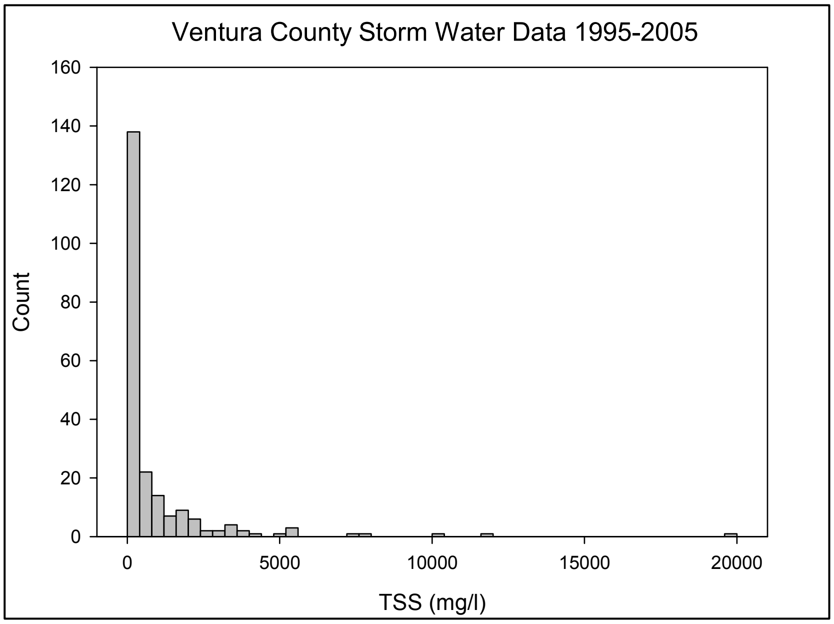


Figure 6. Distribution of TSS data from Ventura County storm water program; data from multiple stations were combined for each data source.; N=39.

Descriptive statistics for pH, TSS, turbidity, indicator bacteria, and metals categorized by data sources are presented in Tables 14 through 15. The statistics include range, minimum, maximum, median, 25th percentile, and 75th percentile. No arithmetic mean, geometric mean, standard deviation or standard error statistics are provided because the majority of data sets are neither normally nor log-normally distributed. Large values of ranges (maximum value – minimum value) indicate large variability in water quality of storm runoff. For instance, turbidity values vary from zero to tens of thousands (NTU). Turbidity data from Sacramento County show relatively low values (Table 14). This is primarily because the majority of stations of Sacramento County are located at either urban tributaries or storm drains, where flow is low and/or it is from less erodible environment such as concrete channels than open land (Table 10).

4.2 Data Distribution and Descriptive Statistics by Watershed

Data from multiple stations were combined and categorized by watershed (instead of data source), and normality tests and descriptive statistical analyses were conducted on the categorized data sets. California's watersheds occur in a variety of geologic and topographic settings, have a variety of soil types, and contain a variety of natural vegetation communities as well as land use types; these factors are known to influence water quality (Johnson et al., 1997; Stein and Yoon, 2007). Thus, storm runoff water quality between different watersheds can vary considerably. To capture this variability of water quality among different watersheds, analyses were conducted on data for each watershed. Watershed information for data from CDEC was not available, and so these data were categorized by river basin.

None of the CDEC pH or turbidity data for northern California, which are continuous flow records and thus contain both dry and wet weather data, and which were categorized by river basin, are either log-normally or normally distributed. Even though the turbidity driven by storm water runoff is of interest, it was beyond the scope of this project to separate wet weather turbidity data from dry weather data primarily because precipitation data were not readily available. Even with precipitation data, it is challenging to define storm flow conditions in highly controlled systems like Sacramento River and San Joaquin River, as reservoir releases and other management actions can have very strong effects on river and stream flows. Therefore the analyses conducted on CDEC data were based on continuous data during both wet and dry seasons.

Descriptive statistics for the CDEC data are presented in Table 16 for turbidity and Table 18 for pH. Depending on river basins, turbidity levels vary from zero to hundreds or thousands of NTU. Turbidity levels above 500 NTU occurred in most river basins. The variability in pH data is also large.

Distribution and descriptive statistics are provided in Tables 19 through 29 for turbidity, TSS, pH, indicator bacteria, and metals for data collected in southern California watersheds and by the County of Sacramento. These data are storm-event data, and thus represent wet weather conditions only. Turbidity and TSS data collected within more than half of watersheds are log-normally distributed, and pH data collected in more than half of the watersheds are normally distributed.

Storm event turbidity levels vary considerably among different watersheds (Table 19). Comparing 75th percentiles in Table 19, some watersheds are an order of magnitude lower than 500 NTU, while storm flows in the Calleguas watershed (Ventura County) occasionally have turbidity values higher than 500 NTU. Maximum turbidity values are higher, on occasion by more than an order of magnitude, than 500 NTU in most cases. TSS levels vary less among the watersheds than turbidity levels. The TSS levels range less than 10 to tens of thousands mg/l. Ratios between Turbidity (NTU) and TSS (mg/l) range from 0.014 to 32 according to the OC data of paired TSS and turbidity. pH levels vary roughly from 6 to 8.

The data from the Natural Loadings study were collected in watersheds with more than 95% undeveloped area and with no or minimal impact from development. Thus, this dataset presents valuable insight on natural background levels of TSS and pH. Table 29 shows descriptive statistics of data from multiple stations. Raw data (i.e., grab samples) that have not been flow-weighted are neither normally nor log-normally distributed. Table 30 shows descriptive statistics calculated using all data from all stations, and Tables 31 and 32 show the statistics by watershed. In general, the variability in these datasets is quite large. For instance, TSS levels in samples collected from tributaries located within the Santa Clara River watershed range from 2 to 103,000 (mg/l).

4.3 Conclusion

The data examined in this report include both continuous data (i.e., “grab samples” or discrete observations collected during both wet and dry conditions) and storm event data. The datasets collected in southern California vary somewhat in data type and quantity from the data collected in northern California, and the range of receiving water bodies represented by the data in these datasets is limited and cannot represent the full range of possible conditions in all of the state’s watersheds. In spite of these limitations, the data provide valuable insight into the range and variability of turbidity and TSS concentrations and pH values throughout the state, and several important conclusions can be drawn even in light of these limitations.

First, there is no single data distribution that can describe storm runoff water quality. Storm flow data cannot be assumed to be either normally or log-normally distributed. While methods for developing either NELs or ALs that utilize these distributional assumptions may be appropriate within a given watershed or at a single location, the assumption that data follow a specific distribution must be tested. Clearly, it is not possible to utilize these distributional assumptions to calculate either ALs or NELs that would apply statewide.

Second, it is clear from the data that storm flow water quality is highly variable. Storm flow constituent concentrations can vary significantly within a single watershed from one storm to another, or between watersheds. Constituent concentrations, especially of TSS and/or turbidity, can exhibit order-of-magnitude differences from one watershed to another or from one region of the state to another.

Third, TSS and turbidity concentrations in storm water runoff are often naturally very high. The Natural Loads study (Stein and Yoon, 2007) demonstrates quite clearly that natural turbidity levels within undeveloped watersheds can range to levels far greater than the proposed AL for turbidity. As discussed in the following section, the introduction of “clean” water (with far lower than natural turbidity levels) to watersheds where turbidity levels are normally far higher can induce channel erosion and other hydromodification impacts. Because of this, natural or ambient receiving water conditions should be considered when any AL or NEL is established, and such limits are appropriate only on a site-specific basis.

5 ASSESSMENT OF EXISTING DATA FOR SEVERAL SELECTED WATERSHEDS AND IMPACT OF LAND USE AND STORM SIZE ON SEDIMENT LEVELS

Flow Science conducted a detailed review of storm water quality data for several watersheds to examine factors that may influence sediment levels in receiving waters. A variety of factors are known to affect water quality. Land use type is one of the most widely studied factors that have a significant impact on water quality (Detenbeck et al., 1993; Johnes et al., 1996; Johnson et al., 1997; Larsen, 1988; Richards et al., 1996). For example, TSS levels are known to be higher in runoff from the agriculture land use type than in runoff from other land uses (Ackerman and Schiff, 2003). In addition, turbidity/sediment loads in undeveloped watersheds are primarily affected by the size of storm generating the runoff. Therefore, sediment levels in receiving waterbodies can change dramatically depending on storm size, receiving water flow conditions, and the nature of the watershed itself. Flow Science has reviewed available literature in order to estimate the possible magnitude of variability in sediment loads among different storm sizes. To the extent possible using readily available data, the effect of land use type and of hydrologic measures of storm response, such as rainfall amount, were assessed for selected watersheds.

The information generated by this review is intended to serve as a first-phase case study to evaluate the information that would be necessary, and the conditions that should be considered, before numeric limits can properly be applied to storm flows.

In this section, the effect of land use type on TSS levels is discussed first, and then correlations between storm hydrologic data and sediment data are summarized.

5.1 Selection of Watersheds

Seven watersheds, which can represent various condition of receiving water quality in California, were selected: Sacramento River, Newport Bay, Los Angeles River, Malibu Creek, San Gabriel River, Calleguas Creek, and Santa Clara River watersheds. Due to limited data availability for the northern California region, only the Sacramento River watershed is included here. Data analyzed here were collected only during storm events and so it was not necessary to separate wet season and dry season data, and CDEC data were not used in this data review. Data for the Sacramento River watershed were obtained from the County of Sacramento's storm water monitoring program.

Storm flow water quality data from four out of seven watersheds, Malibu Creek, Newport Bay, Calleguas Creek, and Santa Clara River, were found to be log-normally distributed (Table 34). Geometric means, geometric standard deviations, upper and lower limits of 95% confidence interval (CI)[14] of turbidity, TSS (mg/l), and pH for the seven watersheds are presented in Tables 34-36. Note that the upper 95% CIs for turbidity at Calleguas Creek and Santa Clara watersheds were 524 and 479 NTU, respectively (i.e., very near and above the proposed AL of 500 NTU).

These two watersheds are also higher in TSS than other watersheds. The higher TSS/turbidity levels in these two watersheds may be explained by the fact that the watersheds are less developed and contain more open land that contribute largely to solids in waterbodies than other more developed watersheds such as typical urban watersheds like the Los Angeles River watershed. Land use information for each station in Los Angeles, Orange, and Ventura Counties are provided in Tables 36-38. Land use information was not available for stations in Sacramento County. pH levels are relatively homogeneous among the different watersheds (Table 35).

5.2 Impact of Land Use

Land use information was available for six of the seven selected watersheds, and these were categorized by dominant land use type. Dominant land use types were defined as the land use type occupied by 60% or more of the overall watershed area. TSS and turbidity data were plotted against dominant land use types and are shown in Figures 7 and 8. Turbidity and TSS levels were similar in watersheds with residential and open land use types, but the highest turbidity/TSS levels were higher in runoff from the open land use type than in runoff from largely residential watersheds. The Kruskal-Wallis ANOVA on Ranks, a nonparametric test that does not require assuming that all samples were drawn from normally distributed populations with equal variances, was used to examine whether or not differences in turbidity and TSS levels between the land use groups were statistically significant. The ANOVA result is summarized in Table 37. Only TSS levels show significant difference between the land use groups, and TSS concentrations were higher in runoff from the open land use group than in runoff from the residential group.

---

[14] The confidence interval represents values for the population parameter for which the difference between the parameter and the observed estimate is not statistically significant at the 5% level.

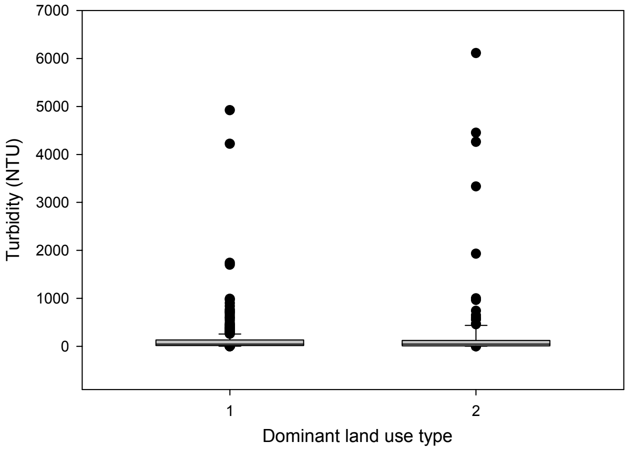


Figure 7. Turbidity in storm runoff in selected watersheds by dominant land use type; 1= Residential (N=376) and 2 = Open land (N=148)[15]

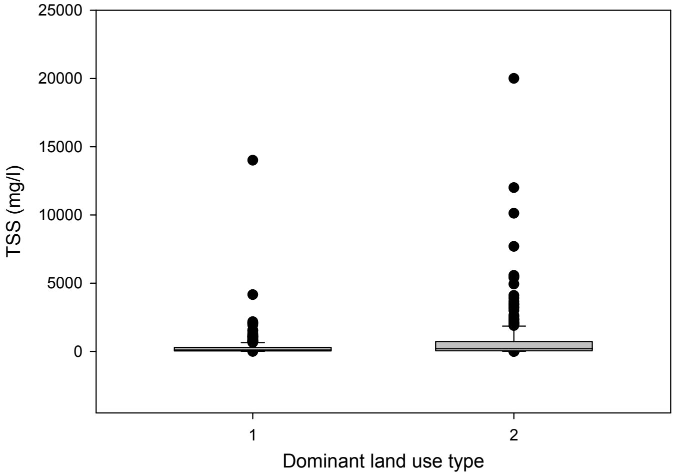


Figure 8. Total suspended solids (TSS) in storm runoff in selected watersheds by dominant land use type; 1= Residential (N=375) and 2 = Open land (N=285).

---

[15] Residential includes upstream areas of Coyote Creek (S13), Dominguez Channel (S28), L.A. River @ Wardlow (S10), Newport Bay (SADF01), Newport Bay (BARSED), San Diego Creek (CMCG02), San Diego Creek (BCF04), San Diego Creek (MIRF07), Santa Ana River (BCC02), Westminster (ABCC03, EGWC05, and WMCC04). Open land includes upstream areas of Calleguas Creek Watershed, Malibu Creek (S02), Newport Bay (WYLSED), San Gabriel River (S14), Santa Clara River (S29), Santa Clara River Watershed (within Ventura County only), Ventura River Watershed. Details on the stations are provided in Tables 2-11 in this document.

5.3 Total Rainfall vs. TSS Load

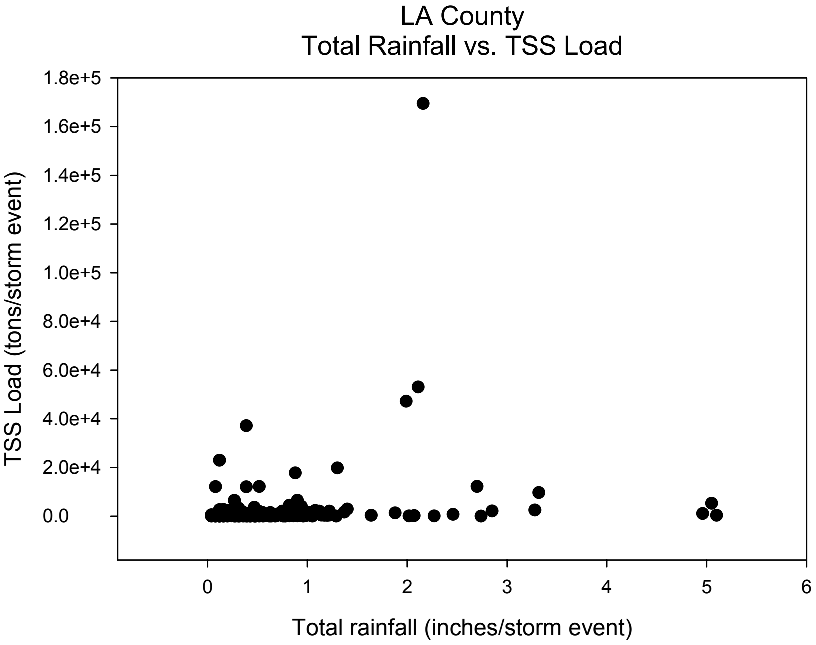
Available data on TSS loads (tons/storm event) and total rainfall (total precipitation/storm event) were obtained for multiple storm events from the storm water quality monitoring programs of Los Angeles, Orange, and Ventura Counties, and included data for five of the seven watersheds examined in detail. Other hydrologic data, such as rainfall intensity and flow, were not available. Rainfall data for Santa Clara River and Sacramento River watersheds were not available. In addition to these parameters, total runoff volume (or total discharge in acre ·feet/storm event) was available only for data obtained from Los Angeles County. Pearson product moment correlation analyses (Pearson analyses)[16] were conducted to investigate the relationship between total rainfall (also total runoff volume for Los Angeles County) and TSS load. These analyses are described below.

5.3.1 Data Categorized by County

Data from multiple storm events and multiple stations in each county were combined, and the correlation analyses were conducted in the data categorized by county. Table 38 shows the strong correlation between rainfall and TSS load. Figures 9 and 10 also show that TSS load are higher when total rainfall amounts are higher.

---

[16] Pearson Product Moment Correlation is used 1) to measure the strength of the association between pairs of variables without regard to which variable is dependent or independent, 2) to determine if the relationship, if any, between the variables is a straight line, and 3) the residuals (distances of the data points from the regression line) are normally distributed with constant variance.



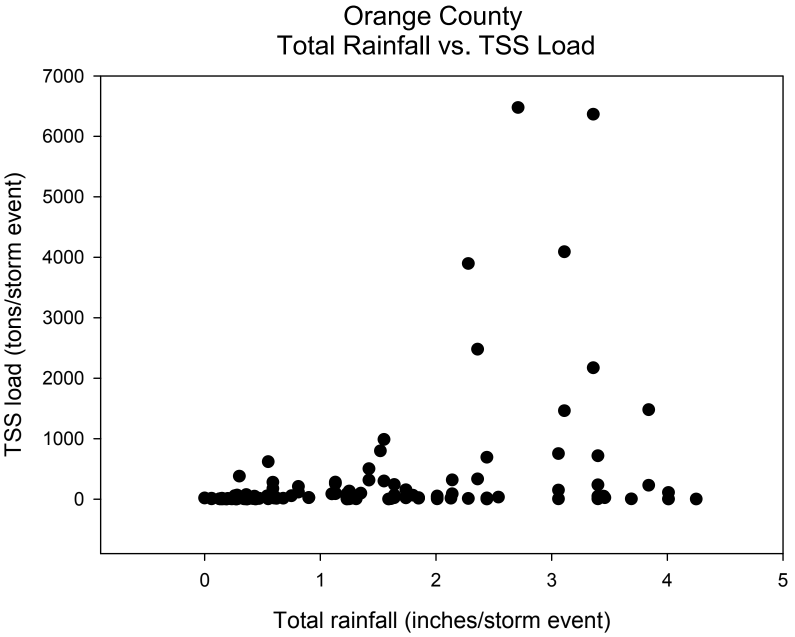


Figure 9. Total rainfall (inch) vs. total suspended solids (TSS) load (ton/storm event) in Los Angeles County; data are from multiple stations in LA and Orange Counties.

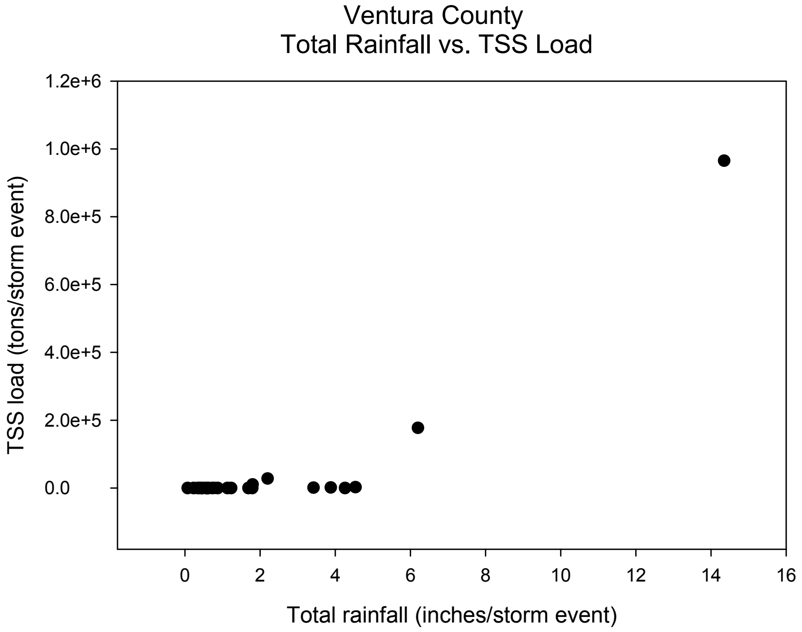


Figure 10. Total rainfall (inch) vs. total suspended solids (TSS) load (ton/storm event) in Orange and Ventura counties; data are from multiple stations in each county.

5.3.2 Data Categorized by Station

Data from multiple storm events at each station were also examined using Pearson analysis. Results are summarized in Table 39. Data from the San Gabriel River watershed, which is not included in the table, do not show any significant correlation between total rainfall and TSS load, perhaps because of water management measures (diversions to groundwater infiltration basins, engineered channels) on the San Gabriel River. Rainfall and TSS loads at six stations in four watersheds show significant correlations, but correlation coefficients (which measure of the strength of the correlation) vary among different stations. Regression analyses also indicated that regression equations describing the relationships between these variables are different among stations. Figure 11 shows examples of three stations in Newport Bay watershed.

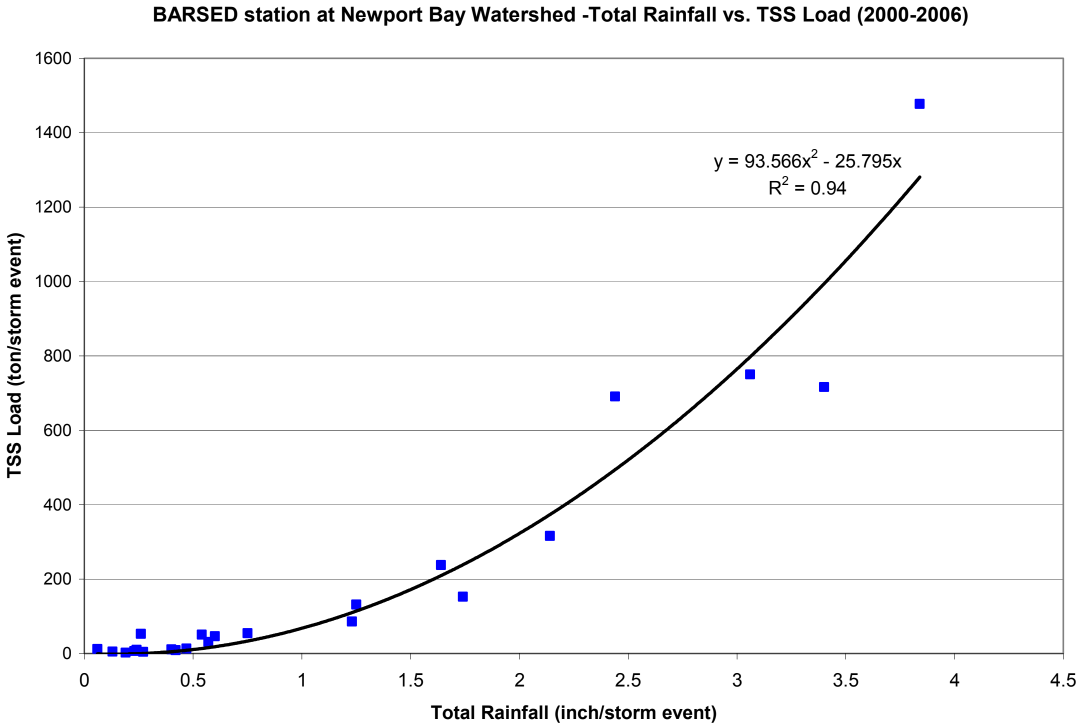


Figure 11.a. Regression analyses on total rainfall vs. TSS load at BARSED station in Newport Bay watershed.

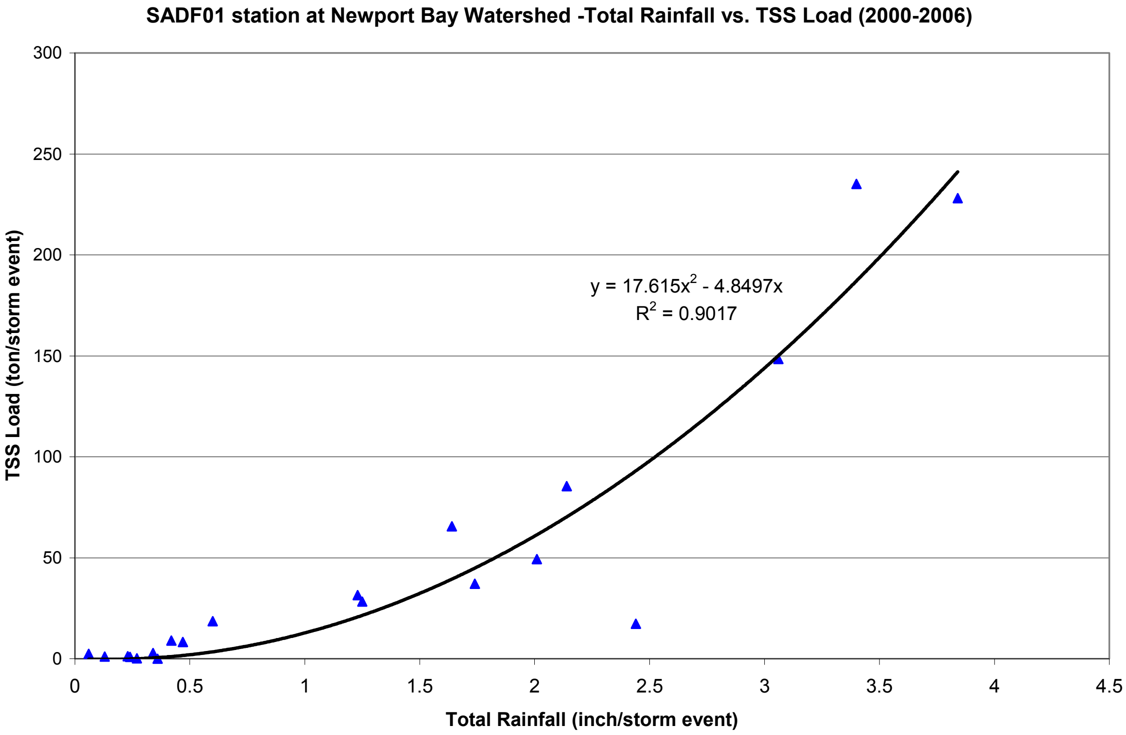


Figure 11.b. Regression analyses on total rainfall vs. TSS load at SADF01 station in Newport Bay watershed.

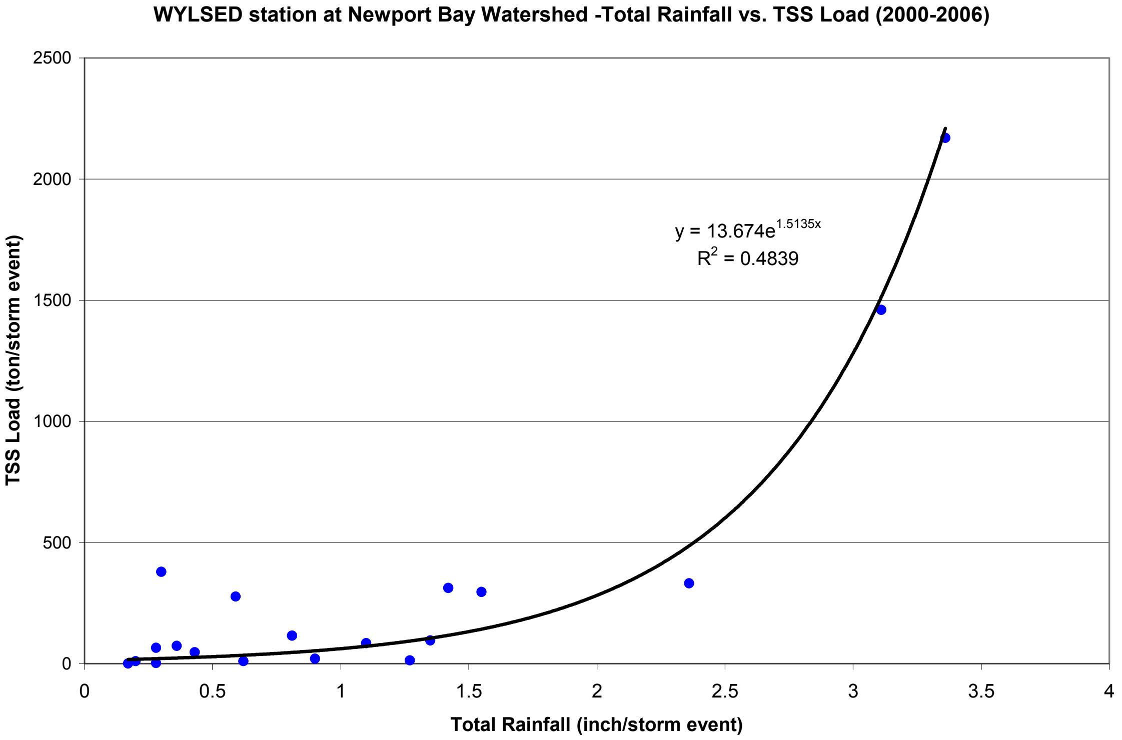


Figure 11.c. Regression analyses on total rainfall vs. TSS load at WYLSED station in Newport Bay watershed.

5.3.3 Total Runoff Volume vs. TSS Load

Available data describing the total runoff volume and TSS load from seven stations in Los Angeles County were examined using Pearson analysis. Table 40 presents the summary of the correlation analyses. At more than half of the stations, total runoff volume and TSS loads do not show any significant correlation.

The correlation and regression analyses of storm hydrologic data and TSS load data indicate that it is difficult to estimate site-specific storm-runoff TSS loads using limited hydrologic data such as total rainfall and total runoff volume. Brezonik and Stadelmann (2002) showed that rainfall amount, rainfall intensity, and drainage area (catchment size) are the most important variables in multiple linear regression models to predict event loads, but uncertainty was high in models, and the most accurate models for event mean concentrations (EMCs) generally were found when sites were categorized according to common land use and size. Therefore, various types of hydrologic data are required to estimate site-specific TSS load, and the estimation of load should be conducted with the consideration of other non-hydrologic data such as land use type and percent impervious area. In addition, it is extremely difficult to predict turbidity levels based on estimation of either TSS load or sediment load because correlation between turbidity and TSS is highly site-specific (Dodds and Whiles, 2004; Schubel et al., 1978), the correlation changes over the course of the year, though the progression is not a consistent one (Manka, 2005), and the suspended sediment-turbidity relationship shifts between the rising and falling limbs of the hydrograph (Knighton, 1998). Further discussion on factors that affect sediment load/turbidity is provided below.

5.4 Turbidity Varies Significantly Depending On a Variety Factors

Instream turbidity levels are highly variable between locations, between times at the same location, and between different channel cross sections at the same location (Davies-Colley and Smith, 2001; NCASI, 1999). Conroy and Barrett (2001) showed highly significant variability in turbidity levels between storm runoff events, within storm runoff events, and between sub-basins of a watershed.

The variations in turbidity readings for a nephelometer[17] are the result of light attenuation by particles (both organic and inorganic) of different size, shape, refractive index, and absorbing properties. In addition, for particles to remain in suspension (resulting in turbidity), they must have slow settling velocities. As such, inorganic soil particles between 0.2 and 5 µm and organic particles between 1 and 20 µm are the most significant contributors to persistent turbidity. This suggests that watersheds with different parent material, particle size distribution, clay mineralogy, and vegetation types would have different turbidity values for comparable flow and suspended sediment concentration values (Davies-Colley and Smith, 2001).

Due to significant differences within and between the factors measured, changes in turbidity levels due to BMP implementation may be very difficult to detect. Monitoring programs designed to test the efficacy of BMPs in reducing turbidity will require lengthy pre- and post-treatment monitoring periods, and monitoring programs will require a large number of monitoring locations in areas that have highly heterogeneous physical characteristics.

---

[17] Nephelometer is an instrument for measuring suspended particulates in a liquid or gas colloid. It does so by employing a light beam (source beam) and a light detector set to one side (usually 90°) of the source beam. Particle density is then a function of the light reflected into the detector from the particles. To some extent, how much light reflects for a given density of particles is dependent upon properties of the particles such as their shape, color, and reflectivity. Therefore, establishing a working correlation between turbidity and suspended solids (a more useful, but typically more difficult quantification of particulates) must be established independently for each situation.

5.5 CLIMATE CONTRIBUTES MORE SIGNIFICANTLY TO SEDIMENT YIELD THAN GEOLOGY DOES

Inman and Jenkins (1999) studied the stream flow and sediment flux characteristics of the 20 largest streams entering the Pacific Ocean along the central and southern California coast, extending for 750 km from Monterey Bay to just south of the U.S./Mexico border (Table 41). Drainage basins ranged in area from 120 to 10,800 km^2, with headwater elevations ranging from 460 to 3770 m. Mean annual stream flow ranged from 0 (m^3/yr) to a maximum of 1×10^9 (m^3/yr) for the Santa Clara River, with an associated suspended sediment flux of 46×10^6 tons between 1944 and 1995 (Table 42). The sediment flux of the rivers during the three major flood years averaged 27 times greater than the annual flux during the previous dry climate period (Table 42). The effects of changes in climate are superimposed on erodibility associated with basin geology. The sediment yield of the faulted, overturned Cenozoic sediments of the Transverse Ranges is many times greater than that of the Coast Ranges and Peninsular Ranges. Thus, the abrupt transition from dry climate to wet climate in 1969 brought a suspended sediment flux of 100 million tons to the ocean edge of the Santa Barbara Channel from the rivers of the Transverse Range, an amount greater than their total flux during the preceding 25-yr dry period.

These differences in sediment concentrations and loads from one year to another highlight the importance of climate in evaluating sediment concentrations and fluxes, and the need to collect data from both dry and wet years in evaluating sediment concentrations and variability. These data demonstrate that any data collection program must span a range of time and climate conditions to be representative of the range of conditions likely to occur, and to be useful in calculating NELs and ALs.

6 THE ECOLOGICAL ROLE OF SUSPENDED SEDIMENT

6.1 Introduction

A number of the world's most productive aquatic ecosystems contain high levels of suspended sediment, while other ecologically important ecosystems are very sensitive to sediment and depend upon water with low suspended sediment concentrations. Optimal levels of suspended sediment vary among different fish habitats. Fish and aquatic life that are native to streams have evolved over time to adapt to varying levels of suspended sediment. Many historically turbid waterbodies in California have been severely altered in order to secure water resources for municipal, industrial, and agricultural uses. In those systems, the delivery of sediment (both suspended sediment and bedload) has declined dramatically due to increasing water diversions and retention in reservoirs. Decreases in sediment concentrations in water have the potential to cause downstream erosion, beach loss, and habitat alteration. Scientists, engineers and planners are starting to recognize that sediment is a valuable resource that recreates and sustains habitats valued, such as salt marshes and mudflats; in some environments, scientists are also recognizing that, instead of too much sediment, there may not be enough sediment to support beneficial uses (Williams, 2001).

The topics to be discussed in this section include: 1) coastal erosion and beach loss by declining sediment transport in California, 2) the ecological role of suspended sediment in aquatic systems, and 3) deleterious effects of sediment in aquatic systems.

6.2 Decline in Sediment Transport Contributes to Coastal Erosion and Beach Loss across Coastal California

The reduction in sediment transport has caused well-documented coastal erosion and beach loss in coastal areas of California, which has resulted in significant impact on local economies, recreation, and public safety as well as ecosystems.

San Pablo Bay and Suisun Bay, for instance, have undergone erosion in shallow areas since the 1950s (Cappiella et al., 1999; Jaffe et al., 2001; Jaffe et al., 1998). In San Pablo Bay, the peak in sedimentation rate corresponds to the peak in hydraulic mining debris entering the Bay, but sedimentation rates then declined sharply until early 1900’s (Jaffe et al., 1998). Sediment rates in these systems stabilized in the early to mid-1900's (Figure 12), but from 1951 to 1983, the sedimentation rate again declined. Decreased sedimentation rates between 1950 to 1983 could be the result of decreased sediment supply, as water projects reduced peak flows (responsible for most of the sediment transport to the Bay), and as sediment was captured behind dams and control structures. San Pablo Bay lost 7 million m^3 of sediment from 1951 to 1983 (Jaffe et al., 1998).

Between 1942 and 1990, more than two-thirds of Suisun Bay was eroding (Cappiella et al., 1999), and from 1867 to 1990, Suisun Bay had a net loss of over 100 million cubic meters of sediment, which is equivalent to a loss of 73.8 cm over the entire Suisun Bay area. This decrease was a result of factors such as the ban on dumping tailings from hydraulic mining that was passed in 1884, and the increase in water distribution and flood control projects during the 20th century (Jaffe et al., 1996). At the same time, sea level at the Golden Gate has risen 21 cm and is predicted to rise further, thus exacerbating the habitat effects of sediment loss (Roos, 2005).

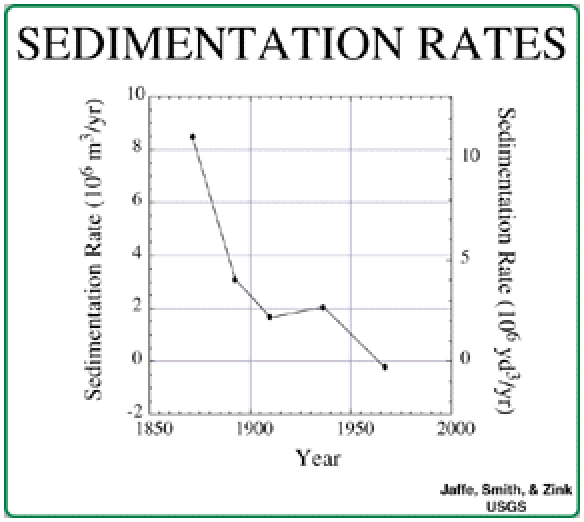


Figure 12. Change in sedimentation in San Pablo Bay during the past 150 years; From Jaffe et al. (1998).

This erosion in bays has resulted in remobilization of buried contaminants contained in sediment buried long ago. For example, in San Francisco Bay, the internal supply of contaminants such as mercury from resuspension and biological recycling is one of the major issues affecting the water quality and biological integrity of the Bay (Jaffe et al., 2001; Johnson and Looker, 2003). Redistribution of eroded sediment influences the availability of the benthic pool of contaminants (Jaffe et al., 2001). In addition, Williams (2001) further predicted that a coupling of a decrease in sediment supply with an increase in sea level will result in conversion of some mudflats to shallow subtidal habitats, resulting in an increase in shoreline erosion and consequent losses of fringing marsh[18] and the undermining of levees.

---

[18] Fringing marsh is marsh attached to the shore of the barrier or mainland

Sandy beaches serve to protect coastal lands from erosion when high-energy winter storms bring heavy surf[19]. Beach sand dissipates the destructive energy of waves and prevents wave damage to sea cliffs and coastal property. In many areas of the state, dams and increasing urbanization have interrupted the necessary supply of beach sand from the watersheds to the beaches, and sand-starved beaches cannot shield the coast from erosion. In the past, up to 90% of natural sand supply for California beaches came from rivers and streams (Patsch and Griggs, 2006b). Water runoff from a natural watershed transports a mixture of sand, silt, and clay to the coast. Silt and clay are then transported to deeper water while the sand remains close to shore and protects the beach. The impervious surfaces of streets, parking lots, and structures further reduce the amount of sediment produced by precipitation and runoff. Additionally, urban drainage systems are designed to control runoff and prevent the transport of sediment and pollutants to waterways and eventually to the ocean.

Damming of rivers or streams reduces sediment delivery to the coast both by trapping sand in the reservoirs and by reducing peak flows that transport the greatest amount of sediment. Most of California's large dams, under good management, have reservoir capacities sufficient to absorb all incoming water during a normal winter, releasing low flows to downstream areas during the spring and summer months. The magnitude and frequency of peak flows are therefore reduced, decreasing the river's ability to transport material downstream. Dams act as complete barriers to bedload and trap most of the suspended sediment load, except during large flood events when flows overtop the dam or pass through the spillway. The average trapping efficiency (the amount of suspended sediment trapped by the dam) for most coastal dams in California is about 84% (Brune, 1953; Willis and Griggs, 2003). Recent work by Willis and Griggs (2003) and Slagel (2005) indicates that the present day delivery of sand to the shoreline has been reduced to about 10 – 11 million yds^3/year, or approximately a 23-25% reduction from natural conditions, due to the more than 500 dams on California's coastal streams. Approximately 3 million yd^3 of sand is trapped each year, and a total of about 163 million cubic yd^3 of sand has now been deposited behind dams on the state's 21 major rivers (Slagel, 2005). The great majority of this reduction is concentrated in southern California (Slagel, 2005; Willis and Griggs, 2003). For instance, in the Santa Barbara littoral cell[20], dams have reduced sediment flux from streams by 41%, and the Silver Strand littoral cell has lost 72% of its natural sand supply (Patsch and Griggs, 2006a). In the Oceanside littoral cell, present sand supply is only 45% of the natural

---

[19] Information on beach loss is obtained from Scripps Institution of Oceanography, Coastal Morphology Group (http://coastalchange.ucsd.edu/index.html).

[20] A coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks.

(pre-1850) sand supply. The 55% reduction in sand flux to the beaches is easily seen during the winter when sand is moved offshore by large waves. In particularly stormy winters, the sand beach disappears and only the wave-cut platform and cobble berm[21] remain.

The loss of beach has severely degraded the recreational value of beaches, and that loss combined with the undercutting bluff erosion creates dangerous overhangs which constitute a serious public safety issue. There have been two fatalities in recent years caused by sudden bluff collapse in Oceanside (http://coastalchange.ucsd.edu/index.html).

Consequently, considerable efforts have been made to prevent further erosion by restoring the beach (building sand bypasses around dams, removing dams, restoring wetlands and recycling sand to the beach, and pumping shelf sand to the beach) or stabilizing the beach with sea walls or riprap. More than 130 million m^3 of sand have been supplied from harbor and other coastal construction projects since 1930 to beaches across the State. Santa Monica and Coronado beaches received most of this sand supply, and beach widths increased to several hundred meters. The first major beach nourishment project in California, carried out solely for the purpose of widening beaches, was completed in San Diego County in 2001. About 1,500,000 m^3 of sand was dredged from six offshore sites and pumped onto 12 different northern San Diego County beaches. The total cost was \$17.5 million, or \$11.67/m^3. However, most of the sand was transported either downcoast or offshore during the first winter, although one of the 12 sites retained sand for more than a year (Griggs, 2005).

6.3 Ecological Impact of Suspended-sediment in Aquatic Systems

A dramatic decline of fish, known as the Pelagic Organism Decline (POD), has occurred in the California Delta[22] in recent years. In the period 2002-2004, abundance indices calculated by the Interagency Ecological Program[23] (IEP) have been at record lows for Delta smelt (*Hypomesus transpacificus)* and age-0 striped bass (*Morone saxatilis)* and near-record lows for longfin smelt (*Spirinchus thaleichthys)* and threadfin shad (*Dorosoma petenense*). Delta smelt is a rare and environmentally-sensitive native species listed as threatened under both the California and US Endangered Species Acts.

---

[21] Flat space between the base of the curtain wall and the inner edge of the moat; level area separating ditch from bank.

[22] The San Joaquin-Sacramento River Delta is an expansive inland river delta in northern California. It is formed at the western edge of the Central Valley by the Sacramento River at its confluence with the San Joaquin River just east of where the river enters Suisun Bay (an upper arm of San Francisco Bay).

[23] http://www.iep.ca.gov/

Water management actions in the estuary are closely tied to protecting delta smelt, even on a daily basis during some portions of the year. For instance, State water officials turned off the export pumps that send water to southern California from the Sacramento-San Joaquin Delta on May 31, 2007, after more than 200 young Delta smelt were killed at the south delta pumps over Memorial Day weekend. Recent court rulings[24] have further restricted water exports from the Delta to protect endangered fish populations. Striped bass and threadfin shad are both introduced species; because they comprise a substantial portion of fish biomass in the ecosystem and support valuable recreational fisheries, their declines are also cause for concern. While these declining species have shown evidence of long-term declines, there appears to have been a precipitous "step-change" to very low abundance by at least 2002-2004 even though flow conditions varied within a usual range (Figure 13).

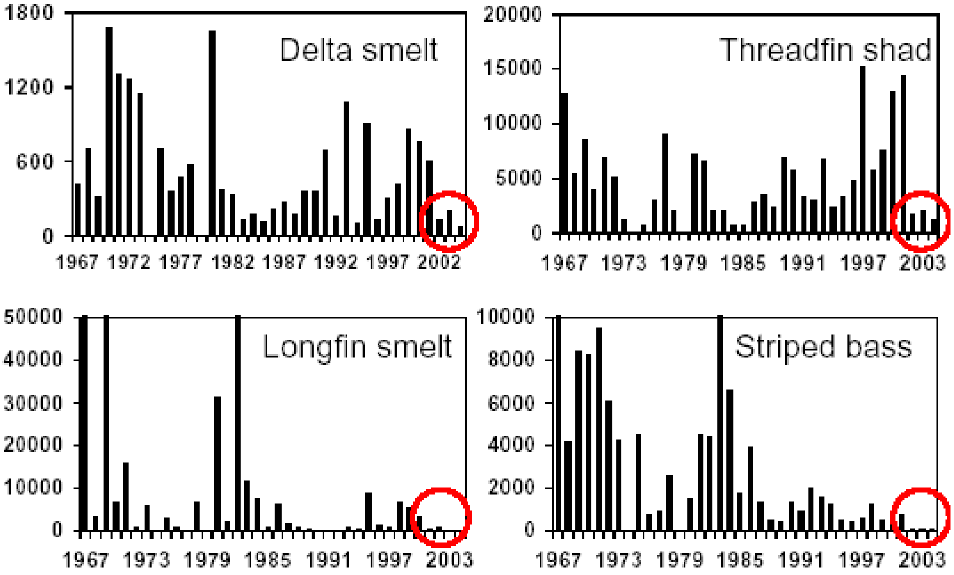


Figure 13. Decline in fish population; Source, Power Point Presentation prepared by Ted Sommer at California Department of Water Resources.

Similar flow conditions have supported modest production of these species in the past. In response to these changes, the IEP formed a Pelagic Organism Decline (POD)

---

[24] In September 2007, U.S. District Judge Oliver Wanger ordered the state to protect the smelt by reducing flows pumped out of the Delta from late December until June, when the fish spawn in the Delta.

work team to evaluate the potential causes of the decline. More than $3.7 million was invested in 2006 alone and numerous studies were conducted.

Wright and Schoellhamer (2004) documented that annual sediment transport to the estuary from the Sacramento River has declined by 50% since 1957. In addition, submerged aquatic vegetation, especially the invasive Brazilian waterweed (*Egeria densa*), has become increasingly abundant in the system during the past 20 years (Foschi, 2000). Non-native striped bass as well as native fish do not use vegetated habitats extensively (Brown, 2003; Nobriga et al., 2005). Brazilian waterweed also increases water clarity by trapping suspended sediment (Nobriga et al., 2005). Therefore, a decline in suitable physical habitat due to decreased turbidity and increased foreign vegetation is one of the possible mechanisms causing the POD. Feyrer et al. (2007) concluded that the decline in suspended-sediment level might have caused, at least in part, the decline of pelagic fish. By examining a 36-year record of concurrent midwater trawl and water quality sampling conducted during fall in the San Francisco Estuary[25], Feyrer et al. (2007) found that suspended sediment (measured as Secchi depth[26]) was an important factor in explaining the occurrence of Delta smelt and striped bass. The results of regression modeling indicated that the increase in Secchi depth (i.e., decreased turbidity) in the Delta is correlated with the decrease in the populations of the Delta smelt and striped bass. Delta smelt require suspended sediment for successful feeding (Baskerville-Bridges et al., 2004), and because predation is mediated by the suspended sediment, it is possible that a long-term increase in Secchi depth may have affected feeding success and predation pressure. In the estuary, regions with high levels of suspended sediment that are associated with low salinity or entrapment zones are important rearing areas for young fishes (Bennett, 2005; Dauvin and Dodson, 1990). The increase in Secchi depth is primarily a function of a decline in total suspended solids (Figure 14; Jassby et al. 2002).

Efforts have being made to reverse the trend of declining suspended sediment for pelagic fish. The POD triggered for several dischargers the adoption of action plans to increase flow and suspended sediment during summer in order to increase the habitat for Delta smelt both by maximizing physical habitat area and by supporting the food web[27].

---

[25] San Francisco Estuary area includes San Francisco Bay, San Pablo Bay, Suisun Bay, and the San Joaquin-Sacramento River Delta (Feyrer et al. 2007). Data were collected from San Pablo Bay, Suisun Bay, and the San Joaquin-Sacramento River Delta.

[26] Secchi depth is a parameter used to determine the clarity of surface waters. The measurement is made with a "Secchi" disk, a black and white disk that is lowered into the water and the depth is recorded at which it is no longer visible. A Secchi depth recording of 5 ft indicates that the device was last visible at 5 ft below the surface. Low readings indicate turbid water which can reduce the passage of sunlight to bottom depths. A decrease in the Secchi depth indicates a decrease in suspended sediment level.

[27] Source: Pelagic fish action plan March 2007 by CA DWR and CA Dept. Fish and Game

However, no significant improvement in fish populations has been observed, and studies to find the cause of POD are still being conducted.

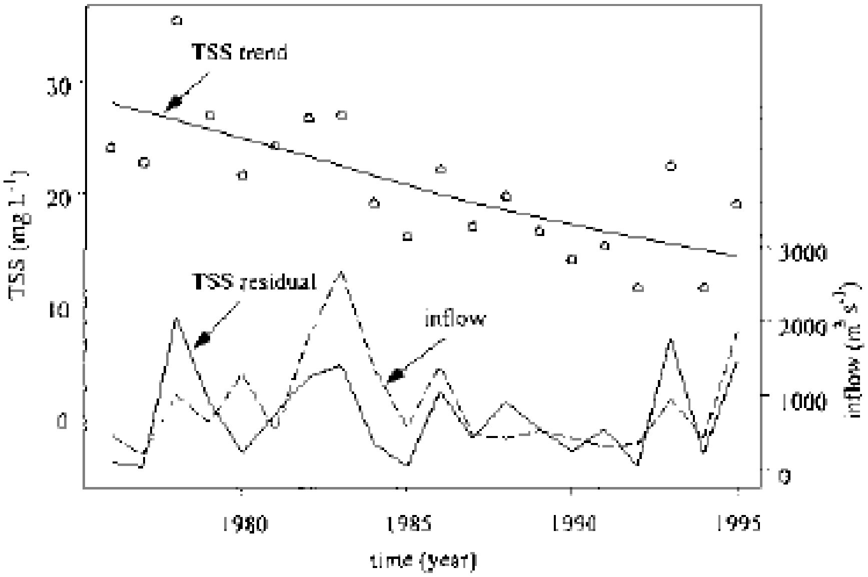


Figure 14. Mean TSS in Delta for the water year with the locally weighted regression trend line and the time series of TSS residuals from trend line. Mean inflow for the water year is also plotted for comparison with the TSS residuals; Source, Jassby et al. (2002).

As seen in the POD case, suspended sediment in water may play an important role in aquatic ecosystem. It is especially true for small prey fish. Suspended sediment and associated turbidity plays a role in 1) providing cover for prey, 2) initiating the upstream migration of sea trout[28], and 3) a nutrition source. Anthropogenic alteration of natural levels of suspended sediment can cause adverse effects on aquatic ecosystem.

Suspended sediment plays a critical role on survival of prey fish. Gregory and Northcote (1993) investigated the effect of turbidity on the foraging behavior of juvenile

---

[28] The sea trout is a migratory form of the common and widely distributed brown trout (*Salmo trutta L.).* It migrates to the sea to feed and grow before returning to fresh water to spawn. The brown trout is widely scattered throughout California. However, the waters in which it is abundant are relatively few. (add citation)

chinook salmon (*Oncorhynchus tshawytscha*) across a range of turbidity levels (<1, 18, 35, 70, 150, 370, and 810 NTU) in the laboratory. While investigating how suspended sediment and the presence of avian predators influenced the foraging behavior of juvenile Chinook salmon, they found that feeding rates for surface and benthic prey increased with intermediate suspended sediment levels (35-150 NTU) but ultimately declined at high suspended sediment levels (>150 NTU). Boehlert and Morgan (1985) also recorded enhanced feeding rates for larval pacific herring (*Clupea harengus pallasi*) feeding at intermediate suspended sediment levels (500 and 1000 mg/l). In this study, feeding Pacific herring larvae were exposed to suspensions of estuarine sediment and Mount Saint Helens volcanic ash at concentrations ranging from 0 to 8000 mg/l.

The positive effect of suspended sediment is pronounced for larval fish, because their visual field is short, and the detection of food sources, such as plankton, is less interfered by suspended sediment. This, together with a decreased risk of predation, makes turbid environments more beneficial for some species and size groups of fish (planktivores[29] and fish larvae) and less so for others (adult piscivore[30] fish). Thus, suspended sediment may have a structuring effect on a fish community (Utne-Palm, 2002).

Although increasing suspended sediment concentration tends to decrease the visual range of fish, a certain degree of suspended sediment, albeit relatively low, may increase the reaction distance (distance between predator and prey at time of detection), the growth and the feeding rates of both fish (Gregory and Northcote, 1993; Rowe and Dean, 1998; Utne, 1997), and fish larvae (Boehlert and Morgan, 1985; Bristow and Summerfelt, 1994; Miner and Stein, 1993) when compared to clear waters. The change in feeding rates over different turbidity conditions varies widely among species (Figure 16), so that it is difficult to assess the exact range of turbidity that increases feeding rates for different fish species.

---

[29] Plankton-eating

[30] Fish-eating

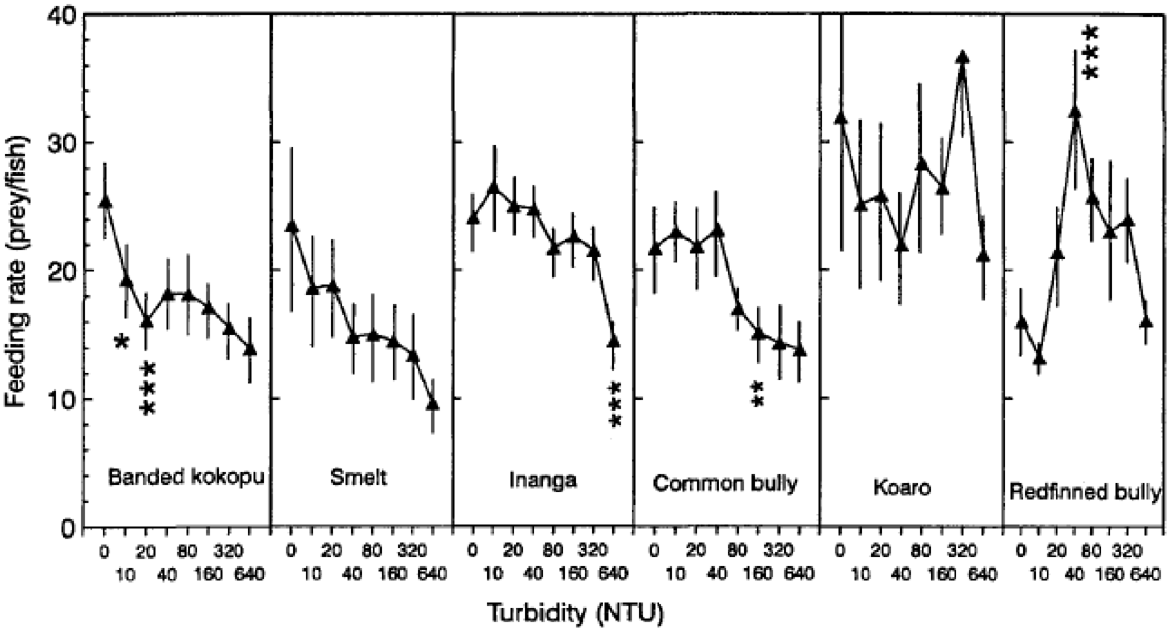


Figure 15. Effects of turbidity level on mean feeding rate (+ SE) for each species. Significant differences to the control (0 Nephelometric Turbidity Units (NTU)) level were determined by one tailed Mests for inanga and common bully and by two tailed Mests for banded kokopu, smelt, and redfinned bully (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$); source, Rowe and Dean (1998).

Native fish are more likely affected by changes in suspended-sediment levels. Alien species most commonly become established in highly altered habitats (Gadomski and Barfoot, 1998; Meng and Matern, 2001; Ross, 1991). Feyrer and Healer (2003) sampled 11 sites in the southern Sacramento-San Joaquin Delta from 1992–1999 to characterize fish communities and their associations with environmental variables. Native species (tule perch, *Hysterocarpus traski*, and Sacramento sucker, *Catostomus occidentalis*) were associated with conditions of high river flow/high levels of suspended sediment, while the majority of the non-native species were associated with either warm water temperature or low river flow conditions. This study shows that decrease in suspended sediment may have an adverse impact on native fish populations that are adapted to naturally high suspended sediment levels. High turbidity levels may indicate high phytoplankton levels as well as high levels of sediment from erosion. However, the populations of zooplankton, which Delta smelt fish feed upon, have not significantly changed (Armor et al., 2006). Therefore, the dominant impact on the turbidity is likely that from erosion-generated suspended sediment.

Suspended-sediment gradients may provide a navigational aid to fish entering estuaries. In the British Isles, Svendsen et al. (2004) showed a positive correlation between stream discharge and the probability of a sea trout initiating upstream migration by monitoring movements of adult female anadromous[31] brown trout *Salmo trutta* (sea trout) during upstream spawning migration and following spawning in a stream with tributaries. Mitchell et al. (2007) also show that abundance of adult spawning salmonids[32] within Catamaran Brook in Canada is logarithmically related to stream discharge and provides good predictive ability. Discharge is moderately exponentially-correlated with suspended sediment level (Dodds and Whiles, 2004). High suspended sediment is likely to reduce the antipredator behavior (Abrahams and Kattenfeld, 1997) of the sea trout. This is in agreement with the impaired foraging success of large piscivorous fishes in turbid water (Utne-Palm, 2002). This hypothesis is also supported by studies suggesting that certain piscivorous avian species prefer occupying watersheds with high transparency (Blair, 1992) where they hunt their prey more effectively (Brenninkmeijer et al., 2002; Eriksson, 1985). Thus, increase in discharge/suspended-sediment level confers protection from predators and initiates the migration.

Suspended sediment is a nutritional source for filter-feeding and sediment-digesting invertebrates such as mayflies, which play an important role in aquatic ecosystem (Broekhuizen et al., 2001; Wallace and Merritt, 1980; Wotton, 1994). Several groups of aquatic insects, with habitats ranging from high elevation streams to saltwater estuaries, use this filter-feeding method and consume significant quantities of suspended sediment, including living organisms and both organic and inorganic detritus. Filter-feeding insects and sediment-digesting invertebrates constitute important pathways for energy flow and are very important in the productivity of aquatic environments (Wallace and Merritt, 1980).

6.4 Deleterious Effects of Sediment in Aquatic Systems

Influx of suspended sediment is a natural and vital process for aquatic systems. The effects of suspended sediments on receiving water ecosystems, however, are complex and multi-dimensional. Elevated sediment can cause deleterious effects on aquatic life that is adapted to a low sediment/turbidity environment.

---

[31] Fish that hatch rear in fresh water, migrate to the ocean (salt water) to grow and mature, and migrate back to fresh water to spawn and reproduce.

[32] Salmonids or Salmonidae is a family of ray-finned fish, the only living family of the order Salmoniformes. It includes the well-known salmons and trouts; the Atlantic salmons and trouts of genus Salmo give the family and order their names.

These effects in estuarine environments were thoroughly reviewed by Wilber and Clarke (2001). Excessive sediments in aquatic systems contribute to increased turbidity leading to altered light regimes which can directly impact primary productivity, species distribution, behavior, feeding, reproduction, and survival of aquatic biota. Reduced light can reduce production of phytoplankton, submerged aquatic vegetation, and the zooxanthellae[33] in corals. Reduced light and increased turbidity can also affect the feeding ability and movements of fish, especially larval fish. Larger fish may be able to reduce some of these effects by avoiding low visibility water. Wildlife may also have trouble hunting in turbid water, but like some fish they may be able to avoid some short-term turbidity events by relocating.

Other direct effects of increased sediment include physical abrasion, and clogging of filtration and respiratory organs. The concentrations of suspended sediment required to cause these sorts of effects are generally very high, but may occur in certain situations such as near dredges (Wilber and Clarke, 2001). In extreme cases, excess sediment can cause burial and smothering of infaunal[34] or epibenthic[35] organisms. Most estuarine benthic organisms are adapted to living in an environment subject to periodic resuspension of sediment and can dig out from under a small amount of sediment (Maurer et al., 1986). Demersal[36] eggs may be particularly vulnerable, however, as only a few millimeters of deposited sediment may prevent them from hatching.

Some of the most important indirect effects of increased sediment in estuarine and marine habitats relate to loss of primary and secondary production. Reductions in primary production effects primary consumers, which in turn affects secondary consumers, and on up the food chain.

In streams and rivers, according to Waters (1995), increased sediment has two major avenues of action: 1) direct effects on biota and 2) direct effects on physical habitat, which results in indirect effects on biota. Examples of direct effects on biota include suppression of photosynthesis by shading primary producers; increased drifting of, and consequent predation on, benthic invertebrates; and shifts to turbidity-tolerant fish

---

[33] Zooxanthellae are unicellular yellow-brown (dinoflagellate) algae which live symbiotically in the gastrodermis of reef-building corals (Goreau et al., 1979). It is the nutrients supplied by the zooxanthellae that make it possible for the corals to grow and reproduce quickly enough to create reefs. Zooxanthellae provide the corals with food in the form of photosynthetic products. In turn, the coral provides protection and access to light for the zooxanthellae.

[34] Infauna: animals living within submerged sediments

[35] Epibenthic: Attached to the bottom

[36] found at or near the bottom of the sea or lake

communities. Indirect effects on biota will occur as the biotic assemblages that rely upon aquatic habitat for reproduction, feeding, and cover are adversely affected by habitat loss or degradation of this habitat. A noteworthy example of indirect effects of sediment in streams and rivers is the loss of spawning habitat for salmonid fishes by an increase in embeddedness, caused by the entrapment of fine material in the gravel. Increased sedimentation can limit the amount of oxygen in the spawning beds which can reduce hatching success, or trap the fry in the sediment after hatching.

To assess the impact of elevated suspended sediment in streams and rivers, in addition to a total load of suspended sediment, the duration of elevated suspended sediment concentrations in a stream is important from a biological and a water quality perspective. Newcombe (1994), Newcombe and MacDonald (1991), and Newcombe and Jensen (1996) synthesized numerous studies on the physiological response of fish to increased suspended sediment concentration. They proposed a severity (SEV) of ill effects index that describes the response of fish to different doses [concentration (mg/l) × duration of exposure (hours)] of sediment. They created a SEV scale of 0-14 based on the regression of exposure duration and sediment concentration in the numerous studies that they examined. This allowed creation of multiple functions based on taxonomy, life stage, and life history. Figure 16 shows relational trends of fresh water fish activity to turbidity values and time. It is a generic, un-calibrated impact assessment model based on Newcombe and Jensen (1996).

6.5 Conclusion

Sediment plays important roles in an ecosystem by providing a supply of sand to beach, a cover for prey, and a nutrition source for filter-feeding organisms, and it cues the migration of fish. The alteration of natural-background levels of suspended sediment can not only influence native species negatively and also can be even beneficial to some non-native species. The example of the decline in the population of Delta pelagic fish appears to show how detrimental the impact of anthropogenic alteration of suspended-sediment level may be to fish populations. Environmental management and regulation have focused primarily on the effort of reducing sediment levels in water, for example, to protect salmon spawning habitats. As shown in the POD case, high suspended-sediment levels that are harmful to spawning salmon in spawning habitat are also necessary to support Delta pelagic fish. In order to avoid any unwanted and/or unexpected consequences that may be brought by any new environmental regulation, it is critical to consider any possible impact on the entire ecosystem and to incorporate local conditions into the new regulation. In the case of sediment, it is important to maintain natural background levels of sediment, and to avoid changes in sediment concentrations that either reduce or increase sediment concentrations and loads beyond the natural range of a particular stream.

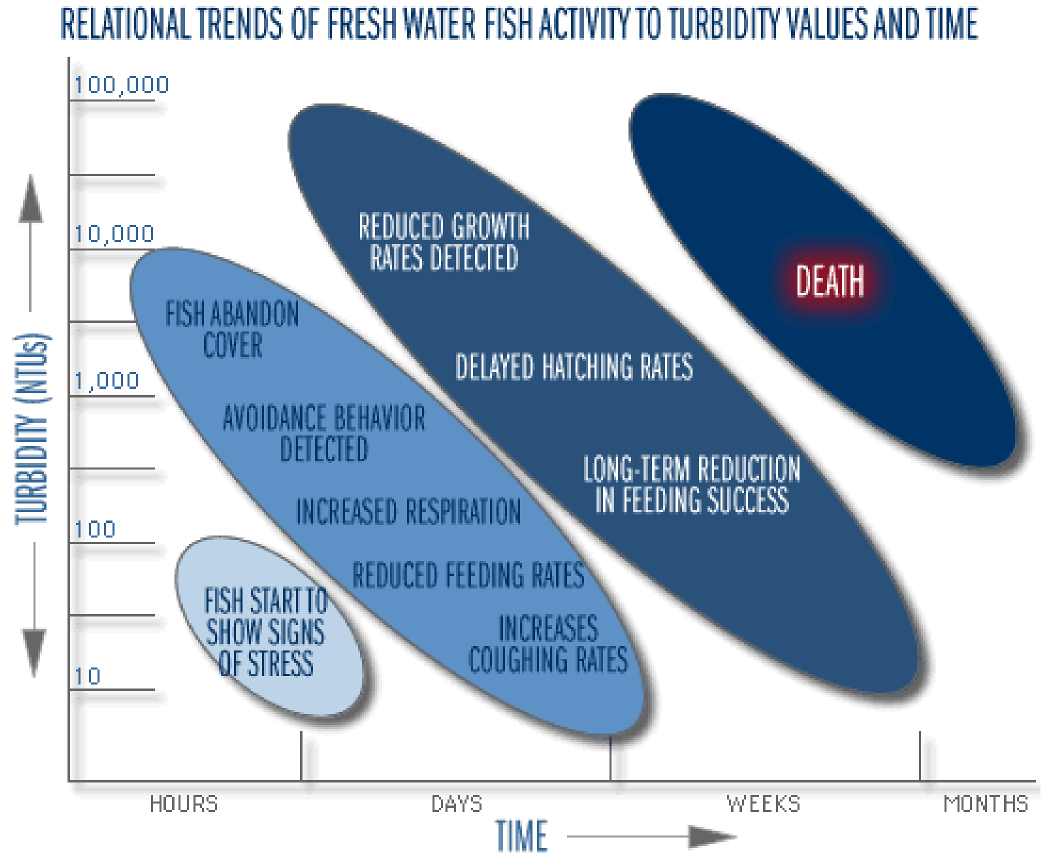


Figure 16. Relational trends of freshwater fish activity to turbidity values and time; source, Water Action Volunteers, Monitoring Factsheet Series, UW-Extension, Environmental Resources Center.

7 CONCLUSIONS AND RECOMMENDATIONS

In assessing the options for numeric effluent limits against which storm water monitoring data from construction sites could be compared, it is important to recognize the unique nature of storm flow runoff. Storm water discharges are quite different from other types of discharges in that they are intermittent and highly variable, both in terms of flow rates/volumes and constituent concentrations. For these reasons, the methods used to develop NELs for steady-state discharges (e.g., POTW discharges, discharges of non-storm industrial process water) are not applicable to storm water discharges generally, including storm water discharges from construction sites. In fact, storm water constituent concentrations are highly variable and typically do not fit into neat normal or log-normal distributions; rather, they tend to be "heavy-tailed" or to fit "extreme value distributions." Thus, it will be necessary for the SWRCB (or USEPA) to develop a new methodology suitable for calculating NELs for discharges of storm water.

The unique nature of storm flows must be considered when any type of numeric limits, benchmarks, or action levels are considered for development. In general, the more stringent the numeric level, the more data are needed to properly develop that level, and the more robust the methodology used to assess compliance with these limits must be. Because few data are available for discharges from construction sites, and because few receiving water data are available for the constituents to be regulated in these discharges, it is important to design a program that will collect the data necessary to develop a methodology for determining and implementing limits/benchmarks/action levels.

Currently available data appear to support the limited development and application of Action Levels (ALs), but not numeric effluent limits (NELs). ALs would be defined as constituent concentrations or levels that would serve to identify storm water discharges with a propensity, based on monitoring data, to contribute disproportionately to water quality concerns or impacts to beneficial uses in receiving waters, to identify BMP failures, and to trigger an iterative best management practice (BMP) management approach. Because ALs would not be used to determine permit compliance (rather, they would trigger an iterative BMP approach), fewer data are necessary, and a less robust process could be used for AL development than would be necessary for NELs.

If Active Treatment Systems (ATS) are used on construction sites, NELs for discharges from these systems appear to be appropriate. It is important to assure that ATS is used only where warranted by ambient environmental and receiving water conditions (e.g., upstream of sensitive habitat, and where the beneficial uses are not dependent upon the presence of sediment to maintain local geomorphology or ecology). Because improper dosing and usage of chemicals associated with ATS can cause toxicity, use of ATS without NELs is likely inappropriate. As detailed separately (Geosyntec 2007), it appears that the appropriate regulatory approach would be to use ATS only where necessary, to make sure personnel implementing ATS are appropriately trained, and to use NELs to minimize the likelihood of adverse environmental effects to receiving waters.

Specific recommendations for the use of ALs and NELs are provided below.

NELs and ALs for pH

Certain materials used at construction sites have the potential to alter pH. For example, lime may be used to stabilize soils, and construction materials related to concrete placement and the vertical build phase may alter pH in storm water runoff. When these materials are not present on site, or when they are kept out of rainfall and runoff, the pH of storm water runoff from the site should closely match background or ambient pH levels.

Natural ambient pH levels may vary significantly. For example, rainfall often has a low (acidic) pH, due to equilibrium of rain water with carbon dioxide (CO_2) in the atmosphere; pH values in the range of 4.5 to 5.0 are common for precipitation. Once rainwater contacts soil, rock, or vegetation, the pH generally rises relatively quickly to a more neutral level. The pH of receiving waters is also affected by the geology and soil type over which rainfall flows, or through which groundwater flows, to reach receiving waters. Similarly, the buffering capacity of a receiving water will affect its response to flows that have higher or lower pH; buffering capacity is also a function of water chemistry, and varies both from one water body to another and seasonally.

As discussed in Section 4 of this report, available receiving water data throughout California indicate that pH exceeds 9 relatively frequently. For instance, flows in the Klamath River would frequently exceed the AL (6.5 – 8.5) proposed in the Preliminary Draft Permit. Nonetheless, available receiving water data generally fall within the range of 6 to 9 with a few exceptions.

The available data indicate that it would be reasonable to establish an AL for pH in runoff from construction sites, such that pH values in runoff from construction sites that are outside the range of 6 to 9 would trigger additional actions and/or study. This range of pH is generally within the "normal" range of pH for receiving water conditions, such that discharges within this range are unlikely to cause adverse impacts. Because the potential to alter pH is significant primarily when certain materials and/or activities are occurring at a site, the AL for pH should only be invoked when those activities/materials are present on site (e.g., use of lime, concrete pouring and curing activities). Further, most receiving waters have relatively large buffering capacities, so that the AL should be used only for high risk construction sites, where high risk sites are identified and include sites upstream of sensitive receiving waters and beneficial uses, or those sites that are large compared to the receiving water watershed.

The State Board should consider allowing the use of pH test strips to determine pH levels in runoff from construction sites because pH meters are not in widespread use. Test strips are available with test increments of 0.5 pH units for the range of $6 < pH < 9$.

Carefully characterizing local conditions and evaluating additional data would be required before NELs could be established because NELs would require that a permit violation occur when exceeded. Any data review conducted in support of NEL development should include, at a minimum, additional examination of receiving water datasets to ensure that NELs are consistent with receiving water quality (especially for waters where pH values are naturally outside of the target pH range) and an evaluation of BMP effectiveness in adjusting pH. If the State Board develops a monitoring program to facilitate the development of ALs and/or NELs for additional constituents, data on pH should be routinely gathered and characterized in a manner that is designed to yield data sufficient to develop NELs.

NELs and ALs for Sediment

Construction sites frequently create the potential for the mobilization of sediment and soil during construction, particularly during mass grading and sub-grade utility phases. Certain construction activities, particularly clearing and grading, may also increase runoff volumes and the frequency with which runoff occurs. The mobilization of sediment has the potential to harm downstream beneficial uses, particularly if those uses are especially sensitive to the presence of sediment (e.g., streams in which salmon spawning occurs). However, the absence of sediment (i.e., the discharge of water that is "too clean") has the potential to result in significant hydromodification, particularly stream bed erosion, if discharges contain significantly less sediment than would be present naturally (Cappiella et al., 1999; Trimble, 1997). Additionally, some streams contain naturally higher levels of sediment and/or turbidity, and native organisms within these systems have adapted to higher sediment levels (Feyrer et al., 2007; Feyrer and Healey, 2003). Sediment that is carried in streams and rivers is often an important source of beach sand (Jaffe et al., 1998). Both discharges that contain "too much" and discharges that contain "too little" sediment can cause harm to receiving waters and beneficial uses downstream of the point of discharge. Thus, it is important in developing ALs for discharges regulated by the General Construction Permit that sediment in discharges from construction sites (measured either as turbidity or total suspended solids) match natural background conditions as closely as possible.

While the PCGP proposed ALs and NELs for turbidity, the State Board did not undertake an analysis of turbidity and/or sediment concentrations in receiving waters in the development of those limits. Our review on existing data for turbidity and TSS (shown in Section 4) show that in some river basins, peak turbidity values in the receiving water are in well in excess of 1000 NTU, while in others, peak values are below 500 NTU. These data apply to drainage from river basins that contain a mixture of developed and undeveloped land uses.

To our knowledge, only one recent dataset is available to illustrate the concentrations of TSS in storm water runoff from natural, undeveloped watersheds (Stein and Yoon, 2007). Their dataset included measurements of TSS in runoff from eleven southern California watersheds (>95% undeveloped). Peak TSS concentrations in runoff from these undeveloped sites are much higher than peak concentrations in runoff from developed watersheds (Stein and Yoon, 2007). The authors also concluded that natural watersheds exhibited far greater variability than developed watersheds, and much higher peak concentrations. In many of these watersheds, it is possible that introducing discharges with sediment loads and concentrations that are significantly below natural levels could induce channel erosion and hydromodification.

For developed watersheds, there are insufficient data to assess which portion of the sediment contribution is "natural" and which is induced by land use changes or construction activities. However, as discussed in Section 6, there is abundant evidence in the literature to suggest that altering sediment concentrations beyond the range of "natural" concentrations (by introducing water with either too little or too much sediment), or by increasing the frequency of discharges, can cause harm within and downstream of receiving waters. These effects should be considered if ALs or NELs are to be established for sediment and/or turbidity in discharges from construction sites. Further, the condition of downstream receiving waters (e.g., hardened channels v. natural channels) should be considered in developing appropriate ALs. We conclude, on the basis of these data alone, that development of turbidity or TSS ALs for storm water discharges from construction sites is premature.

An additional consideration in the development of ALs for sediment is the ability of BMPs and other control measures to control sediment concentrations in discharges from construction sites. Available information on BMP treatment efficiency is generally provided in the form of "percent removal," and does not generally indicate sediment concentrations or turbidity in effluent from construction sites. Further, effluent sediment concentrations and/or turbidity will vary with influent concentrations, site conditions, rainfall conditions, and BMP efficiency. To our knowledge, no studies have characterized these factors to an extent that would allow the development of ALs that would be broadly applicable statewide. Indeed, the Blue Ribbon Panel also acknowledged these considerations and recommended that ALs be developed in consideration of site-specific factors. The final consideration in the development of ALs for construction sites is the measurement metric to be used. Various options have been discussed by SWRCB Staff, including use of turbidity meters, Imhoff cones, and "coffee can" settling tests. Several of the proposed options are new, and no baseline dataset exists to develop or "calibrate" the ALs to be developed. Additional data collection and testing of new measurement metrics should be conducted as part of the AL development process.

In summary, the ALs proposed by SWRCB Staff in the Preliminary Draft Permit were developed without consideration of receiving water condition downstream of the discharges, and without consideration of the unique conditions that may occur in watersheds that are naturally highly erosive, and from which storm water runoff naturally contains high sediment concentrations and loads. Also, there is little evidence available to indicate how effective BMPs deployed in such highly erosive environments would be. It appears that additional data analysis and study would be required to develop ALs for sediment and/or turbidity discharges from construction sites, and a far greater level of study and scrutiny would be required to develop NELs for sediment from construction sites.

ALs for TPH

The Preliminary Draft Permit contained an AL of 15 mg/l for total petroleum hydrocarbons (TPH). To assess this limit, samples must be collected and shipped to a laboratory for analysis, rendering such a limit relatively useless for the purpose of quickly and effectively diagnosing and remedying water quality problems at a construction site.

Samples collected for TPH analysis must be collected by trained personnel using clean sampling techniques and shipped to a laboratory for analysis, with a typical turnaround time of five days (based on contact with analytical laboratories). TPH samples collected from stored/contained storm water would not be representative of discharge conditions, as TPH may volatilize from water.

Because of these considerations, visual observations of sheen are generally a better indicator of the presence of hydrocarbons in storm water, and visual observations will indicate the presence of TPH. We recommend that the permit be modified to require visual observations for sheen instead of laboratory testing.

Discharges from Advanced Treatment Systems (ATS)

In some cases, particularly upstream of sensitive receiving waters that have naturally low levels of sediment, it may be desirable to reduce sediment concentrations and loads in discharges to very low levels, which can be achieved through the use of Advanced Treatment Systems (ATS). Discharges of treated storm water from ATS pose a risk of toxicity to downstream receiving waters, and may have altered chemistry (especially pH) with respect to storm water runoff that is not treated chemically. For this reason, it appears appropriate to require NELs for discharges from ATS. NELs for discharges from ATS would be based upon the ability of the treatment technology to achieve certain limits, and so would be classified as Technology-Based Effluent Limits (TBELs).

When developing TBELs, all applicable standards and requirements for all pollutants that are discharged must be considered. The development of effluent limitation guidelines is based on the best available technology (BAT) standard for non-conventional and toxic pollutants and the best conventional technology (BCT) standard for conventional pollutants. When assessing BAT effluent limits, the cost of attainability must be considered, although it does not need to balance the cost with the effluent reduction benefit. When assessing BCT effluent limits, the reasonableness of the relationship between the cost of attainability and the effluent reduction benefits must be taken into account. If national effluent limitation guidelines have not been developed (USEPA is in the process of developing effluent guidelines for discharges from construction sites), the same performance-based approach should be used by SWRCB Staff to develop TBELs for the Construction General Permit.

The Preliminary Draft Permit contained an NEL for turbidity for discharges from an ATS of 10 NTU. However, as discussed in this report and in Geosyntec (2007), discharges from properly operated ATS systems typically have turbidity levels of near 0 NTU to around 45 NTU. Actual ATS performance data should be used to establish NELs for ATS discharges, and it appears that 10 NTU may be too low. The Preliminary Draft Permit also proposed an NEL for pH for discharges from ATS of 6.5-8.5. As with turbidity, the procedures for establishing TBELs should be followed for pH, but it appears that this limit is likely appropriate.

Case studies conducted by Geosyntec (2007) show that ATS systems may not be cost-effective on small to average-size construction sites, and that they are appropriate for larger sites with large drainage areas. If treatment volume is not large enough, the rental cost of an ATS system can make up of a large portion of the overall cost. Costs of implementation of ATS become prohibitive as volume of runoff decreases. In addition, costs of implementing ATS are significantly higher than those of implementing both standard and/or enhanced traditional BMPs with increased inspection frequencies.

The Preliminary Draft Permit proposed requiring bioassay toxicity tests (both acute and chronic toxicity tests) for discharges from all types of ATS. However, for some coagulant polymers that are used in ATS, the residual concentrations of the chemical additives can be measured at levels that are below toxic thresholds. These polymer residual tests are not available for all chemical additives, but, where appropriate, would provide information much more quickly (i.e., before discharge) than bioassay toxicity tests could. The bioassay toxicity testing proposed in the Preliminary Draft Permit would be appropriate for any storm water to be discharged (regardless of which chemical had been used in the ATS), but the tests themselves require long laboratory analysis times (96 hours for acute toxicity testing and 7 days for chronic toxicity testing) and cannot be conducted "in-situ" (in the field). By contrast, the Preliminary Draft Permit required discharges from ATS to be released within 48 hours, so that toxicity test results would not be available until after the treated water had been released to receiving streams. For these reasons, it would be appropriate for the SWRCB to allow testing for chemical residuals and to allow those results to replace bioassay toxicity tests when residual tests are suitably sensitive. The SWRCB should also consider allowing the use in ATS of only those chemicals for which quick-turnaround, sensitive residual tests are available.

References

Abrahams, M., and Kattenfeld, M. 1997. The role of turbidity as a constraint on predatorprey interactions in aquatic environments. Behavioral Ecology and Sociobiology, **40**: 169–174.

Ackerman, D., and Schiff, K. 2003. Modeling storm water mass emissions to the Southern
California Bight. Journal of Environmental Engineering, **129**: 308-317

Armor, C., Baxter, R., Bennett, B., Breuer, R., Chotkowski, M., Coulston, P., Denton, D., Herbold, B., Kimmerer, W., Larsen, K., Nobriga, M., Rose, K., Sommer, T., and Stacey, M. 2006. Interagency Ecological Program Synthesis of 2005 Work to Evaluate the Pelagic Organism Decline (POD) in the Upper San Francisco Estuary CALFED Science Program

Baskerville-Bridges, B., Lindberg, J.C., and Doroshov, S.I., 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. In: Feyrer, F., Brown, L., Brown, R., and Orsi, J. eds., Early life history of fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Bethesda, MD, pp. 219-228.

Bennett, W. 2005. Critical Assessment of th the Delta Smelt Population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science, **3**: Article 1.

Blair, R.B. 1992. Lake features, water quality and the summer distribution of common loons in New Hampshire. Journal of Field Ornithology, **63**: 1–9.

Boehlert, G., and Morgan, J.B. 1985. Turbidity enhances feeding abilities of larval Pacific herring, *Clupea harengus pallasi*. Hydrobiologia, **123**: 161-170.

Brenninkmeijer, A., Stienen, E.W.M., Klaassen, M., and Kersten, M. 2002. Feeding ecology of wintering terns in Guinea-Bissau. Ibis, **144**: 602–613.

Brezonik, P.L., and Stadelmann, T.H. 2002. Analysis and predictive models of stormwater runoff volumes, loads, and pollutant concentrations from watersheds in the Twin Cities metropolitan area, Minnesota, USA. Water Research
36: 743–1757.

Bristow, B.T., and Summerfelt, R.C. 1994. Performance of larval Walleye cultured intensively in clear and turbid water. J. W. Aqua. Soc., **25**: 454–464.

Broekhuizen, N., Parkyn, S., and Miller, D. 2001. Fine sediment effects on feeding and growth in the invertebrate grazers Potamopyrgus antipodarum (Gastropoda, Hydrobiidae) and Deleatidium sp. (Ephemeroptera, Leptophlebiidae). Hydrologia, **457**: 125-132.

Brown, L.R. 2003. Will tidal wetland restoration enhance populations of native fishes? San Francisco Estuary and Watershed Science, **1**: Article 1.

Brune, G.M. 1953. The trapping effi ciency of reservoirs. Trans. Am. Geophys. Union **34**: 407-418.

CALTRANS. 2002. Caltrans construction sites runoff characterization study, California Department of Transporation, Sacramento, CA.

Cappiella, K., Malzone, C., Smith, R.E., and Jaffe, B.E. 1999. Sedimentation and bathymetry changes in Suisun Bay, 1867–1990, USGS Open-File Report 99-563.

CBIA, and CICWQ. 2007. Comments submitted on the Preliminary Draft Construction Permit (issued March 2, 2007)

Chakravarti, I.M., Laha, R.G., Roy, J., and 1967. Handbook of Methods of Applied Statistics. John Wiley and Sons, New York, NY, pp. 392-394.

Dauvin, J.-C., and Dodson, J.J. 1990. Relationship between feeding incidence and vertical and longitudinal distribution of rainbow smelt larvae (*Osmerus mordax*) in a turbid well-mixed estuary. Marine Ecology Progress Series, **60**: 1–12

Davies-Colley, R.J., and Smith, D.G. 2001. Turbidity, suspended sediment, and water clarity: a review. Journal of the American Water Resources Association, **37**: 1085-1101.

Detenbeck, N., Johnston, C.A., and Niemi, G. 1993. Wetland effects on lake water quality in the Minneapolis/St. Paul metropolitan area. Landscape Ecology, **8**: 39-61.

Dodds, K., and Whiles, M. 2004. Quality and quantity of suspended particles in rivers: continent-scale patterns in the United States. Environmental Management **33**: 355-367.

Earhart, H. 1984. Monitoring total suspended solids by using nephelometry. Journal Environmental Management, **8**: 81-86.

Eriksson, M.O.G. 1985. Prey detectability for fisheating birds in relation to fish density and water transparency. Ornis Scandinavica, **16**: 1–7.

Feyrer, F., and Healey, M.P. 2003. Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta Journal Environmental Biology of Fishes **66**: 123-132.

Feyrer, F., Nobriga, M.L., and Sommer, T.R. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fish and Aquatic Society, **64**: 723-734.

Foschi, P.G. 2000. Egeria densa acreage and percent coverage in the Sacramento-San Joaquin Delta 4, California Department of Boating and Waterways.

FSI, F.S.I. 2005. Storm water and best management practices analysis Report prepared to evaluate storm water discharges from industrial facilities. Feb 2, 2005.

Gadomski, D.M., and Barfoot, C.A. 1998. Diel and distributional patterns of fish embryos and larvae in the lower Columbia and Deschutes rivers. Environmental Biology of Fishes **51**: 353–368.

Galetovic, J.R., Toy, T.J., and Foster, G.R., 1998. Guidelines for the use of the revised universal soil loss equation (RUSLE), version 1.06, on mined lands, construction sites and reclaimed lands. Office of Technical Transfer, Western Regional Coordination Center, Office of Surface Mining, Denver, CO.

Geosyntec. 2007. Evaluation of active treatment systems (ATS) for construction site runoff -Draft report prepared for California Building Industry Association (CBIA), Geosyntec, Portland, Oregon.

Gregory, R.S., and Northcote, T.G. 1993. Surface, planktonic, and benthic foraging by juvenile chinook salmon (Oncorhynchus tshawytscha) in turbid laboratory conditions. Canadian Journal of Fish and Aquatic Society, **50**: 233–240.

Griggs, G.B. 2005. California’s Retreating Coastline: Where do we go from here? Proceedings of the Annual Mtg. American Meteorological Society, San Diego, California

Gumbel, E.J. 1960. Multivariate Extremal Distributions. Bull. Inst. Internat. de Statistique **37**: 471-475.

Hill, B.M. 1975. A simple general approach to inference about the tail of a distribution. Annals of Statistics, **3**: 1163-1174.

Inman, D.L., and Jenkins, S.A. 1999. Climate Change and the Episodicity of Sediment Flux of Small California Rivers. Journal of Geology **107**: 251-270.

Jaffe, B.E., Smith, R., Bouse, R., and Luoma, S. 2001. Sedimentation, erosion, and mercury contamination: the story of hydraulic gold mining debris in north San Francisco Bay. the 5th Biannual State of the Estuary Conference: San Francisco Estuary: Achievements, trends and the future, San Francisco, CA, p. 31.

Jaffe, B.E., Smith, R., and Zink, L. 1996. Sedimentation changes in San Pablo Bay 1856-1983. the 3rd Biennial State of the Estuary Conference, San Francisco, CA.

Jaffe, B.E., Smith, R.E., and Torresan, L.Z. 1998. Sedimentation and bathymetric change in San Pablo Bay 1856-1983, USGS Open-File Report 98-759.

Johnes, P., Moss, B., and Phillips, G. 1996. The determination of total nitrogen and total phosphorous concentrations in freshwaters from land use, stock headage and population data: testing a model for use in conservation and water quality management. Freshwater Biology, **36**: 451-473.

Johnson, L.B., Richards, C., Host, G.E., and Arthur, J.W. 1997. Landscape influence on water chemistry in Midwestern stream ecosystems. Freshwater Biology, **37**: 193-218.

Johnson, W., and Looker, R. 2003. Mercury in San Francisco Bay. Total maximum daily load (TMDL) project report, San Francisco Regional Water Quality Control Board, San Francisco, CA.

Kayhanian, M., Hollingsworth, L., Crandall, L., Spongberg, M., Regenmorter, L.C., and Tsay, K. 2002. Characteristics of stormwater runoff from Caltrans facilities, California Department of Transportation (Caltrans), Sacramento, CA.

Knighton, D., 1998. Fluvial forms and processes, a new perspective. Arnold publishing, London, United Kingdom.

Larsen, D.P. 1988. A region approach for assessing attainable surface water quality: an Ohio case study. J. Soil and Water Conservation: 171-176.

Manka, P., 2005. Suspended sediment yields in tributaries of Elk River, Humboldt County, California. Natural Resources: Watershed Management. Humboldt State University, p. 91.

Maurer, D., Keck, R., Tinsman, J., Leathem, W., and Wethe, C. 1986. Vertical Migration and Mortality of Marine Benthos in Dredged Material: A Synthesis International Revue der Gesamten Hydrobiologie **71**: 49-63.

Meng, L., and Matern, S.A. 2001. Native and introduced larval fishes of Suisun Marsh, California: the effects of freshwater flow. Transactions of the American Fisheries Society, **130**: 750–765.

Miner, G.J., and Stein, R.A. 1993. Interactive influence of turbidity and light on larval bluegill (Lepomis macrochirus) foraging. Can. J. Fish. Aquat. Sci., **50**: 781–788.

Mitchell, S.C., and Cunjak, R.A. 2007. Relationship of upstream migrating adult Atlantic salmon (Salmo salar) and stream discharge within Catamaran Brook, New Brunswick Canadian Journal of Fisheries and Aquatic Sciences, **64**: 563-573.

NCASI. 1999. Scale considerations and the detectability of sedimentary cumulative watershed effects, National Council of the Paper Industry for Air and Stream Improvement, Inc., Research Triangle Park, NC.

Newcombe, C.P. 1994. Suspended sediment in aquatic ecosystems: ill effects as a function of concentration and exposure, Habitat Protection Branch, Ministry of Environment, Lands and Parks, Victoria, BC.

Newcombe, C.P., and Jensen, J.T. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management, **16**: 693-727.

Newcombe, C.P., and MacDonald, D.D. 1991. Effect of suspended sediments on aquatic systems. North American Journal of Fisheries Management, **11**: 72-82.

Nobriga, M.L., Feyrer, F., Baxter, R.D., and Chotkowski, M. 2005. Fish community ecology in an altered river Delta: spatial patterns in species composition, life history strategies and biomass. Estuaries, **28**: 776-785.

Patsch, K.B., and Griggs, G.B. 2006a. Development of Sand budgets for California's Major Littoral Cells: Eureka, Santa Cruz, Southern Monterey Bay, Santa Barbara, Santa Monica (including Zuma), San Pedro, Laguna, Oceanside, Mission Bay, and Silver Strand Littoral Cells, Oakland, CA.

Patsch, K.B., and Griggs, G.B. 2006b. Littoral cells, sand budgets, and beaches: understanding California's shoreline, Institute of Marine Sciences University of California, Santa Cruz.

Peng, L., and Qi, Y. 2006. Confidence regions for high quantiles of heavy tailed distribution Annals of Statistics, **34**: 1964-1986.

Richards, C., Johnson, L.B., and Host, G.E. 1996. Landscape-scale influences on stream habitats and biota. Can. J. Fish. Aquat. Sci., **53**: 295-311.

Roos, M., 2005. Global warming's possible impact on California's water resources. DWR News, Sacramento, CA, pp. 5-9.

Ross, S.T. 1991. Mechanisms structuring stream fish assemblages: are there lessons from introduced species? . Environmental Biology of Fishes, **30**: 359-368.

Rowe, D.K., and Dean, T.L. 1998. Effects of turbidity on the feeding ability of the juvenile migrant stage of six New Zealand freshwater fish species. New Zealand Journal of Marine and Freshwater Research, **32**: 21-29.

Schroeder, W.W., Crozier, G.G., Blancher, E.C., and 1981. Comparison of suspended total solids gravimetry to laboratory in situ nephelometric measurement. Estuaries, **4**: 292.

Schubel, J.R., Carter, H.H., Wilson, R.E., Wise, W.M., Heaton, M.G., and Gross, M.G. 1978. Field investigations of nature, degree, and extent of turbidity generated by open-water pipeline disposal operations, US Army Engineer Waterways Experiment Station, Vicksburg, MI.

Schubel, J.R., Carter, H.H., and Wise, W.M. 1979. Shrimping as a source of suspended sediment in Corpus Christi Bay (Texas). Estuaries, **2**: 201-203.

Shumway, R.H., Azari, R.S., and Kayhanian, M. 2002. Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits. Environmental Science and Technology, **36**: 3345-3353.

Slagel, M.J., 2005. Cumulative Losses of Sediment to the Major Littoral Cells of California by Impoundment Behind Coastal Dams. Department of Ocean Sciences. University of California, Santa Cruz:, Santa Cruz, CA.

State Water Resources Control Board, 2004. Final Functional Equivalent Document for Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List In: SWRCB ed.

Stein, E.D., and Yoon, V.K. 2007. Assessment of water quality concentrations and loads from natural landscapes, Southern California Coastal Water Research Project, Costa Mesa, CA.

Svendsen, J.C., Koed, A., and Aarestrup, K. 2004. Factors influencing the spawning migration of female anadromous brown trout Journal of Fish Biology **64**: 528–540.

Utne-Palm, A.C. 2002. Visual feeding of fish in a turbid environment: Physical and behavioural aspects. Marine and Freshwater Behaviour and Physiology, **35**: 111-128.

Utne, A.C.W. 1997. The effect of turbidity and illumination on the reaction distance and search time of the marine planktivore Gobiusculus flavescens. Journal of Fish Biology, **50**: 926-938.

Wallace, J.B., and Merritt, R.W. 1980. Filter-feeding ecology of aquatic insects. Annual Review of Entomology, **25**: 103-132.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph, **7**: 251.

Wilber, D.H., and Clarke, D.G. 2001. Biological Effects of Suspended Sediments: A Review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management, **21**: 855–875

Williams, P.B. 2001. Is there enough sediment? . the 5th Biannual State of the Estuary Conference: San Francisco Estuary: Achievements, trends and the future, San Francisco, CA, p. 12.

Willis, C.M., and Griggs, G.B. 2003 Reductions in fluvial sediment discharge by California coastal dams and implications for beach sustainability. Journal of Geology, **111**: 167-182.

Wotton, R.S., 1994. The biology of particles in aquatic systems. CRC Press, Boca Raton, FL.

Wright, S.A., and Schoellhamer, D.H. 2004. Trends in the Sediment Yield of the Sacramento River, California, 1957 - 2001. San Francisco Estuary and Watershed Science, **2**: Article 2.

APPENDICES

TABLES

Table 2.a. Information for stations that contain turbidity, TSS, flow, and pH data from CDEC; NA, information is not available.

County	River Basin	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
BUTTE	FEATHER R	FEATHER RIVER NEAR GRIDLEY	GRL	39.3670°N	121.6460°W	FBS, PDE, SFH, SRL
BUTTE	SACRAMENTO R	BIG CHICO CREEK NEAR CHICO	BIC	39.7680°N	121.7770°W	CHR
BUTTE	SACRAMENTO R	BUTTE CREEK NR CHICO	BCK	39.7260°N	121.7090°W	CHR
COLUSA	SACRAMENTO R	BEAR CK AB HOLSTEN CYN NR RUMSEY	BRK	38.9580°N	122.3420°W	MLW
CONTRA COSTA	DELTA	CLIFTON COURT (KA000000)	CLC	37.8330°N	121.5580°W	BXP, HLD, MDH
DEL NORTE	KLAMATH R	KLAMATH R. NR KLAMATH-WATER QUALITY	KKY	41.5110°N	123.9781°W	TUR
HUMBOLDT	TRINITY R	TRINITY R NR WEITCHPEC	WPC	41.1790°N	123.7060°W	HPA
SACRAMENTO	DELTA	HARVEY O BANKS PUMPING P (KA000331)	HBP	37.7980°N	121.6230°W	NA
SACRAMENTO	SACRAMENTO R	SACRAMENTO R AT HOOD	SRH	38.3820°N	121.5190°W	MCM, VNM
SAN JOAQUIN	SACRAMENTO R	PRISONERS POINT	PPT	38.0660°N	121.5620°W	NA
SAN JOAQUIN	SAN JOAQUIN R	ROUGH AND READY ISLAND	RRI	37.9630°N	121.3650°W	BAW, BM2, BRC, SFS, SNR, VRN
SAN JOAQUIN	SAN JOAQUIN R	SAN JOAQUIN R MCCUNE STATION NR VERNALIS	SJR	37.6792°N	121.2638°W	BAW, BM2, BRC, SFS, SNR, VRN
SHASTA	SACRAMENTO R	MCCLOUD RIVER ABOVE SHASTA LAKE	MSS	40.9580°N	122.2190°W	GIB, GRD, HRZ, KWK, LKS, SHK, SHS, SLT
SHASTA	SACRAMENTO R	PIT RIVER NEAR MONTGOMERY CREEK	PMN	40.8430°N	122.0160°W	GIB, GRD, HRZ, KWK, LKS, SHK, SHS, SLT
SHASTA	SACRAMENTO R	SACRAMENTO RIVER AT DELTA	DLT	40.9400°N	122.4160°W	GIB, GRD, HRZ, KWK, LKS, SHK, SHS, SLT

Table 2.b. Information for stations that contain turbidity, TSS, flow, and pH data from CDEC; NA, information is not available.

County	River Basin	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
SOLANO	DELTA	BARKER SLOUGH PUMPING PLANT (KG000000)	BKS	38.2760°N	121.7880°W	NA
SOLANO	DELTA	CORDELIA PUMPING PLANT (KG002111)	CPP	38.2270°N	122.1340°W	NA
TEHAMA	SACRAMENTO R	BALLS FERRY BRIDGE	BSF	40.4170°N	122.1930°W	BSF, THO
TEHAMA	SACRAMENTO R	DEER CREEK NR VINA	DCV	40.0140°N	121.9470°W	BSF, THO
TEHAMA	SACRAMENTO R	JELLYS FERRY	JLF	40.3290°N	122.1900°W	BSF, THO
TEHAMA	SACRAMENTO R	SACRAMENTO R AT RED BLUFF DIVERSION DAM	RDB	40.1530°N	122.2020°W	BSF, THO
TEHAMA	SACRAMENTO R	SACRAMENTO RIVER AT BEND BRIDGE	BND	40.2890°N	122.1860°W	BSF, THO
TRINITY	SACRAMENTO R	WEAVER CREEK NEAR WEAVERVILE	WVC	40.6860°N	122.9330°W	NA
TRINITY	TRINITY R	RUSH CREEK NEAR LEWISTON	RCL	40.7250°N	122.8340°W	BNK, CFR, GVO, LFH, MUD, TGS, TLK, TYR
TRINITY	TRINITY R	TRINITY RIVER BELOW LIMEKILN GULCH	TLK	40.6730°N	122.9190°W	BNK, CFR, GVO, LFH, MUD, TGS, TLK, TYR

Table 3.a. Data availability from CDEC for turbidity, TSS, flow, and pH; NA, information is not available.

Station Name	Station ID	Turbidity (NTU) Type	Turbidity Duration	TSS (mg/l) Type	TSS Duration	pH Type	pH Duration	Flow (cfs) Type	Flow Duration	Precipitation Data
BALLS FERRY BRIDGE	BSF	HOURLY	02/02/1990 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	NA	NA
BARKER SLOUGH PUMPING PLANT (KG000000)	BKS	HOURLY	06/01/1989 to 08/07/2007.	NA	NA	HOURLY	10/30/1992 to 08/07/2007	HOURLY	NA	NA
BARKER SLOUGH PUMPING PLANT (KG000000)	BKS	DAILY	06/01/1989 to 08/07/2007.	NA	NA	DAILY	10/30/1992 to 08/07/2007	DAILY	NA	NA
BEAR CK AB HOLSTEN CYN NR RUMSEY	BRK	EVENT	01/11/2000 to 03/01/2006	NA	NA	EVENT	NA	EVENT	07/26/2000 to 08/07/2007	NA
BIG CHICO CREEK NEAR CHICO	BIC	HOURLY	10/18/1999 to 11/30/2004	NA	NA	HOURLY	NA	HOURLY	07/21/1997 to 08/07/2007	NA
BIG CHICO CREEK NEAR CHICO	BIC	EVENT	03/20/1997 to 07/21/1997	NA	NA		NA	EVENT	03/20/1997 to 01/13/2003	NA
BUTTE CREEK NR CHICO	BCK	HOURLY	10/18/1999 to 01/01/2005	NA	NA	HOURLY	NA	HOURLY	03/14/1997 to 08/07/2007	NA
BUTTE CREEK NR CHICO	BCK	DAILY	NA	NA	NA	DAILY	NA	DAILY	07/21/1999 to 08/07/2007	NA
BUTTE CREEK NR CHICO	BCK	EVENT	NA	NA	NA	EVENT	NA	EVENT	03/12/1997 to 08/07/2007	NA
CLIFTON COURT (KA000000)	CLC	HOURLY	03/10/1988 to 08/07/2007.	NA	NA	HOURLY	09/03/1992 to 08/07/2007	HOURLY	NA	NA
CLIFTON COURT (KA000000)	CLC	DAILY	03/10/1988 to 08/07/2007	NA	NA	DAILY	09/03/1992 to 08/07/2007	DAILY	NA	NA
CORDELIA PUMPING PLANT (KG002111)	CPP	DAILY	03/01/1993 to 08/07/2007	NA	NA	DAILY	NA	DAILY	NA	NA
CORDELIA PUMPING PLANT (KG002111)	CPP	HOURLY	03/01/1993 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	NA	NA
DEER CREEK NR VINA	DCV	HOURLY	10/01/1998 to 03/14/2007	NA	NA	HOURLY	NA	HOURLY	03/14/1997 to 08/07/2007	NA
FEATHER RIVER NEAR GRIDLEY	GRL	HOURLY	03/04/2003 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	01/01/1984 to 08/07/2007	NA
FEATHER RIVER NEAR GRIDLEY	GRL	DAILY	NA	NA	NA	DAILY	NA	DAILY	01/01/1993 to 08/07/2007	NA
HARVEY O BANKS PUMPING P (KA000331)	HBP	DAILY	06/29/1988 to 08/07/2007.	NA	NA	DAILY	07/15/1987 to 08/07/2007	DAILY	NA	NA
HARVEY O BANKS PUMPING P (KA000331)	HBP	HOURLY	06/29/1988 to 08/07/2007	NA	NA	HOURLY	07/15/1987 to 08/07/2007	HOURLY	NA	NA
JELLYS FERRY	JLF	HOURLY	10/27/1998 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	NA	NA

Table 3.b. Data availability from CDEC for turbidity, TSS, flow, and pH.

Station Name	Station ID	Turbidity (NTU) Type	Turbidity Duration	TSS (mg/l) Type	TSS Duration	pH Type	pH Duration	Flow (cfs) Type	Flow Duration	Precipitation Data
KLAMATH R. NR KLAMATH-WATER QUALITY	KKY	NA	NA	NA	NA	EVENT	05/19/2005 to 10/03/2005	NA	NA	NA
MCCLOUD RIVER ABOVE SHASTA LAKE	MSS	HOURLY	11/13/1989 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	08/01/1991 to 08/07/2007	NA
MCCLOUD RIVER ABOVE SHASTA LAKE	MSS			NA	NA		NA	DAILY	01/01/1993 to 08/07/2007	NA
PIT RIVER NEAR MONTGOMERY CREEK	PMN	HOURLY	05/16/1990 to 08/07/2007	NA	NA	HOURLY	NA	DAILY	01/01/1993 to 08/07/2007	NA
PRISONERS POINT	PPT	HOURLY	03/02/2006 to 08/07/2007	NA	NA	HOURLY	03/02/2006 to 08/07/2007	HOURLY	NA	NA
ROUGH AND READY ISLAND	RRI	EVENT	11/13/2001 to 01/01/2007	NA	NA	EVENT	NA	EVENT	08/28/2000 to 08/07/2007.	NA
SAN JOAQUIN R MCCUNE STATION NR VERNALIS	SJR	EVENT	01/20/2005 to 08/07/2007.	NA	NA	EVENT	01/20/2005 to 08/07/2007	EVENT	From 01/20/2005 to 08/07/2007.	NA
RUSH CREEK NEAR LEWISTON	RCL	HOURLY	03/15/2001 to 08/07/2007.	NA	NA	HOURLY	NA	HOURLY	11/25/2002-8/17/2005	NA
SACRAMENTO R AT HOOD	SRH	HOURLY	03/20/2007 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	NA	NA
SACRAMENTO R AT RED BLUFF DIVERSION DAM	RDB	HOURLY	11/13/1989 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	NA	NA
SACRAMENTO RIVER AT BEND BRIDGE	BND	HOURLY	10/10/1989 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	01/01/1984 to 08/07/2007	NA
SACRAMENTO RIVER AT BEND BRIDGE	BND	EVENT	02/01/1996 to 08/07/2007	NA	NA		NA	EVENT	02/24/1995 to 08/07/2007	NA
SACRAMENTO RIVER AT DELTA	DLT	HOURLY	11/13/1989 to 08/07/2007	NA	NA	HOURLY	NA	HOURLY	07/01/1991 to 08/07/2007	NA
SACRAMENTO RIVER AT DELTA	DLT	DAILY	NA	NA	NA	DAILY	NA	DAILY	01/01/1993 to 08/07/2007	NA
TRINITY R NR WEITCHPEC	WPC	NA	NA	NA	NA	HOURLY	05/05/2005 to 10/04/2005	NA	NA	NA
TRINITY RIVER BELOW LIMEKILN GULCH	TLK	HOURLY	3/15/2001-4/12/2007	NA	NA	HOURLY	NA	HOURLY	11/25/2002 to 09/24/2005.	NA
WEAVER CREEK NEAR WEAVERVILE	WVC	HOURLY	11/28/2000 to 01/01/2003	NA	NA	HOURLY	NA	HOURLY	11/02/2000-10/01/2005	NA

Table 4. Information for Los Angeles County NPDES monitoring stations.

County	Watershed	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
Los Angeles	Ballona Creek	Ballona Creek	S01	33.99812	-118.40217	462 B
Los Angeles	Malibu Creek	Malibu Creek	S02	34.07540	-118.70317	435
Los Angeles	Los Angeles River	Los Angeles River	S10	33.81598	-118.20552	415, 1113
Los Angeles	San Gabriel River	Coyote Creek	S13	33.80986	-118.07706	125
Los Angeles	San Gabriel River	San Gabriel River	S14	34.01338	-118.06308	1114 B
Los Angeles	Domingues Channel	Dominguez Channel	S28	33.87260	-118.31114	291, 734 C
Los Angeles	Santa Clara River	Santa Clara River	S29	34.42660	-118.58649	1262, 801 B
Los Angeles	Ballona Creek	Centinela	TS07	33.98495529	-118.4133704	1217
Los Angeles	Ballona Creek	Sepulveda	TS08	33.99799493	-118.4154318	462 B
Los Angeles	Ballona Creek	Benedict	TS09	34.03139884	-118.3733935	462 B
Los Angeles	Ballona Creek	Adams Drain	TS10	34.04424509	-118.3536567	462 B
Los Angeles	Ballona Creek	Fairfax Drain	TS11	34.03853368	-118.3689298	462 B
Los Angeles	Ballona Creek	Cochran	TS12	34.01580303	-118.3904896	462 B

Table 5. Data availability from Los Angeles County storm water monitoring for turbidity, TSS, flow, and pH; A, information is available.

Station Name	**Station ID**	**Turbidity (NTU) Type**	**Turbidity Duration**	**TSS (mg/l) Type**	**TSS Duration**	**pH Type**	**pH Duration**	**Flow (m3/sec) Type**	**Flow Duration**	**Precipitation Data**
Ballona Creek	S01	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Malibu Creek	S02	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Los Angeles River	S10	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Coyote Creek	S13	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
San Gabriel River	S14	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Dominguez Channel	S28	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Santa Clara River	S29	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Centinela	TS07	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Sepulveda	TS08	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Benedict	TS09	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Adams Drain	TS10	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Fairfax Drain	TS11	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A
Cochran	TS12	Event	2000-2005	Event	2000-2005	Event	2000-2005	Event	2000-2005	A

Table 6. Information for Orange County storm water monitoring stations; ‘NA‘, information is not available.

County	Watershed	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
Orange	Westminster	Anaheim Barber City Channel	ABCC03	33-45-5	117-02-10	Garden Grove Alert #1175, Garden Grove Fire Station #229
Orange	Newport Bay	Peters Canyon Channel/Wash	BARSED	33-41-30	117-40-23	Santa Ana Eng Alert#219, Santa Ana #121
Orange	Santa Ana River	Bolsa Chica Channel	BCC02	33-45-32	117-02-34	Garden Grove Alert #1175, Garden Grove Fire Station #229
Orange	Newport Bay	Bonita Canyon Channel	BCF04	33-39-05	117-51-38	San Diego Creek Alert #1125
Orange	Newport Bay	Central Irvine Channel at I-5	CICF25	NA	NA	NA
Orange	Newport Bay	Costa Mesa Channel	CMCG02	33-37-23	117-53-59	Santa Ana Delhi Alert #1111, newport Harbor Master #88
Orange	Westminster	East Garden Grove Wintersburg	EGWC05	33-43-03	117-59-57	Katella Yard Alert #223
Orange	Newport Bay	Hicks Canyon Wash	HCWF27	33-43-25	117-46-02	Lambert Reservoir Alert #217
Orange	Newport Bay	Lane Channel	LANF08	30-40-40	117-50-39	Santa Ana Eng Alert #219
Orange	Newport Bay	El Modena-Irvine Channel u/s Irvine Avenue	MIRF07	NA	NA	NA
Orange	Newport Bay	Santa Ana Delhi Channel	SADF01	33-39-35	117-52-51	Costa Mesa Alert #1150, Costa Mesa #165
Orange	Newport Bay	San Diego Creek at Campus	SDMF05	33-39-19	117-50-43	Lambert Reservoir Alert #217
Orange	Westminster	Westminster Channel	WMCC04	33-45-07	117-59-26	Garden Grove Alert #1175, Garden Grove Fire Station #229
Orange	Newport Bay	San Diego Creek at Culver/ Harvard	WYLSED	33-40-53	117-48-34	Lambert Reservoir Alert #217
Orange	Newport Bay	Aqua Chinon Wash at SDC confluence	ACF18	NA	NA	NA

Table 7. Data availability from Orange County storm water monitoring for TSS, flow, and pH.

Station Name	Station ID	Turbidity (NTU) Type	Turbidity Duration	TSS (mg/l) Type	TSS Duration	pH Type	pH Duration	Flow (m3/sec) Type	Flow Duration	Precip. Data
Anaheim Barber City Channel	ABCC03	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
Peters Canyon Channel/Wash	BARSED	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
Bolsa Chica Channel	BCC02	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
Bonita Canyon Channel	BCF04	NA	NA	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	A
Central Irvine Channel at I-5	CICF25	NA	NA	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	A
Costa Mesa Channel	CMCG02	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
East Garden Grove Wintersburg	EGWC05	NA	NA	Event	1992-2002, 2004-06	Event	1992-2002, 2004-06	Event	1992-2002, 2004-06	A
Hicks Canyon Wash	HCWF27	NA	NA	Event	2004-06	Event	2004-06	Event	2004-06	A
Lane Channel	LANF08	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
El Modena-Irvine Channel u/s Irvine Avenue	MIRF07	NA	NA	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	Event	2000-2001, 2004-06	A
Santa Ana Delhi Channel	SADF01	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
San Diego Creek at Campus	SDMF05	NA	NA	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	Event	1992-2003, 2004-06	A
Westminster Channel	WMCC04	NA	NA	Event	1992-2003, 2005-06	Event	1992-2003, 2005-06	Event	1992-2003, 2005-06	A
San Diego Creek at Culver/ Harvard	WYLSED	NA	NA	Event	2000-2003, 2005-06	Event	2000-2003, 2005-06	Event	2000-2003, 2005-06	A
Aqua Chinon Wash at SDC confluence	ACWF18	NA	NA	Event	2000-01	Event	2000-01	Event	2000-01	A

Table 8. Information for Ventura County storm water monitoring stations.

County	Watershed	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
Ventura	Calleguas	Alamo Street	W-2	34.28639	-118.74845	
Ventura	Calleguas	Calleguas Creek at University Drive	ME-CC	34.17917	-119.03889	Camarillo-Adohr
Ventura	Calleguas	Heywood Street	W-1	34.26807	-118.75896	
Ventura	Calleguas	La Vista Drain	W-3	34.26583	-119.09306	Somis-Bard
Ventura	Malibu Creek	Las Virgenes Canyon	LV-1	34.16866	-118.70196	
Ventura	Santa Clara	Lawrence Way	R-2	34.18617	-119.20622	
Ventura	Malibu Creek	Lindero Canyon	LC-1	34.16884	-118.78668	
Ventura	Malibu Creek	Medea Canyon	MC-1	34.16854	-118.76063	
Ventura	Santa Clara	Ortega Street	I-2	34.24917	-119.2275	
Ventura	Calleguas	Revolon Slough	W-4	34.17056	-119.09528	Oxnard Airport
Ventura	Santa Clara	Santa Clara River at Freeman Diversion	ME-SCR	34.29917	-119.10722	Fillmore Fish Hatchery
Ventura	Santa Clara	Swan Street	R-1	34.25861	-119.195	County Government Center
Ventura	Ventura River	Ventura River at Foster Park	ME-VR	34.35194	-119.30722	
Ventura	Ventura River	Ventura River at Ojai Valley Sanitation	ME-VR2	34.34305	-119.29888	Oja-Stewart Canyon
Ventura	Calleguas	Via Del Norte	C-1	34.22599	-119.14543	
Ventura	Calleguas	Via Pescador	I-1	34.2236	-119.01905	County Government Center
Ventura	Calleguas	Wood Road	A-1	34.17056	-119.09528	Oxnard Airport

Table 9. Data availability from Ventura County NPDES monitoring for turbidity, TSS, flow, and pH.

Station Name	**Station ID**	**Turbidity (NTU) Type**	**Turbidity Duration**	**TSS (mg/l) Type**	**TSS Duration**	**pH Type**	**pH Duration**	**Flow (m3/sec) Type**	**Flow Duration**	**Rain Data**
Alamo Street	W-2	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Calleguas Creek at University Drive	ME-CC	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Heywood Street	W-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
La Vista Drain	W-3	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Las Virgenes Canyon	LV-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Lawrence Way	R-2	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Lindero Canyon	LC-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Medea Canyon	MC-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Ortega Street	I-2	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Revolon Slough	W-4	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Santa Clara River at Freeman Diversion	ME-SCR	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Swan Street	R-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Ventura River at Foster Park	ME-VR	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Ventura River at Ojai Valley Sanitation	ME-VR2	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Via Del Norte	C-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Via Pescador	I-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A
Wood Road	A-1	Event	1995-2006	Event	1995-2006	Event	1995-2006	Event	1995-2006	A

Table 10. Information for Sacramento County storm water monitoring stations; sqm, square mile.

Station Name	**Station ID**	**Catchment size (sqm)**	**Note**	**Dominant Land Use**
Arcade Creek at Watt Avenue	AC03	40	Urban tributary	-
Chicken Ranch Slough	CSRS	-	-	-
Willow Creek at Blue Ravine	FOLSOM_BLUE_RAVINE	-	Urban tributary	-
Willow Creek at Riley	FOLSOM_RILEY	-	Urban tributary	-
Morrison Creek at Brookfield Drive	MC01	105	Urban tributary	-
Morrison Creek Upstream	MC02	-	Urban tributary	-
Natomas East Main Drain Downstream	NEMD01	-	-	-
Natomas East Main Drain Upstream	NEMD02	-	-	-
NA	S034	-	-	-
Strong Ranch Slough (Urban Runoff 2S)	UR2S	5162	Storm drain	Mixed use
Sump 111 (Urban Runoff 3)	UR3	420	Storm drain	-
Sump 104	UR4	2220	Storm drain	-
Willow Creek at Blue Ravine Road	WC01	-	Urban Tributary	-

Table 11. Data availability from Sacramento County storm water monitoring for turbidity, TSS, flow, and pH.

Station Name	Station ID	Turbidity (NTU) Type	Turbidity Duration	TSS (mg/l) Type	TSS Duration	pH Type	pH Duration
Arcade Creek at Watt Avenue	AC03	Event	2003-2005	Event	2003-2005	Event	2003-2005
Chicken Ranch Slough	CSRS	Event	1991-1992	Event	1990-1993	Event	NA
Willow Creek at Blue Ravine	FOLSOM_BLUE_RAVINE	Event	NA	Event	1992-1993	Event	NA
Willow Creek at Riley	FOLSOM_RILEY	Event	1991-1992	Event	1991-1992	Event	NA
Morrison Creek at Brookfield Drive	MC01	Event	2003-2005	Event	2003-2005	Event	2003-2004
NA	S034	Event	1991-1992	Event	1990-1992	Event	NA
Strong Ranch Slough (Urban runoff 2S)	UR2S	Event	2003-2005	Event	1995-2005	Event	1995-2003
Sump 111 (Urban Runoff 3)	UR3	Event	1991-2005	Event	1990-2005	Event	1995-2003
Sump 104	UR4	Event	1991-2005	Event	1990-2005	Event	1995-2003
Willow Creek at Blue Ravine Road	WC01	Event	2003-2005	Event	2003-2005	Event	2003-2005

Table 12. Information for Natural Loadings Study sites.

County	Watershed	Station Name	Station ID	Latitude	Longitude	Rain Gauging Station Nearby
Los Angeles	LA River	Arroyo Seco	NL01	34.2124	-118.178	Flintridge
Los Angeles	San Gabriel	Bear Creek WFSGR	NL02	34.2408	-117.884	SG Dam
Los Angeles	San Gabriel	Cattle Creek EFSGR	NL03	34.2283	-117.767	Tanbark
Los Angeles	San Gabriel	Coldbrook NFSGR	NL04	34.2922	-117.839	SG East Fork
Los Angeles	Malibu Creek	Chesebro Creek	NL05	34.1557	-118.726	Agura
Orange	San Mateo	Cristianitos Creek	NL07	33.4621	-117.561	Segunda Descheca (SEGC1) & Pico Retarding Basin (PIOC1)
Orange	Santa Ana	Santiago Creek	NL09	33.7086	-117.615	215
Orange	San Juan	Bell Creek	NL10	33.6347	-117.557	206 Trabuco Forestry
Orange	Santa Ana	Silverado Creek	NL11	33.7461	-117.601	215
San Bernardino	Santa Ana	Seven Oaks Dam	NL12	34.1477	-117.06	NA
San Bernardino	Santa Ana	Mill Creek	NL15	34.0822	-116.889	Yucaipa Ridge
San Diego	San Luis Rey	Fry Creek	NL16	33.3445	-116.883	NA
Ventura	Santa Clara River	Piru Creek	NL19	34.6911	-118.851	NA
Ventura	Santa Clara River	Sespe Creek	NL20	34.5782	-119.258	152-Piedra Blanca Guard Station
Ventura	Ventura River	Bear Creek Matilija	NL21	34.5184	-119.271	264-Wheeler Gorge
Los Angeles	Calleguas	Runkle Canyon	NL22	34.2408	-118.731	272-Sage Ranch
Riverside	San Mateo	Tenaja Creek	NL23	33.5508	-117.3833	128 Murrieta Ck
Ventura	Arroyo Sequit	Arroyo Sequit	NL24	34.0458	-118.9347	Lechuza Patrol

Table 13. Data availability from Natural Loadings Study for turbidity, TSS, flow, and pH.

Station ID	**Turbidity (NTU) Type**	**Turbidity Duration**	**TSS (mg/l) Type**	**TSS Duration**	**pH Type**	**pH Duration**	**Flow (m3/sec) Type**	**Flow Duration**	**Precipitation Data**
NL01	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL02	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL03	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL04	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL05	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL07	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL09	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL10	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL11	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL12	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL15	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL16	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL19	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL20	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL21	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL22	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL23	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A
NL24	NA	NA	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	Event	12/7/2004-4/4/06	A

Table 14. Descriptive statistics of pH, total suspended solids (TSS (mg/l)), and turbidity (NTU); For LAC, OC, SACTO, and Ventura, data are obtained from storm water monitoring programs in counties and values are observed only in storm water runoff. While data that are obtained from California Data Exchange Center (CDEC) are not separated for dry and wet seasons; data from multiple stations were combined for each data source and statistics were developed using the combined datasets.

Constituent	Source	Normality	Size	Range	Min	Max	Median	25%	75%
pH	CDEC	F	224364	9.9	2.0	11.9	7.6	7.4	7.7
	LAC	F	345	2.9	6.0	8.9	7.2	6.9	7.7
	OC	F	599	4.0	5.6	9.6	7.9	7.6	8.2
	SACTO	F	31	2.1	6.0	8.1	6.8	6.7	7.3
	Ventura	F	226	2.4	6.1	8.5	7.7	7.4	8.0
TSS	LAC	F	347	14003	1	14004	216	102	550
	OC	F	601	4618	3	4620	36	5	160
	SACTO	F	203	1297	3	1300	72	39	120
	Ventura	F	217	20000	1	20000	156	20	921
Turbidity	CDEC	F	51515	2014	0	2014	10	3	41
	LAC	F	347	4920	0	4920	38	7	87
	OC	Log normal	599	2210	0	2210	26	8	78
	SACTO	Log normal	77	343	15	358	45	27	100
	Ventura	Log normal	39	6110	1	6111	60	18	454

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile; CDEC= California Data Exchange Center; LAC=Los Angeles County storm water program; OC=Orange County storm water program; SACTO=Sacramento County storm water program; Ventura=Ventura County storm water program

Table 15. Descriptive statistics of indicator bacteria; data are obtained from storm water monitoring programs in counties; values were observed in storm water runoff; data from multiple stations were combined for each data source and statistics were developed using the combined datasets; a unit is MPN(most probable number)/100ml.

Constituent	Source	Normality	Size	Range	Min	Max	Median	25%	75%
E. coli	SACTO	Log normal	64	499640	360	500000	8000	3000	19500
	Ventura	Log normal	108	287990	10	288000	1000	100	5203
Enterococcus	LAC	F	308	8999960	40	9000000	130000	22000	240000
	Ventura	F	108	165190	10	165200	1000	59	10455
Fecal coliform	LAC	F	309	24000000	0	24000000	80000	17000	240000
	SACTO	F	163	8999760	240	9000000	50000	8250	160000
	Ventura	F	206	1599998	2	1600000	5000	500	16000
Fecal streptococcus	LAC	F	309	15999920	80	16000000	170000	50000	300000
	SACTO	F	86	4999760	240	5000000	130000	21500	240000
	Ventura	F	121	899970	30	900000	22000	2300	90000
Total coliform	LAC	F	309	89999300	700	90000000	300000	137500	625000
	SACTO	F	162	22999760	240	23000000	160000	90000	500000
	Ventura	F	230	5474890	110	5475000	53375	11199	240000

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile; LAC=Los Angeles County storm water program; OC=Orange County storm water program; SACTO=Sacramento County storm water program; Ventura=Ventura County storm water program

Table 16. Descriptive statistics of metals; data are obtained from storm water monitoring programs in counties; values were observed in storm water runoff; data from multiple stations were combined for each data source and statistics were developed using the combined datasets; concentration units are µg/l.

Constituent	Source	Normality	Size	Range	Min	Max	Median	25%	75%
Dissolved Cadmium	LAC	F	347	1	0.0	1	0.0	0.0	0.0
Dissolved Copper	LAC	F	347	31	0.2	31.5	6.7	4.2	10.6
Dissolved Lead	LAC	F	347	12	0.2	12.5	0.2	0.2	1.1
Dissolved Nickel	LAC	F	347	22	0.1	21.8	4.2	2.3	6.7
Dissolved Zinc	LAC	F	347	260	0.5	260	22.6	0.5	57.5
Total Cadmium	LAC	F	348	142	0.0	142	0.0	0.0	0.4
Total Copper	LAC	F	348	699	0.2	699	16.1	10.2	32.3
	OC	F	1170	369	1.0	370	15.0	8.4	25.0
	SACTO	F	266	148	2.4	150	13.0	9.2	23.0
	Ventura	F	864	1749	0.7	1750	12.0	4.0	38.0
Total Lead	LAC	F	348	1070	0.2	1070	2.5	0.7	14.1
	OC	F	1169	140	0.3	140	1.0	1.0	3.7
	SACTO	F	262	270	0.2	270	15.7	9.0	27.0
	Ventura	F	864	448	0.1	448	2.0	0.2	12.0
Total Nickel	LAC	F	348	152	0.1	152	7.1	4.9	13.4
Total Zinc	LAC	F	347	3760	0.5	3760	60.0	22.9	116.0
	OC	F	1170	2699	1.0	2700	33.0	16.0	78.0
	SACTO	F	262	149997	3.1	150000	99.9	68.5	171.0
	Ventura	F	864	2900	0.1	2900	37.0	10.0	113.0

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile; LAC=Los Angeles County storm water program; OC=Orange County storm water program; SACTO=Sacramento County storm water program; Ventura=Ventura County storm water program

Table 17. Statistical summary of turbidity levels (NTU) in northern California by river basin; data are obtained from California Data Exchange Center (CDEC) and the data are not separated for dry and wet seasons; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	River Basin	Size	Range	Min	Max	Median	25%	75%
Butte	Feather River	29954	2001	0	2001	5	3	12
	Sacramento River	44113	1494	0	1494	2	1	6
Colusa	Sacramento River	102746	1956	0	1956	4	2	6
Contra Costa	Delta	6139	690	0	690	12	8	18
Sacramento	Sacramento River	2825	644	0	644	12	8	22
San Joaquin	Sacramento River	12074	655	0	655	7	5	10
	San Joaquin River	381380	217	0	217	0	0	6
Shasta	Sacramento River	280260	1811	0	1811	2	0	7
Solano	Delta	9308	375	0	375	50	31	73
Tehama	Sacramento River	335139	2014	0	2014	5	2	20
Trinity	Trinity River	55079	655	0	655	1	1	4

Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 18. Statistical summary of pH in northern California by river basin; data area obtained from California Data Exchange Center (CDEC) and the data are not separated for dry and wet seasons.

County	River Basin	Size	Range	Min	Max	Median	25%	75%
Contra Costa	Delta Basin	51817	7.5	4.1	11.6	7.7	7.5	7.9
Del Norte	Klamath River Basin	17476	3.9	7.2	11.1	8.3	8.2	8.5
Humboldt	Trinity River Basin	3346	6.8	2.1	8.9	8.2	8.2	8.3
Sacramento	Delta Basin	55140	8.8	2.6	11.4	7.8	7.6	8.0
	Sacramento River Basin	64408	9.6	2.3	11.9	7.5	7.4	7.6
San Joaquin	Sacramento River Basin	10014	5.7	2.5	8.2	7.5	7.3	7.7
	San Joaquin River Basin	27551	1.7	6.7	8.4	7.6	7.2	7.7
Solano	Delta Basin	53097	4.7	4.2	8.9	7.5	7.4	7.7

Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 19. Statistical summary of turbidity levels (NTU) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek Watershed	F	102	391	1	392	9	4	59
	Dominguez Channel Watershed	Log normal	16	73	2	76	11	4	37
	Los Angeles River Watershed	F	95	4920	0	4920	73	32	184
	Malibu Creek Watershed	Log normal	38	1000	0	1000	27	3	109
	San Gabriel River Watershed	F	82	962	1	963	46	9	67
	Santa Clara River Watershed	Log normal	14	945	5	950	46	33	141
Orange	Newport Bay Watershed	Log normal	281	900	1	900	39	14	121
	San Diego Creek Watershed	Log normal	181	647	1	648	22	8	73
	Santa Ana River Watershed	Log normal	25	148	2	150	10	5	17
	Westminster Watershed	Log normal	66	141	1	142	14	5	32
Ventura	Calleguas Watershed	Log normal	17	6104	7	6111	286	30	671
	Santa Clara River Watershed	Log normal	11	4258	2	4260	76	26	449
	Ventura River Watershed	Log normal	11	1339	1	1340	18	2	29
Sacramento	Sacramento River	F	77	343	15	358	45	27	100

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 20. Statistical summary of total suspended solids (TSS) concentrations (mg/l) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	102	2640	2	2642	293	136	548
	Dominguez Channel	Log normal	16	1109	14	1123	105	81	242
	Los Angeles River	Log normal	94	13998	6	14004	263	141	581
	Malibu Creek	Log normal	39	1893	1	1894	89	22	502
	San Gabriel River	Log normal	82	2058	3	2061	143	79	368
	Santa Clara River	Log normal	14	6538	53	6591	776	542	1616
Orange	Newport Bay	F	281	2117	3	2120	64	17	213
	San Diego Creek	F	183	8575	3	860	25	5	140
	Santa Ana River	F	25	734	3	736	16	10	27
	Westminster	F	66	598	3	600	20	5	47
Ventura	Calleguas	Log normal	102	19995	5	20000	480	88	1560
	Malibu Creek	Log normal	14	468	10	478	33	16	184
	Santa Clara	Log normal	62	10118	2	10120	111	26	421
	Ventura River	Log normal	39	7240	1	7240	10	5	113
Sacramento	Sacramento River	Log normal	203	1297	3	1300	72	39	120

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size = number of data points; Range = Maximum – Minimum; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile.

Table 21. Statistical summary of pH in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	102	2.7	6.0	8.8	7.1	6.9	7.7
	Dominguez Channel	Normal	16	2.2	5.9	8.2	6.8	6.5	7.8
	Los Angeles River	Normal	93	2.6	6.1	8.8	7.0	6.7	7.3
	Malibu Creek	Normal	38	1.1	7.4	8.5	8.0	7.7	8.2
	San Gabriel River	Normal	82	1.8	6.3	8.2	7.3	7.1	7.7
	Santa Clara River	Normal	14	1.4	6.7	8.1	7.4	7.1	7.8
Orange	Newport Bay	F	281	2.6	7.0	9.6	7.9	7.7	8.2
	San Diego Creek	Normal	181	3.9	5.6	9.5	7.8	7.4	8.3
	Santa Ana River	Normal	25	1.0	7.4	8.5	8.0	7.7	8.2
	Westminster	F	66	1.7	7.1	8.8	8.0	7.6	8.4
Ventura	Calleguas	F	111	2.0	6.5	8.5	7.6	7.4	7. 9
	Malibu Creek	Normal	14	0.6	7.4	8.0	7.7	7.7	7.9
	Santa Clara	F	62	2.2	6.1	8.4	7.7	7.2	8.0
	Ventura River	F	39	0.8	7.5	8.4	8.0	7.8	8.2
Sacramento	Sacramento River	F	31	2.0	6.0	8.1	6.8	6.7	7.3

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 22. Statistical summary of copper concentration (µg/l) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	103	692.1	6.8	699	26.4	15.2	83.6
	Dominguez Channel	Log normal	16	102.8	12.2	115	27.7	20.2	40.2
	Los Angeles River	F	93	288.5	6.4	295	16.4	11.7	29.7
	Malibu Creek	F	39	91.3	0.2	91.6	8.7	6.2	12.6
	San Gabriel River	F	83	97.2	0.2	97.5	11.5	8.1	16.5
	Santa Clara River	Log normal	14	45.9	7.3	53.3	13.9	10.0	30.4
Orange	Newport Bay	F	543	179.0	1.0	180.0	14.0	8.0	24.0
	San Diego Creek	Log normal	344	368.8	1.3	370.0	17.5	11.0	30.5
	Santa Ana River	Log normal	51	52.3	3.7	56.0	10.0	7.2	18.5
	Westminster	Log normal	140	164.8	5.2	170.0	18.0	11.5	26.5
Ventura	Calleguas	F	416	1749	1	1750	18.8	6.0	62.5
	Malibu Creek	F	40	94	2	96	14.0	7.5	22.0
	Santa Clara	F	252	300.0	1	301.0	12.5	3.8	28.0
	Ventura River	F	156	103.2	0.7	104	3.0	1.5	7.0
Sacramento	Sacramento River	F	262	147.6	2.4	150	13.0	9.2	23.0

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 23. Statistical summary of lead concentrations (μg/l) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	103	448.7	0.2	449.0	7.2	1.9	42.4
	Dominguez Channel	Log normal	16	38.9	0.2	39.2	3.0	2.0	16.3
	Los Angeles River	Log normal	93	1069.7	0.2	1070.0	4.4	1.7	15.5
	Malibu Creek	F	39	21.2	0.2	21.5	0.2	0.2	0.9
	San Gabriel River	F	83	72.8	0.2	73.1	0.7	0.2	3.2
	Santa Clara River	Log normal	14	38.6	1.1	39.8	3.7	2.3	14.5
Orange	Newport Bay	F	542	56.8	0.3	57.0	1.0	1.0	3.8
	San Diego Creek	F	344	139.8	0.3	140.0	1.0	0.9	4.0
	Santa Ana River	F	51	35.8	0.3	36.0	1.0	0.5	2.0
	Westminster	F	140	47.8	0.3	48.0	1.0	1.0	4.3
Ventura	Calleguas	F	416	447.9	0.1	448.0	4.9	0.3	18.0
	Malibu Creek	F	40	91.8	0.2	92.0	1.8	1.0	19.5
	Santa Clara	F	252	62.0	0.1	62.1	2.1	0.2	11.0
	Ventura River	F	156	52.5	0.1	52.6	0.2	0.1	1.5
Sacramento	Sacramento River	F	262	269.7	0.2	270.0	15.7	8.9	27.0

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 24. Statistical summary of zinc concentrations (μg/l) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	103	3759	0.5	3760	95.0	53.0	365.7
	Dominguez Channel	Log normal	16	606	61.0	667	121.5	110.5	214.0
	Los Angeles River	F	93	1029	0.5	1030	66.0	45.7	119.2
	Malibu Creek	F	38	101	0.5	102	4.86	0.5	34.0
	San Gabriel River	F	83	529	0.5	530	32.8	0.5	65.7
	Santa Clara River	Log normal	14	342	10.9	353	56.8	42.0	68.8
Orange	Newport Bay	F	543	866	3.1	870	28.0	14.0	71.8
	San Diego Creek	Log normal	344	2699	1.0	2700	47.5	23.0	94.0
	Santa Ana River	Log normal	51	340	9.8	350	28.0	17.0	46.3
	Westminster	F	140	682	8.0	690	43.0	21.5	76.5
Ventura	Calleguas	F	416	2896	3.6	2900	51.4	19.1	154.5
	Malibu Creek	Log normal	40	229	5.0	234	18.0	7.5	43.5
	Santa Clara	F	252	569	0.6	570	46.5	10.0	120.0
	Ventura River	F	156	530	0.1	531	13.6	6.6	40.1
Sacramento	Sacramento River	F	260	149996	3.1	150000	99.9	68.5	171.0

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 25. Statistical summary of fecal coliform concentrations (MPN/100mL) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	96	15999500	500	16000000	165000	29000	300000
	Dominguez Channel	Log normal	17	495000	5000	500000	30000	17000	232500
	Los Angeles River	Log normal	89	23999200	800	24000000	80000	30000	245000
	Malibu Creek	Log normal	35	1600000	1	1600000	3000	720	22000
	San Gabriel River	F	58	15999700	270	16000000	50000	9000	240000
	Santa Clara River	Log normal	14	298700	1300	300000	65000	16000	170000
Ventura	Calleguas	F	101	1599900	17	1600000	11000	1100	24000
	Malibu Creek	Log normal	18	89900	20	90000	5000	800	22000
	Santa Clara	F	55	159900	14	160000	3000	470	10500
	Ventura River	Log normal	32	16900	2	17000	300	70	3600
Sacramento	Sacramento River	F	163	8999700	240	9000000	50000	8250	160000

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 26. Statistical summary of enterococcus concentrations (MPN/100mL) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	96	8999700	300	9000000	240000	130000	300000
	Dominguez Channel	Log normal	17	895000	5000	900000	90000	29500	240000
	Los Angeles River	F	89	2399860	140	2400000	130000	46500	240000
	Malibu Creek	Log normal	34	899960	40	900000	3250	400	22000
	San Gabriel River	Log normal	58	899920	80	900000	32500	8000	170000
	Santa Clara River	Normal	14	497600	2400	500000	85000	22000	220000
Ventura	Calleguas	F	44	165180	20	165200	3580	290.5	19600
	Santa Clara	Log normal	35	52990	10	53000	478	20	5025
	Ventura River	Log normal	29	16390	10	16400	100	17.5	4200

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 27. Statistical summary of fecal streptococcus concentrations (MPN/100mL) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	96	15999700	300	16000000	240000	160000	500000
	Dominguez Channel	Log normal	17	883000	17000	900000	170000	65000	255000
	Los Angeles River	F	89	15997600	2400	16000000	220000	90000	500000
	Malibu Creek	Log normal	35	1399920	80	1400000	5000	1400	90000
	San Gabriel River	F	58	1599920	80	1600000	90000	17000	170000
	Santa Clara River	Log normal	14	897600	2400	900000	170000	50000	240000
Ventura	Calleguas	F	65	899970	30	900000	50000	7000	160000
	Malibu Creek	Log normal	18	159780	220	160000	12000	2300	30000
	Santa Clara	F	27	159920	80	160000	17000	6500	30000
	Ventura River	Log normal	11	16870	130	17000	1300	750	2675
Sacramento	Sacramento River	F	85	4999760	240	5000000	130000	21500	240000

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 28. Statistical summary of total coliform concentrations (MPN/100mL) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each river basin and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Los Angeles	Ballona Creek	F	96	16979000	21000	17000000	300000	240000	900000
	Dominguez Channel	Log normal	17	2950000	50000	3000000	300000	120000	500000
	Los Angeles River	F	89	89987000	13000	90000000	240000	160000	800000
	Malibu Creek	Log normal	35	1599300	700	1600000	16000	7000	68200
	San Gabriel River	F	58	89997000	3000	90000000	300000	170000	800000
	Santa Clara River	Log normal	14	1578000	22000	1600000	300000	170000	500000
Ventura	Calleguas	F	111	5474700	300	5475000	160000	30000	462500
	Malibu Creek	Log normal	18	159700	300	160000	15500	5000	30000
	Santa Clara	Log normal	62	1934000	1000	1935000	50000	13000	160000
	Ventura River	Log normal	39	488200	100	488400	3840	2000	22100
Sacramento	Sacramento River	F	162	22999700	200	23000000	160000	90000	500000

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 29. Statistical summary of *E. coli* concentrations (MPN/100mL) in receiving water during storm events of California by watershed; data are obtained from storm water monitoring programs in counties; data from multiple stations were combined for each watershed and statistics were developed using the combined datasets.

County	Watershed	Normality	Size	Range	Min	Max	Median	25%	75%
Ventura	Calleguas	Log normal	44	54660	80	54750	2868	430	10000
	Santa Clara	Log normal	35	287990	10	288000	410	40	7800
	Ventura River	Log normal	29	29080	10	29090	130	30	2300
Sacramento	Sacramento River	Log normal	64	499640	360	500000	8000	3000	19500

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 30. Statistical summary of TSS (mg/l) levels in receiving water in undeveloped areas of southern California by watershed during storm events; source (Stein and Yoon, 2007).

	Size	Range	Max	Min	Median	25%	75%
pH	41	1.6	8.5	6.9	7.8	7.1	8.1
TSS	212	103000	103000	0	22	4	170
Cu	212	132	132	0	2	1	8
Pb	212	102	102	0	0	0	3
Zn	209	596	596	0	6	3	22

Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 31. Statistical summary of pH and TSS (mg/l) levels in receiving water in undeveloped areas of southern California by watershed during storm events; source (Stein and Yoon, 2007).

Parameter	Watershed	Size	Range	Min	Max	Median	25%	75%
pH	Calleguas	2	0.0	7.8	7.8	7.8	7.8	7.8
	LA River	4	0.5	7.5	8.0	7.8	7.6	7.9
	San Gabriel	8	0.5	7.7	8.2	8.0	7.9	8.1
	San Luis Rey	11	0.4	6.9	7.3	7.0	7.0	7.1
	San Mateo	4	0.7	7.0	7.7	7.4	7.1	7.7
	Santa Ana	9	0.2	8.3	8.5	8.4	8.3	8.5
	Santa Clara River	2	0.0	7.9	7.9	7.9	7.9	7.9
TSS	Arroyo Sequit	26	2219	1	2220	49	10	153
	Calleguas	6	3149	201	3350	2975	1820	3190
	LA River	13	256	4	260	23	8	115
	Malibu Creek	10	332	10	342	177	32	205
	San Gabriel	32	1098	2	1100	8	2	56
	San Juan	21	930	2	932	51	2	95
	San Luis Rey	20	104	0	104	4	1	9
	San Mateo	17	5098	2	5100	158	10	990
	Santa Ana	29	160	0	161	2	0	5
	Santa Clara River	17	102998	2	103000	269	133	4122
	Ventura River	18	723	1	724	63	10	208

Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 32. Statistical summary of copper and lead (ug/l) in receiving water in undeveloped areas of southern California by watershed during storm events; source (Stein and Yoon, 2007)

		Size	Range	Min	Max	Median	25%	75%
Copper	Arroyo Sequit	27	59.9	1.7	61.6	5.1	2.9	10.8
	Calleguas	6	119.5	6.5	126.0	41.0	23.6	78.5
	LA River	9	7.5	1.9	9.5	5.0	2.4	8.2
	Malibu Creek	11	15.8	2.9	18.7	13.5	6.3	16.1
	San Gabriel	34	93.8	0.2	94.0	1.7	1.1	3.6
	San Juan	21	42.2	0.6	42.8	1.7	0.9	2.8
	San Luis Rey	20	1.3	0.1	1.3	0.2	0.1	0.4
	San Mateo	18	54.1	0.9	55.0	3.2	1.2	14.4
	Santa Ana	29	10.3	0.2	10.4	0.8	0.2	2.0
	Santa Clara River	18	53.0	1.2	54.2	11.9	2.3	43.5
	Ventura River	19	131.0	0.8	131.8	3.2	1.3	7.9
Lead	Arroyo Sequit	27	16.1	0.0	16.1	0.5	0.1	1.1
	Calleguas	6	39.4	1.9	41.3	15.5	10.2	25.0
	LA River	9	5.9	0.4	6.2	2.7	0.7	4.4
	Malibu Creek	11	3.2	0.3	3.5	2.3	0.5	3.1
	San Gabriel	34	102.0	0.0	102.0	0.4	0.1	1.4
	San Juan	21	23.2	0.0	23.2	0.5	0.1	0.9
	San Luis Rey	20	2.2	0.0	2.2	0.2	0.1	0.3
	San Mateo	18	32.6	0.0	32.6	2.3	0.2	11.2
	Santa Ana	29	6.2	0.0	6.3	0.1	0.0	0.4
	Santa Clara River	18	21.9	0.0	22.0	2.9	0.1	14.6
	Ventura River	19	10.3	0.0	10.3	0.5	0.1	1.6

Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 33. Statistical summary of zinc levels (µg/l) in receiving water in undeveloped areas of southern California by watershed during storm events; source (Stein and Yoon, 2007); data are log-normally distributed.

Parameter	Watershed	Size	Range	Min	Max	Median	25%	75%
Zinc	Arroyo Sequit	27	178.6	0.9	179.5	9.3	4.3	18.4
	Calleguas	6	574.3	21.7	596.0	171.3	90.5	370.0
	LA River	9	30.1	2.4	32.5	18.6	4.8	20.7
	Malibu Creek	11	46.9	8.1	55.0	37.4	16.7	48.0
	San Gabriel	34	98.6	0.4	99.0	2.9	1.9	20.0
	San Juan	21	188.2	0.8	189.0	6.1	1.8	8.6
	San Luis Rey	20	13.2	0.8	14.0	3.0	2.2	7.4
	San Mateo	18	240.9	2.1	243.0	14.7	3.3	74.0
	Santa Ana	29	51.8	0.3	52.0	2.0	0.7	9.0
	Santa Clara River	18	164.8	3.0	167.8	23.2	4.8	127.6
	Ventura River	19	53.1	1.7	54.8	4.6	2.8	11.5

Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; 25%=25th percentile; 75%=75th percentile

Table 34. Statistical summary of turbidity (NTU) at 7 selected watersheds in California

Watershed	Normality	Size	Geometric mean	Geometric StDev	Upper limit of CI	Lower limit of CI
Los Angeles River	F	95	68.7	5.0	49.7	95.0
Malibu Creek	Log normal	38	20.9	8.1	10.8	40.7
San Gabriel River	F	82	28.0	5.6	19.3	40.6
Newport Bay	Log normal	281	35.6	4.6	29.7	42.5
Calleguas Creek	Log normal	17	197.9	7.8	74.7	524.0
Santa Clara River	Log normal	11	125.0	9.7	32.6	479.7
Sacramento River	F	77	54.0	2.3	45.0	64.8

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; Geometric StDev = geometric standard deviation; Upper limit of CI = upper limit of 95% confidence interval (CI); Lower limit of CI = lower limit of 95% confidence interval (CI)

Table 35. Statistical summary of TSS (mg/l) at 7 watersheds in California

Watershed	Normality	Size	Geometric mean	GeoStDev	Upper limit of CI	Lower limit of CI
Los Angeles River	F	94	290.0	3.2	229.5	366.4
Malibu Creek	Log normal	39	90.1	7.3	48.3	167.9
San Gabriel River	F	82	149.0	3.9	111.2	199.6
Newport Bay	Log normal	281	56.0	5.2	46.1	67.9
Calleguas	Log normal	17	338.5	7.2	230.5	496.9
Santa Clara River	Log normal	11	109.7	7.9	65.6	183.6
Sacramento River	F	77	68.2	2.5	60.1	77.3

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; Upper limit of CI = upper limit of 95% confidence interval (CI); Lower limit of CI = lower limit of 95% confidence interval (CI)

Table 36. Statistical summary of pH level at 6 watersheds in California.

Watershed	**Normality**	**Size**	**Geometric mean**	**GeoStDev**	**Upper limit of CI**	**Lower limit of CI**
Los Angeles River	Normal	93	7.1	1.1	7.0	7.1
Malibu Creek	Normal	38	8.0	1.0	7.9	8.1
San Gabriel River	Normal	82	7.4	1.1	7.3	7.5
Newport Bay	F	281	7.9	1.0	7.9	8.0
Calleguas Creek	F	111	7.6	1.1	7.5	7.7
Santa Clara River	F	62	7.6	1.1	7.4	7.7
Sacramento River	F	31	7.0	1.1	6.8	7.1

Normality=Normal or log normal distribution test; F= normality or log normality test failed; Size= number of data points; Range = Max – Min; Min = minimum; Max = maximum; Upper limit of CI = upper limit of 95% confidence interval (CI); Lower limit of CI = lower limit of 95% confidence interval (CI)

Table 37. Kruskal-Wallis one way analysis of variance on ranks of TSS concentrations (mg/l) between two different dominant land-use type[37]

Dominant land use type	N	Missing	Median	25%	75%
Residential	376	1	105	28	290
Open land	289	4	199	49.75	714.75

H = 24.181 with 1 degrees of freedom. (P = <0.001); the differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

---

[37] N (Size) The number of non-missing observations for that column or group.

Missing The number of missing values for that column or group.

Median The "middle" observation as computed by listing all the observations from smallest to largest and selecting the largest value of the smallest half of the observations. The median observation has an equal number of observations greater than and less than that observation.

Percentiles The two percentile points that define the upper and lower tails of the observed values.

H Statistic: The ANOVA on Ranks test statistic H is computed by ranking all observations from smallest to largest without regard for treatment group. The average value of the ranks for each treatment group are computed and compared. For large sample sizes, this value is compared to the chi-square distribution (the estimate of all possible distributions of H) to determine the possibility of this H occurring. For small sample sizes, the actual distribution of H is used. If H is small, the average ranks observed in each treatment group are approximately the same. You can conclude that the data is consistent with the null hypothesis that all the samples were drawn from the same population (i.e., no treatment effect). If H is a large number, the variability among the average ranks is larger than expected from random variability in the population, and you can conclude that the samples were drawn from different populations (i.e., the differences between the groups are statistically significant).

P Value The P value is the probability of being wrong in concluding that there is a true difference in the groups (i.e., the probability of falsely rejecting the null hypothesis, or committing a Type I error, based on H). The smaller the P value, the greater the probability that the samples are significantly different. Traditionally, you can conclude there are significant differences when $P < 0.05$.

Table 38. Pearson product moment correlation analysis of total rainfall (inch/storm event) vs. TSS load (ton/storm event); data from multiple stations in each county are combined and the correlation analyses are conducted.

County	Los Angeles County	Orange County	Ventura County
Correlation Coefficient[38]	0.189	0.353	0.891
P Value[39]	0.0222	0.0000533	0.00000000111
Number of Samples	146	125	26

---

[38] Correlation Coefficient: The correlation coefficient r quantifies the strength of the association between the variables. r varies between -1 and +1. A correlation coefficient near +1 indicates there is a strong positive relationship between the two variables, with both always increasing together. A correlation coefficient near -1 indicates there is a strong negative relationship between the two variables, with one always decreasing as the other increases. A correlation coefficient of 0 indicates no relationship between the two variables.

[39] P Value: The P value is the probability of being wrong in concluding that there is a true association between the variables (i.e., the probability of falsely rejecting the null hypothesis, or committing a Type I error). The smaller the P value, the greater the probability that the variables are correlated. Traditionally, you can conclude that the independent variable can be used to predict the dependent variable when $P < 0.05$.

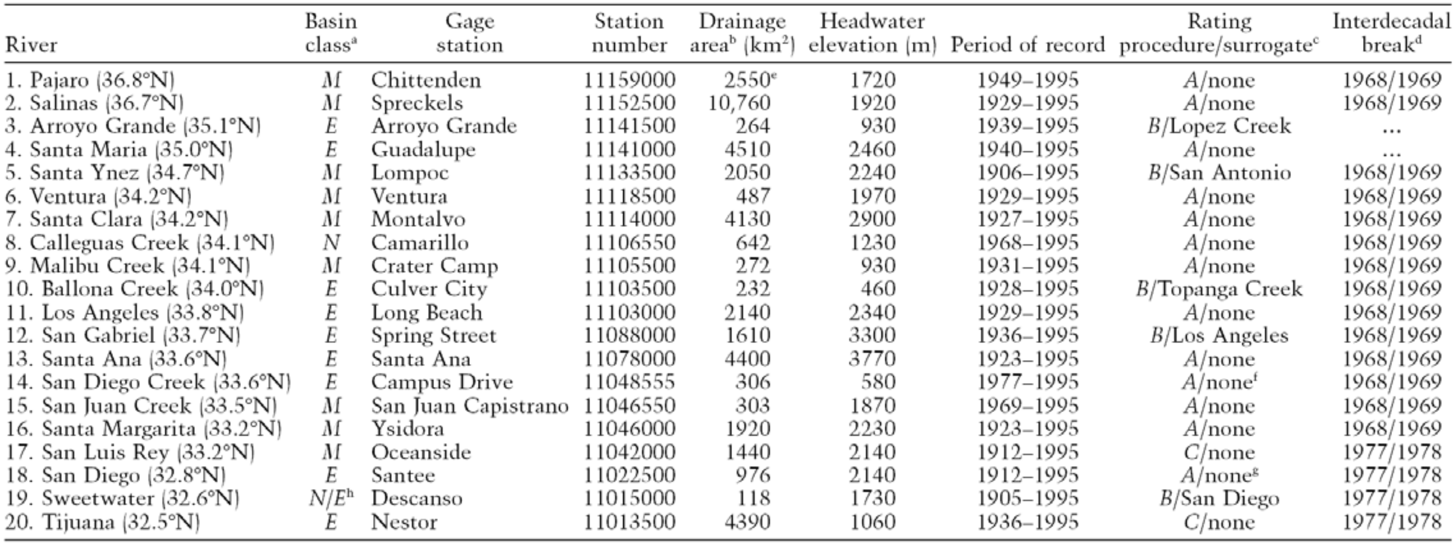
Table 39. Pearson product moment correlation analysis of total rainfall (inch/storm event) vs. TSS load (ton/storm event); the correlation analyses are conducted on data of a single station from multiple storm events from 2000 to 2006.

County	**Los Angeles County**		**Orange County**			**Ventura County**
Watershed	**Los Angeles River**	**Malibu Creek**	**Newport Bay**			**Calleguas Creek**
Station ID	**S01**	**S02**	**BARSED**	**WYLSED**	**SADF01**	**ME CC**
Correlation Coefficient	0.449	0.147	0.92	0.625	0.894	0.798
P Value	0.0279	0.525	5.39E-10	0.00321	1.07E-07	0.00108
Number of Samples	24	21	23	20	20	13

Table 40. Pearson product moment correlation analysis of total runoff volume (acre·feet/storm event) vs. TSS load (ton/storm event); the correlation analyses are conducted on data of a single station from multiple storm events from 2000 to 2006.

	Ballona Creek (S01)	**Coyote Creek (S13)**	**Dominguez Channel (S28)**	**L.A. River @ Wardlow (S10)**	**Malibu Creek (S02)**	**San Gabriel River (S14)**	**Santa Clara River (S29)**
Correlation Coefficient	NA	NA	0.688	0.681	NA	NA	0.811
P Value	> 0.05	> 0.05	0.00158	0.00018	> 0.05	> 0.05	0.0146
Number of Samples	23	23	18	25	19	21	8

Table 41. River and Basin Statistics (Source: Inman and Jenkins (1999)).



River	Basin class[a]	Gage station	Station number	Drainage area[b] (km^2)	Headwater elevation (m)	Period of record	Rating procedure/surrogate[c]	Interdecadal break[d]
1. Pajaro (36.8°N)	*M*	Chittenden	11159000	2550[e]	1720	1949–1995	*A*/none	1968/1969
2. Salinas (36.7°N)	*M*	Spreckels	11152500	10,760	1920	1929–1995	*A*/none	1968/1969
3. Arroyo Grande (35.1°N)	*E*	Arroyo Grande	11141500	264	930	1939–1995	*B*/Lopez Creek	…
4. Santa Maria (35.0°N)	*E*	Guadalupe	11141000	4510	2460	1940–1995	*A*/none	…
5. Santa Ynez (34.7°N)	*M*	Lompoc	11133500	2050	2240	1906–1995	*B*/San Antonio	1968/1969
6. Ventura (34.2°N)	*M*	Ventura	11118500	487	1970	1929–1995	*A*/none	1968/1969
7. Santa Clara (34.2°N)	*M*	Montalvo	11114000	4130	2900	1927–1995	*A*/none	1968/1969
8. Calleguas Creek (34.1°N)	*N*	Camarillo	11106550	642	1230	1968–1995	*A*/none	1968/1969
9. Malibu Creek (34.1°N)	*M*	Crater Camp	11105500	272	930	1931–1995	*A*/none	1968/1969
10. Ballona Creek (34.0°N)	*E*	Culver City	11103500	232	460	1928–1995	*B*/Topanga Creek	1968/1969
11. Los Angeles (33.8°N)	*E*	Long Beach	11103000	2140	2340	1929–1995	*A*/none	1968/1969
12. San Gabriel (33.7°N)	*E*	Spring Street	11088000	1610	3300	1936–1995	*B*/Los Angeles	1968/1969
13. Santa Ana (33.6°N)	*E*	Santa Ana	11078000	4400	3770	1923–1995	*A*/none	1968/1969
14. San Diego Creek (33.6°N)	*E*	Campus Drive	11048555	306	580	1977–1995	*A*/none[f]	1968/1969
15. San Juan Creek (33.5°N)	*M*	San Juan Capistrano	11046550	303	1870	1969–1995	*A*/none	1968/1969
16. Santa Margarita (33.2°N)	*M*	Ysidora	11046000	1920	2230	1923–1995	*A*/none	1968/1969
17. San Luis Rey (33.2°N)	*M*	Oceanside	11042000	1440	2140	1912–1995	*C*/none	1977/1978
18. San Diego (32.8°N)	*E*	Santee	11022500	976	2140	1912–1995	*A*/none[g]	1977/1978
19. Sweetwater (32.6°N)	*N*/*E*[h]	Descanso	11015000	118	1730	1905–1995	*B*/San Diego	1977/1978
20. Tijuana (32.5°N)	*E*	Nestor	11013500	4390	1060	1936–1995	*C*/none	1977/1978

[a] M, E, N 5 moderately developed, extensively developed, and natural, respectively; refer to "Procedure."

[b] Area above gage station.

[c] Sediment-rating procedure: A 5 monthly values summed by water year; B 5 monthly values using surrogates summed by water year; C 5 annual values per Brownlie and Taylor (1981). See Inman et al. (1998) for details.

[d] Indicates water year of the dry to wet climate break; ellipses indicate indeterminate break.

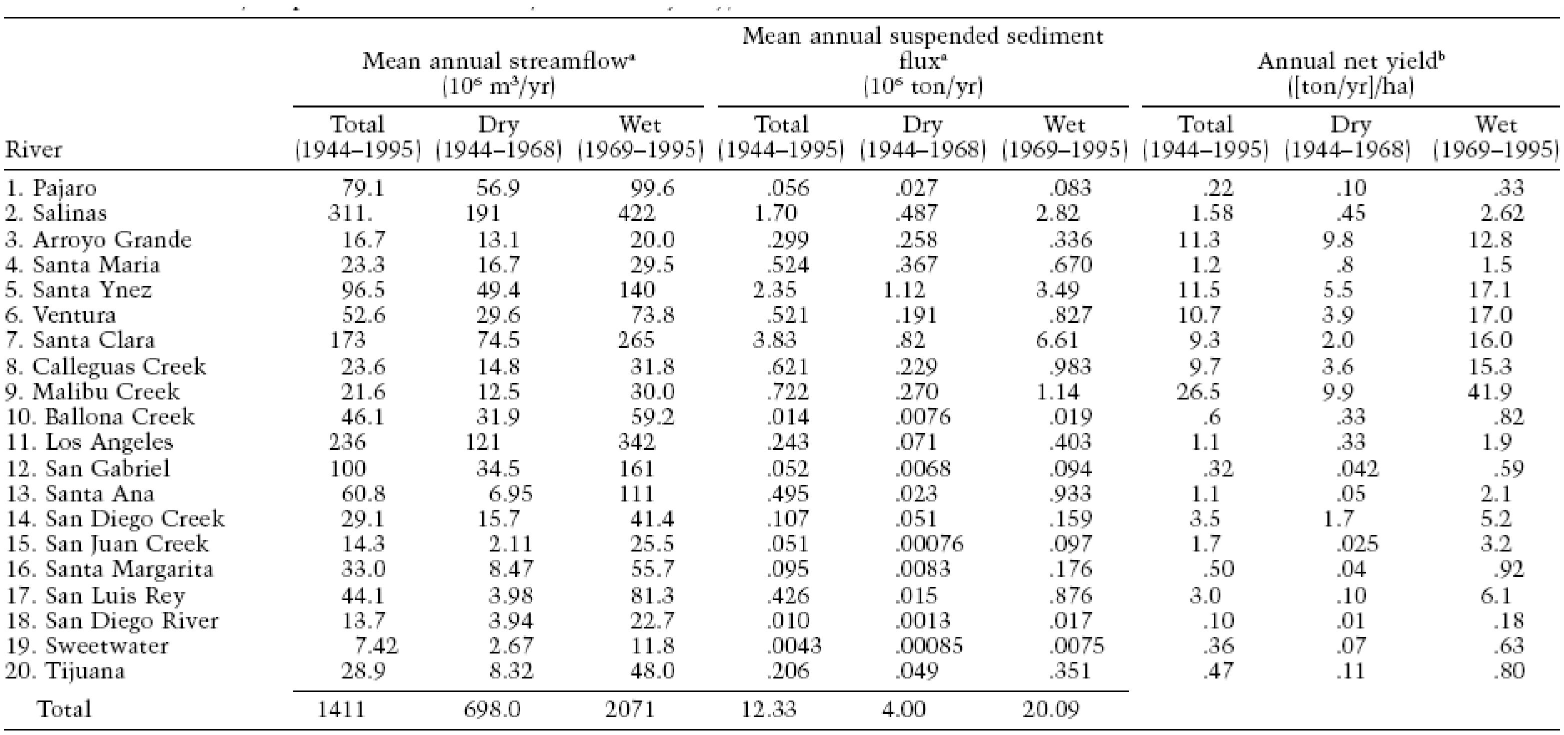
[e] Sediment-rating curve developed from 1952–1992 monitoring data at Chittenden, with stream flow and drainage area from the sum of Gilroy (Pajaro River) and Hollister (San Benito River).

[f] Sediment-rating curve developed from 1972–1985 monitoring data at Culver Drive (11048500), with stream flow from Campus Drive.

[g] Sediment-rating curve developed from 1984 monitoring data at Fashion Valley (11023000).

[h] Natural to gage station at elevation 1030 m; downstream 85% of basin extensively developed.

Table 42. Stream flow, suspended sediment flux, and yield by dry/wet period (Source: Inman and Jenkins 1999).



	Mean annual streamflow[a] (10^6 m^3/yr)			Mean annual suspended sediment flux[a] (10^6 ton/yr)			Annual net yield[b] ([ton/yr]/ha)		
River	Total (1944–1995)	Dry (1944–1968)	Wet (1969–1995)	Total (1944–1995)	Dry (1944–1968)	Wet (1969–1995)	Total (1944–1995)	Dry (1944–1968)	Wet (1969–1995)
1. Pajaro	79.1	56.9	99.6	.056	.027	.083	.22	.10	.33
2. Salinas	311.	191	422	1.70	.487	2.82	1.58	.45	2.62
3. Arroyo Grande	16.7	13.1	20.0	.299	.258	.336	11.3	9.8	12.8
4. Santa Maria	23.3	16.7	29.5	.524	.367	.670	1.2	.8	1.5
5. Santa Ynez	96.5	49.4	140	2.35	1.12	3.49	11.5	5.5	17.1
6. Ventura	52.6	29.6	73.8	.521	.191	.827	10.7	3.9	17.0
7. Santa Clara	173	74.5	265	3.83	.82	6.61	9.3	2.0	16.0
8. Calleguas Creek	23.6	14.8	31.8	.621	.229	.983	9.7	3.6	15.3
9. Malibu Creek	21.6	12.5	30.0	.722	.270	1.14	26.5	9.9	41.9
10. Ballona Creek	46.1	31.9	59.2	.014	.0076	.019	.6	.33	.82
11. Los Angeles	236	121	342	.243	.071	.403	1.1	.33	1.9
12. San Gabriel	100	34.5	161	.052	.0068	.094	.32	.042	.59
13. Santa Ana	60.8	6.95	111	.495	.023	.933	1.1	.05	2.1
14. San Diego Creek	29.1	15.7	41.4	.107	.051	.159	3.5	1.7	5.2
15. San Juan Creek	14.3	2.11	25.5	.051	.00076	.097	1.7	.025	3.2
16. Santa Margarita	33.0	8.47	55.7	.095	.0083	.176	.50	.04	.92
17. San Luis Rey	44.1	3.98	81.3	.426	.015	.876	3.0	.10	6.1
18. San Diego River	13.7	3.94	22.7	.010	.0013	.017	.10	.01	.18
19. Sweetwater	7.42	2.67	11.8	.0043	.00085	.0075	.36	.07	.63
20. Tijuana	28.9	8.32	48.0	.206	.049	.351	.47	.11	.80
Total	1411	698.0	2071	12.33	4.00	20.09			

a Streamflow and suspended sediment flux averaged from annual values (Inman et al. 1998, app. C).
b Net yield is mean suspended sediment flux for period divided by drainage area above gage station; see table 1.