U.S. Environmental Protection Agency

Region IX

# Malibu Creek & Lagoon TMDL for Sedimentation and Nutrients to Address Benthic Community Impairments

**Approved by:**

for Jane Diamond
Director, Water Division
USEPA Region IX

July 2, 2013
Date

(This page left intentionally blank.)

# Table of Contents

**Technical Appendices**

# List of Tables

# List of Figures

# Acronyms

| | |
|---|---|
| AB | Assembly Bill |
| acre-ft/yr | Acre feet per year |
| AFDM | Ash free dry mass |
| Basin Plan | Los Angeles Region Water Quality Control Plan |
| BLM | Bureau of Land Management |
| BMI | Benthic Macroinvertebrate |
| BOD | Biochemical Oxygen Demand |
| BURC | Beneficial Use Risk Categories |
| CADDIS | Causal Analysis/Diagnosis Decision Information System |
| Caltrans | California Department of Transportation |
| CCC | Criterion Continuous Concentration |
| CDFG | California Department of Fish and Game |
| CDPR | California Department of Parks and Recreation |
| CFR | Code of Federal Regulations |
| cfs | Cubic feet per second |
| CIMIS | California Irrigation Management Information System |
| cm | Centimeter |
| cm/year | Centimeters per year |
| CRAM | California Rapid Assessment Methodology |
| CSCI | California Stream Condition Index |
| CTR | California Toxics Rule |
| CWA | Clean Water Act |
| DEM | Digital Elevation Model |
| DO | Dissolved Oxygen |
| EFC | Environmental Flow Components |
| ELS | Early Life Stages |
| EPT | Ephemeroptera-Plecoptera-Trichoptera |
| ESRI | Environmental Systems Research Institute |
| ft | Feet |
| ft/s | Feet per second |
| GIS | Geographic Information System |
| HSG | Hydrologic Soil Group |
| HSPF | Hydrologic Simulation Program Fortran |
| HtB Stream Team | Heal the Bay Stream Team |
| IBI | Index of Biotic Integrity |
| IHA | Indicator of Hydrologic Alteration |
| kg | Kilograms |
| kg/mo | Kilograms per month |

| | |
|---|---|
| LA | Load Allocation |
| LAC MES | Los Angeles County Mass Emissions Station |
| LACDPW | Los Angeles County Department of Public Works |
| LACFCD | Los Angeles County Flood Control District |
| LARWQCB | Los Angeles Regional Water Quality Control Board |
| lbs/day | Pounds per day |
| LU/LC | Land Use/Land Cover |
| LVMWD | Las Virgenes Municipal Water District |
| $m^3$/d | Cubic meters per day |
| MCWMP | Malibu Creek Watershed Management Program |
| mg/L | Milligrams per Liter |
| mg/$m^2$ | Milligrams per square meter |
| MGD | Million Gallons per Day |
| MLRMP | Malibu Lagoon Restoration Monitoring Plan |
| mm/yr | Millimeters per year |
| MOS | Margin of Safety |
| MRLC | Multi-Resolution Land Characteristics |
| MS4 | Municipal Separate Storm Sewer Systems |
| N | Nitrogen |
| $NH_3$ | Un-ionized ammonia |
| $NH_4$ | Ammonium |
| NLCD | National Land Cover Data |
| NMFS | National Marine Fisheries Service |
| NNE | Nutrient Numeric Endpoint |
| $NO_2$ | Nitrite |
| $NO_3$ | Nitrate |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollution Discharge Elimination System |
| NPS | National Park Service |
| NRCS | Natural Resources Conservation Service |
| NTU | Nephelometric Turbidity Unit |
| O/E | Ratio of observed to expected taxa |
| OWDS | Onsite Wastewater Disposal System |
| OWTS | Onsite Wastewater Treatment Systems |
| P | Phosphorous |
| PCH | Pacific Coast Highway |
| pMMI | Predictive multi-metric index |
| QA | Quality Assurance |
| QC | Quality Control |
| RBP | Rapid Bioassessment Protocol |

| | |
|---|---|
| RCD | Resource Conservation District |
| RWQCB | Regional Water Quality Control Board |
| RIVPACS | River Invertebrate Prediction and Classification System |
| SCAG | Southern California Association of Governments |
| SCCWRP | Southern California Coastal Water Research Project |
| SC-IBI | Southern California Benthic Index of Biotic Integrity |
| SCS | Soil Conservation Service |
| SFR | Single Family Residential |
| SI | Stressor Identification |
| SIG | Stressor Identification Guidance |
| SMBRC | Santa Monica Bay Restoration Commission |
| SSC | Suspended Sediment Concentration |
| SSURGO | Soil Survey Geographic |
| STATSGO | State Soil Geographic Database |
| SWAMP | Surface Water Ambient Monitoring Program |
| SWMP | Storm Water Management Program |
| SWRCB | State Water Resources Control Board |
| $t/km^2/yr$ | Tons per square kilometer per year |
| Tapia WRF | Tapia Water Reclamation Facility |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorous |
| TSS | Total Suspended Solids |
| USDA | United States Department of Agriculture |
| USEPA | U.S. Environmental Protection Agency |
| USFS | United States Forest Service |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| WDR | Waste Discharge Requirement |
| WLAs | Waste Load Allocations |
| WQC | Water Quality Criteria |
| WQLS | Water Quality Limited Segments |
| WQO | Water Quality Objective |
| WQS | Water Quality Standard |
| µm | Micrometers |
| µS/cm | Micro Siemens per Centimeter |

# 1. Introduction

The United States Environmental Protection Agency (USEPA) Region IX established Total Maximum Daily Loads (TMDLs) for Malibu Creek and Lagoon in the Los Angeles Region (Figure 1-1). USEPA was assisted in this effort by the Los Angeles Regional Water Quality Control Board (LARWQCB). A variety of water quality impairments have been identified in the watershed. This TMDL specifically addresses the impaired benthic biota in the Malibu Creek main stem and Malibu Lagoon, while discussing conditions throughout the watershed that may impact these impairments. The main tributaries of Malibu Creek, including Las Virgenes Creek, Cold Creek, and Stokes Creek, is a direct source of pollutant loadings to Malibu Creek, and thus, are also addressed in this TMDL.

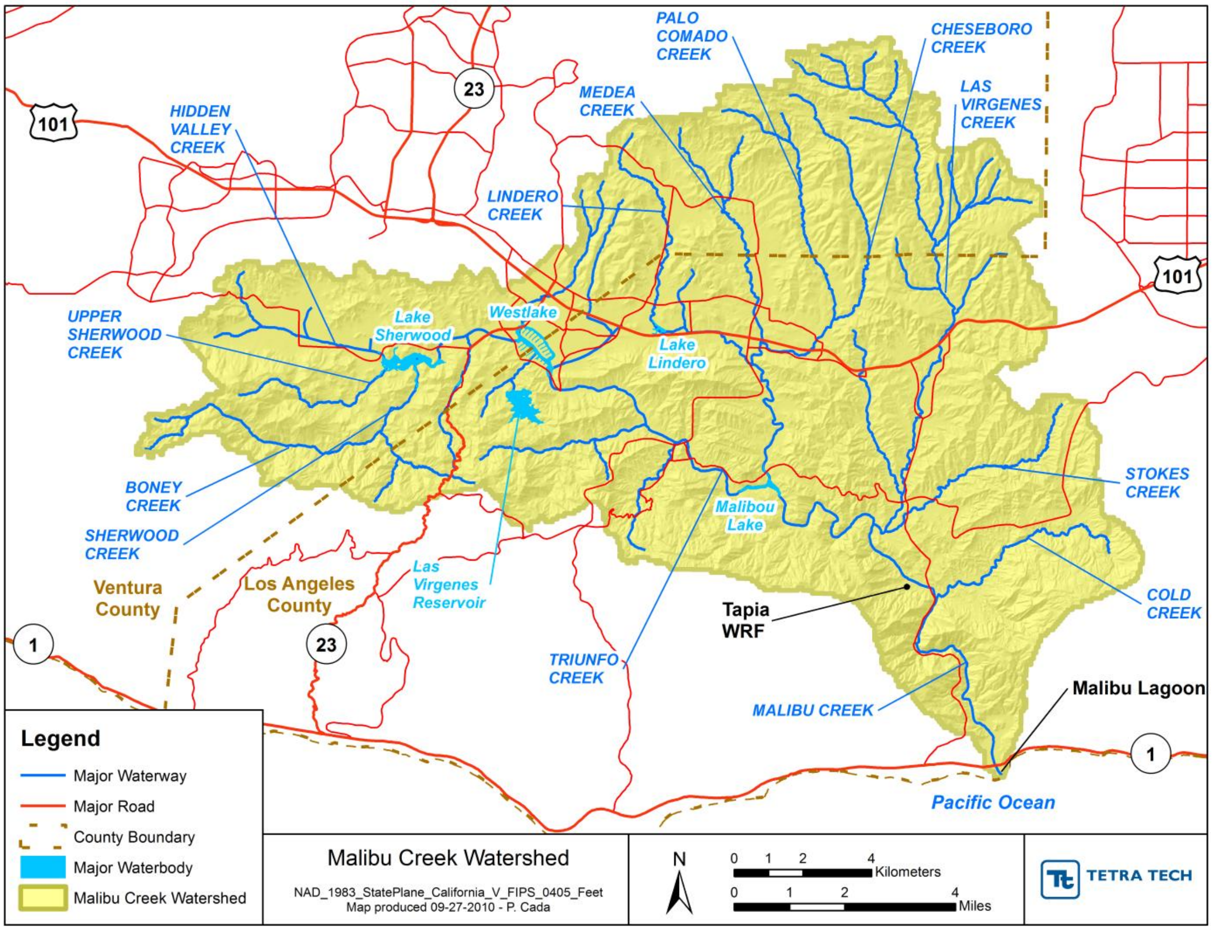



**Figure 1-1. Malibu Creek Watershed**

## 1.1 Regulatory Background

Section 303(d) of the Clean Water Act (CWA) requires that each State "shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality objective applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters.

The elements of a TMDL are described in 40 Code of Federal Regulations (CFR) 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the USEPA Region IX's Guidance for Developing TMDLs in California (USEPA, 2000e). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loads (the loading capacity) is not exceeded. A TMDL is also required to account for seasonal variations and include a margin of safety to address uncertainty in the analysis (CWA 303(d)(1)(C) (USEPA, 2000e).

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. In California, the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB) are responsible for preparing lists of impaired waterbodies and for preparing TMDLs, under the 303(d) program; both these documents are subject to USEPA approval. If USEPA disapproves a TMDL submitted by a state, or if a state does not develop a TMDL in a timely manner, USEPA is required to establish a TMDL for that waterbody. The RWQCBs hold regulatory authority for many of the instruments used to implement the TMDLs, such as National Pollutant Discharge Elimination System (NPDES) permits and state-specified Waste Discharge Requirements (WDRs).

As part of its 1996 and 1998 regional water quality assessments, LARWQCB identified over 700 waterbody-pollutant combinations in the Los Angeles Region where TMDLs would be required (LARWQCB, 1996, 1998). These are referred to as "listed" or "303(d)-listed" waterbodies or waterbody segments. A schedule for development of TMDLs in the Los Angeles Region was established in a Consent Decree approved between USEPA and several environmental groups on March 22, 1999 (Heal the Bay Inc. et al. v. Browner et al. C 98-4825 SBA). Under the Consent Decree, USEPA must establish these TMDLs by March 24, 2013. This deadline was extended to July 2, 2013.

## 1.2 ELEMENTS OF A TMDL

Guidance from USEPA (1991) identifies several elements of a TMDL. Sections 2 through 10 of this document are organized such that each section describes data and background information (Sections 4, 6, 7, and 8) or one of the TMDL elements, including the analysis and findings of these TMDLs for that element. Additionally, implementation and monitoring recommendations are provided in Section 11. TMDL sections are as follows:

- **Section 2: Problem Statement.** Presents the data used to add the waterbody to the 303(d) list, and summarizes existing conditions using that evidence along with any new information acquired since the listing. This element identifies portions of the waterbody that fail to support all designated beneficial uses; the criteria designed to protect those beneficial uses (collectively, the beneficial uses and water quality objectives are the water quality standards [WQS]); and, in summary, the evidence supporting the decision to list, such as the number and severity of impacts observed.
- **Section 3: Numeric Targets.** Sets numeric targets based upon the numeric and narrative water quality objectives described in the Los Angeles Region Water Quality Control Plan (Basin Plan) and the existing USEPA established 2003 Nutrient TMDL for Malibu Creek Watershed.
- **Section 5: Source Assessment.** Describes and identifies the potential point sources and nonpoint sources of sediment and impact to Malibu Creek and Lagoon.
- **Section 9: Linkage Analysis.** Provides an analysis of the relationship between sources and the water quality impairment. This TMDL completed a detailed Stressor Identification or causal assessment to comprehensively evaluate the critical stressors causing the impairment. The linkage analysis separately analyzes the potential sources to comprehensively evaluate which sources contribute to the stressors identified as causing the impairment.

- **Section 10: TMDLs and Pollutant Allocations.** Identifies the quantitative load, concentration-based allocations and, in this case, the necessary numeric biological response numeric targets that need to be achieved to ensure protection of the identified beneficial uses in Malibu Creek and Lagoon. This section addresses the critical conditions, loading, and water quality parameters. Allocations are designed to protect the waterbody from conditions that exceed the applicable numeric target. The allocations are based on critical conditions to ensure protection of the waterbody under all conditions.
- **Section 11: Implementation.** Not considered a required element of a TMDL established by USEPA; this section contains recommendations to the State regarding implementation and monitoring for this TMDL.

Several appendices were also developed to provide additional background information or technical detail. The appendices include:

- Appendix A. Data Inventory and Sources
- Appendix B. Meteorology, Climate, and Fire History and Conditions
- Appendix C. IHA Reference Information
- Appendix D. CSCI Analyses
- Appendix E. Relevant Studies
- Appendix F. Nutrient Numeric Endpoints for TMDL Development: Malibu Watershed Case Study
- Appendix G. Stressor Identification Analyses

## 1.3 Physical Setting

The Malibu Creek Watershed, located west of Los Angeles, California, drains an area of 109 square miles (Figure 1-1). The watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific Coast of Santa Monica Bay at Malibu State Beach (formerly Surfrider Beach). Malibu Lagoon, currently about 31 acres in size, occupies the area behind the beach at the mouth of Malibu Creek. The entire watershed lies within Level 3 sub-ecoregion 6 (Southern and Central California Chaparral) within aggregate nutrient ecoregion 3 (Xeric West; USEPA, 2000c). The geology includes a complex mix of rock of marine and non-marine origin, with naturally elevated erosion potential.

### 1.3.1 Malibu Creek and Tributaries

The Malibu Creek Watershed includes the cities of Agoura Hills, Westlake Village, Calabasas, Thousand Oaks, Hidden Hills, and a portion of Malibu and Simi Valley and has a total population of nearly 100,000. Nearly two-thirds of the watershed is in Los Angeles County, while the remaining portion is in Ventura County. Historically, there is little flow in the summer months; much of the natural flow that does occur in the summer in the upper tributaries comes from springs and seepage areas.

Malibu Creek has several major tributaries and together these make up the Malibu Creek Watershed. These tributaries include streams draining to Lake Sherwood, which discharges to Potrero Creek. This creek then reaches Westlake Lake and flow moves down Triunfo Creek to its confluence with Lobo Canyon Creek, which becomes Malibu Creek. Medea Creek then joins Triunfo Creek to form Malibou Lake. Farther downstream Las Virgenes Creek enters Malibu Creek at Malibu Creek State Park. Stokes Creek, Las Virgenes Creek, and Cold Creek are the major tributaries to Malibu Creek downstream of Malibou Lake. Eventually the creek empties into the 13-acre Malibu Lagoon (see Section 1.3.2 for more details on the Lagoon). The major tributaries of Medea (upstream of Malibou Lake, presented as an example of the upstream drainage) and Las Virgenes Creeks (downstream of Malibou Lake) are described below along with Malibou Lake, which is a major impoundment in the watershed.

Medea Creek has a total length of 7.56 miles. Land use in the Medea Creek subwatershed contains a mix of open space area (mostly chaparral/scrub) and residential and commercial uses. Lower Lindero Creek eventually flows to Medea Creek. Medea Creek also receives drainage from the subwatersheds associated with Palo Comado Creek and Cheseboro Creek and eventually drains into Malibou Lake.

Malibou Lake receives the drainage from most of the subwatersheds in the upper portion of the watershed. The lake has a drainage area of 64 square miles which represents almost 60% of the entire watershed. Water flows from Triunfo and Medea Creek into the 69-acre lake. The lake was constructed in 1922 for swimming, boating and fishing by members and guests of the Malibou Lake Mountain Club, Ltd. Malibou Lake has mud bottom that is dredged on a continual basis because of sediment loadings from upstream sources. The outflow from the lake discharges into Malibu Creek.

Malibu Creek also receives flow from Las Virgenes Creek. Las Virgenes Creek is an 11- mile creek with a 12,456-acre drainage area. Land cover in the Las Virgenes Creek subwatershed is predominantly open space (mostly chaparral/scrub), with some residential and commercial/industrial land. Malibu Creek is a 10-mile creek that runs from Malibou Lake to Malibu Lagoon (see Section 1.3.2). The predominant land cover in the Malibu Creek subwatershed is also open space (primarily chaparral/scrub. The Tapia Water Reclamation Facility (Tapia WRF) is located in this subwatershed and contributes significant flow in the winter months.

About 50 square miles of the watershed (nearly half of the total area) is parkland or conserved land. Some of the protected areas include Peter Strauss Ranch, Cheseboro Canyon, Cold Creek Canyon Preserve, Tapia Park, and Malibu Creek and Lagoon State Parks. The watershed contains a wide variety of diverse habitats including coastal strand, oak and riparian woodlands, chaparral, coastal sage scrub, native grasslands, sulfur springs, and brackish water Lagoon. It is home to several threatened, endangered, or endemic plants and animals. These include the southern steelhead trout, tidewater goby, California brown pelican, California least tern, red-legged frog, San Fernando Valley spineflower, Malibu baccharis, and the arroyo chub, an endemic minnow, which is a California species of special concern.

### 1.3.2 Malibu Lagoon

Malibu Lagoon is located in the City of Malibu, Los Angeles County at the mouth of Malibu Creek. The wetland acreage includes 2/3 mile of the creek corridor east of the Pacific Coast Highway (PCH) and the wetland habitat acreage is approximately 92 acres. The historic wetland size has been documented and estimated to be several times its present size; the wetland had extended through the Civic Center area to the Pepperdine University property. Malibu Lagoon is surrounded by a chaparral ecosystem and experiences Mediterranean-type climate with mild, wet winters and hot, dry summers. Annual precipitation ranges from an average of 13.2 inches falling over the coast and 25.4 inches falling over the mountains.

Early historical accounts of the Chumash Indians, who arrived into the Malibu area more than 20,000 years ago, and ship logs, suggest the Lagoon typically remained open through the summer under pre-development conditions (Ambrose et al., 1995). Prior to 1900's, the Lagoon was described as having been relatively pristine, until the construction of the Rindge railroad line in 1908 that resulted in filling in portions of the Lagoon. In 1929, Caltrans used the site as a dumping ground during the construction of the PCH. Road construction in and around the Lagoon continued throughout the years, including filling additional areas of the Lagoon to construct baseball fields and parking for beach access (Ambrose et al. 1995). The Lagoon is bounded by the public beaches on the south side, the Malibu Colony residential development and a golf course on the west side, the PCH and expanding commercial development on the north side, and the historical Adams House Museum in the eastern adjacent area. The California

Department of Parks and Recreation (CDPR) currently has land management and ownership responsibility of the Malibu Lagoon and adjacent lands.

Malibu Lagoon is a valuable coastal wetland, providing critical habitat for the federally endangered tidewater goby, southern steelhead trout, and the western snowy plover, and a diverse number of shorebirds; the Lagoon is a critical stop over on the Pacific Flyway for migratory birds (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005).

Malibu Lagoon has undergone major changes in recent history due to major road construction, nearby development and upstream anthropogenic activities (Jones and Stokes, 2006; Moffatt and Nichol, 2005). By the late 1970's the site was completely filled and housed two baseball fields (Jones and Stokes, 2006; Moffatt and Nichol, 2005). The impact from the previous construction activities led to loss of native species, increasing urban runoff, and excessive nutrient inputs (Ambrose and Orme, 2000).

In 1983, CDPR restored Malibu Lagoon by creating three channels and re-vegetating with native salt marsh plants (Jones and Stokes, 2006; Moffatt and Nichol, 2005). Malibu Lagoon underwent a restoration which included the removal of construction rubble, excavation of buried fill to create channels, thus increasing the main Lagoon depth, and planting native vegetation. Then, in 1996, the California Department of Transportation (Caltrans) implemented restoration actions to mitigate the Malibu Lagoon/PCH bridge replacement; this restoration effort was mainly focused on the enhancement of tidewater goby (fish species) habitat, re-vegetation of native species (i.e., California bunchgrasses), and removing non-native plant species (i.e., *Myoporum*, black mustard, and hottentot fig) from the Lagoon. CDPR has maintained the site as a wildlife habitat since the first restoration effort. Additional restoration efforts included the re-introduction of the endangered tidewater goby, additional excavation of tidal channels to improve tidal circulation, creation of islands and areas to support bird and tidewater goby habitat (Trim, 1994). Malibu Lagoon is home to many endangered and threatened species, including the California brown pelican, California least tern, double-crested cormorant, California gull, western snowy plover, elegant tern, tidewater goby, and the steelhead trout. In spite of these efforts, the continual development activities adjacent and upstream of the Lagoon continue to impact the ecological viability and health of the benthic community.

In summer 2012, the State of California, Santa Monica Bay Restoration Commission, and CDPR conducted an expansive restoration of Malibu Lagoon. These actions dredged areas with significant anoxic conditions and poor water circulation. Tidal flow and improved water circulation are expected to restore critical habitat for Pacific Flyway migratory birds and endangered and threatened wildlife.

(This page left intentionally blank.)

# 2. Problem Statement

This section describes the beneficial uses identified in the Basin Plan and discusses the applicable water quality objectives for each beneficial use (Los Angeles Board, 1994). It also includes information to describe the basis for each listing.

## 2.1 WATER QUALITY STANDARDS

California state water quality standards include of the following elements: 1) beneficial uses, 2) narrative and/or numeric water quality objectives (WQOs) and numeric water quality criteria (WQC), and 3) an antidegradation policy. In California, beneficial uses are defined by the RWQCBs in the Basin Plans. Numeric and narrative objectives are specified in each region's Basin Plan, designed to be protective of the beneficial uses.

### 2.1.1 Beneficial Uses

The Los Angeles Region Basin Plan lists the beneficial uses of Malibu Creek and Lagoon and major tributaries, which determine the applicable water quality criteria (Los Angeles Board, 1994).

Table 2-1 summarizes the beneficial uses designated for Malibu Creek and Lagoon and tributaries. These waterbodies are designated to provide municipal water supply, water recreation, ecological habitat uses, and the support of rare, threatened, or endangered species.

**Table 2-1. Beneficial Uses for Malibu Creek, Lagoon and Major Tributaries (Los Angeles Board, 1994)**

| Waterbody | Malibu Creek | Malibu Lagoon | Las Virgenes Creek | Upper Medea Creek | Lower Medea Creek |
|---|---|---|---|---|---|
| Municipal and Domestic Supply (MUN) | P* | | P* | P* | I* |
| Agricultural Supply (AGR) | | | | | |
| Industrial Process Supply (PROC) | | | | | |
| Industrial Service Supply (IND) | | | | | |
| Groundwater Recharge (GWR) | | | | | I |
| Freshwater Replenishment (FRSH) | | | | | |
| Navigation (NAV) | | E | | | |
| Hydropower Generation (POW) | | | | | |
| Contact Water Recreation (REC1) | E | E | Em | Im | Em |
| Non-contact Water Recreation (REC2) | E | E | E | I | E |
| Aquaculture (AQUA) | | | | | |
| Warm Freshwater Habitat (WARM) | E | | E | I | E |

| Waterbody | Malibu Creek | Malibu Lagoon | Las Virgenes Creek | Upper Medea Creek | Lower Medea Creek |
|---|---|---|---|---|---|
| Cold Freshwater Habitat (COLD) | E | | P | P | |
| Inland Saline Water Habitat (SAL)_ | | | | | |
| Estuarine Habitat (EST) | | E | | | |
| Marine Habitat (MAR) | | E | | | |
| Wildlife Habitat (WILD) | E | E | E | E | E |
| Preservation of Biological Habitats of Special Significance (BIOL) | | | | | |
| Rare, Threatened, or Endangered Species (RARE) | E | Ee | E | E | |
| Migration of Aquatic Organisms (MIGR) | E | Ef | P | | |
| Spawning, Reproduction, and/or Early Development (SPWN) | E | Ef | P | | |
| Shellfish Harvesting (SHELL) | | | | | |
| Wetland Habitat (WET) | E | E | E | E | E |

Notes:

P Potential beneficial use.

E Existing beneficial use.

I Intermittent beneficial use.

Ee One or more rare species utilize all ocean, bays, estuaries, lagoons and coastal wetlands for foraging and/or nesting.

Ef Aquatic organisms utilize all bays, estuaries, lagoons and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater inputs.

* Beneficial use designated under SB 88-63 and RB 89-03. Some designations may be considered for exemptions at a later date.

m Access prohibited by Los Angeles County DPW in the concrete-channelized areas.

The WARM and COLD aquatic life uses are most relevant to this TMDL. The WARM use is specifically defined as “Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.” The COLD use is defined as “Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates” (Los Angeles Board, 1994).

### 2.1.2 Water Quality Objectives

Water quality objectives for the Malibu Creek Watershed have been established at the federal, state, and regional levels. These objectives support aquatic life by addressing toxicity, nutrients, dissolved oxygen, algae, sediment, and other related constituents. Objectives are primarily based on the California Toxics Rule (CTR) (40 CFR 131 – 65FR 31682, May 18, 2000) and the Los Angeles Basin Plan (Los Angeles

Board, 1994). The Los Angeles Basin Plan defines narrative and numeric WQOs to protect beneficial uses of water and prevent nuisances within a specific area.

The SWRCB is in the process of developing biological objectives (bio-objectives) for California's freshwater streams and rivers and expects to adopt the new objectives in spring of 2014 (see http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml for detailed information on the process and status)..

The applicable narrative objectives for aquatic life within Malibu Creek include those that relate to toxicity, eutrophication, dissolved oxygen, sediment, and other factors potentially impacting benthic biological communities. These include the following:

- **Bioaccumulation:** The Basin Plan states that "toxic pollutants shall not be present at levels that will accumulate in aquatic life to levels which are harmful to aquatic life or human health."
- **Biochemical Oxygen Demand (BOD):** The Basin Plan states that "waters shall be free of substances that result in increases in the BOD which adversely affect beneficial uses."
- **Biostimulatory Substances:** The Basin Plan states that "biostimulatory substances include nutrients (nitrogen, phosphorus) and other compounds that stimulate aquatic growth" and specifies a narrative criterion that "waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growth causes nuisance or adversely effects beneficial uses."
- **Sediment:** The Basin Plan narrative sediment criteria were established to prevent impacts to spawning habitat, benthic organisms, and larval fish as well as other impacts. The Basin Plan states that "waters shall not contain suspended or settleable material in concentrations that cause nuisance or adversely affect beneficial uses."
- **Temperature:** The Basin Plan states that "the natural receiving water temperature of all regional waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses." The Basin Plan also specifies numeric criteria as noted in Table 2-2.
- **Turbidity:** The Basin Plan states that "watersheds shall be free of changes in turbidity that cause nuisance or adversely affect beneficial use" and also specifies numeric criteria as noted in Table 2-2.
- **Toxicity:** The Basin Plan states that "all waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological response in human, plant, animal, or aquatic life."

The numeric criteria most applicable to the protection of aquatic life in the Malibu Creek Watershed are presented in Table 2-2, along with the nitrate-nitrogen criterion that is most relevant to drinking water uses. Ammonia objectives are defined as a function of pH and temperature and metals objectives are defined as a function of hardness. The equations used to calculate these objectives are explained in more detail below. Numeric criteria for other toxins are outlined in the CTR 40 CFR 131.38 (USEPA, 2000a).

The 2003 USEPA-established TMDL set nutrient criteria for "total" nitrogen (specified as the sum of nitrate plus nitrite nitrogen) and total phosphorus based on best available information at the time (USEPA, 2003). These are presented in Table 2-2. Since 2003, a significant amount of additional data and analyses has been completed. This TMDL finds there is strong evidence that the nutrient limits should be revisited.

**Table 2-2. Selected Numeric Water Quality Criteria Applicable to the Malibu Creek Watershed (Los Angeles Board, 1994)**

| Constituent | WQO | Notes |
| --- | --- | --- |
| Ammonia | 30-day average and one-hour acute objectives expressed as functions of temperature and pH; four-day maximum average concentrations shall not exceed 2.5 times the 30-day average objective. | See Equation 2-1 through Equation 2-4 |
| Nitrate-Nitrogen | 10 mg/L | Specific objective for the Malibu Creek Watershed based on MUN use |
| Dissolved Oxygen | For WARM: Mean annual concentration > 7 mg/L; instantaneous > 5 mg/L; as a result of waste discharges: > 5 mg/L instantaneous<br>For COLD: > 6 mg/L instantaneous<br>For COLD and SPWN: > 7 mg/L instantaneous | Objectives differ by beneficial use for waters receiving waste discharges |
| pH | As a result of waste discharges: between 6.5 and 8.5, and no change > 0.5 units from natural conditions | Objective defined for waters receiving waste discharges |
| Temperature | For WARM: no change > 5 degrees F above natural temperature and < or equal to 80 degrees F at all times;<br>For COLD: no change > 5 degrees F above natural temperature | Objectives differ by beneficial use; for Malibu Lagoon, stricter regulations may be induced for individual dischargers under the CA Thermal Plan (SWRCB, 1972) |
| Total Dissolved Solids | 2,000 mg/L | Specific objective for the Malibu Creek Watershed |
| Turbidity | Natural turbidity 0 to 50 Nephelometric Turbidity Units(NTU): increases shall not exceed 20 percent<br>Natural turbidity >50 NTU: increases shall not exceed 10 percent | |
| Chlorophyll-*a* | 150 mg/L for streams and Lagoon (seasonal average) | 2003 Nutrient TMDL |
| Algae cover | 30% Floating algae (seasonal average)<br>60% Bottom algae (seasonal average) | 2003 Nutrient TMDL |
| TN (Nitrate plus Nitrite Nitrogen) | 1.0 mg/L summer (April 15 –November 15)<br>8.0 mg/L winter (November 16- April 14) | 2003 Nutrient TMDL |
| Total Phosphorus | 0.1 mg/L summer (April 15 –November 15) only | 2003 Nutrient TMDL |

The Basin Plan expresses ammonia targets as a function of pH and temperature because un-ionized ammonia ($NH_3$) is toxic to fish and other aquatic life. In order to assess compliance with the standard, pH, temperature, and ammonia must be determined at the same time. The toxicity of ammonia increases with increasing pH and temperature; therefore, ammonia targets depend on the site-specific pH and temperature as well as the presence or absence of early life stages (ELS) of aquatic life.

A December 2005 Amendment to the Basin Plan assumes that ELS are present in any waterbody designated as COLD (Los Angeles Board, 2005a). The 30-day average target concentrations (criterion continuous concentration (CCC)) of ammonia for waterbodies with ELS absent and present can be calculated using Equation 2-1 and Equation 2-2, respectively. The four-day maximum average concentration shall not exceed 2.5 times the 30-day average objective, while the one-hour acute level, with ELS absent and present, can be calculated with Equation 2-3 and Equation 2-4, respectively (USEPA, 1999).

**Equation 2-1. 30-day Average Total Ammonia Concentration for Waterbodies with ELS Absent**

$$\text{30-day Average Concentration (mg/L)} = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right)\cdot 1.45\cdot 10^{0.028(25-MAX(T,7))}$$

**Equation 2-2. 30-day Average Total Ammonia Concentration for Waterbodies with ELS Present**

$$\text{30-day Average Concentration (mg/L)} = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right)\cdot MIN\left(2.85, 1.45\cdot 10^{0.028(25-T)}\right)$$

**Equation 2-3. Acute Criteria for Total Ammonia-Nitrogen for Waterbodies with ELS Absent (USEPA, 1999)**

$$Acute\ Limit\ (mg/L) = \left(\frac{0.41}{1+10^{7.204-pH}}\right)+\left(\frac{58.4}{1+10^{pH-7.204}}\right)$$

**Equation 2-4. Acute Criteria for Total Ammonia-Nitrogen for Waterbodies with ELS Present (USEPA, 1999)**

$$Acute\ Limit\ (mg/L) = \left(\frac{0.267}{1+10^{7.204-pH}}\right)+\left(\frac{39.0}{1+10^{pH-7.204}}\right)$$

### 2.1.3 Antidegradation

State Board Resolution 68-16, "Statement of Policy with Respect to Maintaining High Quality Water in California," known as the "Antidegradation Policy," protects surface and ground waters from degradation. Any actions that can adversely affect high quality surface and ground waters must be consistent with the maximum benefit to the people of the state, must not unreasonably affect present and anticipated beneficial use of such water, and must not result in water quality less than that prescribed in water quality plans and policies. Furthermore, any actions that can adversely affect surface waters are also subject to the federal Antidegradation Policy (40 CFR 131.12). The proposed TMDLs will not degrade water quality, and will in fact improve water quality as they will lead to meeting the water quality standards.

## 2.2 BASIS OF LISTING IN MALIBU CREEK WATERSHED

The 2002 Section 303(d) (Los Angeles Board, 2002) list of impaired waters identified Malibu Creek as impaired by total selenium, total aluminum, nitrite-nitrogen, and sedimentation, while Malibu Lagoon was listed as impaired by sedimentation. The 2010 list (SWRCB, 2010) showed Malibu Creek as impaired due to poor benthic macroinvertebrate bioassessments, excess coliform bacteria, fish barriers (fish passage), invasive species, nutrients (algae), scum/foam (unnatural), sedimentation/siltation, selenium, sulfates, and trash. The 2010 303(d) list also identified Malibu Lagoon as being impaired for benthic community effects, coliform bacteria, eutrophic conditions, swimming restrictions, viruses (enteric), and pH.

A number of these identified impairments have been addressed through completed TMDLs:

- A coliform bacteria TMDL for Malibu Creek was approved by USEPA on January 1, 2002 (USEPA, 2002).
- A nutrient/eutrophication TMDL for the creek and Lagoon was approved by USEPA on March 21, 2003. Allocations are based on growing season concentration targets of 1 mg/L total nitrogen and 0.1 mg/L total phosphorus (USEPA, 2003).
- A coliform bacteria TMDL for Malibu Lagoon was approved on January 1, 2005.
- Swimming restrictions and enteric viruses in the Lagoon are addressed in a TMDL approved January 1, 2006.
- A trash TMDL for the creek and Lagoon was approved on June 26, 2009.

This TMDL is completed in accordance with the 1999 Consent Decree [Heal the Bay Inc., et al. v. Browner, et al. C 98-4825 SBA, March 22, 1999] and the 2010 modification to the Consent Decree (US District Court, September 2, 2010). In 2010, a modification to the Consent Decree resulted in adding additional "pairings of Water Quality Limited Segments (WQLSs) and pollutants". These include Malibu Creek benthic-macroinvertebrate bioassessments, Malibu Creek sedimentation/siltation, and Malibu Lagoon benthic community effects.

This TMDL is addressing benthic macroinvertebrates and sedimentation in Malibu Creek and its main tributaries (Cold Creek, Stokes Creek and Las Virgenes Creek), and benthic community effects in Malibu Lagoon.

### 2.2.1 Basis of the 303(d) Listings for Malibu Creek and Tributaries

The 2002 303(d) Fact Sheet discussed a sedimentation impairment, stating that "Malibu Creek Watershed, including Malibu Creek, Las Virgenes Creek, Triunfo Creek, and Medea Creek, is proposed to be listed in the 2002 305(b) water quality assessment as "Partially Supporting (Impaired)" due to excessive sedimentation. Regional Board staff and James M. Harrington, Staff Environmental Scientist of California Department of Fish and Game (CFDG), evaluated the data and concluded that the Malibu Creek Watershed, with the exception of Cold Creek, is impaired by sedimentation based on both the biological assessment of the macroinvertebrate stream community assemblage and the physical habitat data. Harrington states, 'All of the monitoring sites within the Malibu Creek Watershed (except for the upper reaches of Cold Creek) show typical signs of ecological impairment due primarily to sediment (and nutrient enrichment)…and low physical habitat scores reflect the influence of heavy sediments in causing reduced habitat availability and reduced habitat quality for macroinvertebrates… It is my opinion that Malibu Creek is impaired by excessive sedimentation" (Letter from Harrington to the Regional Board dated December 6, 2001).

The 2010 integrated report for the Los Angeles Region stated "The water quality chemistry and bioassessment data provide a substantial basis that benthic macroinvertebrate populations are impacted by a wide range of anthropogenic stressors." The report from the 2005 Malibu Creek Bioassessment Monitoring Program (Aquatic Bioassay, 2005) examined eight sites in the Malibu Creek Watershed, providing both Index of Biotic Integrity (IBI) and physical habitat scores (including substrate complexity, embeddedness, consolidation, and percent fines). Four of the eight sites (including Malibu Creek above the Lagoon – the only station on the main stem included in that survey) showed physical habitat as optimal or suboptimal and, for these four sites, "stressors other than habitat conditions may have impacted these sites." There are many other potential causes of the poor IBI scores (including excess nutrients, metals, organics, and exotic species).

### 2.2.2 Basis of the 303(d) Listing for Benthic Community Impacts in Malibu Lagoon

Malibu Lagoon was originally included in the 1998 listing for benthic community effects impairment.

According to California State Water Resources Board, Los Angeles Region (L. Nye, 2012, personal communication), the basis of the impairment listing for benthic community impacts in Malibu Lagoon was due to one of the few documented surveys of the benthic community. This is documented in Chapter 6 of "Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek" (Ambrose et al., 1995). This discussion provides a summary of the benthic invertebrate results and analyses provided in the report; the sampling method and other details are not provided in this TMDL, and instead further interest should be directed to the Chapter 6 of the report itself.

A total of three different invertebrate groups were surveyed in the 1993-1994 sampling effort, including zooplankton (small floating species in the water), infauna (species living in the Lagoon sediment), and large invertebrates (e.g., shrimp, crabs). A total of 17 benthic invertebrate taxa were collected, including the mud-flat crab, the introduced oriental shrimp, two polychaete families and other crustacean and bivalve taxa. The most abundant zooplankton taxon was the copepods; other common taxa included ostracods, nauplii, polychaetes, trochophores, nemerteans, and nematodes. According to Ambrose et al. (1995), the distribution and abundance of these floating species in the water column was influenced by the transitory and shallow environment of Malibu Lagoon. Copepods, ostracods and benthic invertebrate larvae were the most common zooplankton species, as would be expected in shallow Lagoon waters.

Infauna inhabiting the sediments of coastal lagoons typically includes clams, shrimp, crustaceans, and worms, among others. Benthic infauna is a highly diverse group with hundreds of species. A typical southern California coastal Lagoon with appropriate tidal flushing should support between 100-200 infaunal species (Zedler et al., 1992; Peterson, 1977). In contrast, coastal lagoons without tidal flushing should see significantly reduced species richness (Nordby and Covin, 1988). The only bivalve crustacean collected was the California jackknife clam, *Tagelus californianus*; a total of 352 live clams were collected. The polychaete, *Polydora nuchalis,* was also collected. Approximately 99% of the clams were collected at the tidal creek site (S-6B), which had finer sediments than other sites sampled in the Lagoon. At sandier substrates, the clams were not collected or had few individuals (n=3 at three sites), suggesting that sandy substrates were not suitable habitat for jackknife clam burrows. There was some indication that peak abundances of the clams coincided with summer breaching events and the first significant precipitation event in 1993. Mud crab burrows and mud crabs were observed in the Lagoon, specifically at trap stations with the steepest banks. The exotic and introduced oriental shrimp was first collected at Malibu Lagoon in September 1987 during a fish survey (Topanga-Las Virgenes Resource Conservation District, 1989). During the 1993-1994 sampling period, a total of 1,125 oriental shrimp were collected across all sampling periods and sites; the majority of the shrimp were collected furthest from the mouth of the Lagoon. The study stated that one major contributing factor to the high shrimp abundances observed was the presence of construction debris, which likely provided habitat shelter for the invertebrates.

The observations and results of the 1993-1994 sampling effort for benthic invertebrates suggest that Malibu Lagoon ranks "poorly at this trophic level when compared to less disturbed southern California estuaries" (Ambrose et al., 1995).

In 2010, supporting information for the 2010 integrated report against delisting this listing for Malibu Lagoon stated that readily available data and information, and weight of evidence, conclude there is "sufficient justification against removing this water segment-pollutant combination from the section 303(d) list." This conclusion is based on the staff findings that:

1. The Malibu Lagoon Restoration Feasibility Study Final Alternatives Analysis describes restoration measures for Malibu Lagoon. These proposed restoration efforts, if fully implemented, are anticipated to correct the conditions which allow the negative indicator species to thrive.
2. The LARWQCB "decided against moving the benthic community effects listing in Malibu Lagoon from the TMDL required portion of the 303(d) list to the being addressed by action other than TMDL portion of the 303(d) list." The source of impairment is indicated as hydromodification.

## 2.3 IMPAIRMENT CONCLUSIONS

Many different datasets were evaluated to characterize and confirm impairments. These data include water quality, biological, and habitat data. Summary highlights (in a summary box) and detailed analyses are presented in Sections 7 and 8. A Stressor Identification Analyses to evaluate the linkage between benthic community species, sedimentation and other relevant stressor variables is presented in Section 9.

Overall, USEPA's comprehensive evaluation of the available data confirmed impairments for benthic macroinvertebrates and benthic community effects in Malibu Creek and Malibu Lagoon, respectively. The sedimentation listing in Malibu Creek was confirmed by both the turbidity data analyses, in which results were an order of magnitude above comparator/reference sites, as well as the calculated 38 percent change in sedimentation rate from natural conditions. Multiple stressors were evaluated with respect to these impairments. The key stressors impacting the biota (both directly and indirectly) were sedimentation and nutrient loading. In addition, nutrient data from the last 10 years suggested that the nutrient concentration numeric limits from the 2003 Nutrient TMDL are not stringent enough to support protection of benthic community in Malibu Creek and Lagoon.

(This page left intentionally blank.)

# 3. Numeric Targets

Numeric targets represent quantitative values that result in attainment of the water quality standards. Since USEPA's assessment of all available data and studies demonstrate that the impairment is a result of multiple interacting stressors, this TMDL identifies multiple numeric targets for the most significant pollutants. The numeric targets were assigned based on response targets and comparisons with natural conditions; these numeric targets include specific quantifiable measures directly associated with biotic impairment and sedimentation.

The key stressors impacting the biota (both directly and indirectly) are sedimentation and nutrient loading, as summarized in Section 9. Excessive levels of sedimentation contributed to suboptimal habitat and transported sediment-associated nutrients and toxics. Excess nutrient loading contributed to overgrowth of algae, including the development of macro-algal mats, which directly impaired the habitat available for benthic macroinvertebrates, while indirectly contributed to exceedances of dissolved oxygen (DO) and pH criteria. Numeric targets associated with these stressors are presented below for Malibu Creek and Lagoon, while the analyses supporting the selection of these targets are documented in Sections 7 through 10 (as well as several associated appendices).

Prior to the establishment of the 2003 Malibu Creek Watershed Nutrient TMDL, numeric nutrient criteria did not exist for the waters of Malibu Creek Watershed. The 2003 USEPA-established TMDL set nutrient criteria for total nitrogen (nitrate-nitrite) and total phosphorus based on best available information at the time. These are presented in Table 2-2. Since 2003, a significant amount of additional data and analyses has been completed in this watershed. California is currently developing a statewide approach for setting nutrient criteria based on the NNE. Based on the listed impairment of benthic macroinvertebrates and benthic community, and the more expansive monitoring, data collection, and in-depth assessments completed to date for Malibu Creek and Lagoon, this TMDL is supporting new targets, reviewing the applicability of past targets set for Malibu Creek and Lagoon.

## 3.1 Malibu Creek and Tributaries Numeric Targets

Numeric targets for Malibu Creek and its major tributaries were identified from several sources. These include the Basin Plan, the 2003 Nutrient TMDL (USEPA, 2003), NNE Analyses (Appendix F), and additional data analyses (Sections 7 and 8); each source are discussed below in the context of this TMDL.

In the 2003 Nutrient TMDL, USEPA utilized the reference waterbody approach to develop numeric targets for impaired streams and lakes within the Malibu watershed based on USEPA guidance (USEPA, 2000a; 2000b; 2003). For streams, the reference approach involves using relatively undisturbed stream segments to serve as examples of background nutrient concentrations (USEPA, 2000a). The 2003 Nutrient TMDL evaluated data from three locations upstream of the Tapia treatment plant with long-term data sets (Upper Malibu Creek (R9), Middle Malibu Creek (R1) and Lower Las Virgenes Creek (R6)). The concentrations for both nitrogen and phosphorus at the Upper Malibu Creek and Middle Malibu Creek stations were much lower than at the Las Virgenes Creek station. Data from stations R9 and R1 were believed to be more appropriate for setting target values using the reference approach. Based on data from these stations, the proposed targets in the 2003 Nutrient TMDL were 1.0 mg/L for total nitrogen and 0.1 mg/L as a target for total phosphorus (Nitrate-N plus Nitrite-N) for the summer period; and 8 mg/L total phosphorus for the winter period (USEPA, 2003).

Since this TMDL is addressing sedimentation and benthic community impairments, USEPA believes data from the last 10 years suggest that the nutrient concentration numeric limits from the 2003 Nutrient TMDL are not quite stringent enough to attain beneficial uses, and that new targets should be set year-round and reduced. This is further supported by conclusions from the 2003 Nutrient TMDL, which concluded at the time, that limited data and uncertainties regarding the relationship between nutrients and aquatic life narrowed the 2003 Nutrient TMDL's focus to protecting for nuisance and recreational beneficial uses.

Since 2003, HtB Stream Team has collected algal coverage data for 2005-2010. These data indicate that the mat algae cover is above the 2003 Nutrient TMDL threshold and the temporal trend does not show any decline over time. In addition, monitoring stations on Malibu Creek demonstrate limited excursions of the summer and winter nutrient targets from the 2003 Nutrient TMDL (see Section 7.6). These analyses support the conclusion that additional nutrient concentration targets are needed.

To identify new nutrient targets, a watershed reference-based approach was used. The analysis of Malibu Creek data and studies to date suggested that the 2003 Nutrient TMDL targets (USEPA, 2003) for the Malibu Creek Watershed of 1 mg/L total nitrogen (Nitrate-N plus Nitrite-N) and 0.1 mg/L total phosphorus (from April 15 to November 15) may not be adequate to support protection of aquatic life, such as the benthic community. We adopted the Reference Watershed Approach and evaluated site in unimpacted areas in the watershed (Section 7.6.4). These results suggested that natural reference conditions in the Malibu Creek Watershed are 0.65 mg/L total N and 0.10 mg/L total P in the summer and 1.0 mg/L total N and 0.2 mg/L total P in the winter.

In summary, the numeric targets for this TMDL that apply to Malibu Creek and tributaries are as follows:

- **SC-IBI**: SC-IBI bioscore is set at a minimum of 40 or better, consistent with at least a "Fair" ranking (Ode et al., 2005). The evaluation should be based on a median over a minimum of four years to account for year-to-year variability.
- **CSCI**: CSCI, pMMI, and CA- O/E scores provide a second line of evidence to complement the SC-IBI. These scores should equal between $5^{th}$ and $10^{th}$ percentile of the model reference distribution. Similar to the SC-IBI, the evaluation should be based on a median over a minimum of four years to account for year-to-year variability.
- **Benthic Algal Coverage**: Consistent with the algal coverage targets established in the 2003 Nutrient TMDL: no more than 30 percent cover for filamentous (floating) algae greater than 2 cm in length and no more than 60 percent cover for bottom algae greater than 0.3 cm thick.
- **Chlorophyll *a* :** to maintain a minimum of 150 mg/L for both streams and Lagoon.
- **Dissolved Oxygen**: Consistent with the 2003 Nutrient TMDL, the target for the mean annual dissolved oxygen concentration is 7 mg/L for all waters in the Malibu Creek Watershed. The Basin Plan standard for waters designated as WARM is that no single determination can be below 5.0 mg/L as a result of waste discharges. This target applies to most tributaries, including Lower Medea Creek. A more restrictive target of 7 mg/L is required for Las Virgenes Creek, Upper Medea Creek, and Malibu Creek to protect existing and potential uses associated with cold-water fisheries and spawning. Recognizing that diel fluctuations in DO are a natural occurrence, we propose that 7.0 mg/L minimum for waters with uses associated with cold water fisheries and spawning (Las Virgenes Creek, Upper Medea Creek, and Malibu Creek) be interpreted as an average daily value.
- **Natural Sedimentation Rate**: The sedimentation rate to protect the health of the Malibu Creek Watershed is set at a 38 percent reduction in sedimentation loading (Section 10.2).
- **Nutrient Concentrations**: The total nitrogen (organic plus inorganic nitrogen) targets are 0.65 mg/L in the summer and 1.0 mg/L in the winter; and total phosphorous targets are 0.1 mg/L in the Creek, major tributaries and in the Lagoon in the summer and 0.2 mg/L in the winter.

## 3.2 MALIBU LAGOON NUMERIC TARGETS

Several sources were also used to identify numeric targets for Malibu Lagoon, including the Basin Plan, the 2003 Nutrient TMDL (USEPA, 2003), and additional data analyses (Sections 7 and 8). These sources are discussed below, including how they apply to this TMDL.

In the 2003 Nutrient TMDL, nutrient targets for the Lagoon were derived from the USEPA/National Oceanic and Atmpospheric Administration (NOAA) guidance for estuaries (NOAA/EPA, 1988). The targets are 1.0 mg/L for nitrogen and 0.1 mg/L phosphorus for the summer period.

Malibu Lagoon currently shows elevated concentrations for the biologically-available nutrients such as nitrate ($NO_3$-N), and ammonium ($NH_4$-N) that contribute to excessive algal growth (see Section 7.7; also Moffatt and Nichol, 2005; 2NDNATURE, 2010). The presence of excessive algae led to greater consumption of the available dissolved oxygen during decomposition, and thus led to anoxic conditions that impacted the survival of the flora and fauna in the Lagoon (Section 8.2). In addition, USEPA collected data during winter 2010 and spring 2011 that showed less than 20 total taxa, which still indicated an impaired system, and Malibu Lagoon Restoration Monitoring in 2006-2007 showed similar results (Section 8.2).

Because baseline data for Malibu Lagoon (prior to the significant impacts in the Lagoon) were not available and reference site data from another similar seasonally tidal coastal Lagoon were also not available, this TMDL based its determination on the best available information and the strong conclusion that we should expect to see greater species and taxa richness from a healthy benthic community in Malibu Lagoon. Consequently, based on our review of other coastal estuaries, we should expect to see a doubling of the species and taxa richness within a ten year time frame. Our best example and most comparable coastal estuary in size and physical behavior is Los Peñasquitos Lagoon in San Diego County. The best indication of the expected increase in benthic infaunal richness was the observed data before and after extended mouth closure due to anthropogenic activities. Los Peñasquitos Lagoon saw approximately three-fold increase of taxa richness (from around 11 to 34) under less impacted conditions. Similarly, San Dieguito, although a much larger estuary, saw a six-fold increase in taxa richness after more natural tidal flushing actions were implemented (from 7 to 42). In Batiquitos Lagoon, a ten year monitoring period following the restoration of the tidal flushing resulted in greater benthic infauna abundance and diversity (Merkel and Associates, 2009). In addition, they found that in the later post-restoration monitoring years, less dominant organisms were observed more regularly, but in small numbers.

The average taxa richness observed during the three sampling periods in Malibu Lagoon over a 15 year time span (1995-2010) was 16 taxa. During the 1995, 2006/07 and 2010/11 sampling periods, the average taxa richness observed was 17, 13.5, and 18.5, respectively. For this TMDL, the numeric target and benthic invertebrate taxa richness goal is set at 40. USEPA believes this is a reasonable target for the rationale provided above, and because this reflects the recent restoration of Malibu Lagoon in summer 2012. This Lagoon restoration was comprehensive, cost approximately $7M, and was designed to increase tidal flushing to all zones of the Lagoon, and to remove the excessively anoxic sediment, particularly in the back sloughs of the Lagoon. These actions should provide the best foundation for building and restoring the benthic community in the Malibu Lagoon. As such, based on our knowledge of coastal estuaries in southern California and the long-term impaired conditions in the Lagoon observed in the last 20 years, an increase to 40 of the benthic infaunal taxa richness is achievable and should provide for improvement and protection of the beneficial use. This is comparable to the approach taken in the Chesapeake Bay TMDLs addressing benthic community impairments due to nutrient and sedimentation imbalance.

USEPA evaluated the impaired conditions of Malibu Lagoon, including the data and assessments completed prior to and following the 2003 Nutrient TMDL. In general, the Malibu Lagoon benthic community conditions were critically impacted, as summarized above. However, during the development of this TMDL, the State implemented an expansive and comprehensive restoration effort for Malibu Lagoon in summer 2012. This restoration effort resulted in removal of anoxic sediment, increasing water circulation and restoration of habitat. These actions are expected to restore critical habitat for Pacific Flyway migratory birds and endangered and threatened wildlife. The largest phase of restoration was conducted by end of 2012, and future phases of restoration activities include monitoring, assessment, and additional activities to maintain and support the long-term success of the restoration. Please visit http://www.restoremalibulagoon.com/ for more detailed information on the restoration project and status.

Due to this restoration effort, Malibu Lagoon's conditions have dramatically changed and the accumulated pollutant load and habitat spaces have been removed. These actions led USEPA to focus on other new and continued sources of impairment to the Lagoon. These new and existing sources are primarily from Malibu Creek Watershed, where all watershed sources drain directly into the Lagoon. These watershed sources are further examined and evaluated in Section 5, 7, and 8.

For these reasons, USEPA is maintaining the existing 2003 Nutrient TMDL targets below:

- **Benthic Community Diversity**: Achieve a goal of increasing species richness in Malibu Lagoon with multiple functional groups. A minimum total number of taxa richness is set at 40 based on annual averages over a 15-year time period.
- **Dissolved Oxygen**: Consistent with the 2003 Nutrient TMDL, the target for the mean annual dissolved oxygen concentration is 7 mg/L for all waters in the Malibu watershed, including Malibu Lagoon. A more restrictive target is required for Malibu Lagoon to protect existing and potential uses associated with cold-water fisheries and spawning. The Basin Plan standard for waters designated as WARM is that no single determination can be below 5.0 mg/L as a result of waste discharges. Recognizing that diel fluctuations in DO are a natural occurrence, we propose that 7.0 mg/L minimum for waters with uses associated with cold water fisheries and spawning be interpreted as an average daily value.
- **Nutrient Concentrations**: Consistent with 2003 Nutrient TMDL, the targets for Malibu Lagoon are 1.0 mg/L total nitrogen and 0.1 mg/L total phosphorus during the summer period (April 15 to Nov 15) and a target of 8.0 mg/L total nitrogen for the winter period (Nov. 16 to April 14).

# 4. Geographic Information and Analysis

Geographic analyses provided a foundation to interpret data analyses and to represent sources and conditions in the watershed. This section presents the geographic data evaluated (see also Appendix A) and associated characterization of the Malibu Creek Watershed. Appendix B provides additional background on watershed characterization.

## 4.1 Inventory of Spatial Data

Spatial data for the Malibu Creek Watershed region were obtained from several different sources. In many cases, the original source data were modified for specific applications to the Malibu Creek Watershed. For example, the Southern California Association of Governments (SCAG) land use and land cover data from 1990, 2005, and 2008 were clipped to the watershed boundaries and simplified through aggregation of the numerous SCAG classes into broader descriptions. Some spatial data were available in tabular format (e.g., latitude and longitude) and then transformed into Geographic Information System (GIS) spatial coverages. Appendix A includes the description of the different spatial datasets assembled to support subsequent work within the watershed.

## 4.2 Jurisdictions

Seven municipalities have jurisdictional boundaries within the Malibu Creek Watershed (Figure 4-1). Five of the municipalities are within Los Angeles County (LA County) and two are within Ventura County. Westlake Village and Agoura Hills jurisdictional areas (both in LA County) are found exclusively within the watershed. The majority of the watershed is outside of existing incorporated municipal jurisdictional boundaries. As of 2010, all areas within the watershed are covered by municipal stormwater permits for LA and Ventura counties, except for state roads, which are covered by Caltrans' permit (see Section 5.1.2).

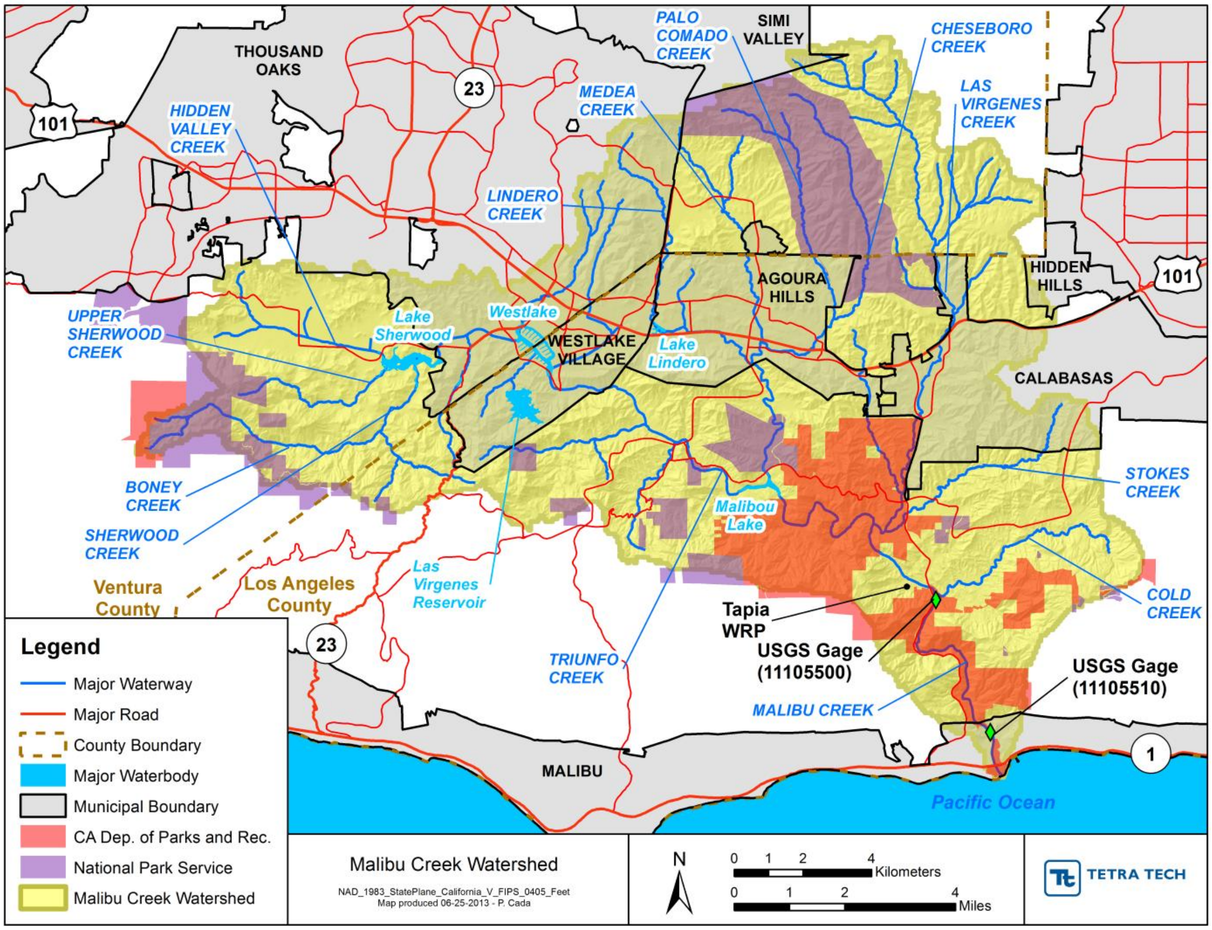



**Figure 4-1. Municipal Jurisdiction Boundaries within the Malibu Creek Watershed**

## 4.3 TOPOGRAPHY

Located in the Peninsular Range physiographic province, the Malibu Creek Watershed is bordered by the Santa Monica Mountain range to the west and Simi Hills to the north. As shown in Figure 4-2, most of the headwater areas are located in Ventura County and many of these areas drain to lakes before converging to form Malibu Creek in the lower watershed. Elevations in the watershed range from sea level at the Malibu Lagoon and Santa Monica Bay to over 900 meters (2,953 feet) in the Santa Monica Mountains and Simi Hills. The watershed elevation and topography shown in Figure 4-2 was based on a 10-meter Digital Elevation Model (DEM) obtained from United States Department of Agriculture (USDA).

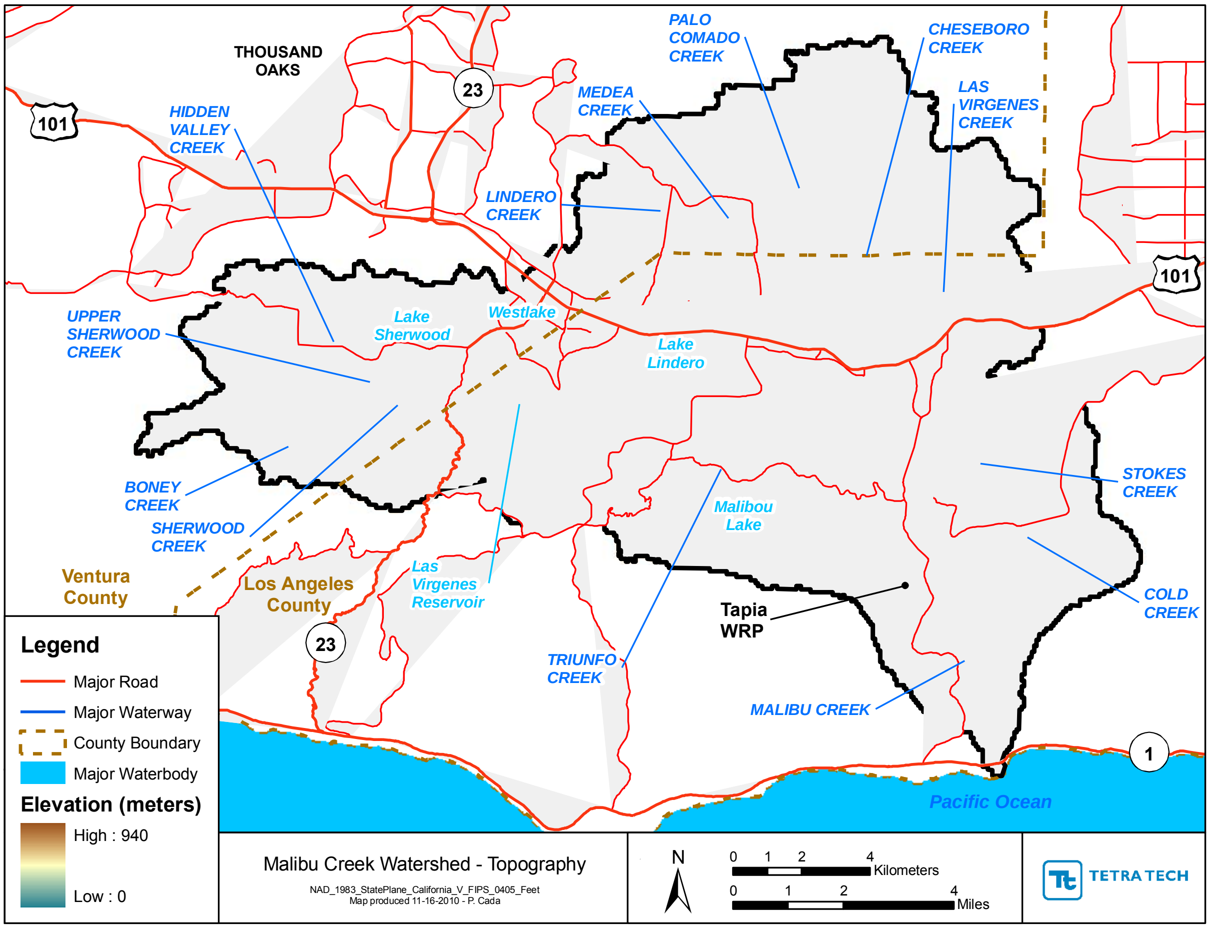



**Figure 4-2. Topography of the Malibu Creek Watershed**

Malibu Lagoon occupies a small prism at the confluence of Malibu Creek with the Pacific Ocean at Malibu Beach (Figure 4-3). Like most southern California estuaries, Malibu Lagoon is open to the ocean on an intermittent basis, with mouth closures due to coastwise sand transport. The image from October 2011 shows a small outflow occurring at the eastern end of the beach. The morphology of the current Lagoon is constrained by the Pacific Coast Highway, the Malibu Civic Center, and areas of fill (including a golf course) between the Pacific Coast Highway and the beach.


**Figure 4-3. Malibu Lagoon in October 2011**

## 4.4 GEOLOGY AND SOILS

Malibu Creek flows from and through the Santa Monica Mountains, a region of active deformation and topographical change. The dynamic nature of this landscape plays an important role in shaping conditions in the stream and Lagoon – and includes naturally enhanced rates of erosion and sediment delivery.

Meigs et al. (1999) estimated that uplift rates on the south flank of the Santa Monica Mountains were approximately 0.5 millimeters per year (mm/yr), while erosion, represented in normalized form as denudation rate, was also on the order of 0.5 mm/yr. This results in sediment yields that are noticeably greater than yields from surrounding portions of southern California. Warrick and Mertes (2009) examined the issue in detail for the Western Transverse Range (Santa Clara, Ventura, and Santa Ynez Mountain drainages), and found that areas with highest sediment yields consistently have weakly consolidated bedrock (Quaternary-Pliocene marine formations) and are associated with the highest rates of tectonic uplift. These areas generated sediment yields on the order of 5,000 tons per square kilometer per year ($t/km^2/yr$), but yields from other portions of the range without Quaternary-Pliocene marine formations were still on the order of 1,000 $t/km^2/yr$. Geology in the basin is mostly non-marine in nature, but does include 38 percent Miocene marine sedimentary rock.

Significant exposures of Miocene-age marine sediments are found in the area immediately north of the 101 Freeway where the Monterey Formation (known locally as the Monterey/Modelo Formation; Figure

4-4) is present at the surface. The Monterey/Modelo Formation is an important source of petroleum in California. Information from LVMWD (2011) suggests that the source of very high levels of sulfate, phosphate, metals, and total dissolved solids is due to drainage originating from the Monterey/Modelo Formation (the report also indicates that other Miocene marine formations may also contribute to elevated solute levels). USEPA reviewed the submitted data, conducted additional evaluation of the information, and examined multiple maps describing the Monterey/Modelo Formation north of Liberty Canyon Creek and the portions near Malibou Lake.

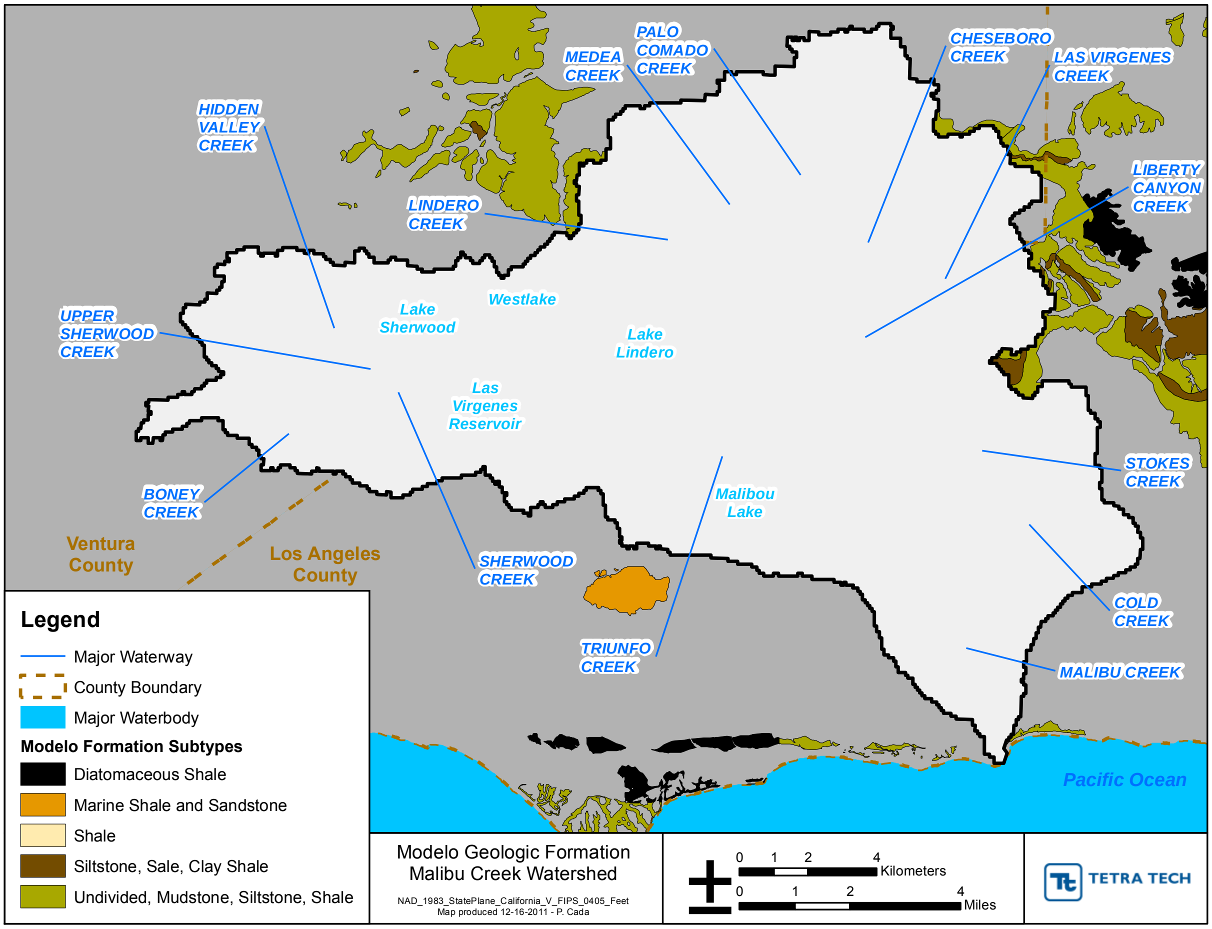



**Figure 4-4. Location of the Monterey/Modelo Formation in the Malibu Creek Watershed**

Source: California Geological Survey, 2009

Soils in the watershed generally reflect the underlying spatial extent of geology derived from sandstone, shale, or volcanic parent material. Soil data were obtained from the National Resource Conservation Service's (NRCS) Soil Survey Geographic (SSURGO) and State Survey Geographic (STATSGO) (for a portion missing SSURGO coverage in northwest LA County) databases. The watershed consists primarily of shallow soils with slow infiltration rates (Group D) on hillsides and mountains with slopes of 30-75 percent and fine-grained soils derived from marine sediments in the flatter central part of the watershed (Group C).

The Hydrologic Soil Group (HSG) classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have lower infiltration rates, while well-drained sandy soils have the greatest infiltration rates. The Soil

Conservation Service (SCS, 1985) has defined four HSG categories for soils as listed in Table 4-1. The distribution of HSGs in the watershed is 56 percent "D," 24 percent "C," 7 percent "B," a fraction of a percent of "A" near the watershed outlet (11 acres), and 13 percent described as "Water or Rock" (Figure 4-5).

**Table 4-1. SCS Hydrologic Soil Groups**

| Hydrologic Soil Group | Description |
|---|---|
| A | Soils with high infiltrations rates. Usually deep, well-drained sands or gravels. Little runoff. |
| B | Soils with moderate infiltration rates. Usually moderately deep, moderately well-drained soils. |
| C | Soils with slow infiltration rates. Soils with finer textures and slow water movement. |
| D | Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff. |

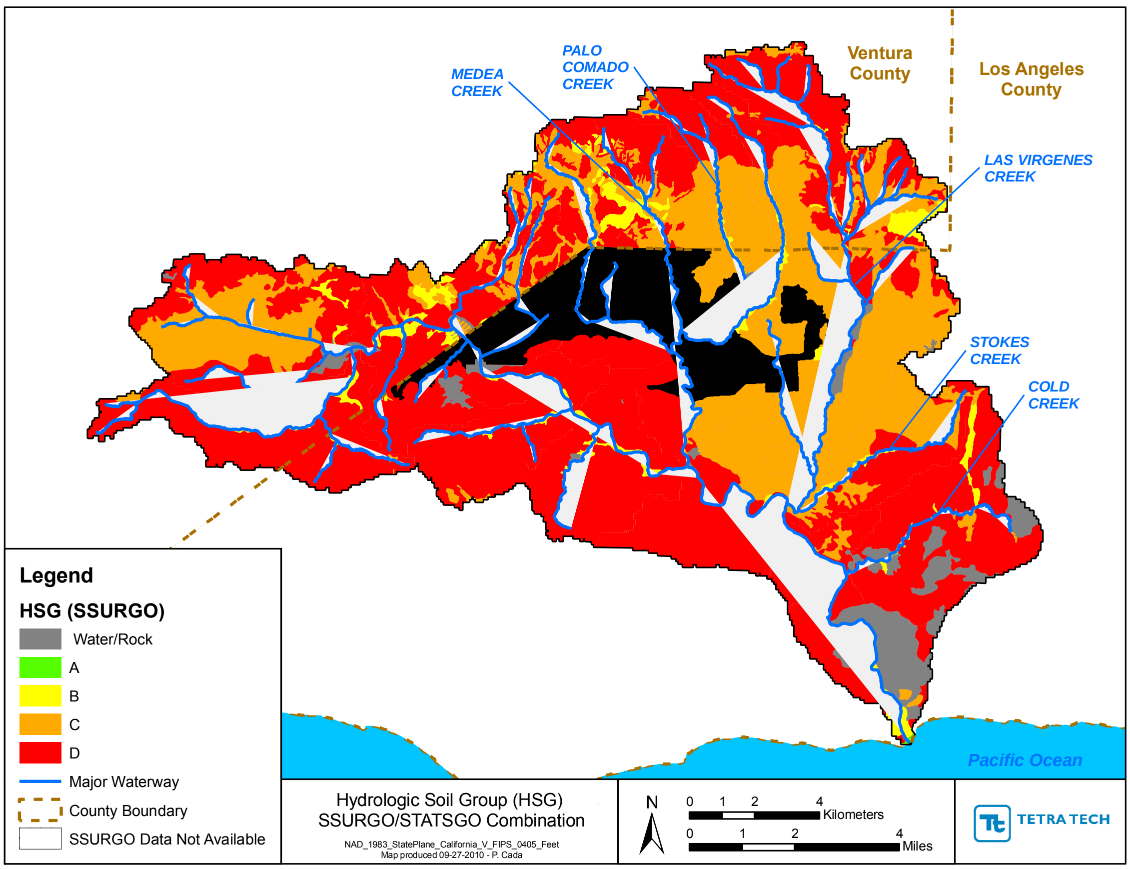



**Figure 4-5. Hydrologic Soil Groups – Malibu Creek Watershed (STATSGO and SSURGO)**

## 4.5 LAND USE/LAND COVER

A number of land use/land cover (LU/LC) GIS products are available for the Malibu Creek Watershed. The National Land Cover Data (NLCD) provides a useful overview, but has limitations in urban areas.

The U.S. Forest Service LANDFIRE dataset (www.landfire.gov) provides a high level of detail about vegetation, but does not represent development. The strongest GIS product for representing developed land uses is the SCAG land use data, which documented land use in 1990, 1993, 2001, 2005, and 2008. Land use is classified using a modified Anderson system, with up to three levels of detail represented by a 4-digit number. In all, there are over 100 distinct classes.

There appear to be some discrepancies between the 2005 and 2008 SCAG land use coverages, and the 2008 results do not always match aerial imagery. The 2008 approach incorporates regional planning data and apparently classifies some small areas that are still in an under- or undeveloped status as highly developed land uses.

### 4.5.1 Analysis of Land Use and Land Cover

To simplify the SCAG data, the original land use and land cover classes were aggregated into more general categories. The generalized SCAG land use was then intersected with the study area boundary for 1990, 2005, and 2008 data to perform a change analysis. The results of the LU/LC analysis are shown in Table 4-2 and Figure 4-6 and Figure 4-7. Most notably, areas of barren and undeveloped SCAG LU/LC had the largest decrease while Single Family Residential (SFR) (<0.5 acres) and office increased the most between 1990 and 2008.

For areas designated as "Undeveloped" by SCAG, the LANDFIRE Existing Vegetation Type dataset was used to supplement the SCAG data in Figure 4-6 and Figure 4-7. The 2005 coverage is shown as it appears to be more accurate than 2008. The 25 different LANDFIRE land cover types in the watershed were aggregated into seven more general land cover descriptions (Table 4-3).

**Table 4-2. Land Use and Land Cover Composition and Change Analysis (SCAG, 1990, 2005, 2008)**

| Land Use/Land Cover Description | 1990 (SCAG) | | 2005 (SCAG) | | 2008 (SCAG) | | Percent Composition Change 1990-2008 |
|---|---|---|---|---|---|---|---|
| | Area (acres) | Percent (%) | Area (acres) | Percent (%) | Area (acres) | Percent (%) | |
| Agriculture | 1,299 | 1.9% | 1,252 | 1.8% | 932 | 1.3% | -0.5% |
| Barren | 1,213 | 1.7% | 371 | 0.5% | 346 | 0.5% | -1.2% |
| Commercial | 403 | 0.6% | 549 | 0.8% | 717 | 1.0% | 0.4% |
| Industrial | 557 | 0.8% | 658 | 0.9% | 953 | 1.4% | 0.6% |
| Institutional | 405 | 0.6% | 513 | 0.7% | 885 | 1.3% | 0.7% |
| Multifamily | 948 | 1.4% | 1,051 | 1.5% | 922 | 1.3% | 0.0% |
| Office | 428 | 0.6% | 579 | 0.8% | 1,574 | 2.2% | 1.6% |
| Open Water | 444 | 0.6% | 469 | 0.7% | 522 | 0.7% | 0.1% |
| Orchards | 95 | 0.1% | 162 | 0.2% | 162 | 0.2% | 0.1% |
| Park – Irrigated | 564 | 0.8% | 688 | 1.0% | 523 | 0.7% | -0.1% |
| SFR <0.5 ac | 4,225 | 6.0% | 4,938 | 7.0% | 5,048 | 7.2% | 1.2% |
| SFR >0.5 ac | 2,495 | 3.6% | 3,798 | 5.4% | 2,830 | 4.0% | 0.5% |
| Transportation (CALTRANS) | 406 | 0.6% | 406 | 0.6% | 406 | 0.6% | 0.0% |
| Undeveloped and Park - Non-irrigated | 56,704 | 80.8% | 54,751 | 78.0% | 54,367 | 77.5% | -3.3% |
| TOTAL | 70,186 | 100% | 70,185 | 100% | 70,187 | 100% | N/A |

N/A = not applicable

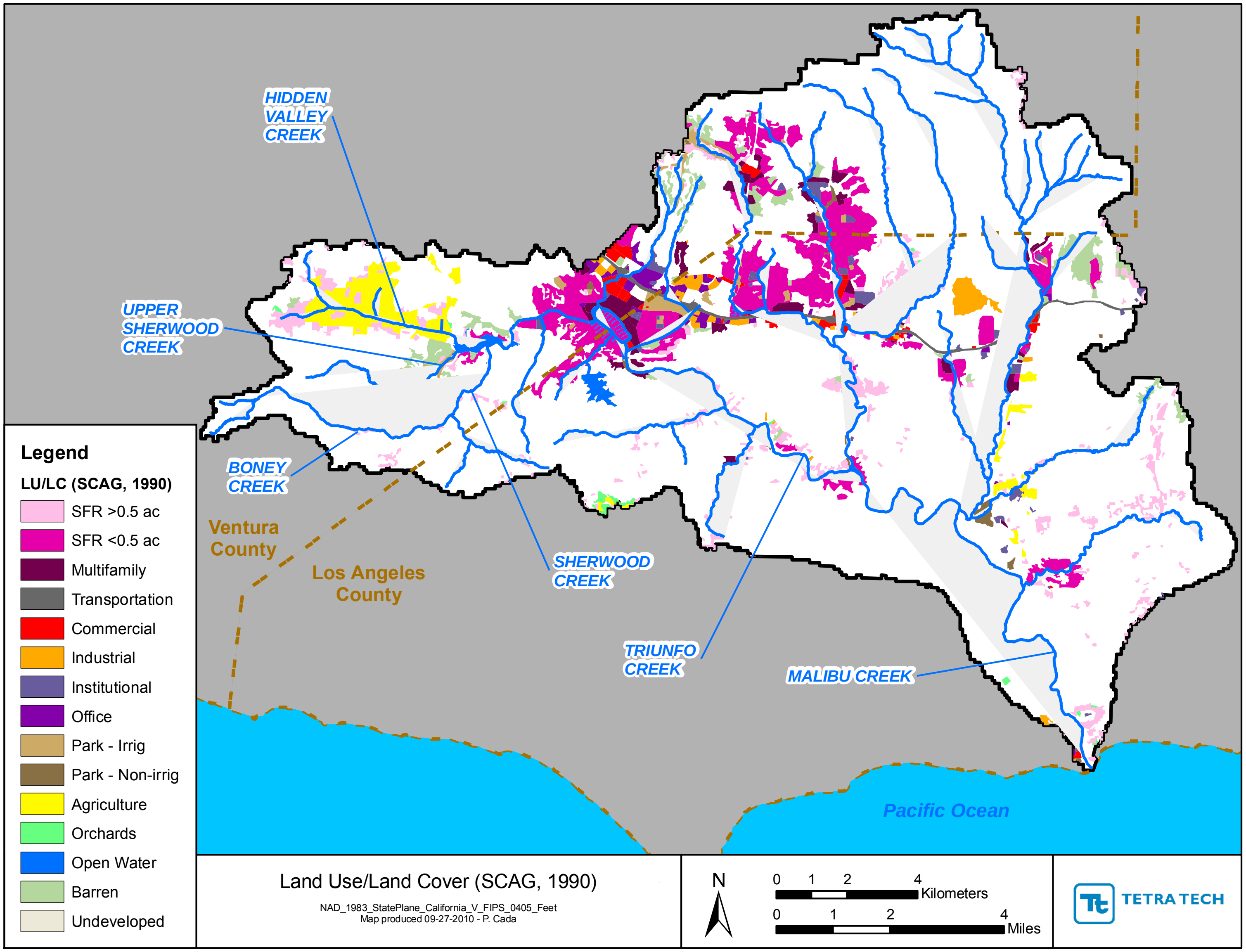



**Figure 4-6. Land Use and Land Cover (SCAG, 1990) – Malibu Creek Watershed**

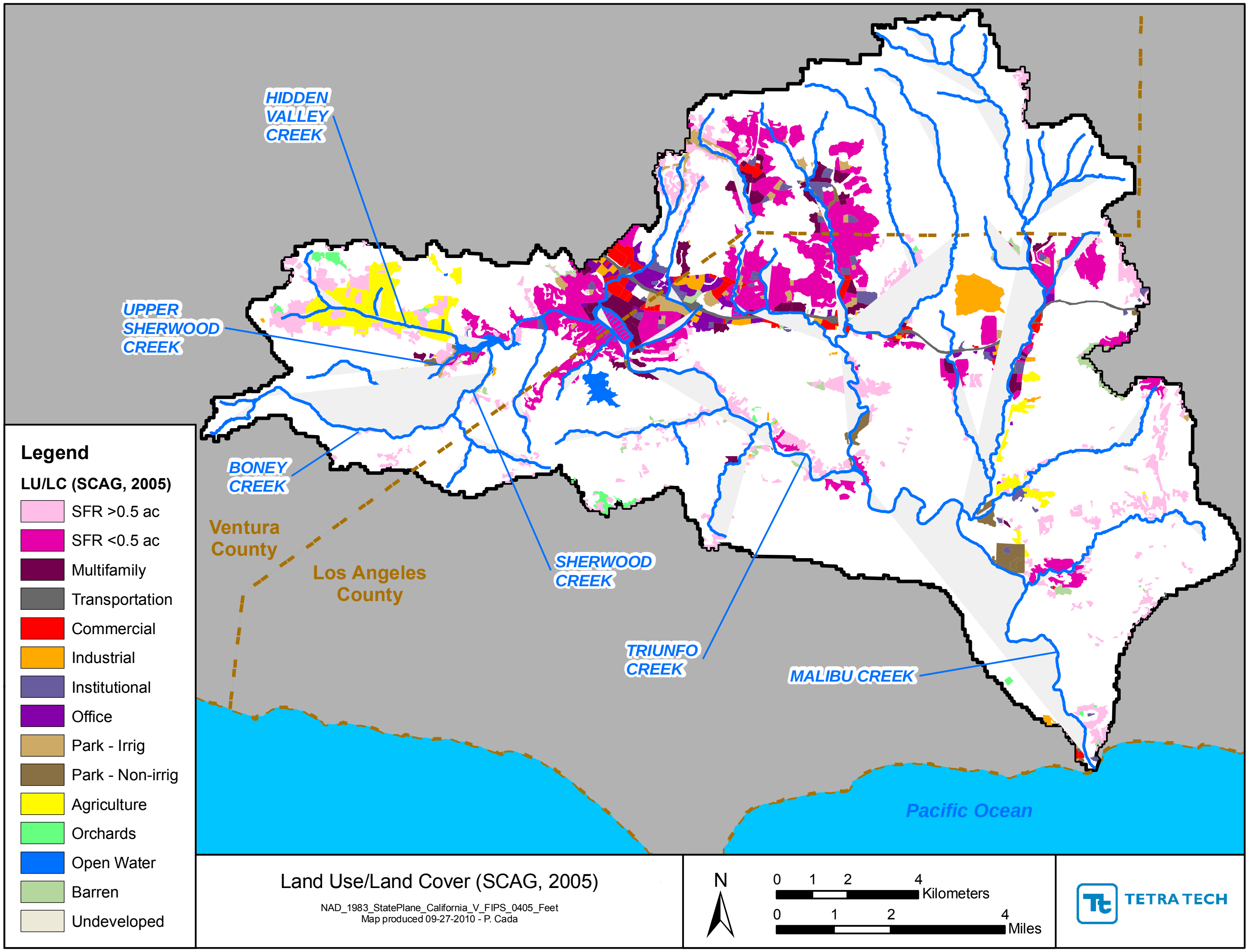



**Figure 4-7. Land Use and Land Cover (SCAG, 2005) – Malibu Creek Watershed**

**Table 4-3. Land Cover within "Undeveloped" SCAG class (LANDFIRE, 2007)**

| Land Cover Description | Percent of Undeveloped Land (SCAG) | | |
|---|---|---|---|
| | 1990 | 2005 | 2008 |
| Open Water | 0.04% | 0.03% | 0.02% |
| Barren/Developed | 2.64% | 1.59% | 1.87% |
| Herbaceous – Grassland | 8.32% | 8.11% | 8.27% |
| Sparsely Vegetated | 0.53% | 0.39% | 0.39% |
| Shrubland (Chaparral/Scrub) | 71.05% | 72.02% | 71.77% |
| Sparse Tree Canopy (Savannah) | 11.77% | 12.07% | 11.93% |
| Open Tree Canopy (Woodland) | 5.64% | 5.79% | 5.75% |

## 4.5.2 Impervious Surfaces

Impervious surfaces encourage direct runoff, rather than infiltration of precipitation. The impervious area in a watershed is thus an important factor in determining the amount and timing of runoff, streamflow characteristics, and pollutant loading.

Impervious surfaces in the watershed include buildings, parking lots, roads, sidewalks, and other features. Determination of an average percent impervious for the aggregated SCAG LU/LC categories (Table 4-2) can assist with the identification and prioritization of environmental stressors. The most recent impervious surface assessment available was created by the Multi-Resolution Land Characteristics Consortium (MRLC) for the NLCD in 2001 (Figure 4-8). The locations of HtB Stream Team biological monitoring stations are also shown in this figure to support subsequent discussions of the relationship of bioscores and impervious areas.

An average percent impervious for each of the aggregated SCAG LU/LC categories was calculated using the SCAG LU/LC 2001 data and the NLCD 2001 impervious surface coverage (Table 4-4). The resulting impervious fraction estimates are generally lower than the estimates of percent impervious by land use provided in the Los Angeles County Hydrology Manual (LACDPW, 2006). The LACDPW estimates are for countywide design purposes and are suspected not to be representative of the specific existing land uses in the Malibu Creek Watershed, where overall development is much less intense than in LA County as a whole.

It is assumed that the average impervious value for each LU/LC category derived in Table 4-4 can also be applied to the earlier (1990) and more recent (2005 and 2008) coverages of the SCAG LU/LC. The resulting analysis shows that imperviousness in the watershed increased from 3,694 to 4,878 acres between 1990 and 2008; however, this still constitutes only a small portion of the total watershed area (6.95 percent) – primarily because undeveloped land still predominates.

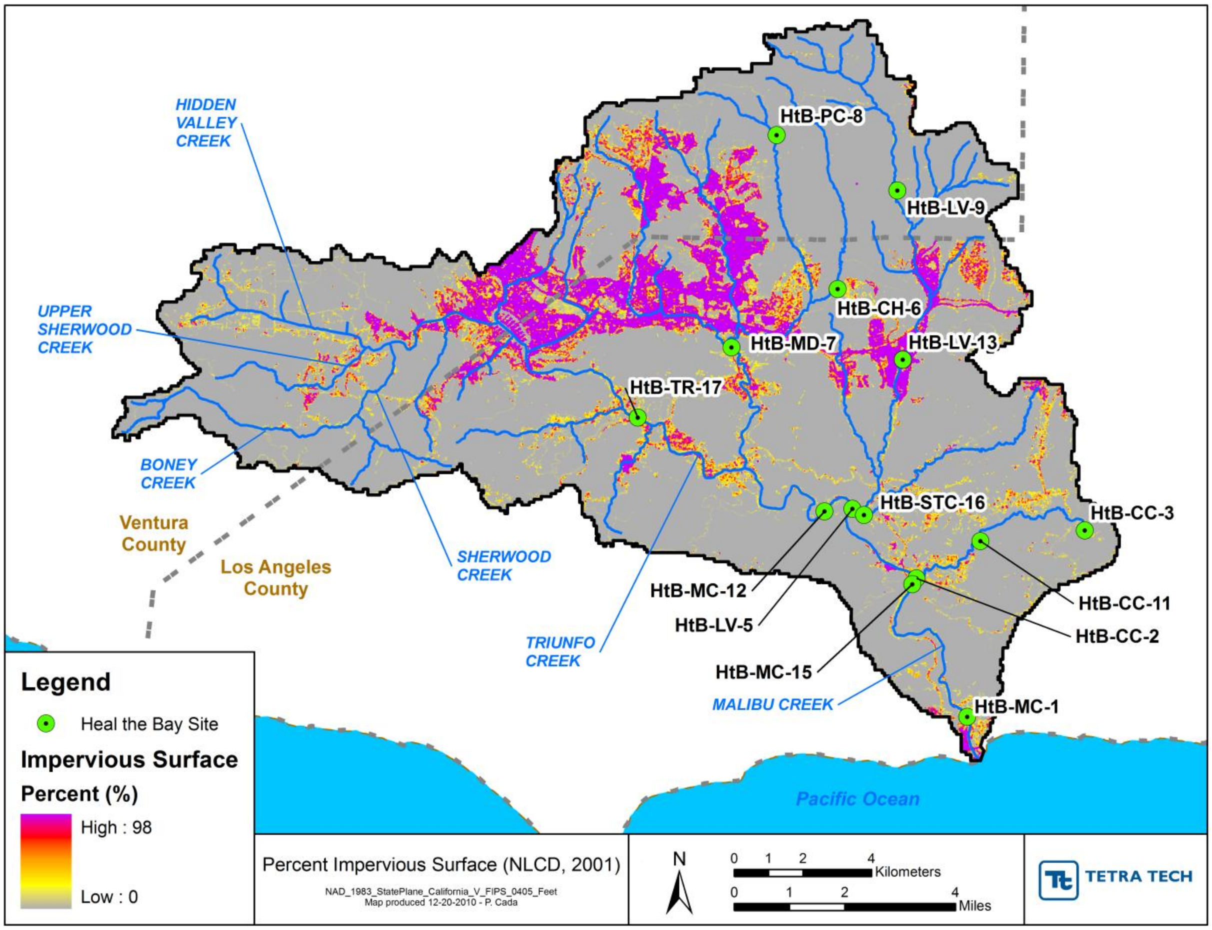



**Figure 4-8. Percent Impervious Surface (NLCD, 2001) – Malibu Creek Watershed**

**Table 4-4. Malibu Watershed Imperviousness by SCAG LU/LC Categories**

| LU/LC Description | Average Imperviousness (%) | Impervious Area 1990 (acres) | Impervious Area 2005 (acres) | Impervious Area 2008 (acres) |
|---|---|---|---|---|
| Agriculture | 1 | 15 | 14 | 10 |
| Barren | 7 | 87 | 27 | 25 |
| Commercial | 51 | 209 | 284 | 365 |
| Industrial | 28 | 156 | 185 | 268 |
| Institutional | 28 | 111 | 141 | 248 |
| Multifamily | 39 | 374 | 415 | 363 |
| Office | 46 | 197 | 266 | 723 |
| Open Water | 2 | 9 | 9 | 11 |

| LU/LC Description | Average Imperviousness (%) | Impervious Area 1990 (acres) | Impervious Area 2005 (acres) | Impervious Area 2008 (acres) |
|---|---|---|---|---|
| Orchards | 3 | 3 | 5 | 5 |
| Park - Irrigated | 7 | 41 | 50 | 38 |
| SFR <0.5 ac | 34 | 1,459 | 1,704 | 1,738 |
| SFR >0.5 ac | 11 | 286 | 436 | 325 |
| Transportation | 49 | 178 | 178 | 200 |
| Undeveloped and Park – Non-irrigated | 1 | 568 | 563 | 559 |
| | **Watershed Total (ac)** | 3,694 | 4,279 | 4,878 |
| | **Percentage Impervious** | 5.26% | 6.10% | 6.95% |

Note: There are some discrepancies in the classification of developed land in the commercial, industrial, institutional, and multifamily categories between the 2005 and 2008 SCAG coverages.

## 4.6 Fire History and Conditions

Fire activity in a watershed can significantly impact the hydrologic response. Severe burns, particularly in natural areas, such as forest or grassland, remove vegetation that holds soil in place and reduce the amount of water lost through evapotranspiration. Floods and massive debris loads are common following extensive fires. These impacts diminish over subsequent years as vegetation is reestablished.

Fire history data were obtained in spatial format from the California Department of Forestry and Fire Protection through 2010 (http://frap.cdf.ca.gov/data/frapgisdata/download.asp?spatialdist=1&rec=fire). The data were reviewed to determine the timing and extent of years with major fire events (defined as a year with events that burned at least 1,500 acres within the watershed). Appendix B presents a summary of these results.

## 4.7 Hydrography

### 4.7.1 Drainage Network

Hydraulic routing of water in the Malibu Creek Watershed includes both the natural drainage network and water management infrastructure. Detailed stormwater network lines were obtained for the watershed (Figure 4-9). Most of the storm drain network is in the developed area upstream of Malibou Lake as well as portions of LA County in the drainages of Las Virgenes and Liberty Canyon creeks.

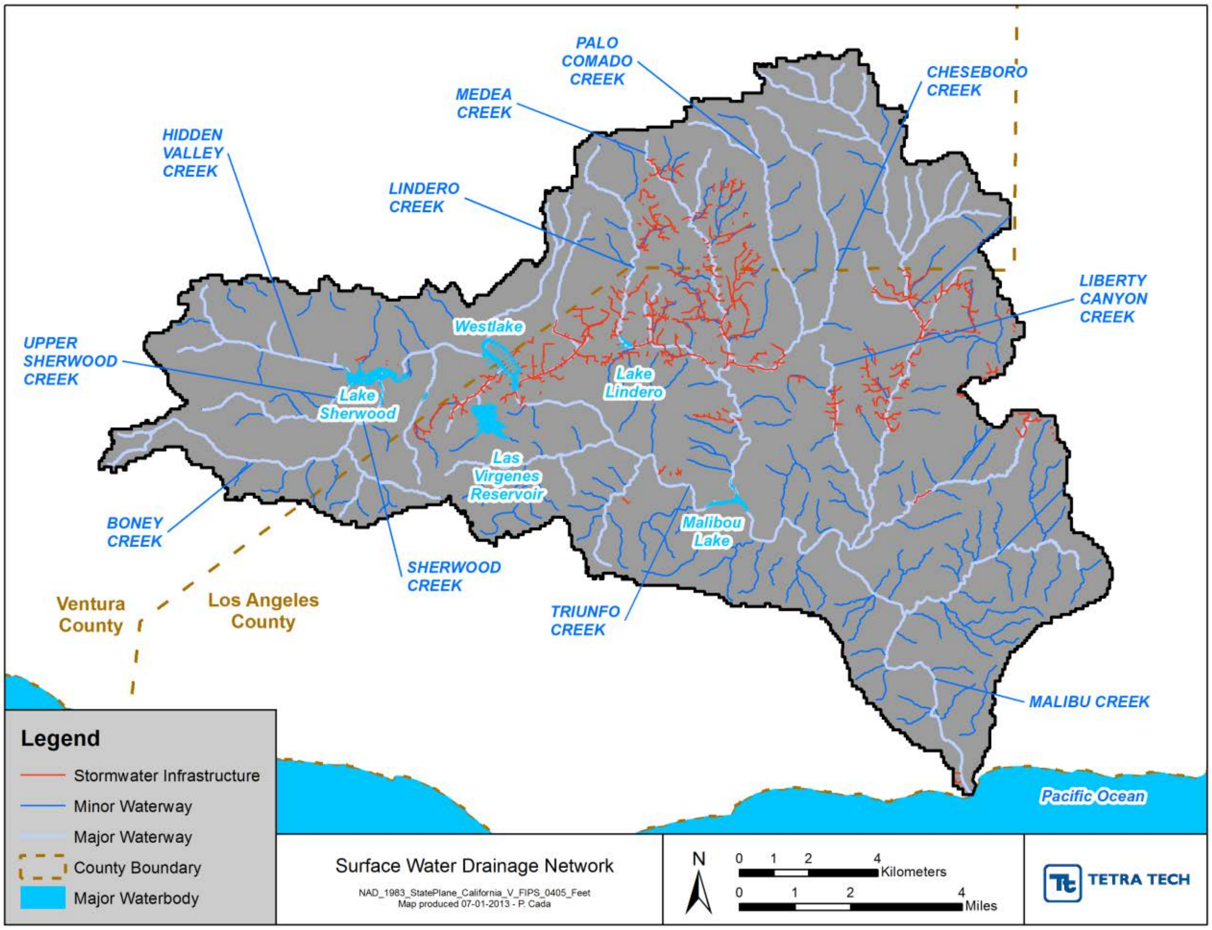



**Figure 4-9. Surface Drainage Network – Malibu Creek Watershed**

## 4.7.2 Subwatershed Delineation

Malibu Creek Watershed was divided into a series of subwatersheds as an aid to data analysis. There are several programs and automated GIS tools available in the public domain that can be used to generate watershed boundaries from a DEM. The tool selected for this project was developed using Environmental Systems Research Institute's (ESRI) Model Builder and available from the ESRI Support Center.[1] The tool involves several steps of DEM processing that produce a stream network layer and watersheds sized based on user specifications.

Several data sources were used to inform the aggregation of catchments into subwatersheds. They included major breaks in hydrography (i.e., stream order), LU/LC as shown by the 2008 SCAG data, monitoring stations, and point sources. GIS layers of stormwater infrastructure were not available for the Ventura County portion of the watershed. The stormwater network coverages in LA County were reviewed but did not result in any modifications to the delineation. The delineation process resulted in an average subwatershed size of 5.22 $mi^2$ (Figure 4-10).

[1] http://support.esri.com/index.cfm?fa=downloads.geoprocessing.filteredGateway&GPID=16

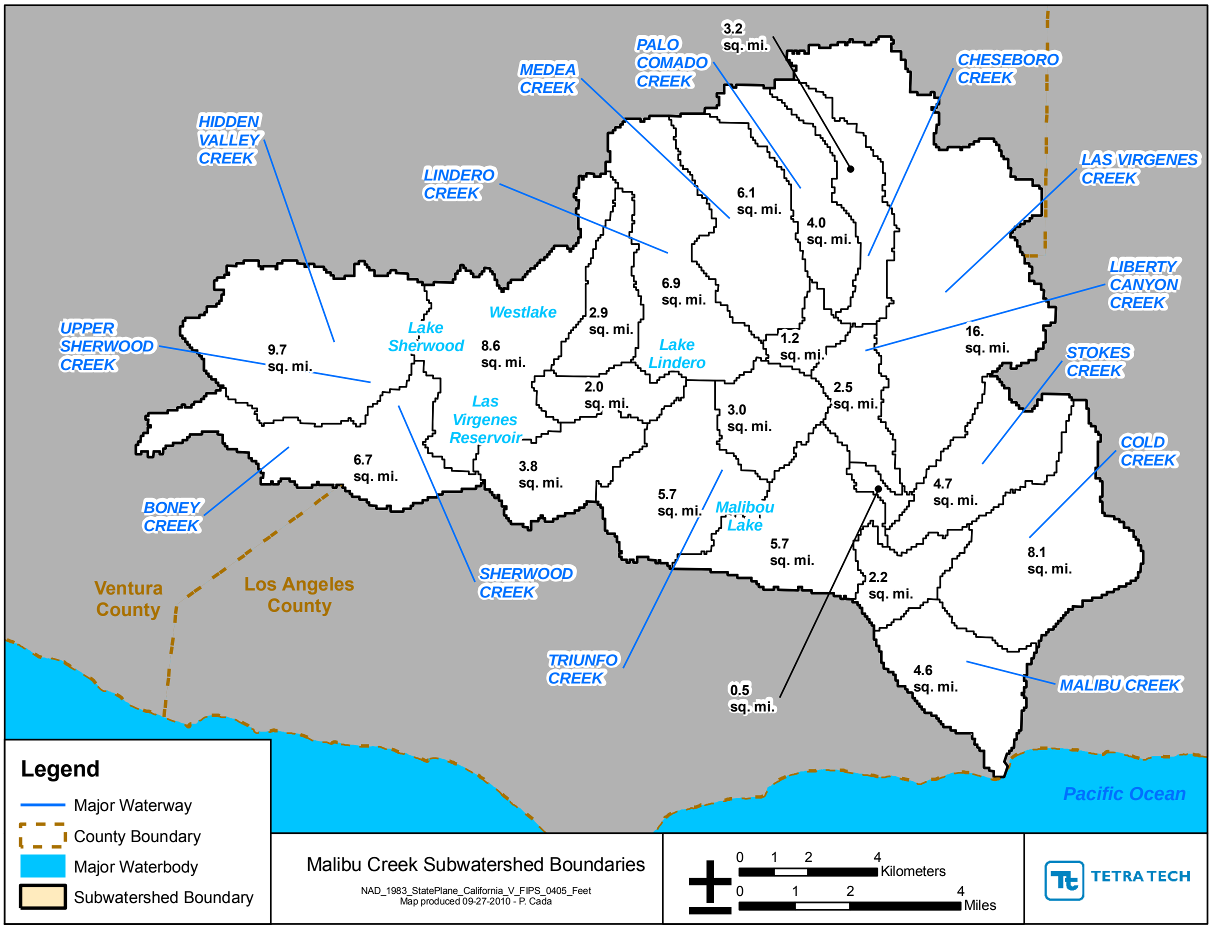



**Figure 4-10. Malibu Creek Subwatersheds**

# 5. Source Assessment

This section identifies the potential sources of pollutants that discharge into the impaired waterbodies. In general, pollutants can enter surface waters from both point and nonpoint sources. Point sources include discharges from a discrete human-engineered outfall. These discharges are regulated through NPDES permits. Nonpoint sources, by definition, include pollutants that reach surface waters from a number of diffuse land uses and activities that are not regulated through NPDES permits. Specific sources for point and nonpoint sources in the Malibu Creek Watershed are presented below.

## 5.1 Point Sources of Pollution

NPDES permits in the watershed include municipal separate storm sewer system (MS4) permits, a Caltrans stormwater permit, and general or individual NPDES permits.

### 5.1.1 Permitted Facilities

The only facility with a permitted wastewater discharge to Malibu Creek or its tributaries is the Tapia Water Reclamation Facility (Tapia WRF). Tapia WRF is operated under a Joint Powers Authority between Las Virgenes Municipal Water District (located in western LA County) and Triunfo Sanitation District (located in eastern Ventura County). The facility is along Malibu Canyon Road in unincorporated LA County. Constructed at a low point in the Malibu Creek Watershed, it allows wastewater to flow by gravity to the treatment facility (see Figure 4-1). It was built in 1965 with a capacity of 0.5 million gallons per day (MGD) and has been expanded several times – in 1968 to a capacity of 2 MGD; in 1972 to a capacity of 4 MGD; in 1984 to a capacity of 8 MGD; in 1986 to a capacity of 10 MGD; and in 1994 to its current capacity of 16 MGD. Tapia WRF began water recycling in 1972 and currently treats an average of 9.5 MGD of wastewater (http://www.lvmwd.com/index.aspx?page=72). The plant was upgraded from secondary to tertiary treatment in 1984.

Tapia WRF applies state-of-the-art technology to transform wastewater into high-quality recycled water that is used to irrigate public and commercial landscaping such as golf courses, school grounds, highway medians, and parks. During the hot summer months, irrigation consumes all the recycled water Tapia produces. When excess effluent is produced, Tapia WRF discharges both to Malibu Creek and to Arroyo Calabasas, a tributary of the Los Angeles River. The main discharge to Malibu Creek occurs about 0.3 miles upstream from the confluence with Cold Creek and about 5 miles upstream from Malibu Lagoon. Excess effluent may also be used for irrigating the farm fields at the Rancho Las Virgenes Composting Facility. LARWQCB Order No. 97-135 contained a provision prohibiting discharges from Tapia WRF to Malibu Creek from May 1st to November 1st each year, except under certain conditions.

Implementation of the prohibition under Order No. 97-135 was subject to further discussions among the Regional Board, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and CDFG. After discussions among these departments, it was concluded that Tapia WRF should apply for an incidental "take" permit as required by Endangered Species Act §10(a)(1)(B). It was also recommended that a minimum flow of 2.5 cubic feet per second (cfs) be maintained throughout the year to sustain endangered species. Also, extreme weather conditions in the winter of 1998 caused the Lagoon to remain open for an extended period. Heavy rains at that time also resulted in more runoff into the Malibu Creek and Lagoon and created a condition resulting in less demand for reclaimed water during the period the discharge prohibition was in effect (Los Angeles Board, 2005b). To address these issues, revisions were made in 1998 through Order 98-030, which directed that Tapia WRF shall "not discharge as otherwise permitted by these requirements to Malibu Creek at any of its discharge points commencing either: (a) May 1st of each calendar year, or (b) the first natural closure of Malibu Lagoon by sand buildup, whichever is later, through and including October 31st of each calendar year." Exceptions are provided for storm events, plant upsets, or "the existence of minimal streamflow conditions that require flow augmentation in Malibu Creek to sustain endangered species." The discharge prohibition is based on a finding that "unseasonable freshwater inputs from Tapia and other sources cause the Lagoon to flood and/or breach when it otherwise would not."

In 1999, Order No. 99-142 modified the discharge prohibitions to Malibu Creek to extend from April 15 to November 15. When discharges occur in the winter, the current permit limits are 8 mg/L total inorganic nitrogen (N) in accordance with the Malibu Watershed nutrient TMDL (USEPA, 2003) and 3 mg/L total phosphorous (P) (added to NPDES permit by LARWQCB based on plant performance). The 2003 Nutrient TMDL limits represent an approximately 43 percent reduction in inorganic N loads relative to the 1997-1999 time period, with no reduction in P concentrations. Tentative limits have also been developed for a suite of metals, organic compounds, and other pollutants. This order also excluded the incidental take permit requirement previously required (and subsequently remanded by the SWRCB) and was substituted with an exception for flows necessary to sustain endangered steelhead trout (2.5 cfs).

Most of the effluent generated by Tapia WRF is used for irrigation during the summer months. At the time of the 2003 Nutrient TMDL for Malibu Creek Watershed, effluent irrigation and sludge injection were estimated to contribute 9 percent of the annual nitrogen load and 6 percent of the annual phosphorus load to the Malibu Creek Watershed. Sludge disposal in the watershed has since ceased, and the 2003 Nutrient TMDL assigned a load allocation of zero to effluent irrigation based on a requirement that applications not exceed agronomic rates. Loading associated with runoff from areas with previously disposed sludge is still a potential legacy source of pollutants in the Malibu Creek Watershed.

### 5.1.2 Stormwater

Stormwater runoff in the Malibu Creek Watershed is regulated through the Los Angeles County MS4 permit, the Ventura County MS4 permit, and the statewide stormwater permit issued to Caltrans. The permitting process defines these discharges as point sources because the stormwater is discharged from the end of a stormwater conveyance system.

#### 5.1.2.1 Municipal Stormwater

USEPA regulates urban stormwater discharges through NPDES permits. These permits apply to stormwater runoff that is transported through regulated MS4s and discharged into waterbodies. To prevent harmful pollutants from being washed or dumped into an MS4, operators must obtain a NPDES permit and develop a stormwater management program.

An MS4 is defined as a conveyance or system of conveyances that is: (1) Owned by a state, city, town, village, or other public entity that discharges to waters of the U.S., (2) Designed or used to collect or convey stormwater (including storm drains, pipes, ditches, etc.), (3) Not a combined sewer, and (4) Not part of a Publicly Owned Treatment Works (sewage treatment plant).

USEPA has extended coverage under the MS4 permitting program in two phases. Phase I, issued in 1990, requires medium and large cities or certain counties with populations of 100,000 or more to obtain NPDES permit coverage for their stormwater discharges. Phase II, issued in 1999, requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges. Each regulated MS4 is required to develop and implement a stormwater management program (SWMP) to reduce the contamination of stormwater runoff and prohibit illicit discharges. Because a NPDES permit is applied, stormwater discharges from a regulated MS4 are subject to wasteload allocations (WLAs) for point sources under the TMDL program, rather than load allocations (LAs) for nonpoint sources.

Los Angeles City and County were covered under Phase I of the stormwater program. The municipalities within Los Angeles County (except for the City of Long Beach) and the unincorporated areas of the county are covered under a unified MS4 permit under California Regional Water Quality Control Board, Los Angeles Region, Order No. 01-182, NPDES Permit No. CAS004001.

The Malibu Creek Watershed also includes areas within unincorporated Ventura County and the City of Thousand Oaks (within Ventura County). These areas are covered by the new MS4 permit for Ventura County (Order R4 2010-0108, NPDES Permit No. CAS004002, July 8, 2010), which unifies MS4 coverage for that county with the Ventura County Watershed Protection District as Principal Permittee.

#### 5.1.2.2 Caltrans

The county MS4 permits do not directly cover runoff from state highways, which are covered under a separate permit. Caltrans is responsible for the design, construction, management, and maintenance of the State highway system, including freeways, bridges, tunnels, Caltrans' facilities, and related properties. Caltrans' discharges consist of stormwater and non-stormwater discharges from State-owned rights-of-way. Before July 1999, stormwater discharges from Caltrans' stormwater systems were regulated by individual NPDES permits issued by the Regional Water Boards. On July 15, 1999, the State Water Board issued a statewide permit (Order No. 99-06-DWQ) which regulated all stormwater discharges from Department-owned MS4s, maintenance facilities and construction activities.

#### 5.1.2.3 Summary

The distribution of watershed land area by jurisdiction is an important input to the TMDL allocation of loads (see Section 10). This analysis is provided in Table 5-1, in which the land uses described in Section 4.5 are summarized by jurisdiction along with associated impervious areas. The specific land use areas that drain to a stormwater conveyance system are subject to the MS4 permits described above, while other areas that discharge to a waterbody without passing through a conveyance system are not (i.e., agricultural and undeveloped lands; see Section 5.2).

**Table 5-1. Land Use Distribution by Jurisdiction**

| Land Use | Los Angeles County | | Ventura County | | Caltrans | |
|---|---|---|---|---|---|---|
| | Total area (ac) | Impervious area (ac) | Total area (ac) | Impervious area (ac) | Total area (ac) | Impervious area (ac) |
| Agriculture | 250 | 3 | 671 | 8 | 0 | 0 |
| Barren | 257 | 20 | 64 | 5 | 0 | 0 |
| Commercial | 238 | 247 | 114 | 118 | 0 | 0 |
| Industrial | 612 | 239 | 73 | 29 | 0 | 0 |
| Institutional | 452 | 176 | 185 | 72 | 0 | 0 |
| Multifamily | 323 | 210 | 236 | 153 | 0 | 0 |
| Office | 245 | 209 | 605 | 515 | 0 | 0 |
| Open Water | 316 | 7 | 195 | 4 | 0 | 0 |
| Orchards | 84 | 2 | 73 | 2 | 0 | 0 |
| Park - Irrigated | 169 | 13 | 316 | 25 | 0 | 0 |
| SFR <0.5 ac | 1,975 | 1,037 | 1,335 | 701 | 0 | 0 |

| Land Use | Los Angeles County | | Ventura County | | Caltrans | |
|---|---|---|---|---|---|---|
| | Total area (ac) | Impervious area (ac) | Total area (ac) | Impervious area (ac) | Total area (ac) | Impervious area (ac) |
| SFR >0.5 ac | 1,925 | 250 | 580 | 75 | 0 | 0 |
| Transportation (Caltrans) | 0 | 0 | 0 | 0 | 206 | 200 |
| Undeveloped* | 33,076 | 344 | 20,731 | 216 | 0 | 0 |
| Total | 39,924 | 27,55 | 25,180 | 1,922 | 206 | 200 |

Note: Based on SCAG 2008 land use with additional interpretation of Caltrans transportation land use areas from state-owned roads coverage. Non-state-owned roads are embedded within the other land uses.

*Undeveloped land includes “protected areas” such as state, federal, and local parks.

## 5.2 NON-POINT SOURCES OF POLLUTION

A nonpoint source is a source that discharges via sheet flow or natural discharges, as well as agricultural stormwater discharges and return flows from irrigated agriculture. Nonpoint sources include areas that do not drain to a storm drain system, agricultural flows, and onsite wastewater disposal (note: equestrian sources that may contribute invasive species and nutrients from excrement may also occur in the watershed; however, their loading is expected to be intermittent and minimal). Flows from properties that drain directly to the creeks without passing through an organized stormwater conveyance represent minimal amounts of impervious area. These areas are considered to be an insignificant contributor to the overall loading to the creek, but are presented below to characterize their potential impact.

Land use and cover changes since 2003 has been minimal. A review of the LU/LC composition change between 2005 and 2008 (Section 4.5.1) showed minimal change for non-point sources; combined agriculture, undeveloped and park lands changed approximately 1% between 2005 and 2008 (Table 4-2 and Table 4-3). Consequently, for the nutrient loading analyses, this TMDL uses the same percentage relative contribution of the non-point source loads that was defined in the 2003 Nutrient TMDL.

### 5.2.1 Agricultural Sources

932 acres of the Malibu Creek Watershed are designated as agricultural (1.3 percent) according to the SCAG 2008 land use layer (Table 4-2). These areas are generally located along Hidden Valley Creek or Malibu Creek (Figure 4-7) and can be sources of nutrients and sediment to the receiving waters. Specifically, agricultural lands introduce nutrients to waterways through both surface runoff and erosion during storms and through shallow groundwater flows. Vineyards are also located in the watershed; however, comparison with the agricultural and orchard categories in the land use layer does not show overlap with the know vineyard locations (Goepel et al., 2012).

### 5.2.2 Onsite Wastewater Disposal

The area around Malibu Lagoon, the Malibu Civic Center, and Malibu Colony is unsewered and residential and commercial wastewater is treated by onsite wastewater disposal systems (OWDS). More than 400 such systems have been identified in the Civic Center area (Stone Environmental, 2010).

OWDS have been implicated as a source of fecal indicator bacteria to Malibu Lagoon and the nearshore ocean. Izbicki et al. (2012) conducted oxygen stable isotope studies and determined that samples from some water-table wells in the area contained as much as 70 percent wastewater. This wastewater ultimately discharges to the Lagoon and to the ocean.

LARWQCB Staff reviewed past studies and also conducted independent modeling estimates of nitrogen mass loadings from OWDS into Malibu Lagoon (Lai, 2009). Specifically, three previous studies were evaluated (Stone Environmental, 2004; Questa, 2005; Tetra Tech, 2002) and summarized by Lai (2009). These results are summarized in Table 5-2. In addition, the in-Lagoon nitrogen concentrations predicted from the mass loading associated with the Stone Environmental and Tetra Tech studies are shown in Figure 5-10. This figure also compares the results with actual nitrogen concentration data (note: the 13 pounds per day [lbs/day] line is associated with the nitrogen numeric target of 1.0 mg/L in the 2003 Nutrient TMDL [USEPA, 2003]).

In addition to the previous studies, the LARWQCB estimated nutrient loadings using a numerical model and a spreadsheet model. LARWQCB staff estimated mass loading into the Lagoon of 34.9 lbs/day using the spread sheet method and showed that this would produce a nitrogen concentration in the Lagoon water of 2.9 mg/L (Table 5-2 and Figure 5-10). The use of another three-dimensional groundwater flow and solute transport model (Questa, 2005) showed an estimated mass loading of 30.2 lbs/day, which resulted in a Lagoon water nitrogen concentration of 2.5 mg/L (Table 5-2 and Figure 5-10). According to the measured data during 1995-1999 (Sutula et al., 2004) and 2002-2003, the nitrogen concentration in the Lagoon water is increasing. As such, the resulting nitrogen concentration of 2.9 mg/L for 2008-2009 falls within the trend of measured data from 1995 to 2003. Thus, the mass loading into the Lagoon of 34.9 lbs/day is considered to be an appropriate and reasonable estimate.

In summary, the LARWQCB analysis concluded that estimates between 30-40 lbs/day of nitrogen are loaded to the Lagoon from OWDS, which exceeds the nutrient TMDL load allocation and results in excursions of the TMDL numeric target from the previous nutrients TMDL (USEPA, 2003).

**Table 5-2. Comparisons of Estimated Nitrogen Mass Loading to Malibu Lagoon (Lai 2009)**

| | Stone Report (2004)[b] | Questa Report (2005)[b] | Tetra Tech Report (2002)[c] | Staff Estimate (Spreadsheet Method)[d] | Staff Estimate (Numerical Model Method)[e] |
|---|---|---|---|---|---|
| 1.Wastewater Flow Rate from Commercial OWDS (gal/day) | 62,166 | 100,000 | 75,000 | 127,241 | 127,241 |
| 2.Concentration in Commercial Wastewater (mg/L) | 50 | 50 | 59.2 | 3 – 110 | 3 – 110 |
| 3.Mass Loading from Commercial OWDS (lbs/day) | 25.94 | 41.73 | 37.05 | 42.1 | 42.1 |
| 4.Wastewater Flow Rate from Residential OWDS (gallons per day) | 126,121 | 126,121 | 54,800 | 139,300 | 139,300 |
| 5.Concentration in Residential Wastewater (mg/L) | 20 | 20 | 59.2 | 45 | 45 |
| 6.Mass Loading from Residential OWDS (lbs/day) | 21.05 | 21.05 | 27.07 | 52.3 | 52.3 |
| 7.Mass Loading from OWDS (lbs/day) | 46.99 | 62.78 | 64.12 | 94.4 | 94.4 |
| 8.Ratio of Mass Loading[a] | 0.36 | 0.32 | 0.50 | 0.37 | 0.32 |
| 9.Mass Loading to Malibu Lagoon (lbs/day) | 17 | 20 | 32 | 34.9 | 30.2 |

Notes: [a] the ratio of mass loading entering Malibu Lagoon versus mass loading from OWDS, i.e., value of row 9 divided by value of row 7.

[b] the nitrogen loads were assumed to be mostly nitrate in the OWDS and the model only simulated the nitrate in the Stone and Questa Modeling Reports.

[c] 50 percent of nitrogen loads from the OWDS were assumed to enter the Malibu Lagoon.

[d] The nitrogen mass loading from OWDS was estimated based on the commercial load from each OWDS and the residential load with an average concentration of 45 mg/L for OWDS. Staff estimated the nitrogen mass loading to Malibu Lagoon by using the spread sheet method.

[e] the nitrogen mass loading based on the commercial load from each OWDS and the residential load with an average concentration of 45 mg/L from OWDS were used in the model. Staff estimated the nitrogen mass loading to Malibu Lagoon by using Questa numerical model results.

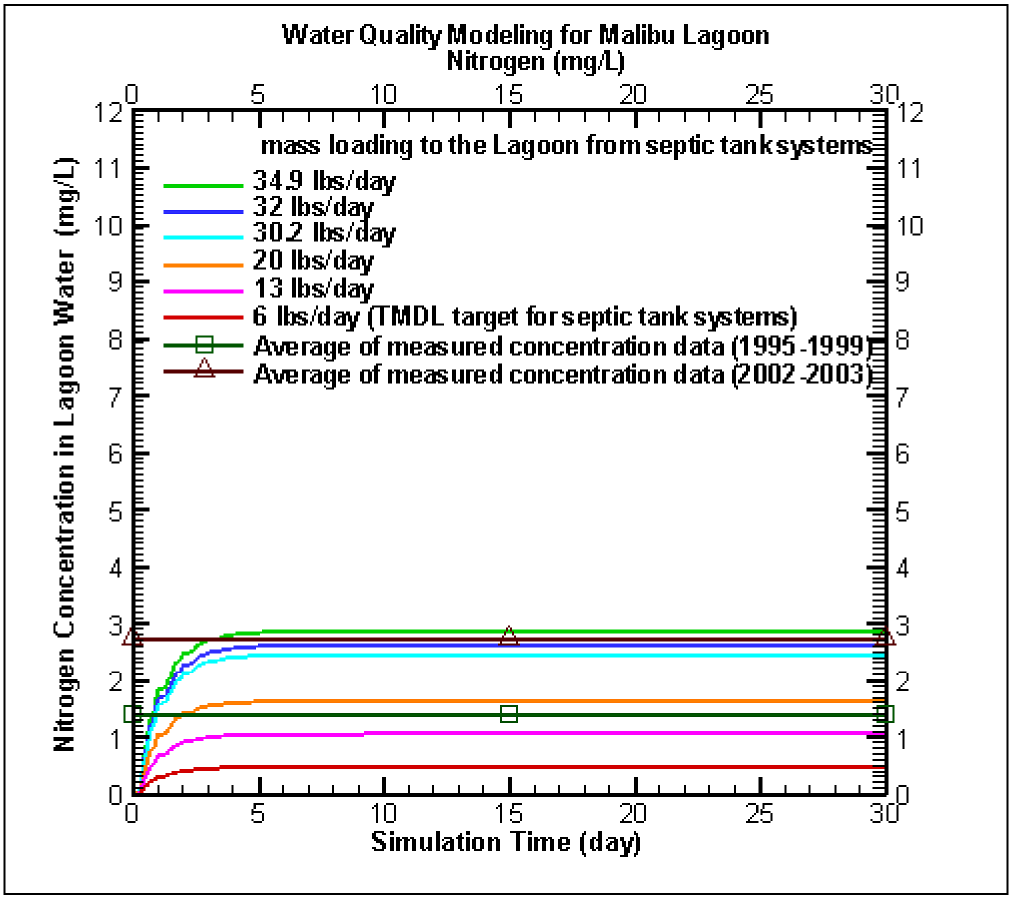



**Figure 5-10. Nitrogen Concentrations in Malibu Lagoon Resulting from Different Mass Loadings from OWDS (Lai, 2009)**

## 5.2.3 Landfills and Dump Sites

There is one major landfill within the Malibu Creek Watershed – the Calabasas Landfill, located on Lost Hills Road, just north of the 101 Freeway, next to the City of Calabasas, and operated by the Sanitation Districts of the County of Los Angeles. This is a non-discharging landfill that should have limited impacts on surface waters.

The Calabasas Landfill is located near Cheseboro Creek. The Sanitation Districts have monitored Cheseboro Creek downstream of the landfill and provided results of 19 stream samples obtained between 1999 and 2009. These revealed no observations of volatile organic compounds above detection limits. Specific conductivity was elevated, but this is consistent with other stations that drain the Monterey/Modelo Formation.

The Calabasas Landfill does not appear to be a major risk to the Malibu Creek Watershed. However, small unmanaged dump sites may be of concern. Heal the Bay Stream Walk activities (Sikich et al., 2012) identified 742 small dump sites scattered throughout the watershed, with an average size of 840 square feet. Their definition of dump sites "included illegal dumping of construction, landscaping, or household waste by haulers or homeowners; street litter and stream washed debris (trash that has entered the storm drain system and is then transported downstream by creek flows); and abandoned structures and materials from agricultural areas, and/or ranches." Many of these small sites were primarily household debris. According to Sikich et al., "The high number of mapped dump sites in Las Virgenes Creek and Medea Creek are especially concerning, with 173 and 161 dump sites, respectively" (2012).

### 5.2.4 Other Non-Point Sources

Other non-point sources potentially contributing to the pollutant loads include overland flow from parks (including golf courses) and forests (i.e., represented by irrigated parks and undeveloped land uses that do not flow to an MS4 conveyance system). This source is not expected to be conveyed via an MS4 system and instead is likely to be part of the overland flow during storm events or unaccounted irrigation activities. More than 75% of the Malibu Creek Watershed is undeveloped land (open space) consisting primarily of chaparral, scrub, and woodlands, with smaller areas of grasslands and forests. The Bureau of Land Management (BLM), NPS, and county and city parks are the primary owners of these undeveloped, or protected, lands. In addition, non-point sources also include atmospheric deposition, lagoon drains, birds, tidal inflow, groundwater, and sediment release.

## 5.3 EXISTING LOADS

USEPA estimated existing nutrient loads in the watershed from different sources and calculated the TMDL based on in-stream nutrient targets and average seasonal flow. To determine the existing total nitrogen and total phosphorus load transported downstream in the watershed, Site MC-1 was selected to represent the furthest downstream point of the watershed. MC-1 is appropriate because it is located just upstream of the Lagoon inlet, at the lowest point of the Malibu Creek main stem, and includes continuous flow, water quality and benthic macroinvertebrate species data. The total watershed load is represented by the sum of all nutrient accumulated loads upstream of MC-1. The current existing total watershed load is approximately 20,442 kilograms per month (kg/mo) total nitrogen (TN) and 2,842 kg/mo total phosphorous (TP).

For comparison purposes, the Los Angeles County Mass Emission Station (LAC MES) a few miles upstream of MC-1 was similarly evaluated. LAC MES is located below the Tapia effluent discharge point and includes continuous flow data and regularly monitored total nitrogen and total phosphorus concentration data. The existing loads of dissolved and total species were both evaluated to assess the robustness of our total watershed load estimate. Both MC-1 and LAC MES, located at the bottom of the watershed along the main stem Malibu Creek, provided comparable estimates.

In evaluating the total watershed load, we noted the total watershed nitrogen load appears to shift from largely inorganic species to higher concentration of organic species during the summer season. The average TN concentration at LAC MES is 1.89 mg/L, and the dissolved inorganic nitrate+ nitrite concentration at MC-1 was 0.15 mg/L. The nitrogen loads, in the summer growing season, are likely converted to organic forms, and explain, in part, the significant algal coverage and load observed in the main stem. Interestingly, the average summer TP level at LAC MES was only slightly higher than the average orthophosphate-P concentration at MC-1, which suggests that most of the total phosphorus load was in the dissolved inorganic form in summer conditions.

### 5.3.1 LVMWD's Tapia Effluent Discharge

Existing loads were calculated using flow and nutrient concentrations measured at the Tapia effluent discharge. We used flow and water quality concentrations monitored after 2005 because this represented the best assessment of existing load and conditions following LVMWD facility's denitrification upgrade. Seasonal average values were computed to appropriately reflect the seasonal variability in flow and concentrations observed since 2005. Existing load and TMDL estimates were calculated for summer and winter periods. We evaluated total and dissolved concentrations of nitrogen and phosphorus measured at Tapia's discharge. The existing seasonal loads are presented in

Table 5-3 and Table 5-4. We calculated the average TN and TP, nitrate plus nitrite, and orthophosphate concentrations, and determined Tapia's relative contribution of the total watershed load. For the winter period, Tapia's discharge contributes 34.7% of the total watershed nitrogen load, and 61.5% of the total watershed phosphorus load. During the summer period, LVMWD is under a no-discharge prohibition except during operational emergencies and required Malibu Creek flow augmentation to support steelhead trout. Between 2000 and 2012, summer period discharge from Tapia occurred briefly in five separate months (September 2007; September 2008; July 2009; September 2009 and October 2009); this represents approximately 6.5% of the time that flow was discharged from Tapia during the summer period, with the remaining summer releases due to rain event storm emergencies in May 2005, April-May 2006, and April 2012, plus an operational emergency in September 2008. During those rare and transient events when discharge was required to maintain flow for protection of steelhead trout or for operational emergencies, the average relative percentages calculated between 2005-2012 were 17% TN and 26.2% TP.

**Table 5-3. Existing Relative Loads During the Winter (Nov 16 to April 14) Period for the Sources of Nitrogen and Phosphorus in the Malibu Creek Watershed based on post-2005 Flows**

| Source | TN (kg/mo) | Relative % | TP (kg/mo) | Relative % |
|---|---|---|---|---|
| Watershed Load | 20, 442 | - | 2,842 | - |
| Tapia WLA (discharge specific) | 7,095 | 34.7 | 1,749 | 61.5 |
| Septic Systems | 1, 967 | 9.6 | 443.2 | 15.6 |
| Urban Runoff* | 2,810 | 13.7 | 85.4 | 3 |
| Golf Courses | 1,129 | 5.5 | 216.7 | 7.6 |
| Agriculture/Livestock | 1,137 | 5.6 | 55.8 | 2 |
| Runoff from Undeveloped Land | 5,155 | 25.2 | 157.6 | 5.5 |
| Other** | 1,150 | 5.6 | 134.6 | 4.7 |

*Urban runoff includes the runoff from developed areas and also the winter dry weather urban runoff from developed areas.

**The other category includes atmospheric deposition, lagoon drains, birds, tidal inflow, groundwater and sediment release.

**Table 5-4. Existing Relative Loads During the Summer (April 15 to Nov 15) Period for the Sources of Nitrogen and Phosphorus in the Malibu Creek Watershed based on post-2005 Flows**

| Source | TN (kg/mo) | Relative % | TP (kg/mo) | Relative % |
|---|---|---|---|---|
| Watershed Load | 789 | - | 140 | - |
| Tapia WLA (discharge specific) | 134 | 1 | 37 | 1 |
| Septic Systems | 180 | 22.8 | 27.6 | 19.7 |
| Urban Runoff * | 154 | 19.5 | 22.3 | 16 |
| Gold Courses | 73 | 9.3 | 20.4 | 14.6 |
| Agriculture/Livestock | 63 | 8 | 5.3 | 3.8 |
| Runoff from Undeveloped Land | 73 | 9.3 | 14.9 | 10.6 |
| Other** | 111 | 14 | 12.7 | 9.1 |

*Urban runoff includes the runoff from developed areas.

**The other category includes atmospheric deposition, lagoon drains, birds, tidal inflow, groundwater and sediment release.

## 5.3.2 Stormwater and Other Sources

We did not observe a significant change in land use cover since the establishment of the 2003 Nutrient TMDL in the Malibu Creek Watershed. Because of this minimal change in land use and land cover since 2003, we used the same modeled relative contribution for the developed land runoff and the other non-point sources as was estimated with the Hydrologic Simulation Program Fortran (HSPF) model (USEPA, 2003). We noted the average flow before 2005 was higher than the average flow after 2005, which is indicative of fewer or smaller storm events since 2005. To determine the existing loads for the watershed, we multiplied historic flow records with existing concentrations at LAC MES. The relative loads for the sources were calculated by applying the relative source contribution from the 2003 Nutrient TMDL, calculated using an HSPF model, to the overall watershed load. Sources due to runoff from developed areas and dry weather urban runoff are defined as the sources for stormwater.

(This page left intentionally blank.)

# 6. Flow Data and Analysis

The hydrology of the Malibu Creek Watershed has changed significantly over the years due to urbanization, the importation of water, the construction of reservoirs, and the discharge of wastewater to Malibu Creek. Most of these changes began in the mid-1960s when urban development accelerated. Urbanization of portions of the upper watershed increased the amount of impervious surfaces, greatly increasing runoff and peak flows during storms and reducing infiltration to soils and groundwater. The resulting increases in runoff and stream flows in turn increased erosion rates, both over the land surface and in the stream channels, causing significant sedimentation in the reservoirs. Approximately 20,000 acre-feet of water per year is currently imported into the watershed (NRCS, 1995; Abramson et al., 1998). Much of this is used for landscape irrigation, which subsequently enters the waterways through shallow groundwater flows or runoff into storm drains. Other portions of this water are used in homes and end up at the Tapia WRF, where, after treatment, much of it is re-used for irrigation at various locations in the watershed.

These changes have increased both storm flows and base flows in the watershed. The NRCS (1995) study estimated that base flows in Malibu Creek have increased by an order of magnitude over pre-development conditions, from about 200 to 2,000 acre-feet per year. Stream flows during storms have almost doubled, from about 11,900 to over 21,000 acre-feet per year (NRCS, 1995). As a result, the average annual flow had more than doubled by 1995, from about 12,000 to 27,000 acre-feet (NRCS, 1995). Some of this (about 4,000 acre-feet) was due to discharges from the Tapia WRF that have since been curtailed. About 3,000 acre-feet of the increased flow is associated with runoff from lawn and home use, and about 500 acre-feet with septic tank seepage (NRCS, 1995).

The Malibu Creek Watershed contains 11 major streams and several other less important tributaries. Prior to development in the watershed, many of these streams were intermittent to ephemeral, except for Las Virgenes Creek, lower Medea Creek, and Cold Creek, which were perennial to intermittent (NRCS, 1995). However, as a result of development and irrigation with imported and reclaimed water, baseflow has generally increased. Specifically, long-term flow records in Malibu Creek show near-zero base flows during the summer/fall, but more recent gage records demonstrate that baseflow has generally increased and the frequency of low flows has decreased following development. A 1995 NRCS study indicated that most of the larger tributaries and all of the main reaches from Westlake Lake to Malibu Lagoon generally have flows all year long (NRCS, 1995). It is assumed that additional development since this 1995 study has resulted in even higher flows.

## 6.1 Stream Flow Gaging

Stream flow monitoring along Malibu Creek is limited to the two gage locations shown in Figure 6-1. The flow gage near Crater Camp (USGS 11105500; LACDPW F-130) contains the longest period of record. United States Geological Survey (USGS) operated this gage between February 1, 1931 and September 30, 1979, after which LACDPW took over operation and continues to monitor the gage to the present. The second flow gage in the Malibu Creek Watershed is USGS 11105510, an active gage located near the mouth of the river, upstream of the Lagoon. This gage has only been in operation since December 6, 2007.

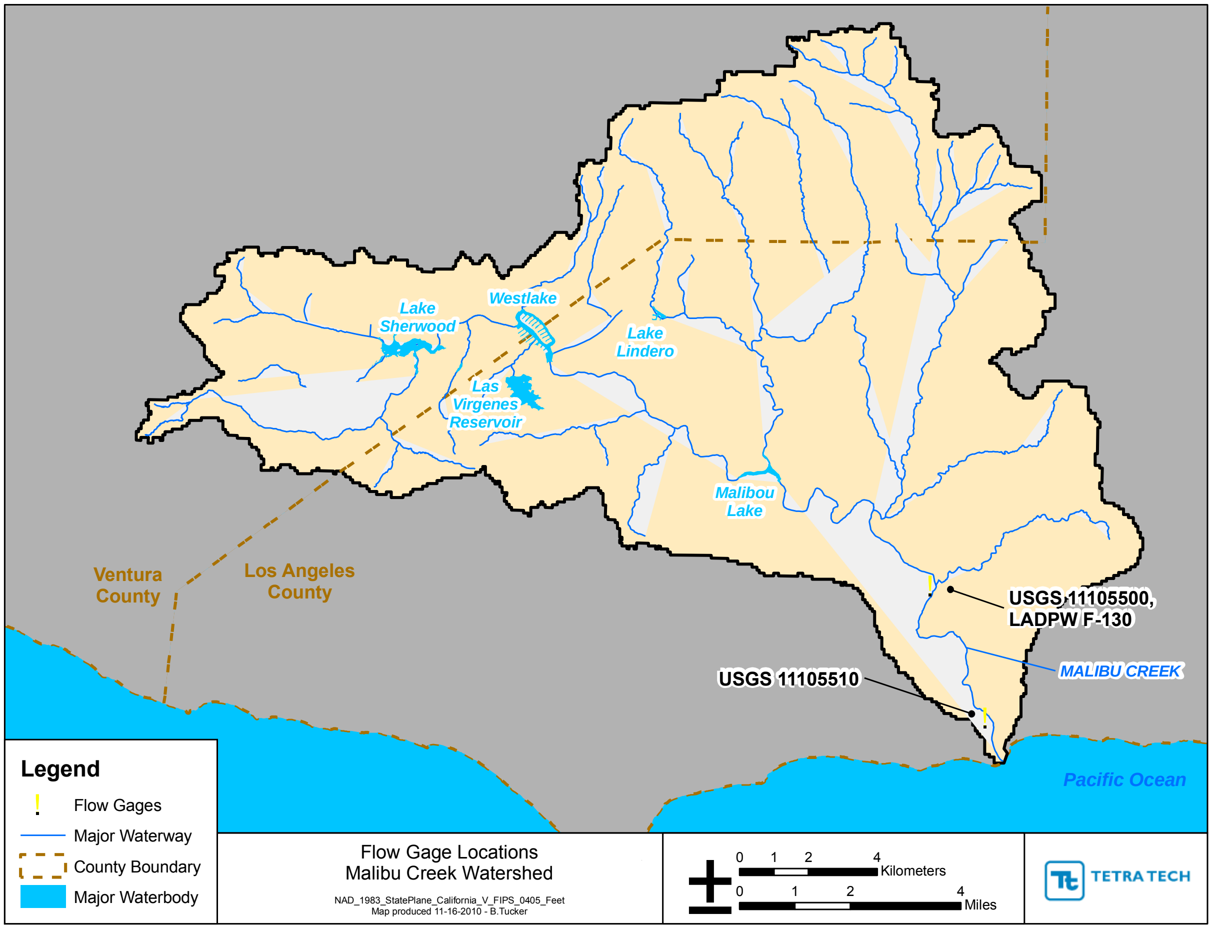



**Figure 6-1. Locations of Flow Gages**

Figure 6-2 and Figure 6-3 show the daily flow time-series for the two flow gage sites, with Figure 6-3 showing both gages for the common period of record. A logarithmic scale is used on the plots; values that fall at or below 0.01 cubic feet per second (cfs) represent zero reported flow. Flows at the two gages match fairly well in the winter; however, during the summer period flow at the upstream F-130 gage remains around 1 cfs, while flow at the downstream USGS gage drops to near zero. The difference is presumably due to evaporation, sinking of flow from the surface to subsurface (hyporheic) pathways in the alluvium, and uptake by riparian vegetation, such as the non-native giant reed, *Arundo donax*.

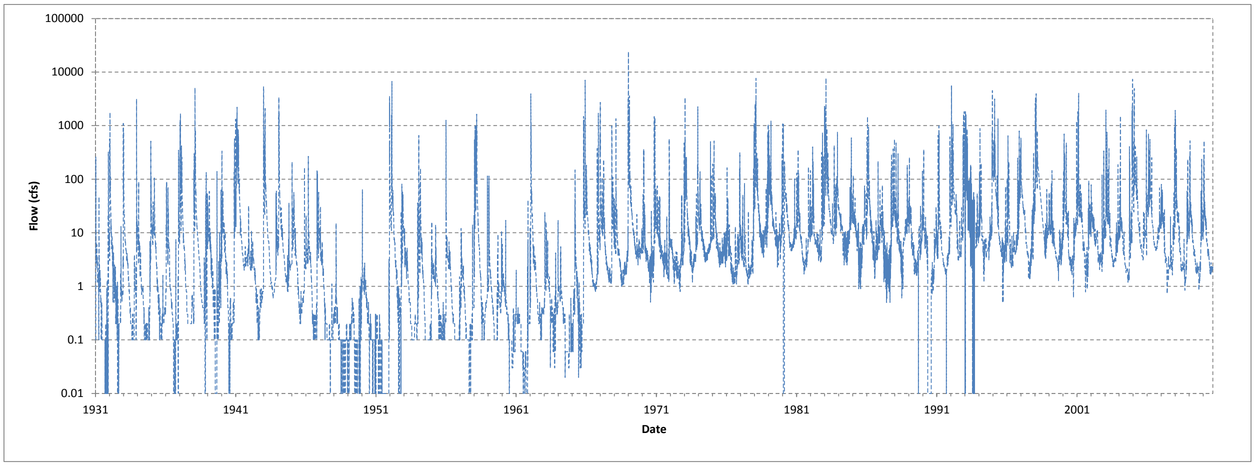



**Figure 6-2. Daily Flow Time-Series for USGS 11105500/LACDPW F-130 Gage**

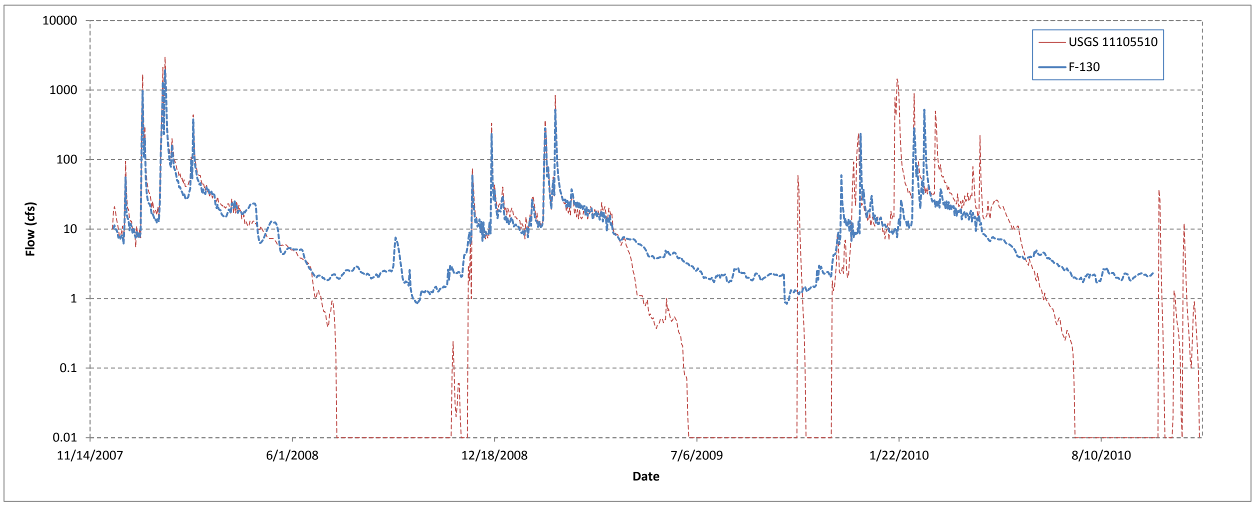



**Figure 6-3. Daily Flow Time-Series for USGS 11105510 Gage**

Table 6-1 provides a statistical summary of the daily flow data, and Table 6-2 shows the monthly averages to demonstrate the extreme seasonal variability in this stream.

**Table 6-1. Statistical Summary of Daily Flow Data (cfs)**

| Gage | Dates | Min | Q25 | Median | Q75 | Max | Mean |
|---|---|---|---|---|---|---|---|
| USGS 11105500, LACDPW F-130 | 4/1/1931 – 9/30/2010 | 0 | 0.8 | 3.9 | 11.7 | 24,200 | 29.4 |
| USGS 11105510 | 12/6/2007 – 9/6/2010 | 0 | 0.01 | 3.6 | 19.0 | 3,010 | 31.2 |

**Table 6-2. Monthly Flow Averages (cfs)**

| Month | USGS 11105500/F-130, 1931-2010 | | USGS 11105510, 12/2007-2010 | | USGS 11105500/F-130, 12/2007-2010 | |
|---|---|---|---|---|---|---|
| | Mean Flow | Median Flow | Mean Flow | Median Flow | Mean Flow | Median Flow |
| Jan | 82.7 | 10.3 | 183.9 | 18.0 | 87.0 | 12.8 |
| Feb | 100.9 | 16.7 | 97.7 | 52.0 | 73.3 | 39.9 |
| Mar | 80.1 | 17.1 | 29.9 | 24.0 | 22.8 | 20.0 |
| Apr | 25.4 | 9.6 | 19.7 | 16.0 | 13.2 | 12.7 |
| May | 10.1 | 5.1 | 6.4 | 5.8 | 6.1 | 5.5 |
| Jun | 6.9 | 3.1 | 1.5 | 1.0 | 3.8 | 3.9 |
| Jul | 3.4 | 2.0 | 0.1 | 0.0 | 2.2 | 2.1 |
| Aug | 2.4 | 1.5 | 0.0 | 0.0 | 2.2 | 2.2 |
| Sep | 2.7 | 1.5 | 0.0 | 0.0 | 2.4 | 2.2 |
| Oct | 3.7 | 1.5 | 2.2 | 0.0 | 1.3 | 1.3 |
| Nov | 10.6 | 2.9 | 3.3 | 0.1 | 7.2 | 2.9 |
| Dec | 26.4 | 6.1 | 27.4 | 13.5 | 20.0 | 12.5 |

As shown in the figures and data summary, long-term flow in Malibu Creek is characterized by extreme seasonal fluctuation between near-zero base flows during the summer/fall and large peak events during the winter. Based on observed flows from the downstream gage (Dec. 2007-present), monthly median flows between July and October are zero while median flows between December and April range between 13.5 cfs and 52.0 cfs. Observed flow data from the long-term gage portrays a significant increase in base flow between the pre-1966 monitoring period and the post-1992 period (see Figure 6-2). Increased baseflow in lower Malibu Creek is in part due to releases from Tapia WRF. While Tapia has had a summer discharge prohibition in effect since 1997, the facility also has a requirement to augment flow for endangered steelhead (also in effect since 1997) that is triggered when flow drops below 2.5 cfs for a specified series of days. Records provided by Tapia show that, since 2000, flow augmentation has occurred only for 9/13-9/18/2007, 9/11-9/15/2008, 7/24-7/28/2009, and 9/1-10/12/2009. Changes in baseflow may also in part be due to the cessation of agricultural diversions said to be present in the earlier period, coupled with imported and reclaimed water use for irrigation. Additional causes of increased baseflow may include loss of riparian vegetation (especially where channel segments have been armored), deepening of channels below the summer groundwater level, minimum flow release requirements for upstream lakes, and artesian flow from uncapped exploratory oil wells.

Predevelopment measurements show that the historical base flow during summer was on the order of 0.18 cfs (NRCS, 1995), but by the 1990s the summer base flow had reached about 4 cfs. The NRCS (1995) study estimated that summer runoff from watering lawns and washing driveways in the upper watershed accounted for about 2.4 cfs of the base flows. About 7.4 cfs of runoff was estimated to be generated, but about two-thirds of that was estimated to be lost through evapotranspiration (NRCS, 1995).

## 6.2 IHA CHANGE ANALYSIS

The Indicators of Hydrologic Alteration (IHA) tool (Nature Conservancy, 2007) was used to compare differences in hydrologic regimes between two time periods and assess how these changes are related to impacts on instream sediment loading and biological health. IHA is used to summarize long periods of daily hydrologic data into a much more manageable series of ecologically relevant hydrologic parameters. As a result, the analyses targeted hydrologic indicators that best represent the impacts on sediment loading and the health of benthic macroinvertebrate communities (see Appendix C for additional detail on the IHA analyses).

Flows were analyzed at the LACDPW monitoring gage on Malibu Creek below Cold Creek (Gage F-130), the same location as the earlier USGS gage on Malibu Creek at Crater Camp (11105500). This gage is located downstream of most of the development in the watershed, as well as the Tapia WRF discharge, and is thus not fully representative of changes in flow upstream of Tapia because the gage record contains the Tapia WRF discharges. IHA was used to do a pre- post-analysis. For the pre-impact period, daily flows were used for Water Years 1932-1965 (10/1/1931 – 9/30/1965) available on the USGS website. The pre-impact period was limited to 1965 because this is when the Tapia discharge and related development came online. The post-impact period used flows for Water Years 1992 to 2009 (10/1/1992 to 9/30/2009) provided by LACDPW as representative of current conditions.

Figure 6-4 shows separate flow duration curves for the pre- and post-periods. Note the significant increase in overall flow during the later monitoring periods, apparently reflecting the combination of the Tapia discharge and use of imported water in the basin. The overall mean flow for the two monitoring periods doubled from 17 cfs during the pre-impact period to 47 cfs during the post-impact period; an increase of 180 percent.

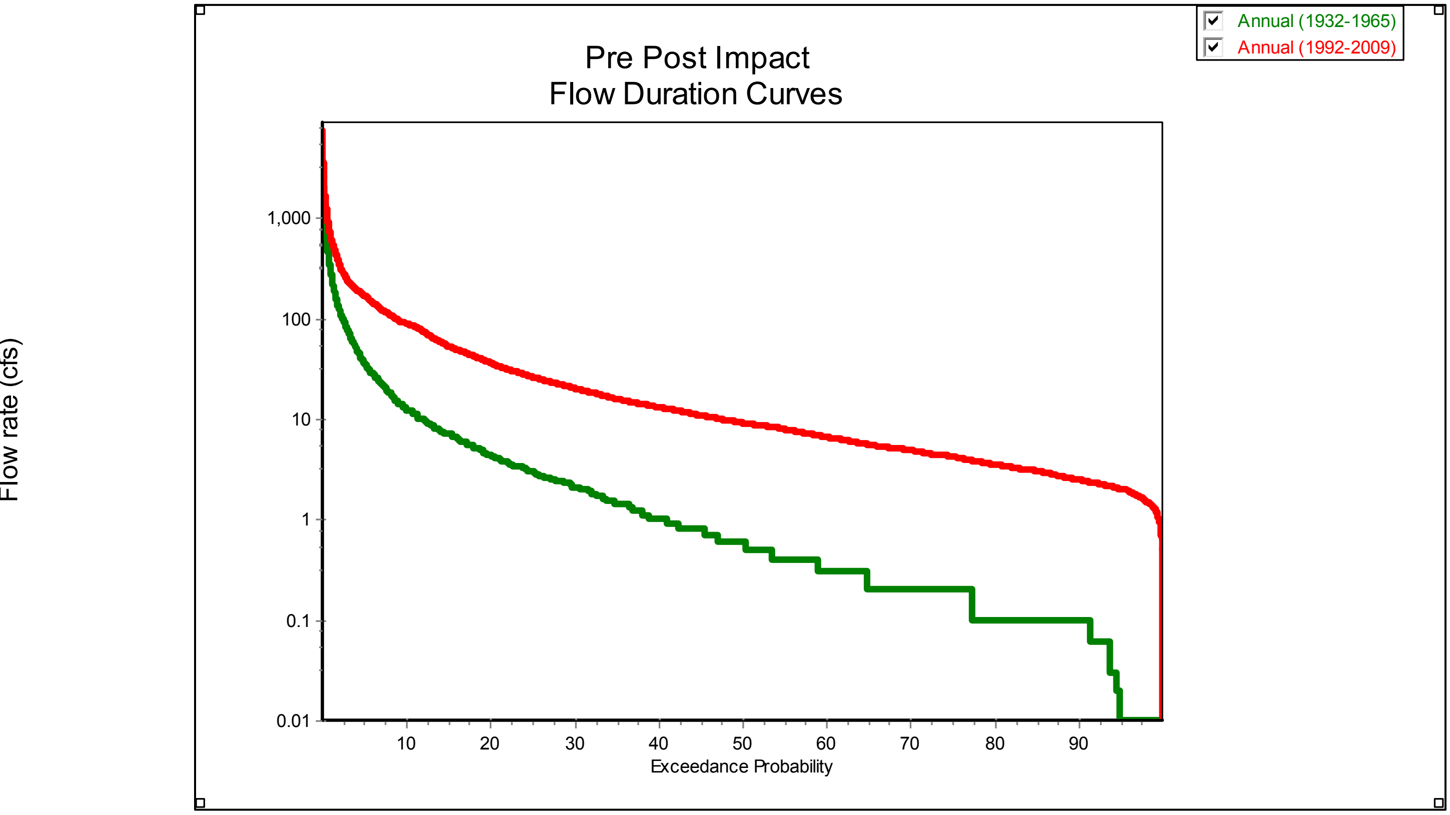



**Figure 6-4. Annual Flow Duration Curves for Pre-Post Monitoring Periods on Malibu Creek at the LACDPW F-130 Gage (downstream of Tapia Outfall)**

The statistical results show a significant increase in the magnitude of annual flows between the pre- and post-impact periods. As shown in Figure 6-5, the median 1-day maximum flows increase from 179 cfs to 860 cfs (an increase of 380 percent). The median monthly flows increase between 505 percent and 3,237 percent between the pre- and post-impact monitoring periods and the annual 30-day maximum values increase by 410 percent. Not only do the median peak flows significantly increase during the post-impact period as expected from the increased development and imperviousness in the watershed, but the median low-flows also increase (+2,310 percent for the 30-day rolling median).

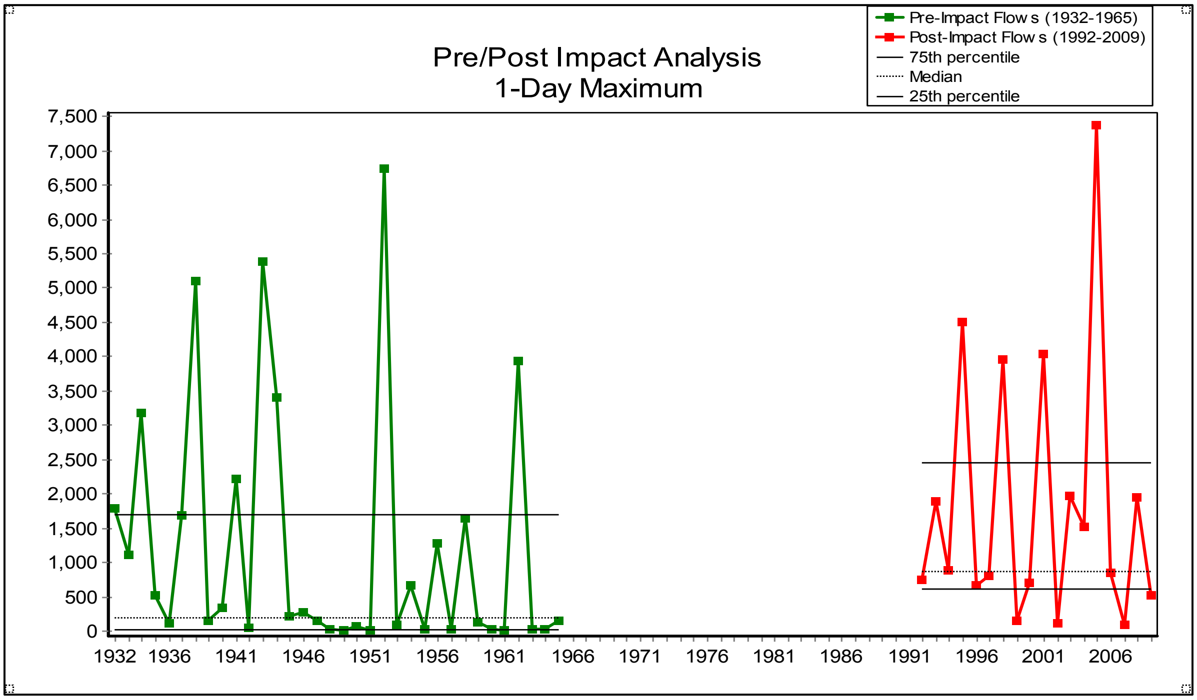



**Figure 6-5. Pre/Post Comparison of Median Daily Maximum Flows on Malibu Creek**

A key feature of the IHA is the evaluation of Environmental Flow Components (EFC). The program categorizes all daily flows as one of the following: extreme low flows, low flows, high flow pulses, small floods, and large floods. For Malibu Creek, extreme low flows are flows less than or equal to 0.1 cfs under pre-impact conditions. The dividing line between low flows (base flows) and high flows is set at 3 cfs by the analysis, while the small flood minimum peak flow is 179 cfs and the large flood minimum peak flow is 4,505 cfs.

The EFC median low flows by month are shown in Figure 6-6 and reveal a dramatic change in pattern over time.

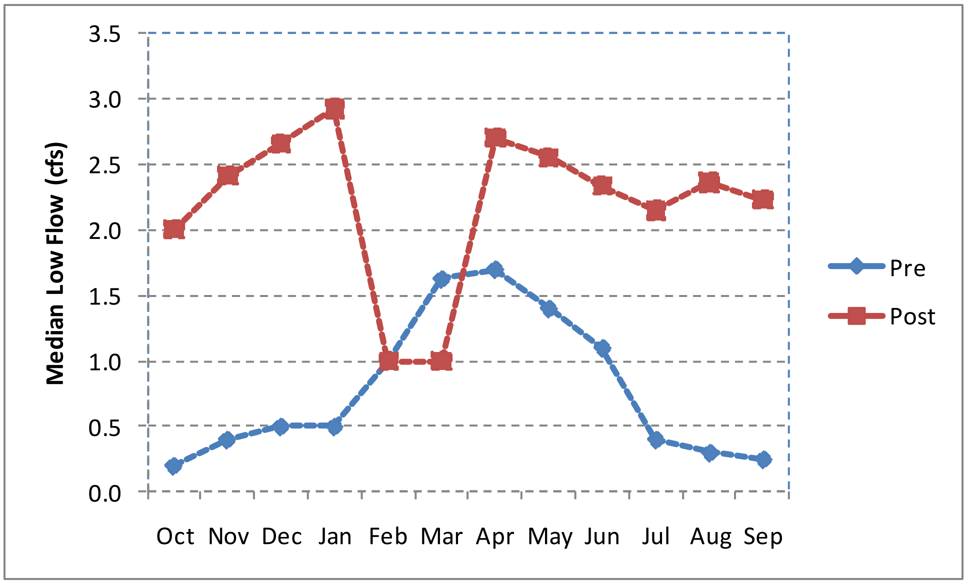



**Figure 6-6. EFC Median Low Flows by Month**

There is a dramatic change in extreme low flow frequency: In the pre-impact period the median number of days with flow less than or equal to 0.1 cfs was four per year, whereas none occur in the post-impact period. This change may decrease the ability of the system to purge invasive species that are more sensitive to dessication than native species.

In general, the rates-of-flow rise and fall do not show statistically significant differences, nor is there much difference in small floods. More significant (< 10 percent) are the changes in high flow pulse (e.g., above base flow) peak and timing and large flood peak and timing. The high flow pulses are smaller and occur later in the year post-impact, while the large flood peaks are greater and occur earlier in the year. Both of these factors are likely to be associated with shaping the physical conditions and morphology of the streambed, while the changes in large floods can also have important consequences for the physical habitat of the floodplain.

The IHA analysis of flood peaks from the gage data likely underestimates the full range of change relative to natural conditions because the "pre-impact" period for the analysis includes gradual increases in development. Additional information on the impact of development on flood peaks is provided by modeling undertaken independently by Owen (1998). Owen used the HEC-1 flood forecast model with design storm information to estimate the magnitude of flood flows of various recurrence intervals for 1998 conditions (including dams within the watershed) and for "natural" conditions based on a 1930-1934 vegetation survey conducted by the U.S. Forest Service (USFS).

Owen concluded that the predicted 2 year, 24 hour flow event at the Malibu Creek outlet had increased from 1,601 to 3,766 cfs, while the 100 year flow increased from 23,056 to 42,090. These changes were attributed to increased impervious surfaces:

> "The modeling has shown that the watershed is yielding a large increase in runoff since predevelopment conditions have changed into the current state of development. Increases greater than 100% are seen in every subshed, most approaching 200% for a two year storm, and the Westlake subshed showing an over 700% increase. …[T]he increase in impervious surface area in each subshed has dramatically increased the runoff into Malibu Creek.
>
> "Although typical (and costly) structural devices such as dams and weirs can be used to control runoff, it is clear that this watershed will yield extreme amounts of runoff as impervious

surfaces increase and, due to the erosive nature of the soils, will render these devices largely ineffective in relatively short periods of time as seen with Rindge Dam which has completely filled with sediment. It would seem that a more comprehensive management of the watershed resources will result in a cost effective and habitat conserving condition."

## 6.3 MALIBU LAGOON MORPHOLOGY

The geologic history of Malibu Lagoon is described in Ambrose and Orme (2000) and Moffatt and Nichol (2005). The form of the Lagoon represents a dynamic balance between sea level rise since the last ice age and high sediment supply due to uplift of the Santa Monica Mountains. In general, the Lagoon has been aggrading over time in concert with sea level rise of approximately 1.8 mm/yr. An image of the Lagoon prior to major disturbances is available from the 1903 topographic map of Calabasas Quadrangle (Figure 6-7). The map shows the Lagoon as closed, with a small area of open water. It is likely that ranching activities since the 1860s had increased sediment supply prior to this map.

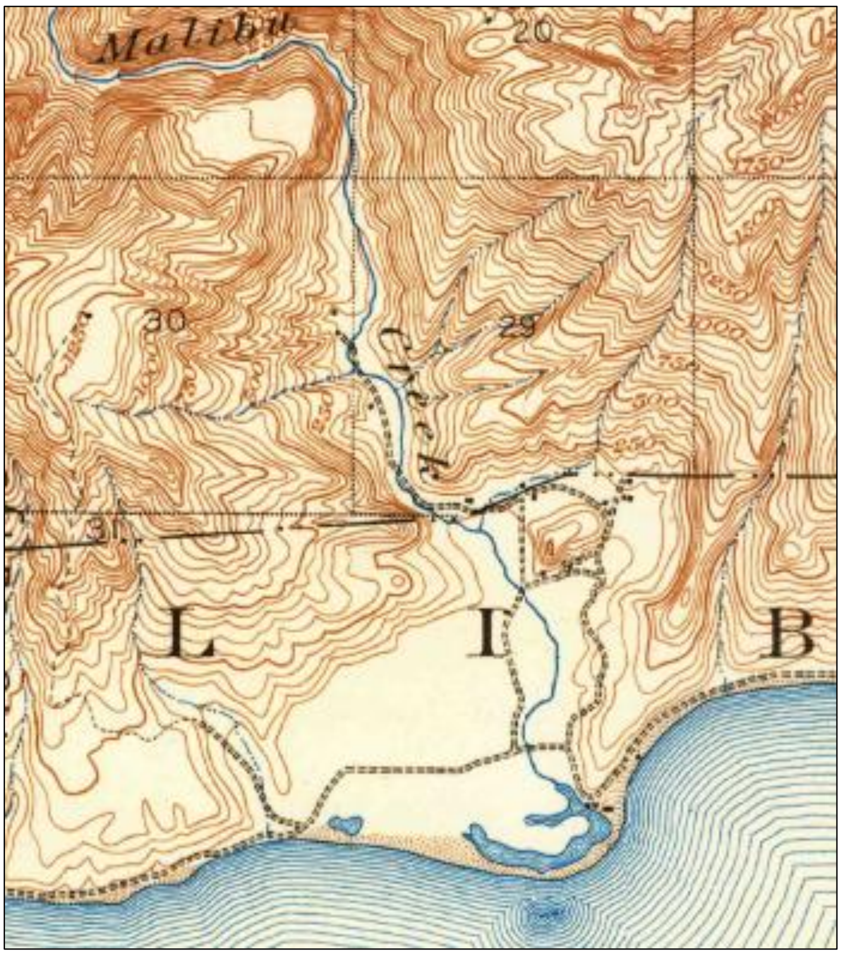
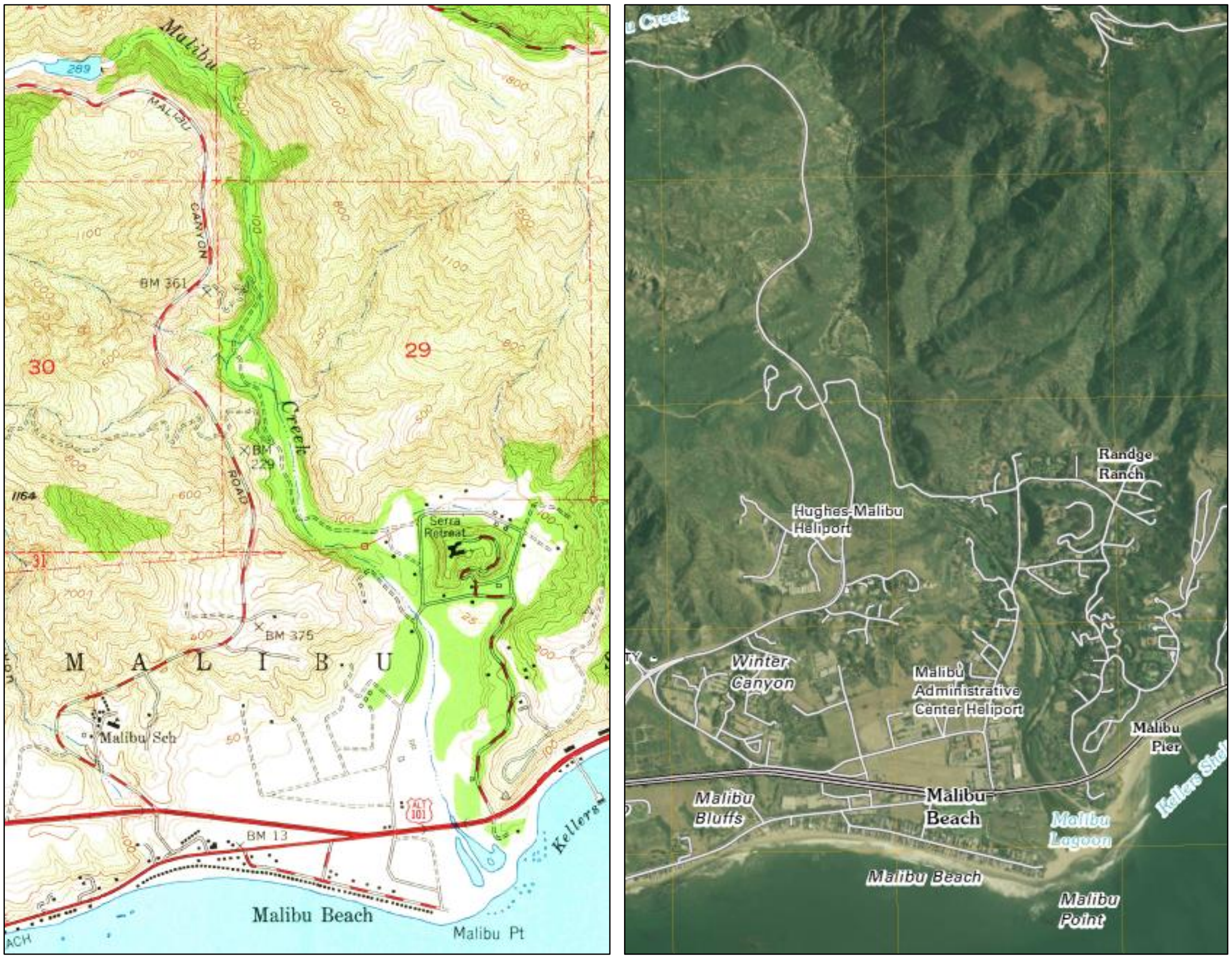



**Figure 6-7. Malibu Lagoon, Detail from 1903 USGS 1:24,000 Map of Calabasas Quadrangle**

(http://ims.er.usgs.gov/gda_services/download?item_id=5500825&quad=Calabasas&state=CA&grid=15X15&series=Map GeoPDF)

As described by Ambrose and Orme (2000), a railway was constructed across the Lagoon in 1908 and transformed into the Pacific Coast Highway in 1929. The western portions of the Lagoon were largely drained between 1920 and 1949 and large portions converted to truck farming. A variety of building projects followed, constraining the natural footprint of the Lagoon. The 1950 map of the same area shows the reduced footprint of the Lagoon and constraint by roads and ongoing building projects (Figure

6-8; left panel). A 2009 revision shows even more constraints on the Lagoon morphology (Figure 6-8; right panel). These constraints have increased aggradation in the remaining footprint of the Lagoon, much of which was noted as being above mean sea level in 2005 (Moffatt and Nichol, 2005). As a result, the Lagoon is much smaller and fresher than was likely the case under natural conditions – occupying only the eastern portion of its original extent.




**1950** **2009 Digital Map**

**Figure 6-8. Malibu Lagoon, Detail from USGS 1:24,000 Malibu Beach Quadrangle**

The Lagoon is naturally a highly dynamic system in which substantial aggradation occurs in cycle with major floods that open the barrier beach and scour out accumulated sediments. Floods in 1938 and 1998 deepened the Lagoon and increased water volume on a temporary basis.

Natural breaching of the Lagoon barrier occurs primarily in response to winter storms. Alterations to the hydrology of the system have affected this natural cycle. Increased flows into the dry season, in conjunction with reduced storage volume in the Lagoon, can result in problems with high water table and flooding during the summer.

Some information may be gleaned from a series of aerial photographs available at www.coastalcalifornia.org. (These are subject to copyright and are thus not reproduced here.) Based on these photographs and information provided in Ambrose and Orme (2000) and Moffatt and Nichol (2005), the following constructed partial chronology gives an example of the breaching activities in the past. We understand the lifeguards at the Malibu Lagoon beach keeps an informal written log of the daily Lagoon outlet status, which is not provided in this TMDL.

| | |
|---|---|
| *1972 [day not stated]* | *Beach open at center, shallow channel* |
| *1979 Oct.* | *Open at center with full ocean exchange* |
| *1997-1998 Winter* | *Fully open to the sea with deepening of Lagoon by 0.5 to 1 m due to major flood event* |
| *1999-2004* | *Largely closed and aggrading* |
| *2002 October* | *Photography shows beach fully closed* |
| *2004 October* | *Open at west end of beach* |
| *2005 June* | *Closed* |
| *2006 September* | *Small overflow channel at west end of beach* |
| *2008 September* | *Closed* |
| *2010 September* | *Closed* |
| *2011 October* | *Small overflow channel at east end of beach* |

# 7. Water Quality Data and Analysis

In this section, we summarized all available water quality data collected for Malibu Creek Watershed to date. Analyses of the data and their relevance to key stressors and impairments are provided. In general, this section provides the critical observations and does not necessarily show all the data or analyses completed or considered because of the large amount of data and analyses generated during our evaluation of the information in the watershed.

### *Water Quality Summary Box*

#### Dissolved Oxygen and Temperature

- Exceedances of the applicable DO criteria for WARM, COLD, and SPWN uses were observed consistently since 1998.
- DO data set collected to date is incomplete and likely underestimates the frequency of critically low DO levels. The DO sampling to date did not capture diel fluctuations and, thus, did not capture pre-dawn DO levels, which represents the most critical condition. Pre-dawn DO levels show the lowest DO levels experienced by aquatic life in a waterbody.
- Average summer temperature was higher in Malibu Creek main stem compared with comparator/reference sites. High temperatures and large temperature fluctuations can negatively impact benthic community or relevant aquatic life.

#### Conductivity

- There is no WQC for electrical conductivity applicable to Malibu Creek, but there is a TDS standard of 2,000 mg/L. LVMWD (2011) developed relationships between TDS and conductivity in samples from the Malibu Creek main stem, suggesting that conductivity of approximately 2,500 µS/cm could be a screening criterion.
- Conductivity measurements occasionally exceed this value in the mainstem, but not at coastal comparator/reference sites.
- The highest conductivity values are found in the Monterey/Modelo Formation, while the main stem exhibits variable levels due to a mixture of upstream drainage areas(e.g., marine sediments; non-marine areas).

#### TSS/Turbidity

- TSS monitoring data are limited. Based on data at the mass emissions station, high suspended solids concentrations do occur. There is a decreasing trend (but not statistically significant) in TSS over time (by LACDPW) since 2002.
- Turbidity WQS indicates a 20 percent increase above background is allowed. Reported turbidity values are generally low, but the main stem is higher than at comparator/reference sites.
- In 2011 and 2012, EPA performed a study to determine if a relationship between turbidity and suspended sediment transport could be established. Results showed that for typical flow ranges, there is a good relationship, suggesting that turbidity can be an excellent surrogate for suspended solids concentration in Malibu Creek.

#### Nutrients

- Majority of sampling for nutrients in Malibu Creek has focused on inorganic nutrient species only; however, it has been found that TN and TP are better predictors of benthic algal response than the inorganic forms.
- Inorganic nutrient concentrations are higher below Tapia (MC-1 and MC-15) and the sites with the highest nitrate concentrations (LV-5, MD-7, LV-13, MC-15) are downstream of developed areas.
- It appears that the elevated nitrate concentrations are influenced by the urban and other development activities upstream, and not necessarily the Monterey/Modelo Formation; this suggests that the increased inorganic N concentrations are more associated with urban and development activities than with geology.
- Undisturbed sites ( those draining and not draining the Monterey/Modelo Formation) have lower median orthophosphate-P concentrations than those that drain urban and development activities. Concentrations downstream of the Tapia WRF are much higher.
- There are no excursions of the acute ammonia criterion.

#### Toxicity

- Sulfate and selenium WQC were exceeded

## 7.1 SOURCES OF DATA

Water quality in the Malibu Creek Watershed has been monitored by many agencies and organizations over time. We relied on numerous data sets, in addition to many reports and studies for our assessment of the conditions observed in the watershed. For instance, a recent report by the Joint Powers Authority of the Las Virgenes Municipal Water District and the Triunfo Sanitation District (LVMWD, 2011) summarized many of the data sets collected in the Watershed. To better our understanding of the complex relationships between biological, physical and chemical variables, we conducted additional analyses that are of particular relevance to biotic impairment in Malibu Creek.

The largest and longest record of data are those collected by the HtB Stream Team, LVMWD, National Park Service (NPS), and the LACDPW. Other data sources include USEPA, Calabasas Landfill Monitoring, and the Malibu Creek Watershed Monitoring Program (MCWMP). The broadest data record collected is by the MCWMP. The critical data analyses and observations are discussed below. Monitoring stations are illustrated in Figure 7-1 and Figure 7-2 (note: the NPS data are labeled separately to reduce clutter in the maps due to the large number of sampling stations). A comprehensive list of the data sets and studies considered and evaluated are included in Appendix A. This appendix also includes a table identifying all sampling sites, the type of data collected, and a description of the setting adjacent to and upstream of each site.

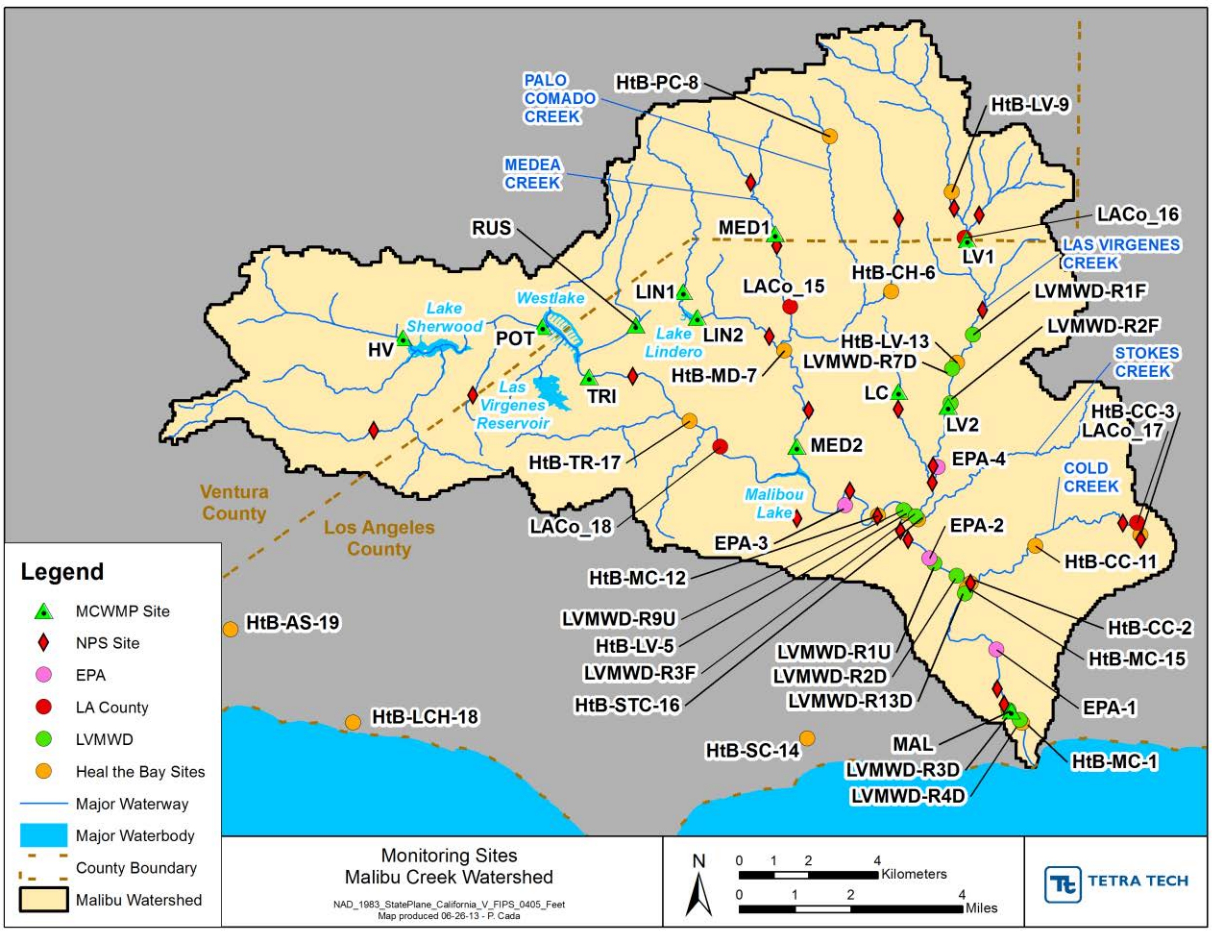



**Figure 7-1. Monitoring Sites in the Malibu Creek Watershed and Adjacent Comparator/reference Sites**

Note: National Park Service sites are labeled separately in Figure 7-2.

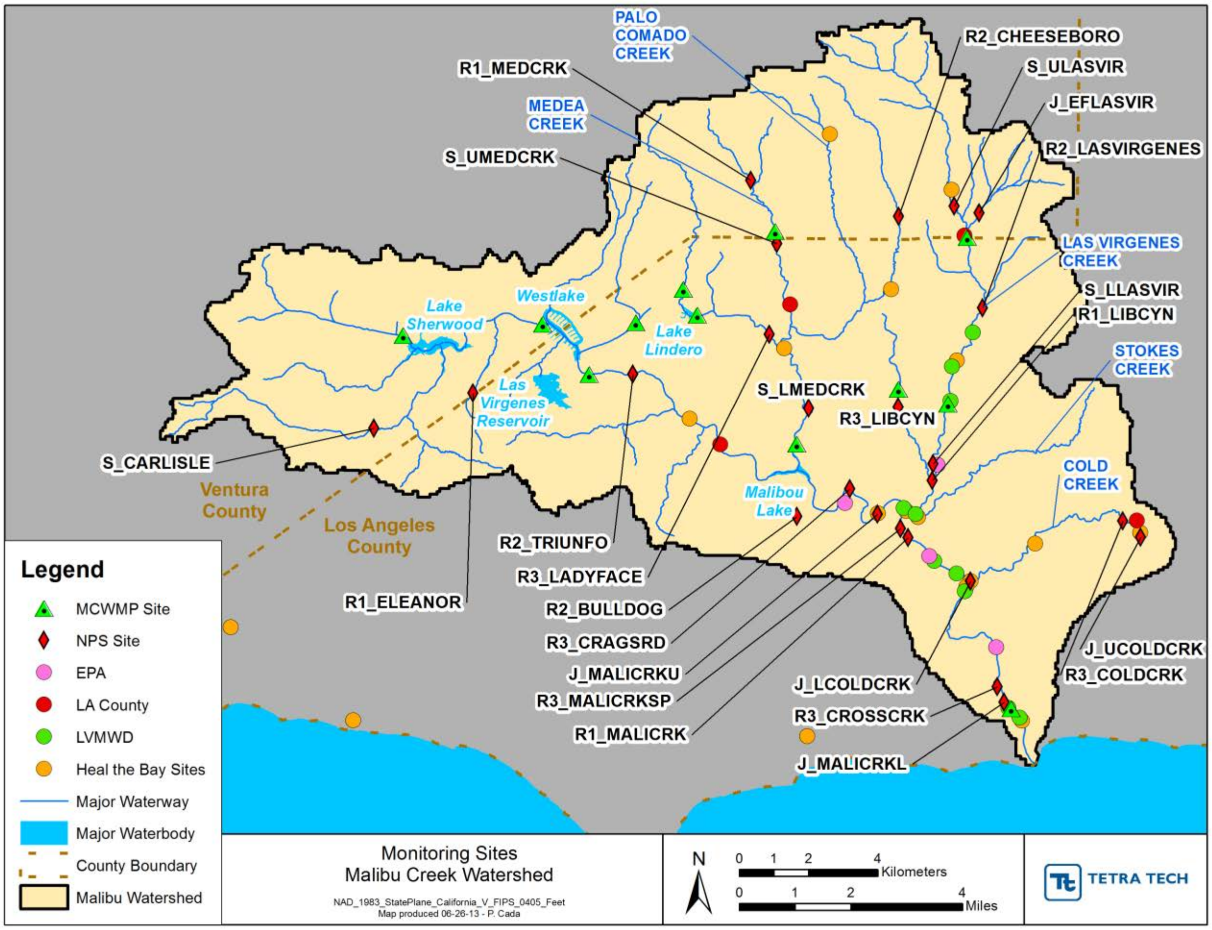



**Figure 7-2. National Park Service Monitoring Sites in the Malibu Creek Watershed**

# 7.2 COMPARATOR/REFERENCE SITES

The data presented below are associated with stations both within the Malibu Creek Watershed and some comparator/reference stations located outside of the watershed. Ideally, the comparator/reference stations would all be located within the Malibu Creek Watershed for comparability. As discussed below, the comparator/references stations evaluated are located both within (CH-6 and LV-9) and near the watershed (SC-14 and LCH-18). The Upper Cold Creek (CC-3) station, which is located in the headwaters of the Cold Creek drainage, was identified as a possible comparator/reference station because it has consistently good biota, water quality conditions and high physical habitat scores relative to other sites. Data associated with this station are presented below because they illustrate a high quality area of the Malibu Creek Watershed. CC-3 was ultimately not presented as a comparator/reference condition due to a combination of factors. CC-3 has a very small drainage, high gradient (11.1%), and is at a higher elevation than any of the impacted or other comparator/reference sites. In addition, the geology is very different from most of the monitoring stations in the watershed, with very low conductivity. It was concluded that CC-3 represents high quality conditions in the watershed, but it does not truly inform the biological potential of the impaired stations in the Malibu Creek Watershed. LV1 was further evaluated and determined that it would not be an appropriate comparator/reference site due to evidence of anthropogenic activities influencing the site.

## 7.3 DISSOLVED OXYGEN AND TEMPERATURE DATA ANALYSES

Malibu Creek has existing aquatic life beneficial uses of WARM, COLD, and SPWN, which are respectively associated with minimum DO criteria of 5, 6, and, 7 mg/L, respectively. Because federal and state regulatory requirements must protect for the most sensitive beneficial use, the applicable minimum DO criteria is 7 mg/L for Malibu Creek main stem. We also evaluated the applicable criteria for WARM and COLD beneficial use because these are critical uses identified for Malibu Creek main stem and the tributaries draining directly into the main stem. Samples from the Malibu Creek main stem show exceedances of the applicable criteria for WARM, COLD, and SPWN. The large database of samples collected by the HtB Stream Team are daytime grab samples that likely did not capture the pre-dawn daily minimum DO. For a point of reference, these results are compared to four comparator/reference sites, Solstice Creek (SC-14), Lachusa Creek (LCH-18), Cheseboro Creek (CH-6), and Las Virgenes Creek (LV-9), in Table 7-1.[2] Downstream of site MC-15 is the Malibu Creek F-130 flow gage. LVMWD monitors at this location (LVMWD-R13D) and these results are included in the table.

**Table 7-1. Stream Team Dissolved Oxygen Sample Summary Malibu Creek Main Stem and Comparator/Reference Sites, 1998-2010**

| Site | MC-1 | MC-12 | MC-15 | LVMWD-R13D | SC-14 | LCH-18 | CH-6 | LV-9 | Applicable Criteria |
|---|---|---|---|---|---|---|---|---|---|
| Sample Count | 111 | 70 | 25 | 244 | 72 | 61 | 49 | 30 | |
| Average | 10.90 | 9.38 | 9.09 | 10.53 | 9.30 | 9.93 | 8.55 | 5.95 | |
| Min | 2.81 | 2.6 | 2.8 | 5.00 | 7.05 | 7.06 | 3.08 | 2.92 | ≥ 7 mg/L |
| Max | 19.68 | 12.92 | 18.14 | 16.40 | 16.17 | 13.28 | 11.10 | 9.14 | |
| Median | 11.04 | 9.82 | 9.40 | 10.20 | 9.25 | 9.84 | 8.78 | 5.36 | |

The SPWN criterion of 7 mg/L and the COLD criterion of 6 mg/L or better are met in all samples from the coastal comparator/reference sites (SC-14 and LCH-18), but not consistently in the main stem or at CH-6 and LV-9. There are also frequent high values in the main stem, attributable to algal photosynthetic production of DO. A box plot of the DO samples (Figure 7-3) shows that the minimum DO criterion of 7 mg/L is met in more than 85 percent of samples, although more than 12 percent of the samples at MC-1 were less than 7 mg/L. In Table 7-2, between 12 and 14 percent of the DO samples at main stem stations MC-1 and MC-12 fall below an applicable criterion. We did not observe any excursions at the comparator/reference sites. Data from Table 7-2 showed there are high levels of DO stress in the main stem and some of the tributaries at different times of the year. Some of these results indicate a complexity that is not fully understood. For example, data at the sites in undeveloped or park areas, SC-14, LCH-18, and LV-5, showed 0 to 5% excursions of the applicable criteria (note: CC-3 also fell within this range, while Lower Cold Creek station [CC-2] that is subject to some anthropogenic influence had more excursions). On the other hand, observations at LV-9, which drains a relatively undisturbed area, were less than 6 mg/L 71 percent of the time. The likelihood of DO stress on biota is further supported by the

[2] In this comparison, we observed that although the average and maximum DO levels are comparable, the minimum DO level is substantially lower at the sites in the main stem, than at the coastal comparator/reference sites SC-14 and LCH-18. Because the critical level of concern for aquatic life is ensuring that a minimum level of DO is maintained, the observed minimum DO levels around 2 mg/L is of potential concern. We note that although some of the samples at MC-1 are associated with zero reported flow at the downstream USGS gage in 2008 and 2009 during the summer season, the majority of samples with DO below 7 mg/L, were associated with “steady” flow.

fact that diel fluctuations, including pre-dawn data (i.e., lowest DO levels experienced by aquatic life), were not captured in these data sets.

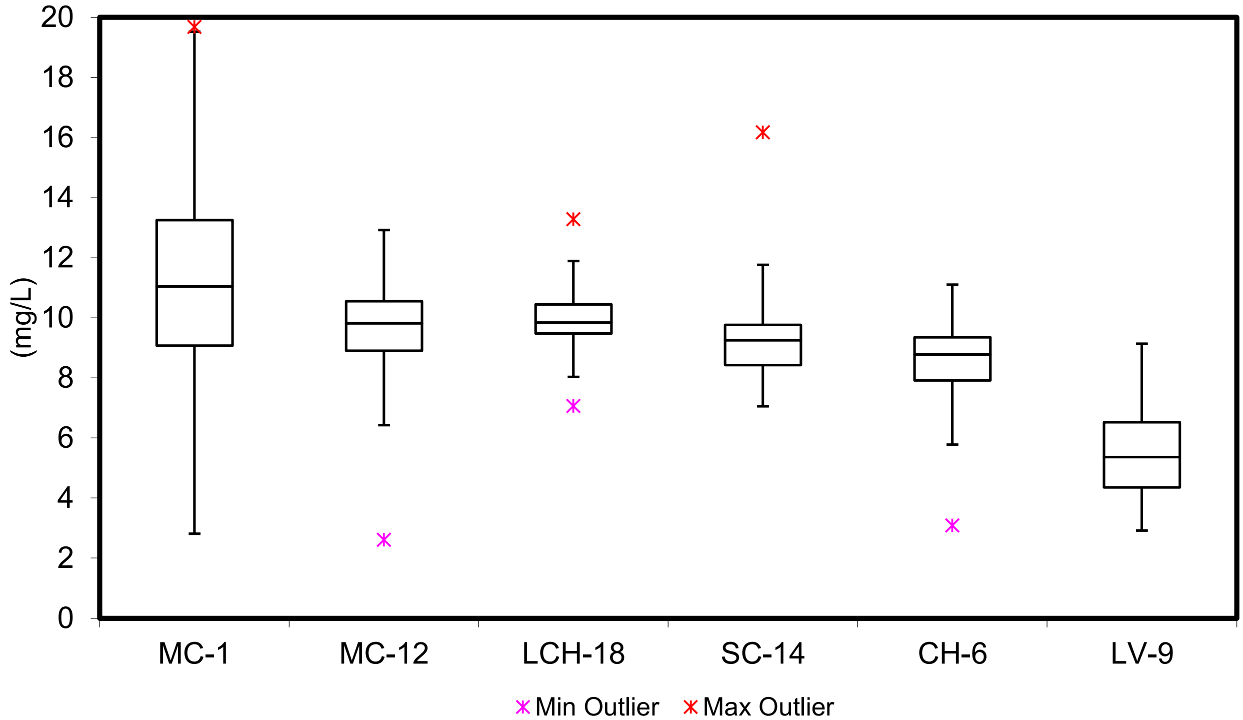



**Figure 7-3. Box Plot of Stream Team DO Samples from Malibu Creek and Comparator/Reference Sites**

**Table 7-2. Frequency of Low DO Samples at Malibu Creek Stations, 1998-2010**

| Station | Description | < 7 mg/L | <6 mg/L | <5 mg/L |
|---|---|---|---|---|
| HtB-MC-1 | Malibu Creek, Cross Creek Rd. | 13.60% | 9.30% | 7.10% |
| HtB-MC-15 and LVMWD R -13D | Malibu Creek at F-130 gage | 3.3% | 1.0% | 0.7% |
| HtB-MC-12 | Malibu Creek at Malibu Creek State Park | 12.70% | 7.80% | 5.30% |
| HtB-SC-14 | Solstice Creek. National Park Service Area, upstream of bridge | 0% | 0% | 0% |
| HtB-LCH-18 | Lachusa Creek | 0% | 0% | 0% |
| HtB-CC-2 | Cold Creek at Piuma Rd | 11.40% | 8.90% | 4.40% |
| HtB-CC-3 | Cold Creek at Stunt Rd | 4.40% | 3.00% | 0.90% |
| HtB-LV-5 | Las Virgenes Creek at Malibu Creek State Park | 4.70% | 2.40% | 2.00% |
| HtB-CH-6 | Cheseboro Creek, Agoura Hills | 11.20% | 5.00% | 3.60% |

| Station | Description | < 7 mg/L | <6 mg/L | <5 mg/L |
|---|---|---|---|---|
| HtB-MD-7 | Medea Creek, Cornell at Kanan Rd. | 11.60% | 2.20% | 0% |
| HtB-PC-8 | Palo Comado Creek | 33.30% | 22.10% | 15.50% |
| HtB-LV-9 | Las Virgenes Creek | 79.60% | 71.00% | 38.10% |
| HtB-CC-11 | Cold Creek | 18.40% | 13.30% | 11.10% |
| HtB-LV-13 | Las Virgenes Creek, Lost Hills Rd east of Malibu Hills Rd. Apartments | 19.90% | 4.30% | 0% |
| HtB-MC-15 | Malibu Creek, Malibu Canyon Rd. upstream of LA County Stream Gauge | 14.70% | 11.30% | 9.20% |
| HtB-STC-16 | Stokes Creek Outlet | 0% | 0% | 0% |
| HtB-TR-17 | Triunfo Creek, Corner of Kanan Rd. at Troutdale upstream of bridge | 36.80% | 23.80% | 17.50% |
| HtB-AS-19 | Arroyo Sequit, up Mulholland Highway 1.1 miles | 8.20% | 6.50% | 0% |

The observations to date show that critically low DO levels, below the applicable criteria, exist in the Malibu Creek Watershed, in the main stem and along the tributaries. Occasional low DO is a source of stress to the benthic community and fish life in Malibu Creek. However, the DO data from HtB Stream Team and LVMWD sampling appears incomplete at this point because these data sets do not capture the diel fluctuations inherent in these waterbodies; and most critically, the pre-dawn DO conditions were not captured. Pre-dawn DO data are important because they reflect the lowest DO concentrations experienced by aquatic life in the waterbody. Many locations in the Creek contain high densities of benthic algae, which are an important indicator of the organic processes taking place between the water column and the biota. Benthic algae create oxygen during daytime photosynthesis and consume oxygen during overnight respiration, resulting in a diurnal pattern in which DO concentrations tend to be lowest around dawn. Single grab samples, as reported by HtB Stream Team and LVMWD, are thus of limited use in evaluating the full range of the DO levels experienced by biota over the course of the day. Gilbert (2009) demonstrated the existence of strong daily cycles of DO concentration in Malibu Creek, which could result in acute stress to the benthic community. Gilbert's work noted a strong correlation between pH and DO, indicating that algal production and respiration cycles, which respectively increase and decrease pH, are a major factor in observed DO concentrations. Other researchers have shown that pre-dawn DO data are more representative of the lowest DO levels experienced by aquatic life (Naiman and Bilby, 1998). In conclusion, there is a high probability that the grab sample data set collected to date underestimates the actual minimum DO levels experienced by the benthic community or other aquatic life.

The Stream Team DO samples in the main stem do not seem to show a clear trend over time (Figure 7-4). This may likely be due to the single grab samples captured during the daytime which do not reflect lowest DO concentrations experienced in a 24 hour period.

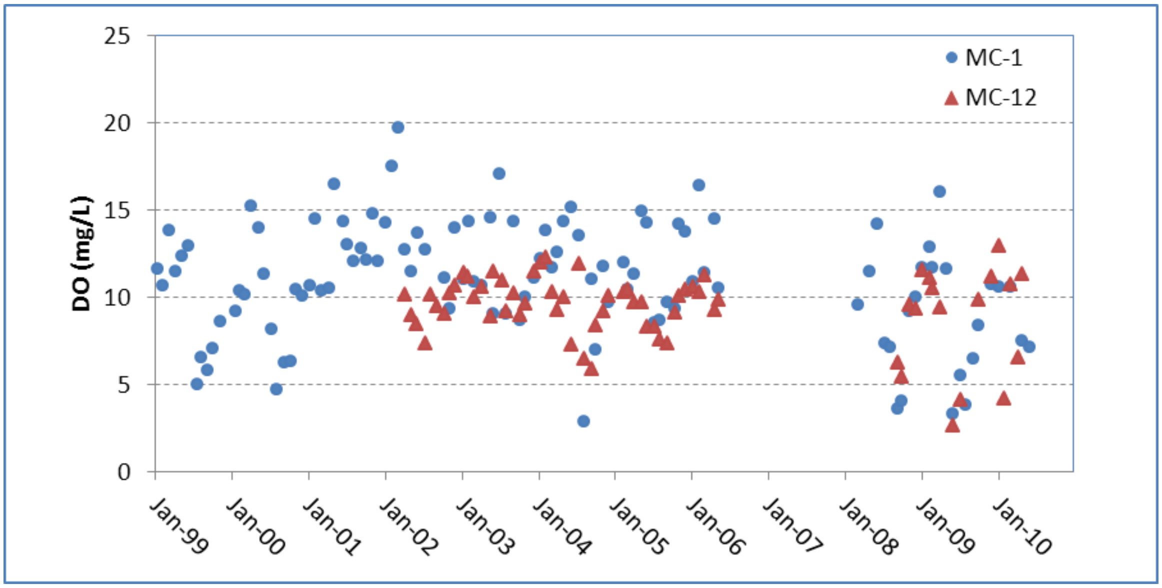



**Figure 7-4. DO Concentration versus Time at Malibu Creek Stream Team Stations 1 and 12**

Dissolved oxygen concentrations in shallow flowing streams are strongly affected by temperature, as water temperature is a major determinant of the saturation DO concentration. The wider range of DO concentrations observed in the Malibu Creek main stem compared to the coastal comparator/reference stations may also be due to greater variability in temperature. Elevated summer temperatures in Malibu Creek also likely exacerbate algal growth problems. In general, summer temperatures are higher in Malibu Creek compared with comparator/reference sites and winter temperatures are similar in Malibu Creek compared with coastal comparator/reference sites. The MC-12 site was approximately 4 °C cooler during the winter and 4 °C warmer in the summer than the comparator/reference sites. The MC-1 site has temperatures that are similar to the comparator/reference sites during the winter months but elevated relative to the comparator/reference sites by about 2-3 °C during the summer. The temperature patterns in Malibu Creek likely reflect a combination of effects, including (1) the watershed drains inland areas that are expected to have higher summer air temperatures than comparator/reference sites in the coastal strip, (2) the various impoundments in the watershed may further increase summer water temperatures, and (3) effects of development, including the presence of concrete channels and reduced riparian cover, can lead to increased stream heating.

Although only limited data are available on daily cycles of dissolved oxygen in the watershed, low DO is known to occur in some locations with slow-moving pooled water. The *State of the Watershed Report* (Sikich et al., 2012), states the following: “24-hour samples taken by the Santa Monica Mountains Resource Conservation District (RCD) at three sites within the watershed show that some areas experience significantly decreased dissolved oxygen concentrations during the early morning hours. Continuous monitoring provides a better assessment of actual DO levels since time of day is taken into account for each location. DO at some of the RCD sites was highly variable throughout the day, dropping far below the 7 mg/L standard for waters designated as COLD… and SPAWN… in Malibu Creek, and below the 5mg/L standard for waters designated as WARM… in the remaining tributaries of 5 mg/L.” Sikich et al. (2012) then presented a figure, described as “Continuous monitoring DO profiles for the Lunch and Start Pools in lower Malibu Creek, 2010 Water Quality Monitoring Final Progress Report, Resource Conservation District of the Santa Monica Mountains. Data graphed were collected between August 11, 2009 and September 1, 2009. Start Pool is approximately 250m upstream of Site 1 (outlet of Malibu Creek) and Lunch Pool is approximately 720m upstream of Start Pool.” This figure is reproduced below (Figure 7-5).

Note that the Start Pool sonde recorded about 8 hours below 2 mg/L, a condition that would be fatal to many aquatic organisms. Thus, there are at least some locations where low DO is a significant problem in the watershed; however, the spatial extent of such conditions is not known. Severe diel depression of DO is less likely to occur in shallower, faster flowing reaches of the stream.

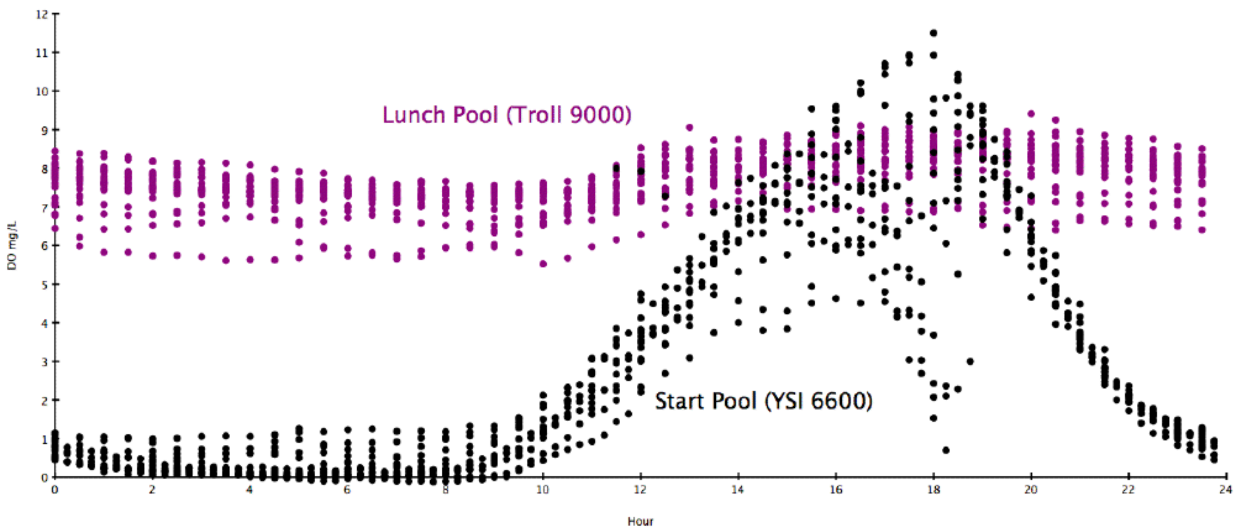



**Figure 7-5. Dissolved Oxygen Profiles in Lower Malibu Creek Pools (from Sikich et al., 2012)**

LVMWD provided continuous DO monitoring in the Tunnel Pool and Mott Road Pool in 2010, which showed similar trends to those shown in Figure 7-5 for Lunch Pool; the average concentration in Tunnel Pool was 8.3 mg/L (.4.5 percent of observations were below 7 mg/L

Sikich et al. (2012) also discuss low DO within Malibu Lagoon (citing Briscoe et al., 2002, and Ambrose et al., 1995): "The Malibu Lagoon suffers low Dissolved Oxygen (DO) levels, a condition that threatens aquatic life. In a 2005 study, pre-dawn dissolved oxygen concentrations averaged 1.15 ± 0.12 mg/L SE, significantly below Basin Plan thresholds. Concentrations below 5 mg/L threaten aquatic life survival, and periods of low dissolved oxygen and low species diversity have been recorded in the Lagoon since the early 1990s. For this reason, along with extensive sedimentation and eutrophication, a comprehensive planning effort was initiated in the late 1990s and early 2000s to restore the Malibu Lagoon, with the primary objectives of improving water quality through increased circulation and enhancing Lagoon habitat for birds, fish and invertebrates."

## 7.4 CONDUCTIVITY AND DISSOLVED SOLIDS DATA ANALYSES

Malibu Creek is characterized by brackish water, with median specific conductance greater than 1,800 micro Siemens per centimeter (µS/cm) in the lower creek below the LA County gaging station and higher concentrations, typically greater than 3,000 µS/cm, in the northern headwaters above the 101 freeway (LVMWD, 2011). HtB Stream Team specific conductivity sampling for the main stem stations and comparator/reference sites is shown in Table 7-3. Results from the MCWMP MAL station are similar to those reported for MC-1 (MAL has an average of 1,862 µS/cm). The Calabasas Landfill sampling in Cheseboro Creek confirms an average conductivity of 3,408 µS/cm for CH-6 ). The station on Upper Cold Creek (CC-3) had conductivity measurements well below even the comparator/reference sites (median of 708 µS/cm and an average of 799 µS/cm), while Lower Cold Creek station (CC-2), which is influenced by development and agriculture, was similar to SC-14 or LCH-18 (Table 7-4).

**Table 7-3. Stream Team Specific Conductivity Sample Summary, 1998-2010 (µS/cm)**

| Site | MC-1 | MC-12 | MC-15 | SC-14 | LCH-18 | CH-6 | LV-9 | Target |
|---|---|---|---|---|---|---|---|---|
| Sample Count | 117 | 70 | 25 | 72 | 61 | 49 | 30 | |
| Average | 1,877 | 2,287 | 2,151 | 1,185 | 1,505 | 3,544 | 3,361 | ~2,500 (based on TDS of 2,000 mg/L) |
| Min | 13 | 903 | 1,030 | 368 | 16 | 2,700 | 2,766 | |
| Max | 3,690 | 15,500 | 3,080 | 1,424 | 1,702 | 8,100 | 4,310 | |
| Median | 1,869 | 2,070 | 2,260 | 1,210 | 1,546 | 3,364 | 3,208 | |

There is no water quality criterion for electrical conductivity applicable to Malibu Creek. Elevated conductivity and total dissolved solids (TDS) are primarily due to ionic salt content of the water. There is a TDS standard of 2,000 mg/L as a specific objective for the Malibu Creek Watershed in the Basin Plan.

The relationship between TDS and conductivity depends on the specific ions involved, their molecular weight, and their valence. LVMWD (2011) developed relationships between TDS and conductivity in samples from the Malibu watershed as a whole, and submitted analyses for the main stem only in comments. These analyses suggest that conductivity of approximately 2,500 µS/cm could be an informative screening criterion for TDS in Malibu Creek. Conductivity measurements occasionally exceed this value in the Malibu Creek main stem (7 percent at MC-1 and 21 percent at MC-12), but not in the coastal comparator/reference sites (Figure 7-6). The elevated conductivity levels range between 2000-3000 µS/cm along the main stem Malibu Creek and in the Monterey/Modelo Formation regions.

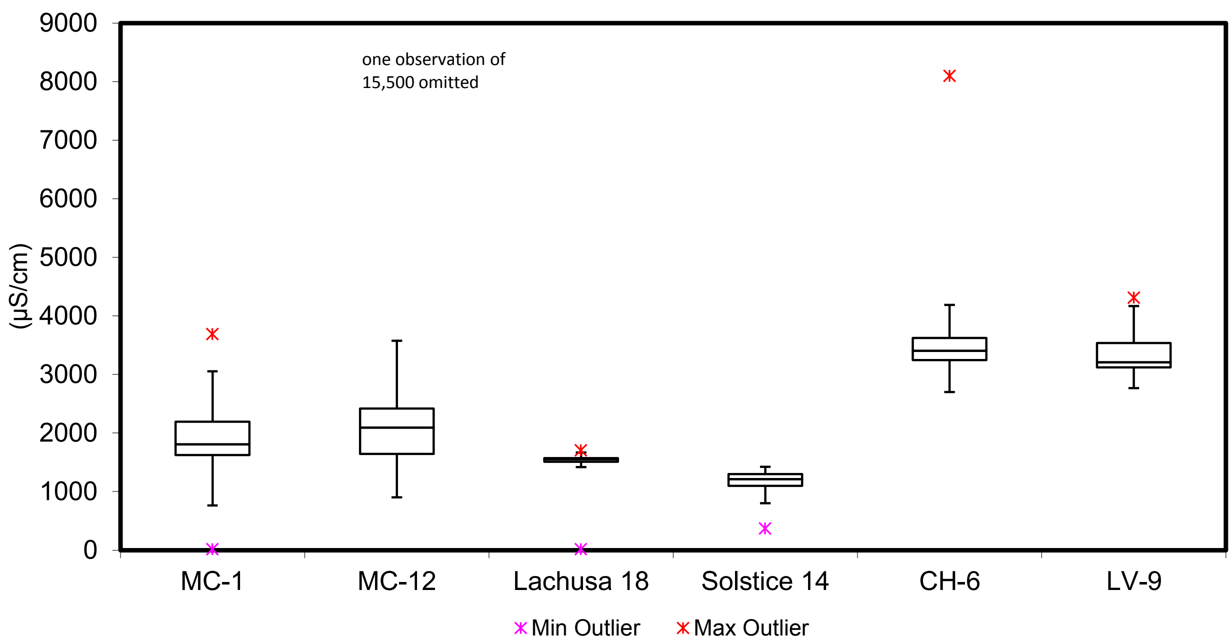



**Figure 7-6. Box Plot of Specific Conductivity Measurements from Malibu Creek and Comparator/reference Sites**

The distribution of conductivity throughout the watershed is revealed by the measurements taken at the many NPS and HtB Stream Team sites, along with smaller data sets from other programs. LVMWD

(2011) has studied this issue in detail as shown in Figure 7-7. It appears that the highest conductivity values are found in the Monterey/Modelo Formation, while the Malibu main stem exhibits an intermediate level due to a mixture of drainage from these marine sediments and from non-marine areas. However, it should be noted that the comparator/reference sites, not located in the Monterey/Modelo Formation regions, are similarly influenced by upstream Monterey/Modelo Formation regions; this is comparable to the sites along the Malibu Creek main stem. In fact, the Solstice Creek comparator/reference site also drains the Monterey/Modelo Formation near the coast.

**Average Specific Conductivity (µS/cm) in Malibu Creek and major tributaries in relation to MF rock, 1998 - 2009.** Note low SC in east and west subdrainages (= Cold Creek and Carlise Creek, respectively) with minimal MF rock. See Fig. 1 for station ID's

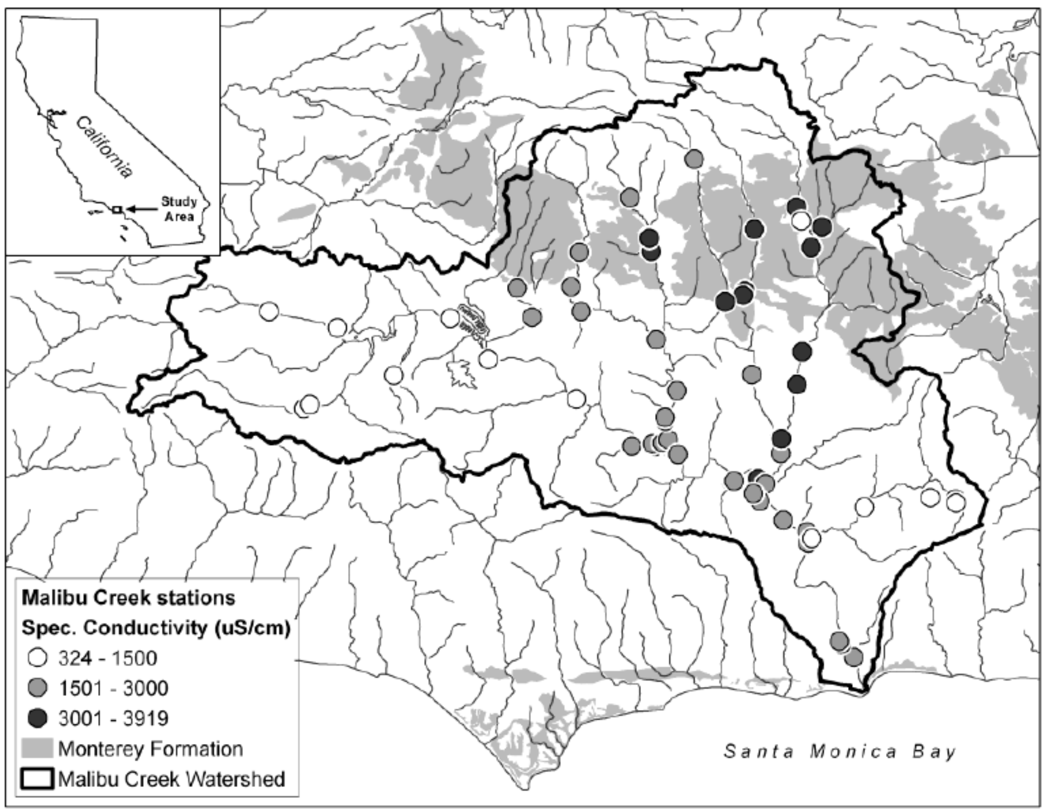



**Figure 7-7. Spatial Distribution of Specific Conductivity Measurements in the Malibu Watershed (from LVMWD, 2011)**

The distribution of the median and average specific conductivity from all the HtB Stream Team sites is summarized in Table 7-4. Sites with specific conductivity greater than 2,800 µS/cm are associated with drainage from the Monterey/Modelo Formation, while other sites range from 504 to 1,860 µS/cm.

**Table 7-4. Distribution of Specific Conductivity at HtB Stream Team Monitoring Sites**

| Station | Median (µS/cm) | Average (µS/cm) | Predominant Upstream Geology |
|---|---|---|---|
| HtB-MC-1 | 1,810 | 1,878 | Mixed |
| HtB-CC-2 | 1,289 | 1,459 | Non-Modelo |
| HtB-CC-3 | 708 | 799 | Non-Modelo |
| HtB-MAL-4 | 2,478 | 2,321 | Mixed |
| HtB-LV-5 | 3,380 | 3,335 | Modelo Formation |
| HtB-CH-6 | 3,405 | 3,544 | Modelo Formation |
| HtB-MD-7 | 2,969 | 2,890 | Modelo Formation |
| HtB-PC-8 | 1,789 | 1,860 | Non-Modelo |
| HtB-LV-9 | 3,208 | 3,361 | Modelo Formation |
| HtB-WC-10 | 504 | 510 | Non-Modelo |
| HtB-CC-11 | 1,367 | 1,402 | Non-Modelo |
| HtB-MC-12 | 2,080 | 2,279 | Mixed |
| HtB-LV-13 | 3,645 | 3,517 | Modelo Formation |
| HtB-SC-14 | 1,211 | 1,183 | Non-Modelo |
| HtB-MC-15 | 2,325 | 2,141 | Mixed |
| HtB-STC-16 | 1,607 | 1,591 | Non-Modelo |
| HtB-TR-17 | 1,323 | 1,268 | Non-Modelo |
| HtB-LCH-18 | 1,550 | 1,505 | Non-Modelo |
| HtB-AS-19 | 1,025 | 984 | Non-Modelo |

# 7.5 SUSPENDED SOLIDS AND TURBIDITY DATA ANALYSES

## 7.5.1 Suspended Solids

Monitoring of suspended solids in Malibu Creek is limited. MCWMP samples from station MAL showed an average total suspended solids (TSS) concentration of 3.6 mg/L, based on only two wet weather samples in the database.

LACDPW does collect TSS data under wet and dry conditions at their mass emissions station coincident with the F-130 flow gage on Malibu Creek. They report several wet and dry weather events per year as flow-weighted composites. The mass emissions station monitoring showed high suspended solids concentrations during wet weather events. The maximum reported concentration is 3,196 mg/L and the 90th percentile value is 394 mg/L (Figure 7-8).

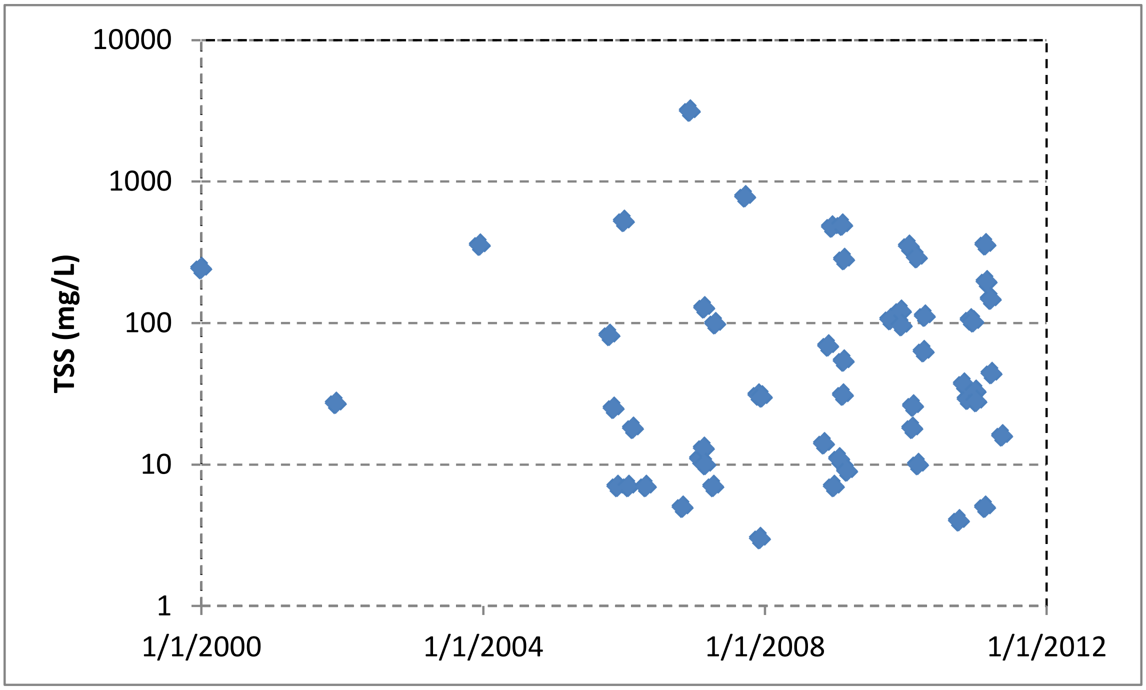



**Figure 7-8. TSS Observations at the LACDPW Mass Emissions Station on Malibu Creek, 2000-2011**

LACDPW has performed trend analysis on TSS data collected at the Malibu Creek mass emissions station. LACDPW (2010) detected a slight decreasing trend that was not statistically significant at the 5 percent level.

## 7.5.2 Turbidity

The WQSs for turbidity are based on elevation relative to natural conditions: A 20 percent increase above background is the maximum allowed. The turbidity values reported in HtB Stream Team sampling are generally low (Table 7-5). Maximum turbidity in the main stem of Malibu Creek is greater than at the comparator/reference sites, with the exception of SC-14 (Table 7-5 and see outliers on Figure 7-9). The median turbidity values are shown in Figure 7-9 and the comparator/reference sites are generally lower than the main stem of Malibu Creek, with the exception of LV-9.

**Table 7-5. HtB Stream Team Turbidity Sample Summary, 1998-2010**

| Site | | MC-1 | MC-12 | MC-15 | SC-14 | LCH-18 | CH-6 | LV-9 |
|---|---|---|---|---|---|---|---|---|
| Sample Count | | 117 | 70 | 25 | 72 | 61 | 50 | 30 |
| Turbidity (NTU) | Average | 1.94 | 1.31 | 2.62 | 0.75 | 0.27 | 0.85 | 0.83 |
| | Min | 0 | 0.03 | 0 | 0 | 0 | 0.005 | 0.005 |
| | Max | 40 | 14.9 | 35.5 | 39.5 | 3.1 | 15 | 3.4 |

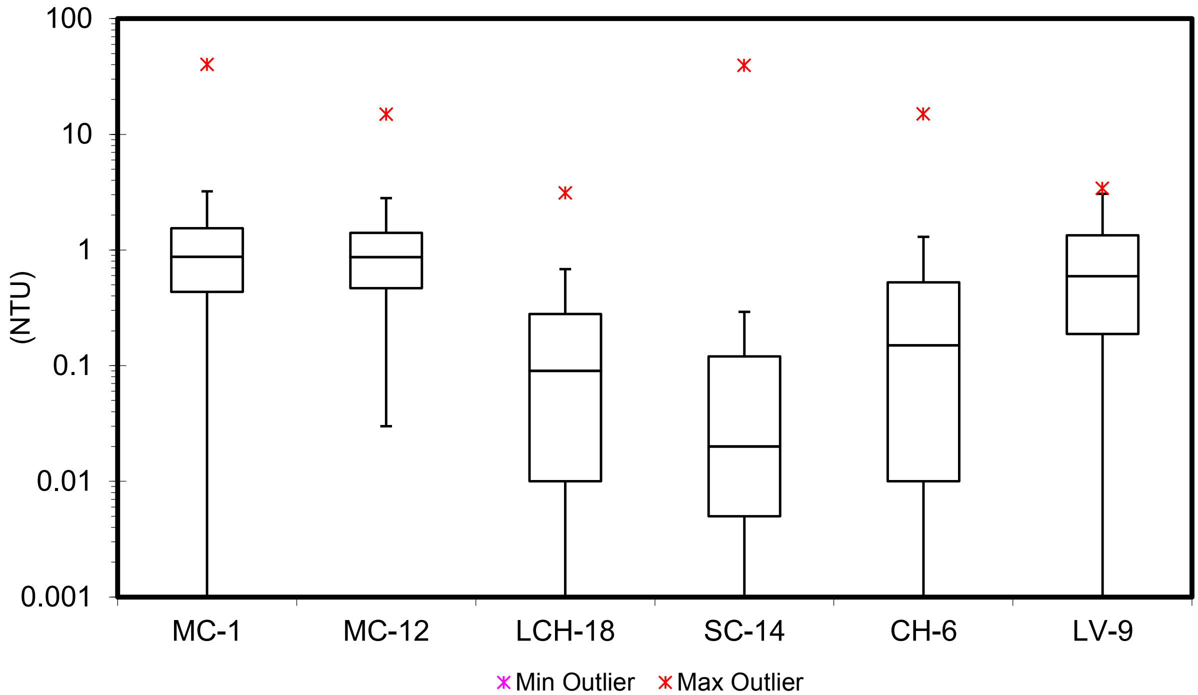



**Figure 7-9. Box Plot of Turbidity Measurements from Malibu Creek and Comparator/reference Sites**

Average reported turbidity values are compared by month in Table 7-6. For most months, average turbidity in the main stem is on the order of 1 NTU. In most months, the turbidity levels are higher in Malibu Creek main stem than at the coastal comparator/reference sites LCH-18 and SC-14.

**Table 7-6. Average Monthly Turbidity in Malibu Creek, HtB Stream Team Data**

| Month | MC-1 | | MC-12 | | LCH-18 | | SC-14 | | CH-6 | | LV-9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count |
| January | 0.89 | 9 | 1.52 | 5 | 0.15 | 3 | 0.02 | 4 | 0.28 | 5 | 0.63 | 2 |
| February | 5.63 | 10 | 4.47 | 6 | 0.21 | 4 | 7.12 | 6 | 0.25 | 5 | 0.42 | 2 |
| March | 5.57 | 11 | 2.80 | 6 | 0.71 | 6 | 0.22 | 7 | 0.25 | 5 | 1.26 | 2 |
| April | 1.23 | 10 | 0.61 | 7 | 0.08 | 7 | 0.11 | 7 | 0.32 | 5 | 0.25 | 2 |
| May | 1.41 | 10 | 0.51 | 6 | 0.17 | 5 | 0.24 | 7 | 0.14 | 5 | 0.37 | 3 |
| June | 1.01 | 10 | 0.80 | 5 | 0.28 | 5 | 0.16 | 5 | 0.33 | 5 | 1.36 | 3 |
| July | 1.13 | 9 | 0.71 | 5 | 0.29 | 4 | 0.15 | 6 | 2.27 | 4 | 0.59 | 3 |
| August | 1.03 | 8 | 1.05 | 4 | 0.24 | 4 | 0.04 | 6 | 2.90 | 2 | 0.46 | 3 |
| September | 1.38 | 8 | 0.90 | 6 | 0.09 | 5 | 0.20 | 5 | 0.32 | 3 | 1.54 | 3 |

| Month | MC-1 | | MC-12 | | LCH-18 | | SC-14 | | CH-6 | | LV-9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count | Ave. | Count |
| October | 0.79 | 9 | 0.47 | 6 | 0.15 | 5 | 0.17 | 5 | 7.50 | 2 | 1.36 | 3 |
| November | 1.01 | 10 | 0.88 | 6 | 0.05 | 4 | 0.01 | 6 | 0.59 | 4 | 0.82 | 2 |
| December | 1.29 | 10 | 0.85 | 6 | 0.67 | 5 | 0.24 | 5 | 0.33 | 5 | 0.53 | 2 |

### 7.5.3 Analysis of TSS and Turbidity Relationship

Between February 16, 2011 and April 25, 2012, USEPA completed turbidity and suspended sediment sampling at Malibu Creek site MC-1. A multiparameter datasonde with real time web available data was deployed at the site on lower Malibu Creek during this time period; this was connected to an automatic sampler, set to trigger on pre-set turbidity measurements. The goal of this sampling effort was to determine if a relationship between turbidity and suspended sediment transport in the Creek could be established.

A water quality monitoring station was established on February 16, 2011 on Malibu Creek, about 250 meters northwest and upstream from the Cross Creek Road Bridge. The USGS Gaging Station 11105510 on Malibu Creek is located just upstream of that bridge. Discharge data used in our analysis came from that gaging station. The gaging station collects discharge and stage data on a 15 minute interval. The monitoring station included a multiparameter water quality datasonde, a datalogger, a cell phone modem for real time access to the data, and an automated composite sampler. During the original set up, the sampler was programmed to collect samples when turbidity was > 20 NTUs.

On March 20, 2011 a flood of about 9,000 cfs occurred in the watershed and the equipment was damaged. During the remainder of the monitoring period, the turbidity trigger was set to >50 NTU to avoid sample collection of data that did not correspond to real rain/sediment transport events.

The station collected 27,128 data points during the deployment. During the same time period, the USGS gaging station collected 39,273 data points out of a possible 39,399. After review of all the data, data of questionable quality were removed from the data set, based on USEPA's best professional judgment. Since the turbidity sensor was occasionally impacted by debris or dirt, resulting in spurious values, some values were removed resulting in a total of 26,913 turbidity values collected. Turbidity values were assessed with other indicators of flow (i.e., increases in depth or discharge, rainfall at the local meteorological stations, or decreases in conductivity). The subsequent load estimates were made with both the raw turbidity and the edited turbidity values.

Rainfall data from two nearby California Irrigation Management Information System (CIMIS) weather stations (Camarillo and Santa Monica) was used to assess the potential for turbidity events in the data analysis described below. During the deployment period, rainfall data indicated that there were 17 potential rainfall events that may have generated storm-related turbid flows. Due to sampler damage and non-triggering turbidity levels, only three of the rainfall events led to successful collection of samples (i.e., concurrent data pairs).

For the three successfully sampled events there were 54 samples generated where there were concurrent measurements of turbidity, suspended sediment concentration (SSC), and flow. The samples span the range of flows from 9.8 cfs to 1,660 cfs. Of the 39,273 readings recorded during the deployment period, only 67 (0.17%) were greater than 1,660 cfs. The flow in the creek was between 9.8 cfs and 1,660 cfs 42% of the time. Storm flows that generate high turbidity and solids transport are very rare at flows lower than those that were sampled. This data set included values that represent the typical ranges of flows in the system, with the exception of large events. The impact of really large events is difficult to characterize and may be very significant in terms of material moved.

Figure 7-10 shows the linear relationship based on the 50 concurrent data pairs used in the analysis of the SSC-turbidity relationship. This final linear relationship does not included data with low turbidities and was based on a best fit line drawn. Use of this equation provides an estimate of 2,366,713 kilograms (kg) or 2,608 English tons of suspended sediment during the 68.3 percent of the time period successfully sampled between 2/16/11 and 4/25/12, most of it within the large event of 3/25/12. Total loads were evidently much higher, as the very large event of 3/20/11 was not successfully sampled. This result shows that for average typical ranges of flows in the Creek, there is a good relationship between turbidity and suspended solids, and suggests that turbidity can be an excellent surrogate for suspended solids concentration in Malibu Creek. This relationship indicates that the observed high turbidity levels measured consistently in the past translate into high concentrations of suspended solids transported down the watershed.

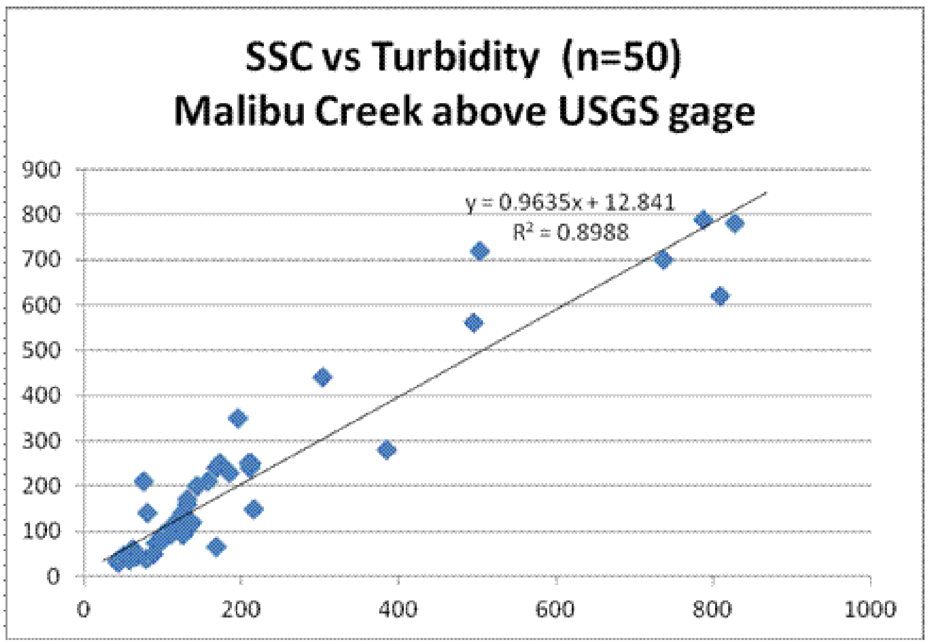



**Figure 7-10. Linear relationship between suspended sediment concentration and turbidity at Malibu Creek above the USGS gage station**

Further investigation of the turbidity concentration from a representative non-impacted portion of the watershed could better inform the change in sediment loading overtime.

## 7.6 NUTRIENTS DATA ANALYSES

The majority of sampling for nutrients in Malibu Creek has focused on inorganic nutrient species only (note: some datasets were reported as nitrate-N, while others reported nitrate- plus nitrite-N; these are distinguished, where possible). This can be problematic in areas of high algal density since algae may quickly take up and convert inorganic nutrients to organic forms, rather than the inorganic nutrients controlling the algal density; for this reason, Dodds et al. (2002, 2006) found that TN and TP are better predictors of benthic algal response than the inorganic forms. In Malibu Creek streams, we find algal response may be better indicated by TN and TP.

The HtB Stream Team collected only inorganic nutrients. Results for the main stem Malibu stations are shown in Table 7-7. Concentrations are higher below Tapia (MC-1 and MC-15), as reflected by samples collected during discharge periods and before the prohibition on summer discharges. The table also compares nitrate-N and orthophosphate-P concentrations for the Tapia WRF discharge and non-discharge periods for 2005-2010.

**Table 7-7. HtB Stream Team Malibu Creek Main Stem Nutrient Sample Summary, 1998-2010**

| Site | | MC-1 | MC-12 | MC-15 | Applicable Criteria |
|---|---|---|---|---|---|
| Sample Count | | 117 | 70 | 25 | |
| Nitrate and Nitrite as N (mg/L) | Average | 2.46 | 0.08 | 2.18 | <1 mg/L in main stem, 4/15-11/15 (2003 Nutrient TMDL); <8 mg/L winter |
| | Median | 0.35 | 0.03 | 1.27 | |
| | Min | 0 | 0 | 0.04 | |
| | Max | 13.05 | 0.86 | 6.84 | |
| | Average, discharge season, 2005-2010 | 4.27 | 0.21 | 4.15 | |
| | Average, non-discharge season, 2005-2010 | 0.16 | 0.05 | 0.67 | |
| | Excursions of summer target | 7.69% | 0% | 30.8% | |
| | Excursions of summer target 2005+ | 4.17%[1] | 0% | 30.8% | |
| | Excursions of winter target | 12.5% | 0% | 0% | |
| Total Ammonia as N (mg/L) | Average | 0.17 | 0.07 | 0.30 | pH dependent (1.2 – 28 mg/L) |
| | Median | 0.06 | 0.05 | 0.09 | |
| | Min | 0 | 0 | 0 | |
| | Max | 7.05 | 0.5 | 2.57 | |
| $PO_4$-P[2] (mg/L) | Average | 0.59 | 0.09 | 0.49 | <0.1 mg/L in main stem, 4/15-11/15 (2003 Nutrient TMDL) |
| | Median | 0.46 | 0.09 | 0.21 | |
| | Min | 0.11 | 0.01 | 0.05 | |
| | Max | 1.76 | 0.16 | 1.65 | |
| | Average, discharge season, 2005-2010 | 0.77 | 0.08 | 0.90 | |
| | Average, non-discharge season, 2005-2010 | 0.32 | 0.09 | 0.19 | |
| | Excursions[3] | 100% | 43.9% | 71.4% | |
| | Excursions 2005+[3] | 100% | 45.0% | 71.4% | |

Notes: 1. This percentage represents one excursion on 5/8/2005.

2. HtB Stream Team reports $PO_4$ as $HPO_4$. The results have been converted to $PO_4$ as P.

3. $PO_4$-P excursions are tabulated only for the non-discharge season; a numeric criterion is not specified for the discharge season.

Median concentrations at other HtB Stream Team stations are summarized in Table 7-8. The sites with the highest nitrate concentrations (LV-5, MD-7, LV-13, MC-15) are all downstream of developed areas. Seven of the sites (CC-3, CH-6, PC-8, LV-9, SC-14, LCH-18, and AS-19) drain relatively undisturbed areas, including stations that are identified as comparator/reference sites for this TMDL. Median nitrate-N concentrations at these undisturbed sites, which include Upper Cold Creek [CC-3], but not Lower Cold Creek [CC-2]) range from 0.01 to 0.03 mg/L. Only Solstice Creek (SC-14) reports a median greater than 0.01 and Sikich et al. (2012) report that nitrogen concentrations at this site are influenced by a leaking septic system. Two of the relatively undisturbed sites (CH-6 on Cheseboro Creek[3] and LV-9, on Upper Las Virgenes Creek) predominantly drain the Monterey/Modelo Formation, but do not show elevated nitrate-N concentrations. In contrast, for orthophosphate-P, there appears to be a difference, on average, for sites that drain the Monterey/Modelo Formation: the undisturbed sites that do not drain the Monterey/Modelo Formation have median orthophosphate-P concentrations that range from 0.02 to 0.05 mg/L, while the two sites draining the Monterey/Modelo Formation have median orthophosphate-P concentrations of 0.14 and 0.18 mg/L.

**Table 7-8. HtB Stream Team Median Nutrient Concentrations at All Stations**

| Station | Nitrate-plus-Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Inorganic N (mg/L) | Orthophosphate-P (mg/L) |
|---|---|---|---|---|
| HtB-MC-1 | 0.350 | 0.060 | 0.460 | 0.457 |
| HtB-MC-1 (non-discharge, 2005-2010) | 0.040 | 0.040 | 0.098 | 0.390 |
| HtB-CC-2 | 0.430 | 0.030 | 0.525 | 0.077 |
| HtB-CC-3 | 0.010 | 0.010 | 0.030 | 0.019 |
| HtB-LV-5 | 4.240 | 0.040 | 4.345 | 0.142 |
| HtB-CH-6 | 0.005 | 0.030 | 0.035 | 0.134 |
| HtB-MD-7 | 0.740 | 0.090 | 0.820 | 0.126 |
| HtB-PC-8 | 0.005 | 0.030 | 0.035 | 0.040 |
| HtB-LV-9 | 0.005 | 0.020 | 0.040 | 0.177 |
| HtB-WC-10 | 0.010 | 0.030 | 0.040 | 0.039 |
| HtB-CC-11 | 0.020 | 0.030 | 0.055 | 0.048 |
| HtB-MC-12 | 0.030 | 0.050 | 0.090 | 0.089 |
| HtB-MC-12 (non-discharge, 2005-2010) | 0.030 | 0.060 | 0.090 | 0.090 |
| HtB-LV-13 | 1.220 | 0.070 | 1.290 | 0.223 |
| HtB-SC-14 | 0.030 | 0.030 | 0.088 | 0.026 |

[3] Note that the CH-6 station is near the Calabasas Landfill, but nutrient concentrations do not appear to be impacted by the presence of the landfill.

| Station | Nitrate-plus-Nitrite-N (mg/L) | Ammonia-N (mg/L) | Total Inorganic N (mg/L) | Orthophosphate-P (mg/L) |
|---|---|---|---|---|
| HtB-MC-15 | 1.225 | 0.090 | 1.290 | 0.210 |
| HtB-MC-15 (non-discharge, 2005-2010) | 0.315 | 0.060 | 0.330 | 0.144 |
| HtB-STC-16 | 0.450 | 0.060 | 0.520 | 0.123 |
| HtB-TR-17 | 0.150 | 0.040 | 0.190 | 0.103 |
| HtB-LCH-18 | 0.010 | 0.030 | 0.045 | 0.039 |

The Calabasas Landfill sampling on Cheseboro Creek used higher detection limits, but is generally consistent with the CH-6 results, with all nitrate-N samples less than a detection limit of 0.05 mg/L, except for one sample reported at 0.3 mg/L, and all ammonia-N samples less than a detection limit of 0.1 mg/L. Phosphorus concentrations were not reported.

As noted above, LVMWD monitoring has focused on sites along Las Virgenes Creek and Malibu Creek main stem. The monitoring included total and inorganic nitrogen. Results for 2000 to the end of 2010 are summarized in Table 7-9. These results confirmed the presence of elevated nutrient concentrations in Las Virgenes Creek and suggested its effect on increasing concentrations in the main stem; this is indicated by increasing concentrations from station LVMWD-R9U to LVMWD-R1U.

Total N concentrations reported by LVMWD from Las Virgenes Creek and Malibu Creek main stem generally show nitrate- plus nitrite-N in the range of 80 to 87 percent of total N (Table 7-9). However, some upstream sites on Las Virgenes Creek (e.g., LVMWD-R1F) showed nitrite- plus nitrate-N as between 60-70 percent of total N. These stations are all downstream of significant development and thus do not provide information on comparator/reference conditions.

**Table 7-9. Summary of LVMWD Nutrient Monitoring, 2000-2010**

| Site | Sample Count | Median $NO_2$+$NO_3$-N (mg/L) | Median Inorganic N (mg/L) | Median Total N (mg/L) | Median $PO_4$-P (mg/L) | Ratio $NO_2$+$NO_3$-N to Total N |
|---|---|---|---|---|---|---|
| ***Las Virgenes Creek*** | | | | | | |
| R1F | 56 | 1.25 | 1.60 | 2.10 | 0.80 | 0.603 |
| R7D | 30 | 1.45 | ND | 2.38 | 0.85 | 0.654 |
| R2F | 60 | 3.55 | 3.60 | 4.20 | 1.00 | 0.822 |
| R3F | 58 | 4.28 | 4.70 | 4.95 | 0.65 | 0.868 |
| ***Malibu Creek above Las Virgenes Creek*** | | | | | | |
| R9U | 84 | 0.20 | 0.20 | 0.55 | 0.12 | 0.700 |
| ***Malibu Creek below Las Virgenes Creek and above Tapia WRF Discharge*** | | | | | | |
| R1U | 106 | 1.00 | 0.80 | 1.30 | 0.14 | 0.805 |

| Site | Sample Count | Median $NO_2$+$NO_3$-N (mg/L) | Median Inorganic N (mg/L) | Median Total N (mg/L) | Median $PO_4$-P (mg/L) | Ratio $NO_2$+$NO_3$-N to Total N |
|---|---|---|---|---|---|---|
| ***Malibu Creek below Tapia WRF Discharge, All Seasons, 2000-2010*** | | | | | | |
| R2D | 108 | 1.70 | 1.35 | 1.90 | 0.875 | 0.830 |
| R13D | 110 | 1.20 | 1.05 | 1.55 | 0.64 | 0.843 |
| R4D | 91 | 2.00 | 1.80 | 2.60 | 0.75 | 0.815 |
| ***Malibu Creek below Tapia WRF Discharge, Non-discharge Season, 2005-2010*** | | | | | | |
| R2D | 50 | 0.70 | 0.60 | 1.00 | 0.26 | 0.737 |
| R13D | 51 | 0.60 | 0.40 | 0.90 | 0.45 | 0.664 |
| R4D | 34 | 0.20 | 0.20 | 0.60 | 0.34 | 0.457 |

Note: Full separation into organic and inorganic N species is available only from 2005 on. ND = no data.

LVMWD (2011) also compiled a comprehensive summary of inorganic nutrient data in the watershed. NPS also provided broad spatial coverage of inorganic concentrations. The overall medians compiled by drainage area are summarized in Table 7-10 and are consistent with results presented in Table 7-7 and Table 7-8.

**Table 7-10. Median Inorganic Nutrient Concentrations from All Sources as Reported in LVMWD (2011)**

| Area | Nitrate as N (mg/L) | Orthophosphate as P (mg/L) |
|---|---|---|
| Northern drainages affected by Monterey/Modelo Formation (Cheseboro, Las Virgenes, Liberty Canyon, Lindero, Medea, Palo Comado, Russell) | 0.94 | 0.14 |
| Eastern drainages – non-marine geology (Cold, Stokes) | 0.02 | 0.05 |
| Western drainages above Westlake | 0.84 | 0.05 |
| Central drainages, Westlake to Cold Creek (Malibou, Malibu, Triunfo) | 0.80 | 0.09 |
| Malibu main stem downstream of Cold Creek and Tapia WRF | 1.50 | 0.48 |

The HtB Stream Team and LVMWD data summaries showed that inorganic P concentrations are elevated in sites draining the Monterey/Modelo Formation. Sites downstream of the Tapia WRF discharge showed the highest inorganic P concentrations.

High concentrations of nitrate N were observed at some locations in the northern drainages. These appear to be associated with the extent of development, rather than geology. In particular, the medians at stations draining developed areas on Las Virgenes Creek ranged from 1.19 to 5.63 mg/L, whereas sites from the upstream undeveloped areas on Las Virgenes Creek showed concentrations of 0.35 mg/L or less. This is consistent with results in Table 7-8 which showed elevated nitrate-N concentrations at the development impacted site, HtB-LV-5, but markedly lower concentrations at LV-9 and CH-6, sites draining the Monterey/Modelo Formation and located upstream of development. The nitrate-N concentrations at station CH-6 also show significantly elevated conductivity levels, and low nitrate-N and ammonia-N concentrations.

As noted above, inorganic nutrient concentrations alone do not fully represent the maximum potential for nutrient-induced algal growth. The best evidence for the spatial distribution of TN concentrations in the watershed is from the MCWMP data set (which did not include TP). Data for the main stem (MAL) site, located downstream of the Tapia winter discharge, and other sites are presented in Table 7-11. The CC station is in a relatively undisturbed area and consistently shows low median inorganic N concentrations (0.01 mg/L in both summer and winter), and different median total N concentrations in the winter period (0.06 mg/L in summer and 0.56 in winter). Many of the remaining stations are influenced by development or agriculture, except for the MCWMP station LV1, which is upstream of most anthropogenic influences (and downstream of HtB-LV-9). Concentrations of inorganic N at LV1 are higher than at HtB-LV-9, with inorganic N averaging 0.3 mg/L in summer and 0.35 mg/L in winter and with total N averages of 1.33 and 1.73 mg/L in the summer and winter, respectively.

**Table 7-11. MCWMP Nutrient Sampling, Median Results by Season, 2005-2007**

| Station | TN (mg/L) | | | Inorganic N (mg/L) | | | Inorganic P (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Summer | Winter | All | Summer | Winter | All | Summer | Winter | All |
| MAL | 0.49 | 3.27 | 0.86 | 0.04 | 2.12 | 0.46 | 0.21 | 0.50 | 0.26 |
| CC | 0.06 | 0.56 | 0.43 | 0.01 | 0.01 | 0.01 | 0.05 | 0.04 | 0.04 |
| MED1 | 0.84 | 0.75 | 0.80 | 0.01 | 0.01 | 0.01 | 0.09 | 0.09 | 0.09 |
| MED2 | 0.67 | 0.96 | 0.75 | 0.03 | 0.08 | 0.07 | 0.12 | 0.09 | 0.10 |
| LV1 | 1.33 | 1.73 | 1.56 | 0.30 | 0.35 | 0.35 | 0.07 | 0.11 | 0.09 |
| LV2 | 3.36 | 4.51 | 3.94 | 3.01 | 3.19 | 3.06 | 0.22 | 0.19 | 0.20 |
| LC | 1.52 | 2.10 | 1.96 | 0.04 | 0.23 | 0.08 | 0.08 | 0.12 | 0.09 |
| LIN1 | 1.40 | 1.51 | 1.45 | 1.02 | 1.01 | 1.01 | 0.10 | 0.13 | 0.12 |
| LIN2 | 1.69 | 1.75 | 1.75 | 0.05 | 0.02 | 0.04 | 0.05 | 0.06 | 0.06 |
| POT | 0.78 | 2.80 | 1.60 | 0.05 | 0.02 | 0.02 | 0.05 | 0.11 | 0.09 |
| RUS | 2.34 | 2.73 | 2.40 | 1.41 | 2.01 | 2.01 | 0.25 | 0.15 | 0.19 |
| TRI | 0.03 | 0.87 | 0.04 | 0.03 | 0.06 | 0.05 | 0.03 | 0.03 | 0.03 |

Additional monitoring of total N concentrations in the watershed has been conducted by LACDPW at the mass emissions station on Malibu Creek, downstream of the Tapia WRF discharge. This monitoring focused on winter wet weather events, with relatively small amounts of sampling during the summer dry period. Monitoring at this station (Table 7-12) showed that organic nitrogen often constitutes a significant amount of total N. The overall, full-year statistics are elevated by the Tapia winter discharges, with median TN concentrations of 4.88 mg/L. The median TN concentrations during the dry season non-discharge period since 2005 decreased to 1.65 mg/L (Table 7-12). Furthermore, elevated nutrients during the winter season are likely to result in elevated residual concentrations in the summer. Analysis on a seasonal basis confirms that nitrogen concentrations in the listed reaches of lower Malibu Creek are elevated in both the summer and winter.

**Table 7-12. Total and Nitrate-N Statistics at LACDPW Mass Emissions Station on Malibu Creek**

| | Count | TN, median | $NO_3$-N, median | Inorganic N, median | TN, average | $NO_3$-N, average | Inorganic N, average |
|---|---|---|---|---|---|---|---|
| All Data | 64 | 4.15 | 2.23 | 2.56 | 4.32 | 2.65 | 2.77 |
| Non-discharge period (Apr. 15 – Nov. 15) | 21 | 2.59 | 1.17 | 2.31 | 3.02 | 1.82 | 2.35 |
| Discharge period (Nov. 16- Apr. 14) | 43 | 4.88 | 2.60 | 2.60 | 4.95 | 3.05 | 2.95 |
| Non-discharge period, 2005-2011+ | 11 | 1.65 | 0.95 | 1.00 | 1.89 | 1.11 | 1.84 |

Total nutrient concentrations are also available from a special study conducted in 2001 and 2002 reported by Busse et al. (2003, 2006). Busse et al. classified sites as Reference (minimal human impact), Rural, or one of several developed categories (Residential, Commercial, Multiple, Horse, Golf), along with sites upstream and downstream of Tapia. Several of the stations correspond to the HtB Stream Team sampling sites. Samples were taken in August and October 2001 and June and August 2002. The sites identified by Busse as reference sites, as well as several of the other sites, show inorganic N as a small fraction of total N.

**Table 7-13. Total and Inorganic Nutrient Statistics from Busse et al. (2003)**

| Site | Sample Count | Total N (mg/L) | Inorganic N (mg/L) | Total P (mg/L) | Inorganic P (mg/L) |
|---|---|---|---|---|---|
| ***Reference Sites*** | | | | | |
| Cold Creek, Mountains Restoration Trust Lands | 4 | 0.666 | 0.025 | 0.070 | 0.026 |
| Palo Comado Creek, Santa Monica Mountains National Recreation Area | 2 | 0.371 | 0.010 | 0.028 | 0.008 |
| ***Rural Sites*** | | | | | |
| Cold Creek at Piuma Road | 2 | 0.441 | 0.266 | 0.076 | 0.028 |
| Cold Creek off Cold Canyon Road | 2 | 0.546 | 0.073 | 0.037 | 0.019 |
| ***Developed Sites*** | | | | | |
| Medea Creek at Conifer St. in Agoura Hills | 4 | 0.566 | 0.070 | 0.130 | 0.096 |
| Lindero Creek near Falling Star Lane | 2 | 0.839 | 0.222 | 0.112 | 0.026 |
| Lindero Creek at Lindero Country Club | 2 | 1.525 | 0.422 | 0.144 | 0.085 |
| Triunfo Creek off Triunfo Canyon Road | 2 | 0.394 | 0.022 | 0.098 | 0.028 |
| Medea Creek close to Chumash Park | 4 | 1.000 | 0.455 | 0.143 | 0.074 |
| Medea Creek south of Agoura Road | 1 | 1.418 | 0.427 | 0.087 | 0.092 |
| Las Virgenes Creek at the intersection of Lost Hills and Las Virgenes Road in Calabasas | 1 | 2.748 | 2.828 | 0.296 | 0.268 |
| ***Downstream Sites*** | | | | | |
| Malibu Creek, Malibu State Park, above Tapia | 2 | 0.564 | 0.043 | 0.118 | 0.058 |
| Malibu Creek, upstream of gaging station, below Tapia | 3 | 1.060 | 0.473 | 0.211 | 0.165 |

The marine sedimentary geology of the Monterey/Modelo Formation could also result in some increases in total N loading. Stein and Yoon (2007) found that total Kjeldahl nitrogen (TKN; sum of organic and ammonia nitrogen) was positively correlated with sedimentary geology in Southern California, while nitrate-N was negatively correlated with sedimentary geology and positively correlated with igneous rock. Nitrogen is stored in marine sedimentary rock in both organic and ammonium mineral forms. Most of the organic nitrogen is typically present as recalcitrant kerogen, while the ammonia fraction is mostly bound in silicate materials (Holloway and Dahlgren, 2002). Weathering can gradually release both fractions as ammonium and this can be a contributor to the overall N balance in streams. However, in the Malibu Creek Watershed, ammonium data did not show evidence of increases associated with marine sedimentary geology and total N and TKN data also did not provide evidence of elevated levels from geologic formation influence.

## 7.6.1 Nitrate plus Nitrite N Trends

The 2003 Nutrient TMDL established targets of less than 1 mg/L nitrate- plus nitrite-N nitrite in the Malibu Creek main stem for the summer period of April 15 to November 15, and a nitrate+nitrite concentration less than 8 mg/L for the winter period. The Los Angeles Region's Basin Plan set a numeric objective of 10 mg/L nitrate-N. Examination of the HtB Stream Team data (all years and all seasons) shows that concentrations are elevated at the downstream station, MC-1, downstream of Tapia WRF, while concentrations upstream of Tapia at MC-12 are somewhat elevated compared with the comparator/reference sites (Figure 7-11). The dry weather median concentration of nitrate- plus nitrite-N at MC-12 is 0.03 mg/L, while the comparator/reference site medians range from 0.005 mg/L (LV-9) to 0.02 mg/L (SC-14).

Results reported by LVMWD (2011) indicate that the median nitrate-N concentration is about 1.0 mg/L upstream of the Tapia discharge and 1.90 mg/L downstream over all years and all seasons. Time series plots of observations at station MC-1 showed little evidence of trend over time, either on a full year basis or for the non-discharge season, except that the highest concentrations were observed prior to 2002 (Figure 7-12). The right panel of Figure 7-12 suggested that the non-discharge season target of 1 mg/L has been met since 2006.

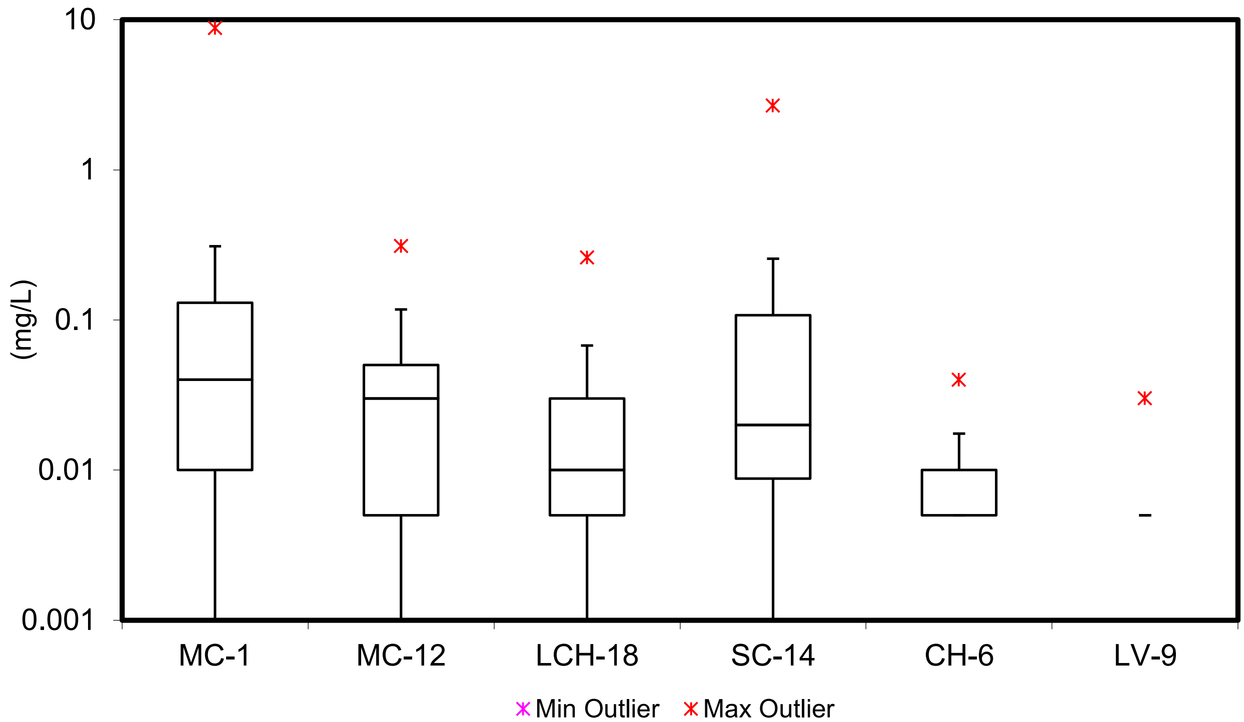
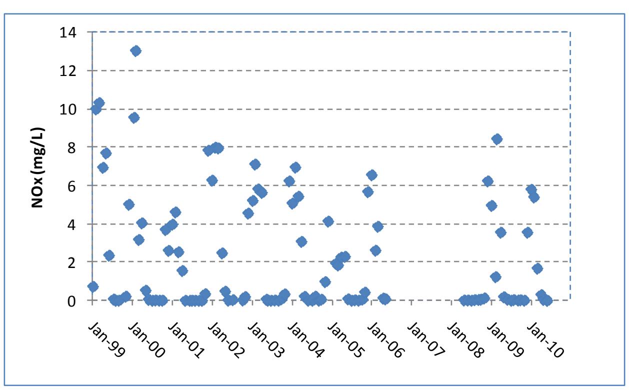



**Figure 7-11. Boxplot of Nitrate plus Nitrite-N Measurements from HtB Stream Team Malibu Creek Main Stem and Comparator/Reference Sites (April 15 – Nov. 15 Data)**



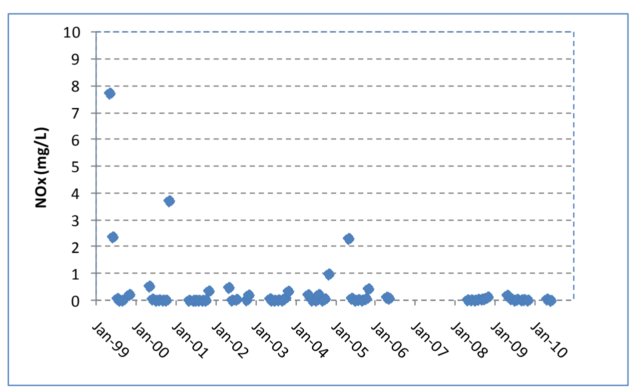




**Figure 7-12. Time Series of Nitrate plus Nitrate N at Station MC-1 for the Full Year (left) and for April 15 – November 15 (right)**

As noted above, comments received during the development of the TMDL suggested that nitrogen concentrations may be naturally elevated in runoff from the Monterey/Modelo Formation. Figure 7-13 compares average nitrate- plus nitrite-N concentrations at stations with numerous data points. Sites LV-9 and CH-6, drain the Monterey/Modelo Formation and yielded extremely low nitrate-N (and also ammonia-N) concentrations. These two stations are upstream of high density development in the watershed, whereas the other Monterey/Modelo Formation sites with elevated nitrate-N concentrations are downstream of high density development areas.

Las Virgenes Creek site LV-9, located upstream of development, showed an average nitrate- plus nitrite-N concentration of 0.009 mg/L; site LV-13, in the development area near highway 101, showed an average of 1.26 mg/L nitrate- plus nitrite-N; and LV-5, downstream of development showed an average of 4.25 mg/L nitrate- plus nitrite-N. Similarly, site CH-6, in the Modelo/Monterey Formation upstream of development, shows a very low average nitrate- plus nitrite-N concentration. These observations suggest that elevated nitrate concentrations are associated with development activities and not significantly influenced, by the Monterey/Modelo Formation. Concentrations in the Malibu Creek main stem are influenced by combined effects of all in-Creek and upstream activities.

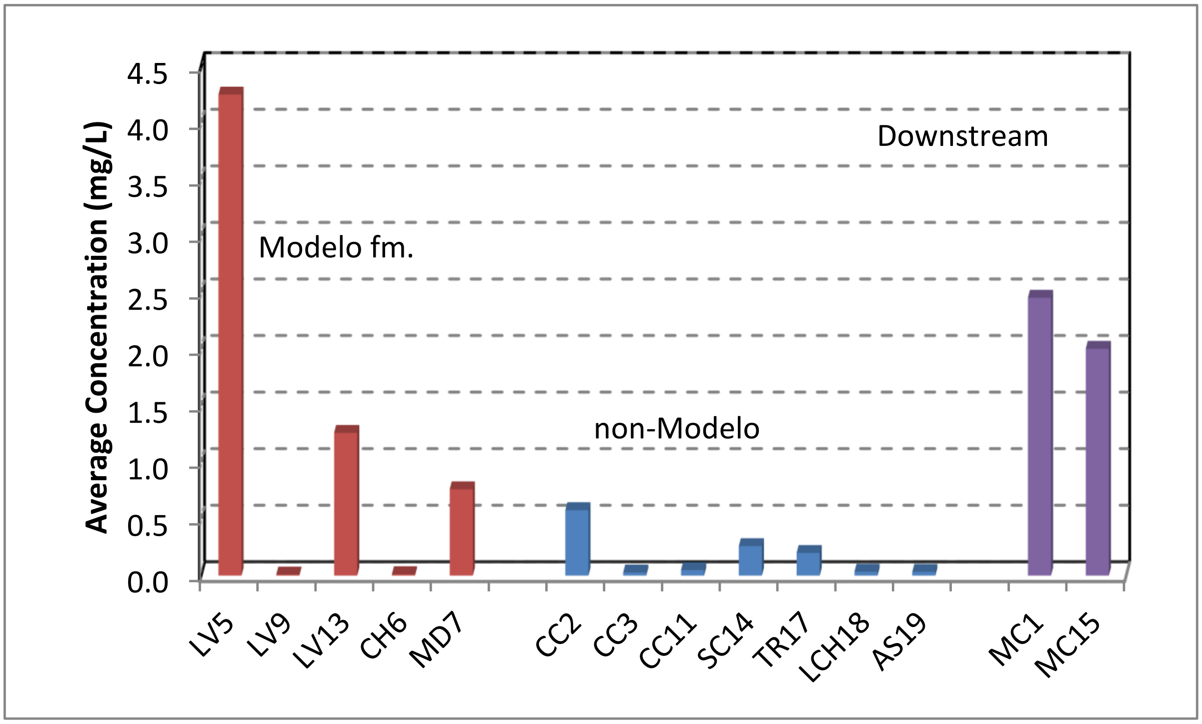



**Figure 7-13. Average Nitrate- plus Nitrite-N Concentrations at HtB Stream Team Sampling Sites**

Results from MCWMP sampling provided similar insights. Both stations LV1 and LV2 drain the Monterey/Modelo Formation, but LV2 is downstream of development while LV1 drains open space, with some anthropogenic activities observed. Summer median inorganic N concentration was 0.30 mg/L at LV1, and 3.01 mg/L at the LV2 site (Table 7-11). These observations suggest the increased inorganic N concentrations are associated with development, rather than with geology. The undeveloped CC station also showed low nitrogen concentrations.

## 7.6.2 Ammonia N Trends

Ammonia concentrations were generally low in the Malibu Creek main stem, with a few high outliers. The main stem stations may be slightly elevated relative to the comparator/reference sites (Figure 7-14). Station MC-12, on the main stem upstream of Tapia WRF, showed a median ammonia-N concentration of

0.05 mg/L, while the comparator/reference site medians ranged from 0.02 to 0.03 mg/L (note CC-3 had an even lower median concentration of 0.01 mg/L). The acute criteria for ammonia are pH dependent. Comparing each observation to the corresponding acute criterion concentration (including recent data from MC-15, just below Tapia WRF) revealed no excursions of the acute ammonia criterion.

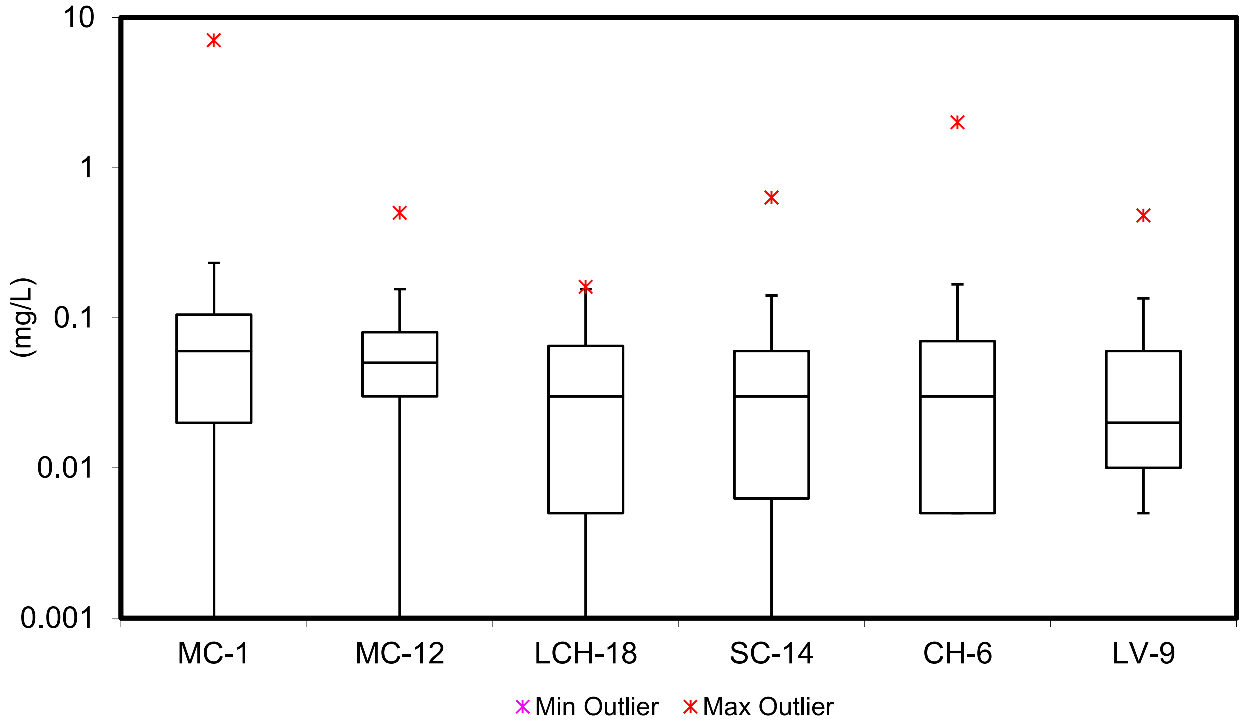



**Figure 7-14. Boxplot of Ammonia as N Measurements from Malibu Creek Main Stem and HtB Stream Team Comparator/Reference Sites**

### 7.6.3 Orthophosphate as P Trends

The 2003 Nutrient TMDL established a target concentration of 0.1 mg/L for total P between April 15 and November 15. The data set from the HtB Stream Team monitored orthophosphate concentrations ($PO_4$-P). Average concentrations of orthophosphate-P (all time periods) in the Stream Team sampling are greater than 0.1 mg/L at both MC-1 and MC-15, downstream of the Tapia discharge, and are clearly elevated compared with MC-12, upstream of Tapia, and the comparator/reference sites during the dry weather non-discharge period (Figure 7-15). These observations indicate elevated levels downstream of Tapia (during the non-discharge period) and markedly lower concentrations upstream of Tapia. Concentrations at MC-12 show lower orthophosphate concentrations than sites downstream of Tapia and are comparable to the other comparator/reference sites in un-impacted areas with and without Monterey/Modelo Formation (CH-6, LV-9, LCH-18, SC-14).

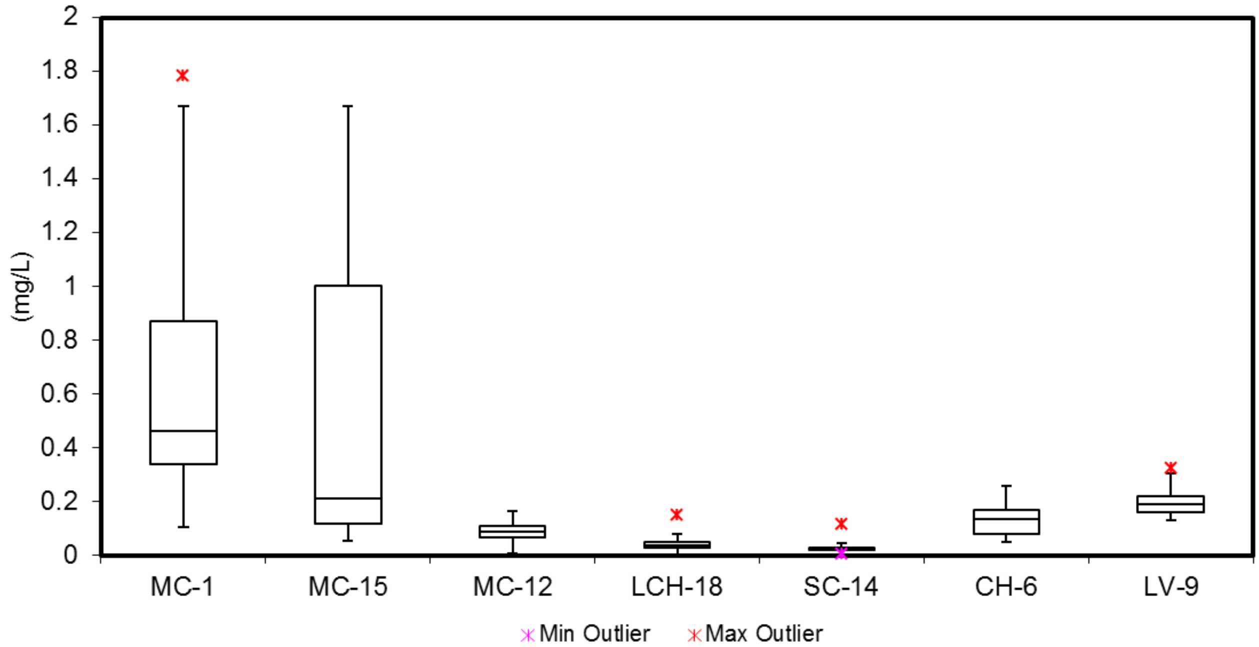



**Figure 7-15. Boxplot of $PO_4$-P Measurements from Malibu Creek Main Stem and Stream Team Comparator/Reference Sites During the Non-discharge Period (April 15 – Nov. 15)**

LVMWD (2011) showed similar orthophosphate-P concentrations in lower Malibu Creek with an overall median of 0.48 mg/L; well above the target. Average concentration during the non-discharge season of 2009 at MC-1 was reported as 0.36 mg/L. In general, the 2003 Nutrient TMDL total phosphorus (as orthophosphate) targets have not been achieved. This is likely due to the lack of a phosphorus limit during the winter season. Year round loading would impact summer growing season and downstream Malibu Lagoon concentrations. Orthophosphate-P concentrations in lower Malibu Creek are highly elevated, and typically higher than the inorganic N concentrations, suggesting that phosphorus is at excessively high concentrations, that it cannot singularly limit algal growth. The high nutrient concentrations present at MC-1 suggest that both phosphorus and nitrogen are present at concentrations that likely promote algal growth. This matches well with the results from USEPA's physical habitat assessment, which showed a high percentage of algal cover in the stream at MC-1.

Time series of observations at MC-1 during the summer TMDL non-discharge period showed little decline with time and they continued to be frequently above the 0.1 mg/L target (Figure 7-16). This provides evidence that orthophosphate levels are continuously loading into the Creek and Lagoon system through the year, including the winter season.

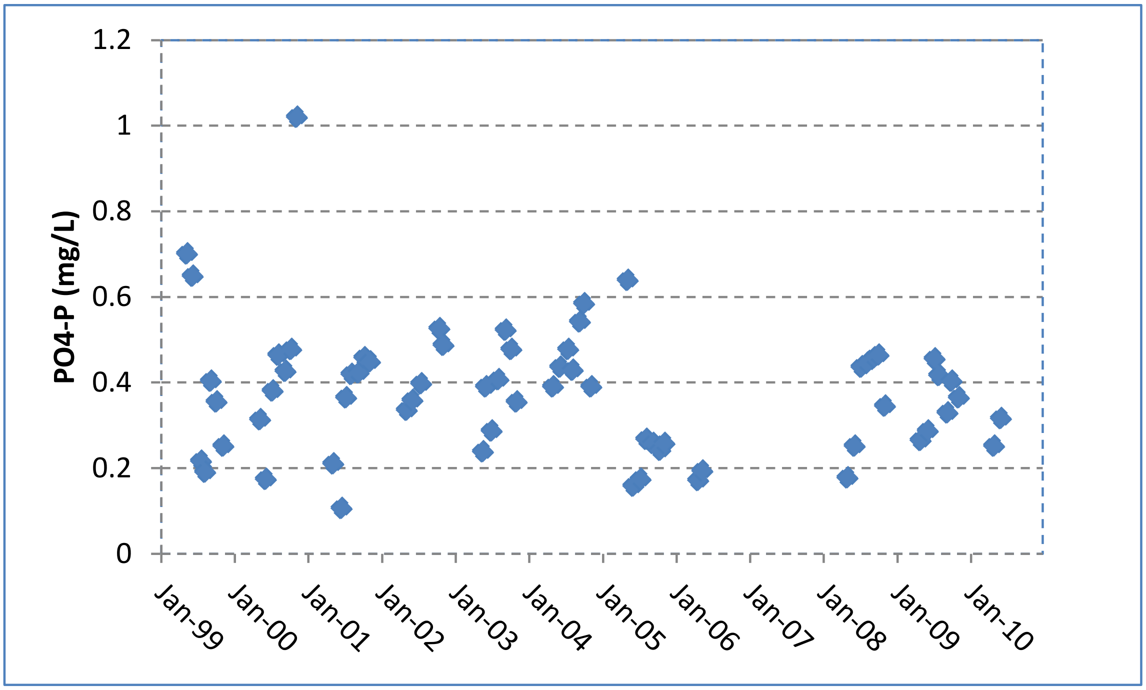



**Figure 7-16. Time Series of $PO_4$-P Concentrations at MC-1 during the Summer (4/15-11/15) Period**

Comments received during the development of the TMDL (LVMWD, 2011) suggested that elevated P concentrations in the watershed were mainly due to runoff from the Monterey/Modelo Formation. Average orthophosphate-P concentrations in the lower main stem were compared to concentrations in upstream stations monitored by the HtB Stream Team in Figure 7-17. Although orthophosphate-P concentrations in the Monterey/Modelo Formation tended to be slightly elevated compared with some other areas, orthophosphate-P concentrations at station LV2, downstream of development, is higher than at LV1, upstream of development (see Table 7-11 above).

Concentrations of orthophosphate-P in the lower main stem are significantly higher than those observed at any of the upstream stations – likely due to continued cycling of phosphorus previously discharged to the system and stored in stream sediments. This provides further evidence that phosphorus is loading the system year round. However, the markedly elevated concentrations at MC-1 and MC-15, downstream of Tapia, indicated that the Monterey/Modelo Formation is not the primary cause of elevated orthophosphate concentrations in the watershed. MC-12, upstream of Tapia showed significantly lower orthophosphate concentrations than MC-1 and MC-15. Site CH-6, a relatively un-impacted site draining the Monterey/Modelo Formation, showed average orthophosphate-P concentrations of 0.13 mg/L. Overall, the average phosphate concentrations are elevated four-fold at those sites draining the Monterey/Modelo Formation, and near twenty-fold higher at the sites downstream of Tapia's discharge; non-Monterey/Modelo Formation sites yielded concentrations below the criterion level (Figure 7-17). These observations suggest that phosphate concentrations are consistently elevated in the water throughout the year, and a large contributing source of energy for primary production.

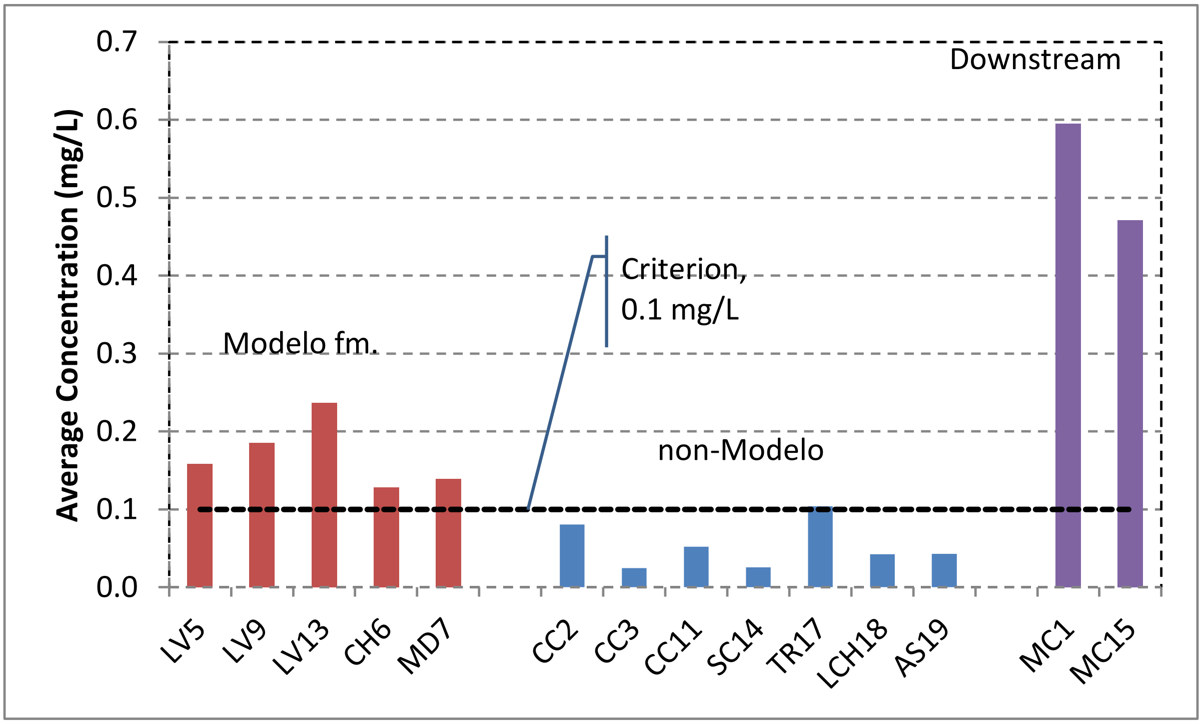



**Figure 7-17. Average $PO_4$-P Concentrations at HtB Stream Team Monitoring Sites**

## 7.6.4 Nutrient Reference Conditions in the Malibu Creek Watershed

The Malibu Creek Watershed is clearly influenced by elevated nutrients. However, in some circumstances nutrients may be elevated due to natural geological conditions, such as drainage from marine sediments. A detailed review of the natural or reference conditions helped define the minimum level of nutrient enrichment that is attainable in the watershed,

Similar to the 2003 Nutrient TMDL, USEPA used the reference waterbody approach to develop numeric targets for impaired waterbodies within the Malibu watershed. This approach is described in USEPA guidance (USEPA, 2000a, 2000b). For streams, the reference approach involves using undisturbed stream segments to serve as examples of background nutrient concentrations (USEPA, 2000b). USEPA assessed the natural background or reference conditions for nutrients in the Malibu watershed based on the best available data and information. Although available data exist to determine the best approximation of the natural background levels of TN and TP, there is some uncertainty due to observations that eutrophic systems, such as Malibu Creek Watershed (with high total N and total P), may show low inorganic N or inorganic P concentrations if more bioavailable forms of nutrients are already rapidly taken up by algae (as they become available through the decay of organic matter). Thus, primarily examining the inorganic N or P concentrations may not capture the excessive concentrations already converted to organic forms (i.e., algae). This trend has been observed in this watershed when extensive algal coverage was observed in conjunction with very low nitrate concentrations.

Malibu Creek Watershed has unique geology, with areas of marine sediments associated with the Modelo/Monterey Formation. For nitrate- plus nitrite-N, median concentrations at comparator/reference sites without significant anthropogenic disturbance appear to be less than 0.03 mg/L and mostly less than 0.01 mg/L for many sites both in and outside the Monterey/Modelo Formation. Higher concentrations at the MCWMP LV1 station (median 0.30 and 0.35 mg/L in summer and winter, respectively) may be due to the presence of illegal dump sites and unstable stream banks in this reach (Table 7-14). In contrast, sites downstream of development tend to have higher concentrations of both nitrate and total N. Similar results are seen in the NPS sampling. NPS sites upstream of development within the Monterey/Modelo

Formation on Las Virgenes (J_EFLASVIR, S_ULASVIR), Cheseboro Creek (R2_Cheseboro), and Medea Creek (R1_MEDCRK) had a median nitrate-N concentration of 0.22 mg/L (data for 2008 through March 2011; the average cannot be accurately determined because not all detection limits were documented.)

Reference sites reported by Busse et al. (2003) on Cold Creek and Palo Comado Creek appear to have lower total N concentrations (averages of 0.67 and 0.37 mg/L). Unfortunately, the total N concentration at other comparator/reference sites has not been monitored and is not known. For comparison, the survey of nutrient data for Level 3 ecoregion 6 (Southern and Central California Chaparral and Oak Woodlands, which includes the Malibu watershed; USEPA, 2000d) suggested reference conditions of 0.155 mg/L nitrate- plus nitrite-N and 0.518 mg/L total N. Interestingly, averaging the TN concentrations from Cold and Palo Comado Creek together results in 0.52 mg/L, a close approximation to the recommended reference condition for a Level 3 ecoregion 6 area. The data in Busse et al. (2003) suggest that the inorganic N to total N ratio at comparator/reference sites may be as high as 38. Thus, a nitrate- plus nitrite-N concentration on the order of 0.01 – 0.03 mg/L would correspond to a total N concentration in the range of 0.38 to 1.1 mg/L. The detailed discussion provided earlier suggested that the presence of Monterey/Modelo Formation drainage has little effect on inorganic and organic nitrogen levels in this watershed.

For phosphorus, the Monterey/Modelo Formation may result in somewhat elevated levels at un-impacted natural areas. Only inorganic P has been monitored at comparator/reference sites, except for the results in Busse et al. (2003), which do not include undisturbed sites within the Monterey/Modelo Formation drainage. Median orthophosphate-P concentrations at comparator/reference sites *outside* the Monterey/Modelo Formation appear to be 0.05 mg/L or less (with average total P concentrations of 0.07 mg/L or less at Busse's reference sites); however, the reported median concentrations at relatively undisturbed HtB Stream Team stations within the Monterey/Modelo Formation are as high as 0.18 mg/L (at LV-9). NPS sites upstream of development within the Monterey/Modelo Formation on Las Virgenes (J_EFLASVIR, S_ULASVIR), Cheseboro Creek (R2_Cheseboro), and Medea Creek (R1_MEDCRK) together showed a median orthophosphate-P concentration of 0.16 mg/L (although higher concentrations were consistently noted at J_EFLASVIR (0.60 to 1.62 mg/L)).

The relatively high phosphorus concentrations suggested that nitrogen is likely the limiting nutrient for algal growth under natural conditions within this watershed, with P typically present at concentrations in excess of algal growth requirements based on a typical ratio of plant cell concentration of 7.2:1 N:P on a mass basis (Table 7-14). However, it should be reiterated that considerably elevated concentrations at MC-1 and MC-15 suggest the Monterey/Modelo Formation is not the only cause of elevated orthophosphate concentrations in the watershed. Although there was some indication that Monterey/Modelo Formation leads to somewhat elevated TP concentrations, the substantial elevated orthophosphate levels downstream of Tapia's discharge (more than twenty-fold) suggest that phosphorus concentrations are consistently elevated in the Creek and a consistent source available for algal production.

In sum, evidence to date indicate that natural reference-like conditions for the Malibu Creek Watershed have a central tendency for the summer period of between 0.52 - 0.67 mg/L total N and 0.07 mg/L total P outside the Monterey/Modelo Formation, and around 1.30 mg/L total N and 0.20 mg/L total P within the Monterey/Modelo Formation. For total N outside the Monterey/Modelo Formation the lower end of the range was the average of Cold Creek and Palo Comado results, while the upper value was equal to the results from Palo Comado Creek. The estimate for total P assumed that most phosphorus would be present as orthophosphate in areas of significant P surplus, as is reported by Busse for Las Virgenes Creek in Calabasas, and the estimate of 0.2 mg/L is based on rounding up the orthophosphate-P value of 0.18 mg/L.

**Table 7-14. Summary of Median Observed Nutrient Concentrations at Comparator/reference Sites for the Malibu Creek Watershed**

| Site/Source | TN (mg/L) | $NO^2$+$NO_3$-N (mg/L) | TP (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|
| Comparator/Reference Sites[1] | | <0.03 | | |
| w/o Monterey/Modelo | | 0.01-0.03 | | <0.05 |
| w/ Monterey/Modelo | | 0.01-0.03 | 0.20 | <0.18 |
| Cold Creek | 0.67 | | 0.07 | |
| Palo Comado Creek | 0.37 | | | |
| Level 3 Ecoregion (USEPA, 2000d) | 0.518 | 0.155 | 0.028 | |

[1] Inorganic nutrient comparator/reference sites are HtB Stream Team stations CC-3, PC-8, CC-1, SC-14, LCH-18, and AS-19 outside the Monterey/Modelo Formation, and CH-6 and LV-9 within the Model Formation (see Table 7-8).

## 7.7 NUTRIENT CONCENTRATIONS IN MALIBU LAGOON

In summer of 2012, Malibu Lagoon underwent an extensive restoration to improve circulation, tidal flows, and removal of anoxic sediments. This section provides data collected prior to the recent restoration efforts.

LVMWD has monitored nutrient concentrations in the upper part of Malibu Lagoon (their station R11D) since 1978. Prior to 1995, median wet season (Nov. 16 – Apr. 14) concentrations of nitrite- plus nitrate-N ranged from 2 to 6 mg/L by year, with median dry season (April 15 – Nov. 15) concentrations ranging from less than 1 to greater than 5 mg/L (Figure 7-18). Following discharge restrictions, concentrations declined significantly with dry season medians of 1 mg/L or less; however, wet season concentrations are still often near 2 mg/L.

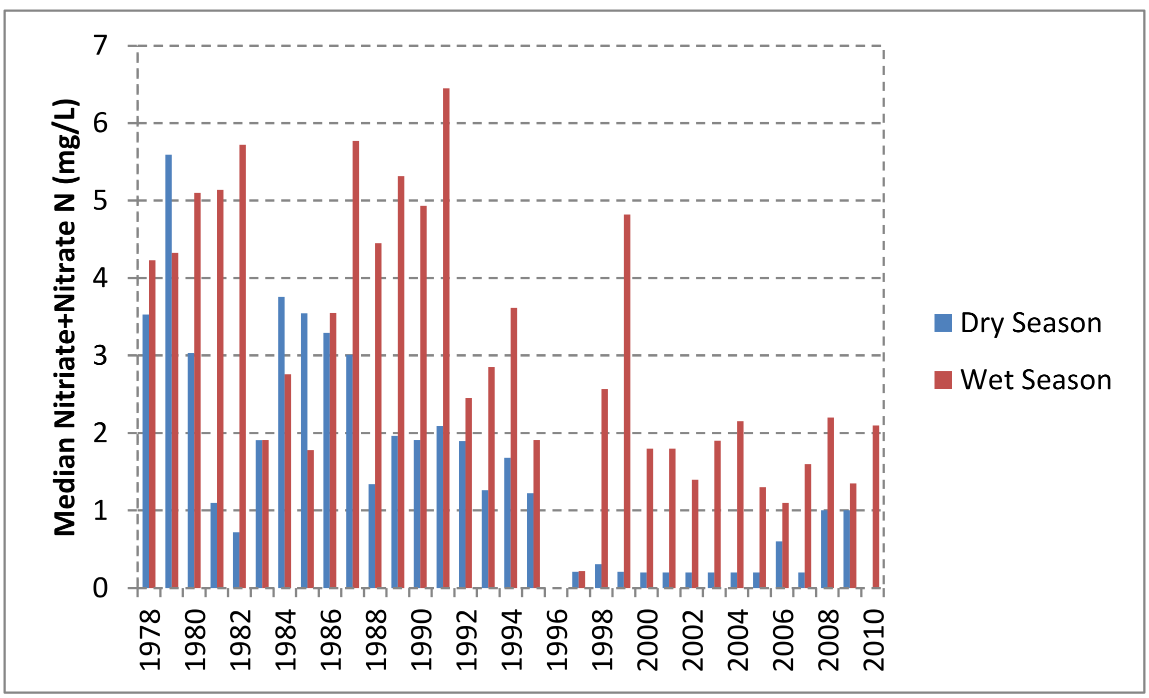



**Figure 7-18. Median Nitrate plus Nitrite as N Concentrations in Malibu Lagoon by Season**

Total N concentrations were available only since 2005 and appeared to show much higher dry season concentrations of total N as compared to nitrate- plus nitrite-N (Figure 7-19). This likely reflects conversion of inorganic N loaded during the wet season to organic forms due to algal uptake.

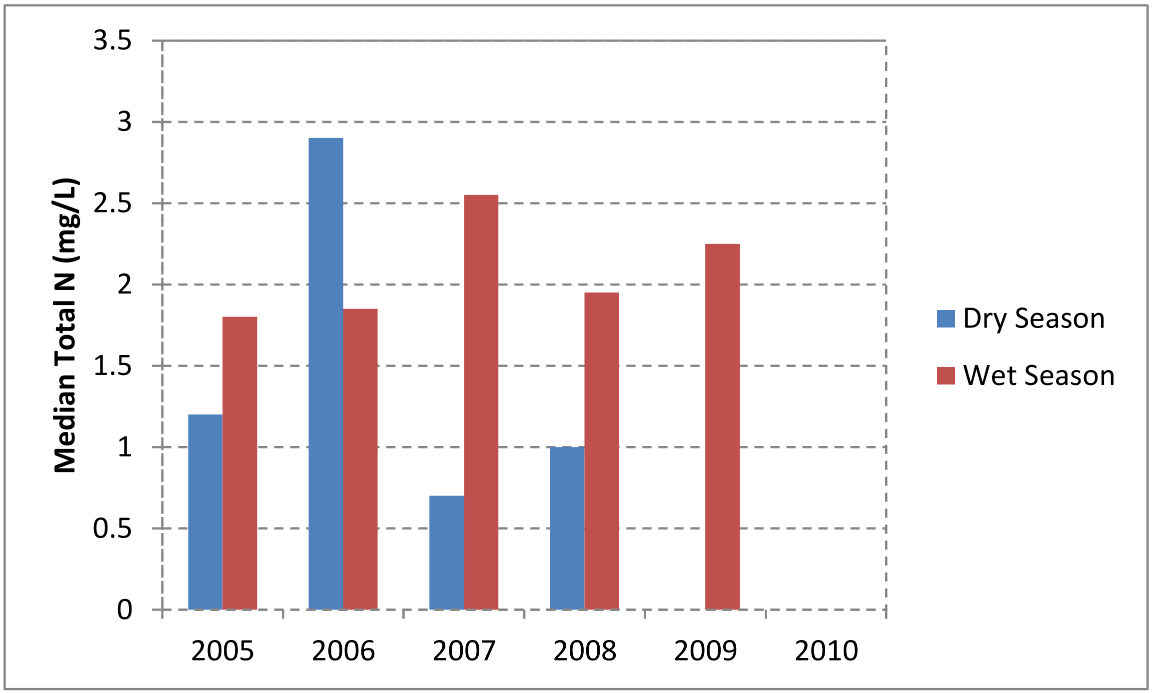



**Figure 7-19. Median Total N Concentrations in Malibu Lagoon by Season**

Inorganic phosphorus concentrations have also improved over time, but remain high during the wet season (Figure 7-20).

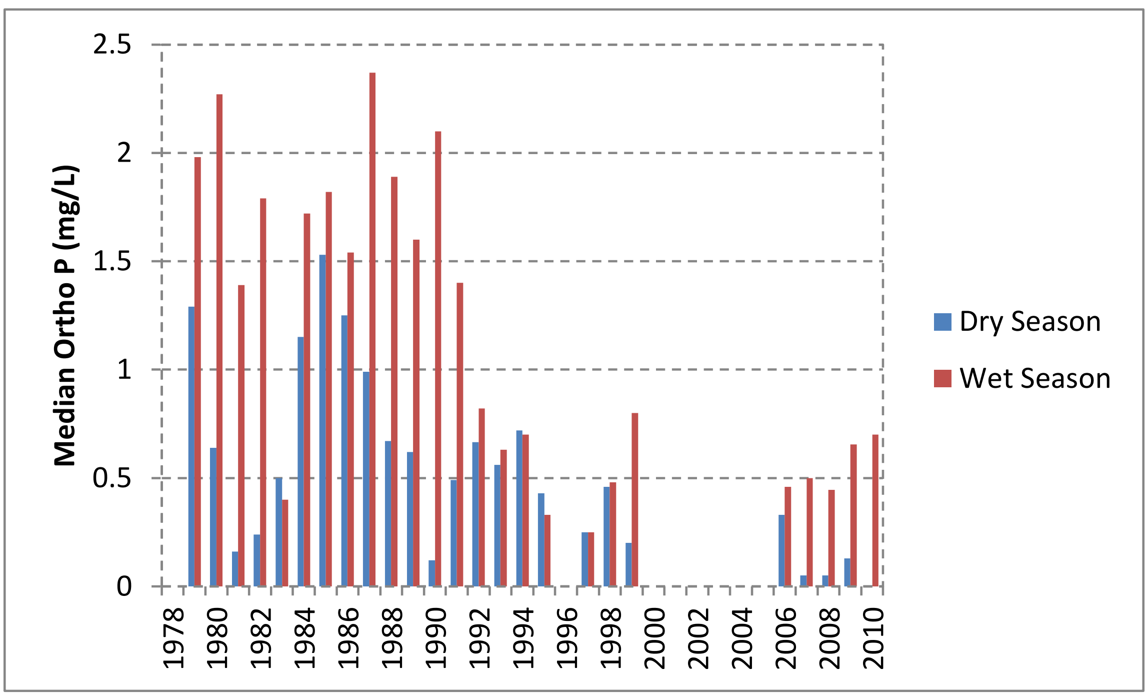



**Figure 7-20. Median Total Orthophosphate as P Concentrations in Malibu Lagoon by Season**

Current conditions in the lagoon are summarized by medians for the 2005-2010 period in Table 7-16.

**Table 7-15. Median Concentrations at Malibu Lagoon Station LVMWD-R11, 2005-2010**

| Parameter | Wet (Discharge) Season | Dry (Non-discharge) Season |
|---|---|---|
| Median $NO_2$+$NO_3$-N (mg/L) | 1.4 | 0.2 |
| Median Total N (mg/L) | 1.85 | 1 |
| Median $PO_4$-P (mg/L) | 0.59 | 0.13 |

## 7.8 TOXICS AND PESTICIDES DATA ANALYSES

To screen for other potential stressors of aquatic life, wet and dry weather water quality data collected at the Malibu Creek Mass Emissions Station (S02) just downstream of the Cold Creek confluence with Malibu Creek were compiled for the period from October 2000 through March 2010. Data for constituents identified as of potential concern in proposed Section 303(d) listings and LACDPW's annual monitoring reports (2003 through 2010) were compared to chronic (Criterion Continuous Concentrations, or CCC) and acute (Criterion Maximum Concentrations, or CMC) WQC (Table 7-16). The Ammonia CMC is pH dependent (USEPA, 1999), while all total metals CMCs and CCCs are hardness dependent. Because there is currently no CCC benchmark for sulfate, nor a CMC benchmark for diazinon, calculation of percent exceedances was not possible for these constituent – criterion combinations. For ammonia, there is a 30-day CCC; however, this is calculated as a function of water temperature, which was not recorded.

**Table 7-16. Percent Excursions of Acute and Chronic Benchmarks at Malibu Creek Mass Emissions Station – Select Constituents, 2003 – 2010**

| Constituent of Interest | Percent Exceedance of CMC (%) | | Percent Exceedance of CCC (%) | |
|---|---|---|---|---|
| | Dry | Wet | Dry | Wet |
| Ammonia | 0 | 0 | 0 | 0 |
| Cyanide | 5 | 0 | 21 | 6 |
| Diazinon | NA | NA | 5 | 2 |
| Sulfate | 53 | 51 | NA | NA |
| Total Aluminum | 0 | 0 | 0 | 0 |
| Total Beryllium | 0 | 0 | 0 | 0 |
| Total Cadmium | 0 | 2 | 0 | 4 |
| Total Copper | 0 | 4 | 0 | 9 |
| Total Lead | 0 | 0 | 0 | 4 |

| Constituent of Interest | Percent Exceedance of CMC (%) | | Percent Exceedance of CCC (%) | |
|---|---|---|---|---|
| | Dry | Wet | Dry | Wet |
| Total Nickel | 0 | 0 | 0 | 0 |
| Total Selenium | 0 | 0 | 63 | 53 |
| Total Zinc | 0 | 2 | 0 | 2 |

NA = Not applicable

Frequencies of excursions are low for most constituents, consistent with the TMDL listing decisions summarized in Section 2. Impairments associated with frequent excursions of the selenium and sulfate criteria are listed for future TMDL development. Elevated sulfate concentrations in the watershed are believed to be due to naturally occurring marine deposits (LACDPW, 2010). Selenium is also apparently from natural sources, primarily leaching from Miocene marine shales and siltstones in the Monterey/Modelo Formation (Hibbs and Ellis, 2009; LVMWD, 2011). Selenium is most often associated with sulfide deposits, and the elevated levels of selenium and sulfate are evidently linked.

Selenium is a priority pollutant and has been of greatest concern in the environment due to potential toxicity to fish, birds, mammals, and humans. Toxicity of selenium to invertebrates is not particularly well documented; however, a review by de Bruyn and Chapman (2007) suggested that selenium can cause acute lethality in some invertebrates at levels similar to or lower than the body burden thresholds needed to protect birds and mammals that consume invertebrates. In Malibu Creek Watershed, selenium data is limited and thus, evidence of selenium's non-natural level's impact on benthic macroinvertebrate condition is inconclusive. Future monitoring and examination is recommended.

The Basin Plan sets a site-specific objective of 500 mg/L sulfate for Malibu Creek (Los Angeles Board, 1994). In contrast to selenium, there are no national USEPA criteria for sulfate for the protection of freshwater aquatic life. States in USEPA Region 5 have, however, recently conducted additional analyses of sulfate toxicity to invertebrates and have proposed hardness-based water quality criteria for sulfate for the protection of aquatic life. For example, Iowa's sulfate criteria range from 500 mg/L sulfate at less than 100 mg/L hardness to 2,000 mg/L sulfate at a hardness of 500 mg/L or greater (IDNR, 2009). As the average hardness reported for Malibu Creek is 700 mg/L, sulfate concentrations greater than the basin plan objective of 500 mg/L may well be consistent with support of aquatic life. The maximum sulfate concentration reported from the Malibu Creek main stem is 1,250 mg/L.

Brown and Bay (2005) conducted additional studies of organophosphorus pesticides in the Malibu Creek Watershed, sampling two dry and two storm events in 2002-2003. Diazinon was the only organophosphorus pesticide detected in any of the creek samples, with measurable amounts in most of the dry-weather samples from Medea Creek, and both of the stormwater samples from Malibu Creek. Concentrations of diazinon in some samples exceeded the CDFG chronic criterion by up to a factor of 14 in Medea Creek. Concentrations within the Malibu Creek main stem did not appear sufficiently high to be a significant source of toxicity. It is also noted that the Los Angeles County West Vector Control District regularly treats all of Malibu Creek, including those portions within the State Parks, with the bacterial larvicide BTi (*Bacillus thuringiensis* var. *israelensis*) to control blackflies. BTi has been reported to have no direct effect on aquatic invertebrates other than mosquitos (Culicidae), blackflies (Simuliidae), and chronomids (Glare and O'Callaghan, 1998). Toxicity data from Malibu Creek are summarized in Section 7.8.

(This page left intentionally blank.)

# 8. Biological and Habitat Data and Analysis

A comprehensive evaluation of all available benthic macroinvertebrate data to date was conducted during the development of this TMDL. This assessment included our assiduous efforts to incorporate and match the methodologies and approaches developed by the SWRCB to establish Statewide Biological Objectives for California (i.e., CSCI). Below, we included the data and analyses of the benthic macroinvertebrate data collected in the Malibu Creek Watershed. We generated multiple lines of evidence in our analysis of the benthic macroinvertebrate and bioassessment condition. These data are described in detail below.

This section presents the data, scientific methods, and analyses to evaluate the condition of benthic macroinvertebrates in Malibu Creek. Multiple steps were taken to demonstrate biological condition impairment and identify the critical stressors. First, all available methods to determine the biological condition were computed, including the SC-IBI and SWRCB's recommended CSCI scoring tools, which are currently used to develop Statewide Biological Objectives. Second, we compared sites in impacted areas with those in natural, un-impacted areas to assess the relative level of impairment. Third, stressors and other water quality and physical habitat variables (nutrients, grain size, etc.) collected in the same period as the benthic macroinvertebrates were analyzed. Finally, multiple statistical methods were applied to evaluate the relationship between benthic macroinvertebrates and its stressors, including impervious areas, physical habitat, algae, and nutrients. A summary of the conclusions is provided in the text boxes below.

### *Biological Condition Summary Box*

**Benthic Macroinvertebrate Condition**

- Based on conditions observed from multiple data sources, the evidence confirms that the benthic macroinvertebrate community in Malibu Creek is impaired.

**Biological Scoring Results**

- This TMDL evaluated the benthic macroinvertebrate data from multiple entities including data collected by Heal the Bay Stream Team, Las Virgenes Municipal Water District, Los Angeles County, USEPA and Los Angeles County Flood Control District.
- This TMDL computed multiple bioscoring methods for all benthic macroinvertebrate data in the Malibu Creek Watershed. These included the Southern California Index of Biotic Integrity, California Stream Condition Index, which includes the O/E and pMMI.
- The SC-IBI, CSCI and pMMI show comparable results that the benthic macroinvertebrate community is impaired in Malibu Creek and its primary tributaries.
- The O/E results show different trends, but this scoring tool also did not incorporate the consideration of critical environmental factors for this watershed, such as geology and soil erodibility.

**Natural Conditions Currently in Watershed**

- We identified appropriate comparator/reference sites that represented the natural characteristics of the watershed including gradient, elevation and presence of the Monterey/Modelo geologic formation.
- Consistent and distinct difference in benthic macroinvertebrate condition was observed between impacted sites and comparator/reference sites along Malibu Creek mainstem.
- The natural, un-impacted conditions are based on the conditions currently observed in the Malibu Creek watershed, demonstrating these are achieveable biological conditions.

***Biological Condition Relationships with Stressors Summary Box***

**Relationship to Water Quality and Physical Habitat**

- Correlation analysis showed that mixed results for conductivity; in general, conductivity, by itself, can not explain the benthic macroinvertebrate condition.
- Elevated nutrient concentrations is one critical factor negatively impacting the benthic community condition.
- As impervious area increases, benthic community condition (bioscores) worsens. Greater area of development is linked with poorer benthic community condition; areas with increasing impervious cover are associated with high nutrient load, algal mat cover, increased flows and degraded habitat.
- Increasing inorganic nitrogen concentrations resulted in greater mag algae coverage. At the same time, increasing mat algae coverage resulted in lower benthic biological condition(bioscores). These analyses provide evidence that excess algal growth and nitrogen are strong factors impairming the benthic community.
- Multiple regression analysis revealed that physical habitat measures (e.g., sedimentation, bank stability), imperviousness, and nutrients were the stressors that best explained impacts on the benthic macroinvertebrate condition.

**Malibu Lagoon**

- Sediment loading into Malibu Lagoon is much higher than naturally expected. The excess sediment accumulate in the Lagoon tidal channels and carry greater nutrient loads and cause algae blooms.
- Sources of sediment and nutrient loads are from the upstream Malibu Creek and onsite wastewaterd disposal systems.
- Benthic invertebrates (e.g., crustaceans, clams, shrimp) in Malibu Lagoon are inhabitated by few highly tolerant species, This indicates a benthic community that is highly impacted because a naturally functioning coastal lagoon would be expected to be species rich and diverse as observed in other comparable estuaries in Southern California.

# 8.1 Malibu Creek and Main Tributaries

## 8.1.1 Benthic Macroinvertebrate Condition

The main stem of Malibu Creek is listed as impaired based on poor benthic macroinvertebrate bioassessment scores (bioscores). Malibu Creek was also listed as impaired for sediment based on the condition of macroinvertebrate communities and their habitat.

This report focuses on samples collected from the main stem and the primary tributaries draining into Malibu Creek (Las Virgenes Creek, Cold Creek, and Stokes Creek). In addition to these primary tributaries, conditions throughout the watershed were presented to better determine the causes of low bioscores.

## 8.1.2 Bioscoring Tools

The impairment condition of Malibu Creek and Lagoon are based on benthic macroinvertebrate species and abundance data, and physical habitat data collected in Malibu Creek and its tributaries. The benthic macroinvertebrate data were used to compute an overall bioscore representative of species type (e.g., pollution sensitive or tolerant), species function (e.g., scraper or grazer), species abundance, and the overall community composition. Prior to 2013, the most common bioscore index used was the IBI. Recently, SWRCB developed new bioassessment scoring tools, the CSCI, O/E, and pMMI, to assess the condition of the benthic macroinvertebrate community in our streams. Furthermore, this specific assessment was complemented by the results of other methodologies (i.e., CSCI) that predicted expected condition based on pre-determined independent variables, such as climate, elevation, geology, conductivity, etc. The evaluation of the benthic macroinvertebrates in these multiple ways generates a robust assessment of benthic macroinvertebrate condition in Malibu Creek main stem and the main tributaries.

#### 8.1.2.1 Southern California Index of Biotic Integrity

In 2005, a region-specific IBI was developed for Southern California; the SC-IBI (Ode et al., 2005) is a multi-metric index designed to evaluate functional measures of ecological health. Metrics include Coleoptera richness, EPT (Ephemeroptera-Plecoptera-Trichoptera) richness, predator richness, % collector individuals, % intolerant individuals, % non-insect taxa, and % tolerant taxa. The raw data are counts of individuals and measures of richness for taxonomic groups. Metric scores from zero to 10 are assigned to each of the seven metrics, which are then summed (with a maximum score of 70) and normalized to a scale of zero to 100. Ode et al. (2005) used a statistical criterion of two standard deviations below the mean score from un-impacted reference sites to establish a value of SC-IBI as an impairment threshold. The final category rankings are 0-19 = "very poor," 20-39 = "poor," 40-59 = "fair," 60-79 = "good," and 80-100 = "very good." Benthic macroinvertebrate data were collected according to Surface Water Ambient Monitoring Program (SWAMP) protocols and converted to bioassessment scores using the SC-IBI (Ode et al., 2005).

Since the majority of the reference sites[4] considered in the SC-IBI study (Ode et al. 2005) showed moderate to high gradients, some concerns regarding the applicability of the scoring for low gradient stream sites were raised (e.g., slope of 1 percent or less). But, Mazor et al.'s (2010) assessment demonstrated that the SC-IBI yields reasonably consistent results even in low gradient sites. In our analysis, approximately 27% of sites assessed are considered low gradient (slope of less than 1%). However, 73% of the sites exhibited slopes equal to or greater than 1 percent and are not considered low gradient (Table 8-2). For these reasons, the SC-IBI is applicable as a bioassessment tool for this watershed. Analyses of these sites were also conducted using the CSCI scoring tools to compare and confirm the assessed benthic macroinvertebrate condition.

Another consideration raised following the application of the SC-IBI is that standard sampling methodologies often fail to return the requisite sample size of at least 500 individuals for low gradient sites. But, all the HtB Stream Team samples from the main stem appear to have achieved the requisite sample size of 500.[5] Nonetheless, to address these concerns, we provided multiple methods of assessment and ensured the currently developed statewide methodologies were incorporated.

#### 8.1.2.2 California Stream Condition Index

California recently completed draft development of a new, statewide bioassessment scoring tool that combines two modeled endpoints to achieve statewide consistency and site-specificity. This alternative to the SC-IBI approach, called the California Stream Condition Index, or CSCI, uses a combination of the O/E ratio (based on the benthic macroinvertebrate assemblage) and the pMMI method (based on ecological structure metrics), which is similar to the SC-IBI approach, but accounts for site-specific variability using a predictive modeling approach. In general, O/E refers to the specific percent of taxa expected in the absence of disturbance, where O represents the number of observed taxa at the site and E represents the number of taxa expected in the absence of disturbance. E is a function of physical habitat predictors and is derived using an approach developed in Great Britain (Moss et al., 1987; Wright, 1995;

[4] The reference sites defining the SC-IBI are based on two Omernik Level III ecoregions in coastal California: chaparral and oak woodlands (ecoregion 6) and southern California mountains (ecoregion 8).

[5] We noted the group and laboratory that completed the species processing and identification, in addition to the data analysis were primarily completed by staff scientists at the CDFG, who are responsible for developing the statewide sampling methodology for bioassessment.

Clarke et al., 2003) known as the River Invertebrate Prediction and Classification System (RIVPACS). RIVPACS-type models have been developed for southern California, as described below. The O/E presentation provides a useful addition to IBI-based scoring. The models can be applied to any site, and the differences between the expected and observed assemblages or metric scores indicate the site impairment. The CSCI scoring tool independently models the ratio of observed vs. expected taxa (O/E) and multi-metric endpoints (pMMI). These independent scores are then combined as an average, yielding the CSCI.

To develop the draft scoring tool, California utilized a set of reference calibration sites consisting of 473 sites across the state, along with sites representative of stressed conditions at the other extreme. Some of the reference calibration sites selected were located adjacent to the Malibu Creek Watershed; five were located in the Monterey/Modelo Formation just north of the Malibu Creek Watershed. For all three bioscores (O/E, pMMI, and CSCI), the higher the score, the higher quality the site. SWRCB is currently developing appropriate thresholds for impairment for California. Similar approaches in other states utilize a threshold based on the $10^{th}$ or $5^{th}$ percentile confidence intervals around the mean score for all reference sites. Sites with scores above the $10^{th}$ percentile of the confidence interval is generally considered to be attaining near reference conditions. Sites below the $5^{th}$ percentile can generally be considered to not be attaining near reference conditions. In other words, these thresholds help determine if the observed score computed for the site falls within or outside of the reference population. For the purpose of providing context regarding streams in the Malibu Creek Watershed, we identify sites with scores between the $5^{th}$ and $10^{th}$ percentile for the relevant model. Table 8-1 presents the thresholds for each score produced by the CSCI model using a one-tailed estimate of confidence intervals.

**Table 8-1. Threshold values used to provide perspective for biological condition for sites in the Malibu Creek Watershed**

| Index | Mean and standard deviation for each index score for reference calibration data (473 sites) | 10% Threshold | 5% Threshold |
|---|---|---|---|
| CSCI | 1.01 (SD = 0.12) | 0.85 | 0.81 |
| pMMI | 1.00 (SD = 0.08) | 0.89 | 0.86 |
| O/E | 1.02 (SD = 0.19) | 0.78 | 0.71 |

### 8.1.3 Comparator/Reference Sites in the Malibu Creek Watershed

Expected biological community composition is influenced by a variety of factors including elevation (and associated micro-climate characteristics), gradient, and geology. Selection of traditional biological baseline or reference sites was challenging for Malibu Creek. First, monitoring data of Malibu Creek's condition prior to human-related activities were not available. The reference sites in some data sets were well defined, truly reference like, and considered the unique watershed characteristics. Other sites, identified as sampling sites, were selected because they represented minimally disturbed areas, unique geological features, and/or comparable elevation; these sites are located in undeveloped or un-impacted areas where human-related activities are not present or observed. Subsequently, we selected sites appropriate for comparison analysis based on the location and expected natural conditions as described in the original source data report or land use analysis. These "comparator/reference sites" were used as a basis of comparison against impacted sites and as general reference of best available natural conditions observed in the watershed currently. The primary purpose of comparator /reference sites is to provide an indication of the biological potential consistent with the landscape, climate, and geology.

Sites with a minimum of five BMI samples were used to account for temporal variability in bioscores. HtB Stream Team identified Lachusa Creek (LCH18) and Solstice Creek (SC14) as appropriate reference comparator/reference sites for the Malibu main stem. These stations are located at comparable elevations and coastal proximity as the sites on the Malibu main stem. The Solstice Creek site drains the Monterey/Modelo Formation marine sediments. Both SC14 and LCH18 show lower conductivity than the Malibu Creek main stem. Cheseboro Creek (CH-6) and upper Las Virgenes Creek (LV-9) sites were selected to provide comparable conductivity levels. These sites are located in undeveloped portions of the watershed[6] and drains the Monterey/Modelo Formation. Both sites typically exhibited conductivity levels around 3,500 µs/cm (i.e., more saline than the Malibu Creek main stem), and achieved fair to good SC-IBI scores. Site PC-8 on Palomado Creek did not meet the minimum requirement of five samples (n=2) and, thus, was not included as part of our comparator/reference group. These comparator/reference sites provided a solid basis of comparison with impacted sites because they reflected local watershed characteristics and consistently good benthic macroinvertebrate condition. We note that the Monterey/Modelo Formation is in many regions of Malibu Creek Watershed and its adjacent coastal watersheds. As a result, other sites draining undeveloped portions of the upper watershed are also influenced by runoff from the Monterey/Modelo Formation.

Other sites were also considered for use as comparator/reference sites for this assessment. However, most other sites (including HtB Stream Team and MCWMP sites) had less than 5 sets of BMI observations and were not included.

The relatively pristine HtB Stream Team upper Cold Creek site (CC-3), which has multiple samples, excellent biology, and good physical habitat, was not used as a comparator/reference site due its higher elevation and higher gradient relative to impaired stations in the watershed.

MCWMP site LV1 is not included as a comparator/reference site because it has only two samples (from a single year) and, as noted in the comment "is not a pristine site." It is located downstream of LV-9 near the point where residential development commences. LA County Site 16 has four reported scores. However, the two sites are approximately co-located and could be evaluated together. The results show poor biology, with much lower scores than at the upstream LV-9 station (median SC-IBI of 29; median pMMI of 0.67). It is important to note that this location was not selected as a reference site by either MCWMP or LA County, but rather was selected because it is located near the county line. Aquatic Bioassay (2005, p. 14) describes the physical habitat at this site as follows: "The upper Las Virgenes Creek site (LV1) was the only site that ranked in the poor category. This site has been heavily impacted by bank erosion and sedimentation. The western bank is cement stabilized with a road on top and a residential community up above. There are several drainage pipes lying in the streambed and exposed in the eastern bank. Recent fires have helped to denude the banks of vegetation and the streambed is filled with reeds and cattails. As a result this reach scores low for instream cover, embeddedness, channel alteration, riffle frequency, and vegetative protection." Sampling notes from LA County in later years suggest that physical habitat at this site continued to be poor. For example, in 2008 turbidity was measured at 93.9 NTU during dry weather conditions, an order of magnitude higher than seen at other sites.

The evidence thus indicates that LV1/LA County 16 is not an appropriate comparator/reference site; indeed, it appears to be a highly impacted with degraded physical habitat due at least in part to anthropogenic disturbances.

### 8.1.4 Inventory of Biological and Habitat Data

Many organizations have collected benthic macroinvertebrate samples and habitat data in the Malibu Creek Watershed (Table 8-2 and Figure 8-1). Of all the data sets evaluated, the HtB Stream Team provided the longest period of record since 2000 (see Luce, 2003, for description of site selection and

[6] Sikich et al. (2012) provides some descriptive evidence of physical habitat disturbance at LV-9 (e.g., trail activity, etc).

methods). LVMWD and Los Angeles County also have collected considerable data for the Malibu Creek Watershed. USEPA collected macroinvertebrate samples from Malibu Creek and the Lagoon in 2010 and 2011. Lastly, Los Angeles County Flood Control District (LACFCD) (Weston, 2009, 2011) monitored fixed sites from 2003 through 2008, and sampled additional randomized sites between 2009 and 2011. Only the fixed sites are shown in the table and figure. A complete data inventory is provided in Appendix A. Slope gradient of each site was determined to provide additional site definition.

**Table 8-2. Biological Sampling Sites in Malibu Creek Watershed**

| Site ID | Location | Organization | Slope |
|---|---|---|---|
| HtB-AS-19 | Arroyo Sequit | HtB Stream Team | 3.7% |
| HtB-CC-11 | Cold Creek | HtB Stream Team | 4.6% |
| HtB-CC-2 | Cold Creek | HtB Stream Team | 1.9% |
| HtB-CC-3 | Cold Creek | HtB Stream Team | 11.1% |
| HtB-CH-6 | Cheseboro Creek | HtB Stream Team | 2.2% |
| HtB-LCH-18 | Lachusa Creek | HtB Stream Team | 6.6% |
| HtB-LV-13 | Las Virgenes Creek | HtB Stream Team | 1.7% |
| HtB-LV-5 | Las Virgenes Creek | HtB Stream Team | 1.8% |
| HtB-LV-9 | Las Virgenes Creek | HtB Stream Team | 1.7% |
| HtB-MC-1 | Malibu Creek near mouth | HtB Stream Team | 0.5% |
| HtB-MC-12 | Malibu Creek above Las Virgenes Creek | HtB Stream Team | 9.5% |
| HtB-MC-15 | Malibu Creek below Cold Creek | HtB Stream Team | 3.5% |
| HtB-MD-7 | Medea Creek | HtB Stream Team | 1.2% |
| HtB-PC-8 | Palo Comado Canyon | HtB Stream Team | 2.9% |
| HtB-SC-14 | Solstice Creek | HtB Stream Team | 3.7% |
| HtB-STC-16 | Stokes Creek | HtB Stream Team | 3.9% |
| HtB-TR-17 | Triunfo Creek | HtB Stream Team | 0.5% |
| HV | Hidden Valley Creek | Malibu Creek WMP | 0.1% |
| LC | Liberty Canyon Creek | Malibu Creek WMP | 2.1% |
| LIN1 | Lindero Creek | Malibu Creek WMP | 0.9% |
| LIN2 | Lindero Creek | Malibu Creek WMP | 2.8% |
| LV1 | Las Virgenes Creek | Malibu Creek WMP | 1.2% |
| LV2 | Las Virgenes Creek | Malibu Creek WMP | 1.6% |
| MAL | Malibu Creek near Mouth | Malibu Creek WMP | 1.7% |

| Site ID | Location | Organization | Slope |
|---|---|---|---|
| MED1 | Medea Creek | Malibu Creek WMP | 1.3% |
| MED2 | Medea Creek | Malibu Creek WMP | 1.2% |
| PC | Potrero Creek | Malibu Creek WMP | 0.5% |
| TRI | Triunfo Creek | Malibu Creek WMP | 1.0% |
| LVMWD-R11 | Malibu Lagoon | LVMWD | NA |
| LVMWD-R4D | Malibu Creek | LVMWD | 0.5% |
| LVMWD-R3D | Malibu Creek | LVMWD | 1.0% |
| LVMWD-R13D | Malibu Creek | LVMWD | 0.3% |
| LVMWD-R2D | Malibu Creek | LVMWD | <0.1% |
| LVMWD-R1U | Malibu Creek | LVMWD | 0.5% |
| LVMWD-R9U | Malibu Creek | LVMWD | 0.3% |
| LVMWD-R7D | Las Virgenes Creek | LVMWD | 1.6% |
| LACo_15 | Medea Creek | LA Co. FCD | 2.1% |
| LACo_16 | Las Virgenes Creek | LA Co. FCD | 1.2% |
| LACo_17 | Cold Creek | LA Co. FCD | 4.4% |
| LACo_18 | Triunfo Creek | LA Co. FCD | 0.8% |
| EPA-1 | Malibu Creek | USEPA | 2.5% |
| EPA-2 | Malibu Creek | USEPA | 2.0% |
| EPA-3 | Malibu Creek | USEPA | 0.8% |
| EPA-4 | Las Virgenes Creek | USEPA | 0.6% |

Notes: LVMWD = Las Virgenes Municipal Water District; LA Co. FCD = Los Angeles County Flood Control District; USEPA = United States Environmental Protection Agency .

Stream gradient was determined by evaluating the 10 meter (m) DEM (as well as a 3 m DEM available for the coastal area only), using the following procedure: (1) Buffer each monitoring point by a circle with radius of 1,000 feet, (2) Determine stream elevations at the upstream and downstream locations where the stream crosses the circle, and (3) Divide by the stream reach length (from National Hydrography Dataset [NHD]) to estimate the gradient.

These gradient estimates should be used with caution because the 10-m DEM may not resolve the stream surface elevation well. MCWMP sites in the 2005 report showed different percent gradient results (e.g., lower Malibu Creek site had a 3 percent gradient) (MCWMP, 2005). The MCWMP results were obtained using an inclinometer to provide a gross measure (whole percent integers only) over a thalweg distance of 100 meters (i.e., whole integers of 1, 2, or 3 percent were provided).

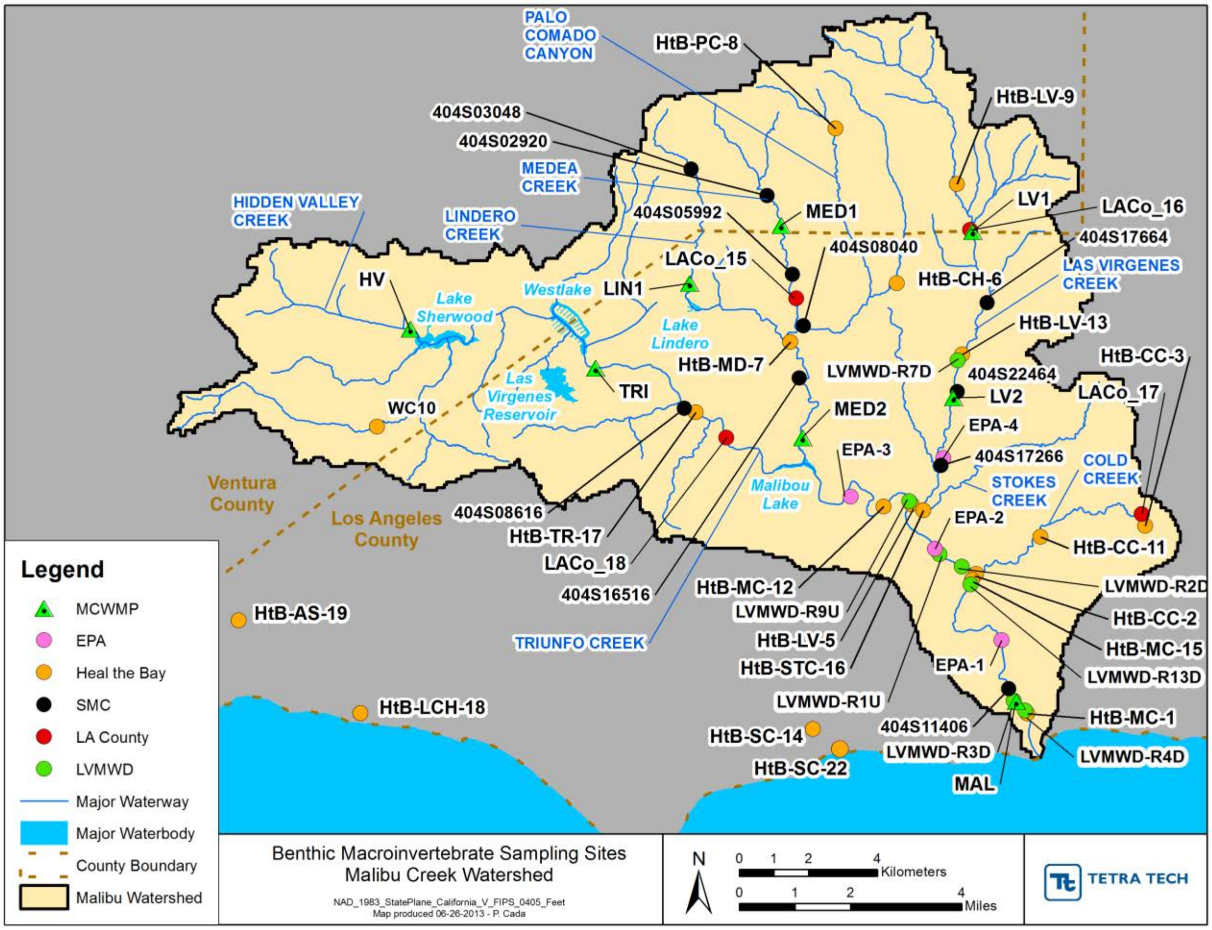



**Figure 8-1. Benthic Macroinvertebrate Sampling Sites in the Malibu Watershed**

## 8.1.5 SC-IBI Analyses of Benthic Macroinvertebrate Data

We estimated SC-IBI scores for each Malibu Creek Watershed site where such estimates were possible. These analyses help to confirm impairments and are useful for comparison with other bioscores.

### 8.1.5.1 HtB Stream Team Benthic Macroinvertebrate Data

A summary of HtB Stream Team SC-IBI results for the main stem of Malibu Creek (Table 8-3 and Figure 8-2) showed that 45 of 47 samples (96%) are rated as either poor (yellow) or very poor (red) on the SC-IBI scale. Table 8-4 shows SC-IBI scores from selected sites in Malibu Creek tributaries and nearby Solstice and Lachusa Creek (some stations with only one or two samples are omitted). Medea Creek, Triunfo Creek, and Las Virgenes Creek show a preponderance of poor or very poor results.

**Table 8-3. HtB Stream Team SC-IBI Bioscores for Main Stem Malibu Creek, 2000 - 2011**

| Station | Spring 2000 | Fall 2000 | Spring 2001 | Fall 2001 | Spring 2002 | Fall 2002 | Spring 2003 | Fall 2003 | Winter 2005 | Spring 2006 | Fall 2006 | Spring 2008 | Spring 2009 | Spring 2010 | Spring 2011 | Median (n>5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MC-1 | 16 | 24 | | 39 | 19 | | 26 | 23 | 26 | | 26 | 21 | 30 | 6 | | 25 |
| MC-1B | | | 26 | | | | | | | | | | | | | |
| MC-12 | | 23 | | | 33 | 27 | 21 | 31 | 20 | | 17 | | 17 | 3 | 13 | 21 |
| MC-12A | | | 20 | 37 | | | | | | | | | | | | |
| MC-13 | | 39 | 23 | | | | | | | | | | | | | |
| MC-15 | | | | | 40 | 24 | 34 | 23 | | | 17 | | 19 | 6 | 16 | 24 |
| MC-8 | 36 | 37 | | | | | | | | | | | | | | |
| MC-8B | | 23 | | | | | | | | | | | | | | |
| MC-9 | 33 | 17 | 24 | 43 | | | | | | | | | | | | |
| MC-20 | | | | | | | | | | 3 | | | | | | |
| MC-21 | | | | | | | | | | 4 | | 29 | | | | |

Note: SC-IBI scores rated as “poor” are shown in yellow; scores rated as “very poor” are shown in red.

**Table 8-4. HtB Stream Team SC-IBI Bioscores for Selected Tributaries to Malibu Creek and Nearby Streams, 2000 - 2011**

| | Spring 2000 | Fall 2000 | Spring 2001 | Fall 2001 | Spring 2002 | Fall 2002 | Spring 2003 | Fall 2003 | Winter 2005 | Spring 2006 | Fall 2006 | Spring 2008 | Spring 2009 | Spring 2010 | Spring 2011 | Median (n>5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cold Creek** | | | | | | | | | | | | | | | | |
| CC-2 | 36 | | 46 | 73 | 53 | | 44 | | 27/36 | 31/42 | | | 27 | 20 | 19 | 40 |
| CC-3 | 80 | 76 | 92 | 76 | 83 | 80 | 84 | 64 | 61 | 73 | | 67 | 79/80 | 82 | 66 | 76 |
| CC-11 | 54 | 46 | 56 | 54 | 49 | | 40 | | | 47 | | | 57 | 37/43 | 67 | 54 |
| **Las Virgenes Creek** | | | | | | | | | | | | | | | | |
| LV-5 | 29 | 34 | 33 | 33 | 39 | 26 | 20 | 29 | 17/19 | 14/17 | | | 26 | 10 | | 29 |
| LV-9 | | | | | 59 | 26 | 46 | | 34 | 34 | | | 42 | 39 | 49 | 41 |
| LV-13 | | | | | 26 | 24 | 21 | 27 | 11 | 18 | | | 8 | 13 | | 20 |
| **Medea Creek** | | | | | | | | | | | | | | | | |
| MD-7 | 23 | 26 | 19 | 34 | 23 | | 9 | 9 | 10 | 20 | | | 19 | 14 | | 19 |
| **Solstice Creek** | | | | | | | | | | | | | | | | |
| SC-14 | | | | 87 | 76 | 76 | 67 | 70 | 63 | 60 | | 56 | 69 | 49 | 59 | 67 |
| SC-22 | | | | | | | | | | 64 | | | 53 | 44/46 | 58 | 58 |
| **Arroyo Sequit** | | | | | | | | | | | | | | | | |
| AS-19 | | | | 70 | 72 | 66 | 72 | 70 | 64 | 57 | | 50 | 70 | 70 | 64 | 70 |
| **Cheseboro Creek** | | | | | | | | | | | | | | | | |
| CH-6 | | | 59 | 57 | 64 | | 49 | | 54 | 43 | | | | 34 | | 54 |
| **Lachusa Creek** | | | | | | | | | | | | | | | | |
| LCH-18 | | | | 73 | 72 | 76 | 54 | 61 | 54 | 11 | | | 57 | 47 | 51 | 56 |
| **Triunfo Creek** | | | | | | | | | | | | | | | | |
| TR-17 | 20 | | 19 | | 19 | | 4 | | 0 | 20 | | | 18 | 3 | 11 | 18 |
| **Palo Comado Creek** | | | | | | | | | | | | | | | | |
| PC-8 | | | 60 | | | | | | 40 | | | | | | | |

Note: SC-IBI scores rated as “poor” are shown in yellow; scores rated as “very poor” are shown in red.

### 8.1.5.2 LA County Flood Control District Benthic Data

The LACFCD has conducted bioassessment in the watershed since 2003; we obtained data from 2003 to 2010 (Weston, 2011). Fixed stations were used through 2008, with a switch to randomized stations in 2009. The fixed station sampling locations did not include Malibu Creek main stem (see Table 8-2 and Figure 8-2). However, in 2009 and 2010, there were randomized samples from the main stem. In 2009 a sample was collected at a site below Cold Creek, near HtB Stream Team station MC-15. This yielded an SC-IBI bioscore of 29. In 2010 a sample was collected in the main stem just upstream of the confluence with Las Virgenes Creek, yielding an SC-IBI bioscore of 17. Both results are generally consistent with the results reported by HtB Stream Team. Results for Los Angeles County's fixed stations are summarized in Table 8-5.

**Table 8-5. Los Angeles County SC-IBI Bioscores for Fixed Sample Sites in the Malibu Creek Watershed**

| Location | Station | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Median |
|---|---|---|---|---|---|---|---|---|
| Las Virgenes | LACo_16 | | | 39 | 24 | 29 | 23 | 26 |
| Cold Creek | LACo_17 | 60 | 74 | 70 | 76 | 74 | 79 | 74 |
| Triunfo Creek | LACo_18 | 31 | | 29 | 26 | 27 | 21 | 27 |
| Medea Creek | LACo_15 | 4 | 7 | 10 | 6 | 3 | 10 | 6 |

Note: Weston (2011) reports raw results on a 0 – 70 scale; these have been renormalized to the 0 – 100 scale for consistency with other sampling efforts. SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red.

### 8.1.5.3 LVMWD Benthic Data

LVMWD collected benthic macroinvertebrate data since 2006 in connection with the Tapia WRF permit. The LVMWD sampling stations are summarized in detail in Table 8-6 (from Aquatic Bioassay, 2010) and their locations are shown on Figure 8-2 below. LVMWD's station LVWMD-R4D approximately coincides with HtB Stream Team station MC-1.

**Table 8-6. Malibu Creek Watershed LVMWD Benthic Macroinvertebrate Sampling Stations**

| Station ID | Name | Position from Tapia WRF Outfall | Distance (m) from Tapia WRF Outfall | Latitude (N) | Longitude (W) | Elev. (ft) |
|---|---|---|---|---|---|---|
| LVWMD-R11D | Malibu Lagoon | Downstream | 7,470 | 34.03378 | 118.68291 | 3 |
| LVWMD-R4D | Malibu Creek | Downstream | 6,290 | 34.04365 | 118.68488 | 26 |
| LVWMD-R3D | Malibu Creek | Downstream | 5,860 | 34.04622 | 118.68847 | 44 |
| LVWMD-R13D | Malibu Creek | Downstream | 930 | 34.07642 | 118.70230 | 458 |
| LVWMD-R2D | Malibu Creek | Downstream | 150 | 34.08105 | 118.70500 | 468 |
| LVWMD-R1U | Malibu Creek | Upstream | 560 | 34.08423 | 118.71202 | 478 |
| LVWMD-R9U | Malibu Creek | Upstream | 2,500 | 34.09798 | 118.72170 | 495 |
| LVWMD-R7D | Las Virgenes Creek | Upper Watershed | 7,650 | 34.13485 | 118.70682 | 721 |

SC-IBI scores reported by LVMWD have all been in the "poor" or "very poor" category (Table 8-7; see also Figure 8-2 below).

**Table 8-7. SC-IBI Scores from LVMWD Stations**

| Season | Year | LVWMD-R4D | LVWMD-R3D | LVWMD-R13D | LVWMD-R2D | LVWMD-R1U | LVWMD-R9U | LVWMD-R7D |
|---|---|---|---|---|---|---|---|---|
| Fall | 2006 | 24.3 | 20.0 | 25.7 | 17.2 | 22.9 | Dry | 24.3 |
| Spring | 2007 | 5.7 | 8.6 | 31.5 | 15.7 | 8.6 | 12.9 | 12.9 |
| Spring | 2008 | 22.9 | 14.3 | 11.4 | 8.6 | 1.4 | 2.9 | 2.9 |
| Spring | 2009 | 11.4 | 14.3 | 11.4 | 14.3 | 18.6 | 5.7 | 11.4 |
| Spring | 2010 | 23.0 | 13.0 | 27.0 | 9.0 | 19.0 | 7.0 | 14.0 |
| Spring | 2011 | 15.7 | 11.4 | 8.6 | 24.3 | 18.6 | 15.7 | 11.4 |

Note: SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red. Scores renormalized to 0-100 scale.

### 8.1.5.4 MCWMP Benthic Data

As part of the MCWMP, spring and fall BMI samples were collected in 2005 (Aquatic Bioassay, 2005). Their sampling sites coincided with water quality sites, and the locations are shown above in Figure 8-1. Of these sites, MAL approximately corresponds to the HtB Stream Team MC-1 site and LV1 approximately coincides with LACo-16. Results are shown in Table 8-8.

**Table 8-8. SC-IBI Scores from MCWMP Stations**

| Location | Station Code | Spring 2005 | Fall 2005 |
|---|---|---|---|
| Malibu Creek | MAL | 47 | 24 |
| Las Virgenes Creek | LV2 | 17 | 16 |
| Las Virgenes Creek | LV1 | 36 | 33 |
| Medea Creek | MED2 | 19 | 16 |
| Medea Creek | MED1 | 14 | 14 |
| Lindero Creek | LIN1 | 17 | 24 |
| Triunfo Creek | TRI | 19 | 4 |
| Hidden Valley | HV | 17 | NS |

Note: SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red. Scores have been renormalized to a 0-100 basis from the results shown in Aquatic Bioassay (2005).NS = not sampled.

### 8.1.5.5 USEPA 2010-2011 Benthic Data

USEPA sampled benthic macroinvertebrates in Malibu Creek main stem to provide additional data and support (Table 8-9). USEPA sampled five sites, two of which overlap stations previously sampled by HtB Stream Team and LVMWD. Because there are many comparator/reference sites in other parts of the watershed, additional sites in Malibu Creek main stem were sampled. USEPA sampled three sites along the main stem that are located adjacent to undeveloped areas without observed human related activities nearby (e.g., sites in Malibu Creek State Park and Malibu Canyon). These sites provided an estimate of the main stem sections that would only be impacted by upstream activities and loading, and not due to adjacent impact activities.

USEPA sampled at MC-1, which is located in the private residential Serra Retreat Community, and is the same long-term site sampled by HtB Stream Team. EPA-1 is located in Malibu Creek main stem, upstream of MC-1, and in a section of the main stem that is parallel to Malibu Canyon Road; access to this site was a 30 minute hike down into the Creek from Malibu Canyon Road. MC1 and EPA-1 are located downstream of Tapia WRF discharge. Sites EPA-2 (near Mott Road) and EPA-3 (near the MASH site) are located in the expansive 7,000 acre Malibu Creek State Park downstream of Triunfo Creek, which flows into Malibu Creek main stem upstream of Malibou Lake. EPA-2 and EPA-3 are compared with the impacted sites downstream of Tapia WRF in Malibu Creek because they are in the same main stem and located in an area without adjacent anthropogenic activities.

**Table 8-9. Benthic Metrics, Abundance and SC-IBI Scores for the USEPA Sampling Conducted in Spring 2011**

| | EPA-1 | EPA-2 | EPA-3 | EPA-4 | MC-1 |
|---|---|---|---|---|---|
| EPT Index (%) | 56 | 6 | 1 | 33 | 48 |
| EPT Taxa | 7 | 4 | 2 | 4 | 6 |
| Percent Chironomidae | 11 | 5 | 17 | 9 | 16 |
| Percent Dominant Taxon | 22.1 | 80.9 | 80.7 | 23.1 | 23.4 |
| Percent EPT Taxa | 26 | 19 | 10 | 16 | 19 |
| Percent Grazer Taxa | 0 | 0 | 0 | 0 | 0 |
| Percent Intolerant | 1 | 1 | 0 | 0 | 2 |
| Percent Mollusca | 15 | 81 | 0 | 23 | 9 |
| Percent Non-Insecta Taxa | 33 | 29 | 35 | 28 | 29 |
| Percent Oligochaeta Taxa | 4 | 5 | 5 | 4 | 3 |
| Percent Predator Taxa | 19 | 24 | 20 | 20 | 29 |
| Percent Collectors | 56 | 13 | 96 | 56 | 53 |
| Percent Scrapers | 16 | 82 | 0 | 23 | 10 |
| Percent Shredders | 0 | 0 | 0 | 0 | 0 |
| Percent Predators | 5 | 1 | 1 | 4 | 9 |
| Percent Tolerant | 31 | 88 | 3 | 50 | 29 |
| Taxonomic Richness | 27 | 21 | 20 | 25 | 31 |
| Tolerance Value | 6.13 | 7.71 | 6 | 6.79 | 6.18 |
| Total Abundance (#/sample) | 12,460 | 13,114 | 3,301 | 5,923 | 10,702 |
| SC-IBI scores* | 20 | 17 | 20 | 3 | 13 |

Note: SC-IBI scores rated as “poor” are shown in yellow; scores rated as “very poor” are shown in red.

* Based on the calculation of biological metrics from a group of 500 organisms from a composite sampled collected at each stream reach. The 500 organisms were used to compute the seven biological metrics used in computing the SC-IBI score.

For the two USEPA sites in Malibu Creek State Park, a single dominant taxon (*Potamopyrgus* and *Simulium*, respectively) accounted for over 80% of the individuals collected whereas the other three sites outside of the park had approximately a fifth of the individuals as a single dominant taxon. Of all the five sites collected during this sampling effort, the highest percentage of tolerant species was observed at EPA-2, since *Potamopyrgus* is a tolerant invertebrate. EPA-3, upstream of EPA-2, dominated by *Simulium*, had the lowest percent tolerant species (3%) and the highest percentage of collectors (96%). Despite differences in dominance, taxonomic richness was comparable at all sites. All five sites sampled by USEPA in May 2011 showed SC-IBI scores of "very poor" to "poor" conditions, with a SC-IBI score of 20 being the highest value sampled (EPA-1 and EPA-3). Site EPA-4, located upstream and outside of the Park, but immediately downstream of a large residential development, showed the lowest SC-IBI score of 3. These scores are likely due to immediate impacts of the upstream residential development. These results are valuable as an addition to the larger benthic macroinvertebrate data set and as a means to confirm the data collected to date. However, the results from these five sites are based on a single sampling season, and therefore should not be assessed independently due to the low sample size and limited temporal coverage (i.e., does not capture interannual variability).

#### 8.1.5.6 SC-IBI Conclusions

Based on the similar trends of "poor to very poor" conditions observed from different data sets, the evidence confirms that Malibu Creek is impaired for benthic macroinvertebrate community. While the current TMDL effort focuses on the Malibu Creek main stem downstream of Malibou Lake, it is informative to examine SC-IBI scores in the context of the whole watershed. Median scores for 2000-2010 are summarized in Figure 8-2. Within the watershed, the median scores range from a low of 6 to a maximum of 78, with the highest score appearing in the un-impacted headwaters of Cold Creek. The lowest median scores are found in the main stem and in the lower portions of the Triunfo Creek, Medea Creek, and Las Virgenes Creek tributaries to Malibu Creek.

**Comparison Between Un-Impacted and Impacted Sites**

When comparing between un-impacted and impacted sites, SC-IBI scores show a clear difference between the comparator/reference sites and those along the Malibu Creek main stem; this trend was consistent across time. A spatial trend is also evident in the watershed based on median scores. As seen in Figure 8-2, the tributary stations with low scores are upstream of the impaired portions of the Malibu Creek main stem and are also downstream of developed areas of the watershed, while stations upstream of developed areas had higher scores. A graphical comparison is provided by box and whisker plots, in which the central box represents the interquartile range, with a central line indicating the median (Figure 8-3). The whiskers extend to 1.5 times the interquartile range above and below the third and first quartile values, while outliers beyond this range are shown as individual points. The comparison shows no overlap of the interquartile ranges between the Malibu Creek main stem stations and the comparator/reference sites; in fact, there is a clear delineation between the sites along the main stem and those of the comparator/reference sites.

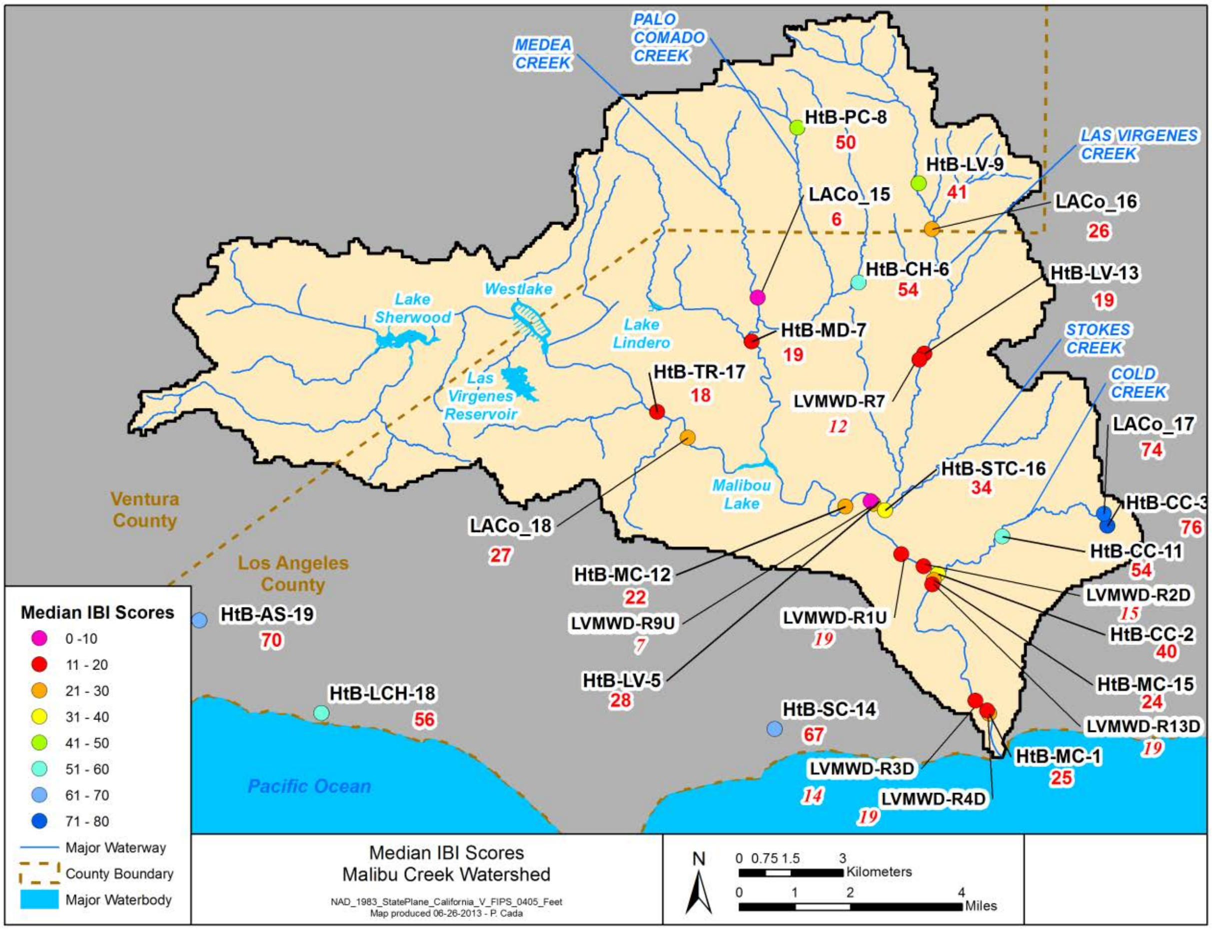



**Figure 8-2. Median SC-IBI Scores (2000-2011) for the Malibu Creek Watershed and Adjoining Reference Stations**

Note: MCWMP results are not shown as they provide a maximum of only two samples per station.

CC-3 was also evaluated. This site, in the undeveloped headwaters of Cold Creek had the highest values, much higher than the comparator/reference sites in the same watershed (CH-6 and LV-9). Although Cold Creek is distinct from the other comparator/reference sites in terms of elevation and geology, it provides valuable information regarding the capacity for certain areas within this watershed to support high biota scores, thus biological condition. In addition, there is little difference between the three main stem sites, even though they represent different stream gradients (0.5 to 9.5 percent) and include stations both upstream and downstream of the Tapia discharge. These observations suggest that (1) the Tapia WRF discharge is not the single factor causing the observed impairment in the Malibu Creek main stem, and (2) high conductivity or other constituents associated with the Monterey/Modelo Formation are also not sufficient by themselves to explain the impairment. Furthermore, the differences in the sites' gradients also indicate that, at least for impacted sites, gradient is not a factor affecting condition. These data further confirm the impaired condition of the benthic macroinvertebrate community in Malibu Creek and indicate that both upstream watershed activities and Tapia WRF are impacting the main stem benthic condition; the two sources together provide an additive impact to the benthic macroinvertebrates inhabiting Malibu Creek and Lagoon.

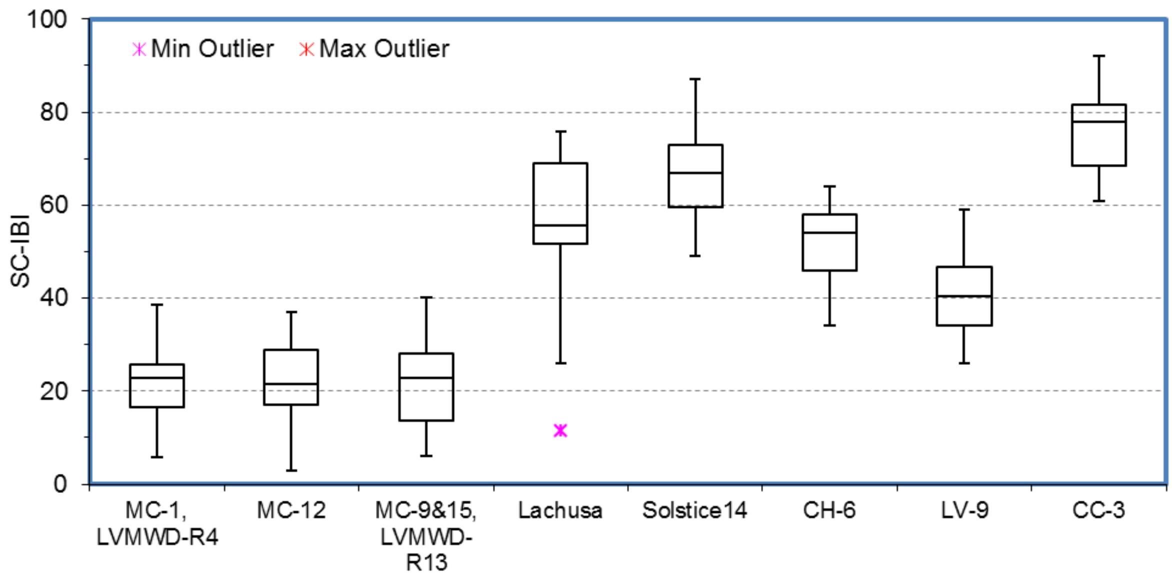



**Figure 8-3. Comparison of SC-IBI Distribution for Malibu Creek to Comparator/Reference Sites, 2000-2011**

### 8.1.6 CSCI Analysis of Benthic Macroinvertebrate Data

We estimated CSCI scores for each Malibu Creek Watershed site where such estimates were possible. The calculation of the CSCI scores was conducted in collaboration with the CSCI Science Team (see Appendix D). As an effort to ensure that this assessment followed the state's current development of biological objectives, the State Board and its CSCI Science Team provided invaluable technical support and time to assist USEPA with the calculation of CSCI bioscores. The CSCI Science Team provided the R programs constituting the CSCI scoring tool, guidance for calculating input parameters and creating the necessary input files, and independently calculated a subset of the bioscores along with USEPA. Following the calculation of the bioscores, USEPA consulted with the CSCI Team to evaluate the results to ensure appropriate interpretation of the data. Appendix D presents a detailed discussion of the steps required for calculating the CSCI and the methods used by the CSCI Science Team and USEPA to ensure accurate results. The CSCI score is the average of the O/E and pMMI bioscores. To compute the O/E and pMMI models, independent predictor variables were collected. These predictor variables included location, catchment size, geology, and climate variables.

Table 8-10 lists the predictors required and indicates which are used in the O/E model and which are used for each of the pMMI metrics.

**Table 8-10. Model Predictors for Malibu Watershed**

| Predictor | Variable Name | Predictor Scale | Data Source | Metrics/Scores using predictor | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | O/E | Shannon Diversity Index | % intolerant taxa | Tolerance value | % collector taxa | Shredder taxa | Clinger taxa | Coleoptera taxa | % non-insect taxa |
| Location | | | | | | | | | | | | |
| Latitude (DD) | New_Lat | Site | HtB, LVMWD, MCWMP, SMC, LACFCD, and USEPA | X | X | X | X | X | X | X | X | X |
| Longitude (DD) | New_Long | | | | X | X | X | X | X | X | X | X |
| Site Elevation (m) | SITE_ELEV | Site | Gesch 2007 and Gesch et al. 2002 | X | X | X | X | X | X | X | X | X |
| **Catchment** | | | | | | | | | | | | |
| Area (km$^2$) | AREA_SQKM | Catchment | Gesch 2007 and Gesch et al. 2002 | X | | | X | X | X | | X | |
| Watershed Elevation Range | ELEV_RANGE | Catchment | Gesch 2007 and Gesch et al. 2002 | | X | | X | X | X | X | | |
| **Climate** | | | | | | | | | | | | |
| Average Annual Maximum Temperature, 2000-2009 (°C × 100) | TEMP_00_09 | Site | PRISM Climate Group 2013 | X | X | X | X | X | X | X | X | X |
| Average Annual Precipitation, 2000-2009 (mm/yr × 100) | PPT_00_09 | Site | PRISM Climate Group 2013 | X | X | X | X | X | X | X | X | X |
| Mean of Mean June-Sept 1971-2000 Monthly Precipitation (mm/yr × 100) | SumAveP | Catchment | PRISM Climate Group 2013 | | X | X | X | X | X | X | X | X |
| **Geology** | | | | | | | | | | | | |
| Mean Soil Erodibility (K) Factor | KFCT_AVE | Catchment | Olson and Hawkins 2012 | | X | X | X | X | X | | X | |
| Mean Bulk Density | BDH_AVE | Catchment | Olson and Hawkins 2012 | | X | | X | X | X | X | X | X |
| Mean Soil Permeability | PRMH_AVE | Catchment | Olson and Hawkins 2012 | | X | X | X | X | | | X | X |

| Predictor | Variable Name | Predictor Scale | Data Source | Metrics/Scores using predictor | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | O/E | Shannon Diversity Index | % intolerant taxa | Tolerance value | % collector taxa | Shredder taxa | Clinger taxa | Coleoptera taxa | % non-insect taxa |
| Mean Log Geometric Mean Hydraulic Conductivity | LPREM_ mean | Catchment | Olson and Hawkins 2012 | | | X | X | | X | | X | X |
| Percent Sedimentary Geology | PCT_ SEDIM | Catchment | Olson and Hawkins 2012 | | X | | | X | | | X | X |
| Mean Whole Rock Magnesium oxide | MgO_ Mean | Catchment | Olson and Hawkins 2012 | | X | | X | X | X | | X | X |
| Mean Whole Rock Phosphorus | P_MEAN | Catchment | Olson and Hawkins 2012 | | X | | X | X | X | | X | X |
| Mean Whole Rock Calcium oxide | CaO_ Mean | Catchment | Olson and Hawkins 2012 | | X | | X | X | X | | X | X |
| Mean Whole Rock Sulfur | S_Mean | Catchment | Olson and Hawkins 2012 | | X | | X | X | X | | X | |
| Mean Whole Rock Nitrogen | N_MEAN | Catchment | Olson and Hawkins 2012 | | | | X | X | | | X | |

For each predictor variable, we extracted site- or catchment-specific data from the GIS source data specified in Table 8-10 according to the detailed methods presented in Appendix D. We conducted quality control analysis on these predictor estimates, and compared a subset of our results with the CSCI Tool Development Team's independent estimates for the same sites (R. Mazor, 2013, personal communication). Most of the predictor variables are required for the pMMI model; the O/E model only requires latitude, site elevation, catchment area, average annual maximum temperature, and average annual precipitation. The O/E model does not use any of the geology predictor variables. The geologic data set included mean soil erodibility factor, mean bulk density, mean soil permeability, mean log geometric mean hydraulic conductivity, and mean whole rock sulfur content, % sedimentary geology, mean whole rock calcium oxide, magnesium oxide, nitrogen, and phosphorus. Quality assurance and quality control (QA/QC) were implemented for these predictor estimates; the CSCI Tool Development Team's (R. Mazor, 2013, personal communication) independently conducted quality control of these bioscore estimates.

We took existing benthic macroinvertebrate data collected by HtB Stream Team, LVMWD, MCMWP, Stormwater Monitoring Coalition (SMC), LACFCD, and USEPA (Table 8-11 and Figure 8-4) and condensed them into a list of benthic macroinvertebrate observations for each sample and sampling station. Each observation included taxonomic identification and abundance. In addition, lifestage, and a distinct flag indicating whether or not the specimen was sufficiently distinct for a certain taxonomic identification were maintained for each observation (if lifestage or the distinct flag were provided with the raw taxonomic data). Samples were assigned unique site-date identifiers.

**Table 8-11. Benthic Macroinvertebrate Sampling Data Available by Organization and Year**

| Organization | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HtB Stream Team | X | X | X | X | | X | X | | X | X | X | X |
| LVMWD | | | | | | | X | X | X | X | X | X |
| MCMWP | | | | | | X | | | | | | |
| SMC | | | | | | | | | | X | | |
| LACFCD | | | | X | X | X | X | X | X | X | X | X |
| USEPA | | | | | | | | | | | | X |

Note: blank cells indicate no data available for that organization-year combination.


**Figure 8-4. Sites with Benthic Macroinvertebrate Data used in CSCI Analysis**

We resolved taxonomic nomenclature (e.g., corrected misspellings) using the SWAMP taxonomic lookup file list (SWRCB, OrganismLookUp - SAFIT Benthic Macroinvertebrate [BMI] list), available at http://ftp.mpsl.mlml.calstate.edu/LookUpLists.php). Sixteen individual taxa or unresolved species pairs were not listed in this lookup file. These taxa were resolved in coordination with Southern California Coastal Water Research Project (SCCWRP) biologists (R. Mazor, 2013, personal communication).

#### 8.1.6.1 Applicability of the CSCI to Malibu Creek Watershed

USEPA considered the applicability of the CSCI scoring tool to the Malibu Creek Watershed. For example, the models must be able to accurately predict the expected taxonomic composition and metrics for sites that may be affected by unique geology, like that of the Monterey/Modelo Formation. Table 8-12 compares the predictor values for five reference calibration sites located in the Monterey Formation north of Malibu Creek Watershed with the predictor variables for sites located in the Malibu Creek Watershed's Monterey/Modelo Formation. The five reference calibration sites lie approximately 12 to 17 miles to the north, but exhibit similar geologic predictors to those in the Malibu Creek Watershed.

**Table 8-12. Comparison of Predictor Variables and Scores for Malibu Creek Watershed Sites in the Monterey/Modelo Formation to Reference Sites within the Monterey/Modelo Formation**

| Variable | Reference Calibration Sites in the Monterey/Modelo Formation (5 sites) | | Malibu Creek Watershed Sites in the Monterey/Modelo Formation (13 sites) | |
|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum |
| Percent Catchment Draining Monterey/Modelo Formation | 13 | 42 | 15 | 62 |
| ***Location*** | | | | |
| New_Lat | 34.350789 | 34.43276 | 34.09655 | 34.18426 |
| New_Long | -118.900982 | -118.579687 | -118.79089 | -118.69752 |
| SITE_ELEV | 196 | 505 | 150 | 349 |
| ***Catchment*** | | | | |
| AREA_SQKM | 9.83 | 19.96 | 3.91 | 181.51 |
| ELEV_RANGE | 633 | 1,180 | 340 | 791 |
| ***Climate*** | | | | |
| TEMP_00_09 | 2,420 | 2,482 | 2,478 | 2,588 |
| PPT_00_09 | 44,011 | 52,926 | 43,587 | 57,303 |
| SumAve_P | 319 | 552 | 318 | 341 |
| ***Geology*** | | | | |
| KFCT_AVE | 0.218 | 0.307 | 0.234 | 0.298 |
| BDH_AVE | 1.563 | 1.577 | 1.548 | 1.581 |
| PRMH_AVE | 2.193 | 5.000 | 2.517 | 5.195 |
| LPREM_mean | -0.799 | -0.766 | -0.745 | -0.318 |
| PCT_SEDIM | 100 | 100 | 40 | 100 |
| MgO_Mean | 2.85 | 6.28 | 4.76 | 6.36 |
| P_MEAN | 0.111 | 0.130 | 0.112 | 0.204 |
| CaO_Mean | 5.30 | 17.55 | 10.84 | 17.78 |
| S_Mean | 0.366 | 1.276 | 0.523 | 1.255 |
| N_MEAN | 0.0547 | 0.0607 | 0.0456 | 0.1294 |
| ***CSCI Model Output*** | | | | |
| pMMI | 0.92 | 1.06 | 0.31 | 0.99 |
| E | 10.59 | 12.80 | 6.85 | 11.02 |
| O/E | 0.98 | 1.25 | 0.11 | 1.16 |
| CSCI | 0.99 | 1.15 | 0.30 | 1.02 |

When comparing the reference calibration sites in Monterey/Modelo Formation with Malibu Creek Watershed sites in Monterey/Modelo Formation, we noted that the maximum observed pMMI, O/E, and CSCI scores are similar, which suggested that high-quality sites in the Monterey/Modelo Formation in the Malibu Creek Watershed are scored accurately with the CSCI scoring tool. In a few cases, the geology predictors vary somewhat between the Monterey/Modelo reference calibration sites and the Malibu Creek sites. In particular, the maximum observed whole rock mean nitrogen and phosphorus are somewhat higher for Malibu Creek Watershed sites than for these reference calibration sites.

USEPA also noted that the California O/E model does not utilize geology predictors. The predictors used by the O/E model include latitude, elevation, catchment area, average annual maximum temperature and average annual precipitation. Temperature and precipitation are comparable between the reference calibration sites and those in the Malibu Creek Watershed sites. Latitude, catchment size, and elevation differ slightly.

Finally, some concern about the limited number of low gradient coastal sites included in the development of the SC-IBI raised questions about the applicability of bioassessment scoring tools in Malibu Creek Watershed. The CSCI Science Team determined that the models showed a lack of bias to stream gradient (R. Mazor, 2013, personal communication), and, therefore, should not be a limiting factor when applying the CSCI bioassessment scoring methods.

#### 8.1.6.2 O/E, pMMI, and CSCI Results

For all three models (O/E, pMMI, and CSCI), higher scores represent higher benthic community quality or condition at the site. As described above, California has not yet set thresholds for impairment; however, threshold values were provided for each score produced by the CSCI model (Table 8-1). Sites with scores above the 10$^{th}$ percentile threshold are considered attaining near reference conditions, while sites below the 5$^{th}$ percentile threshold are considered to not be attaining reference conditions.

Scores at Malibu Creek sites for all three indices range from approximately zero (0) to approximately 1.3. Table 8-13 through Table 8-15 present the CSCI, O/E, and pMMI results, respectively. Scores falling between the 5$^{th}$ and 10$^{th}$ percentile thresholds for each model were printed in yellow on a yellow background, and scores falling below the 5$^{th}$ percentile threshold were printed in red on a red background. Asterisks in Table 8-14 and Table 8-15 identify samples with warning flags for ambiguous individuals (for the O/E model) or insufficient organism count (for the pMMI model). Scores with asterisks should be interpreted with caution. (See Appendix D for a detailed discussion of warning flags.)

**Table 8-13. CSCI Scores for Sites in the Malibu Creek Watershed, Grouped by Stream and Presented Downstream to Upstream**

| Stream Name | Site | CSCI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Malibu Creek | HtB-MC-1 | 0.71 | 0.46 | 0.76 | 0.76 | 0.68 | | 0.82 | 0.66 | | 0.70 | | 0.65 | | 0.42 | 0.51 | 0.46 | 0.82 |
| | LVWMD-R4D | | | | | | | | | | | | 0.71<br>0.19 | 0.61 | 0.49 | 0.48 | 0.65 | 0.51 |
| | MAL | | | | | | | | | | 0.77 | 0.65 | | | | | | |
| | LVWMD-R3D | | | | | | | | | | | | 0.57<br>0.14 | 0.56 | 0.52 | 0.55 | 0.60 | 0.56 |
| | 404S11406 | | | | | | | | | | | | | | | 0.58 | | |
| | EPA-1 | | | | | | | | | | | | | | | | | 0.83 |
| | SMC01384 | | | | | | | | | | | | | | | 0.81 | | |
| | LVWMD-R13D | | | | | | | | | | | | 0.73 | 0.67 | 0.56 | 0.59 | 0.47 | 0.52 |
| | HtB-MC-15 | 0.92 | | 0.84 | | 0.79 | 0.65 | 0.86 | 0.70 | | | | 0.73 | | | 0.39 | 0.38 | 0.68 |
| | LVWMD-R2D | | | | | | | | | | | | 0.60<br>0.42 | 0.78 | 0.50 | 0.54 | 0.59 | 0.57 |
| | LVWMD-R1U | | | | | | | | | | | | 0.61<br>0.37 | 0.67 | 0.45 | 0.58 | 0.58 | 0.60 |
| | EPA-2 | | | | | | | | | | | | | | | | | 0.66 |
| | LVWMD-R9U | | | | | | | | | | | | | 0.68 | 0.43 | 0.45 | 0.53 | 0.62 |
| | HtB-MC-12 | | 0.84 | 0.73 | 0.88 | 0.76 | 0.84 | 0.76 | 0.82 | | 0.59 | | 0.68 | | 0.60 | 0.30 | 0.42 | 0.46 |
| | EPA-3 | | | | | | | | | | | | | | | | | 0.56 |
| Cold Creek | HtB-CC-2 | 1.02 | | 0.97 | 1.01 | 1.06 | | 0.98 | | | 0.87<br>0.93 | | 0.69<br>0.92 | | | 0.79 | 0.67 | 0.72 |
| | HtB-CC-11 | 1.01 | 0.57 | 0.95 | 0.99 | 1.10 | | 0.81 | | | | | 0.81 | | | 0.99 | 0.70<br>0.74 | 1.03 |

| Stream Name | Site | CSCI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Cold Creek (cont.) | LACo_17 | | | | | | | 0.80 | | 0.91 | 0.84 | | 0.91 | 1.00 | 0.83 | | | |
| | HtB-CC-3 | 1.04 | 1.03 | 1.11 | 1.01 | 1.11 | 1.00 | 1.04 | 1.01 | | 0.74 | | 0.96 | | 0.80 | 0.90<br>1.03 | 0.85 | 0.88 |
| Stokes Creek | HtB-STC-16 | | | | | 0.94 | | | | | | | 0.83 | | | | | |
| Las Virgenes Creek | HtB-LV-5 | 0.82 | 0.70 | 0.75 | 0.86 | 0.94 | 0.77 | 0.82 | 0.81 | | 0.70<br>0.67 | | 0.58<br>0.69 | | | 0.63 | 0.43 | |
| | 404S17266 | | | | | | | | | | | | | | | 0.65 | | |
| | EPA-4 | | | | | | | | | | | | | | | | | 0.79 |
| | LV2 | | | | | | | | | | 0.73 | 0.36 | | | | | | |
| | 404S22464 | | | | | | | | | | | | | | | 0.48 | | |
| | LVWMD-R7D | | | | | | | | | | | | 0.57 | 0.57 | 0.36 | 0.49 | 0.43 | 0.53 |
| | HtB-LV-13 | | | 0.67 | | 0.65 | 0.74 | 0.63 | 0.73 | | 0.62 | | 0.61 | | | 0.48 | 0.55 | |
| | 404S17664 | | | | | | | | | | | | | | | 0.52 | | |
| | SMC01640 | | | | | | | | | | | | | | | 0.38 | | |
| | LV1 | | | | | | | | | | 0.85 | 0.80 | | | | | | |
| | LACo_16 | | | | | | | | | | 0.85 | | 0.44 | 0.50 | 0.31 | | | |
| | HtB-LV-9 | | | 0.96 | 0.95 | 0.93 | 0.87 | 0.89 | | | 0.85 | | 0.84 | | | 0.72 | 0.63 | 0.84 |
| Cheseboro Creek | HtB-CH-6 | | | 1.02 | 0.93 | 1.02 | | 0.87 | | | 0.75 | | 0.73 | | | | 0.63 | |
| Palo Comado Canyon | 404S08040 | | | | | | | | | | | | | | | 0.45 | | |
| | HtB-PC-8 | | | 1.04 | | | | | | | 0.86 | | | | | | | |
| Medea Creek | MED2 | | | | | | | | | | 0.43 | 0.39 | | | | | | |
| | HtB-MDC-21 | | | | | | | | | | | | 0.37 | | | | | |
| | 404S16516 | | | | | | | | | | | | | | | 0.51 | | |

| Stream Name | Site | CSCI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Medea Creek (cont.) | HtB-MD-7 | 0.80 | 0.79 | 0.59 | 0.84 | 0.66 | | 0.71 | 0.66 | | 0.37 | | 0.53 | | | 0.26 | 0.44 | |
| | LACo_15 | | | | | | | 0.34 | | 0.43 | 0.40 | | 0.19 | 0.30 | 0.54 | | | |
| | 404S05992 | | | | | | | | | | | | | | | 0.45 | | |
| | MED1 | | | | | | | | | | 0.71 | 0.33 | | | | | | |
| | 404S02920 | | | | | | | | | | | | | | | 0.50 | | |
| Lindero Creek | LIN1 | | | | | | | | | | 0.59 | 0.65 | | | | | | |
| | 404S03048 | | | | | | | | | | | | | | | 0.72 | | |
| Triunfo Creek | LACo_18 | | | | | | | 0.62 | | | 0.73 | | 0.52 | 0.56 | 0.70 | | | |
| | HtB-TR-17 | | | 0.62 | | 0.73 | | 0.63 | | | 0.42 | | 0.61 | | | 0.53 | 0.39 | 0.54 |
| | 404S08616 | | | | | | | | | | | | | | | 0.46<br>0.37 | | |
| | TRI | | | | | | | | | | 0.52 | 0.43 | | | | | | |
| Hidden Valley Creek | HV | | | | | | | | | | 0.71 | | | | | | | |
| West Carlyle Creek | HtB-WC-10 | | | 0.84 | | | | 0.88 | | | | | | | | | | |
| Arroyo Sequit | HtB-AS-19 | | | | 0.95 | 1.13 | 1.12 | 1.16 | 1.13 | | 0.96 | | 0.79 | | 0.96 | 0.99 | 1.03 | 0.83 |
| Lachusa Creek | HtB-LCH-18 | | | | 1.17 | 1.20 | 1.11 | 1.08 | 1.01 | | 0.84 | | 0.73 | | | 0.90 | 0.86 | 0.84 |
| Solstice Creek | HtB-SC-14 | | | | 1.22 | 1.22 | 1.11 | 0.95 | 1.00 | | 0.89 | | 0.73 | | 0.80 | 0.93 | 0.78 | 0.90 |
| | HtB-SC-22 | | | | | | | | | | | | 0.80 | | | 0.73 | 0.62<br>0.62 | 0.71<br>0.80 |

**Table 8-14. O/E Scores for Sites in the Malibu Creek Watershed, Grouped by Stream and Presented Downstream to Upstream (asterisks indicate samples flagged for >20% ambiguous individuals)**

| Stream Name | Site | E | O/E | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Malibu Creek | HtB-MC-1 | 7.58 | 0.85 | 0.49 | 1.00 | 0.90 | 0.81 | | 1.07 | 0.82 | | 0.79 | | 0.66 | | 0.47 | 0.59 | 0.49 | 1.05 |
| | LVWMD-R4D | 7.58 | | | | | | | | | | | | 0.66*<br>0.13 | 0.88 | 0.40* | 0.53* | 0.78 | 0.53* |
| | MAL | 7.70 | | | | | | | | | | 0.99 | 0.76 | | | | | | |
| | LVWMD-R3D | 7.70 | | | | | | | | | | | | 0.52<br>0.13 | 0.74 | 0.52* | 0.60* | 0.63 | 0.65* |
| | 404S11406 | 7.70 | | | | | | | | | | | | | | | 0.71 | | |
| | EPA-1 | 7.71 | | | | | | | | | | | | | | | | | 1.06 |
| | SMC01384 | 7.75 | | | | | | | | | | | | | | | 0.88 | | |
| | LVWMD-R13D | 7.75 | | | | | | | | | | | | 0.65 | 0.74 | 0.64 | 0.65* | 0.39 | 0.52* |
| | HtB-MC-15 | 7.75 | 1.14 | | 1.01 | | 0.90 | 0.83 | 1.06 | 0.80 | | | | 0.77* | | | 0.39* | 0.39* | 0.77* |
| | LVWMD-R2D | 7.75 | | | | | | | | | | | | 0.52<br>0.46 | 1.03 | 0.52* | 0.64* | 0.64* | 0.61* |
| | LVWMD-R1U | 7.76 | | | | | | | | | | | | 0.52<br>0.26 | 1.00 | 0.52* | 0.64* | 0.73 | 0.64* |
| | EPA-2 | 7.76 | | | | | | | | | | | | | | | | | 0.93 |
| | LVWMD-R9U | 7.75 | | | | | | | | | | | | | 0.90 | 0.39* | 0.39* | 0.52* | 0.65* |
| | HtB-MC-12 | 7.69 | | 0.98 | 0.98 | 1.01 | 1.00 | 1.11 | 1.02 | 0.99 | | 0.52 | | 0.76 | | 0.61 | 0.26 | 0.39 | 0.39* |
| | EPA-3 | 7.66 | | | | | | | | | | | | | | | | | 0.74 |
| Cold Creek | HtB-CC-2 | 10.48 | 1.16 | | 1.02 | 0.95 | 1.22 | | 1.21 | | | 0.86<br>0.94 | | 0.67<br>0.95 | | | 0.86 | 0.67* | 0.76* |

| Stream Name | Site | E | O/E | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Cold Creek (cont.) | HtB-CC-11 | 8.90 | 1.04 | 0.34 | 0.88 | 1.07 | 1.16 | | 0.96 | | | | | 0.76 | | | 0.90* | 0.56*<br>0.67* | 1.01* |
| | LACo_17 | 6.83 | | | | | | | 0.64 | | 0.71 | 0.65 | | 0.73 | 0.86 | 0.56 | | | |
| | HtB-CC-3 | 6.84 | 1.02 | 0.96 | 1.05 | 0.97 | 1.08 | 0.86 | 0.94 | 0.98 | | 0.52 | | 0.86 | | 0.58 | 0.72<br>0.88 | 0.58* | 0.88* |
| Stokes Creek | HtB-STC-16 | 10.97 | | | | | 1.12 | | | | | | | 0.82* | | | | | |
| Las Virgenes Creek | HtB-LV-5 | 7.75 | 0.92 | 0.76 | 0.99 | 1.03 | 1.16 | 0.98 | 1.10 | 1.05 | | 0.77<br>0.77 | | 0.65<br>0.75 | | | 0.77* | 0.39 | |
| | 404S17266 | 8.84 | | | | | | | | | | | | | | | 0.83 | | |
| | EPA-4 | 8.85 | | | | | | | | | | | | | | | | | 1.01 |
| | LV2 | 8.87 | | | | | | | | | | 0.89 | 0.41 | | | | | | |
| | 404S22464 | 8.87 | | | | | | | | | | | | | | | 0.60 | | |
| | LVWMD-R7D | 9.37 | | | | | | | | | | | | 0.57 | 0.71 | 0.32 | 0.43* | 0.41 | 0.50 |
| | HtB-LV-13 | 9.90 | | | 0.77 | | 0.76 | 0.85 | 0.78 | 0.89 | | 0.61 | | 0.61 | | | 0.51* | 0.51 | |
| | 404S17664 | 10.98 | | | | | | | | | | | | | | | 0.58 | | |
| | SMC01640 | 11.02 | | | | | | | | | | | | | | | 0.33 | | |
| | LV1 | 8.82 | | | | | | | | | | 1.02 | 0.87 | | | | | | |
| | LACo_16 | 8.81 | | | | | | | | | | 0.79* | | 0.23* | 0.34* | 0.11 | | | |
| | HtB-LV-9 | 8.30 | | | 1.07 | 0.94 | 0.92 | 0.99 | 0.95 | | | 0.84* | | 0.84* | | | 0.60* | 0.48* | 0.84* |
| Cheseboro Creek | HtB-CH-6 | 7.68 | | | 1.13 | 0.87 | 1.09 | | 0.98 | | | 0.64 | | 0.65* | | | | 0.52 | |
| Palo Comado Canyon | 404S08040 | 10.96 | | | | | | | | | | | | | | | 0.46 | | |
| | HtB-PC-8 | 6.73 | | | 1.18 | | | | | | | 0.89* | | | | | | | |
| Medea Creek | MED2 | 8.90 | | | | | | | | | | 0.45 | 0.44 | | | | | | |

| Stream Name | Site | E | O/E | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Medea Creek (cont.) | HtB-MDC-21 | 8.90 | | | | | | | | | | | | 0.34 | | | | | |
| | 404S16516 | 8.90 | | | | | | | | | | | | | | | 0.63 | | |
| | HtB-MD-7 | 8.89 | 0.95 | 0.90 | 0.74 | 1.01 | 0.84 | | 0.86 | 0.87 | | 0.32 | | 0.55 | | | 0.21 | 0.45 | |
| | LACo_15 | 8.82 | | | | | | | 0.32 | | 0.40 | 0.41 | | 0.08 | 0.23 | 0.53 | | | |
| | 404S05992 | 8.33 | | | | | | | | | | | | | | | 0.60 | | |
| | MED1 | 8.22 | | | | | | | | | | 0.93 | 0.45 | | | | | | |
| | 404S02920 | 7.58 | | | | | | | | | | | | | | | 0.60 | | |
| Lindero Creek | LIN1 | 8.31 | | | | | | | | | | 0.72 | 0.72 | | | | | | |
| | 404S03048 | 6.85 | | | | | | | | | | | | | | | 0.96 | | |
| Triunfo Creek | LACo_18 | 8.32 | | | | | | | 0.60* | | | 0.72* | | 0.36 | 0.48* | 0.70* | | | |
| | HtB-TR-17 | 8.86 | | | 0.81 | | 0.86 | | 0.81 | | | 0.45 | | 0.68* | | | 0.56 | 0.34* | 0.56* |
| | 404S08616 | 8.85 | | | | | | | | | | | | | | | 0.54<br>0.45 | | |
| | TRI | 8.87 | | | | | | | | | | 0.67 | 0.54 | | | | | | |
| Hidden Valley Creek | HV | 8.23 | | | | | | | | | | 0.72 | | | | | | | |
| West Carlyle Creek | HtB-WC-10 | 8.21 | | | 0.90 | | | | 0.87 | | | | | | | | | | |
| Arroyo Sequit | HtB-AS-19 | 8.95 | | | | 0.99 | 1.15 | 1.24 | 1.22 | 1.22 | | 0.89 | | 0.74 | | 1.01* | 1.01* | 1.01* | 0.78 |
| Lachusa Creek | HtB-LCH-18 | 6.68 | | | | 1.27 | 1.33 | 1.15 | 1.16 | 1.05 | | 0.75* | | 0.90 | | | 0.90* | 0.90* | 0.90* |
| Solstice Creek | HtB-SC-14 | 7.67 | | | | 1.25 | 1.28 | 1.11 | 0.91 | 0.94 | | 0.65* | | 0.52* | | 0.78* | 0.78 | 0.65* | 0.76* |
| | HtB-SC-22 | 7.73 | | | | | | | | | | | | 0.65* | | | 0.65* | 0.52*<br>0.52* | 0.65*<br>0.78* |

**Table 8-15. pMMI Scores for Sites in the Malibu Creek Watershed, Grouped by Stream and Presented Downstream to Upstream (asterisks indicate samples flagged for <450 individuals)**

| Stream Name | Site | pMMI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Malibu Creek | HtB-MC-1 | 0.58 | 0.43 | 0.52 | 0.62 | 0.55 | | 0.57 | 0.50 | | 0.60 | | 0.64 | | 0.36 | 0.42 | 0.43 | 0.59 |
| | LVWMD-R4D | | | | | | | | | | | | 0.77<br>0.25 | 0.34 | 0.59 | 0.42 | 0.51 | 0.49 |
| | MAL | | | | | | | | | | 0.56 | 0.54 | | | | | | |
| | LVWMD-R3D | | | | | | | | | | | | 0.62<br>0.15 | 0.38 | 0.52* | 0.49 | 0.57 | 0.47 |
| | 404S11406 | | | | | | | | | | | | | | | 0.44 | | |
| | EPA-1 | | | | | | | | | | | | | | | | | 0.60 |
| | SMC01384 | | | | | | | | | | | | | | | 0.73 | | |
| | LVWMD-R13D | | | | | | | | | | | | 0.81 | 0.59 | 0.48 | 0.54 | 0.56 | 0.53 |
| | HtB-MC-15 | 0.71 | | 0.67 | | 0.68 | 0.47 | 0.65 | 0.61 | | | | 0.68 | | | 0.39 | 0.37 | 0.58 |
| | LVWMD-R2D | | | | | | | | | | | | 0.69<br>0.37 | 0.52 | 0.48 | 0.44 | 0.53 | 0.53 |
| | LVWMD-R1U | | | | | | | | | | | | 0.71<br>0.49 | 0.34 | 0.39 | 0.51 | 0.43 | 0.55 |
| | EPA-2 | | | | | | | | | | | | | | | | | 0.38 |
| | LVWMD-R9U | | | | | | | | | | | | | 0.46 | 0.48* | 0.51 | 0.54 | 0.60 |
| | HtB-MC-12 | | 0.71 | 0.48 | 0.75 | 0.51 | 0.58 | 0.50 | 0.66 | | 0.66 | | 0.60 | | 0.59 | 0.34 | 0.45 | 0.52 |
| | EPA-3 | | | | | | | | | | | | | | | | | 0.38 |
| Cold Creek | HtB-CC-2 | 0.88 | | 0.93 | 1.07* | 0.91 | | 0.74 | | | 0.89<br>0.92 | | 0.71<br>0.88 | | | 0.72 | 0.68 | 0.69 |

| Stream Name | Site | pMMI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Cold Creek (cont.) | HtB-CC-11 | 0.97 | 0.81 | 1.03 | 0.92* | 1.03 | | 0.66 | | | | | 0.87 | | | 1.08 | 0.85<br>0.81 | 1.04 |
| | LACo_17 | | | | | | | 0.97 | | 1.11 | 1.03 | | 1.09 | 1.14 | 1.10 | | | |
| | HtB-CC-3 | 1.07 | 1.10 | 1.17 | 1.04 | 1.14 | 1.13 | 1.14 | 1.04 | | 0.96 | | 1.06 | | 1.02 | 1.09<br>1.19 | 1.12 | 0.89 |
| Stokes Creek | HtB-STC-16 | | | | | 0.76 | | | | | | | 0.84 | | | | | |
| Las Virgenes Creek | HtB-LV-5 | 0.72 | 0.65 | 0.52 | 0.68 | 0.72 | 0.55 | 0.54 | 0.56 | | 0.63<br>0.56 | | 0.52<br>0.62 | | | 0.49 | 0.48 | |
| | 404S17266 | | | | | | | | | | | | | | | 0.48 | | |
| | EPA-4 | | | | | | | | | | | | | | | | | 0.58 |
| | LV2 | | | | | | | | | | 0.57 | 0.32 | | | | | | |
| | 404S22464 | | | | | | | | | | | | | | | 0.36 | | |
| | LVWMD-R7D | | | | | | | | | | | | 0.58 | 0.43 | 0.40 | 0.56 | 0.45 | 0.56 |
| | HtB-LV-13 | | | 0.56 | | 0.54 | 0.63 | 0.48 | 0.58 | | 0.63 | | 0.62 | | | 0.46 | 0.60 | |
| | 404S17664 | | | | | | | | | | | | | | | 0.45 | | |
| | SMC01640 | | | | | | | | | | | | | | | 0.42 | | |
| | LV1 | | | | | | | | | | 0.69 | 0.74 | | | | | | |
| | LACo_16 | | | | | | | | | | 0.91 | | 0.65 | 0.65 | 0.51 | | | |
| | HtB-LV-9 | | | 0.85 | 0.96 | 0.94 | 0.75 | 0.84 | | | 0.85 | | 0.84 | | | 0.83 | 0.79 | 0.84 |
| Cheseboro Creek | HtB-CH-6 | | | 0.90 | 0.99 | 0.95 | | 0.76 | | | 0.85 | | 0.82 | | | | 0.74 | |
| Palo Comado Canyon | 404S08040 | | | | | | | | | | | | | | | 0.43 | | |
| | HtB-PC-8 | | | 0.89 | | | | | | | 0.82 | | | | | | | |
| Medea Creek | MED2 | | | | | | | | | | 0.41 | 0.34 | | | | | | |

| Stream Name | Site | pMMI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 (early) | 2000 (late) | 2001 (early) | 2001 (late) | 2002 (early) | 2002 (late) | 2003 (early) | 2003 (late) | 2004 | 2005 (early) | 2005 (late) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Medea Creek (cont.) | HtB-MDC-21 | | | | | | | | | | | | 0.39 | | | | | |
| | 404S16516 | | | | | | | | | | | | | | | 0.39 | | |
| | HtB-MD-7 | 0.64 | 0.67 | 0.44 | 0.67 | 0.47 | | 0.57 | 0.46 | | 0.42 | | 0.51 | | | 0.31 | 0.44 | |
| | LACo_15 | | | | | | | 0.36 | | 0.47 | 0.39 | | 0.29 | 0.38 | 0.54 | | | |
| | 404S05992 | | | | | | | | | | | | | | | 0.31 | | |
| | MED1 | | | | | | | | | | 0.49 | 0.22 | | | | | | |
| | 404S02920 | | | | | | | | | | | | | | | 0.39 | | |
| Lindero Creek | LIN1 | | | | | | | | | | 0.46 | 0.57 | | | | | | |
| | 404S03048 | | | | | | | | | | | | | | | 0.49 | | |
| Triunfo Creek | LACo_18 | | | | | | | 0.65* | | | 0.73 | | 0.67* | 0.63 | 0.70 | | | |
| | HtB-TR-17 | | | 0.43 | | 0.61 | | 0.45 | | | 0.39 | | 0.53 | | | 0.50* | 0.44 | 0.52 |
| | 404S08616 | | | | | | | | | | | | | | | 0.38<br>0.30 | | |
| | TRI | | | | | | | | | | 0.37 | 0.32 | | | | | | |
| Hidden Valley Creek | HV | | | | | | | | | | 0.70 | | | | | | | |
| West Carlyle Creek | HtB-WC-10 | | | 0.78 | | | | 0.89 | | | | | | | | | | |
| Arroyo Sequit | HtB-AS-19 | | | | 0.92 | 1.11 | 0.99 | 1.09 | 1.04 | | 1.04 | | 0.83 | | 0.91 | 0.97 | 1.05 | 0.88 |
| Lachusa Creek | HtB-LCH-18 | | | | 1.08 | 1.06 | 1.08 | 0.99 | 0.98 | | 0.92 | | 0.56 | | | 0.90 | 0.82 | 0.78 |
| Solstice Creek | HtB-SC-14 | | | | 1.18 | 1.16 | 1.11 | 0.99 | 1.07 | | 1.12 | | 0.94 | | 0.82 | 1.08 | 0.91 | 1.04 |
| | HtB-SC-22 | | | | | | | | | | | | 0.95 | | | 0.82 | 0.72<br>0.72 | 0.77<br>0.83 |

**General Trends**

The SC-IBI results presented earlier show that the benthic macroinvertebrate community in Malibu Creek and its primary tributaries is impaired. The highest median SC-IBI scores appeared in the un-impacted headwaters of Cold Creek (CC-3), and the lowest median SC-IBI scores appeared in the main stem and in lower portions of Triunfo Creek, Medea Creek, and Las Virgenes Creek. The tributary stations with low scores are located upstream of the impaired portions of the Malibu Creek main stem and are downstream of developed areas of the watershed, while stations upstream of developed areas had consistently higher scores.

The SC-IBI trends are similarly observed with the CSCI and pMMI results (Table 8-13 and Table 8-15). The box plot comparing the Malibu Creek main stem sites to comparator/reference sites for the pMMI shows qualitatively the same results as the SC-IBI (Figure 8-5) (CC-3 has the highest pMMI of all comparator/reference sites). In contrast, the O/E results do not show the same temporal trend as the other indices. Instead, the O/E results indicate higher watershed scores overall until 2005 (Table 8-14). The O/E scores show that the main stem Malibu Creek sites are similar to the comparator/reference sites and Upper Cold Creek (CC-3), both within and outside of the Monterey/Modelo Formation (Figure 8-6). The CSCI, or California Stream Condition Index, is an average of the O/E and the pMMI.

Unlike the pMMI scores, the O/E results (Figure 8-6) do not appear to differentiate between reference and impaired sites in the Malibu Creek Watershed (Figure 8-5). Because CSCI is the average of pMMI and O/E, the CSCI results, by definition, fall between the pMMI and O/E results (Figure 8-7). As an average of two endpoints having different sensitivities in different settings, SWRCB expects the CSCI to retain high sensitivity across all environmental settings on a statewide basis; however, the averaging approach may obscure information reflective of an individual watershed. In many ways, this is not unexpected since the O/E and pMMI methods provide different information about the benthic community. The O/E method is generally more sensitive to species loss and able to reflect the impact of species loss to the benthic community; pMMI is sensitive to community function and reflect better the characteristics of the benthic species' function (e.g., presence of scrapers, grazers, etc.) (K. Schiff , 2013, personal communication,; See draft documents on CSCI applicability as a bioassement scoring tool: http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml).

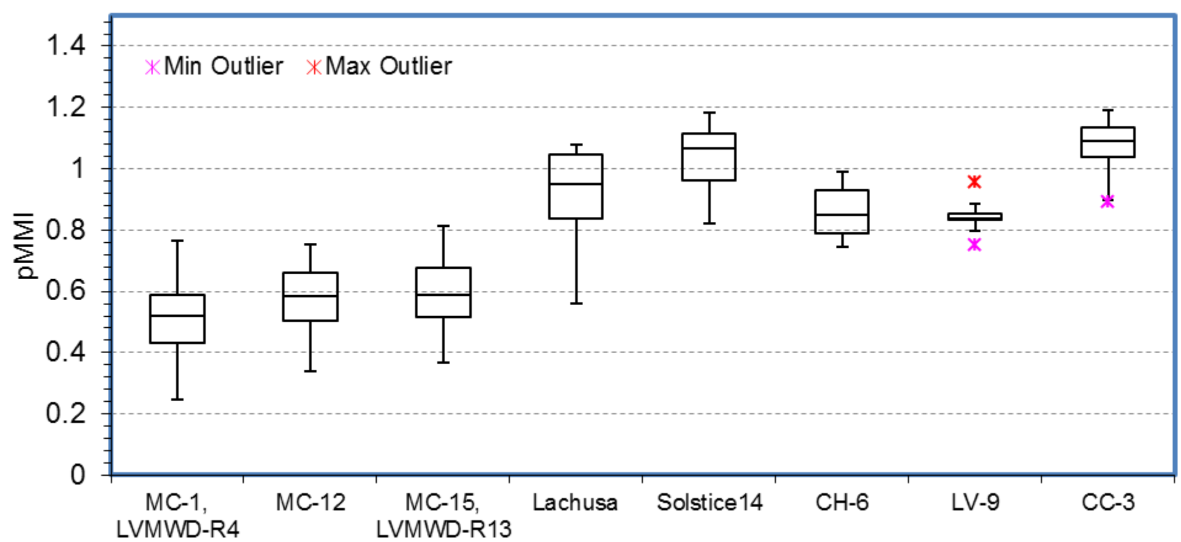



**Figure 8-5. Comparison of pMMI Distributions for Malibu Creek to Local Comparator/Reference Sites, 2000-2011**

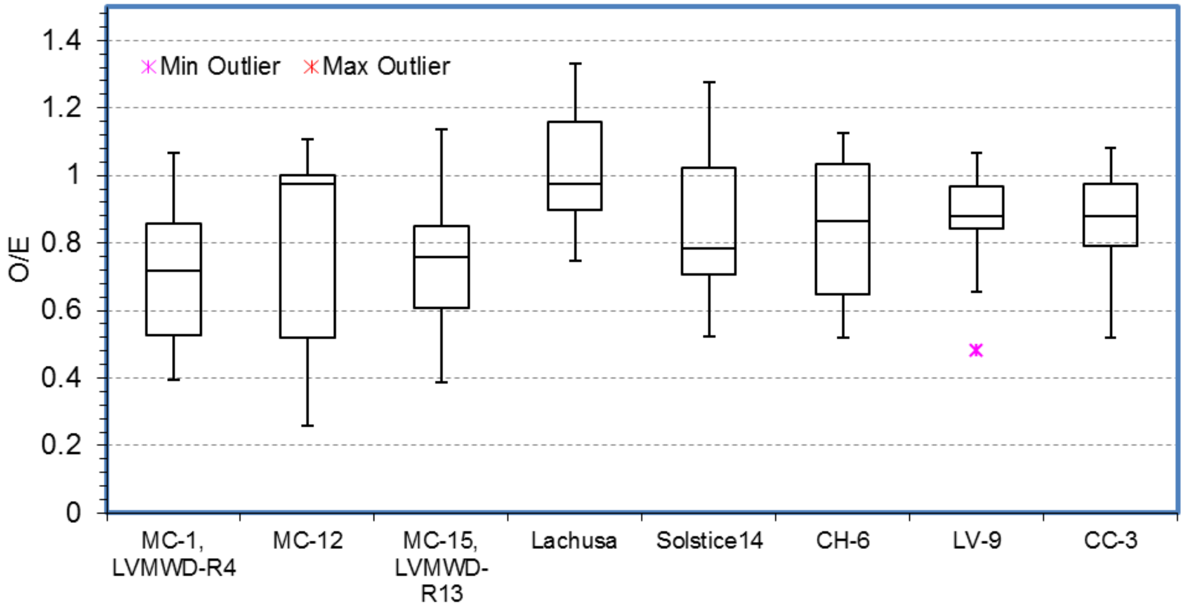



**Figure 8-6. Comparison of O/E Distributions for Malibu Creek to Local Comparator/reference Sites, 2000-2011**

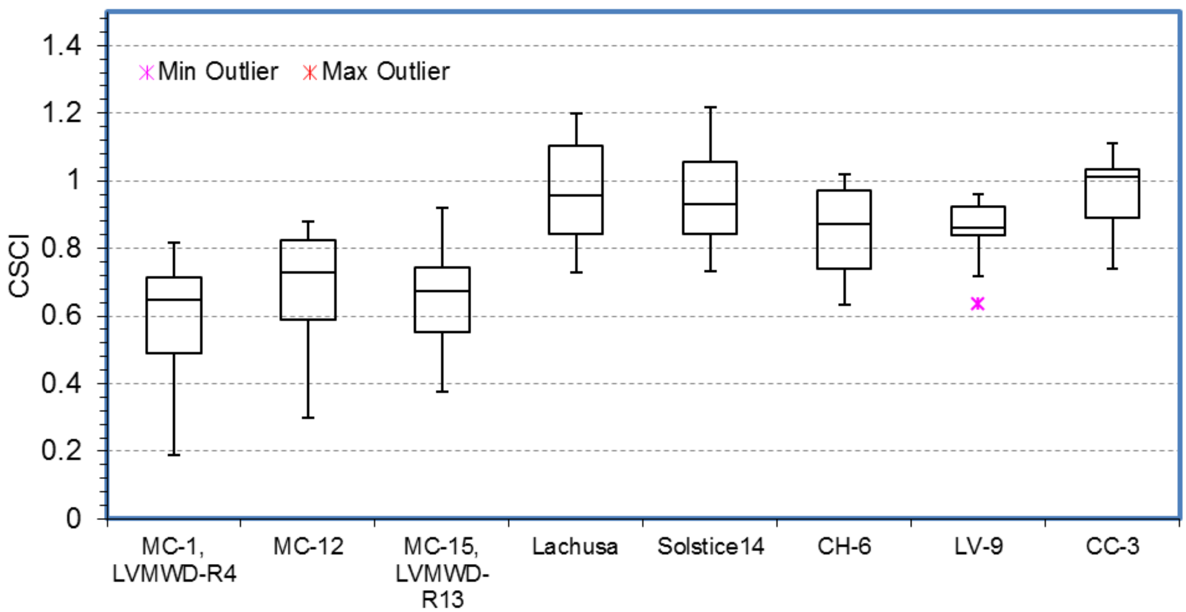



**Figure 8-7. Comparison of CSCI Distributions for Malibu Creek to Local Comparator/reference Sites, 2000-2011**

### Difference Between O/E and pMMI

In general, the O/E results exhibit a positive bias relative to the pMMI results for the Malibu Creek Watershed (Figure 8-8). In other words, where results between the O/E and the pMMI disagree, the O/E generally indicates better stream condition than the pMMI, or in other words, overestimates the quality of the stream condition. This is consistent with findings presented by the CSCI development team (R. Mazor, 2013, personal communication).

Further evaluation of the O/E results shows that the expected number of taxa (E, Table 8-14) for all sites in the watershed ranged from 6.7 to 11, with the majority of sites having E values less than 9.5. The CSCI Science Team found that disagreement between O/E and pMMI occurred more frequently when E was low (e.g., <10). When E is low or few sensitive taxa are expected, O/E exhibited a limited range of response. With few taxa expected, the O/E scores tend to be less robust because the variable range is narrow and sensitive taxa or natural variability are not reflected. Consistent predictions of sensitive taxa were observed only when E ≥ 14 (R. Mazor, 2013, personal communication).

Moreover, as noted above, the O/E model does not include geology variables, but only includes location, elevation, catchment area, and climate variables as predictors. Exactly how much this affects the expected taxonomic composition at sites in the Malibu Creek Watershed was not clear, but the pMMI model, which does use geology variables as predictors, provided a better representation of conditions observed in the watershed. In sum, geology appeared to be a factor in the watershed (see below) and should not be discounted. However, in the Malibu Creek Watershed, geology by itself was not a factor negatively impacting benthic macroinvertebrate condition, but instead, an important consideration when determining overall condition.

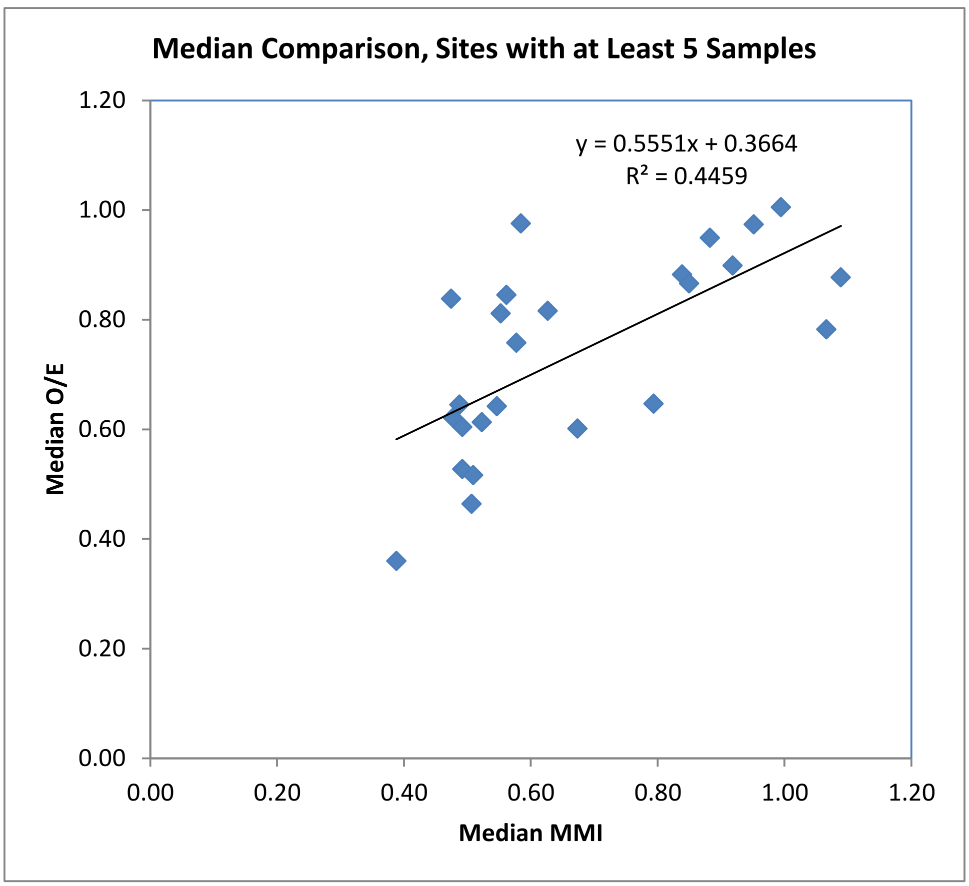



**Figure 8-8. Positive bias observed for O/E scores relative to pMMI scores**

## 8.1.7 Benthic Macroinvertebrates & Other Stressors

USEPA examined other variables and their potential relationships to the benthic macroinvertebrate bioscores.

### 8.1.7.1 Conductivity

Specific conductivity is a measure of ionic strength (saltiness). Elevated conductivity is associated with drainage from marine sediments, such as the Monterey/Modelo Formation, and is also associated with urban and agricultural runoff in warm, dry climates. Figure 8-9 shows the correlation between median SC-IBI and median conductivity for sites with at least five samples from 2000 through 2010 (water quality data were not yet available for 2011). Higher conductivity values separate out those sites within the Monterey/Modelo Formation and those with substantial contribution from urban runoff activities.

**Biological Condition and Conductivity Trends**

In-depth analyses demonstrated that focusing on conductivity as an independent stressor can be misleading and challenging because of the multiple stressors and sources at play. For instance, the simple linear regression equation computed to evaluate the relationship between median conductivity and median SC-IBI suggests a weak negative correlation exists. However, note that Malibu Creek main stem (MC-1) and Triunfo Creek (TR-17) stations show intermediate conductivity levels and very low SC-IBI bioscores. Furthermore, the un-impacted Cheseboro Creek station (CH-6), in the Monterey/Modelo Formation, exhibited high conductivity levels and high median SC-IBI bioscores; these bioscores are as high as the LCH-18 reference station, which is *not* in the Monterey/Modelo Formation. This indicates that conductivity, by itself, can neither provide a trend nor explain the benthic macroinvertebrate community response. The simple linear regression estimate is not predictive, but a statistical tool to identify if a single variable can explain the observed biological response. In this case, conductivity does not explain the biologic response well. The geologic characteristics of the sites are highlighted in the regression graph (i.e., green and pink circles) and show that CH-6 and LV-9 in Monterey/Modelo Formation have comparable bioscores as those in non-marine geology.

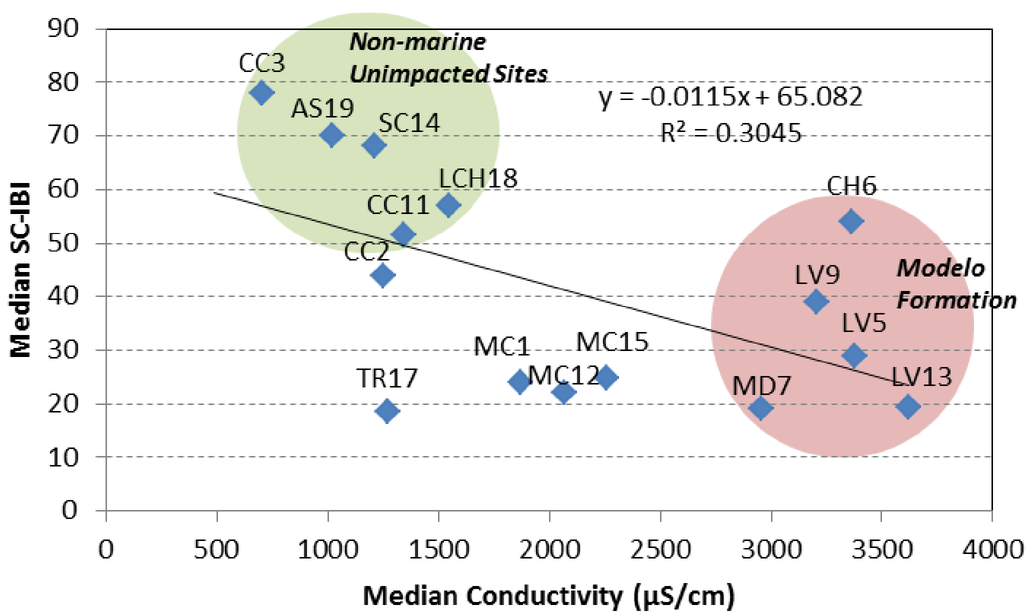



**Figure 8-9. Correlation of Median SC-IBI Scores with Median Conductivity**

Note: Sites with at least five observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples.

Further examination of the graph above show that the Monterey/Modelo Formation is located north of the Interstate 101 corridor and in the region of high density development. Factoring for this additional variable, the results appear to correlate better with the presence of upstream high density development (refer to Figure 4-7) than with Monterey/Modelo Formation drainage (Figure 8-10). This is evidenced by the following: the Cheseboro station (CH-6) is in the Monterey/Modelo Formation, drains an un-impacted/undeveloped area, and exhibits high SC-IBI and pMMI scores; the Triunfo station (TR-17) exhibits low conductivity, drains upstream development, and shows very low SC-IBI and pMMI scores.

We note that the Miocene Monterey Formation is not unique to Malibu Creek Watershed and in fact is widely present in the California Coast Ranges, Transverse Ranges, and adjacent basins (e.g., San Joaquin Valley, the onshore Santa Maria basin, and the Ventura basin) (Isaacs, 1984). In our assessment of the benthic macroinvertebrate community condition and related benthic measures, sites located in the Monterey/Modelo Formation areas and un-impacted by upstream or adjacent anthropogenic activities consistently demonstrated high bioscores compared to other sites in the watershed.

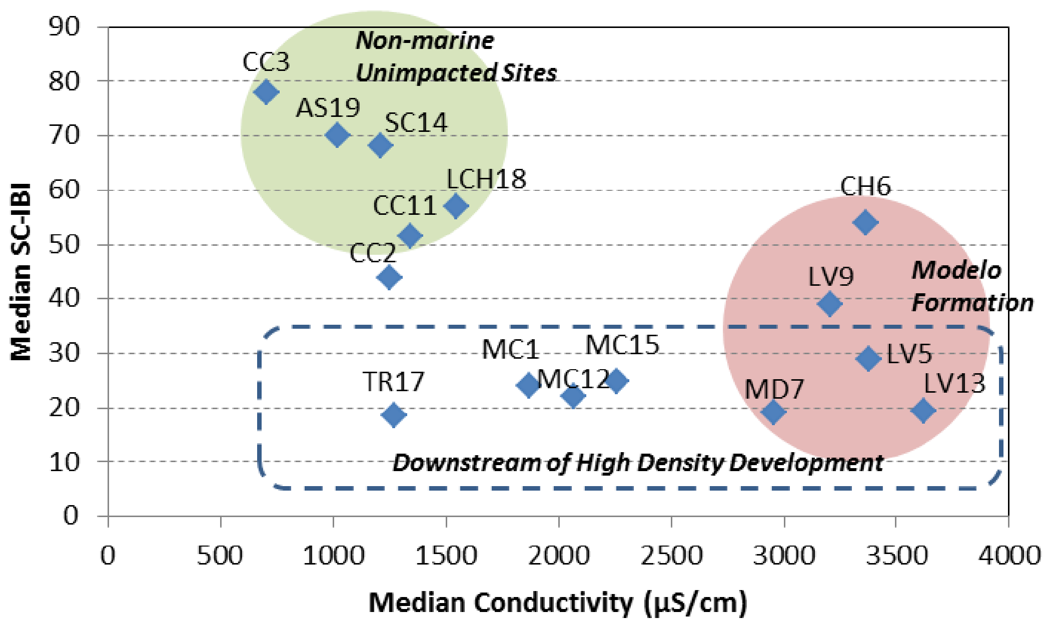



**Figure 8-10. Correlation of Median SC-IBI Scores with Upstream High Density Development**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples.

The pMMI bioscore response to conductivity levels are comparable with the SC-IBI trends in that the correlation analysis showed a weak relationship, but the pMMI scores separated out better the difference between undeveloped sites and those sites downstream of high density development (Figure 8-11). In other words, the gap between comparator/reference sites (LCH-18, SC-14, CH-6, LV-9; as well as CC-3 in Upper Cold Creek) and impaired sites (TR-17, MC-1, MC-12, MC-15, MD-7, LV-5, and LV-13) are greater than observed for the SC-IBI. The O/E bioscores regression estimate with conductivity did not show a relationship (Figure 8-12). Analysis of water quality results in Section 7 indicated that influence of marine sedimentary geology would result in elevated salts, and thereby, most likely, elevated conductivity levels. But, the distinct impact of conductivity on biologic condition is confounded by the mix of sources from the natural Monterey/Modelo Formation and urban runoff; both these sources can result in elevated conductivity levels. Finally, the multiple lines of bioscore data and observed trends presented demonstrate that conductivity alone does not reflect well the biological response of the macroinvertebrate community.

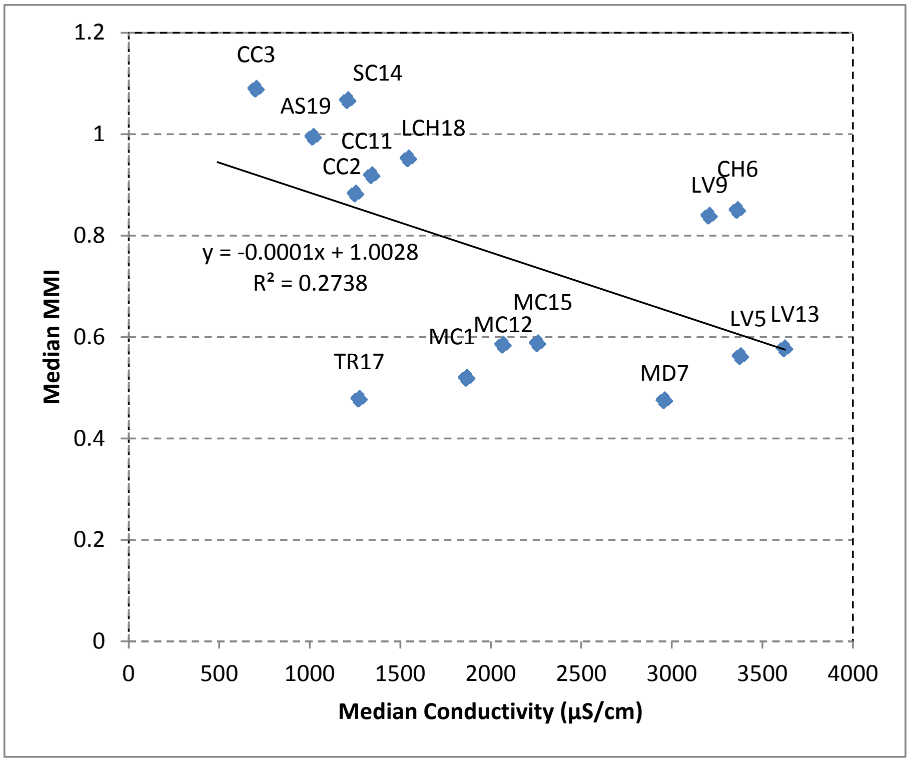



**Figure 8-11. Correlation of Median pMMI Scores with Median Conductivity, All Sites with More than Five Samples**

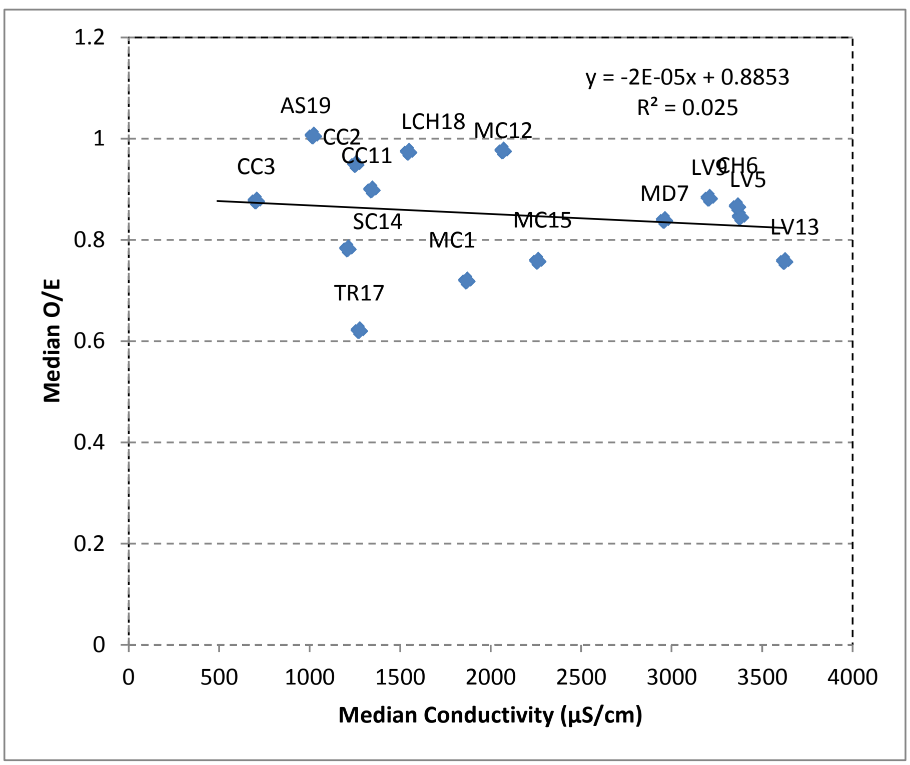



**Figure 8-12. Correlation of Median O/E Scores with Median Conductivity, All Sites with More than Five Samples**

The role of conductivity was further examined by analyzing the larger sample size data collected by HtB Stream Team for those sites draining un-impacted areas (Figure 8-13). Interestingly, the regression estimate for un-impacted areas showed a strong correlation between conductivity levels and SC-IBI ($R^2$ = 0.78); this was also the case for pMMI ($R^2$ = 0.88) (Figure 8-14). But, all the un-impacted sites in the regression analysis showed fair to very good SC-IBI bioscores, indicating that even at the highest conductivity levels, the benthic community condition can be good. The range of SC-IBI scores observed between these un-impacted sites likely represent the natural variability in this watershed. Similarly, the O/E results did not show any correlation ($R^2$ = 0.03) (Figure 8-15).

Among sites located in the Monterey/Modelo Formation, there is a distinct difference between the impacted sites (LV-13 and MD-7 ) and un-impacted sites (CH-6 and LV-9).

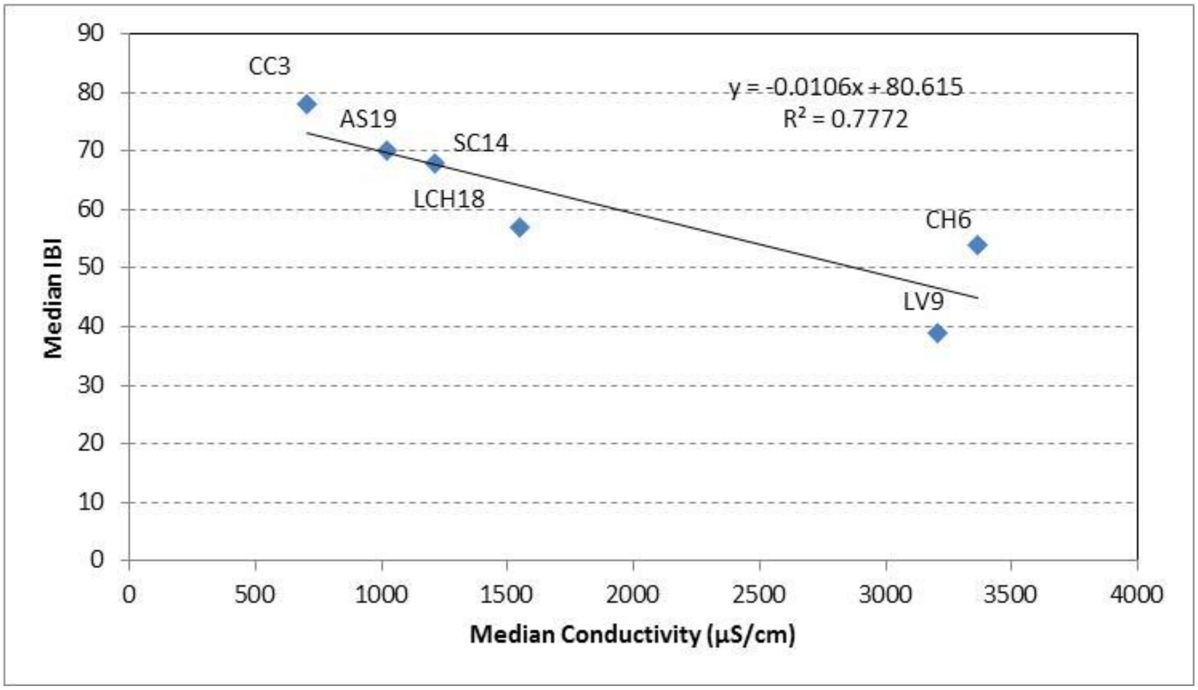



**Figure 8-13. Correlation of Median SC-IBI Scores with Median Conductivity at Un-impacted Sites**

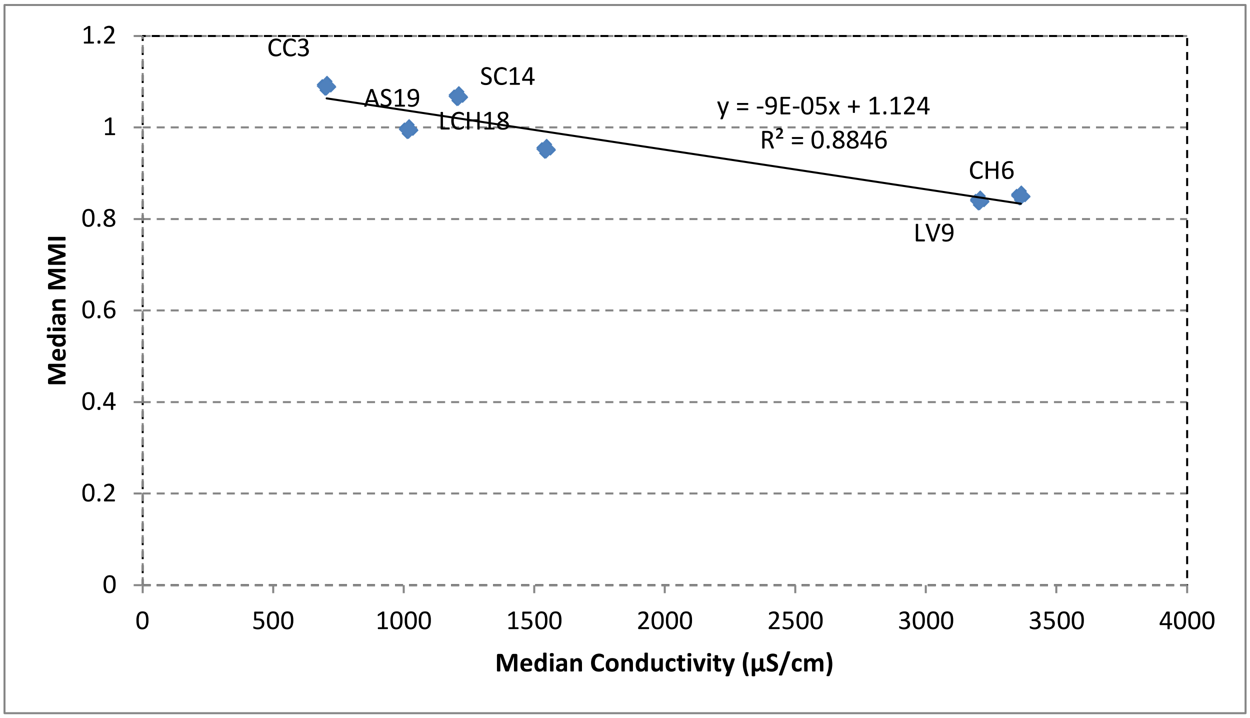



**Figure 8-14. Correlation of Median pMMI Scores with Median Conductivity at Un-impacted Sites. Note that although the $R^2$ value is relatively high, the tightness of the fit is over a very small range**

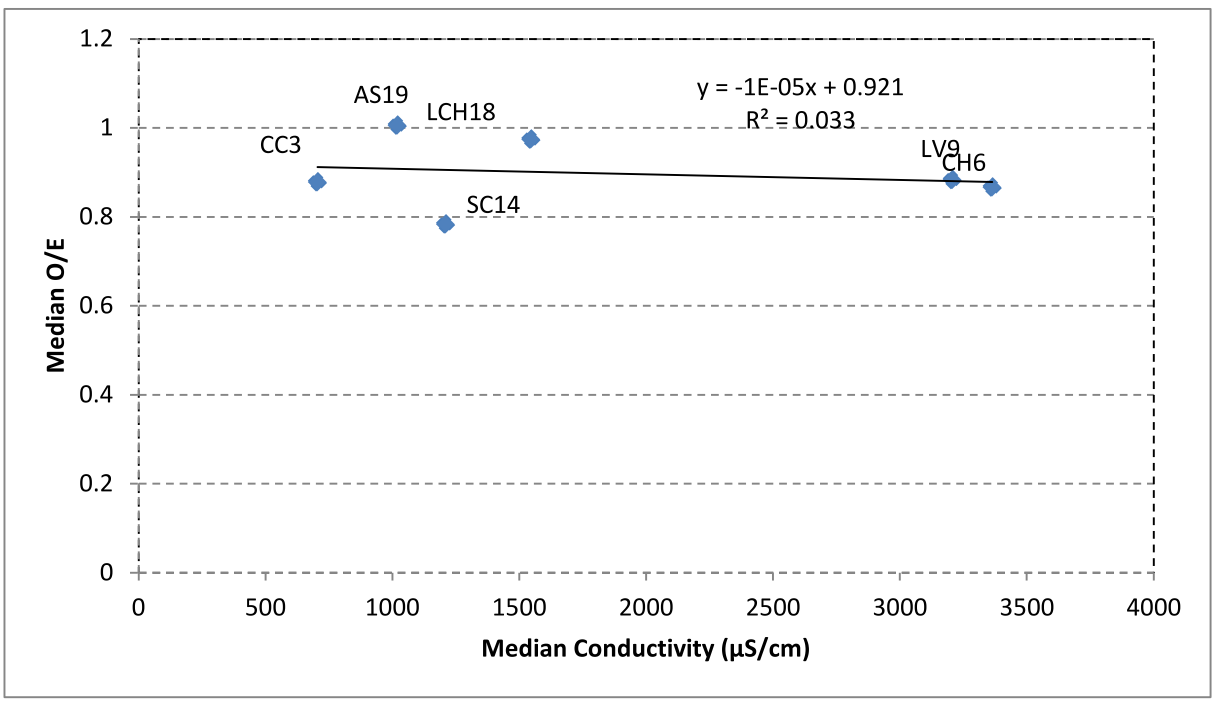



**Figure 8-15. Correlation of Median O/E Scores with Median Conductivity at Un-impacted Sites**

Consideration of whether low SC-IBI scores are due to high sulfate levels originating from the Monterey/Modelo Formation (Figure 4-4 in Section 4) was included in our assessment. Although sulfur seeps and springs within the Monterey/Modelo Formation support sulfur-reducing microbial communities [i.e., reduces sulfate to hydrogen sulfide gas ($H_2S$)] (LVMWD 2011), $H_2S$, toxic to most forms of aquatic life, is quickly oxidized, which reduces the likelihood of impacts except in the immediate area of sulfur seeps.

Luce (2003) conducted multiple regression analyses of SC-IBI's relationship with other multiple benthic macroinvertebrate measures, such as habitat and chemical variables. She reported that the most significant correlations of benthic macroinvertebrate metrics were substrate embeddedness (negative), percent canopy cover (positive), and conductivity (negative). No significant correlation was found to percent fines, percent sand, or macroalgal cover (e.g., *Cladophora*); however, microalgal cover (e.g., periphytic diatoms) emerged as a significant variable (with positive coefficient) for the EPT index and percent filterers. The relationship to conductivity was significant and negative for most benthic macroinvertebrate indices (except percent dominant species and percent filterers). Luce associates all three of the primary explanatory variables (embeddedness, canopy cover, and conductivity) with urbanization, but also noted that elevated conductivity occurred at some sites that lacked impervious cover and "increased conductivity must therefore have some other source, such as the geology of the watershed…" As was discussed above, it appears likely that SC-IBI scores are responding to urbanization as well as to conductivity directly. Consequently, conductivity appears to reflect sources from natural geology, as well as urbanization. Conductivity may, in part, be a surrogate for urban stormwater input, as was suggested by Walsh et al. (2001) for studies in Australia and Wenger et al. (2009) as part of a global urban stream syndrome.

#### 8.1.7.2 Nutrients

Bioscores would be expected to correlate with nutrient concentrations if excess algal growth is a limiting factor on benthic communities; in other words, if excess algal growth is the singular factor affecting the benthic community. However, we have demonstrated that certain nitrogen species are strongly correlated with development, such as nitrate- plus nitrite-N concentrations, which are elevated at sites downstream of urban and development-related activities or landuse (Section 7.5). Figure 8-16 shows that median SC-IBI scores greater than 30 are only found at those sites that have an average nitrate-N concentration less than 1 mg/L (red line). This suggests that nutrient impacts may be one critical factor depressing benthic biotic health in the system.

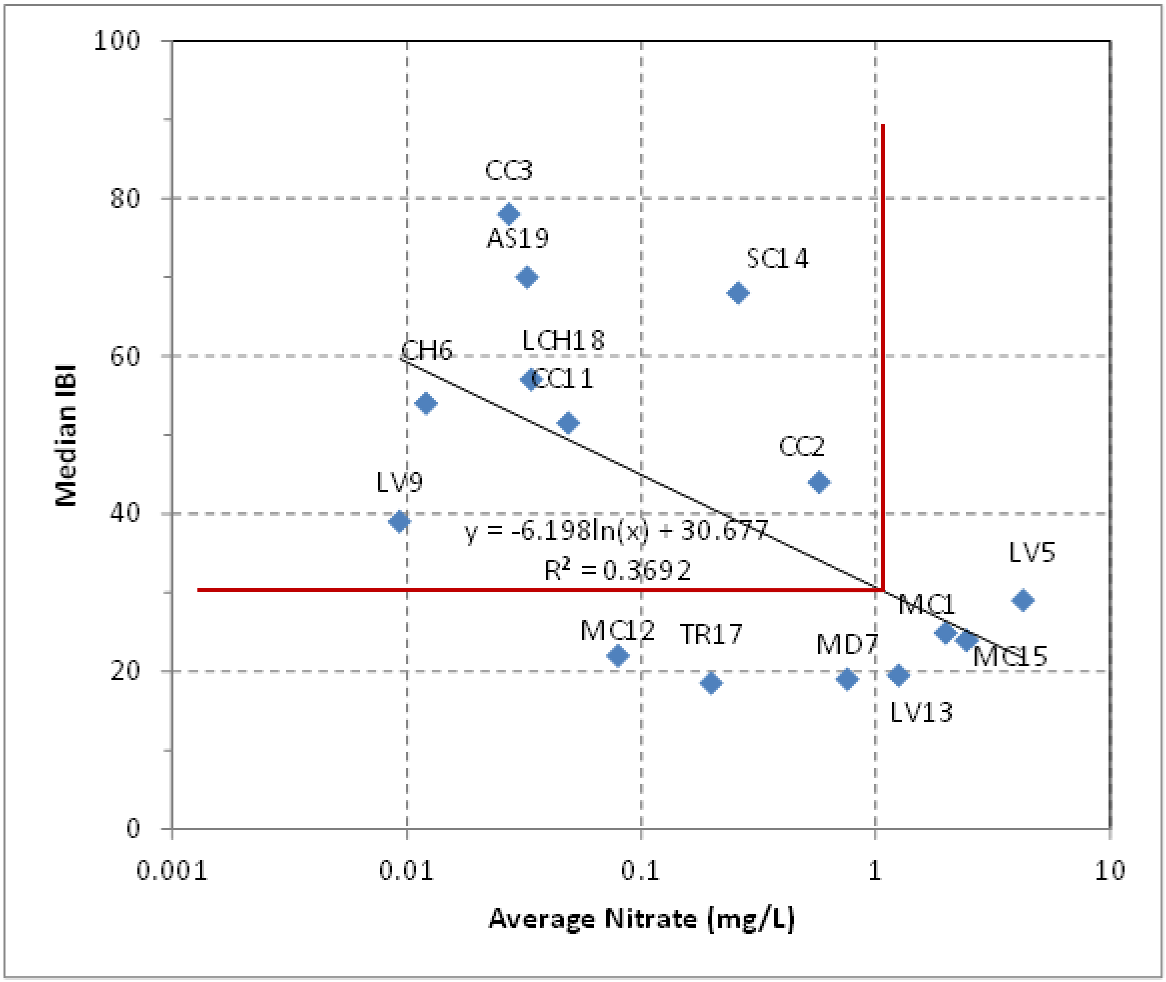



**Figure 8-16. Correlation of Median SC-IBI Scores with Average Nitrate- plus Nitrite-Nitrogen Concentration**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples. Concentrations reported are nitrate- plus nitrite-N. The red line denotes that median SC-IBI bioscores greater than 30 are only found at sites with less than 1 mg/L nitrate- plus nitrite-N.

Similarly shown with other relationships between the O/E and potential stressors, there was no clear break point or identifiable threshold for average nitrate-nitrogen (Figure 8-17). The SC-IBI and pMMI bioscores show a weak negative relationship with average nitrate-nitrogen (Figure 8-18). No pMMI scores greater than the lower threshold (5$^{th}$ percentile, 0.86) are found at sites with average nitrate nitrogen greater than 1 mg/L. The correlation of bioscores to nitrate concentrations is likely a result of the impact of algal overgrowth. As is discussed below in Section 8.1.7.4, the bioscores at HtB Stream Team sites show a strong inverse relationship to percent algal coverage.

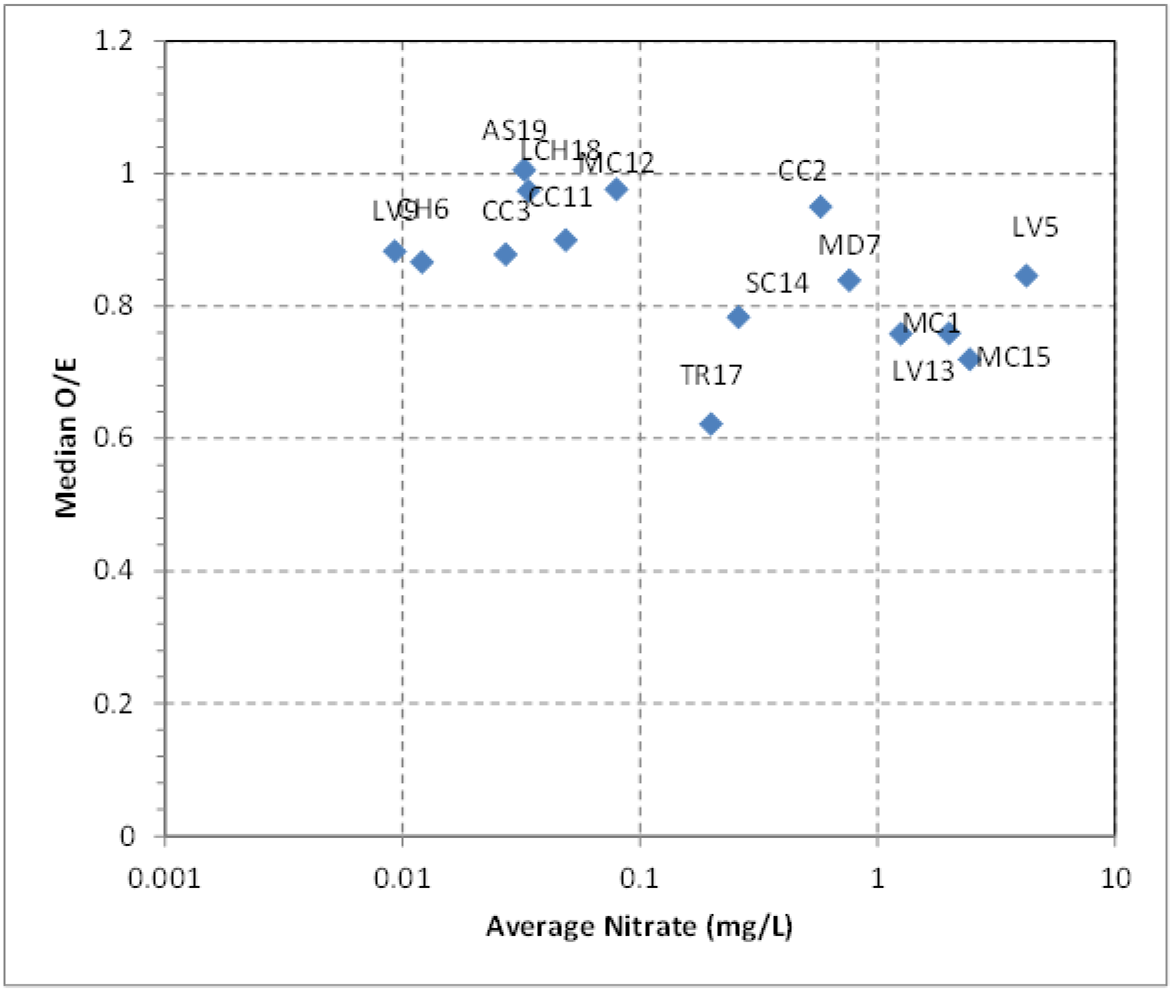



**Figure 8-17.** **Correlation of Median O/E Scores with Average Nitrate- plus Nitrite-Nitrogen Concentration**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples. Concentrations reported are nitrate- plus nitrite-N.

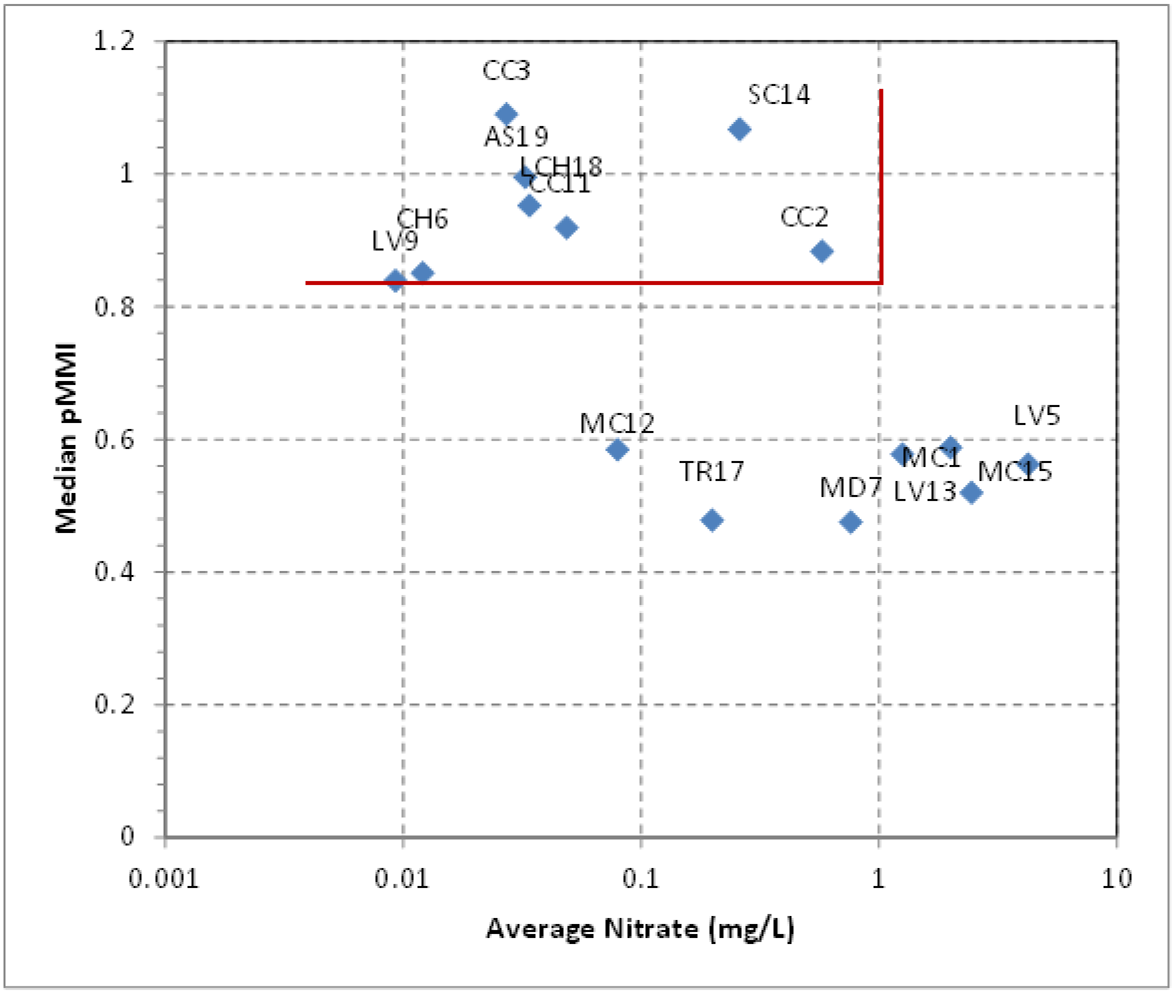



**Figure 8-18. Correlation of Median pMMI Scores with Average Nitrate- plus Nitrite-Nitrogen Concentration**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples. Concentrations reported are nitrate- plus nitrite-N. The red line denotes that no pMMI scores greater than the lower threshold ($5^{th}$ percentile, 0.86) were found at sites with average nitrate- plus nitrite-N higher than 1 mg/L.

### 8.1.7.3 Imperviousness

Bioscores were compared to the fraction of total upstream area that is impervious (Figure 8-19 to Figure 8-21). The relationship to imperviousness is strongest for the pMMI and SC-IBI, where 79 percent and 69 percent, respectively, of the variance is explained by presence of impervious cover. Because these regression estimates showed a strong correlation, these results could be translated to demonstrate that an SC-IBI of 40 would require cumulative upstream imperviousness of 3.3 percent or less; and a pMMI of 0.85 (the $10^{th}$ percentile threshold) would require cumulative upstream imperviousness of 2.0 percent or less. The O/E correlation with imperviousness is weak with only 23 percent of the variance explained by impervious cover ($10^{th}$ percentile O/E threshold is at 0.78); this weak correlation may be affected by the presence of low expected taxa, where the range of natural variability is not captured. These results suggest that imperviousness and urban development are significant indicators and factors affecting biological condition in the Malibu Creek Watershed.

The observed correlation of bioscores to imperviousness is likely related to two factors. First, increased urban development may be associated with increased nutrient load and growth of algal mats. The strong inverse correlation between bioscores and algal mat coverage is demonstrated in Section 8.1.7.4. Second, increased imperviousness can lead to increased flows and degraded habitat. The correlation between bioscores and physical habitat measures is shown in Section 8.1.7.5.

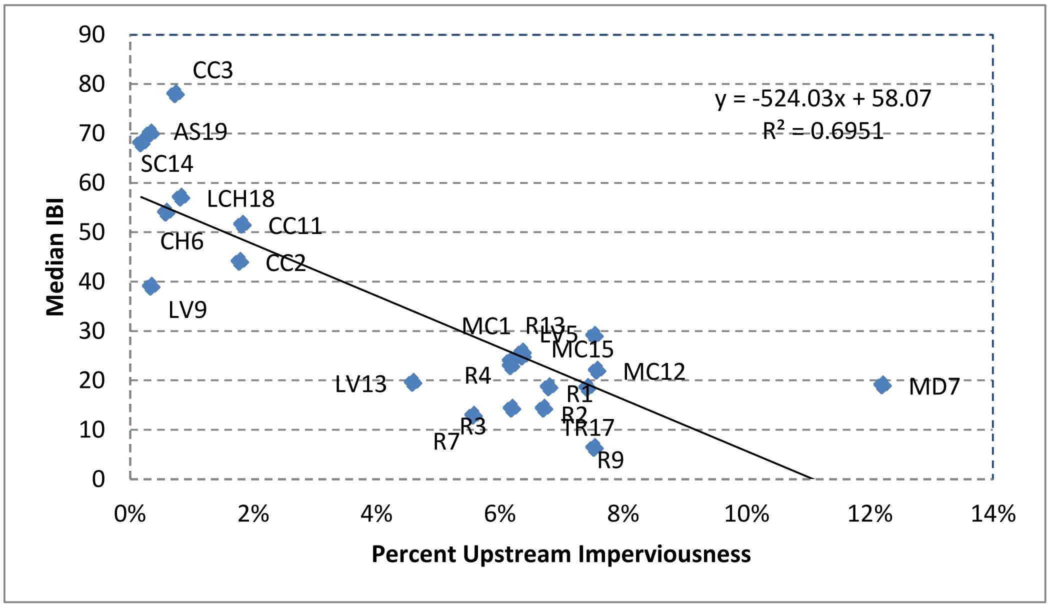



**Figure 8-19. Correlation of Median SC-IBI Scores with Percent Upstream Imperviousness**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples.

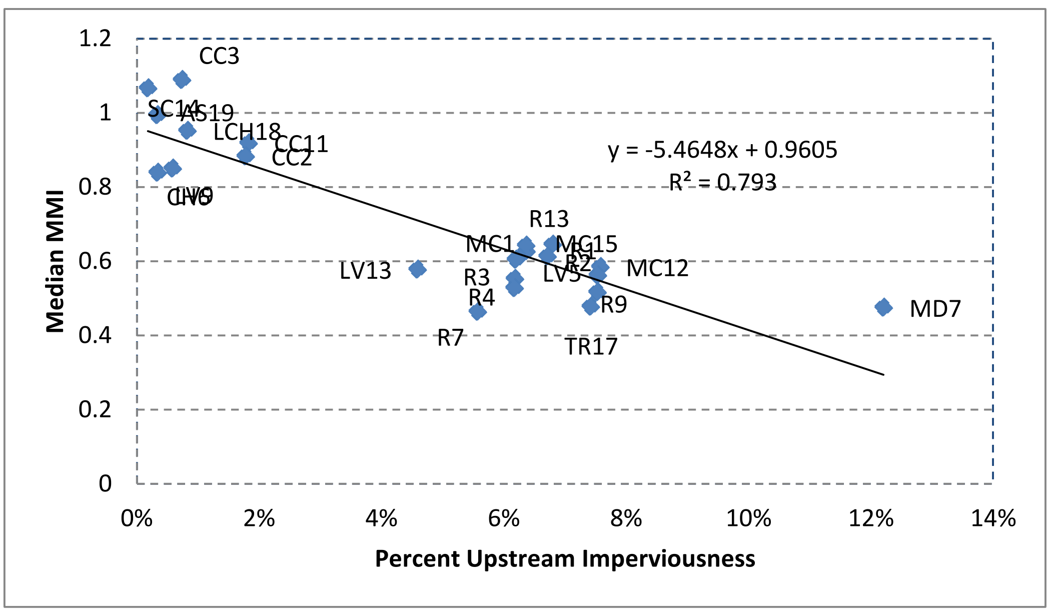



**Figure 8-20. Correlation of Median pMMI Scores with Percent Upstream Imperviousness**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples.

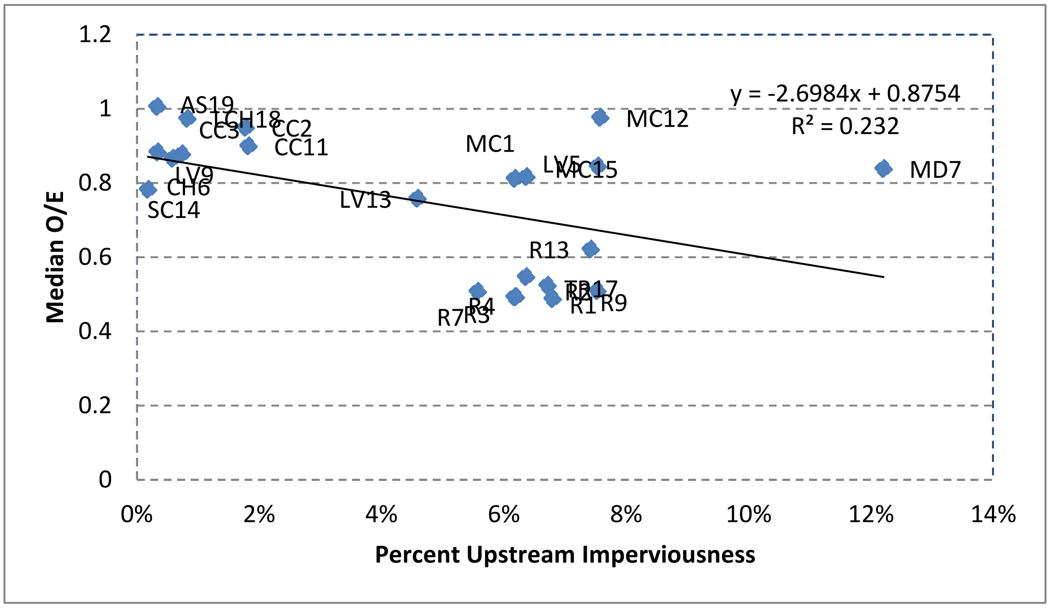



**Figure 8-21. Correlation of Median O/E Scores with Percent Upstream Imperviousness**

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD-R4D samples; median shown for MC-15 combines LVMWD-R13D samples.

### 8.1.7.4 Benthic Algal Data

The 2003 Nutrient TMDL (USEPA, 2003) established thresholds of 30 percent coverage for floating algae and 60 percent coverage for mat algae. Based on comments and additional submitted or identified data during the public comment period of this Draft TMDL, USEPA reevaluated all the available data and conducted additional analysis, including multiple regression and correlation analyses. The updated assessment and conclusions are discussed below.

Coverage by mat or periphytic algae was (and continues to be) a noted problem in Malibu Creek and its tributaries, and was listed as impaired on the CWA 303(d) Impaired Waters List; this resulted in the development of the 2003 Nutrient TMDL.

Growth of periphytic algae is controlled by a variety of factors, including nutrient availability, light availability, temperature, substrate composition, grazing, and flow-induced scour. Extensive data on total algal coverage between 1983 and 1999 were collected by the Tapia WRF and summarized by USEPA (2003). Six sites on the main stem all had more than 10 percent of observations with greater than 30 percent algal coverage, as did one station in the Lagoon. Busse et al. (2003) found that at most sites the study's sites, algal biomass was at such high concentrations, that the singular nutrient factor did not influence algal biomass levels; instead, light availability and flow limited algae, and could more immediately trigger high algae biomass levels. USEPA further investigated the data to determine the complex relationships associated with benthic algae, nutrients and algae. Our analyses showed that the inherent dynamic interactions between nutrient cycling, benthic response and algae are strongly influenced by temporal variability; by focusing on temporality, clearer trends showed a correlation between algae coverage and nutrients, and benthic condition and algae coverage. Nutrients and benthic condition is thus linked.

#### Algal Cover Trends

HtB Stream Team sampling of algal coverage data resulted in a substantially large and continuous data set. Due to this available data set, we further examined whether conditions of excess algal growth, and impacts to in-stream biota, are currently present. Averages of reported algal coverage for 2005-2010 at the two main stem sites are shown in Table 8-16. Both sites have average coverage of mat algae between 65 to 87 percent, which are substantially above the 2003 Nutrient TMDL (USEPA, 2003) and this TMDL's biological benthic algae threshold. Note that the mat algae cover is high during the summer growing season and winter period. This further demonstrates the observed impact of algae throughout the year, regardless of the season.

**Table 8-16. Average Algal Cover in Malibu Creek, HtB Stream Team Data for 2005-2010**

| Station | Floating Algae | | | Mat Algae | | |
|---|---|---|---|---|---|---|
| | All | Summer | Winter | All | Summer | Winter |
| MC-1 – Malibu Creek near Mouth | 23.0% | 32.1% | 2.7% | 60.1% | 64.3% | 51.4% |
| MC-12 – Malibu Creek above Las Virgenes Creek | 1.8% | 2.3% | 1.1% | 79.7% | 86.5% | 68.6% |

Note: Cover estimates are based on visual observations.

The data at these two stations from 1999 to 2010 are plotted against time in Figure 8-22 and Figure 8-23, along with a 12-point moving average to explore the annual trends. Floating algae coverage tends to be greater at MC-1, near the mouth (Figure 8-22). Mat algae concentrations are frequently very high at both stations, and do not show any declining trend with time (Figure 8-23). Based on this recent data set, the observed trend for floating algae is below the 30 percent threshold, while mat algae is above the 60 percent threshold. The data are averaged annually and thus, underestimates the frequent events where algal coverage is excessively high, denoted by the data points. We note that high mat algae coverage (at or near 100 percent) is observed in the winter as well as in the summer growing season. This provides evidence that loading of nutrients, sediments, or other sources, are occurring year round.

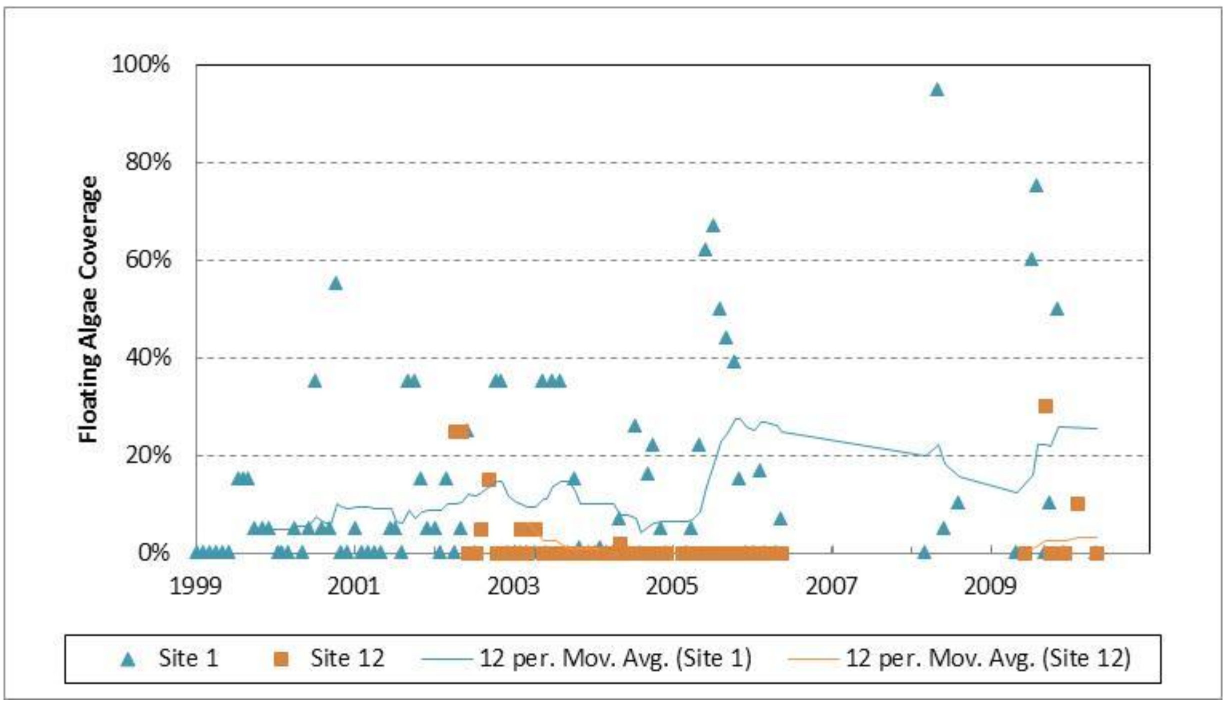



**Figure 8-22. Temporal Trends in Floating Algae Coverage in Malibu Creek Main Stem**

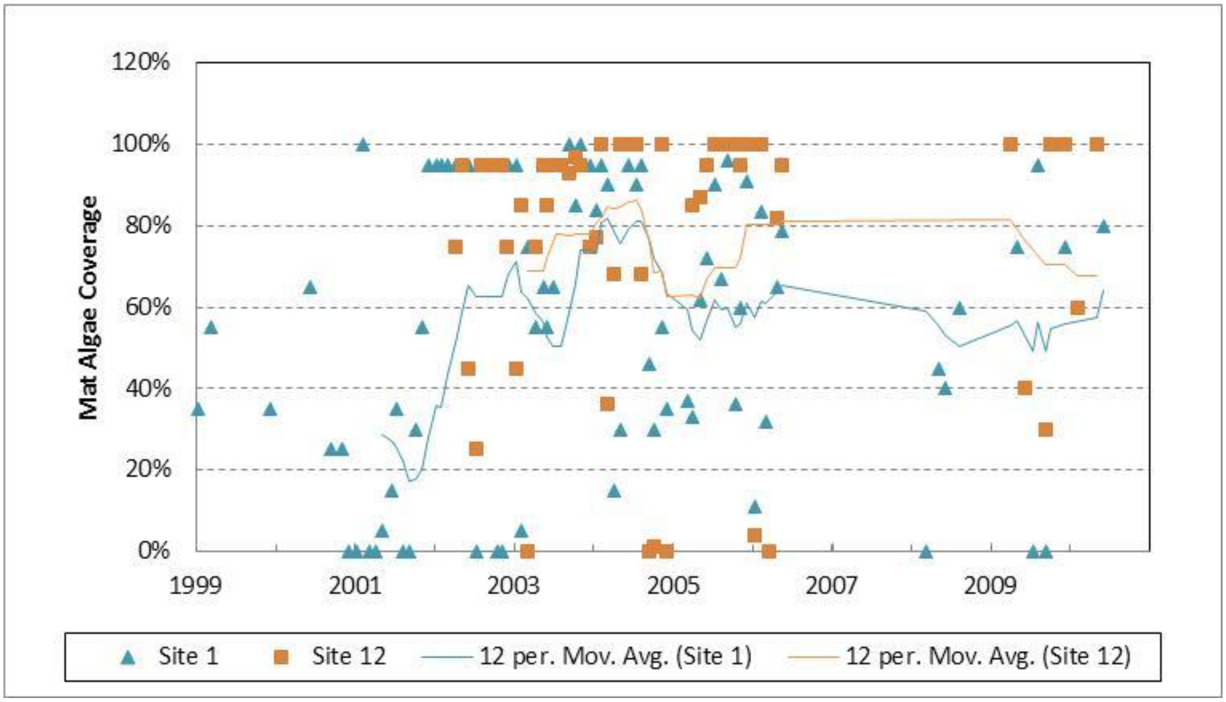



**Figure 8-23. Temporal Trends in Mat Algae Coverage in Malibu Creek Main Stem**

Box and whisker plots of the distribution of mat algae coverage at three main stem sites (also including MC-15, Malibu Creek below Cold Creek, for which smaller amounts of data were available) are provided in Figure 8-24 and compared to results for the four comparator/reference sites (SC-14, LCH-18, CH-6, and LV-9). Mat algae coverage is greater in Malibu Creek than at the comparator/reference sites.

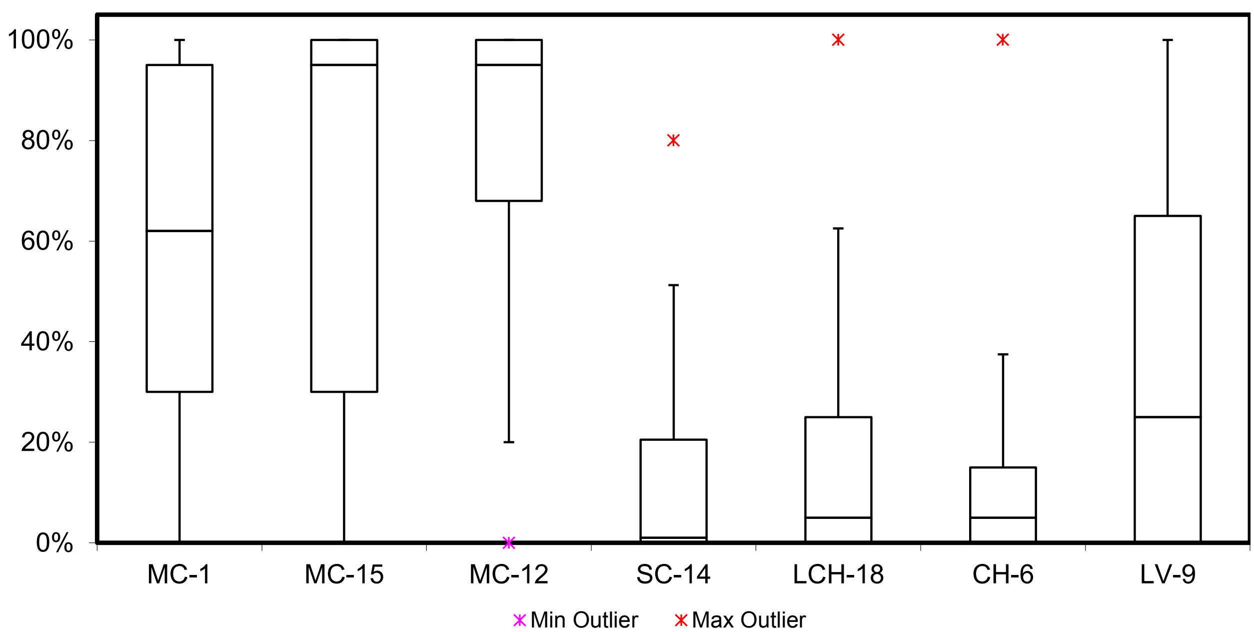



**Figure 8-24. Box and Whisker Plots Comparing Mat Algae Coverage in Malibu Creek Main Stem to Comparator/Reference Sites**

An examination of all the mat algae coverage data showed that there was no relationship between algal coverage and the concurrent measurement of either inorganic N or inorganic P concentrations ($R^2$ values were 0.03 and 0.06, respectively). This lack of correlation is expected because 100 percent cover can occur at the lowest inorganic nutrient concentrations, while very low cover is often found at high inorganic nutrient concentrations. A major cause of the poor correlation is temporal variability in exposure concentrations: the algal coverage present at a site is a result of nutrient availability over the previous 1-2 weeks, and not because of the instantaneous nutrient concentration observed at the time of sampling. Further, nutrient concentrations in Malibu Creek are often sufficiently high that algal growth may be more limited by light availability than by nutrient concentrations. In addition, inorganic nutrient measurements alone may not provide an adequate indicator of algal growth potential as various researchers have found that total nutrient concentrations are better predictors of benthic algal density than inorganic nutrient concentrations due to rapid cycling of the inorganic forms (e.g., Dodds et al., 1997, 2002, 2006; Biggs, 2000b).

Because we understand that seasonal differences are observed elsewhere, we further investigated the relationship between mat algae and nutrient concentrations, the nutrient data were averaged for each site to reduce the noise in individual data points. Figure 8-25 plots the same data as average growing season/summer mat algae coverage versus average inorganic N concentration. The resulting fit (with $R^2$ = 40%) suggests that inorganic N concentrations explain a substantial amount of the variability in mat algal coverage over time. The regression relationship also indicates that the existing inorganic N target of 1.0 mg/L is likely too high to achieve the stated goals of reducing mat algae coverage to 60 percent or less. This is evidenced by the way highlighting the types of data points clustered together.

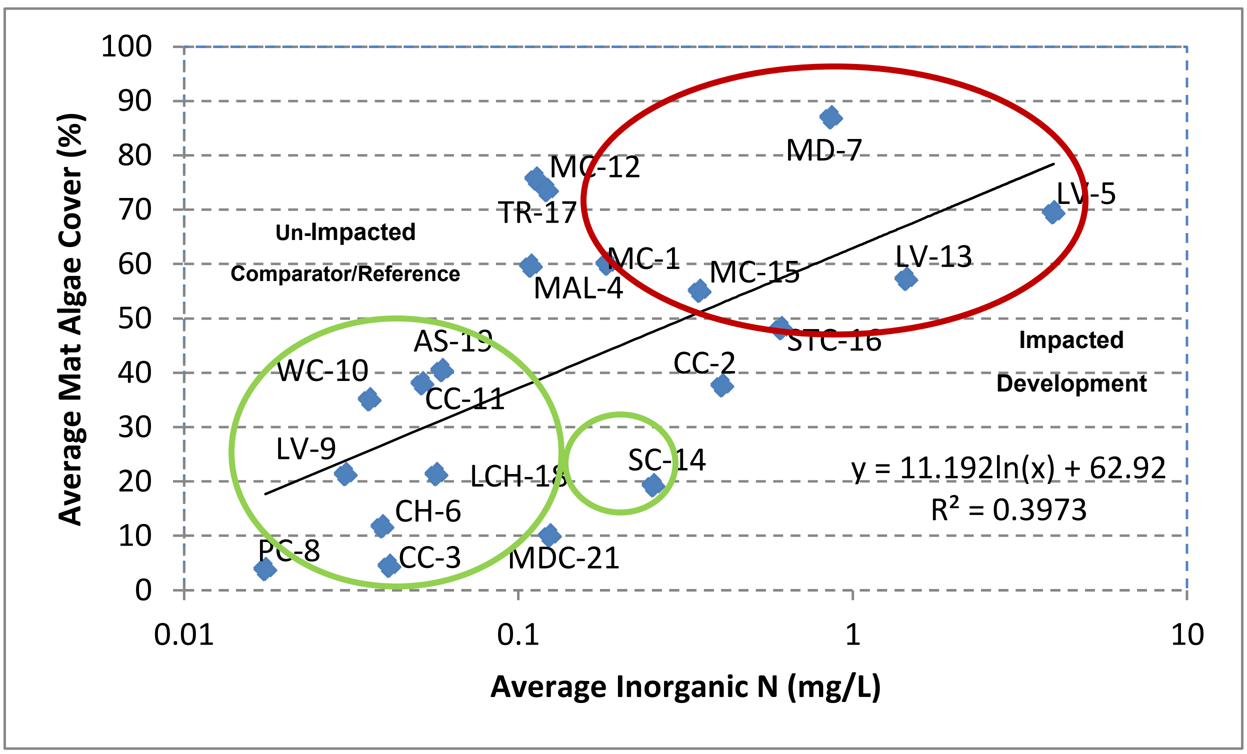



**Figure 8-25. Correlation between Average Mat Algae Coverage and Average Inorganic Nitrogen Concentrations in HtB Stream Team Data during the Summer Growing Season (April 15 – November 15). Green circle shows the clusters of the un-impacted and comparator/reference sites. Red circle shows the cluster of the impacted sites**

Note: Results based on 1999-2010 measurements except for stations below Tapia, which are restricted to 2005-2010 results to reflect changes in wastewater discharges.

Overall, comparator/reference sites, along with other un-impacted sites (WC-10, AS-19), show low algal coverage when the inorganic N concentrations are around 0.1 mg/L; impacted sites show significantly higher algae coverage associated with higher inorganic N concentrations. The relationship in Figure 8-25 suggests that inorganic N concentrations in the range of 0.05 mg/L may be needed to limit mat algae coverage to 30 percent or less, while an inorganic N concentration around 0.8 mg/L might be needed to limit mat algae coverage to 60 percent or less.

Figure 8-25 shows the correlation between mat algal cover and inorganic N concentrations. Figure 8-16 through Figure 8-18 plots showed similar trends. The latter relationship was likely mediated by growth of algal mats. Not surprisingly, both the median SC-IBI (Figure 8-26) and pMMI (Figure 8-27) bioscores had a strong negative correlation to median growing season mat algae cover at the HtB Stream Team Stations (mat algae cover is generally not available for biological samples collected by other agencies). For pMMI, the correlation explained nearly 85 percent of the total variability in medians by site. These graphs further demonstrate that sites with median mat algae cover greater than 60 percent (the threshold specified in the 2003 Nutrient TMDL) are associated with impaired benthic condition, while those with less than 40 percent mat algae cover had acceptable median bioscores.

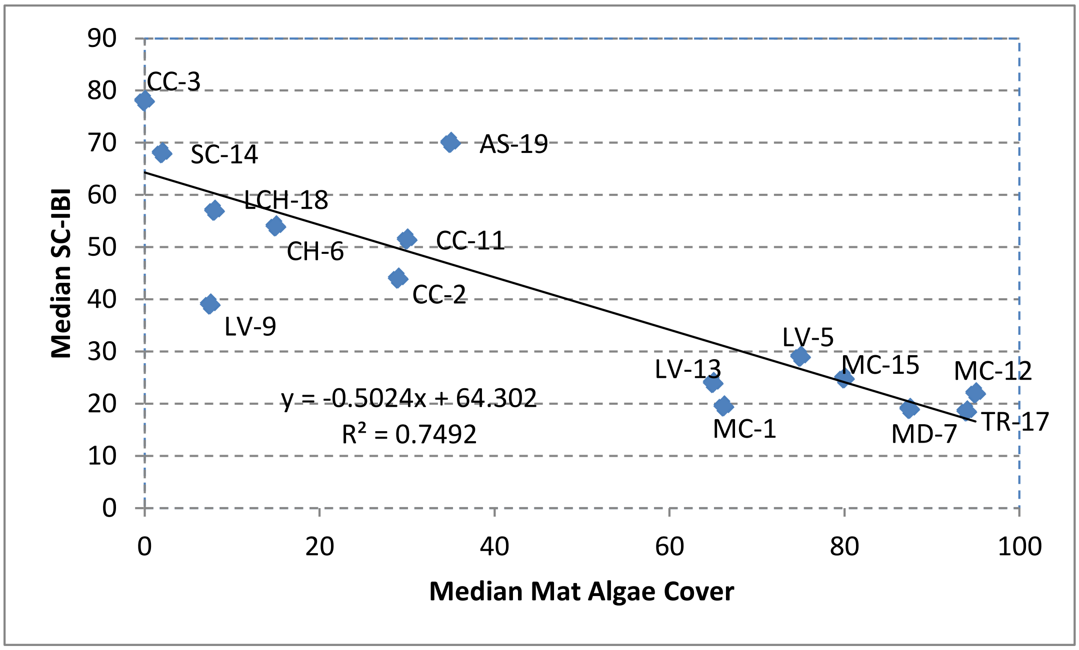



**Figure 8-26. Correlation between SC-IBI Bioscores and Percent Mat Algae Cover during the Growing Season (Apr. 15 – Nov. 15)**

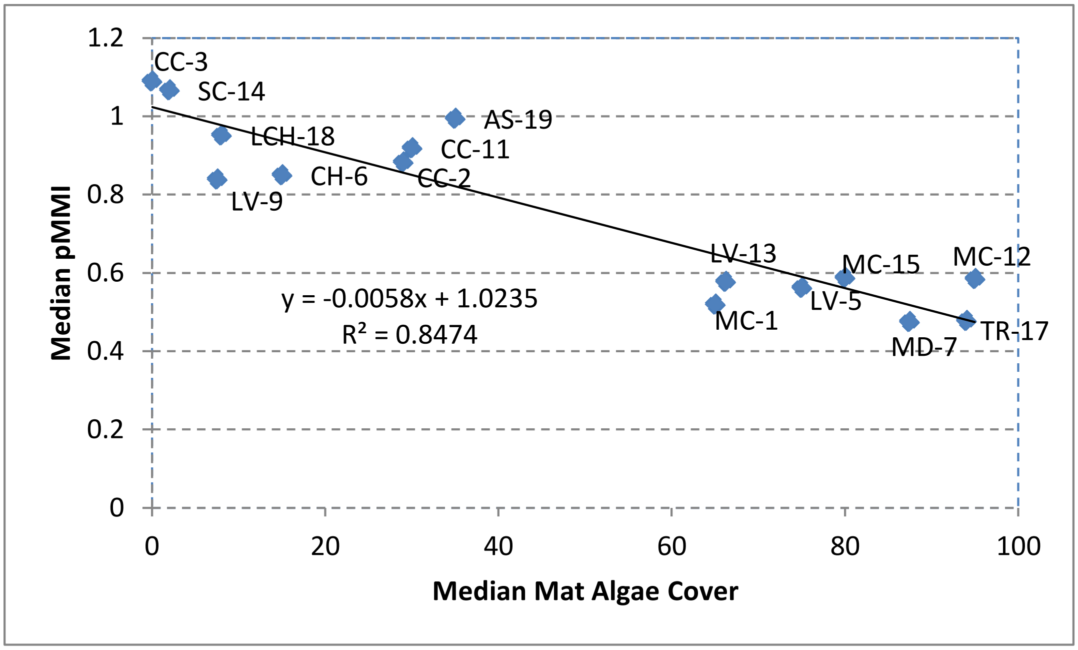



**Figure 8-27. Correlation between pMMI Bioscores and Percent Mat Algae Cover during the Growing Season (Apr. 15 – Nov. 15)**

As described further in Appendix F, Busse et al. (2003) collected direct measurements of benthic algal density as mg/$m^2$ chlorophyll *a* during 2001 and 2002 at multiple sites in the Malibu Creek Watershed. Busse et al. (2003) concluded that most developed sites in the Malibu Creek Watershed had chlorophyll *a* concentrations that "exceed suggested thresholds for acceptable levels." Maximum density was generally observed during the August 2002 survey and is summarized in Table 8-17. These results support that impacted sites are associated with significantly higher benthic algal density levels than those un-impacted sites (Cold Creek). See Appendix F for further details on the sampling sites.

**Table 8-17. Summary of Chlorophyll *a* and AFDM Data from the August 2002 Survey (Busse et al., 2003). Bolded text represent the reference waterbodies**

| Waterbody | Land Use | Sub-Habitat | Benthic chlorophyll *a* (mg/$m^2$) | Benthic plus Planktonic chlorophyll *a* (mg/$m^2$) |
|---|---|---|---|---|
| Medea Creek | Residential 1 | Sun Riffle | 165.1 | 165.1 |
| Medea Creek | Residential 1 | Shade Riffle | 50.0 | 50.0 |
| Medea Creek | Commercial 1 | Sun Run | 969.2 | 969.2 |
| Medea Creek | Commercial 1 | Sun Riffle | 110.9 | 110.9 |
| Medea Creek | Commercial 2 | Sun Pool | 133.1 | 413.0 |
| Medea Creek | Commercial 2 | Sun Run | 73 | 123.5 |
| Medea Creek | Commercial 2 | Sun Riffle | 66.9 | 66.9 |
| Las Virgenes | Multiple 1 | Shade Run | 383.9 | 383.9 |

| Waterbody | Land Use | Sub-Habitat | Benthic chlorophyll *a* ($mg/m^2$) | Benthic plus Planktonic chlorophyll *a* ($mg/m^2$) |
|---|---|---|---|---|
| Las Virgenes | Multiple 1 | Shade Riffle | 504.0 | 504.0 |
| Las Virgenes | Multiple 2 | Sun Run | 102.6 | 102.6 |
| Las Virgenes | Multiple 2 | Shade Run | 531.1 | 531.1 |
| Las Virgenes | Multiple 2 | Shade Riffle | 255.9 | 255.9 |
| Malibu Creek | Below Tapia | Shade Run | 341 | 341 |
| Malibu Creek | Below Tapia | Sun Riffle | 230.3 | 230.3 |
| Malibu Creek | Below Tapia | Shade Riffle | 258.1 | 258.1 |
| Cold Creek | Reference 1 | Sun Pool | 75.0 | **75.0** |
| Cold Creek | Reference 1 | Shade Pool | 6.5 | **6.5** |
| Cold Creek | Reference 1 | Sun Run | 8.3 | **8.3** |
| Cold Creek | Reference 1 | Shade Run | 3.2 | **3.2** |
| Cold Creek | Reference 1 | Sun Riffle | 9.6 | **9.6** |
| Cold Creek | Reference 1 | Shade Riffle | 16.2 | **16.2** |

Luce (2003) reports multiple regression analyses of algal cover at HtB Stream Team sampling sites for 1998 – 2002. She found positive correlations between nutrient concentrations and macroalgal cover, although the relationships were somewhat complex. Phosphate had a significant positive correlation with macroalgal cover in all seasons at sites with nitrate less than 0.1 mg/L, but not at sites with higher nitrate concentrations. Nitrate was positively correlated with macroalgal cover in the spring, but negatively correlated in the fall. Canopy cover did not appear strongly related to macroalgal density, except at sites with low nitrate where there was a negative relationship in the spring (increasing macroalgal density with decreasing canopy cover) and a positive relationship in the fall. For all sites, regardless or nitrate or phosphate concentration, the strongest relationship was a positive correlation between nitrate and visible microalgal cover in fall. Although Luce (2003) found a strong relationship between SC-IBI and canopy cover, our assessment of other data sets and combined physical habitat measurements collected by Heal the Bay, did not show canopy cover to be a primary factor affecting benthic macroinvertebrate condition overall. Canopy cover is likely a contributing limitor of growth, but it is the presence of the excess nutrient load that directly addresses the pollutant source.

LVMWD (2011) suggests that high levels of algal growth in Malibu Creek are due to naturally elevated levels of phosphate and nitrate in drainage from the Monterey/Modelo Formation. The nature of these sediments may indeed enhance nutrient concentrations; however, nutrient, sediment, and other source loads are not all natural; earlier results and analyses have demonstrated that Malibu Creek and its tributaries are influenced by altered flows and human-related activities that increase erosion.

This excess algal growth does not appear to strongly affect DO concentrations in the creek, as excursions of the DO criterion exist, but are infrequent (see Section 7.3); however, early morning DO measurements that would accurately assess the extent to which DO drops during algal respiration overnight are lacking. Additionally, excess growth of periphytic and attached algae can also have a direct deleterious impact on habitat suitability and can increase organic matter and nutrient loading downstream through export of algal biomass.

Based on a synthesis of all of the analyses presented in this section, including those based on recent data, the algae-related impairment in the Malibu Creek main stem continues to be significant factor in affecting benthic macroinvertebrate condition. Therefore, excess algal growth remains a potential stressor that could limit biological conditions in Malibu Creek. Regression analyses showed that both SC-IBI and pMMI bioscores exhibited a strong negative correlation to median mat algae cover, suggesting that excess algal growth is indeed a factor in impaired biota.

#### 8.1.7.5 Physical Habitat Information

HtB Stream Team analyzed physical habitat quality scores using the Rapid Bioassessment Protocol (RBP) from 2000 through 2008. The RBP (Barbour et al., 1999) analyzes 10 different metrics for physical habitat. These metrics vary somewhat for high gradient and low gradient streams; the low gradient options are shown in parentheses below:

1. Epifaunal substrate/available cover
2. Embeddedness (or pool substrate)
3. Velocity/depth combination (or pool variability)
4. Sediment deposition
5. Channel flow status
6. Channel alteration
7. Frequency of riffles/bends (or channel sinuosity)
8. Bank stability
9. Bank vegetative protection
10. Riparian zone width

Each component receives a score from 0 to 20 and the individual scores are added to form a physical habitat score with a potential range from 0 to 200. Scores from 150 to 200 are considered optimal, those from 100 to 150 suboptimal, from 50 to 100 marginal, and below 50 poor. The range of results are shown in Table 8-18 and compared to comparator/reference sites in Figure 8-28. The average RBP scores showed either optimal or suboptimal conditions for the sites sampled. Malibu Creek (MC-1 and MC-15) RBP scores are lower than those for the comparator/reference sites. HtB Stream Team did not provide individual component metrics for these data.

**Table 8-18. Physical Habitat Scores (RBP) for Malibu Creek, HtB Stream Team 2000 - 2008**

| Station | Count | Range | Average |
|---|---|---|---|
| MC-1 (Malibu Creek at Discharge) | 6 | 123 – 151 | 142 (suboptimal) |
| MC-15 (Malibu Creek below Tapia WRF) | 6 | 122 – 159 | 142.2 (suboptimal) |
| MC-12 (Malibu Creek upstream of Bridge Rock Pool) | 5 | 141 – 178 | 167.2 (optimal) |
| LCH-18 (Lachusa Creek) | 4 | 131 – 182 | 163.2 (optimal) |
| SC-14 (Solstice Creek) | 4 | 138 – 179 | 155.2 (optimal) |
| CH-6 (Cheseboro Creek) | 3 | 134 - 139 | 136.3 (suboptimal) |

Las Virgenes Municipal Water District also reports RBP Physical Habitat Scores for their monitoring stations sampled in 2006, 2008, 2009, and 2010 (Table 8-19 and Figure 8-28). The average RBP scores are lower than those observed at the HtB Stream Team sites, showing between marginal to sub-optimal conditions. Sites with low RBP scores are associated with poor or marginal ratings on embeddedness, sediment deposition, and riffle frequency measures.

**Table 8-19. Physical Habitat Scores (RBP) for Malibu Creek (LVMWD, 2010)**

| Station | Count | Range | Average |
|---|---|---|---|
| LVMWD-R13D | 4 | 128 – 155 | 145 (suboptimal) |
| LVMWD-R2D | 4 | 101 – 117 | 111 (suboptimal) |
| LVMWD-R1U | 4 | 73 – 119 | 92 (marginal) |
| LVMWD-R9U | 3 | 84 – 106 | 98 (marginal) |
| LVMWD-R4D | 4 | 74 – 120 | 91 (marginal) |
| LVMWD-R3D | 4 | 91 – 136 | 112 (suboptimal) |

Both sets of physical habitat scores are compared to comparator/reference sites in Figure 8-28. HtB Stream Team RBP scores on lower Malibu Creek (MC-1 and MC-15) are lower than those for the comparator/reference sites. Several of the LVMWD sites from the main stem show even lower physical habitat scores compared with the comparator/reference sites.

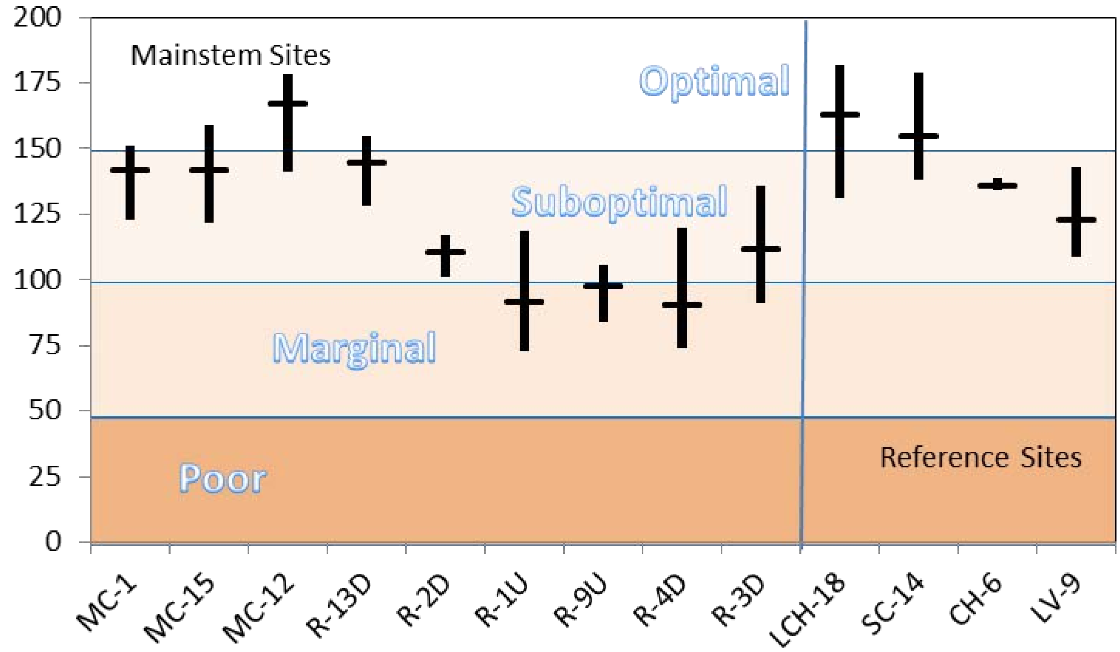



**Figure 8-28. Range of Physical Habitat Scores at Malibu Creek Main Stem and Comparator/Reference Sites**

Note: Maximum, minimum, and average RBP Physical Habitat Scores from HtB Stream Team and LVMWD sampling.

The 2005 Malibu Creek Bioassessment Monitoring Program Report (Aquatic Bioassay, 2005), conducted as part of the Malibu Creek Watershed Monitoring Program, provided data for eight sites in the Malibu Creek Watershed. This included SC-IBI results and physical habitat scores (including substrate complexity, embeddedness, consolidation, and percent fines). For four of the eight sites (including Malibu Creek above the Lagoon – the only station on the main stem included in that survey), the physical habitat was rated as optimal or suboptimal. The report concludes that, for these four sites, "stressors other than habitat conditions may have impacted these sites." A few of the sites in the watershed studied in 2005 show that poorly rated physical habitat conditions are associated with evidence of excessive sedimentation.

Los Angeles County also computed RBP physical habitat scores from their fixed sites between 2003 and 2008. These do not include stations on the main stem of Malibu Creek. Stations on Medea, Las Virgenes, and Triunfo creeks showed poor to very poor SC-IBI scores, marginal to sub-optimal physical habitat scores ranging from 85 to 141. The reference site, Cold Creek station exhibited good macroinvertebrate bioscores and optimal physical habitat scores ranging from 164 to 170.

In 2009, Los Angeles County switched to randomized monitoring sites and substituted the SWAMP physical habitat procedure for the RBP methods (Weston, 2009, 2011). The physical habitat measures are summarized using the California Rapid Assessment Methodology (CRAM) score, which ranges from 25 to 100. Both 2009 and 2010 Los Angeles County data included randomized sites on the Malibu Creek main stem. In general, the 2009 and 2010 CRAM scores were high and associated with stable banks; the two sampled sites are located in Malibu Creek in Malibu Creek State Park and adjacent to Malibu Canyon Road with no observable human-related activities nearby to the stream. These scores may be better at reflecting the immediate physical surroundings, rather than upstream impacts. Thus, CRAM does not appear to be a good predictor of SC-IBI at these Malibu Creek stations, and have not shown to reflect similar results as those of the SWAMP physical habitat methodology.

In 2009 and 2010, HtB Stream Team collected SWAMP physical habitat measures and as yet have not reported the RBP scores. An interpretation of these data is currently in preparation and not yet available to USEPA.

These data suggest habitat conditions can vary in both space and time. At MC-1, percent fines in the substrate increased from 7 percent in 2009 to 48 percent in 2010, while the percent riffle habitat declined from 46 percent to 2 percent and cobble embeddedness decreased from 50 to 37 percent. In the same years MC-12 had 16 and 22 percent fines and embeddedness of 6 and 16 percent. The differences between 2009 and 2010 at MC-1 likely reflect a resetting of conditions by winter storms. These observations also indicate the strong sedimentation that can occur during certain periods and storm events.

Benthic macroinvertebrate bioscores appear to be strongly correlated with RBP physical habitat scores in tributaries draining into Malibu Creek main stem. In contrast, the main stem show poor correlation between the physical habitat scores and benthic macroinvertebrate bioscores. Figure 8-29 and Figure 8-30 show the correlation to physical habitat scores for SC-IBI and pMMI respectively, including all instantaneous paired data available from the HtB Stream Team and LVMWD sampling efforts. The correlation is indeed poor for the main stem sites ($R^2$ of 20 and 14 percent, respectively, for SC-IBI and pMMI). However, for all non-main stem sites the correlation is significantly stronger, with RBP physical habitat scores explaining 47 and 44 percent of the variability in SC-IBI and pMMI. Note further in both figures that the relationship between bioscores and physical habitat is essentially identical for main stem and other stations when the physical habitat score is less than 100. The main stem sites appear to show a small response to improved physical habitat, suggesting the larger cumulative impacts in the main stem; large-scale watershed efforts would be necessary to result in observed improvement. This is not unexpected considering the main stem is the downstream waterbody receiving all upstream activities and impacts. These results suggest physical habitat is an important factor in the health of benthic macroinvertebrate communities throughout the Malibu Creek Watershed, but that other factors are also limiting biological potential in the Malibu Creek main stem.

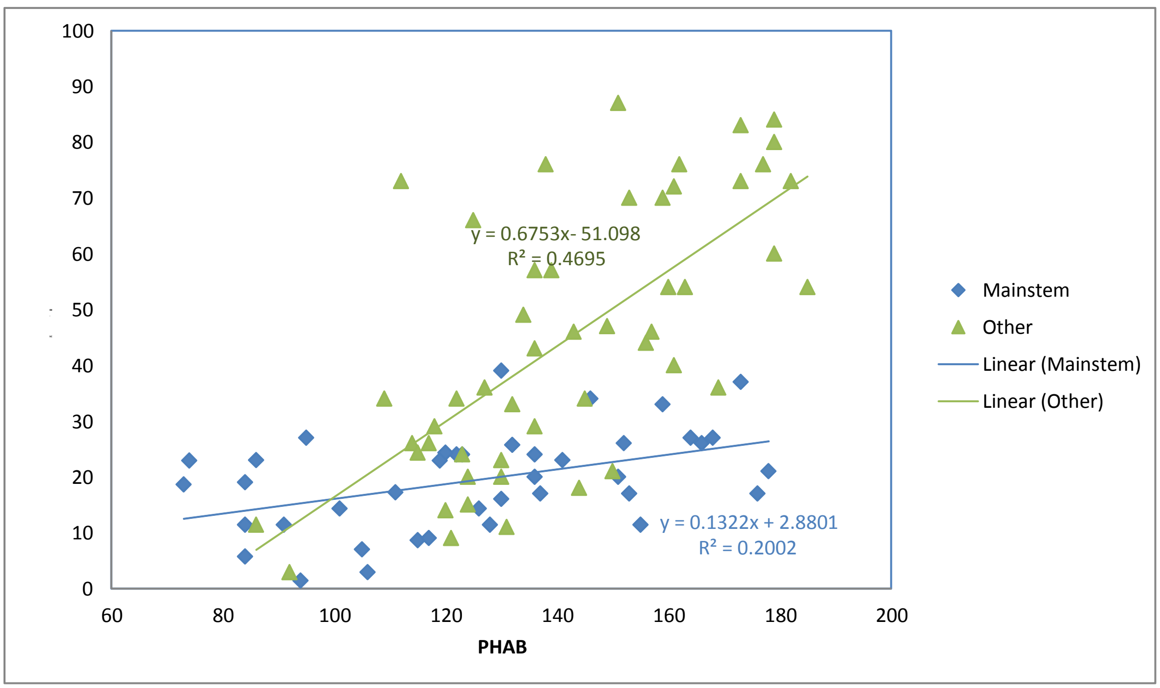



**Figure 8-29. Correlation of SC-IBI and Physical Habitat Scores**

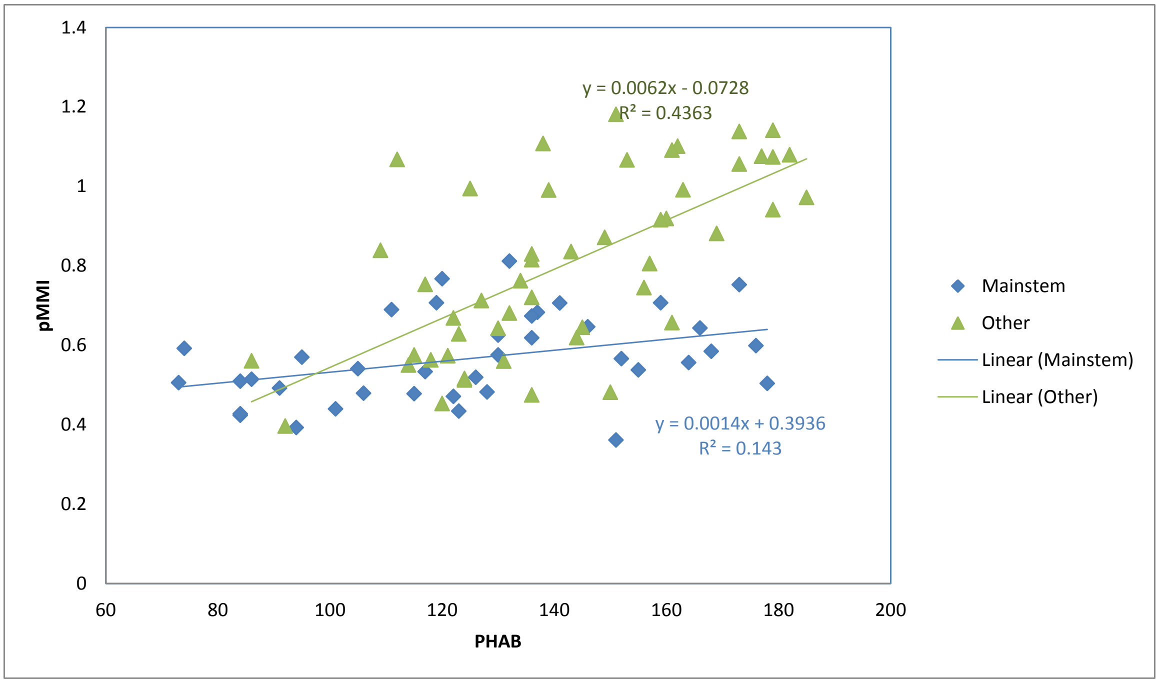



**Figure 8-30. Correlation of pMMI and Physical Habitat Scores**

### Multiple Stressors Analyses

The importance of physical habitat to benthic biology was further supported by a stepwise multiple regression analysis constructed to predict pMMI scores from local environmental variables. This statistical tool assesses multiple variables simultaneously to determine if a few certain critical stressors can explain the observed response.

Because individual data points show a lot of scatter and biota are likely to respond to average conditions over time, the median pMMI score at each long-term HtB Stream Team and LVMWD site was evaluated. The SC-IBI showed similar trends. The following potential predictor variables, or stressor or explanatory variables, were considered (using water quality data from 1999 to present only); this list was restricted by the available variables for each site:

IMPERV: Fraction of the upstream drainage area that is impervious.

SEDMT: Fraction of the upstream drainage area in sedimentary geology

COND: Median specific conductivity (µS/cm)

NO3N: Median summer (dry) season $NO_3$-N concentration (mg/L)

PO4P: Median summer (dry) season $PO_4$-P (mg/L)

NH4N: Median summer (dry) season $NH_4$-N (mg/L)

TIN: Median summer (dry) season total inorganic N (mg/L)

PHAB: Average RBMP physical habitat score

SLOPE: Estimated stream slope at sampling location from DEM (ft/ft).

The variables are displayed in a scatterplot matrix below (Figure 8-31). Some potential predictors are nearly collinear or show the same trend and response (e.g., relationship between NO3N and TIN). PHAB is strongly correlated to stream slope -- where lower PHAB scores are associated with lower slopes (which are likely to be depositional areas).

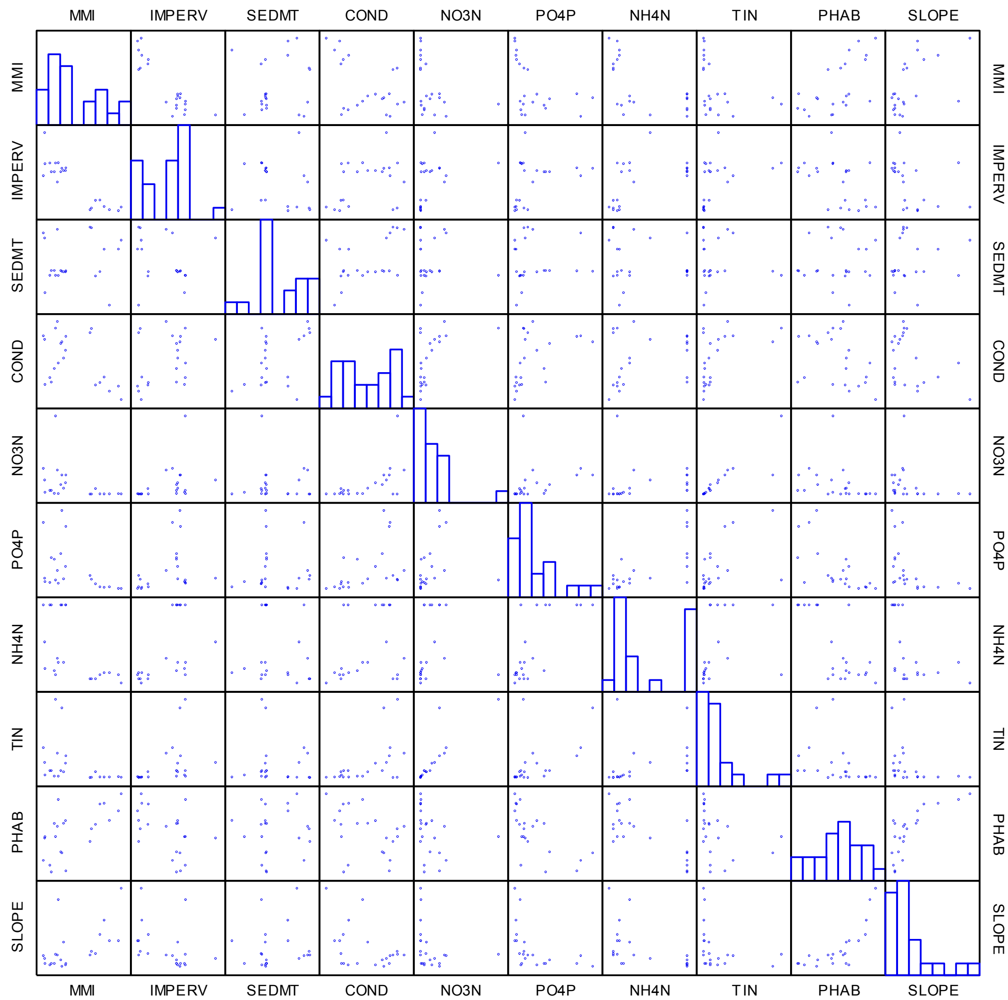



**Figure 8-31. Scatterplot Matrix for MMI and Predictors**

A Pearson correlation matrix (Table 8-20) quantifies the visual relationships. Overall, pMMI is negatively correlated with IMPERV, COND, and nutrients; and positively correlated with PHAB and SLOPE. The pMMI bioscore showed the strongest relationship to IMPERV.

Due to the strong correlations among predictors, appropriate model formulations were investigated using both forward and backward stepwise regression, specifying a probability value of 0.15 for entry or deletion of variables. Both cases converged to a model that included only IMPERV and PHAB as the best explanatory variables.

The resulting linear model is:

$$pMMI = 0.624 - 4.700 \times IMPERV + 0.00226 \times PHAB$$

The adjusted squared multiple R of the regression is 0.833 (indicating that the model explains over 83 percent of the variability in median pMMI by site) with a standard error of estimate of 0.083. The overall regression has an F-ratio of 53.510 and a probability value of < 0.001. All three coefficients are significantly different from 0, with a minimum probability value of 0.015 (for PHAB). PHAB enters the model as a significant regressor despite its strong negative correlation to IMPERV.

Nutrient concentrations are not part of the final model, but this is because nutrient concentrations had a strong collinear relationship with IMPERV.[7] Table 8-20 showed the nutrient concentrations as positively correlated with IMPERV. This may be due to the fact that increased nutrient concentrations are associated with wet and dry-weather runoff from development and septic systems.

**Table 8-20. Pearson Correlation Matrix for pMMI and Predictors**

| | MMI | IMPERV | SEDMT | COND | NO3N | PO4P | NH4N | TIN | PHAB | SLOPE |
|---|---|---|---|---|---|---|---|---|---|---|
| **MMI** | 1.000 | | | | | | | | | |
| **IMPERV** | -0.891 | 1.000 | | | | | | | | |
| **SEDMT** | 0.125 | -0.221 | 1.000 | | | | | | | |
| **COND** | -0.476 | 0.344 | 0.465 | 1.000 | | | | | | |
| **NO3N** | -0.389 | 0.387 | -0.001 | 0.558 | 1.000 | | | | | |
| **PO4P** | -0.469 | 0.351 | 0.047 | 0.474 | 0.265 | 1.000 | | | | |
| **NH4N** | -0.587 | 0.552 | -0.118 | 0.282 | 0.146 | 0.729 | 1.000 | | | |
| **TIN** | -0.388 | 0.398 | -0.048 | 0.530 | 0.869 | 0.527 | 0.307 | 1.000 | | |
| **PHAB** | 0.624 | -0.465 | 0.055 | -0.400 | -0.284 | -0.663 | -0.749 | -0.360 | 1.000 | |
| **SLOPE** | 0.568 | -0.401 | 0.129 | -0.427 | -0.265 | -0.479 | -0.516 | -0.328 | 0.760 | 1.000 |

The untransformed regression model can be used to estimate the pMMI score that would be expected in the absence of impervious development and with a PHAB score of 150 (the minimum for the optimal range). This yields a predicted median pMMI score of 0.963 (with a two standard error range of ± 0.166). At the maximum PHAB of 200 the predicted MMI score would be 1.076.

The regression model shows a strong correlation between bioscores and both physical habitat and impervious area. This further supports the results discussed earlier. Physical habitat itself is degraded by increased flow energy, resulting in sediment transport associated with increased impervious area. Impervious area is also a surrogate for development and associated increases in loads of pollutants such as nutrients.

### Conclusions

The results presented here are consistent with the findings of Isham (2005), who undertook a summary study of the relationship between SC-IBI scores and physical habitat quality scores from monitored sites in Los Angeles, Orange, and San Diego counties. The comparator/reference sites showed good benthic macroinvertebrate bioscores (e.g., SC-IBI, pMMI) and good physical habitat scores. However, impacted

[7] The model was built on a range of IMPERV from 0.18 to 12.2%. The linear relationship is obviously not valid for higher levels of IMPERV that would result in a negative MMI prediction. Alternatively, a strong model (adjusted R2 = 0.835) can be created for the natural logarithm of MMI, which is constrained to be greater than zero:

$$\text{Ln (MMI)} = -0.476 - 6.515 \times \text{IMPERV} + 0.00295 \times \text{PHAB}$$

sites consistently showed lower bioscores regardless of physical habitat score, indicating "that there was virtually no relationship between macroinvertebrate community quality and physical habitat quality in the presence of urban runoff," suggesting that restoring physical habitat alone would not be sufficient to achieve good IBI scores.

As demonstrated earlier, human related activities' impact on benthic community is accomplished by more than one critical stressors. The study suggests that urban sites require mitigation of multiple stressors, including both reduced pollutant loads and consistently adequate physical habitat to support a full natural benthic macroinvertebrate community. In the Malibu Creek Watershed, nutrient loadings and related physical habitat are both important to supporting a healthy benthic community. The physical habitat assessment in this case can be an appropriate indicator of sedimentation processes, contributing to the transport of sediment loads from urban areas or the transport capacity of sediment from its natural habitat (e.g., erosion, etc.).

#### 8.1.7.6 Invasive Species

The New Zealand mudsnail (*Potamopyrgus antipodarum*) was first documented in samples from the Malibu Creek Watershed in 2005 (Abramson, 2009). This invasive species is of concern because it can reproduce clonally and rapidly create massive colonies that have the potential to disrupt the food web and displace native benthic macroinvertebrates. While New Zealand mudsnails have been documented in many western states, their presence was not known in the Santa Monica Bay watershed prior to the analysis of the 2005 samples.

Individual mudsnails are tiny (3-5 mm in length), but may reach densities of 500,000 organisms per square meter (Dorgelo, 1987). Unfortunately, they are easily transported from stream to stream by attaching themselves to shoes and boots, fishing gear, bicycle tires, boats, and animals.

The snail is a "nocturnal grazer, feeding on plant and animal detritus, epiphytic and periphytic algae, sediments and diatoms" (Benson and Kipp, 2008). "Because of their massive density and quantity, the New Zealand mudsnail can out-compete and reduce the number of native aquatic invertebrates that the watershed's fish and amphibians rely on for food" (Heal the Bay, 2011; http://sites.healthebay.org/news/2006/06_08_nzmudsnail/default.asp). The snail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and have been found on more than 70 percent of substrate samples in Malibu Creek (Abramson et al., 2009).

The mudsnails appear to be spreading in the Malibu Creek Watershed. Work by HtB Stream Team has documented the spread beginning in 2006. In that year, the mudsnails were found at 14 of 44 sites (32 percent) in Medea, Las Virgenes, and Malibu Creek proper, including sites on Malibu Creek above and below Cold Creek and near the mouth. In 2007 they were found at 20 of 56 sites (36 percent), including sites in Lindero and lower Solstice Creek (a comparator/reference site for Malibu Creek). The mudsnails had spread to Cold Creek and Triunfo Creek by 2008, and in 2009 were also found in Ramirez Creek.

Jim Harrington (2010, personal communication) began examining the relationship between SC-IBI scores and New Zealand mudsnail density in the samples and to date, has not found a correlation. Mudsnails constituted only 3 percent of the biological sample in spring 2006 at MC-1 and 81 percent of the sample in Spring 2009, yet the SC-IBI scores were 26 and 27, pMMI scores were 0.64 and 0.42, and O/E scores were 0.66 and 0.59, respectively. Anomalously low SC-IBI scores in Spring 2010 also had low densities of mudsnails (from less than 1 percent at MC-1 to 13 percent at MC-15). These limited data were insufficient to conduct detailed analyses and did not show conclusively if New Zealand mudsnails were impacting the benthic condition. Further monitoring and examination is needed.

#### 8.1.7.7 Toxicity Data

Water column toxicity in Malibu Creek has been frequently assessed at the mass emission station coincident with the stream gauge downstream of the Tapia WRF. Bay et al. (1996) examined two stormwater samples in Malibu Creek using the 48-h red abalone larval development and 20-min purple sea urchin fertilization tests and found no toxicity. Since then, LACDPW conducted two wet and two dry water column toxicity tests per year at the mass emissions station, using *Ceriodaphnia dubia* (water flea) survival and reproduction, and *Strongylocentrotus purpuratus* (purple sea urchin) fertilization tests as part of their MS4 NPDES permit requirements. Annual results for the 2001-2002 through 2003-2004 seasons showed no water column toxicity in Malibu Creek. (There is no published report for 2004-2005). Occasional toxicity has been observed since 2003-2004. Sea urchin fertilization was impacted in 2006-2007, 2007-2008, and 2008-2009 wet weather samples, as well as a 2009-2010 dry weather sample, while *C. dubia* survival was impacted in the 2008-2009 wet weather samples and *C. dubia* reproduction was impacted in the 2005-2006 and 2007-2008 dry weather samples. However, in each case, the toxic effect apparently dissipated after holding the sample; therefore, the annual modeling reports attribute the cause to volatile chemicals.

Brown and Bay (2005) examined toxicity in eight dry weather and two stormwater samples from Malibu Creek at the MC-1 station near the mouth. One out of eight dry weather samples showed acute toxicity (survival) and two out of eight showed chronic toxicity (reproduction) to *C. dubia*. The analysis was focused on organophosphorus pesticides and concluded that these were unlikely to be the causes of the observed toxicity. Higher levels of toxicity were observed in Las Virgenes Creek (likely associated with salts) and Medea Creek (likely associated, at least in part, with diazinon). These limited data were insufficient to show conclusively or quantitatively that the benthic macroinvertebrate condition is impacted by toxicity. Further monitoring and examination is needed.

# 8.2 MALIBU LAGOON

Southern California's estuaries are categorized into seven different types: river mouth estuaries, canyon mouth estuaries, lagoonal estuaries, coastal dune-creek estuaries, bay estuaries, structural basin estuaries, and artificial drain estuaries (Ferren et al., 1996). Malibu Lagoon is a lagoonal estuary defined by seasonally opened mouths, usually closed by sand bars most of the year, and brackish fringe-marshes rather than vegetated flats. Salinities can approach fresh water and the estuary can support fauna living in brackish to fresh water conditions (often fresh water input is due to wastewater discharge and agricultural or urban runoff) (Lafferty, 2005).

## 8.2.1 Ocean and Freshwater Inputs

An estuary is defined by its tidal influence, water source, water regime and unique composition of landforms (e.g., beds, bars reefs, levees, buoys, etc.). Historically, the beach barrier was breached by winter and spring runoff allowing tidal exchange, and then restructured again, remaining closed throughout summer and fall (Ambrose et al., 1995; Topanga-Las Virgenes Resources Conservation District ,1989, 1995). However, the impact of anthropogenic activities in the past has resulted in an altered pattern of Lagoon formation and breaching. Malibu Creek, which flows into the Malibu Lagoon, now receives year-round flow (by surface and subsurface pathways) due to irrigation water, treated wastewater inputs, onsite wastewater disposal systems, and other urban-related runoff. Year-round flow creates higher summer water levels in the Lagoon, and the sand barrier overtops at times during the summer. In the past, the sand barrier was artificially breached by the County to allow tidal exchange and clearing, and release of nutrient buildup in the Lagoon. Although this would temporarily improve water quality conditions, the practice directly affected the life history of fish, such as the endangered tidewater goby, and the benthic community. The practice has been discontinued, although some illegal intentional breaching may still occur. The amount and seasonality of freshwater input and the presence of a bar that can close off the mouth of the estuary from the ocean both strongly influence habitat condition and the benthic community residing in the Lagoon. Periods of low salinity, high salinity and tidal flushing varies with the season (Lafferty, 2005).

The opening and closing of the Lagoon berm and other exchanges with the ocean create highly variable salinity and dissolved oxygen conditions that are likely stressful to benthic biota. During the dry period of July 2009, Izbicki et al. (2012) noted that, while the Lagoon was not open to the ocean, overtopping of the berm occurred during high tides. The introduced ocean water with higher salinity and lower temperature than water in the Lagoon, which resulted in stratification in the water column. Earlier dissolved oxygen measurements also showed stratification in the Lagoon and highly variable ranges. Diel dissolved oxygen was surveyed between July 1993 and April 1994. Morning concentrations at the westerly channel site showed a Lagoon bottom range between 2.6 mg/L to 10 mg/L and surface water range between 3.2 mg/L to 13.3 mg/L; the mid Lagoon site showed a bottom water range between 5.5 mg/L to 12.2 mg/L, and a surface water range between 6.2 mg/L to 16.8 mg/L (Ambrose et al., 1995). There were many occasions when the DO concentrations exceeded the basin plan water quality objective. Salinity concentrations from the Ambrose et al. (1995) report similarly showed stratification in the Lagoon and a wide range of salinity levels dependent on the flow of freshwater and opening of the mouth.

Construction of the PCH bridge and its approach ramps, the older Malibu Road, the Malibu Colony Road, Cross Creek Road and its upstream crossing impact drainage; constrains, diverts or causes ponding surface water; and impedes exchange of subsurface water. Extensive areas of impermeable surface affect local hydrology, inhibiting infiltration, causing ponding or diversion of drainage into ditches and culverts. This results in a Malibu Colony area that is mostly impermeable to direct precipitation and its impact on direct ocean-back water exchange. Additional physical constraints include variable upstream channelization and levee construction and riprap placed alongside Malibu Creek near the shopping center.

### 8.2.2 Loss of Benthic Species

Increasing urban development and decades of soil dumping have led to a dramatic loss of species in the Lagoon (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005), including benthic species such as crabs, shrimps, clams and other invertebrates that are a main component of the food chain for many fish and birds impacted by impaired conditions in Malibu Lagoon (Shifting Baseline, 2011; 2NDNATURE, 2010). Degraded by nutrient and bacteria pollution, as well as excessive sedimentation, these problems are exacerbated by poor circulation within Malibu Lagoon's boundaries (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010).

### 8.2.3 Sedimentation

Measurements of sediment in 1987 suggested the average rate of sedimentation since 1983 was 10 cm/year; this level of sedimentation is estimated to be nearly ten times the rate that would have occurred in pre-European settlement periods (Topanga-Las Virgenes Resources Conservation District, 1989). During the flood of February 6, 1999, LACDPW data showed that 2,321 mg/L of suspended sediment was carried through Malibu Creek. Samples show that the Lagoon has higher sediment concentrations than stations farther upstream. Due to low flushing, fine sediments accumulate in the tidal channels. These sediments are associated with greater nutrient loads that cause algae blooms, which results in eutrophication (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). Eutrophication can be natural or caused by nutrient enrichment from anthropogenic activities. Malibu Lagoon currently shows elevated concentrations of the biologically-available nutrients nitrate ($NO_3$), nitrite ($NO_2$), and ammonium ($NH_4$) (Moffatt andNichol, 2005; 2NDNATURE, 2010). Presence of excessive algae leads to greater consumption of dissolved oxygen during decomposition, leading to anoxic conditions that impact the survival of the flora and fauna in the Lagoon.

## 8.2.4 Septic Systems

Upstream runoff from residential areas and irrigation is estimated at a rate of 2,500 – 3,500 acre-feet annually. Multiple sources have estimated the seepage of septic tanks into the Lagoon, including an estimated rate of 500 acre-feet per year (acre-ft/yr) (Topanga-Las Virgenes Resources Conservation District, 1995), and a more recent estimate that recharge from onsite wastewater disposal systems in the Malibu Civic Center area contributes about 1,050 cubic meters per day ($m^3$/d) (311 acre-ft/yr; McDonald Morrissey, 2010). The hydrologic flow and fate of dissolved or suspended material, such as nutrients, is complicated by the opening or closing of the Lagoon mouth. Multiple factors influence the mouth condition, including erosion of sand from the mouth, large tidal flow, large freshwater input, long-shore sand transport and storms. All of these factors can affect how the mouth and the hydrologic regime in the Lagoon will behave, which then impacts the biota that live in the Lagoon ecosystem.

Direct input of inorganic nitrogen from onsite wastewater disposal systems to Malibu Lagoon is a concern (Callaway et al., 2009). The City of Malibu does not provide regional sewage collection or treatment, and high water tables decrease the efficiency of onsite wastewater treatment. The Malibu Creek Watershed 2003 Nutrient TMDL assigned a load allocation of 6 lbs/day of inorganic nitrogen; however, the LARWQCB staff estimated that current loads from onsite wastewater disposal in the Civic Center area amount to 30-35 lbs/day. As a result, an amendment to the Water Quality Control Plan was made to prohibit new on-site wastewater disposal systems in the area. The evidence suggests, however, that existing loads may be sufficient to cause ongoing problems, as the overall TMDL for total inorganic nitrogen in the summer season is only 27 lbs/day (see Section 5.2.2).

## 8.2.5 Estuarine Benthic Community

Estuarine invertebrates are found in the water, on vegetation, on the mud, and in the mud (Lafferty, 2005). Most species have the highest abundance in the summer and lowest abundance in winter and after high freshwater flows. In particular, the invertebrate community can be a useful indicator of the type of tidal inundation that an estuary receives. As mentioned earlier, invertebrates are particularly sensitive to variations in salinity (especially compared with fishes and birds). Sandoval and Lafferty (1995) found that the invertebrate community of estuaries with regular tidal influence is dominated by relatively *marine* species such as crabs, shrimp, polychaete worms, clams, mussels, and horn snails. In estuaries with variable salinity, these species are usually absent.

Marsh invertebrates are often inconspicuous, but they are a diverse group that includes benthic infauna and crustaceans in the lower marsh, and insects and spiders in the upper marsh (Josselyn, 1983; Zedler et al., 1992). A recent settlement plate survey done in Elkhorn Slough salt marshes found 25 different species of invertebrates including crustaceans, insects, spiders, snails, bivalves, and polychaetes (Griffith, personal communication). Although not as species rich as adjacent tidal creeks, California salt marsh sediments can provide habitat for dense populations of oligochaetes and polychaete worms, while the lower elevation marsh surface is often dominated by gastropods, amphipods, isopods, and crabs (MacDonald, 1969, Talley and Levin, 1999, Williams and Desmond, 2001). These species play important roles as detrital processors, algal grazers, and predators (Josselyn, 1983).

Infauna inhabiting coastal lagoon sediments typically includes clams, shrimp, crustaceans, and worms, among others. A typical southern California coastal Lagoon with appropriate tidal flushing should support between 100-200 infaunal species (Zedler et al., 1992; Peterson, 1977). In contrast, coastal lagoons *without* tidal flushing will see significantly reduced species richness (Nordby and Covin, 1988). Benthic community condition is a measure of the species composition, abundance and diversity of the invertebrates inhabiting surficial sediments. The benthic community measure is used to assess impacts to the primary receptors targeted for protection of aquatic life. Benthic community composition is a measure of the biological effects of both natural and anthropogenic stressors.

In 1993 and 1994, Ambrose et al. (1995) collected benthic invertebrate data from Malibu Lagoon. Infauna was collected from three sites in the Lagoon; large infauna was collected with a small clam gun, small infauna was collected with a 10-centimeter (cm) deep sediment core, and zooplankton was sampled with a 153-micrometer (µm) mesh plankton net. The largest proportion of infauna biomass was the collection of a single polychaete species. Other benthic invertebrate taxa collected included the California jackknife clam, two species of polychaetes, oligochaetes, ribbon worms, mud-flat clam, snails, crabs and the introduced oriental shrimp. Zooplankton species were dominated by copepods, ostracods and nematodes. This study's results of very low benthic species taxa became the basis of the impairment listing for Malibu Lagoon.

### 8.2.6 Malibu Lagoon USEPA Sampling 2010-2011

USEPA conducted benthic invertebrate sampling at Malibu Lagoon during winter 2010 (November 8-9, 2010) and summer 2011 (May 24-26, 2011). To capture the largest range of benthic populations, USEPA applied four sampling methods to collect small infauna, large infauna, and invertebrates in the littoral zone and estuarine sediment at eight sites in Malibu Lagoon.

A total of 18 and 19 total taxa were collected in winter 2010 and spring 2011, respectively (Table 8-21 and Table 8-22). The spring 2011 sample collection resulted in near twenty times the total abundance collected in winter 2010 (230,621 individuals in spring compared with 12,104 individuals in winter across all eight sites). Greater diversity and abundance are expected because of the climatic and flow conditions in the intertidal zone during the spring season.

Sites S-02 and S-03 are located in the back sloughs where flow and circulation are limited; S-01 is located at C channel closest to the sand berm at the mouth; S-05 and S-06 are located on the eastern channel while S-07 and S-08 are located on the western channel of the Malibu Lagoon. For both winter and spring, the most abundant species collected were podocopid ostracod species, microscopic bivalve crustaceans commonly found in the littoral and sublittoral faunas of southern California (south of Point Conception). Podocopids are tolerant benthic species, crawling over or burrowing beneath the sediment surface, through the interstices of shelly sands and gravels, over rocks and plants, or through microalgae.

Located at the head of the estuary with consistent upstream freshwater flow, Site S-08 showed the largest number of taxa collected. Sites S-02, located in the back channels with limited flow, and S-04, located closest to the Lagoon mouth in the central part of the Lagoon, showed the largest abundance (3,428 and 3,401, respectively; Table 8-21). However, most of the species collected for S-02 and S-04 were podocopids and nematode round worms, both of which are highly tolerant species that can survive in highly impacted conditions. Sites S-02 and S-05 had the highest taxa richness collected. Similarly, most of the species collected from S-05 are podocopids and nematode round worms. Less tolerant species, such as a few of the aquatic and terrestrial insects, had between 1-10 individuals. These results strongly suggest poor benthic community diversity and abundance.

In spring 2011, Sites S-01, S-04, and S-05 (129,289; 40,904; and 43,610; respectively; Table 8-22) showed a significantly greater number of individuals collected. Note that these three sites are located closest to the sand berm and mouth. Site S-04 is located in the Lagoon mid-channel about 20 feet behind the sand berm and mouth; S-05 is located along the eastern shore of the main Lagoon channel and about 50 m south of the PCH bridge/overpass. These three sites are located in the intertidal zones along the western shore, main channel and eastern shore of the Lagoon closest to the mouth. Also, we should note that over 97% of the abundance is from the littoral sweep method of sample collection. The different sampling methods will need to be further evaluated, but the objective was to use methods similar to the ones used for Malibu Lagoon Restoration Monitoring Plan (MLRMP), to allow comparison between the 2006-2007 data and data collected during these sampling events.. The 2010 and 2011 sampling results, at least for density, were comparable in density of invertebrates to collections during the 1993-1994 sampling period, which showed that the infauna at Malibu Lagoon then was dominated by a single species of clam. Nordby and Zedler (1991) found that freshwater from sewage spills or winter rains lowered water salinities and had major impacts on the channel organisms of southern California coastal wetlands. Benthic infaunal assemblages responded more rapidly to reduced salinity than did fishes, with continued salinity reduction leading to the extirpation of most species.

**Table 8-21. Benthic Invertebrate Species List, Abundance and Taxa Richness Collected during Winter 2010 USEPA Malibu Lagoon Sampling Effort**

| Taxa List | S-01 | S-02 | S-03 | S-04 | S-05 | S-06 | S-07 | S-08 |
|---|---|---|---|---|---|---|---|---|
| **ANNELIDA** | | | | | | | | |
| Oligochaeta | 6 | 104 | 11 | 60 | 3 | 8 | 51 | 50 |
| **ARTHROPODA** | | | | | | | | |
| Atylus tridens | | | | | 1 | | | |
| Carinonajna bicarinata group | | | | | | 3 | | |
| Chironomidae | 3 | 82 | 7 | 9 | 1 | 15 | 1 | 9 |
| Coleoptera | | 1 | | | 1 | | | |
| Copepoda - Calanoida sp. | | | | | | | | 2 |
| Copepoda - Harpacticoda sp. | | | 9 | 4 | | 4 | | 4 |
| Ephydridae - Ephydra sp. | | 1 | | | | | | |
| Gammarus lacustris | | 1 | | | | | | |
| Hemiptera sp. 1 | 2 | 5 | 1 | | | | | |
| Hemiptera sp. 2 | | 2 | | | 1 | | | |
| Holmesimysis costata | | | | 4 | | | | |
| Isopoda cf Flabillifera sp. | | | | | 1 | | | |
| Megalorchestia cf benedicti | | | | | 1 | | | |
| Ostracoda - Podocopida sp. | 508 | 2,057 | 794 | 2,817 | 454 | 935 | 475 | 427 |
| Palaemon macrodactylus | | | | | | | | 4 |
| Traskorchestia traskiana | 19 | 3 | 1 | 2 | 16 | 115 | 14 | 7 |
| **MISCELLANEOUS PHYLA** | | | | | | | | |
| Nematoda | | 1172 | 260 | 505 | 82 | 368 | 275 | 326 |
| | | | | | | | | |
| **Abundance** | **538** | **3,428** | **1,083** | **3,401** | **561** | **1,448** | **816** | **829** |
| **Taxa Richness** | **5** | **10** | **7** | **7** | **10** | **7** | **5** | **8** |

**Table 8-22. Benthic Invertebrate Species List, Abundance and Taxa Richness Collected during Spring 2011 USEPA Malibu Lagoon Sampling Effort**

| Taxa | S-01 | S-02 | S-03 | S-04 | S-05 | S-06 | S-07 | S-08 |
|---|---|---|---|---|---|---|---|---|
| **ANNELIDA** | | | | | | | | |
| Oligochaeta | 5,033 | 264 | 22 | 3016 | 1430 | 992 | 663 | 1612 |
| Platynereis bicanaliculata | | | | | | 1 | | |
| **MOLLUSCA** | | | | | | | | |
| Sacoglossa sp. | | | | 88 | 2 | 19 | | 10 |
| **CRUSTACEA** | | | | | | | | |
| Arachnida sp. | 1 | | | | | | | |
| Coleoptera | | 10 | 1 | 118 | | | | |
| Collembola sp. | 1 | | | | | | | |
| Copepoda - Calanoida sp. | 1 | | 1 | 5 | | 14 | 132 | 123 |
| Copepoda - Harpacticoda sp. | 2 | 83 | 4 | 32 | | 1 | | |
| Decapoda sp. larvae | | | | | | | | 1 |
| Diptera sp. midge | 4 | 6 | 14 | 88 | 211 | 64 | 6 | 54 |
| Eogammarus confervicolus | 2 | 6 | 1 | 5 | 59 | 137 | 2 | 59 |
| Hemiptera sp. | 37 | 338 | 238 | | 8 | 10 | 1 | 1 |
| Insecta spp. | 1 | 14 | 4 | 1 | 2 | | | |
| Ostracoda sp. | 124,139 | 5,443 | 2,983 | 37,428 | 41,768 | 914 | 158 | 1,756 |
| Talitridae sp. | 1 | 1 | | | | | | |
| Traskorchestia traskaian | | | 1 | | | | | |
| **MISCELLANEOUS** | | | | | | | | |
| Chironomidae | | | | | 1 | | | |
| Chordata Juv. | | | | | 0 | 1 | | |
| Nematoda | 67 | 365 | 27 | 123 | 129 | 124 | 6 | 131 |
| | | | | | | | | |
| **Abundance** | 129,289 | 6,530 | 3,296 | 40,904 | 43,610 | 2,277 | 968 | 3,747 |
| **Taxa Richness** | 12 | 10 | 11 | 10 | 9 | 11 | 7 | 9 |

## 8.2.7 Malibu Lagoon Restoration Monitoring 2006-2007

Santa Monica Bay Restoration Commission (SMBRC) collected a representative benthic macroinvertebrate survey by conducting a benthic grab sample and littoral sweep at a total of six sites during 2006 (Table 8-23) and five sites in 2007 (Table 8-24). In 2006, a total of 24 distinct taxa were observed and the combined sampling methods resulted in collecting a total of 65,302 individuals. Ostracods were the most abundant species collected at all sites (76% of total individuals). Sites ML-5 and ML-6 showed the most number of individuals collected (>21,000). Taxa richness ranged between 9-13 species per site. For every site, the littoral sweep of a pre-defined area resulted in collecting more taxa and individuals than other sampling methods. In 2007, a total of 34 distinct taxa were observed and the combined sampling methods resulted in a total of 2,274 individuals collected. This is a significant difference between the two years, and likely due to the very different tidal exchange conditions observed between 2006 and 2007.

In fall 2006, the Lagoon was *open* for approximately two weeks prior to sampling, compared with a 1 to 150 days closure prior to sampling. Percent algal cover was significantly greater in fall 2007, between 14-38%, compared with 0-15% in fall 2006. The channel wetted width for Malibu Lagoon was also markedly different, between 75-135 feet in channel width in 2007, compared with 50-60 ft in channel width in 2006. The greater coverage of water over the intertidal zone and for extended period in 2007 likely flooded some of the benthic invertebrate habitat and also modified the freshwater and saltwater balance.

Although total abundance was higher in 2006, total taxa richness was higher in 2007. Examination of the species composition showed that approximately 51% of the species composition was due to *Corisella* species, a hemipteran aquatic insect that is highly tolerant to high chemical levels and physical disturbance (Foltz, 2009). Approximately 25% of the species were ostracods and cyclopoid copepods. The nutrient load (TN, TP and organic carbon) associated with sediment appear to decrease with increasing sand composition of the substrate. In conjunction with the increasing thickness of organic detritus and distance to the hydrologic connection of the main channel Lagoon, this resulted in decreasing the role of tidal exchange; sites closer to hydrologic connection showed greater abundance and taxa richness in general. In 2006, better tidal exchange resulted in sites further away from the main channel of the Lagoon and mouth (back channel sites) having greater abundance; in these conditions, floating microscopic bivalve crustacean ostracods dominated the species composition. In 2007, with limited to no tidal exchange, sites adjacent to or in the main channel of the Lagoon had greater abundance; the highly tolerant *Corisella* aquatic insect dominated the species composition.

**Table 8-23. Benthic Community Species Collected for the Baseline Malibu Lagoon Restoration Monitoring Project in 2006 (2NDNATURE, 2008)**

| Insecta Taxa | ML2 | ML4 | ML5 | ML6 | ML7 | ML8 |
|---|---|---|---|---|---|---|
| *Corisella sp.* | 0 | 0 | 0 | 3 | 0 | 0 |
| *Corixidae* | 61 | 19 | 903 | 2,058 | 1 | 58 |
| *Trichocorixa sp* | 13 | 3,859 | 251 | 1,018 | 1 | 42 |
| **Coleoptera** *Berosus sp* | 0 | 3 | 0 | 0 | 0 | 0 |
| **Coleoptera** *Hygrotus sp* | 0 | 0 | 13 | 4 | 0 | 0 |
| **Coleoptera** *Ochthebius sp* | 0 | 0 | 0 | 0 | 0 | 1 |
| **Diptera** *Clunio sp* | 0 | 1 | 0 | 0 | 1 | 0 |
| **Diptera** *Cricotopus sp* | 1 | 1 | 2 | 1 | 0 | 0 |
| **Diptera** *Dasyhelea sp* | 1 | 0 | 0 | 0 | 0 | 0 |
| **Diptera** *Dolichopodidae* | 0 | 0 | 5 | 0 | 0 | 0 |
| **Diptera** *Ephydra sp* | 190 | 189 | 144 | 51 | 3 | 0 |
| **Diptera** *Tanytarsus sp* | 1 | 0 | 0 | 0 | 0 | 0 |
| **Non-Insecta** | | | | | | |
| **Nematoda** | 1015 | 1852 | 69 | 276 | 2 | 19 |
| **Oligochaeta** | 63 | 74 | 53 | 64 | 146 | 40 |
| **Polychaeta** | 0 | 0 | 0 | 0 | 0 | 2 |
| **Ophiuroidea** | 0 | 0 | 0 | 0 | 0 | 1 |

| Insecta Taxa | ML2 | ML4 | ML5 | ML6 | ML7 | ML8 |
|---|---|---|---|---|---|---|
| **Ostracoda** | 3,314 | 7,132 | 19,923 | 16,911 | 1,925 | 606 |
| **Amphipoda** *Hyalella sp* | 1 | 61 | 3 | 0 | 0 | 0 |
| **Cyclopoida** *Cyclopoida* | 118 | 27 | 2 | 0 | 2 | 25 |
| **Decapoda** *Palaemonetes sp* | 0 | 0 | 0 | 0 | 0 | 130 |
| **Hoplonemertea** *Prostoma sp* | 7 | 0 | 0 | 0 | 0 | 0 |
| **Hypsogastropoda** *Hydrobiidae* | 0 | 0 | 0 | 0 | 0 | 1 |
| **Hypsogastropoda** *Tryonia sp* | 56 | 543 | 279 | 1,438 | 207 | 14 |
| **Mytiloida** *Mytilidae* | 0 | 0 | 0 | 0 | 0 | 2 |
| ***Abundance*** | **4,841** | **13,761** | **21,647** | **21,824** | **2,288** | **941** |
| ***Taxa Richness (Across all sites n=24)*** | **13** | **12** | **12** | **10** | **9** | **13** |

**Table 8-24. Benthic Community Species Collected for the Baseline Malibu Lagoon Restoration Monitoring Project in 2007 (2NDNATURE, 2008)**

| Insecta Taxa | ML1 | ML2 | ML4 | ML6 | ML7 |
|---|---|---|---|---|---|
| **Collembola** *Isotomidae* | 3 | 0 | 0 | 0 | 2 |
| **Ephemeroptera** *Callibaetis sp* | 28 | 9 | 14 | 19 | 39 |
| **Odonata** *Aeshna sp* | 1 | 0 | 0 | 0 | 0 |
| **Odonata** *Ischnura sp* | 0 | 0 | 0 | 1 | 0 |
| **Odonata** *Libellula sp* | 0 | 0 | 0 | 1 | 0 |
| **Hemiptera** *Abedus sp* | 0 | 0 | 2 | 1 | 0 |
| **Hemiptera** *Corisella sp.* | 3 | 13 | 0 | 0 | 1 |
| **Hemiptera** *Corixidae* | 30 | 397 | 31 | 5 | 691 |
| **Hemiptera** *Macrovellidae* | 5 | 0 | 0 | 56 | 0 |
| **Hemiptera** *Trichocorixa sp* | 4 | 27 | 1 | 0 | 22 |
| **Coleoptera** *Berosus sp* | 5 | 2 | 8 | 0 | 3 |
| **Coleoptera** *Enochrus sp* | 0 | 0 | 0 | 2 | 0 |
| **Coleoptera** *Ochthebius sp* | 1 | 4 | 0 | 0 | 0 |
| **Coleoptera** *Rhantus sp* | 0 | 0 | 0 | 0 | 1 |
| **Coleoptera** *Tropisternus sp* | 1 | 0 | 2 | 0 | 1 |
| **Diptera** *Anopheles sp* | 0 | 1 | 1 | 11 | 6 |
| **Diptera** *Apedilum sp* | 3 | 2 | 0 | 4 | 0 |
| **Diptera** *Atrichopogon sp* | 1 | 0 | 0 | 0 | 0 |
| **Diptera** *Chironomidae* | 1 | 0 | 0 | 0 | 0 |
| **Diptera** *Chironomus sp* | 0 | 0 | 0 | 0 | 1 |
| **Diptera** *Cricotopus sp* | 7 | 0 | 0 | 10 | 12 |
| **Diptera** *Culex sp* | 0 | 0 | 0 | 1 | 0 |

| Insecta Taxa | ML1 | ML2 | ML4 | ML6 | ML7 |
|---|---|---|---|---|---|
| **Diptera** *Dicrotendipes sp* | 0 | 1 | 0 | 0 | 2 |
| **Diptera** *Ephydra sp* | 0 | 0 | 0 | 0 | 4 |
| **Diptera** *Goeldichironomus sp* | 69 | 1 | 3 | 25 | 0 |
| **Diptera** *Polypedilum sp* | 1 | 0 | 0 | 0 | 0 |
| **Diptera** *Tanypus sp* | 0 | 0 | 0 | 0 | 2 |
| **Non-Insecta Taxa** | | | | | |
| **Nematoda** | 0 | 1 | 0 | 0 | 0 |
| **Oligochaeta** | 5 | 0 | 0 | 0 | 0 |
| **Ostracoda** | 2 | 151 | 0 | 88 | 1 |
| **Amphipoda** *Hyalella sp* | 2 | 3 | 33 | 1 | 0 |
| **Basommatophora** | 0 | 0 | 0 | 0 | 0 |
| *Physa/Physella sp* | 1 | 0 | 2 | 0 | 0 |
| **Cyclopoida** | | | | | |
| *Cyclopoida* | 264 | 0 | 0 | 108 | 4 |
| **Diplostraca** | | | | | |
| *Chydoridae* | 3 | 0 | 0 | 0 | 0 |
| ***Abundance*** | **440** | **612** | **97** | **333** | **792** |
| ***Taxa Richness (Across all sites n=34)*** | **22** | **13** | **10** | **15** | **16** |

In summer 2012, the State completed an extensive restoration of Malibu Lagoon, where decades of accumulated sediment were dredged and the Lagoon's habitats were re-contoured to reflect a larger and area to support native bird, fish and benthic species. Natural hydrology were also restored to allow for tidal flow and movement of water. These actions will result in improved water quality conditions, including dissolved oxygen levels and lower nutrient and sedimentation loading. For detailed up-to-date information, plans, background studies and reports, and current status, please visit web-link: http://www.restoremalibulagoon.com/overview/

### 8.2.8 Malibu Lagoon Toxicity

Sediment toxicity in Malibu Lagoon has been examined with amphipod toxicity tests as part of the "Bight" sampling program conducted every five years. In both 1998 and 2003 no toxicity was reported for Malibu Lagoon (Bay et al., 2000; Bay et al., 2005). A total of seven sites were analyzed in Malibu Lagoon in 2003. Bight 2008 (Bay et al., 2011) did not include sediment toxicity results for Malibu Lagoon.

Additional sediment toxicity results for a sample collected in Malibu Lagoon in 1993 are reported in Anderson et al. (1998). This report confirms the absence of toxicity to amphipods. Mussel development tests apparently showed some impact from exposure to subsurface water, although the results are not discussed in the text.

### 8.2.9 Species Richness

In comparison to other southern California Lagoons, Malibu Lagoon exhibits exceptionally low species richness. For example, in 1993-1994, only two families of polychaetes were observed; this is significantly fewer families than observed in Los Peñasquitos Lagoon (between 6 to 11 polychaete taxa), a southern California estuary similar in size to Malibu Lagoon and frequently closed to tidal flushing (Nordby and Covin, 1988). The species richness for crustaceans and bivalves in Malibu Lagoon was similarly low. In contrast, variability in benthic communities at Mugu Lagoon from 1969 to 1972 showed consistent community composition and little temporal variability in the population densities of the most abundant species of a sandy-bottom benthic community (Peterson, 1977). Furthermore, 31 species were observed at Upper Newport Bay, 31 species at Tijuana Estuary and 52 species at Mugu Lagoon. These species richness observations indicate strongly that Malibu Lagoon, in comparison, has significantly lower species richness overall. Other coastal estuaries in southern California with poor tidal flushing also show similarly low invertebrate species richness, such as Los Peñasquitos Lagoon (n=20); San Dieguito (n=7), and Batiquitos Lagoon (n=9). These latter three Lagoon estuaries' reported species richness in the 1970's are reflective of long periods of prolonged mouth closure (Mudie et al., 1974, 1976). After Los Peñasquitos and San Dieguito had been opened to the ocean (at least intermittently) in the 1990s, the invertebrate species richness increased to 34 and 100, respectively. This compares well to the 100-200 types of invertebrate species observed for those coastal wetlands with good tidal flushing and ocean exchange.

**Expected Malibu Lagoon Benthic Species Richness**

Based on these comparable coastal estuaries and the three fold increase in observed species diversity following improved flow and water quality conditions, Malibu Lagoon should at a minimum achieve a species diversity richness of 40. This is further expected because of the full restoration of Malibu Lagoon recently in summer 2012. The restoration actions provided improved tidal flow, water movement in critical native species habitat and higher water quality conditions. This species diversity target should include native or highly pollution in-tolerant species. Like other similar coastal estuaries, a high species diversity richness of invasive or pollution tolerant species is not the expected un-impacted condition for Malibu Lagoon.

Since the 1993-1994 sampling period, benthic macroinvertebrate data for Malibu Lagoon have been collected as part of the Bight 1998, Bight 2003, and Bight 2008 surveys (Ranasinghe et al., 2010). Researchers have also developed a benthic response index for California bays and estuaries (Smith et al., 2003; Ranasinghe et al., 2009). However, this is applicable only to haline (high salinity) and euryhaline (tolerating a wide range of salinities) communities. The majority of the samples obtained in Malibu Lagoon have been freshwater species (mostly larval beetles and flies), so the estuarine IBI is not applicable. On the other hand, the gradient within the Lagoon is essentially zero, so the stream-based SC-IBI for freshwater is also not applicable.

# 9. Linkage Analyses

Our evaluation of the extensive benthic macroinvertebrate data showed that the assemblages in Malibu Creek and Estuary have been adversely affected and have changed from that expected in the absence of human disturbance. This section evaluates the available evidence and identifies the primary stressors and sources impairing the beneficial uses associated to the benthic macroinvertebrate community. Since a single stressor was not identified as the source of benthic assemblage degradation during the listing of the impairment, and complex interactions are at work between biological communities and their chemical and physical environment, it was critical for this TMDL to evaluate the linkage relationships associated with the impairment. USEPA conducted a detailed and structured examination of the potential stressors to identify candidate causes of impairment. To accomplish this, the methodology outlined in USEPA's Stressor Identification Guidance (SIG) (USEPA, 2000b), which constitutes Volume 1 of the Causal Analysis/Diagnosis Decision Information System (CADDIS; http://www.epa.gov/caddis/) was followed in this section.

The linkage analysis identified the connection between environmental responses and identified pollutant sources and is used to construct and support the cause-and-effect relationship between the selected indicators, stressors, and the identified sources; this model is then used to support the associated numeric targets for the stressors. This analysis provided the basis for estimating total assimilative capacity and any needed load reductions. Additional background information is provided in Appendix E, which summarizes some key studies in the watershed. A hypothetical linkage analysis example is presented at the end of Appendix G to illustrate how this approach considers the multiple variables to determine the critical stressors and causes. Appendix G also provides additional details on the Stressor Identification (SI) performed for this TMDL.

This TMDL must identify the critical water quality related stressors that are impacting the beneficial uses, identify appropriate water quality based numeric targets and set wasteload and load allocations that will result in protection of the designated beneficial uses for Malibu Creek and Lagoon. The Stressor Identification analysis identified all critical stressors and sources in the Malibu Creek Watershed. This TMDL set loading capacities and wasteload and load allocations for the identifiable pollutants determined by the SIG. Consequently, this TMDL may not address some stressors due to the nature of the impact. Nevertheless, it is important to identify all potential stressors and begin the process of restoration, which may take multiple steps, phases and/or programs.

## 9.1 Role of Benthic Macroinvertebrates

Macroinvertebrates are a critical part of the ecosystem structure of streams and estuaries. This diverse fauna inhabits the full breadth of aquatic habitats, control algal and detrital resources, and provide a food source for fish, birds, and other animals; in so doing, they have a role in recycling nutrients and supporting the production of commercially and recreationally valuable vertebrate species. Benthic macroinvertebrates include taxa in all consumer categories including herbivores, detritivores, predators, omnivores, and parasites. Additionally, they feed from a variety of food sources using a variety of functional methods that frequently are used in classification. These include filter feeders (collecting plankton or fine organic particulates from the water column or benthos), shredders (consuming terrestrial plant material in the stream), scrapers/grazers (consuming algae/plants from submerged surfaces), piercers (sucking plant or animal fluids), and predators.

As with other taxonomic groups, macroinvertebrates include many species that are sensitive to pollutants and others that are tolerant. Some will tolerate low dissolved oxygen conditions better than others, for example, some midges (Diptera – Chironomidae) typically tolerate very poor conditions while stoneflies (Plecoptera) require well-oxygenated water. Some taxa are highly tolerant to multiple stressors (e.g., many chironomids), while others are highly sensitive to many stressors (many Plecoptera and Ephemeroptera). Benthic macroinvertebrates frequently do not exhibit a large spatial range. Consequently, they often cannot escape stressors in the same manner as animals capable of migrating over a larger range. Moreover, aquatic insects exhibit varied lengths during which they exist in aquatic life stages. Some are aquatic for their entire life histories (e.g., the predaceous diving beetle, *Thermonectus* sp.), while most emerge as adults after some time period. The aquatic stage of some benthic macroinvertebrates is very short (e.g., mosquitoes, Diptera – Culicidae, which may last only a few days) while for many it is long, often greater than one year (e.g., some dragonflies, Odonata, which may last up to four years) (Merritt et al., 2007). These life history traits allow the benthic macroinvertebrate community to integrate the cumulative effects of stressors impacting a waterbody. As a result of their diversity, habitat breadth, ecosystem importance, life histories, and sensitivity, the richness and abundance of macroinvertebrates are good indicators of water quality condition and overall water quality (e.g., Barbour et al., 1999). Under minimally disturbed reference conditions, ecosystems will contain a balanced diversity and abundance of taxa consistent with the limitations presented by the available resources and natural environmental variability alone. As anthropogenic disturbance occurs, the natural environmental condition is altered, novel stressors are introduced, and the macroinvertebrate assemblage changes.

## 9.2 STRESSOR IDENTIFICATION

The ability to accurately identify stressors and defend those findings with evidence is an important step in developing strategies to improve the quality of aquatic resources. The SIG lays out a detailed and rigorous approach to identify the stressor or combination of stressors causing biological impairment in aquatic ecosystems while providing a structure to organize the scientific evidence supporting the conclusions. The objective of the SI process in this TMDL was to identify the primary pollutant stressors causing the adverse changes observed in the benthic assemblage.

The SI approach involved the following steps:

1. List Candidate Causes
    a. Identify stressor sources
2. Analyze Evidence of the following types, depending on availability:
    a. Measurements of the causes and responses in the Malibu Creek Watershed;
    b. Measurements of similar causes and responses outside of the Malibu Creek Watershed;
    c. Measurements of exposure at the site;
    d. Measures of effects from laboratory studies; and
    e. Site measurements and intermediate steps in a chain of causal processes.
3. Characterize Causes
    a. Eliminate Alternatives
    b. Diagnostic Analysis
    c. Strength of Evidence Analysis
    d. Identification of Probable Cause

A detailed discussion of the major steps is provided in Appendix G. This section summarizes the SI analysis and lays out the underlying linkage between the benthic macroinvertebrates and the stressors impacting them.

## 9.2.1 List Candidate Causes

The first step in investigating the potential causes of the degraded benthic macroinvertebrate assemblage was to develop a list of potential causes.

In this TMDL, the listed impairments are sedimentation and benthic macroinvertebrate community, which may be stressed by multiple factors, such as:

- Degraded habitat,
- Physical stressors that cause deviations from natural conditions,
- Degraded water quality conditions (e.g., low DO, excessive nutrient levels, temperature, toxic ions etc.), or
- Invasive species.

Furthermore, habitat is itself an integrative indicator as degraded habitat can be caused by factors such as flow alteration, increased sedimentation or poor sediment quality, increased erosion, and/or excess algal density that reduce favorable habitat conditions.

During the stressor identification, a conceptual model was developed (Figure 9-1), describing the pathways by which stressor sources generate stressors that impact the benthic macroinvertebrate community. Proximate and interacting stressors and stressor sources were identified. Proximate and interacting stressors (termed Major Stressors in this document) are conditions that occur at an intensity, duration, and frequency of exposure that results in a change in ecological condition. Sources, which are evaluated in Section 2 of Appendix G, are origins of stressors that release or impose a stressor into a waterbody. The conceptual model helps guide the analyses and characterizations. Detailed descriptions of the next steps are provided in Appendix G. In Malibu Creek and Lagoon, several candidate stressors potentially impact the benthic macroinvertebrate community. Furthermore, these multiple causes of impairment in Malibu Creek and Lagoon interact with one another in complex ways. In Malibu Creek and Lagoon, there are five major stressors that were potential causes of biological impairment, as described below.

**A1. Reduced Habitat Quality from Sedimentation**

Excess sedimentation was documented in Malibu Creek and Lagoon, and is a known cause of habitat degradation with likely adverse impacts on benthic macroinvertebrates (Harrison et al. 2007). Benthic macroinvertebrates are impacted by sedimentation when their substrate composition is altered, their drift is increased due to sediment deposition or substrate instability, their respiration is affected by silt deposits on their physiological structures, their respiration is impacted due to low oxygen concentrations, their feeding activities are impeded by suspended sediment concentrations, or their migration or movement is impacted by sand deposition (Wood and Armitage 1997). In Malibu Creek Watershed, where naturally steep mountains exist and development activities have occurred, sedimentation problems are expected, especially with sharp changes in flow regime; this leads to sediment transport and channel instability. Impervious surfaces in a watershed can cause increased peak runoff, increased flow energy channel erosion and subsequent sedimentation impacts. During storms, water runs off impervious surfaces quickly, rather than infiltrating into the ground and slowly draining to streams through groundwater. Rapid runoff increases stream channel flow and power, exacerbating downstream channel erosion and contributing to increased sediment loads (Trimble, 1997, Coats et al., 2008, Walsh et al., 2007).

Because sediment-related habitat metrics are low, sediment appears to be a plausible cause of stress in Malibu Creek main stem. Increased sediment transport also impacts habitat in Malibu Lagoon by filling in and aggrading the lagoon. In addition to direct impacts on benthic habitat quality, the reduced water volume can increase temperature and dissolved oxygen stresses on lagoon benthic biota.

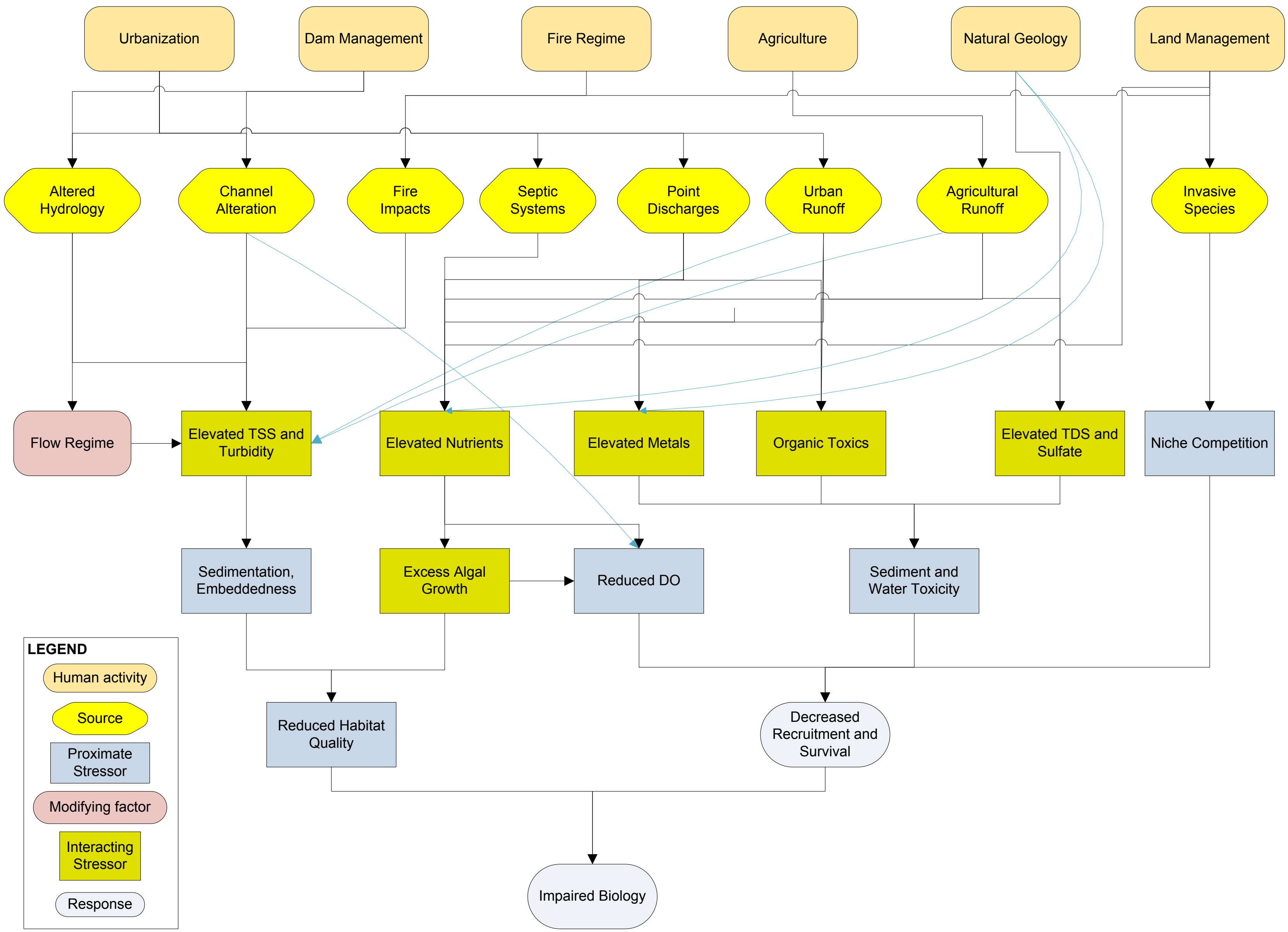



**Figure 9-1. Conceptual Model of Candidate Causes of Impaired Biology in Malibu Creek and Lagoon**

### A2. Reduced Habitat Quality from Excess Algal Growth

Excess algal growth associated with nutrient enrichment has long been observed in the Malibu Creek Watershed. Sikich et al. (2012) note that high nutrient concentrations in the watershed are likely to contribute to the excessive algal growth throughout the watershed, with mat algal cover exceeding 30% at almost all of HtB Stream Team's monitoring sites. The presence of excessive algae can result in loss of invertebrate taxa through habitat alteration. Extensive algal mat coverage can result in eutrophic conditions, and low dissolved oxygen concentrations, which would negatively impact aquatic life, including the benthic macroinvertebrate assemblage.

### A3. Reduced DO from Excess Algal Growth or Oxygen-demanding Waste

Low DO has been observed in both Malibu Creek and its tributaries, although observations of daytime DO meet the minimum DO criterion most of the time (see Section 7.3). Data show that early morning DO levels were well below the criterion for some pools in lower Malibu Creek. Reduced DO may result from excess algal growth, and can also be caused by discharges of oxygen demanding wastes, such as decomposable or labile organic matter. It is exacerbated by elevated water temperatures, which in turn may be linked to impervious surface runoff, impoundments, and removal of riparian vegetation. Regardless of the cause of low DO, benthic macroinvertebrates require adequate DO for survival, and low DO is a stressor that can potentially cause biological impairment.

### A4. Toxicity from Metals or Organic Toxics

Occasional water column toxicity has been reported for Malibu Creek since 2005 (Brown and Bay 2005). In Malibu Lagoon, two sediment sites out of eight exhibited toxicity (Meyers et al., 2001). A variety of substances, including various metals, ammonia, and organic chemicals such as pesticides, herbicides, and petroleum products can cause acute (e.g., lethality) or chronic toxicity (e.g., reduced reproductive success) in benthic macroinvertebrates. In many watersheds, toxicity is most commonly associated with anthropogenic loads (wastewater discharges, urban runoff); however, in some instances, it may also reflect naturally elevated water column or sediment concentrations for some chemicals. For instance, sulfate and selenium concentrations are naturally elevated in the Malibu basin due to its geology (LVMWD, 2011).

Stormwater in Malibu Creek often has elevated toxicant concentrations. Those increased pollutant levels have been shown at times to have deleterious effects based on toxicity tests in Malibu Creek (see Section 7.8). Monitoring data also indicated that selenium exceeded acute standards in 63 percent of the dry weather samples and exceeded chronic standards in approximately half the wet samples reported at LACDPW's mass emission station on Malibu Creek from 2003-2010. Sulfate acute and chronic standards were exceeded in approximately half of both the wet and dry samples. The toxicity analyses of Brown and Bay (2005) described in Section 7.8 suggested that sulfate and other dissolved salts were the likely cause of observed dry and wet weather toxicity.

### A5. Niche Competition from Invasive Species

New Zealand mudsnails have been observed in Malibu Creek since 2005, and are spreading in the watershed. Abramson et al. (2009) report that the New Zealand mudsnail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and have been found on more than 70 percent of substrate samples in Malibu Creek. Other non-native invasive plants and animals, including red swamp crayfish, bullfrogs, and mosquitofish, were also reported in the watershed

(Sikich et al., 2012). In general, invasive species impair native ecosystems by outcompeting native species for resources such as food or habitat, ultimately reducing species diversity (Strayer, 2010).

### 9.2.2 Analyze Evidence and Characterize Stressors

This section explores the linkages between each stressor and observations of biological impairment. Later, potential sources are identified and linkages between them and stressors that have not been eliminated in this section are evaluated (Section 2 in Appendix G and Section 9.3). The strength of evidence for each candidate cause is presented within this discussion, to maintain coherence between the presentation of the evidence and the conclusions drawn from it.

Each of the stressors listed as candidate causes above were discussed with respect to the evidence supporting or refuting them as possible causes of benthic macroinvertebrate impairment in Malibu Creek and Lagoon, regardless of the possible sources of the stressors.

**A1. Reduced Habitat Quality from Excess Sedimentation**

Possible sources of excess sedimentation include altered hydrology, channel alteration, fire impacts, urban runoff, including construction site impacts (often resulting from urban development), agricultural runoff, or natural geology. Figure 9-2 shows the linkage between excess sedimentation and impaired biology, along with the possible sources.

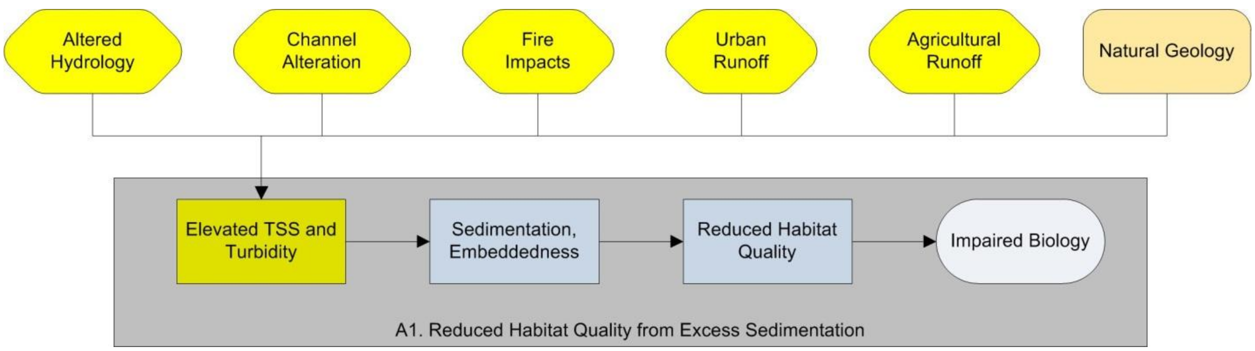



**Figure 9-2. Illustrated Linkage between Excess Sedimentation and Impaired Biology**

Many examples from literature support the adverse effects of sedimentation on aquatic biota. For example, Wood and Armitage (1997) indicated that sedimentation predominantly impacts primary productivity, faunal diversity, and abundance. Dudgeon (1994) and Armitage (1995) found that increases in fine sediment favor chironomids and oligochaetes. Sensitive EPT taxa were most commonly adversely affected (Harrison et al., 2007).

**Malibu Creek**

HtB Stream Team sites with impaired bioscores on the main stem (e.g., MC-1, MC-12, and MC-15) all showed increased turbidity relative to the comparator/reference sites, with averages at the impacted sites ranging from 1.31 to 2.62 NTU compared to 0.27 to 0.75 NTU at the comparator/reference sites (the averages are low because these are dry weather samples). Excess sedimentation also has been demonstrated by increased sedimentation rates in the Lagoon versus historic natural rates (see below) and the rapid filling of the pool behind Rindge Dam (Ambrose and Orme, 2000). Furthermore, HtB's Stream Walk program reported that 21.29 miles of 68 surveyed stream miles were impacted by excess fine sediments. Only 0.29 miles of the impacted streams occurred upstream of developed areas. Biological impairment largely occurred in or downstream of areas where excess sedimentation was observed. The RBP Physical Habitat scores showed that sites with lower RBP scores tended to have received poor or marginal ratings on the embeddedness, sediment deposition, and riffle frequency measures. Tributary and main stem sites had similar poor bioscores at sites with low physical habitat scores. Evidence also showed that benthic macroinvertebrate assemblage was limited by physical habitat and other factors. EPT taxa counts at impacted sites in Malibu Creek were demonstrably lower than at comparator/reference sites. Luce (2003) found that benthic macroinvertebrate metrics including EPT richness, EPT index, and sensitive EPT index were significantly negatively correlated with percent embeddedness, although there was not a significant relationship between benthic macroinvertebrates and percent fines in that study. Coarse sediments and sand have been demonstrated to cause benthic macroinvertebrate assemblage impairment in other areas with highly erosive geology, even in the absence of significant fine sediments (Longing, 2006; Gilmore, 2002; Spindler, 2004).

Stepwise multiple regression analyses indicated that bioscores are strongly predicted by a multivariate model that includes both physical habitat scores and percent of upstream impervious area as predictors. Physical habitat itself may be degraded by increased flow energy and resulting sediment transport associated with increased impervious area. Impervious area was also a surrogate for development and associated increases in loads of pollutants such as nutrients. Results suggested that aspects of physical habitat associated with sediment stability and sediment transport capacity were one important limiting factor on the benthic macroinvertebrate assemblage in the watershed.

Overall, most lines of evidence support sedimentation as a contributing cause of benthic macroinvertebrate assemblage impairment.

**Malibu Lagoon**

Malibu Lagoon is also impacted by sedimentation. The Lagoon is a naturally dynamic system with regards to sediment where cycles of aggradation and scour occur. Substantial aggradation occurred during lagoon closure, whereas major winter floods that open the barrier beach scoured accumulated sediments. Detailed maps of the Lagoon showed that increased aggradation combined with proximate development that constricts the Lagoon footprint has resulted in a smaller and fresher Lagoon than was likely the case under natural conditions.

Due to low flushing, sediments accumulate in the Lagoon's tidal channels. These sediments deliver nutrient loads that contribute to excess algal blooms (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). In addition, the reduced volume of the Lagoon and isolation of side channels contributed to reduced DO and elevated water temperature.

Measurements in 1987 suggested the average rate of sedimentation since 1983 was 10 cm/year. This level of sedimentation is estimated to be nearly ten times the rate that would have occurred during pre-European settlement periods (Topanga-Las Virgenes Resources Conservation District, 1989). During the flood of February 6, 1999, LACDPW data shows that 2,321 mg/L of suspended sediment was carried through Malibu Creek into the Lagoon.

The data evaluating the benthic invertebrate assemblage composition in Malibu Lagoon indicated that the Lagoon invertebrate assemblage was impaired. Recent sampling performed by USEPA found that a site closest to the head of the estuary with consistent upstream freshwater flow had the greatest number of taxa collected. Sites located in back channels with limited flow, or closest to the Lagoon mouth in the central part of the Lagoon, showed the largest abundance of organisms. However, these organisms were primarily highly tolerant species from fewer taxa that can survive in highly impacted conditions. Results of this sampling effort strongly suggested poor benthic assemblage diversity and abundance.

Several restoration efforts have addressed sedimentation impacts in the Lagoon, including excavation of tidal channels to improve circulation and excavation to increase the main Lagoon depth, both designed to improve habitat, including support for the endangered tidewater goby. These habitat improvements are threatened by ongoing sedimentation.

Overall, the lines of evidence support sedimentation as a cause of impairment of the Lagoon's benthic macroinvertebrate assemblage.

**A2. Reduced Habitat Quality from Excess Algal Growth:** Sources of excess algal growth include excess nutrients resulting from fire impacts, septic systems, point source discharges, non-point sources attributable to urban runoff, agricultural runoff, and natural geology. The following discussion presents the evidence for linkage between excess nutrients, excess algal growth, and reduced habitat quality for benthic macroinvertebrates (Figure 9-3).

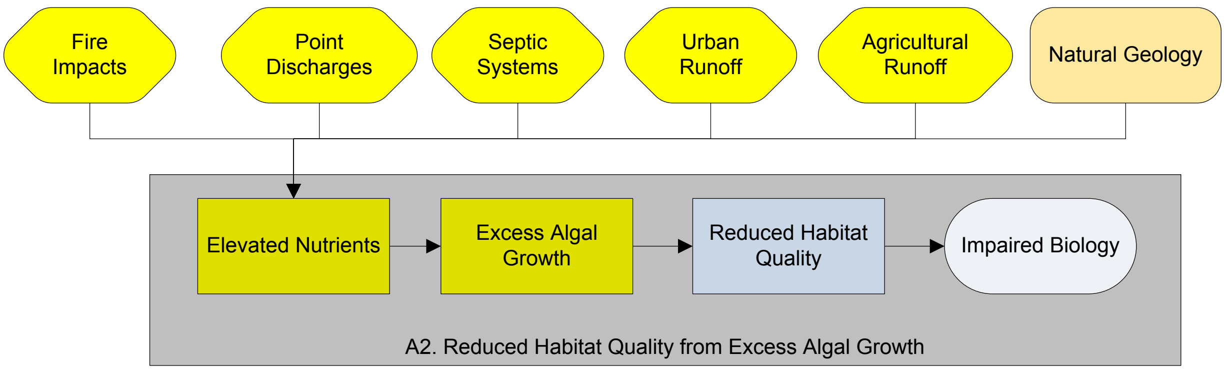



**Figure 9-3. Illustrated Linkage between Elevated Nutrients and Impaired Biology as a Result of Excess Algal Growth and Reduced Habitat Quality**

The following information on nutrients and algal growth was excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Fish and invertebrates are usually not directly adversely affected by excess nutrient concentrations, but rather are affected by other proximate stressors resulting from nutrient enrichment. For example, increases in dissolved N and P can lead to increases in plant and microbial biomass or productivity, which may lead to greater microbial infection of invertebrates or fish, or altered benthic organic matter processing (e.g., faster processing rates). Increased respiration of microbes and plants often leads to decreases in DO concentrations, especially during times when photosynthesis is limited (e.g., at night). In addition, increased photosynthesis may lead to increased pH; this increase may be especially important when N is elevated, as unionized ammonia, a toxic form of N, is more prevalent at high pH. Blooms of certain algal taxa also may result in increased production and release of toxins that can affect fish or invertebrates.*
>
> *Increased plant or algal production may translate to increased food resources, which can benefit herbivorous organisms but may adversely impact other taxa by altering the food resources derived from detritus. Changes in plant assemblage structure also may occur with enrichment, and these changes can affect aquatic fauna by altering habitat structure or by altering the quantity or quality of food resources. Changes in community structure may occur even without overall increases in primary producers, due to alterations of nutrient availability ratios. Increases in suspended organic matter (i.e., phytoplankton or suspended benthic algae) also can negatively affect aquatic biota, for example by increasing turbidity.*

Although algal growth can benefit a stream by providing a food source, habitat (cover), and thermal buffering, excess growth of periphytic and attached algae can have a direct deleterious impact on habitat suitability. Excess algal growth can cover suitable habitat (Allan, 1995) and may depress overall invertebrate taxa richness (Yuan, 2010) or shift invertebrate assemblage composition toward grazers and scrapers (Feminella and Hawkins, 1995; Quinn et al., 1997).

**Malibu Creek**

Nutrient concentrations in Malibu Creek were elevated in many locations based on measurements of inorganic N and P species; data on total nutrient concentrations were available at only a limited number of sites, but show even higher concentrations. Notably, average concentrations of nitrate- and nitrite-N, ammonia-N, and $PO_4$ as P in data collected by the HtB Stream Team were higher at impacted Malibu Creek main stem sites than at comparator/reference sites, as shown in Table 7-14. Orthophosphate-P concentrations appear to be naturally elevated within the Modelo/Monterey Formation; however, both orthophosphate and nitrate concentrations increase dramatically as streams pass through the developed area in the I-101 corridor. Available information suggested that total N concentrations (which include organic forms) were much higher than inorganic N concentrations, except at sites downstream of the Tapia discharge and in the developed areas of Las Virgenes Creek (see Section 7.6). Many organic forms of N (and P) can be rapidly broken down into inorganic forms by biological activity, becoming available to support plant growth. As with the HtB Stream Team samples, the LVMWD summary (Table 7-9) shows that inorganic P concentrations are elevated in streams that drain the Monterey/Modelo Formation. Concentrations downstream of the Tapia WRF discharge are much higher during the winter discharge season (see Table 7-7).

Algal cover has been measured directly at the impacted Malibu Creek sites and percent coverage by algae is much greater than observed at comparator/reference sites; moreover, algal coverage has increased since 2000 (Figure 8-22and Figure 8-23). In addition, the 2003 Nutrient TMDL developed for Malibu Creek by USEPA (2003) had a target of achieving not more than 30 percent coverage for filamentous algae greater than 2 cm in length and not more than 60 percent cover for bottom algae greater than 0.3 cm thick. Although the 2003 Nitrogen TMDL limits appear to have largely been achieved at the downstream station MC-1, the algal density targets have not. Mean mat algae coverage at the impacted main stem sites range between approximately 65% to approximately 90%, compared to means between 5% and 10% at comparator/reference sites. Busse et al. (2006) measured periphyton chlorophyll *a* densities and nutrients, light, and flow velocity, and concluded that nutrient concentrations were sufficiently high that they were not limiting algal growth in Malibu creek. Instead, periphytic algae varied positively with light and negatively with winter season scouring flows. Luce (2003) reported somewhat more complex, but still positive, relationships between nutrient concentrations and algal cover. HtB and MCWMP data from the June to September growing season showed a positive correlation between average inorganic nitrogen (nitrate- plus nitrite-N) and algal mat cover (Figure 9-4).

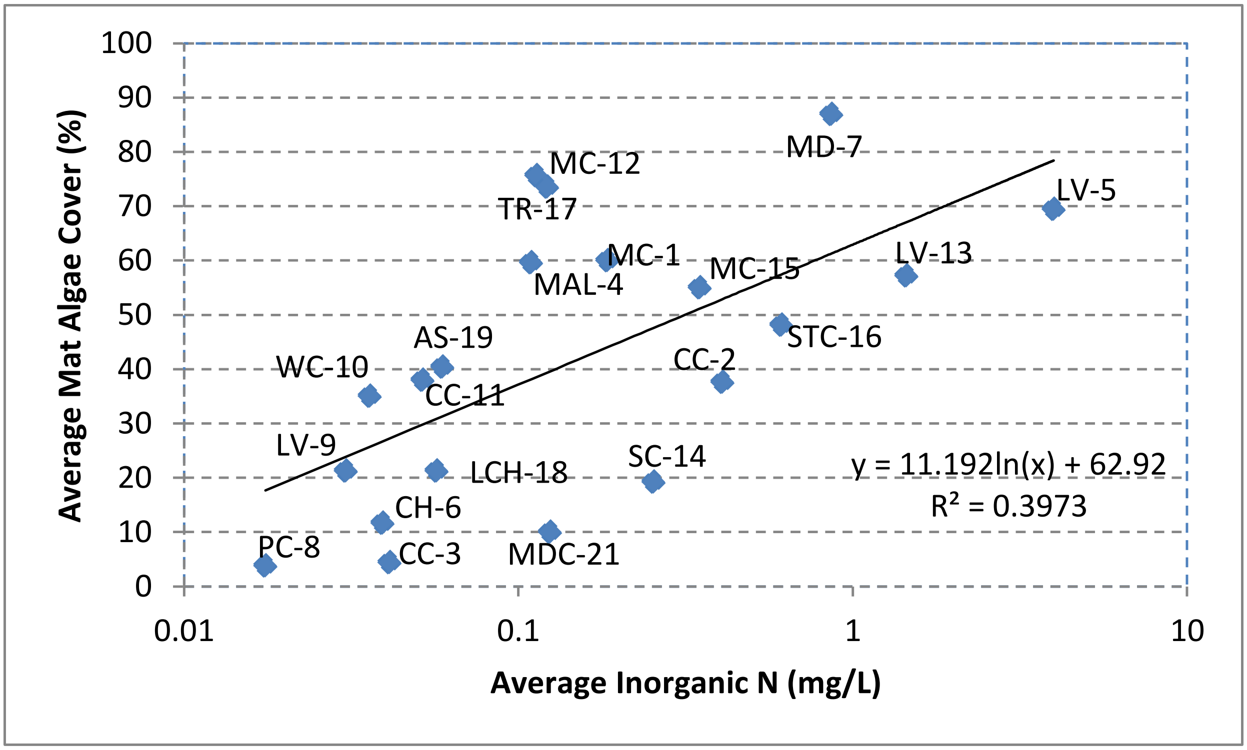



**Figure 9-4. Correlation of Algal Mat Cover and Inorganic N Concentrations during the Growing Season in HtB Stream Team Data**

Sites exhibiting excess algal growth also exhibited SC-IBI scores lower than the comparator/reference sites. HtB Stream Team (Sikich et al., 2012) reported that benthic algal cover was lowest at reference sites and highest at outlet sites, and that the vast majority of sites with the highest algal coverages occurred downstream of development.

As Figure 8-16 shows, there was a negative correlation between median SC-IBI score and average total inorganic N concentration. The pMMI showed a negative relationship with average inorganic N that appears very similar to that with the SC-IBI (Figure 8-18). Moreover, median SC-IBI scores greater than 30 only occurred at sites with average nitrate-N concentrations less than 1 mg/L. Similarly, no pMMI scores greater than the lower threshold ($5^{th}$ percentile, 0.86) were found at sites with average nitrate-N greater than 1 mg/L, suggesting that nutrient impacts were likely depressing biological condition in the watershed.

Excess nutrients co-occur with excess algal growth, excess algal growth co-occurs with lower biological scores, and excess nutrients co-occur with lower biological scores. At many sites, nutrients appeared to be present in excess of levels that maximize algal growth; however, only at sites with reduced inorganic N did we find consistently reduced average algal mat coverage and increased biological scores. The data showed strong evidence of a linkage between benthic macroinvertebrate bioscores, algal growth, and nutrients.

### Malibu Lagoon

Benthic aquatic life in Malibu Lagoon is "impaired by eutrophication resulting from excessive nitrogen loads" (Callaway et al., 2009). Malibu Lagoon currently shows elevated concentrations of biologically-available nutrients such as nitrate and nitrite and ammonium ($NH_4$) (Moffatt and Nichol, 2005; 2NDNATURE, 2010) and excessive algal growth.

Excessive algal growth can affect habitat quality in an estuary in much the same way that it affects habitat quality in a stream. Little direct information was available on benthic habitat quality in the Lagoon, except with regard to excessive sedimentation and reduction in quantity due to changes in the Lagoon footprint. The Lagoon does experience excess algal growth that reduces habitat quality directly resulting in decreased diversity and abundance. Although specific habitat quality data were limited, it is likely that the algal growth has reduced habitat quality.

The lines of evidence demonstrate that nutrients in the Lagoon were associated with increased algal growth and decreased benthic macroinvertebrate diversity and abundance.

**A3. Reduced DO:** Reduced DO from excess algal growth/excess nutrients can be caused by fire impacts, septic systems, point source discharges, urban runoff, agricultural runoff, or natural geology. Reduced DO can also result from oxygen-demanding wastes from point source discharges, or by altered hydrology leading to stagnant conditions. The following discussion presents the evidence for the linkage between reduced DO and impact to benthic macroinvertebrates (Figure 9-5 through Figure 9-7).

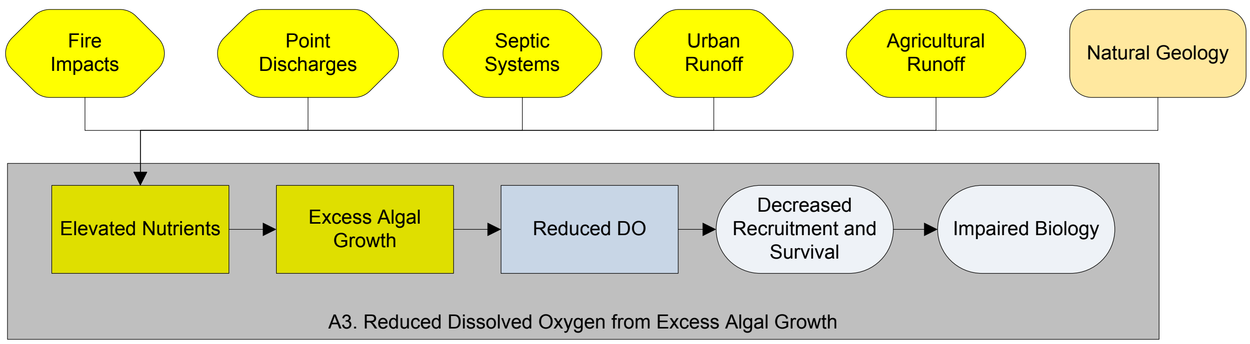



**Figure 9-5. Illustrated Linkage between Elevated Nutrients and Impaired Biology as a Result of Excess Algal Growth and Reduced Dissolved Oxygen**

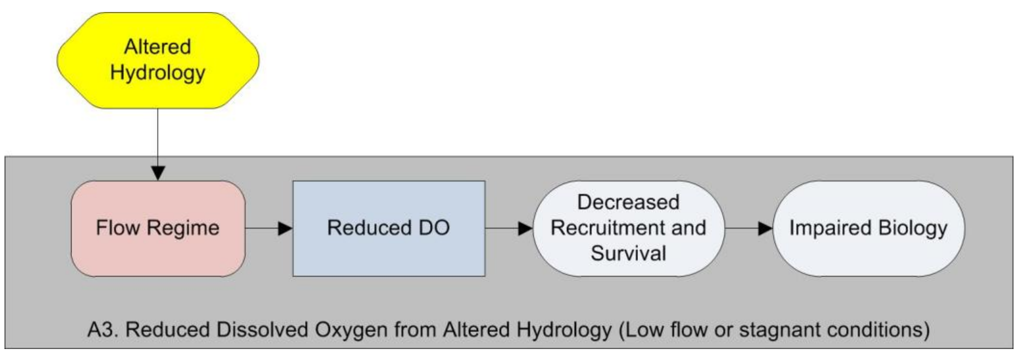



**Figure 9-6. Illustrated Linkage between Altered Hydrology and Impaired Biology as a Result of Low Flow or Stagnant Conditions and Reduced Dissolved Oxygen**

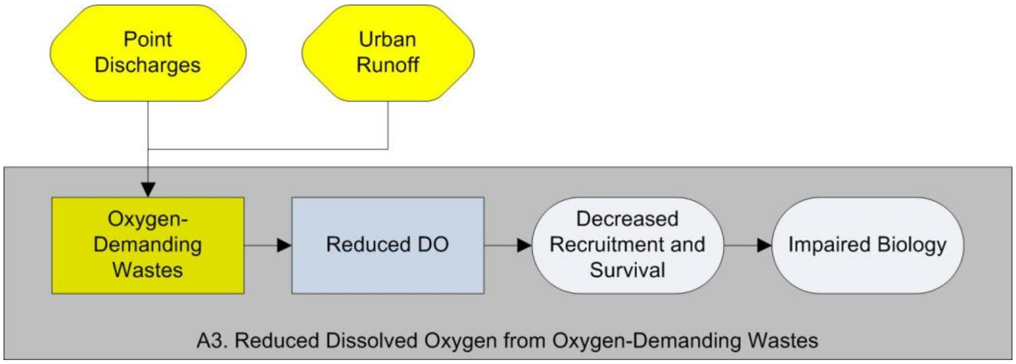



**Figure 9-7. Illustrated Linkage between Oxygen-demanding Wastes and Impaired Biology as a Result of Reduced Dissolved Oxygen**

Decreased dissolved oxygen in Malibu Creek can result from increased water temperature or increased biological oxygen demand (due to excessive algal growth and increased plant and microbial respiration, A2, discussed above). The following information on enrichment/DO was excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Low or extremely high DO levels can impair or kill fishes and invertebrates. In addition, large fluctuations in DO levels over relatively short periods of time (e.g., daily) can stress aquatic organisms. Human activities can significantly affect DO concentrations in streams, most notably by decreasing oxygenation and by increasing chemical or biochemical oxygen demand. Agricultural practices, forestry practices, and other activities may involve channel alteration (e.g., straightening or deepening of streams) or impoundments downstream of a location, which may decrease aeration and the diffusion of oxygen into water. Impoundments upstream of a location may discharge low oxygen water downstream, but releases also may increase turbulence and oxygenate water. These land use practices also may directly introduce nutrients (e.g., fertilizers, animal wastes), chemical contaminants (e.g., heavy metals), or organic matter (e.g., sewage, animal wastes) to streams, or indirectly increase the delivery of these substances to streams via land cover alteration. The resulting chemical reactions and increased respiration of microbes and plants can increase oxygen demand in streams, leading to decreases in DO.*

DO saturation occurs at lower concentrations in warm versus cold water, so factors contributing to increased water temperatures (e.g., loss of riparian cover, warm effluents) may contribute to decreased DO concentrations.

### Malibu Creek

Impacted sites in Malibu Creek show average dissolved oxygen concentrations that were similar to concentrations at comparator/reference sites, ranging between 9.09 and 10.90 mg/L at impacted sites for which sufficient data were available, and 9.30 and 9.93 mg/L for comparator/reference sites. These average concentrations were above applicable water quality standards; the data, however, consisted of day-time grab samples that are unlikely to measure the minimum overnight concentration due to respiration demand. The frequency of low DO observations (<5 mg/L, the WARM criterion) at impacted sites was higher than at some comparator/reference sites, ranging from 0% to 17.5% at impacted sites compared to 0% at comparator/reference sites SC-14 and LCH-18, and 3.6% to 38.1% at comparator/reference sites CH-6 and LV-9, respectively. Higher DO criteria of 6 mg/L for the COLD use and 7 mg/L for the SPAWN use apply to most of the streams in the watershed. About 13 percent of observations were less than 7 mg/L at the mouth of Malibu Creek (MC-1) and in Malibu Creek upstream of Tapia (MC-12). Concentrations immediately below the Tapia discharge at the F-130 gage were less than 7 mg/L about 3 percent of the time.

Excess algal growth was present throughout the Malibu Creek Watershed, and can lead to increased DO during daytime photosynthesis coupled with depleted DO during nighttime respiration. The extent to which this is a significant problem in the watershed was unclear due to a shortage of continuous DO sampling. Low flow or stagnant conditions have occurred historically in some areas of the watershed during summer/fall; however, recent gage records demonstrate that baseflow has generally increased and the frequency of low flows has decreased following development. Moreover, measurements of biochemical oxygen demand, a measure of oxygen-demanding wastes, showed that most observations were at the detection limit of 2 mg/L. It is clear that DO criteria for protection of aquatic life are not always met in the watershed. The most serious problems are documented for Las Virgenes Creek, which has a SPAWN designation with an accompanying 7 mg/L DO standard, but for which nearly 80 percent of samples were less than 7 mg/L, and 38 percent of samples less than 5 mg/L, at Station LV-9 (see Table 7-2); however, the median SC-IBI score at this site is in the “Fair” range.

Overall, the evidence showed that occasional low DO levels are documented to co-occur at sites with impaired bioscores, but there was incomplete data because DO data were not collected during the critical conditions (e.g., night and early morning samples) when DO levels are expected to be the lowest. Consequently, the DO data were incomplete and additional diel DO data from multiple locations in the watershed would resolve inconsistencies and gaps in the data.

**Malibu Lagoon**

Malibu Lagoon also experienced low DO conditions, starting at the Malibu Creek outlet, as demonstrated by the DO results for the Start Pool. Start Pool experienced a wide range of DO measurements, with greater DO (up to approximately 12 mg/L, attributable to algal photosynthesis) occurring in mid to late afternoon, and hypoxia (less than 2 mg/L) occurring from about 11 p.m. until about 11 a.m. (Sikich et al., 2012). Sikich et al. (2012) also presented data for Malibu Lagoon, based on a study by Briscoe, stating that pre-dawn DO levels averaged 1.15 ± 0.12 mg/L SE in Malibu Lagoon. Ambrose et al. (1995) obtained diel DO levels between July 1993 and April 1994 at a westerly channel site in the Lagoon and at a mid-Lagoon site. The westerly channel site exhibited bottom water ranges between 2.6 and 10 mg/L DO, and the mid-Lagoon site had bottom water DO concentrations ranging between 5.5 and 12.2 mg/L. The general DO standard of 5 mg/L applies to the Lagoon.

Benthic aquatic life in Malibu Lagoon is “impaired by eutrophication resulting from excessive nitrogen loads” (Callaway et al., 2009). As in the stream, the impacts of excess algal growth due to eutrophication included the potential for depressed DO during nighttime respiration. Natural reaeration in the Lagoon has also been reduced through sedimentation that leads to stagnant side channels. Most observations of 5-day biological oxygen demand downstream of the Tapia WRF discharge are at the detection limit of 2 mg/L, indicating that oxygen-demanding wastes are not present in concentrations great enough to result in reduced DO concentrations in the Lagoon. The extent to which the discharge may include more refractory organic compounds that can exert an oxygen demand on a period of longer than 5 days is not known. Such refractory compounds, if present, could pose an issue for the Lagoon.

Malibu Lagoon exhibited diminished species richness compared to other, similar California estuaries, and benthic faunal sampling in 2006 and 2007 demonstrated that sites with better hydrologic connection had greater abundance and taxa richness, consistent with greater flow and greater oxygenation.

The available lines of evidence show low DO and reduced benthic assemblage taxonomic richness were occurring. However, insufficient data were available on both DO concentrations and the benthic macroinvertebrate assemblage in the Lagoon to draw firm conclusions.

**A4. Toxicity from Metals, Elevated Salt Concentrations, or Organic Toxics:** Toxicity from metals, elevated salt concentrations, or organic toxics can be caused by urban runoff, agricultural runoff, or natural geology. The following discussion presents the evidence for linkage between toxicity and impaired benthic macroinvertebrates (Figure 9-8).

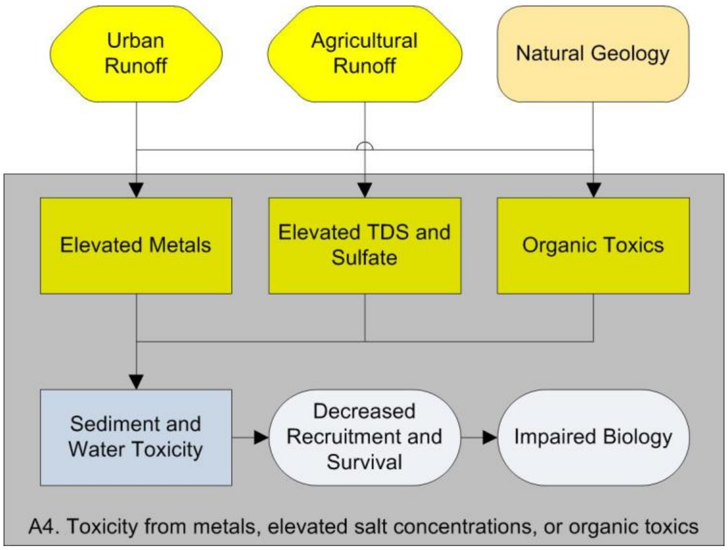



**Figure 9-8. Illustrated Linkage between Toxics and Impaired Biology**

Occasional water column toxicity has been observed since 2005 in wet and dry weather surface water samples from Malibu Creek, using *Ceriodaphnia dubia* (water flea) survival and reproduction and *Strongylocentrotus purpuratus* (purple sea urchin) fertilization tests. LADPW reports indicated that the toxic effect apparently dissipated after holding the sample, and suggested that the cause might be volatile organic chemicals. In a separate study, Brown and Bay (2005) examined Malibu Creek water near the mouth under both wet and dry conditions. One out of eight dry weather samples showed acute toxicity (survival) and two of eight showed chronic toxicity (reproduction) to *C. dubia*.

Conductivity measurements at impacted sites in the Malibu Creek main stem were higher than those in comparator/reference sites, ranging from 1,877 – 2,287 µS/cm on average for the main stem sites compared to 1,185 – 1,505 µS/cm for comparator/reference sites. Sites upstream within the Monterey/Modelo Formation exhibited much higher specific conductivity measurements of approximately 3,400 µS/cm and included sites that have acceptable bioscores. There was a negative correlation between conductivity and SC-IBI and between conductivity and pMMI; however, stepwise multiple regression analysis showed that there was a stronger correlation to upstream impervious area, much of which is located downstream of the Monterey/Modelo Formation in the I-101 corridor.

Another possible cause of benthic macroinvertebrate toxicity included agents used by the Los Angeles County West Vector and Vector-Borne Disease Control District. The Control District primarily uses *Bacillus thuringiensis* var. *israelensis* (*Bti*) or methoprene (Altosid) for mosquito control (LA County West Vector and Vector-borne Disease Control District N.D.). *Bti* has been reported to have no direct effect on aquatic invertebrates other than mosquitos (Culicidae), blackflies (Simuliidae), and chironomids (Glare and O'Callaghan, 1998). Methoprene, on the other hand, is toxic to freshwater invertebrates (USEPA, 1991). No data were available regarding application agent, locations, dates, rates, or relationship to observed benthic macroinvertebrate impairment.

Any loss of Chironomidae and Simuliidae would not affect the O/E, because these are flagged as ambiguous taxa, and very few Culicidae appear in the data. SC-IBI, and to a lesser extent, pMMI bioscores could be negatively affected by loss of these groups; however, experiments with the CSCI code with and without groups susceptible to *Bti* showed only small differences in bioscores.

Diazinon, an organophosphate pesticide, was detected in creek samples collected in 2002-2003. Concentrations of diazinon in some samples exceeded the CDFG chronic criterion by up to a factor of 14 in Medea Creek. However, concentrations within the Malibu Creek main stem did not appear sufficiently high to be a significant source of toxicity.

Overall, multiple inconsistencies existed in the lines of evidence for toxicity as a primary cause of impaired biology in Malibu Creek Watershed. There were insufficient data to evaluate the spatial distribution of organic toxics. Although areas draining primarily the Monterey/Modelo Formation exhibited the highest median conductivity levels, direct toxicity testing results are not consistent and bioscores were high at comparator/reference sites located in Monterey/Modelo Formation areas without nearby anthropogenic activity.

**Malibu Lagoon**

Sediment toxicity tests using amphipods have shown no toxicity to Malibu Lagoon sediments (Bay et al., 2000; Bay et al., 2005). Anderson et al. (1998) alluded to mussel development tests that apparently showed some impact from exposure to subsurface water in Malibu Lagoon, but results are not available for review. Meyers et al. (2001) performed sea urchin pore water toxicity testing for eight sites in Malibu Lagoon. Of those eight sites, two exhibited toxicity. Both toxic sites were located upstream, and were not the farthest upstream sites tested in the Lagoon. Sites farthest upstream were hypothesized to be the most likely to exhibit toxicity, as they are first to come into contact with water discharging from the watershed. However, these spatial patterns were not upheld in Malibu Lagoon. This likely reflects a flawed hypothesis, as the areas with greatest toxicity were likely those with greater deposition of fine sediments that magnify concentrations of metals and/or organic toxins. No data were available for specific organic toxins in the Lagoon.

The lines of evidence were weak and did not indicate that toxicity was a primary cause of impaired biology in Malibu Lagoon.

**A5: Niche Competition:** Invasive species can impair benthic macroinvertebrate communities through niche competition. This section evaluates the linkage between invasive species (specifically the New Zealand mudsnail) and biological impairment (Figure 9-9).

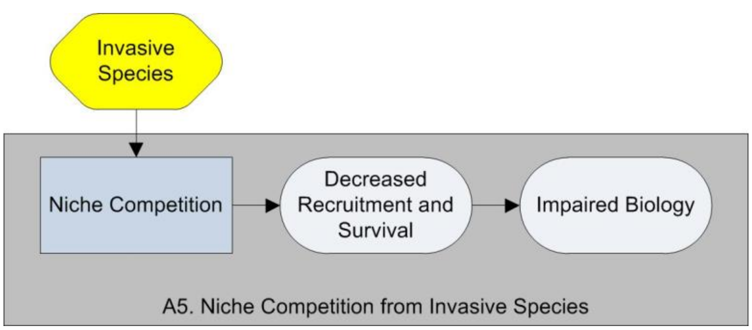



**Figure 9-9. Illustrated Linkage between Niche Competition and Impaired Biology.**

**Malibu Creek**

The presence of the invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) has been increasing in the Malibu Creek and surrounding watersheds. The mudsnail is very easily spread by fishermen and other stream visitors due to its small size and resistance to desiccation (CDFG, 2012). The New Zealand mudsnail was first detected in samples collected by the City of Calabasas in 2005, and they are now found in eight streams in the Santa Monica Mountains. Abramson et al. (2009) reported that the New Zealand mudsnail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and that mudsnails have been found in more than 70 percent of samples in Malibu Creek.

In general, invasive species impair native ecosystems by outcompeting native species for resources such as food or habitat and ultimately reduce species diversity (Strayer, 2010). If the New Zealand mudsnail were causing impairment of benthic biota in the Malibu Creek Watershed, sites with a high density of the snails would be expected to have lowered SC-IBI scores. However, in spring 2006, mudsnails constituted three percent of the biological sample at MC-1, which had an SC-IBI score of 30. By spring 2009, the biological sample at the same site contained 81% mudsnails, but the corresponding SC-IBI score was 27. The pMMI scores for MC-1 showed an opposite trend, with spring 2006 scores of 0.64, declining to 0.36 in 2008 and 0.42 in 2009, as snail densities increased; however, similar low pMMI scores are found prior to the documented presence of mudsnails (e.g., 0.43 in 2000). Low SC-IBI scores in spring 2010 also had low densities of mudsnails (from less than 1 percent at MC-1 to 13 percent at MC-15). Further evaluation is necessary to identify the impact of the New Zealand mudsnails on the benthic assemblage in the Malibu Creek Watershed.

Although other invasive species exist in the watershed (e.g., red swamp crayfish, bullfrogs, and mosquitofish), data are not available describing their locations or abundances. Therefore, no evaluation of their potential impacts on the benthic macroinvertebrate assemblage was performed.

Overall, the evidence to date was inconsistent for indicating the New Zealand mudsnails as a primary cause of biological impairment. Although New Zealand mudsnails are present and growing in abundance in the Malibu Creek Watershed, data were limited and did not confirm negative interactions with the native benthic macroinvertebrates.

**Malibu Lagoon**

The New Zealand mudsnail is a freshwater species that currently is not observed in the Lagoon. No data on invasive species in the Lagoon were available. There was no evidence to support this linkage in Malibu Lagoon.

## 9.2.3 Characterize Causes: Identify Probable Cause

The stressor identification process has identified a number of potential causes for the reduced quality of benthic macroinvertebrate assemblages in Malibu Creek and Lagoon. The analysis did not identify a single primary cause. The impaired condition of macroinvertebrate biology in the stream and Lagoon is due to the impact of multiple stressors. For example, bioscores (SC-IBI and pMMI) throughout the watershed appear to be reduced where physical habitat is sub-optimal or worse; however, Malibu Creek main stem stations also show poor bioscores for sites with optimal physical habitat. Biology at these sites is evidently co-limited by other factors such as excess algal growth.

Based on the weight of evidence summarized, the following two stressors emerged as likely causes of biological impairment in the streams of Malibu Creek Watershed:

A1. Reduced Habitat Quality from Sedimentation

A2. Reduced Habitat Quality from Excess Algal Growth

The following three stressors emerge as the likely causes of biological impairment in Malibu Lagoon:

A1. Reduced Habitat Quality from Sedimentation

A2. Reduced Habitat Quality from Excess Algal Growth

A3. Reduced Dissolved Oxygen from Excess Algal Growth

A2 (Reduced Habitat Quality from Excess Algal Growth) is closely related to A3 (Reduced DO). DO appears to be a more significant constraint on biology in the Lagoon than in the stream, so candidate cause A3 is also listed for the Lagoon.

All these stressors have previously been proposed as causes of impairment in the watershed (e.g., Ambrose and Orme, 2000; Sikich et al., 2012; USEPA, 2003); the critical concern in this TMDL is to evaluate the harm against benthic macroinvertebrates. These stressors rank high on all considerations of the evidence. Each stressor provides a plausible and consistent pathway from exposure to effect.

Sulfate and selenium concentrations were present in excess of water quality criteria, apparently due to natural geologic background. LVMWD (2011) has proposed that impaired biotic conditions in the watershed are in part due to high-sulfate discharge coming from the area where the marine Monterey/Modelo Formation is exposed. These toxicity stressors can affect the biological potential of the main stem and various tributaries to Malibu Creek. Specifically, elevated conductivity levels appear to reduce EPT taxa. However, this set of stressors alone does not appear sufficient to result in impaired biology as unimpaired SC-IBI and pMMI scores were found at stations within the Modelo Formation with similar stressor levels, while low SC-IBI and pMMI scores were found at stations that do not drain this formation but have these stressors elevated (see Section 8). Therefore, toxicity associated with natural geology appears to be a contributing stressor, but not the primary stressor resulting in impaired biology.

The New Zealand mudsnail remains a potential contributor to impairment; however, the mudsnail was not confirmed to be present until 2005, whereas the low bioscores have been documented in the Malibu Creek main stem since 2000. If the mudsnail was absent prior to 2005, it is not clear how this can be a significant cause of impairment. There also does not appear to be a temporal correlation between mudsnail density and SC-IBI scores.

In sum, benthic macroinvertebrates in the Malibu Creek Watershed and Malibu Lagoon are impacted by multiple stressors, all of which may contribute to the documented biological impairment. The sum of the evidence suggested that the dominant stressors were sedimentation and nutrients/algae. Mitigating these stressors should result in the support of benthic macroinvertebrate communities.

## 9.3 SOURCE IDENTIFICATION

### 9.3.1 List Candidate Sources

Sources represent the origin of stressors that may contribute to adverse biological responses in a waterbody. Seven groups of stressor sources were listed as potential causes of observed impairment for further evaluation and are described below.

**B1. Altered Hydrology**: Altered hydrology, in addition to changing the flow regime, caused increased erosion and sedimentation. Hydrology in Malibu Creek has been altered by a combination of increased impervious area (which increases flow peaks), irrigation and onsite wastewater disposal (which increase base flow levels), and impoundments (which decrease net flows and smooth out peaks. Hydrology in the Malibu Lagoon has been altered due to changes in upstream flow, filling and constrictions of the Lagoon, and changes in the rate of opening to the ocean.

**B2. Channel Alteration**: Hydromodification to the stream channel has the potential to change the shape of the stream, redistribute sediments, change sediment sizes, and erode channels. The major alterations to the channel of Malibu Creek and its tributaries have been the creation of several lakes or impoundments that trap sediment, changing the sediment balance, modifying the flow, and changing sediment transport capacity. Malibu Lagoon has been extensively modified over the years by sediment fill, surrounding development, construction of railroad and road crossings, and intentional breaching of the barrier beach to allow draw down of impounded water.

**B3. Fire Impacts**: Fire is a recurrent and important factor of the landscape in southern California that can cause important temporary changes in runoff and sediment loading. In the years after intense fires, the lack of vegetation results in increased peak runoff and elevated sediment loads; these actions can impact biology directly (Minshall, 2002). Although fire is a natural phenomenon in chaparral landscapes, human activity has increased the frequency of accidental and intentionally started fires. Malibu Creek Watershed has experienced many significant fires over the past several decades, including the Topanga fire in late September 2005 and the Foothill, Canyon, and Corral fires in January, October, and November of 2007, respectively.

**B4. Septic Systems:** Septic systems can be significant sources of nutrients, even when they are well sited and functioning properly, since they introduce nutrients to shallow groundwater that may eventually enter surface waters. Nitrogen is particularly mobile in groundwater, while phosphorus has a tendency to be adsorbed by soils. Septic systems are used in low-density rural residential areas and a few communities in the watershed, as well as part of the City of Malibu that falls within the watershed. These septic systems are estimated to contribute significant nitrogen to surface waters in the watershed. LARWQCB staff estimated that current loads from onsite wastewater disposal in the Civic Center area amount to 30-35 lbs/day. This could be a potentially significant source of nutrients into the groundwater and Lagoon.

**B5. Point Source Discharges**: Wastewater treatment plants and other permitted point source discharges can contribute to excess loads of nutrients, oxygen-demanding waste (e.g., decomposable or labile organic matter or organic chemicals), and other pollutants. Within the Malibu Creek Watershed, the only traditional permitted point source discharge is the Tapia WRF. The Tapia WRF, built in 1965, originally discharged to Malibu Creek along Malibu Canyon Road throughout the year. Discharges from Tapia were severely restricted by orders of the RWQCB in 1997-1999. Since then, discharges to Malibu Creek have been prohibited from April 15 to November 15 (except as needed for flow augmentation to support steelhead). Much of the reclaimed water is used for irrigation. Winter discharges occur, but are restricted to 8 mg/L total inorganic N and 3 mg/L total P in accordance with the 2003 Nutrient TMDL and 2005 and 2010 permit modifications.

**B6. Urban Runoff**: Urbanization accounts for an increase in impervious surface in the watershed from near zero in the 1960s to 5.26% in 1990 and to 6.95% in 2008. While most of the watershed remains undeveloped, this impervious area percentage increase is concentrated along the I-101 corridor. Impervious surfaces alter the flow regime by reducing infiltration and increasing surface runoff. This leads to increased flood frequencies and magnitudes, resulting in the common "flashiness" of urban streams, and the concomitant channel morphological changes (Paul and Meyer, 2001). Additionally, urban runoff is a potential source of a variety of pollutants, such as bacteria, dissolved solids, nutrients, metals, pesticides, herbicides, and petroleum products (Paul and Meyer, 2001). Active urban development (active construction) resulted in increased sedimentation from surface runoff. Urban runoff in Los Angeles and Ventura Counties is covered by two unified NPDES MS4 point source discharge permits.

**B7. Agricultural Runoff**: In many watersheds, agricultural runoff (including irrigation return flow) is a potential cause of impairment. Agricultural runoff can contribute to elevated levels of sediment, nutrients, pesticides, and herbicides. Satellite imagery data indicated that agricultural land use in the Malibu Creek Watershed had decreased from 1.9% in 1990 to 1.3% in 2008 (Section 4.5). However, Goepel et al. (2012) reported that many existing vineyards are small, situated adjacent to residential structures, and likely represent "hobby vineyards."

**B8. Modified Exposure of Natural Geology.** In some watersheds, certain natural geological related stressors may be elevated due to unnatural conditions (anthropogenic activities, i.e., construction, mining, etc.). The Malibu Creek Watershed contains the unique geology of the Santa Monica Mountains and the Monterey/Modelo Formation. The Santa Monica Mountains are an area of rapid geologic uplift, resulting in naturally high rates of erosion and sedimentation (see Section 4.4). The marine sedimentary Monterey/Modelo Formation outcrops exhibit elevated levels of sulfate, phosphate, and various metals, including selenium, (LVMWD, 2011). These deposits may contribute to selenium, orthophosphate, sulfate, and total dissolved solids. Unnatural conditions, such as accelerated erosion of these deposits from human activities would contribute to unexpected elevated levels of these ions. Impacts or alterations of the natural geology potentially could result in biological impairment from sedimentation and reduced habitat quality or toxicity. The Monterey/Modelo Formation comprises a large area of surficial geology in southern California, and the state has identified several reference calibration sites in the Formation outside of the Malibu Creek Watershed that can be used for comparative purposes (see Appendix D for a description of the reference calibration sites).

## 9.3.2 Analyze Evidence and Characterize Sources

This section presents an analysis of the evidence for each of the seven groups of stressor sources that are also enumerated as potential causes of observed impairment for further evaluation. This section explores the linkages between potential sources and stressors. To further examine the complex interactions between stressors and sources, it is useful to identify the multiple pathways that flow from source to stressor. Below, multiple causal pathways (depicted in Figure 9-1) are presented and evaluated. It is important to note that these causal pathways are not independent and can involve one or more interacting stressors or factors.

**Stressor to Source Pathways**

1. Reduced habitat quality from excess sedimentation caused by:

   altered hydrology, channel alteration, fire impacts, urban runoff, including runoff from construction sites, agricultural runoff, or altered natural geology.

2. Reduced habitat quality from excess algal growth caused by:

nutrients in septic systems, point source discharges, urban runoff, agricultural runoff, or exacerbated by naturally elevated nutrient concentrations in parts of the watershed.

3. Reduced DO caused by:

   altered hydrology leading to stagnant conditions, excess algal growth or oxygen-demanding wastes resulting from septic systems, point source discharges, urban runoff, or agricultural runoff, or altered natural geology.

4. Toxicity from metals, elevated salt concentrations, or organic toxics caused by:

   urban runoff or altered natural geology.

5. Niche competition caused by invasive species.

**Source to Stressor Pathways**

1. **Altered hydrology** can cause reduced habitat quality from excess sedimentation  or reduced DO
2. **Channel alteration** can cause reduced habitat quality from excess sedimentation
3. **Fire impacts** can cause reduced habitat quality from excess sedimentation or increased nutrient concentrations that cause excess algal growth reducing habitat quality or dissolved oxygen
4. **Septic systems** can contribute excess nutrients that cause excess algal growth that diminishes habitat quality or results in reduced DO, or oxygen-demanding wastes that cause reduced DO .
5. **Point source discharges** can contribute either excess nutrients that cause excess algal growth that diminishes habitat quality or results in reduced DO, or oxygen-demanding wastes that cause reduced DO
6. **Urban runoff** can cause reduced habitat quality from excess sedimentation, reduced habitat quality from excess algal growth from increased nutrient concentrations, reduced DO resulting from increased nutrients or oxygen demanding wastes, or toxicity from metals, elevated salt concentrations, or organic toxics
7. **Agricultural runoff** can cause reduced habitat quality from excess sedimentation, reduced habitat quality from excess algal growth from increased nutrient concentrations, or reduced DO resulting from increased nutrients or oxygen demanding wastes
8. **Modified Exposure of Natural geology** can cause reduced habitat quality from excess sedimentation, reduced habitat quality from excess algal growth, reduced DO from excess algal growth, or toxicity from metals, elevated salt concentrations, or organic toxics

The following sections provides a summary of the weight of evidence for the linkages between sources and stressors, as listed in 1-8 above.

**B1. Altered Hydrology:**

This section evaluates the linkages between 1) altered hydrology and increased sedimentation and 2) altered hydrology and reduced DO (Figure 9-10).

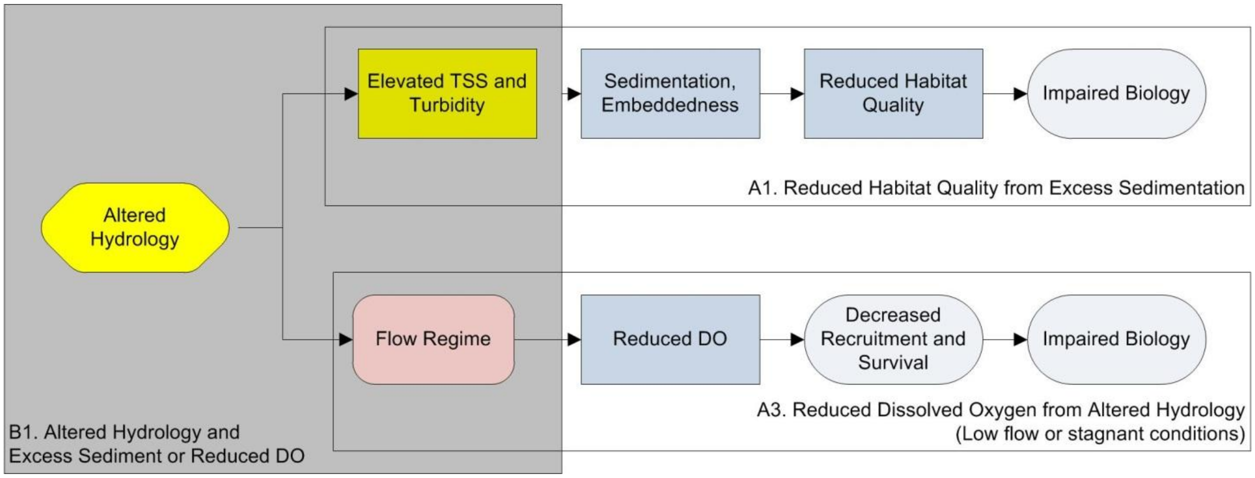



**Figure 9-10. Illustrated Linkage between Altered Hydrology and Excess Sedimentation or Reduced Dissolved Oxygen**

### Malibu Creek

Stream flows have been altered in impaired reaches of the watershed, due to urbanization, water importation, reservoir construction, and wastewater discharges to Malibu Creek. An evaluation of flow gauge data revealed that both peak flows and base flows have increased with urbanization.

Altered hydrology can result in excess sedimentation. HtB Stream Team's Stream Walk program documented unstable stream banks that had been scoured or eroded by stream flows, surface runoff from outflow pipes, and poorly drained roads and trails, along 19.5 linear miles of 68 miles mapped in the watershed (Sikich et al., 2012). Unstable stream banks occurred in both developed and undeveloped areas.

Altered hydrology can also result in reduced dissolved oxygen when alterations result in very low flows and disconnected or stagnant water. High flows are more likely to experience turbulent mixing, which increases reaeration. Disconnected pools and stagnant water experience less mixing, and tend to be shallower and warmer, resulting in reduced dissolved oxygen. Long-term flow records in Malibu Creek show near-zero base flows during the summer/fall, but more recent gage records demonstrate that baseflow has generally increased and the frequency of low flows has decreased following development. Owen (1998) reported results from the HEC-1 flood forecast model indicated that "…the watershed is yielding a large increase in runoff since predevelopment conditions have changed into the current state of development. Increases greater than 100% are seen in every subshed…"

The weight of evidence supports the linkage between altered hydrology and increased sedimentation. On average, flows have increased across the watershed, which is inconsistent with increased occurrence of low flows and stagnant water. Therefore, evidence supporting the linkage between altered hydrology and low dissolved oxygen is weak due to the observed inconsistencies in the limited data.

### Malibu Lagoon

Review of historical maps for Malibu Lagoon revealed alterations to the Lagoon's morphology, resulting from altered flow regimes, increased sedimentation, and development constricting the size and volume of the Lagoon. Flow alterations in Malibu Creek are believed to have increased erosion and sediment transport capacity. Sediment that is flushed from the watershed during storm events is deposited in the Lagoon. Constraints on the lagoon footprint have limited the surface area over which sediments can be deposited, such that fine sediments accumulate in tidal channels. The Topanga-Las Virgenes Resources Conservation District (1989) estimate 1987 levels of sedimentation to be nearly ten times the rate that would have occurred pre-development. The physical modifications of the Lagoon, beginning with the railway construction in 1908, pre-date increases in sedimentation.

The strength of the evidence supporting the causal pathway between altered hydrology and sedimentation in Malibu Lagoon is strong.

The linkage between altered hydrology and reduced DO in Malibu Lagoon cannot be fully evaluated due to lack of data. Effects of changed morphology are addressed under the heading "Channel Alterations."

### B2. Channel Alteration:

This section evaluates the linkage between channel alteration, and increased sedimentation. This section evaluates the linkage between channel alteration and sedimentation (Figure 9-11).

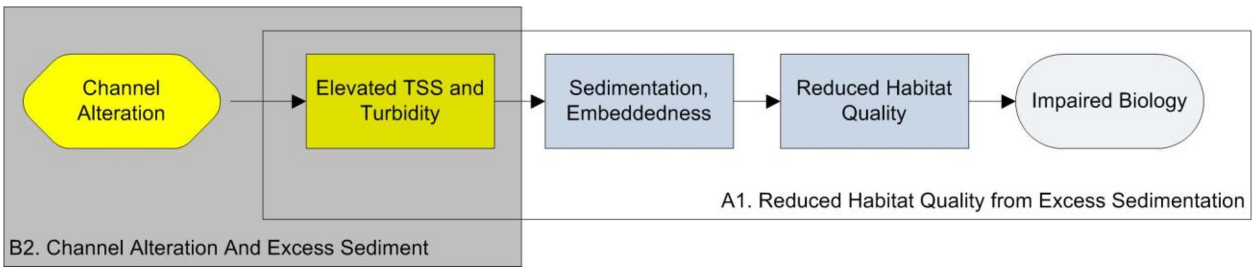



**Figure 9-11. Illustrated Linkage between Channel Alteration and Excess Sedimentation**

Channel alteration can take many forms. The following information on physical habitat alteration was excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Direct alteration of streams channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities and depths), creating barriers to movement, decreasing riparian habitat and altering the structure of stream geomorphological units (e.g., by increasing the prevalence of run habitats, decreasing riffle habitats, and increasing or decreasing pool habitats). Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat, decreased riffle habitat) or reduced habitat quality (e.g., increased fine sediment cover), which may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these effects may result in changes in population and community structure and ecosystem function.*

### Malibu Creek

Heal the Bay's Stream Walk program documented 987 streambank modifications, with a total of 20.9 linear miles engineered with hardened materials. Observed modifications included streambank reinforcement with concrete, boulders, fencing, planted vegetation, and other materials, intended to prevent or repair unstable stream banks (Sikich et al., 2012). The Stream Walk program consistently documented increased erosion and sedimentation downstream of modified stream banks. These modifications support the suggestion that channel alteration largely resulted from development of the watershed.

Numerous cases of stream bank modification were documented, along with evidence of increased erosion and sedimentation downstream. However, a quantitative analysis between channel alteration and sedimentation was not available. Consequently, the strength of evidence supporting the causal pathway between channel alteration and sedimentation is moderate.

**Malibu Lagoon**

Review of historical maps for Malibu Lagoon clearly revealed alterations to the Lagoon's morphology, attributable in part to alterations of the channel through fill and building encroachment constricting the size, volume, and flushing capacity of the Lagoon. The Topanga-Las Virgenes Resources Conservation District (1989) reports a nearly ten-fold greater rate of sedimentation in the Lagoon that would have occurred prior to European settlement periods.

Historical topographic maps and aerial photography depicted clear changes in the Lagoon footprint. These changes, particularly physical constraints resulting from increasing development, occurred prior to observations of increased sedimentation. Moreover, channel alterations upstream occurred concurrently with increased sedimentation in the Lagoon.

The strength of the evidence supporting the causal pathway between channel alteration in Malibu Creek and Lagoon and sedimentation in Malibu Lagoon is strong.

**B3. Fire Impacts:** Fire impacts are closely related to altered hydrology and can cause increased sedimentation and nutrient concentrations which increase algal growth reducing habitat quality and dissolved oxygen. This section evaluates the linkages between fire impacts and increased sediment or nutrient concentrations (Figure 9-12).

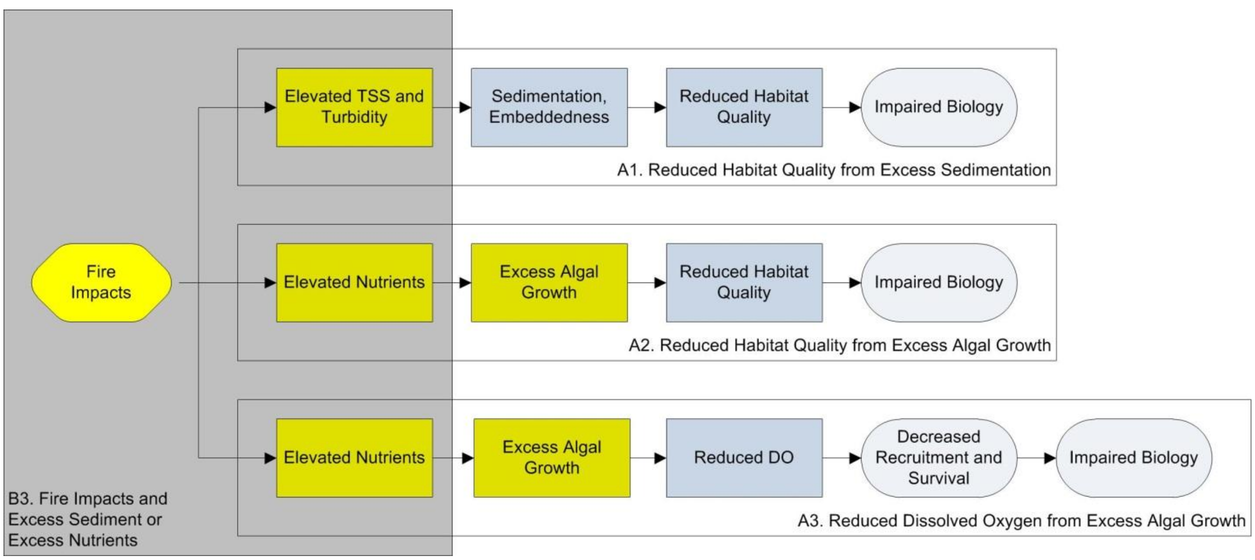



**Figure 9-12. Illustrated Linkage between Fire Impacts and Excess Sediment or Elevated Nutrient Concentrations**

**Malibu Creek**

Wildfires can increase sedimentation in streams by altering soil structure, removing vegetation and debris cover from the land surface, and eliminating a functioning riparian buffer. Plants in a functioning buffer help retain stream banks and filter sediment from surface runoff. Additionally, they slow the rate of runoff, which decreases erosion. Wildfires also increase nutrient concentrations in streams because of the amount of dead plant matter that enters the stream after a fire. Instream impacts resulting from wildfires included initial decreases in in-stream woody debris, followed by substantial increases, and increased nutrient concentrations (Gresswell, 1999).

Studies of wildfire impacts revealed that flood flows following fire events can be damaging, leading to increased base flows, annual water yields and peak flows (Neary et al., 2005), which may substantially increase sedimentation and channel modification. The Malibu Creek Watershed has experienced many significant fires over the past several decades (see Appendix B). Wildfires have occurred in areas where sampling sites are located. Few data were available to assess the potential for increased sedimentation; however, the RBP data that were available for before and after comparisons show a decline in habitat condition consistent with increased sedimentation.

There was consistent evidence supporting a causal pathway between wildfires and increased sedimentation in Malibu Creek. However, both RBP habitat scores and benthic bioscores suggested that the impacts of fires were relatively short-lived. This is consistent with other wildfire studies that have shown that effects of most wildfire events are short-lived.

The evidence supporting an observed causal pathway fire regime and increased nutrient loads were weak. Wildfires have occurred in areas where sampling sites are located. However, monitoring data were insufficient to determine whether average nutrient concentrations and loads increased due to fire. There were insufficient nutrient monitoring data to detect any significant changes in nutrient loads in response to the temporal sequence of wild fires.

**Malibu Lagoon**

The effects of fire impacts in the upper reaches of the watershed would be expected to result in increased sediment load and increased nutrient loads delivered to Malibu Lagoon. The October 2007 wildfires in the watershed were severe, leading to extensive damage that would be expected to influence nutrient loading and biogeochemical cycling in Malibu Lagoon. Sediment data (TSS or turbidity) and nutrient data were very limited for the Lagoon during the period following wildfires (Lin et al., 1995); therefore, it was not possible to evaluate the linkage.

**B4: Septic Systems:** Septic systems can cause increased sedimentation and nutrient concentrations that cause excess algal growth and reduced habitat quality or reduced DO, and increased oxygen-demanding wastes that reduce DO. This section evaluates the linkages between septic systems and increased or nutrient concentrations or oxygen-demanding wastes (Figure 9-13).

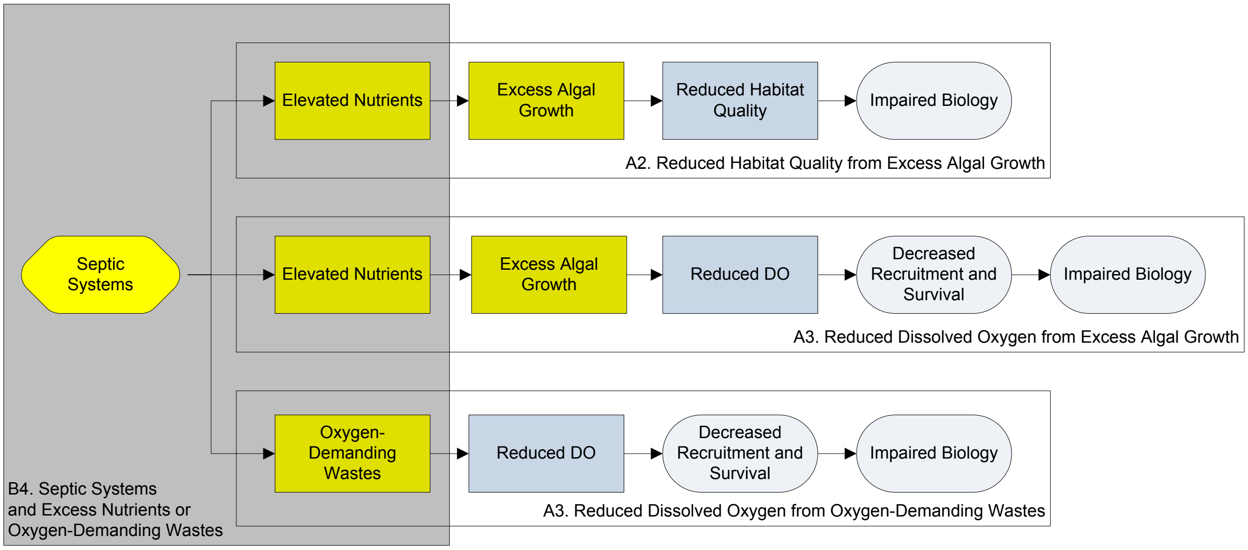



**Figure 9-13. Illustrated Linkage between Septic Systems and Excess Nutrients or Oxygen-Demanding Wastes**

**Malibu Creek**

Septic systems can be significant sources of nutrient loads, even when they are well sited and functioning properly, since they introduce nutrients to shallow groundwater that may eventually enter surface waters. Nitrogen is particularly mobile in groundwater, while phosphorus has a tendency to be adsorbed by soils. Septic systems are also a potential source of oxygen-demanding wastes if insufficient treatment is achieved.

The upper part of the Malibu Creek watershed is mostly sewered, with sewage being treated by the Tapia WRF. However, there are septic systems in various areas above the Lagoon, such as on Cold Creek. According to the 2003 Nutrient TMDL (USEPA, 2003), there were an estimated 2,200 septic systems upstream of Malibu Lagoon, with the largest numbers on Triunfo Creek (820), Hidden Valley Creek (625), and Cold Creek (300). These systems are estimated to contribute 602,800 gpd (675 acre-ft/yr) of effluent, contributing an estimated 300 lbs/day of N. The 2003 Nutrient TMDL (USEPA, 2003, Appendix A) estimated that septic systems contributed 23% of the N and P load to the basin as a whole, including direct loading to the lagoon. For the watershed upstream of the lagoon, the growing season (April 15 – November 15) loads of N were attributed as 16% from septic systems while the growing season P loads were 10% from septic systems.

*Weight of Evidence for Septic Systems and Nutrient Loads*

1. Co-occurrence: Septic systems occur upstream in the watershed, especially along several tributaries to Malibu Creek. Increased nitrogen concentrations are observed downstream of development, and therefore downstream of septic systems. Evidence for septic systems co-occurring with impairment is therefore compatible.

2. Temporality: The Malibu Creek watershed has exhibited steady growth through time including during the period of concern. Increased nitrogen concentrations downstream of development and downstream of septic systems, are consistent with this increase in development and therefore support temporality.

3. Response gradient: Nutrients (total nitrogen and total phosphorus) were positively correlated with the proportion of upstream land covered by impervious surfaces (Busse et al., 2006). Increased

nitrate concentrations are observed at the series of monitoring stations on Cold Creek, where many residences on septic systems are located. The 2003 Nutrient TMDL and supporting modeling found that a significant nitrogen load from septic systems was compatible with monitoring data. Evidence for the gradient between septic systems and increased nitrogen is strong.

4. Complete exposure pathway: There is evidence for all steps in the exposure linking septic systems to excess nitrogen concentrations. The evidence for phosphorus is incomplete as much of the phosphorus load generated by septic systems is likely to be retained in the soil matrix and high natural background concentrations of phosphorus are already present in much of the watershed.
5. Plausibility: A large body of scientific literature supports a linkage between septic systems and increased nutrient concentrations.
6. Analogy: Many examples of septic systems causing elevated nutrient concentrations are found in the literature.
7. Predictive performance: There is no evidence of predictive performance.
8. Consistency of evidence: All lines of evidence for a linkage between septic systems and elevated nitrogen in the creek are consistent.
9. Coherence of evidence: There are no inconsistencies in the evidence for increased nitrogen from septic systems.

The evidence supporting the causal pathway between septic systems and downstream elevated nutrient concentrations is strong.

*Weight of Evidence for Septic Systems and Oxygen-Demanding Wastes*

Limited data were available regarding oxygen-demanding wastes in Malibu Creek, but there was no evidence for excess levels of such wastes and observed BOD5 concentrations were generally low. While it is plausible that septic systems leach oxygen-demanding wastes into groundwater, it is not known if, or how much, of the wastes enter the surface waters of the Malibu Creek Watershed. Most such wastes should be consumed in the septic tank and leach field of properly operating systems. Therefore, we are unable to fully evaluate the linkage between septic systems and oxygen-demanding wastes in Malibu Creek; however, the weight of evidence for this pathway is weak.

**Malibu Lagoon**

Multiple sources have estimated the seepage of septic tanks into the Lagoon, including an estimated rate of 500 acre-ft/yr (Topanga-Las Virgenes Resources Conservation District, 1995) and a more recent estimate that recharge from OWDS in the Malibu Civic Center area contributes about 1,050 $m^3$/d (311 acre-ft/yr; McDonald Morrissey, 2010). Soil conditions are such that limited removal of nitrogen in effluent occurs. LARWQCB staff estimated that current loads of inorganic nitrogen to Malibu Lagoon from onsite wastewater disposal in the Civic Center area amount to 30 – 35 lbs/day. Therefore the non-point source discharges of nutrients directly to the Lagoon were of concern.

Based on monitoring conducted by LVMWD in the Lagoon at LVMWD-R11 during the winter discharge season, BOD5 concentrations in the Lagoon (average 2.3 mg/L) are similar to those seen upstream in Malibu Creek. However, the dry, non-discharge season average concentration of 3.3 mg/L appears to be elevated relative to upstream concentrations. This suggests there is an increase in BOD5 in the Lagoon during the non-discharge season that is likely, at least in part, associated with seepage from septic tanks. Increased BOD5 could also result from the growth and decay of algae stimulated by excess nutrient loads derived from the watershed and from the winter discharges from Tapia WRF.

*Weight of Evidence for septic systems and excess nutrients loads*

1. Co-occurrence: Analysis of onsite wastewater disposal seepage to the Lagoon provides evidence for co-occurrence of septic systems and excess nitrogen loads.
2. Temporality: The City of Malibu does not provide centralized wastewater treatment. Onsite wastewater disposal has always been used and has increased over time. Therefore, the evidence is compatible for temporality.
3. Response gradient: The Lagoon is a small, relatively well-mixed volume so there is no evidence available with which to establish a response gradient for direct nutrient loading.
4. Complete exposure pathway: There is evidence for all steps in the pathway between septic systems (onsite wastewater disposal) and excess nutrients in the Lagoon.
5. Plausibility: A large body of scientific literature supports a linkage between septic systems and increased nutrient loads into estuaries.
6. Analogy: Many examples of septic systems causing increased nutrient loads are found in the literature.
7. Predictive performance: There is no evidence of predictive performance.
8. Consistency of evidence: All lines of evidence are consistent with the linkage between septic systems and increased nutrient loads to the Lagoon.
9. Coherence of evidence: No inconsistencies are present in the evidence. The lack of response gradient is explained by the fact that the Lagoon is a well-mixed waterbody, in which all areas are approximately equally affected by nutrient loads.

The strength of evidence supporting the causal pathway between septic systems and increased nutrient loads to Malibu Lagoon is strong.

*Weight of Evidence for septic systems and oxygen-demanding wastes direct to Malibu Lagoon*

1. Co-occurrence: Septic systems (onsite wastewater disposal) contribute nutrient loads to Malibu Lagoon and are also likely to contribute oxygen-demanding wastes. Slightly elevated BOD5 concentrations within the Lagoon suggest co-occurrence.
2. Temporality: The City of Malibu does not provide centralized wastewater treatment. Onsite wastewater disposal has always been used and has increased over time. Therefore, the evidence is compatible with temporality.
3. Response Gradient: The Lagoon is a small, relatively well-mixed volume so there is no evidence available with which to establish a response gradient for direct loading of oxygen-demanding wastes.
4. Complete exposure pathway: There is incomplete evidence for the pathway between septic systems and increased oxygen demanding wastes in the Lagoon as the amount of loading of BOD5 has not been estimated.
5. Plausibility: Scientific literature supports a linkage between septic systems and increased loads of oxygen-demanding waste.
6. Analogy: Examples of septic systems causing increased loads of oxygen-demanding waste are found in the literature.
7. Predictive performance: There is no evidence of predictive performance.
8. Consistency of evidence: Multiple inconsistencies exist in the lines of evidence for the linkage between septic systems and increased oxygen-demanding waste the Lagoon.

9. Coherence of evidence: It is unclear whether increased BOD5 observations represent oxygen-demanding wastes resulting from septic systems, the Tapia WRF, or the growth and decay of algae stimulated by excess nutrient loads. Additional data might resolve this uncertainty.

The strength of evidence supporting the causal pathway between septic systems and increased oxygen-demanding wastes to Malibu Lagoon is weak.

**B5: Point Source Discharges:** Point source discharges can contribute excess nutrients that contribute to excess algal growth and reduced DO, or oxygen-demanding wastes that result in reduced DO. This section evaluates the linkage between point source discharges and increased nutrients or oxygen-demanding wastes (Figure 9-14).

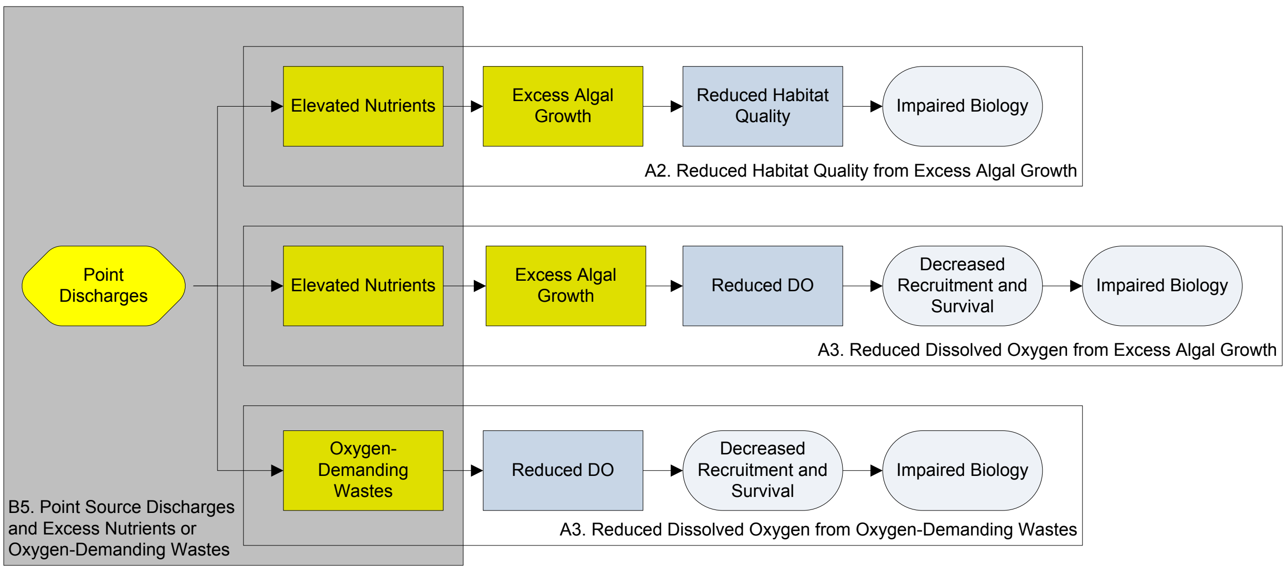



**Figure 9-14. Illustrated Linkage between Point Source Discharges and Elevated Nutrient Concentrations or Oxygen-demanding Wastes**

The Tapia WRF is the only facility with a traditional permitted wastewater discharge to Malibu Creek or its tributaries. Originally built in 1965, the facility has been expanded beyond its original design capacity to a current capacity of 16 MGD. In 2003, discharge prohibitions were extended from April 15$^{th}$ to November 15$^{th}$ of each year (with infrequent exceptions for flow augmentation releases to support steelhead) and a TMDL established nutrient targets for two seasons to address nuisance effects such as algae, odors, and scum. Summer targets (April 15 – November 15) for nitrate- plus nitrite-N and total P are 1.0 and 0.1 mg/L, respectively. During the winter months (November 16 – April 14), the nitrate- plus nitrite-N target is 8 mg/L and no total P target is applied.

In accordance with the existing 2003 Nutrient TMDL, Tapia is permitted to discharge significant amounts of nutrient loads during the winter discharge season, while almost no direct discharges occur during the summer growing season. Two unresolved questions are (1) the extent to which winter discharges are retained in the system and result in increases in summer concentrations, and (2) the extent to which winter loads of nutrients are stored in the Lagoon and become available to support summer algal growth.

Table 9-1 compares the nutrient concentrations at main stem sites upstream and downstream of the Tapia WRF discharge to 2003 Nutrient TMDL target concentrations. During the discharge season, the presence of the discharge results in high concentrations of nitrate-N and orthophosphate-P downstream of Tapia. Concentrations are much lower in the non-discharge season, but still appear to be elevated relative to the upstream monitoring station.

**Table 9-1. Average Nutrient Concentrations at Sites Upstream and Downstream of the Tapia WRF Discharge (2005 – 2010) Compared to TMDL Targets**

| Nutrient Parameter | Measurement | Main Stem Sites | | | 2003 Nutrient TMDL Target |
|---|---|---|---|---|---|
| | | Downstream | | Upstream | |
| | | MC-1 | MC-15 | MC-12 | |
| $NO_3 + NO_2$-N (mg/L) | Median | 0.35 | 1.27 | 0.03 | N/A |
| | Discharge (11/15 – 4/15) | 4.27 | 4.15 | 0.21 | < 8 |
| | Restricted (4/15 – 11/15) | 0.16 | 0.67 | 0.05 | < 1 |
| Total $NH_3$-N (mg/L) | Median | 0.06 | 0.09 | 0.05 | N/A |
| $PO_4$-P (mg/L) | Median | 0.46 | 0.21 | 0.09 | N/A |
| | Discharge (11/15 – 4/15) | 0.77 | 0.90 | 0.08 | No target |
| | Restricted (4/15 – 11/15) | 0.32 | 0.19 | 0.09 | <0.1 |

LVMWD monitoring shows similar results, with non-discharge season median concentrations immediately below Tapia WRF of 0.70 mg/L nitrate-N, 1.0 mg/L total N, and 0.26 mg/L orthophosphate as P (Section 7.6).

Tapia WRF also discharges oxygen-demanding wastes. However, this is an advanced treatment facility that achieves low levels of readily decomposable biochemical oxygen demand (measured as 5-day BOD or BOD5). LVMWD monitoring shows most BOD5 observations at the detection limit of 2 mg/L with no detectable difference, on average, in concentrations upstream and downstream of the Tapia discharge. The extent to which discharge may include more refractory organic compounds that can exert an oxygen demand on a period longer than 5 days is not known. Such refractory compounds would likely not have much of an effect on the stream, but could pose an issue for the Lagoon, where residence time is longer. Based on these observations, Tapia WRF does not appear to generate oxygen-demanding wastes in amounts likely to be associated with reduced DO.

The evidence supporting the causal pathway between the Tapia WRF discharge and downstream elevated nutrient concentrations is strong for the winter discharge season. The strength of the evidence supporting the causal pathway between the Tapia WRF point source discharge and elevated nutrients in Malibu Creek downstream of the Tapia WRF discharge during the summer non-discharge season is moderate.

**B6: Urban Runoff:** Urban runoff can cause increased sedimentation, excess nutrients/excess algal growth/reduced habitat quality, reduced DO from excess algal growth or oxygen-demanding wastes, or toxicity from metals, elevated salt concentrations, or organic toxics. It is also associated with altered hydrology and channel alteration. This section evaluates the linkage between urban runoff and increased sediment, increased nutrients, oxygen-demanding wastes, and increased toxicity from metals or organic toxics (Figure 9-15).

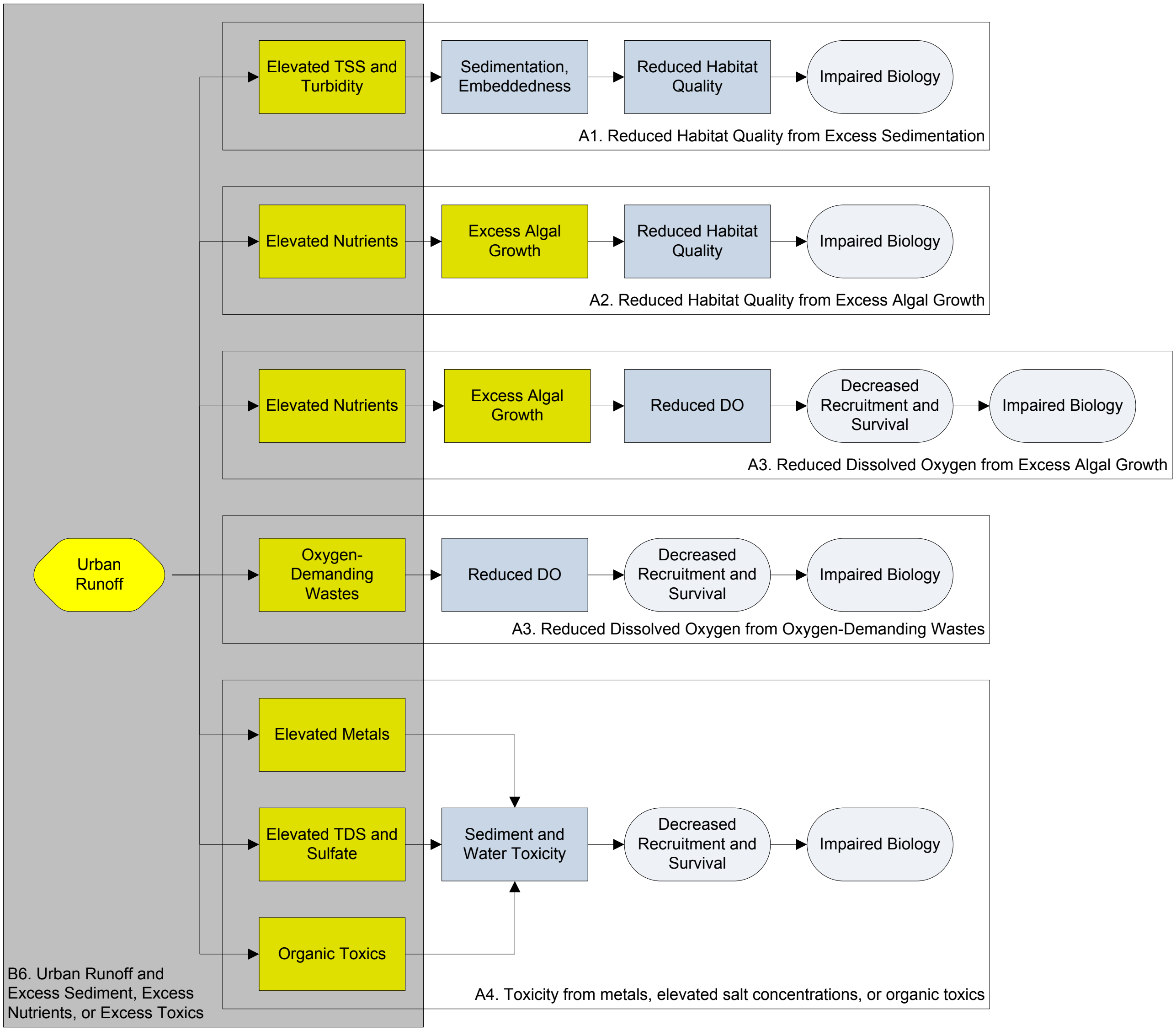



**Figure 9-15. Illustrated Linkage between Urban Runoff and Excess Sedimentation, Elevated Nutrients, Oxygen-demanding Wastes, and Toxicity**

## Malibu Creek

Although still largely undeveloped, the Malibu Creek Watershed has seen a history of urban growth. Areas of barren and undeveloped LU/LC had the largest decrease of all LU/LC types between 1990 and 2008, while both density classes of SFR land use increased the most. This increased urbanization of portions of the upper watershed increased the amount of impervious surfaces from 3,694 to 4,878 acres. As of the 2008 SCAG land use coverage, the Malibu Creek Watershed was 6.95% impervious. Using the Simple method rule (Caraco et al., 1998) that the impervious land generates surface runoff relative to pervious land in a ratio of 0.95/0.05, impervious surfaces were estimated to yield about 59 percent of the surface runoff in the watershed.

Increasing levels of urban development and imperviousness have been directly associated with effects on aquatic life, with biological effect levels perceived at or below 10 percent urban development and 5 percent impervious cover (Yoder et al. 1999; CWP 1999; Roy et al. 2003; Cuffney et al. 2010).

*Excess sediment.* Increased impervious surface has long been demonstrated to increase stream flashiness (e.g., Walsh et al., 2005; Allan, 1995). Altered flood hydrology increases stream bank erosion, resulting in excess sedimentation downstream and increased turbidity, particularly during storm events. Limited sampling shows high TSS/SSC concentrations during storm events in the Malibu Creek Watershed. USEPA measured both turbidity and suspended sediment concentration concurrently between February 16, 2011 and April 25, 2012, to evaluate the relationship between the two measures. These results showed that for an average range of flows, turbidity was a good surrogate for suspended sediment in the Malibu Creek main stem.

*Excess nutrients.* Busse et al. (2006) found that total nitrogen, total phosphorus, and total chlorophyll *a* concentrations were all positively correlated with the proportion of upstream land covered by impervious surfaces. Average phosphate concentrations were elevated at those sites draining the Monterey/Modelo Formation. However, it appears that increased erosion and sediment transport capacity associated with urban runoff lead to increases in nutrient loading from these natural geological sources.

*Oxygen-demanding wastes.* Urban runoff can contribute organic detritus (e.g., leaves and lawn clippings) and chemicals (e.g., anti-freeze, oil and grease) that contribute to oxygen demand.

*Toxics.* Only occasional water column toxicity has been observed since 2005 in wet and dry weather surface water samples from Malibu Creek, as described above. Water quality data for both sulfate and selenium reportedly demonstrated frequent excursions of water quality standards. However, selenium and sulfate data have not been routinely obtained across the watershed. Instead, conductivity data may be used as a surrogate measure for toxicity from metals or elevated salt concentrations. The highest median conductivity values were found in the Monterey/Modelo Formation. Urban runoff can be a source of elevated conductivity, as well.

The strength of evidence supporting the causal pathway between urban runoff and increased sedimentation is strong.

The strength of evidence supporting the linkage between urban runoff and increased nutrients (especially nitrogen) in Malibu Creek is strong.

Limited data were available regarding the types, amounts, or concentrations of oxygen-demanding wastes in the Malibu Creek Watershed. The strength of evidence supporting the linkage between urban runoff and oxygen-demanding wastes cannot be evaluated.

The strength of evidence supporting the linkage between urban runoff and increased toxics concentrations in Malibu Creek is weak, due to conflicting evidence, limited frequency at which toxicity is observed and the inconsistent results of natural geology (i.e., conductivity was an indicator).

**Malibu Lagoon**

Conditions in Malibu Lagoon are affected by loads from the upstream watershed and by direct urban runoff from the adjacent parts of the City of Malibu. This section addresses direct loading from the City of Malibu to the Lagoon,

*Excess sediment.* Little information was available on rates of sediment loading in direct runoff from the City of Malibu to Malibu Lagoon.

*Excess nutrients.* Direct stormwater runoff is a known source of nutrient loading to the Lagoon. Fertilizers used to improve landscaping and lawns often run off with surface runoff when watering lawns, commercial grounds, golf courses, and other landscaped areas. Pet wastes may also be a source of nutrients in urban runoff. Therefore the non-point source discharges of nutrients directly to the Lagoon were of concern.

*Oxygen-demanding wastes.* Direct urban stormwater loads have the potential to add oxygen-demanding wastes to the Lagoon.

*Toxics loads.* Urban runoff was a potential source of direct toxics loading to the Lagoon. However, specific evidence is not available.

The strength of evidence supporting the causal pathway between urban runoff and increased nutrient loads to Malibu Lagoon is moderate.

Evidence was not available to support or refute a linkage between direct urban runoff and increased sediment or significant toxics loading to Malibu Lagoon. Limited toxicity detected in lagoon sediments has not been shown to be derived from urban runoff.

The strength of evidence supporting the linkage between urban runoff and oxygen-demanding wastes to Malibu Lagoon is weak.

**B7: Agricultural Runoff:** Agricultural runoff can affect benthic macroinvertebrates by causing increased sediment, increased nutrient concentrations resulting in excess algal growth and reduced habitat quality, and reduced DO resulting from increased nutrient concentrations from excess algal growth. Depending on the type of agriculture, increased toxics (pesticides and nutrients) can also occur. This section evaluates the linkage between agricultural runoff and increased sedimentation, nutrient concentrations, and toxics (Figure 9-16).

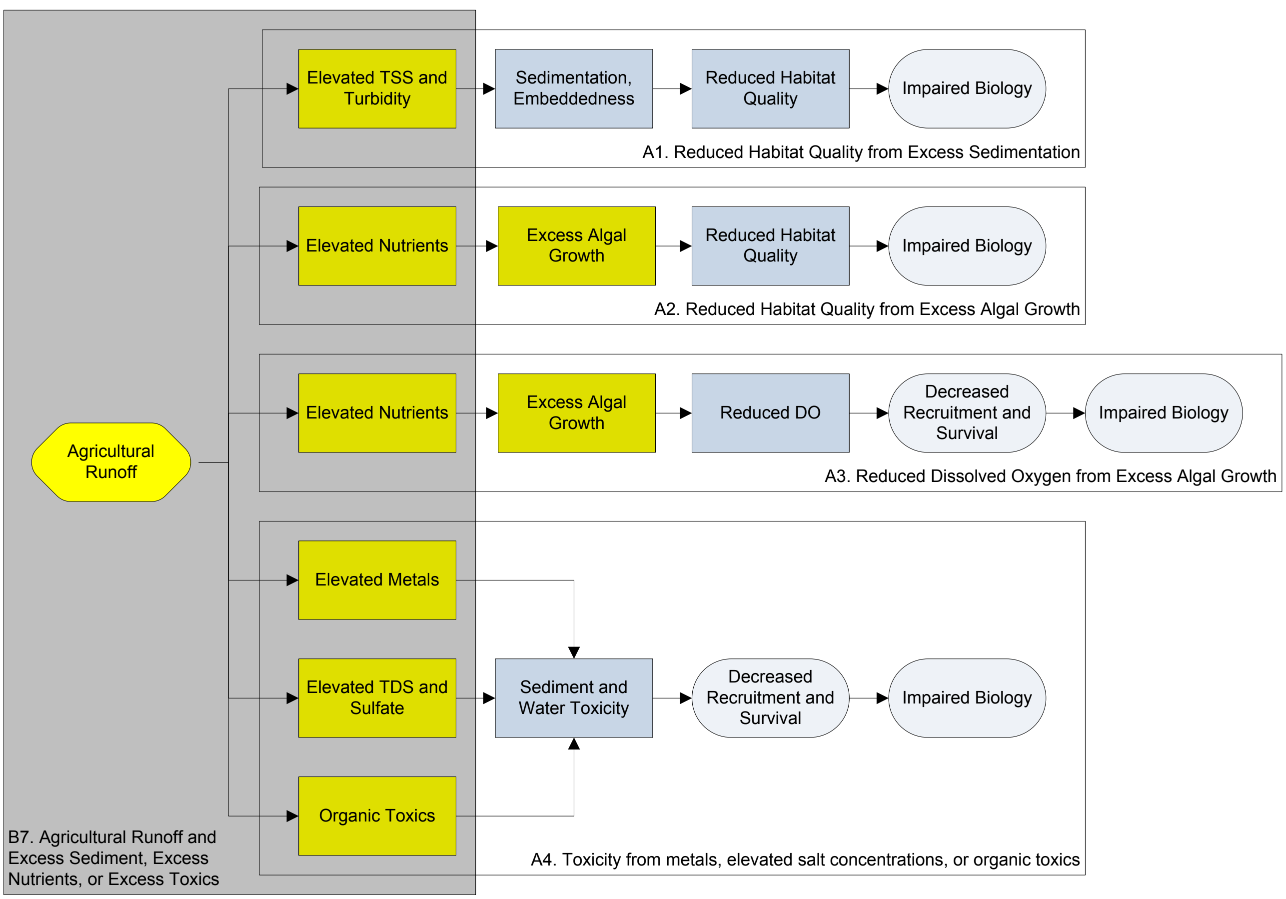



**Figure 9-16. Illustrated Linkage between Agricultural Runoff and Excess sediment, Elevated Nutrient, Oxygen-demanding Waste, or Toxics Loads**

Agricultural land use (as identified in the SCAG coverage) comprised only about 2 percent of the Malibu

Creek Watershed. In general, the agricultural land use identified in the Malibu Creek Watershed occurred upstream, in relatively less impacted areas of the watershed. Goepel et al. (2012) identified small vineyards that appear to exist as accessory uses to structures such as residences, and likely represent "hobby vineyards." These areas were not identified as agricultural land uses on the interpreted satellite imagery, so agricultural land use may occupy a somewhat larger area than tabulated. Currently, the amount of agricultural runoff within the watershed appears to be minimal, but improved land use information and monitoring data will provide a better indication of this source.

There was limited monitoring data and insufficient evidence for agricultural land use leading to increased sediment, increased nutrients, reduced DO, or toxicity from metals, elevated salt concentrations, or organic toxics in Malibu Creek Watershed, including both the Creek and the Lagoon.

**B8: Modified Exposure of Natural Geology:** The geologic constituents in the Malibu Creek Watershed (including the Santa Monica Mountains and the marine sedimentary deposits associated with the Monterey/Modelo Formation) have been suggested as a potential source of increased sediment, increased nutrients resulting in reduced habitat quality or reduced DO and increased toxicity or other sublethal biological impacts associated with elevated conductivity. This section evaluates the linkage between modified exposure of natural geology, and increased sediment, increased nutrients, or increased toxics (Figure 9-17).

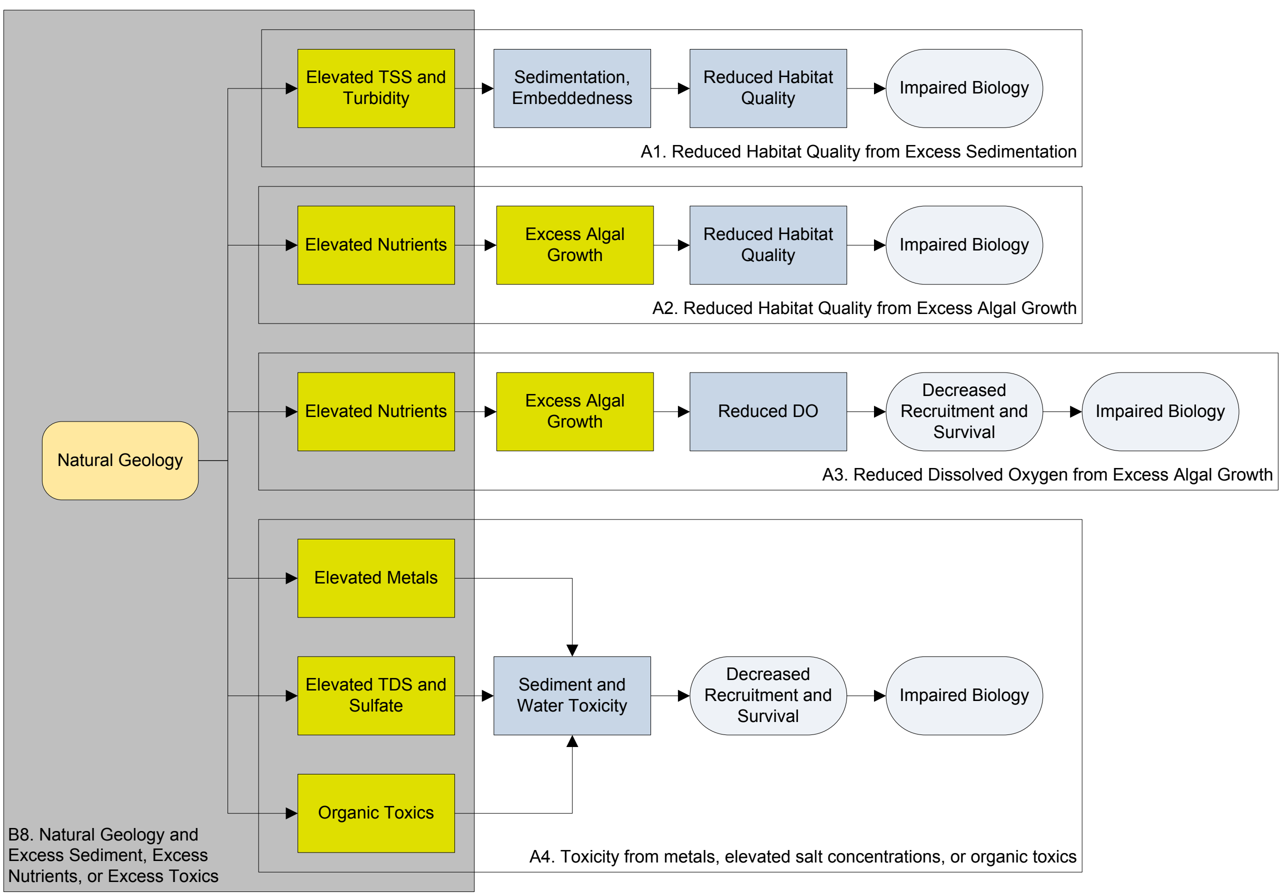



**Figure 9-17. Illustrated Linkage between Modified Exposure of Natural Geology and Excess Sedimentation, Elevated Loads of Nutrients, or Elevated Loads of Toxics**

When evaluating geology as a potential source of the probable stressors affecting benthic macroinvertebrates in the Malibu Creek watershed, it is important to distinguish between undisturbed and disturbed conditions, each of which will be discussed in more detail below. Under natural (undisturbed) conditions, stressors resulting from the underlying geology would always have been present. For this reason, it is important to identify and evaluate sites reflective of these conditions, such as CH-6 and LV-9. The biological community established at undisturbed sites would reflect these natural conditions. This may result in a biological community that appears to be impaired compared with sites outside the watershed, but this level of "impairment" reflects natural conditions at these sites. The underlying geology then can only be responsible for true impairment (impairment beyond what is observed at undisturbed sites) if it somehow contributes excess stressors to the streams. In other words, the underlying geology must be disturbed in such a manner as to cause unnatural erosion, sediment loading, or leaching of toxins. Two issues are considered: 1) if the underlying geology of the Monterey/Modelo Formation contribute stressors at a background level; and 2) if it i possible that disturbance of the Monterey/Modelo Formation contributes stressors in excess of background. Since Malibu Lagoon is the terminus for flow from the Malibu Creek watershed, excess stressors (over background) contributed by the underlying geology impacts the Creek and the Lagoon similarly.

The natural background stressor levels were examined. In general, under natural conditions, sites draining the Monterey/Modelo Formation were on slopes lower than sites draining non-marine geology (i.e., less erodibility and sediment yield) and contributeed higher conductivity and phosphorus levels (see Appendix G). In this watershed, the biota inhabiting these undisturbed regions of Monterey/Modelo Formation appear to still support conditions comparable to those undisturbed sites not draining Monterey/Modelo Formation.

There are many onditions that could result in excess sedimentation, increased nutrient concentrations, or increased toxics include both natural and anthropogenic events. Natural events include naturally-caused wild fires, which can denude the landscape amd alter the hydrologic regime. Increased peak flows above natural flow events can substantially increase excess sedimentation and channel modification. Eroded particulates have the potential to release more soluble components (e.g., salts, metals, and nutrients) than the intact parent material, since eroded particulates expose more surface area to water than does the intact parent material. Other anthropogenic events/activities that result in similar effects include, for example, construction/development, agricultural uses, and increased impervious surfaces.

Data were not available to evaluate the effect of ground disturbance (in the absence of other possible sources, e.g., development/increased impervious surface) on the release of salts, nutrients, and sediment from Monterey/Modelo Formation geology. While it appears that disturbances (e.g., ground movement by heavy equipment as during construction, altered hydrology, or channel alteration) would increase erosion and therefore be likely to increase surface water conductivity, nutrient concentrations, or sedimentation, more focused data are needed to quantify the potential magnitude of the impacts.

**Table 9-2. Median Nutrient Concentrations in Comparator/Reference Sites Relative to Monterey/Modelo Formation Drainage**

| Site | Percent Modelo Geology | Average Turbidity (NTU) | Median Conductivity (µS/cm) | Median Nitrate-N (mg/L) | Median Ammonia-N (mg/L) | Median Orthophosphate-P (mg/L) |
|---|---|---|---|---|---|---|
| CH-6[1] | 51 % | 0.85 | 3,405 | 0.005 | 0.030 | 0.134 |
| LV-9[1] | 20 % | 0.83 | 3,208 | 0.005 | 0.020 | 0.177 |
| SC-14[2] | 0 % | 0.75 | 1,211 | 0.030 | 0.030 | 0.026 |
| LCH-18[2] | 0 % | 0.27 | 1,550 | 0.010 | 0.030 | 0.039 |

[1] Comparator/reference site draining the Modelo/Monterey Formation.

[2] Non-marine geology comparator/reference site.

*Excess sedimentation.* Geology in the Malibu Creek Watershed is approximately 38 % Miocene marine sedimentary rock, with individual site catchments draining between zero and 62 % marine sedimentary rock. Warrick and Mertes (2009) determined that the similar marine formations of the Western Transverse range were highly erodible and generated approximately five times more sediment than other portions of the range. However, these high rates represent natural conditions for the watershed and thus cannot be considered *excess* sedimentation. Further, net sedimentation in the stream network appeared to be controlled more by sediment transport capacity than by sediment supply, particularly within the lower gradient portions of Malibu Creek.

*Increased nutrient loads.* LVMWD (2011) suggested that high levels of phosphorus are attributable to drainage originating from the Monterey/Modelo Formation. Table 9-2 presents a subset of data for comparator/reference sites located both in and outside the formation. These data indicated that orthophosphate (as P) concentrations were, on average, greater for sites with a greater proportion of their catchment in the Monterey/Modelo Formation than for sites with a smaller proportion of their catchment in the Formation, consistent with LVMWD (2011). In contrast, nitrate concentrations are comparable between comparator/reference sites draining the Monterey/Modelo Formation (CH-6 and LV-9) and comparator/reference sites outside the formation (SC-14 and LCH-18).

*Toxics loads.* LVMWD (2011) showed that the high levels of sulfate, selenium, and total dissolved solids found in portions of the Malibu Creek Watershed were due to drainage originating from the marine sedimentary Monterey/Modelo Formation.

The strength of evidence supporting the causal pathway between the modified exposure of natural geology and increased sedimentation is moderate because this geology existed prior to the elevated sediment levels. It may contribute and interact with other stressors to increase instream sedimentation, but it is not the only or primary cause. Moreover, such geologic formations are natural conditions for Malibu Creek Watershed, and have been present since before human related activities. As such, the benthic assemblage was likely adapted to the sedimentation associated with natural geologic sources, and thus, argues against simple natural geology as being a primary source of stressful levels of sediment in the watershed.

Increased inorganic phosphorus concentrations occurred as a result of natural geology of the Monterey/Modelo Formation, mostly in the upper reaches of the watershed. However, nitrogen concentrations were similar between comparator/reference sites in the Monterey/Modelo Formation and those that do not drain the formation. Thus, co-occurrence was demonstrated for P, but not for N. This was potentially significant as N concentrations appeared to exert greater control on algal response in this watershed.

The strength of evidence supporting the causal pathway between pure natural geology and increased phosphorus is strong. The strength of evidence supporting the causal pathway between natural geology and increased nitrogen is weak because this geology is not associated with elevated nitrate where comparator/reference conditions exist. Moreover, the fact that the benthic assemblage likely was adapted to the nutrients associated with natural geologic sources argues against natural geology being a primary source of stressful levels of nutrients.

The strength of evidence supporting the causal pathway between modified exposure of natural geology and increased toxicity loads for salts, sulfate, and selenium was strong.

**Malibu Lagoon**

Malibu Lagoon, located directly downstream of the lower reaches of Malibu Creek, receives all sediment, nutrient, and toxic inputs that are discharged from the Creek. Therefore, the analysis regarding the weight of evidence for natural geology and excess sediment, nutrients, or toxics also applies to impacts in the lagoon. However, it is important to recognize the distance between sites in the Monterey/Modelo Formation and the Lagoon. It is likely that other stressors, with sources between the Monterey/Modelo Formation and Malibu Lagoon, contributed to biological impairment and confounded the effects of stressors from the modified exposure of natural geology.

### 9.3.3 Eliminate Sources

Sources were only eliminated where the lack of evidence for causing the likely stressors was unambiguous. As a result, two of the seven candidate sources listed above were eliminated as highly unlikely to be a significant and sufficient cause of the likely stressors (these sources may contribute in a minor way to the candidate stressors). The eliminated sources were: Fire Regime and Agricultural Runoff.

### 9.3.4 Characterize Sources: Identify Probable Sources

All of the stressor sources presented were credibly related to one or all of the probable stressors (reduced habitat quality from sedimentation and reduced habitat quality from excess algal growth for Malibu Creek and Lagoon, and reduced DO from excess algal growth for Malibu Lagoon; these are linked to impairments associated with benthic macroinvertebrates). However, the evidence was stronger for some sources than for others. The following stressor sources were strongly associated with the impairment in the flowing Creek and main tributaries of the Malibu Creek Watershed:

- Altered Hydrology
- Septic Systems
- Point Source Discharges
- Urban Runoff

Both Altered Hydrology and Urban Runoff, in the form of increased peak flows derived from impervious surfaces, contributed to sedimentation in the streams. Septic Systems, Point Source Discharges, and Urban Runoff also appeared to be a key source of nitrogen loading in the system, which resulted in excess algal growth. Natural geology, which is a source of increased phosphorus loading, was not listed here as a key source because algal response appears to be controlled primarily by nitrogen availability.

For Malibu Lagoon the key sources were identified as:

- Altered Hydrology
- Channel Alteration
- Septic Systems
- Point Source Discharges
- Urban Runoff

In the Lagoon, sedimentation and reduced DO stressors were more strongly linked to the physical modifications to the lagoon morphometry; therefore, Channel Alteration was listed. In addition, Septic Systems, Point Source Discharges, and Urban Runoff likely play an important role in impairment of conditions in Malibu Lagoon by excess algal growth. Point Source Discharges are listed despite the growing season discharge prohibition because winter discharges of nutrient loads can collect in the lagoon and support excess algal growth later in the season.

Natural geology, when disturbed by unnatural conditions such as construction or altered hydrology, associated with runoff from the Monterey/Modelo Formation, contributed to some elevated candidate stressors in the main stem and various tributaries to Malibu Creek. These included phosphorus, ions such as sulfate, and metals (see LVMWD, 2011). However, these stressors do not appear to limit the biological potential of the system. Natural geology appeared to be a contributing source, but not an unnatural source contributing to these stressors.

The sum of the evidence suggested that altered hydrology, septic systems, urban runoff, channel alteration, and point sources are the dominant sources responsible for generating the dominant stressors.

(This page left intentionally blank.)

# 10. TMDLs and Allocations

Malibu Creek and Lagoon benthic communities and Malibu Creek sedimentation are identified as impaired on the Clean Water Act Section 303(d) list. This impairment is caused by the interaction of a variety of stressors. The CWA states that the TMDL must achieve water quality standards and must be expressed in terms of the maximum daily load (or "other appropriate measure") of a pollutant that a water body can receive and still support its beneficial uses. Since USEPA's assessment of all available data and studies demonstrated that the impairment was a result of multiple interacting stressors, this TMDL identifies multiple numeric targets and allocations for the most significant pollutants.

A TMDL is a means for recommending controls needed to restore and maintain the quality of water resources (USEPA, 1991). TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes allowable loadings for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. 40 CFR §130.2(i) states that a TMDL calculation is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background in a given watershed, and that TMDLs can be expressed in terms of either mass per time, concentration, toxicity, or other appropriate measure.

The TMDL must also consider seasonal variations and include a margin of safety (MOS) that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the wasteload and load allocations, the margin of safety (and any reserve capacity) must be equal to or less than the loading capacity.

A TMDL targets a level of pollutant loading by adding the pollutant sources, both point and nonpoint, and a margin of safety. A TMDL is typically expressed as:

$$\mathbf{TMDL = WLA + LA + MOS}$$

where:

> WLA = Waste Load Allocation – the portion of the loading to the water body assigned to each existing and future permitted point source of the pollutant
>
> LA = Load Allocation – the portion of the pollutant loading assigned to existing and future nonpoint sources of the pollutant
>
> MOS = Margin of Safety – an accounting of the uncertainty of the pollutant load and the quality of the water body

To effectively address the benthic macroinvertebrate community impairments in Malibu Creek and Lagoon and sedimentation impairment in Malibu Creek, this TMDL considered all stressors and causes to critically identify the pollutants of concern. The key stressors impacting the biota (both directly and indirectly) were sedimentation and nutrient loading, as summarized in Section 9. Excessive levels of sedimentation cause suboptimal habitat, and were also associated with the movement of sediment-associated nutrients and toxics. Excess nutrient loading caused overgrowth of algae including the development of macro-algal mats, which also directly impaired the habitat available for benthic macroinvertebrates, while indirectly contributing to exceedances of DO and pH criteria.

Our initial assessment efforts to focus only on the main stem resulted in uncertainty and critical data gaps associated with our understanding of the stressors and causes of the observed results. USEPA determined that to properly capture the sources and stressors of the observed impaired condition in Malibu Creek, it was necessary to evaluate the benthic community and water quality conditions of the major tributaries feeding into Malibu Creek main stem. In many cases, the water quality and benthic community conditions showed worse water quality conditions. For instance, physical habitat condition reflected the excess sedimentation in the tributaries, which then directly affected the main stem (see Section 9.3). Consequently, based on our comprehensive evaluation of the main stem and the major tributaries, this proposed TMDL concluded that Malibu Creek main stem and the major tributaries were impaired by sedimentation and nutrients, which were directly linked to negative impacts to the benthic community condition. This was similar to many TMDLs in other states addressing benthic community impacts (e.g., Benthic TMDL Development Report Turley Creek and Long Meadow Run Rockingham County, Virginia 2012; Cuyahoga River Watershed TMDLs, Ohio for nutrient, bacteria and benthic habitat 2003).

## 10.1 BIOLOGICAL RESPONSE TARGETS FOR THE WATERSHED

The TMDL for Malibu Creek and Lagoon identified multiple targets that, in combination, defined the support of beneficial uses in the listed waterbodies. A series of responses were specified, and these were the specific measures directly associated with the biotic impairment that can be measured and assessed (e.g., SC-IBI). The response targets ensured that the TMDL achieved beneficial use protection and provided a valuable means of tracking progress.

Response targets are defined as measures of effect that provide direct evidence of whether aquatic life uses are supported. Specifically, these response targets are defined in terms of measures of benthic community health, including the SC-IBI, the CSCI/pMMI, and the benthic algal coverage targets previously developed for the 2003 Nutrient TMDL.

**SC-IBI**: SC-IBI bioscore is set at a minimum of 40 or better, consistent with at least a “Fair” ranking (Ode et al., 2005). The evaluation should be based on a median over a minimum of four years to account for year-to-year variability.

**CSCI/pMMI/O/E**: CSCI, pMMI, and CA- O/E scores provide a second line of evidence to complement the SC-IBI. These scores should equal between 5$^{th}$ and 10$^{th}$ percentile of the model reference distribution. Similar to the SC-IBI, the evaluation should be based on a median over a minimum of four years to account for year-to-year variability.

**Benthic Algal Coverage**: Consistent with the algal coverage targets established in the 2003 Nutrient TMDL: no more than 30 percent cover for filamentous (floating) algae greater than 2 cm in length and no more than 60 percent cover for bottom algae greater than 0.3 cm thick.

**Chlorophyll *a* :** to maintain a minimum of 150 mg/L for both streams and Lagoon.

## 10.2 SEDIMENTATION LOADING CAPACITY FOR THE WATERSHED

As described in Section 9.2.3, sedimentation – the excess movement and deposition of sediment – is a critical problem in Malibu Creek, its tributaries, and the Lagoon; it negatively impacts the benthic biotic communities and results in a less than healthy biological community. Sedimentation can be indicative of a variety of stressor sources that are associated with urban runoff and altered hydrology, as in the case in Malibu Creek Watershed.

While there is evidence of high sedimentation rates in the Malibu Creek Watershed, there was general recognition that this watershed was also expected to have naturally elevated sediment yield due to the presence of erodible soils and comparatively rapid geologic uplift of the Santa Monica Mountains; this was characterized by mean uplift and denudation rates of around 0.5 mm/yr (Meigs et al., 1999). Unfortunately, other appropriate reference sites in southern California with comparable highly erodible geology, size, and lack of significant human influences, do not exist. In the absence of data prior to human-related activities and another comparable watershed, a reasonable sedimentation rate to protect the health of the Malibu Creek Watershed is determined by evaluating the natural capacity of flow to move sediment in the Malibu Creek Watershed.

As noted above, USEPA concluded and acknowledged that upland sediment supply will be naturally high in the Santa Monica Mountains, based on the watershed's natural erodible geologic characteristics. Since the supply of detached sediment was not limiting, the important variable feature was the capacity of flow to move sediment into and through the channel network. In addition, we considered the history of extensive human-related activities in this watershed causing significant alterations to its flow regime, which increased sediment transport capacity. This calculation assumes that the change in sediment transport capacity is due to the transport of sediment from developed areas or erosive movement of sediment in the stream due to the impact of altered flow (i.e., flow due to urban runoff, irrigation, residential overland flow, etc.). In other words, this calculation is estimating sedimentation due to non-natural conditions or activities.

The objective of this TMDL should demonstrate how best to reduce elevated sedimentation and stream sediment transport rates to those reflective of natural conditions.

## 10.2.1 Sediment Transport Capacity

To determine the *change* in the system to move sediment as a result of development or related anthropogenic activities, the sediment transport capacity was estimated. Most of the sediment mass moving through Malibu Creek leads to the filling of natural pools and clogging of substrate, and then moves as bedload during major storm events. Bedload transport theory allowed the examination of the sediment transport capacity of the stream as a function of critical shear stress (the force applied to the bed necessary to dislodge and erode sediment), which in turn depends on slope and flow depth. Specifically, the focus was on effective work, which was the integrated product of *excess* shear stress and velocity. This was the product of force and the distance through which effective work acts. This work combined both the detachment and the movement of sediment and thus represented the forces that lead to *downstream sedimentation*.

Meyer-Peter and Muller (1948), as revised by the analysis of Wong and Parker (2006), determined that bedload transport varied as a function of $8 \cdot (\tau^* - \tau_C)^{3/2}$, where $\tau^*$ is the boundary shear stress and $\tau_C$ is the critical shear stress for incipient motion, approximated in general as 0.0495 g/cm$^2$. When $\tau^* \leq \tau_C$, bedload transport is zero.

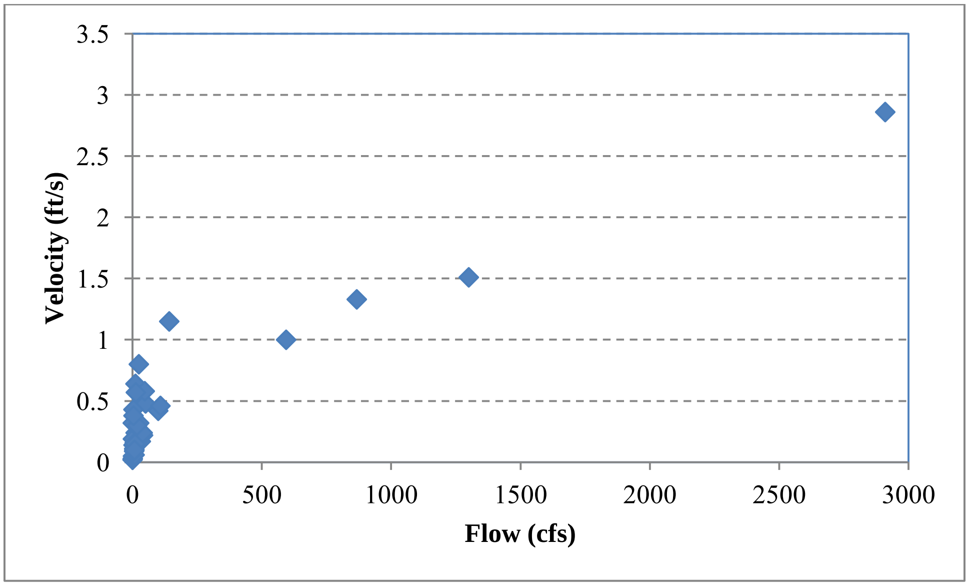
Effective work, W, is obtained by integrating the product of the excess shear stress formula for bedload transport and the stream velocity, V: $W = K \int (\tau^* - 0.0495)^{3/2} V\,dt$, where t is time, K is an appropriate units conversion factor, and both $\tau^*$ and V are functions of time. The boundary shear stress is given by $\tau^* = S \cdot \gamma \cdot H$, where S is the slope (dimensionless), $\gamma$ is the density of water (1 gm/cm$^3$) and H is the hydraulic radius. The hydraulic radius can in turn be calculated as $(D \cdot W)/(2\,D + W)$, where D is the average depth of a cross section and W is the top width.

A complete analysis of effective work required integration (or piece-by-piece summation) over the complete time series distribution of $\tau^*$ and V. Sufficient information was not currently available to complete such an analysis for Malibu Creek Watershed. But more importantly, the necessary component was an estimate of the *relative* change in effective work in Malibu Creek compared to natural conditions.

Most of the work on natural channels (that is, the movement of sediment) occurred at flows between 1-year and 10-years recurrence. Smaller storms were not able to mobilize large amounts of sediment. Storms larger than a 10-year recurrence can move more sediment, but occur so infrequently that they account for a smaller amount of the total load. The IHA analysis presented in Section 6-5 showed that both the 10-year and 2-year storm magnitudes in lower Malibu Creek have increased significantly following development. For example, at the LACDPW F-130 gage, the estimated 10-yr peak increased from 5,370 to 7,360 cfs, while the estimated 2-yr peak increased from 1,180 to 1,697 cfs; comparing this with flow prior to development, this difference was likely due to increases of impervious areas in the watershed. These estimates were taken as representative of the whole watershed because the drainage area between this gage and the mouth of Malibu Creek is small.

Calculating shear stress requires establishing a relationship between depth, top width, and flow velocity. This information is available from field measurements collected by USGS in the process of calculating rating curves at gage 11105510, in the natural channel near the mouth of Malibu Creek. (Note that the LACDPW F-130 stream gage is located on a grouted weir, not a natural channel section, and does not require field calibration.)

Analysis of the field measurement data at gage 11105510 showed the following relationships to flow in ft, feet per second (ft/s), and cfs: $H = 0.3054\ Q^{0.4023}$ and, for flows greater than about 500 cfs, $V = 0.000803 \cdot (Q - 594) + 1$ (see Figure 10-1).



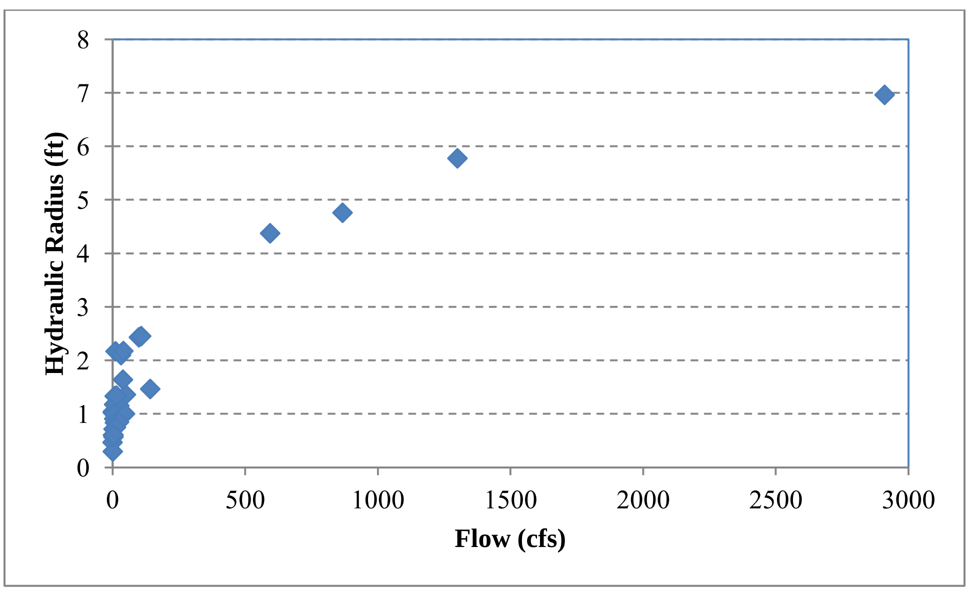




**Figure 10-1. Velocity and Hydraulic Radius as a Function of Flow at USGS Gage 11105510**

Boundary shear stress also depends on slope. Slope tends to increase with distance upstream in the Malibu Creek main stem. USGS gage 11105510 is near sampling station MC-1, where the estimated slope is 0.5%, increases to 3.5% at MC-15 (below Cold Creek), and is about 9.5% at MC-12 (above Las Virgenes Creek).

### 10.2.2 Excess Work and Change in Sedimentation Rate

The *change* in effective work, or sediment transport energy, can be approximated by estimating the change in instantaneous work at the 2-year and 10-year recurrence levels, spanning the major range over which the majority of total work on the channel was expected to occur (Table 10-1). The sensitivity of the result to slope was tested by running the analysis at both 0.5 and 10 percent slopes (which increased the effective shear). The results were consistent for both 2- and 10-year events and for 0.5 and 10 percent slopes; this suggested that work being done on the channel is about 160 percent of that done in pre-development conditions (i.e., $W_{post}/W_{pre} \approx 1.6$). In other words, the predevelopment work on the channel was 1/1.6 ≈ 62 percent of that under current conditions, and a reduction of approximately 0.6/1.6 ≈ 38 percent from existing conditions would be needed to restore an approximately natural sedimentation regime.

**Table 10-1. Analysis of Change in Effective Work in Malibu Creek**

| Slope | 0.5% | | | | 10% | | | |
|---|---|---|---|---|---|---|---|---|
| Recurrence | 10-year | | 2-year | | 10-year | | 2-year | |
| Condition | Post | Pre | Post | Pre | Post | Pre | Post | Pre |
| Flow (cfs) | 7,360 | 5,370 | 1,697 | 1,180 | 7,360 | 5,370 | 1,697 | 1,180 |
| V (m/s) | 1.961 | 1.474 | 0.575 | 0.448 | 1.961 | 1.474 | 0.575 | 0.448 |
| H (cm) | 334.6 | 294.7 | 185.4 | 169.2 | 334.6 | 294.7 | 185.4 | 169.2 |
| τ* (g/cm$^2$) | 1.673 | 1.474 | 0.927 | 0.801 | 33.460 | 29.475 | 18.543 | 16.021 |
| $W_{post}/W_{pre}$ | 1.619 | | 1.618 | | 1.610 | | 1.598 | |
| Needed Reduction | 38.2% | | 38.2% | | 37.9% | | 37.4% | |

Note: "Condition" refers to the IHA analysis, where the "Pre" condition is based on flow records from water years 1932 – 1965 and the "Post" condition is based on water years 1993 – 2009. Flow records are from LACDPW gage F-130. V is stream velocity, H is hydraulic radius, τ* is boundary shear stress, and W is instantaneous work, proportional to $(\tau^* - 0.0495)^{3/2}$ V. Needed reduction (to reduce work to pre-impact levels) is $(W_{post}-W_{pre})/W_{post}$. Available data allows calculation of the $W_{post}/W_{pre}$ ratios, but not their individual values.

Because effective work is a measure of the power to transport sediment, in this case as a measure of the movement of sediment due to development or other human-related activities, the 38 percent reduction in work was equivalent to a 38 percent reduction in channel sediment transport. The reduction goal can be converted to a load basis by examining sediment transport at the LACDPW F-130 mass emissions station.

Estimates of long-term load required average flow and TSS concentrations in the stream. The best estimate of long-term load was provided by a stratified flow-weighted averaging estimator (Preston et al., 1989). A natural stratification of the results appeared to occur at a flow of about 80 cfs. Flows less than this amount (as a daily average) had an average flow-weighted concentration of 125.9 mg/L. Flows greater than or equal to 80 cfs had an average flow-weighted concentration of 301.8 mg/L.

Applying these estimators to the flow series observed from water years 1993 through 2010 yielded an estimate of the current conditions average annual load passing station F-130 of 11,038 tons/yr. Estimated annual loads range from 1,360 tons in water year 2002 to 43,000 tons in water year 1993; this range was generally consistent with the partial load estimates calculated by USEPA based on turbidity and suspended solids monitoring in 2011-2012 (Section 7.5.3). The TMDL target is a 38 percent reduction in the average annual load, resulting in a loading capacity of 6,844 tons/yr – as a long term average. The conversion to daily load resulted in a requirement not to exceed 301.8 mg/L suspended solids (on average) for daily flows greater than 80 cfs.

Monitoring at the mass emissions station has generally not reported data from the highest flow range, when sampling can be dangerous. In addition, sediment transport in a flashy system like Malibu Creek is more a function of instantaneous peak flow than daily average flow. Thus, there is not a strong relationship between the reported flow-weighted TSS concentration and *daily* average flow. This was accounted for above by using a stratified flow-weighted averaging estimator. Any additional uncertainty related to this will be further considered in the margin of safety determination.

## 10.2.3 TMDL Allocations for Sedimentation in the Watershed

The goal of a TMDL is to ensure that the impaired waterbody will attain water quality standards. The TMDL determines the amount of a given pollutant that can be loaded to the water body and still meet water quality standards (the loading capacity) and allocates that load among the various sources.

Identification of the pollutant's loading capacity for a water body is an important step in developing a TMDL. USEPA defines the loading capacity as "the greatest amount of loading that a water body can receive without violating water quality standards" (USEPA, 2000e). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular point source is termed a wasteload allocation, while the portion of the receiving water's loading capacity assigned to one or more nonpoint sources is termed a load allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

### 10.2.3.1 Total Sedimentation Allowable Load for Point Sources

For sedimentation in Malibu Creek, the loading capacity was 6,844 tons/yr of sediment movement past the F-130 gage (see Section 10.2.2). The work that moves sediment in the channel is due primarily to stormwater runoff; therefore the allocations are proportional to the fraction of stormwater generated by a given source.

Stormwater draining through an MS4 conveyance system in the entire Malibu Creek Watershed is subject to one of three MS4 permits: the Los Angeles County Unified MS4 Permit, the Ventura County Unified MS4 Permit, and the Caltrans MS4 Permit.

This TMDL addresses the impacts of sedimentation to Malibu Creek main stem and tributaries draining into the Creek. Based on information submitted during the public comment period and further examination of the hydrological connections of the complex network of stream channels and water impoundments (i.e., dams and lakes) in the watershed, USEPA determined that the applicable WLAs cover only the catchments downstream of major dams and lakes. In this case, flow is distinctly different from Malibu Creek to Triunfo Creek and those tributaries upstream of Malibou Lake for the western section of the watershed. Tributaries in the eastern section of the watershed flow directly into Malibu Creek; these include Cold Creek, Stokes Creek and Las Virgenes Creek.

Due to these differences in hydrological connections in the watershed, USEPA assigns a WLA to the MS4 permittees that cover the Triunfo Creek catchment downstream of Malibou Lake and Las Virgenes Creek, Stokes Creek and Cold Creek catchments.. The areas upstream of Malibou Lake are assigned a load allocation for sedimentation as the lake changes the sediment transport capacity in the watershed, and sedimentation is of potential concern during large storm events, which may move accumulated sediment load.

The Tapia discharge was not considered a significant contributor ; therefore, Tapia WRF must meet the existing TSS and turbidity limits in their current NPDES permit.

**Sedimentation WLA**

The point source allocatable load is divided up among the two MS4 permits on the basis of relative contributions to stormwater flow (note: The Tapia discharge must meet their existing TSS and turbidity NPDES limits). The analysis of flow was based on Schueler's Simple method, as presented in Caraco et al. (1998). In this formulation, storm runoff depth is expressed as 0.9 x P x (0.05 + 0.09 Ia), where P is precipitation and Ia is the impervious area fraction. Alternatively, this implies that the total storm runoff volume is a function of (0.95 x Imp + 0.05 x Perv) times a units conversion. The sedimentation WLAs were assigned proportional to the flow from each jurisdiction. For any jurisdiction *i,* this is simply:

$$Allocation_i = \frac{0.95\,x\,\mathrm{Imp}_i + 0.05\,x\,\mathrm{Perv}_i}{0.95\,x\sum \mathrm{Imp}_i + 0.05\,x\sum \mathrm{Perv}_i}$$

Land use and imperviousness was determined from the 2008 SCAG coverage and tabulated by jurisdictional area, as shown in Table 5-1 above. The resulting allocations are shown in Table 10-2, which account for a 15 percent Margin of Safety from the loading capacity of 6,844 tons/yr, so the total allocatable load distributed below is 5,817 tons/yr.

It should be emphasized that the sedimentation wasteload allocations were written in terms of sediment mass moving past the F-130 gage. The WLAs do *not* explicitly require a limitation on the upland sediment load from jurisdictions in the watershed. Rather, the WLAs required limits on sedimentation defined as the sediment transport capacity within the system. The WLAs can thus be achieved, in whole or in part, by limiting the flow energy that transports sediment through the stream network.

An explicit MOS of 15 percent of the loading capacity (1,027 tons/yr) is assigned to account for uncertainty in the TMDL. The results of the TSS and turbidity relationship illustrated the significant amount of load that can be transported down the watershed along the main stem Malibu Creek during typical sized storm events. As a case in point, during the sampling period between 2011 to 2012, the largest storm event, with a measured flow of over 10,000 cfs, was not captured because the equipment was flooded and damaged. Since we do not have a comparable data set collected prior to a modified Malibu Creek Watershed (i.e., hydrology, imperviousness, etc.), we believe that an explicit MOS of 15% accounts for the uncertainty related to greater transport of sediment load during high flow events or year.

Sedimentation in Malibu Creek and Lagoon presented a long-term cumulative threat to the support of aquatic life. Therefore, allocations to individual seasons were not needed. However, seasonal variations are addressed in the TMDL because the allocations were proportional to flow, which varies seasonally.

### 10.2.3.2 Sedimentation Load for Non-Point Sources

The watershed includes a complex web of jurisdictions. The MS4 system or permitted area covers a large portion of the watershed. However, there are areas of unincorporated and protected lands that do not drain to an MS4 conveyance system before reaching a waterbody.. These unincorporated and protected lands are therefore assigned load allocations. In addition, LAs were also applied to the combined area upstream of Malibou Lake. This is because Malibou Lake changes the sediment transport capacity (i.e., work) in the watershed. The LAs for the Malibu Creek Watershed non-point sources are presented in Table 10-2. A load allocation is applied to a compliance point below Malibou Lake to account for the large movement of sediment during large storm events. At this time, there is a large load of sediment held back behind impoundments in the watershed; however, there is insufficient evidence to quantify this potential discharge of sediment load. USEPA recommends that more investigation be conducted to determine the rate and amount of sediment transported from the impoundments. If information changes, the State may reconsider this allocation, and identify applicable WLAs.

Based on our evaluation of the landuse and jurisdictional maps of the watershed, the areas upstream of Malibou Lake include those lands covered primarily by the Ventura County MS4 Co-permittees and state and federal parks and forested regions.

**Table 10-2. Allocations for Sedimentation (based on SCAG 2008 land use and Jurisdictional maps provided by MS4 Co-permittees)**

| Type of Allocation | Responsible Party | Impervious Area (acres) | Pervious Area (acres) | Allocation Fraction | Sedimentation Allocation (tons/yr) |
|---|---|---|---|---|---|
| WLA | Los Angeles Co. below Malibou Lake | 887 | 10,612 | 17.4% | 1,012 |
| WLA | Caltrans below Malibou Lake | 60 | 61 | 0.8% | 44 |
| LA | Unincorporated area draining Las Virgenes Creek** | 8 | 267 | 0.3% | 16 |
| LA | Protected land below Malibou Lake* | 253 | 16,820 | 13.7% | 796 |
| LA | Load Allocation at outlet of Malibou Lake | 3,669 | 37,550 | 67.9% | 3,950 |
| **Total** | | **4,878** | **65,310** | **100.0%** | **5,817** |

* Protected land includes BLM, NPS, county and city parks, etc.

** This area of unincorporated lands covers open space and small private lands in Ventura County. There are no County maintained roads or MS4 system in this area. Some evidence indicates that private residences are likely dependent on on-site septic systems.

## 10.3 NUTRIENT ENDPOINTS

USEPA established a nutrient TMDL for Malibu Creek Watershed in 2003 (USEPA, 2003). This established nutrient targets for two seasons: During the summer (April 15 – November 15) nitrate-plus-nitrite-N and total P targets were 1.0 and 0.1 mg/L, respectively. (The 2003 Nutrient TMDL refers to "total N" but explicitly defines this as "nitrate-nitrite" [USEPA, 2003, pp. 18-19].) During the winter months (November 16 – April 14) the nitrate-plus-nitrite-N target was 8 mg/L and no total P target was applied. It is important to note that the summer nutrient targets were based on a reference approach reflecting concentrations observed in "relatively undisturbed stream segments" on Upper Malibu Creek and Middle Malibu Creek. However, the 2003 Nutrient TMDL based the reference approach on two reference sites, while this TMDL, applying the same reference approach, considered many additional comparator/reference sites reflecting the local geology and characteristics of the Watershed (these data were not available prior to the establishment of the 2003 Nutrient TMDL). The 2003 Nutrient TMDL's winter target represented a 20 percent margin of safety adjustment on the existing 10 mg/L numeric objective provided in the basin plan, which is based on human health limits in drinking water, not aquatic life use protection. The existing TMDL clearly states that the factors controlling algal growth in Malibu Creek were not fully understood at that time and contains language suggesting the potential need to reopen the TMDL if more stringent limits were necessary following additional study. In light of the additional data and specific studies on nutrients in Malibu Creek Watershed conducted in the last 11 years, USEPA re-evaluated the record and provided modifications, where applicable.

The 2003 Nutrient TMDL was based on achieving a threshold of 30 percent or less cover by filamentous (floating) algae greater than 2 cm in length and a threshold of 60 percent cover for bottom algae greater than 0.3 cm thick. Water quality monitoring data from Malibu Creek showed that the TMDL nitrate targets have generally been met in the Malibu Creek main stem (see Figure 7-12); however, this has not been sufficient to achieve the stated thresholds for filamentous and bottom algae coverage, which are particularly critical to the support and protection of the benthic community and its habitat (see Section 8). The data and analyses since 2003 have demonstrated that additional reductions in nutrient loads and concentrations are needed to achieve the protection of beneficial uses being addressed in this TMDL. Similarly, the NNE for Malibu Creek Watershed, completely after the development of the 2003 Nutrient TMDL, included detailed analysis that the appropriate nutrient concentrations needed to achieve protection of beneficial uses will have to be lower than those established in the 2003 Malibu Creek Watershed Nutrient TMDL (Appendix F).

### 10.3.1 Relevance of CA Nutrient Numeric Endpoint Approach

USEPA reviewed and applied the best available information and tools to evaluate the sources and causes of the impaired condition. This included the California NNE (Tetra Tech, 2006) framework applied to Malibu Creek (Appendix F). The NNE framework is a process for developing site-specific nutrient targets based on secondary indicators, such as benthic algal density. The NNE approach also incorporated risk cofactors that affect algal productivity, including light availability, temperature, flow characteristics, and biological factors. As part of the NNE development, Tetra Tech (2006) provided simplified scoping tools to estimate algal response to nutrient concentrations, including a benthic biomass predictor that can be used to estimate nutrient concentrations consistent with achieving a specified algal density target. Our evaluation of past and recent data confirmed that assessing the condition based on a single line of evidence (i.e., inorganic levels of nitrogen and phosphorus) was not sufficient and may provide a false conclusion of in-stream condition (i.e., low $NO_3$-N concentrations suggest impairment is addressed, but high TN and extensive mat algal coverage was observed indicating impairment still persisted). The results of our re-evaluation and the results of the applied NNE framework in Malibu Creek supported the need for evaluating multiple lines of evidence.

The CA NNE recommended targets are currently under consideration by the SWRCB, and have not yet been officially adopted. However, the basis of the scientific study specific to Malibu Creek was critical for this re-evaluation and provided greater depth of explanation for our observed data results in the Creek and main tributaries. The approach recommended setting response targets for benthic algal biomass in streams based on maximum density as $mg/m^2$ chlorophyll *a*. Targets for a site are defined in terms of beneficial uses and Beneficial Use Risk Categories (BURCs).[8] A TMDL should, at a minimum, reduce average concentrations below the BURC II/III threshold. In the case of Malibu Creek, there was evidence that nutrient levels are naturally elevated to some extent due to the presence of marine sedimentary rocks, further suggesting use of the BURC II/III threshold as a target.

[8] BURCs establish ranges for the interpretation of nutrient criteria, similar to the approach that USEPA has promulgated for nutrient criteria for Florida lakes (75 FR 75762, Dec. 6, 2010). BURC I water bodies have nutrient concentrations sufficiently low that they are not expected to exhibit impairment due to nutrients. BURC III water bodies have nutrient concentrations sufficiently high and with a high likelihood of exhibiting impairment due to nutrients; these are assumed to require nutrient reductions. Finally, BURC II water bodies are in an intermediate range of concentrations that may require additional information and analysis to determine appropriate site-specific protective nutrient criteria. For a given beneficial use designation, the BURC I/II threshold represents a protective level below which there is general consensus that nutrients will not present a significant risk of impairment. (This threshold should also be set so that is not less than the expected natural background.) Conversely, the BURC II/III threshold represents a level that is sufficiently high with general consensus that risk of use impairment by nutrients is probable.

## 10.3.2 CA NNE for Malibu Creek Watershed

The COLD and SPWN beneficial use designations, which have the most stringent BURC thresholds, are applicable to the Malibu Creek main stem. Under the current proposed CA NNE approach, these have a BURC II/III threshold of 150 $mg/m^2$ maximum benthic chlorophyll *a*.

The NNE analysis for Malibu Creek and tributaries was based on detailed surveys undertaken in 2001 and 2002 (Busse et al., 2003; Busse et al., 2006). These studies reported algal biomass (both benthic and floating), nutrient levels (nitrogen and phosphorus), and physical conditions in multiple stream reaches with different surrounding land uses and habitat conditions. Reported benthic algal densities measured as chlorophyll *a* were quite high (up to 717 $mg/m^2$ in the Malibu Creek main stem), but the ratio of chlorophyll *a* to ash free dry mass (AFDM) was also elevated, so that a moderate amount of algal biomass can lead to very high chlorophyll *a* densities. The benthic biomass predictor "Revised QUAL2K" steady state method appeared to provide reasonable predictions of the maximum observed benthic chlorophyll *a* density at each site.

The benthic biomass predictor contained a variety of methods, of which the Revised QUAL2K method (with accrual adjustment) provided the best fit to observations in Malibu Creek. Three individual sites in the main stem were analyzed. To reduce uncertainty, the results were averaged, yielding an estimate that the appropriate numeric nutrient goals to achieve the 150 $mg/m^2$ maximum benthic chlorophyll *a* target are:

- 0.24 mg/L total N and/or 0.0033 mg/L total P for the summer period.
- 0.65 mg/L TN and 0.090 mg/L TP during the winter period (11/16 – 4/16), with lower light availability.

These target concentrations are most appropriately interpreted as seasonal median concentrations as they were based on a steady-state model.

A second line of evidence was provided by the empirical analyses of Dodds et al. (2002, corrected 2006), which predict benthic chlorophyll *a* based on TN and TP concentrations, but did not include shading or temperature as independent variables. The Dodds equations suggested that an appropriate target for achieving the 150 $mg/m^2$ chlorophyll *a* goal would be a TN concentration of 0.585 and a TP concentration of 0.081 mg/L (selected from the continuous curve at a point where the mass-based Redfield ratio of 7.23 is achieved). These values fell between the summer and winter targets developed using the QUAL2Kw approach. The QUAL2K-based approach assumes that algal growth was controlled by the most limiting nutrient. Therefore, achieving *either* the TN goal *or* the TP goal, above, should be sufficient to attain the algal density target.

The NNE framework made clear that appropriate nutrient targets cannot be less than natural background. The discussion of natural reference conditions in Section 7.6.4 suggested that the natural background concentration for total N in the watershed is below 0.67 mg/L outside the Monterey/Modelo Formation and approximately 1.3 mg/L within the Monterey/Modelo Formation, both greater than the NNE target. Section 7.6.4 also presented a natural background concentration of 0.14 mg/L total P outside the Monterey/Modelo Formation and 0.6 mg/L within the Monterey/Modelo Formation, both well in excess of the target yielded by the NNE analysis.

Although the NNE study specific to Malibu Creek is not yet final, the NNE analyses provided valuable background information regarding lower nutrient targets in Malibu Creek. It is critical that this TMDL included the most recent information and analyses available. The information on natural background concentrations suggested that attaining the NNE target of 150 $mg/m^2$ chlorophyll *a* was likely not feasible in this watershed. As such USEPA proposed to establish targets based on the reference data estimated using the reference approach. USEPA believes that the numeric targets provided in this TMDL are appropriate for Malibu Creek and the main tributaries.

In summary, the detailed NNE analysis for Malibu Creek Watershed, and the detailed data analyses of the reference conditions and local characteristics in Malibu Creek Watershed (Sections 7 and 8) strongly suggested that the nutrient load or concentrations in the streams must be reduced if the benthic community is to be protected.

### 10.3.3 TMDL Loading Capacity and Allocations for Nutrients in the Watershed

The 2003 Nutrient TMDL for Malibu Creek Watershed (USEPA, 2003) established loading capacities for nutrients and summer and winter allocations to protect for aesthetic and recreational uses. Sedimentation and impacts to the benthic macroinvertebrate community were additional listed impairments for Malibu Creek Watershed that were not addressed in the 2003 Nutrient TMDL. This required additional assessment and a TMDL to examine the applicable stressors and water quality standards that would protect for sedimentation and benthic macroinvertebrate community; these listings are associated with different beneficial uses.

USEPA evaluated all available data, including the additional background data collected since 2003, and concluded the loading capacity for nutrients, and thus the allocations, need to be reduced in order to support the beneficial uses and address impairments of the benthic macroinvertebrate community (see Linkage Analysis, Section 9.3.4). Our assessment of the data to date and the large body of evidence showed lower in-stream targets are needed to support a healthy benthic community. USEPA also considered the State's evidence presented in 2005 to the public on the need for re-evaluation of the 2003 nutrient limits in Malibu Creek Watershed (Los Angeles Board, 2005c). In this updated and comprehensive TMDL assessment, we identify complex interactions and multiple stressors.

Since the listed benthic macroinvertebrate bioassessment impairment considers impacts to the benthic macroinvertebrate community, USEPA conducted a comprehensive assessment and evaluated all variables potentially impacting the benthic macroinvertebrate species and the associated benthic community condition. USEPA's extensive assessment of the stressors and causes of impairments to the benthic community finds both sedimentation and nutrients as ongoing critical contributors to benthic community impairment. To clarify, the 2003 Nutrient TMDL for Malibu Creek Watershed specifically addressed nutrient compounds that "exceed the water quality objectives (WQOs) for ***nuisance*** effects such as algae, odors, and scum (RWQCB, 1996)" (USEPA 2003). Specifically, the 2003 Nutrient TMDL was addressing depressed dissolved oxygen and excess nutrient loads that resulted in "nuisance" impacts that addressed primarily recreational use, including the negative visual and odorous presence of scum and algae.

This TMDL is supporting beneficial uses linked to the benthic community impacts, which include "preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates". Such impacts would result in serious disruption to the complex benthic community food web, nutrient cycling, and impaired Creek and Lagoon condition.

Growing season nitrogen targets established by the 2003 Nutrient TMDL for the Malibu Creek main stem have generally been achieved, while phosphorus targets have not, and were apparently constrained by natural geology. While some nutrient targets established in the 2003 Nutrient TMDL have been met in some instances in Malibu Creek main stem, Busse et al.'s (2003) study, analyses of available data on the algae and macroalgal coverage in the streams and main stem since the 2003 Nutrient TMDL, and the CA NNE analysis all suggested the nutrient assimilative capacity may have been overestimated, particularly to protect aquatic life habitat. Due to the presence of geologic sources of phosphorus, nitrogen appears to be the limiting factor on algal growth and eutrophication in Malibu Creek and its tributaries. Further, a negative correlation was demonstrated between inorganic N concentrations and bioscores (see Figure 8-16 through Figure 8-18). However, the data show that the reduction in the summer inorganic N concentrations achieved to date did not stimulate a prolonged positive benthic community response and therefore, additional nutrient reductions are evidently needed. Furthermore, the inclusion of the 2003 Nutrient TMDL allocations (through the implementation of the allocations) did not result in consistently reduced nutrient levels; benthic community response have not improved in Malibu Creek main stem or the tributaries since 2003. Nutrient enrichment impacts have not only continued, but in some cases (e.g., percent macroalgal cover) appear to have increased in Malibu Creek (see Section 8). Finally, our evaluation of the benthic community condition in the main stem and at the major tributaries showed severe impact with very poor scores compared to comparator/reference sites, even when the unique geological conditions of the Monterey/Modelo Formation was factored into our analysis.

The weight of evidence showed that nutrient loads need to be further reduced, as overall water quality and benthic community condition has not improved since 2003, although we recognize that additional data collection and analysis could support a more precise evaluation of loading capacity and needed reductions in the future.

The importance of adaptive review and management is acknowledged by all interested parties. Consequently, an adaptive management approach to support nutrient reductions is warranted, and, due to the complexity of the ecological relationship between benthic macroinvertebrate community, algae, and nutrient cycling, we promote adaptive management in this TMDL and during the development of the implementation actions. (The TMDL implementation plan will be developed by the LARWQCB.) First, because biological interactions and nutrient cycling are dynamic, future examination is appropriate to adjust the response to implemented nutrient loading controls. Second, USEPA recognizes that further monitoring and examination of the response to adjusted assimilative capacity in the waterbody may also be appropriate. Finally, the LARWQCB has verbally informed USEPA of its intention to incorporate opportunities to review and add to the existing data record, as necessary, to adaptively manage the impact of nutrient loading in Malibu Creek Watershed. The LARWQCB plans to develop a detailed implementation plan describing the time schedule to adopt regulatory programs (i.e., NPDES permits, waste discharge requirements, etc.) and the-ground best management practices to ensure final wasteload and load allocations will be achieved.

In consideration of these factors, USEPA has determined that this TMDL will incorporate multiple variables and a stepwise reduction approach to set TMDLs and associated allocations. This approach involves setting both in-stream loading capacities, discharger specific wasteload allocations (to be measured at point of discharge), and load allocations.

USEPA recommends that the implementation of these concentration-based in-stream loading capacities, load allocations for non-point sources, and discharger specific wasteload allocations for both interim and final allocations be phased over time. For example, attainment of the final allocations may require multiple phases, which may also span multiple permit cycles. Please see Section 11, Recommendations.

#### 10.3.3.1 Loading Capacity

USEPA considered all the relevant factors in our loading capacity determination, including relative contribution and allocations of the multiple sources. For these reasons and the observed worsening of conditions in recent years, this TMDL is providing an in-stream nutrient loading capacity.

USEPA concluded that expressing loading capacity and allocations for nutrients on a concentration basis is an appropriate approach towards addressing benthic community impairment. In the 2003 Nutrient TMDL, mass-based nutrient loads were assigned to the various sources; however, our review of the most recently available data showed continued in-stream degradation (BMI and algae) and, therefore, in this TMDL we have determined that specifying the loading capacity in terms of in-stream concentration will be more effective in addressing the stressors causing the impact to the benthic community. By setting in-stream targets, we intend to provide a more direct evaluation of in-stream response due to reduced nutrient (and sediment) loads in the Creek and tributaries.. In this TMDL, TN and TP concentration targets (Table 10-3) are set as the concentration-based allowable loading capacities for Malibu Creek main stem and the major tributaries feeding into the main stem; these concentrations are based on average natural background in-stream levels observed in the watershed (see Section 7.6.4). The data show that three tributaries feeding into the main stem were as impaired, if not more impaired, than the main stem. It would be difficult to separate out the impact of the impaired tributaries from the main stem. As such, the concentration-based in-stream loading capacities also apply to those tributaries directly feeding the main stem: Cold Creek, Stokes Creek, and Las Virgenes Creek.

The in-stream loading capacities were based on the reference data for nutrients and macroinvertebrate communities at the sampling sites in un-impacted or reference regions of the Malibu watershed, which showed very low nutrient levels and "good" benthic macroinvertebrate index scores.

USEPA is setting the allowable in-stream nutrient loading capacities as shown in Table 10-3. In determining the nutrient in-stream loading capacities for this TMDL, USEPA weighed the factors listed above and determined the appropriate targets are 0.65 mg/L TN for summer, and 1.0 mg/L TN for winter; the latter is more stringent than the winter loading capacity established by the existing 2003 Nutrient TMDL. For TP, the original target of 0.1 mg/L is maintained as the summer loading capacity for this TMDL; the target of 0.2 mg/L is set as the winter loading capacity. (Note: The 2003 Nutrient TMDL did not set a TP TMDL for the winter period). The TN in-stream loading capacities are to be measured as seasonal summer and winter averages since TN discharges vary substantially within seasons, and short term pulses of high nutrient loading have not shown to be specifically responsible for short term benthic algal growth increases or benthic community index decreases. This TMDL focuses on reducing loads on a seasonal basis. Evidence suggests that phosphorus is consistently loading into the Creek system throughout the year, irrespective of season.

It is necessary to consider the nutrient assimilative capacity in this watershed, and this must be linked to the algal coverage criterion. If the nutrient allocations are met but the algal coverage targets are not met, the TMDL should be reviewed and considered for possible revisions, consistent with the adaptive management approach recommended above. Furthermore, we considered the natural nutrient assimilative capacity when setting the discharger specific wasteload allocations.

**Table 10-3. Allowable In-stream Concentration-Based Loading Capacity and Response Indicator Targets for TN and TP in Malibu Creek, Main Tributaries**

| Time Period | TN* (mg/L) (seasonal average) | TP (mg/L) (seasonal average) |
|---|---|---|
| Summer (April 15-November 15) | 0.65 | 0.1 |
| Winter (November 16-April14) | 1.0 | 0.2 |

* TN = total nitrogen concentration includes the sum of the organic and inorganic species.

USEPA is setting the limits at the upper end of the observed reference data due to remaining uncertainties over the precise relationship between concentrations of inorganic and organic species of nitrogen and phosphorus in the Malibu Creek Watershed. We set a loading capacity for TP at 0.2 mg/L in the winter season based on reference data for those monitoring sites within and outside of the Monterey/Modelo Formation and the expectation that influence from wash off from the developed and undeveloped lands during wet events will occur.

**Biological Threshold Action Levels**

In this TMDL, USEPA is including biological threshold action levels to address the impaired biological condition. This TMDL appropriately requires pollutant load reductions and ambient monitoring to effectively determine if the impairment conditions are corrected. The biological thresholds include the benthic algal coverage target and the 5-10% probability based threshold for the CSCI bioscores. Excursions of these threshold actions levels will trigger in-stream monitoring and additional activities to reduce nutrient pollutant loads to the Watershed. These biological threshold action levels are not WLAs, rather they serve as action levels to inform the monitoring program requirements, assist with the assessment of performance towards meeting the TMDLs and water quality objectives, and ensure protection of beneficial uses.

- Benthic Algal Coverage: ≤30% filamentous algae and ≤ 60% bottom algae
- CSCI Biological Threshold: $5^{th}$-$10^{th}$ percentile probability based threshold based on the model reference distribution

### 10.3.3.2 TMDLs and Allocations for Nutrients

This section explains the development of allocations for nutrients in the Malibu Creek main stem and tributaries draining directly into the main stem. USEPA regulations require that a TMDL include waste load allocations (WLAs), which identify the portion of the loading capacity allocated to existing and future point sources (40 CFR §130.2(h)) and load allocations (LAs), which identify the portion of the loading capacity allocated to nonpoint sources (40 CFR §130.2 (g)).

In the Malibu Creek Watershed, the observed impaired biological condition and water quality impacts are due to watershed-wide sedimentation and loading of nutrients. Therefore, allocations are designed to reduce loads watershed-wide from all sources. The feasibility of implementation and the relative source contribution of each source were considered when assigning allocations and any associated required load reductions.

The allowable loading capacities for Malibu Creek were determined by calculating the product of the average seasonal flow in the Creek and the numeric target for nitrogen and phosphorus. This generates the total maximum allowable load for Malibu Creek main stem. The existing mass load for the watershed was determined by multiplying the long-term flow by the recent average seasonal concentration at LAC MES (data 2005 and later). The relative existing mass load from each source in Malibu Creek Watershed was then calculated by applying the relative load from the 2003 Nutrient TMDL (because the sources and LU/LC has not changed significantly since the 2003 HSPF modeling effort). The allowable in-stream concentration-based loading capacities for TN and TP apply throughout the Malibu Creek main stem and the tributaries that flow directly into Malibu Creek. The TN and TP loading capacities are to be measured on a seasonal average basis. Because nutrients have been identified as one of the major contributing factors in the biotic impairment of Malibu Creek and Lagoon, assigning allowable in-stream concentration-based loading capacities will directly address the nutrient stressors that are impacting the benthic community. For future assessment, mass-based allowable loading capacities can be calculated by taking the product of the in-stream concentration based numeric targets and the average flow conditions observed in Malibu Creek main stem.

It is necessary to specify WLAs for individual NPDES discharges. In our consideration of the appropriate WLAs, we considered assimilative capacity of each discharge source into the stream. As discussed above, USEPA is setting final wasteload allocations (WLAs) applicable to the Tapia WRF as well as the three municipal stormwater permittees (MS4s) who discharge to the watershed. We note that the MS4 WLAs are applicable only to municipal stormwater discharges under the management of the permittees.

#### 10.3.3.2.1 Wasteload Allocations

### Tapia WRF Wasteload Allocation

For TN, USEPA is setting seasonal discharge-specific WLAs applicable to Tapia's discharge equal to 1.0 mg/L for the summer period and 4.0 mg/L for the winter period, to be averaged seasonally. USEPA is setting TP discharge specific WLAs for Tapia equal to 0.1 mg/L during summer, 0.2 mg/L during winter dry, and current performance during winter wet. See Table 10-4 at the end of this section.

#### Summer Season WLAs

In the summer period, Tapia is prohibited from discharging into Malibu Creek between April 15 and November 15, except for storm-event emergencies and those singular events necessary to maintain a certain flow level, as required by USFWS, to protect the steelhead population. Between 2005 and 2012, summer period discharge from Tapia occurred in five months (Sept 2007; Sept 2008; July 2009; Sept 2009 and Oct 2009); this represents less than 6% of the time that flow was discharged from Tapia during the summer period, with the remainder mostly due to summer storm-event emergencies. Consequently, Tapia contributes minimum nutrient loading, if any, during the summer period (except for operational emergencies) and is expected to achieve the summer discharge specific WLAs while not contributing to exceedances of the allowable in-stream TN loading capacity.

We are setting a summer season concentration-based WLA (1.0 mg/L) higher than the estimated in-stream loading capacity (0.65 mg/L) because the State's current permit prohibits discharges from Tapia to Malibu Creek except in rare, exceptional circumstances (e.g., to provide for instream flow requirements to address Endangered Species Act requirements). We strongly recommend retention of this summer season conditional prohibition in the NPDES permit for Tapia. As Tapia summer discharge are rare (i.e., less than twice per dry season on average for short periods), the summer dry season discharge is unlikely to constitute a significant proportion of the total nutrient loading to Malibu Creek during the summer season in comparison with other loading sources.

During the summer season, the reduction of the nutrient loads can be achieved in the following way:

1. Meet a concentration-based discharge specific limit, calculated as an average seasonal load:
   a. TN of 1.0 mg/L for summer season
   b. TP of 0.1 mg/L during summer season
2. A load reduction is not required during the summer season due to the discharge prohibition. Exceptions to this prohibition are during the following conditions:
   a. operational emergencies
   b. certain rain events when all other disposal options are exhausted
   c. creek flow augmentation for the steelhead trout (cannot cause the sand berm to open, max flow of 2.5 cfs at the County gauging station)

#### Winter Season WLAs

In the winter period, Tapia discharges treated effluent into the Malibu Creek main stem between November 16 and April 14. Based on the relative contribution of Tapia's load on an annual basis (i.e., none to minimal discharge in the summer period; significant discharge in the five month winter discharge period) compared to the contribution of other sources in the watershed) and contribution of other sources in the watershed, USEPA set Tapia's discharge specific WLA at 4 mg/L TN during the winter season. Tapia's discharge should be able to discharge higher concentrations of TN (4 mg/L) without causing an exceedance of the required allowable in-stream concentration of 1.0 mg/L TN for the winter season. This is based on the observation of improvement in plant performance in the last permit cycle, the relative contribution of Tapia's loading in the entire watershed, and the feasibility of implementation based on current technology (USEPA, 2008). If any improvements or additional evidence informs differently, this WLA may be modified by the State. USEPA is setting TP discharge specific WLAs for Tapia equal to 0.1 mg/L during summer season and 0.2 mg/L during winter period; these are equivalent to the in-stream loading capacity concentrations. In the winter season, although Tapia's relative load contribution is 35% of the estimated total nitrogen load coming down the main stem during winter season, greater wet weather variability (e.g., wet weather flows) and in-stream assimilative capacity will dissipate some of Tapia's discharge flows. It should be possible for the in-stream loading capacity to be achieved below Tapia's discharge point even if Tapia's occasional discharges are up to 4 mg/L TN in the winter season. Furthermore, Tapia has implemented advance nutrient removal technology which should be capable of achieving the discharge specific WLA. As discussed above, we recommend the State continue to review data for the discharge specific WLAs and in-stream nutrient TMDLs and response indicator target levels to evaluate the effectiveness of these allocations over time.

During the winter period, the reduction of the nutrient loads can be achieved in the following way:

Meet a concentration-based discharge specific limit, calculated as an average seasonal load: TN of 4.0 mg/L for winter period; and TP of 0.2 mg/L during winter period. In evaluating the appropriate compliance limits, it may be helpful to determine both concentration and mass-based load reductions. As an example, the concentration-based discharge specific WLAs could be translated into a mass-based discharge specific WLA in the winter season to be: an average 35% of the TN (kg/mo) from the total watershed existing load; and an average of 62% of TP (kg/mo) from the total watershed existing load; this total watershed load would be measured at MC-1 or an appropriate downstream site representative of the accumulated watershed nutrient load.

### Municipal Stormwater Discharge Wasteload Allocations

#### *LA County MS4 and Caltrans*

Sources from developed areas runoff and dry weather urban runoff are defined as the sources for the municipal storm water.

##### Summer Season WLAs

During the summer season, the reduction of the nutrient loads can be achieved in the following way: meet a concentration-based end of pipe limit, calculated as an average seasonal load of TN of 1.0 mg/L for summer season and TP of 0.1 mg/L during summer season

In evaluating the appropriate compliance limits, it may be helpful to determine both concentration and mass-based load reductions. As an example, the concentration-based discharge specific WLAs could be translated into a mass-based discharge specific WLA in the summer season to be: an average 20% of the TN (kg/mo) from the total watershed existing load; and an average of 16% of TP (kg/mo) from the total watershed existing load; and this total watershed load would be measured at MC-1 or an appropriate downstream site representative of the accumulated watershed nutrient load.

We are setting a concentration-based summer season WLA higher than the allowable instream TMDL because summer season rainfall runoff events are rare in the Malibu Creek Watershed. Dry season discharges from the MS4s are unlikely to constitute a significant proportion of the total nutrient loading to Malibu Creek during the dry season in comparison with other loading sources. To the extent nutrient discharges from the MS4s are occurring during dry periods, those discharges are prohibited under the current permits and should be fully controlled. Therefore we believe it should be possible for the allowable in-stream TMDL to be achieved even if the MS4s discharge up to 4 mg/L in TN during the winter period.

**Winter Season WLAs**

During the winter period, the reduction of the nutrient loads can be achieved in one of the following ways Meet a concentration-based discharge specific limit, calculated as an average seasonal load of TN of 4.0 mg/L for winter period and TP of 0.2 mg/L during winter period.

In evaluating the appropriate compliance limits, it may be helpful to determine both concentration and mass-based load reductions. As an example, the concentration-based discharge specific WLAs could be translated into a mass-based discharge specific WLA in the winter season to be: an average 14% of the TN (kg/mo) from the total watershed existing load; and an average of 8% of TP (kg/mo) from the total watershed existing load; and this total watershed load would be measured at MC-1 or an appropriate downstream site representative of the accumulated watershed nutrient load.

As discussed above, we recommend the State continue to review data for the end of pipe discharge WLAs, in-stream nutrient loading capacities and response indicator target levels to evaluate the effectiveness of these allocations over time.

***Ventura County MS4***

Based on more detailed information of Ventura County's jurisdiction, it appears tributaries within the County's region drains into an impoundment (lake or dam). Because this TMDL only addresses the Malibu Creek main stem and the tributaries directly feeding into the main stem, the tributaries upstream of Malibou Lake are not assigned a WLA. A WLA is not identified for Ventura County MS4 Co-Permittees in this TMDL. The County and Co-Permittees should continue to meet the requirements of their existing permit as applicable (Ventura County MS4 NPDES Permit No. CAS00402, adopted on May 7, 2009, with an expiration date of May 7, 2014). If new information should arise that identifies specific discharges from Ventura County and Co-Permittees, the State has the authority to identify appropriate WLAs. See Section 10.3.3.2.3 below.

#### 10.3.3.2.2 Load Allocations

Load allocations were assigned to non-point sources in the watershed, as described below.

**Overflow from Lakes/Dams**

Water from lakes, impoundments, and dams, in many cases, may flow into Malibu Creek main stem or a primary tributary via a spillway or channel. The nature of lakes or water impoundments allows the holding of water for extended period in one location; this creates suitable conditions for nitrogen fixation. The subsequent movement of this water portion, via spillway or channel, out of the lake or dam becomes a source of nitrogen loading. The water overflow or surplus of water may add to the nutrient loading downstream to Malibu Creek or its main tributaries. For instance, visual observation of excessive algal coverage in Malibou Lake suggest nutrient concentrations may be elevated and accumulating in the suspended flow behind the dam/lake (J. Newman, 2012, personal communication). Consequently, to account for this nutrient load, a concentration-based allocation is applied downstream of the lake or dam, and prior to the confluence of any other mixing of lower watershed sources (i.e., at outlet of the lake or dam). The concentration based limits are provided in the Table 10-3.

### On-Site Waste Disposal Systems

In addition to the allowable in-stream loading capacities, load allocations are provided for nutrients transported to waterbodies as a result of onsite wastewater disposal. Load allocations were calculated by applying the 2003 Nutrient TMDL percent reductions to the existing nitrogen (summer and winter) and phosphorous (summer only) concentrations (calculated from Table 21 in USEPA, 2003). These 2003 Nutrient TMDL target concentrations were then scaled by a factor equal to the ratio between the 2003 and 2012 instream targets to obtain the OWDS discharge concentration targets for this TMDL. Overall, a total nitrogen discharge concentration of 2.49 mg/L applies in the summer and 6.75 mg/L applies in the winter. The total phosphorous discharge concentration of 0.99 mg/L applies year-round. These concentrations assume that the OWDS discharge rates remain consistent with levels used in the 2003 Nutrient TMDL. These concentration-based load allocations apply at the point of discharge of OWDS effluent to the ground.

The load allocations for the OWDS are set at levels that will require large reductions in nutrient loading from septic tanks throughout the watershed (most of the OWDS occur in the lower and middle watershed [Tetra Tech, 2002]). Implementation of the load allocation of OWDS will probably necessitate aggressive actions to identify and repair septic systems whose seepage is most likely to reach surface waters and that do not function properly. The highest priority for OWDS implementation is to ensure that discharges from commercial septic systems do not cause or contribute to nutrient discharges to surface waters, particularly in the Malibu Lagoon area. We expect that actions taken to address septic systems will provide improvements in discharge quality throughout the year.

### Protected Land and Other Non-point Sources

In the winter period, approximately 25% of TN and 6% of TP load is due to undeveloped land runoff; in the summer season, approximately 9% of TN and 11% of TP load is due to undeveloped land runoff. The remaining sources are attributable to non-point sources. These include sources from golf courses, agriculture/livestock, and other. These account for a summed total of 17% TN and 15% of TP load in the winter season; and 31% TN and 28% of TP load in the summer season.

### 10.3.3.2.3 Future Growth/Conditions

Since approximately 20 percent of Malibu Creek Watershed is developed in some manner, it is possible that future growth could lead to additional point and non-point sources. For instance, during the public comment period, stakeholders informed USEPA of the growing presence of vineyards in the watershed. Due to very limited data, our assessment did not quantitatively show vineyards as a substantive source. However, future agriculturally related activities and urban development could lead to new sources. In the event that new sources are identified, the TMDL must be re-evaluated by the State to incorporate these sources into the TMDL.

Furthermore, if any sources currently assigned load allocations are later determined to be point sources requiring NPDES permits, those load allocations are to be treated as wasteload allocations for purposes of determining appropriate water quality-based effluent limitations pursuant to 40 CFR 122.44(d)(1).

**Table 10-4. Discharge-Specific Wasteload Allocations and Load Allocations for TN and TP in Malibu Creek and Main Tributaries[¥]**

| Discharge Specific Allocation | TN (mg/L) | TN mg/L | TP (mg/L) Summer* | TP (mg/L) |
|---|---|---|---|---|

| | Summer* | Winter* | | Winter* |
|---|---|---|---|---|
| Wasteload Allocation (at discharge points)<br>Tapia WWTP (ongoing discharge)<br>Los Angeles County MS4 Permittees<br>Caltrans MS4 Permittee | 1.0 | 4.0 | 0.1 | 0.2 |
| Load Allocation<br>• Agriculture<br>• Tapia WWTP spray field<br>• Overflow from Lakes/Dams<br>• Other nonpoint sources (including parks and forested lands) | 0.65 | 1.0 | 0.1 | 0.1 |
| Load Allocation (discharge)<br>Onsite Waste Disposal Systems | 2.49 | 6.75 | 0.99 | 0.99 |

[¥]Tributaries = Cold Creek, Stokes Creek, Las Virgenes Creek.

*Summer = April 15 to November 15; Winter = November 16 to April 14.

### 10.3.4 Biological Threshold for Malibu Lagoon

During the development of this TMDL, the State implemented an expansive and comprehensive restoration effort for Malibu Lagoon in summer 2012. This restoration effort resulted in removal of anoxic sediment, increasing water circulation and restoration of habitat. These actions are expected to restore critical habitat for Pacific Flyway migratory birds and endangered and threatened wildlife.

Due to this restoration effort, Malibu Lagoon's conditions have dramatically changed and the accumulated pollutant load and habitat spaces have been removed. These actions led USEPA to focus on other new and continued sources of impairment to the Lagoon. These new and existing sources are primarily from Malibu Creek Watershed, where all watershed sources drain directly into the Lagoon. For these reasons, USEPA is maintaining the existing 2003 Nutrient TMDL targets for Malibu Lagoon (see Section 3.2).

Since the watershed sediment and nutrient loads are transported to the Malibu Lagoon, it is critical that appropriate targets and wasteload and load allocations are established to protect benthic community habitat in Malibu Lagoon. This TMDL sets wasteload and load allocations to Malibu Creek main stem, Stokes Creek, Cold Creek and Las Virgenes Creek. Since extensive restoration of Malibu Lagoon started in summer 2012, USEPA expects that the Lagoon has significantly removed the accumulated sediment and nutrient loads in the Lagoon and can thus support the aquatic and wild life species and their habitat. Consequently, USEPA is not setting additional wasteload or load allocations to Malibu Lagoon. Because the primary source of pollutant loads are from upstream watershed sources, the identification of loading capacities and establishment of discharge specific wasteloads and load allocations to Malibu Creek and its main tributaries should sufficiently address future loads to Malibu Lagoon. Because sedimentation and excessive nutrient loading into the Lagoon will continue to directly impact the benthic community condition in Malibu Lagoon in the near term (i.e., until pollutant loads in the watershed are controlled), a monitoring site or compliance point just upstream of the estuary inlet should be identified by the State.

Until upstream sources are fully addressed, these habitat restoration improvements are threatened by ongoing sedimentation.

Consequently, appropriate response targets for Malibu Lagoon are critical to ensure that designated beneficial use goals are protected. Consequently, to ensure that the benthic community condition in the Lagoon improves overtime, as restoration actions are fully completed, this TMDL is setting biological threshold action levels (Section 10.3.4 above). Based on the observed species richness both for Malibu Lagoon and for other southern California coastal estuaries, it is reasonable and appropriate to expect greater number of taxa/functional categories (i.e., species richness) as the Lagoon's conditions improve; this improvement would reflect the restored diverse benthic community. Given the best available information to date and the most recent restoration efforts in Malibu Lagoon, we should expect to see increased taxa richness over time.

In addition, a wealth of evidence from other southern California coastal estuaries shows much greater taxa richness compared with Malibu Lagoon. Based on the historical accounts for Malibu Lagoon and the detailed benthic invertebrate community evaluations of other coastal estuaries in southern California, the minimum total number of taxa richness is set at 40 based on annual averages over a 15-year time period. This biological goal should include a diverse benthic community with native species and/or pollution intolerant organisms. The evaluation should be based on a median over a minimum of 4 years to account for significant year-to-year variability in individual measurements.

The biological response numeric targets for Malibu Creek and Lagoon are directly linked to the allocations and should be placed into the applicable regulatory mechanism (i.e., NPDES permit) in order to ensure that the benthic community condition achieves the water quality objectives. This biological threshold is an action level. Excursions of this threshold actions level will trigger Malibu Lagoon monitoring and additional activities to reduce sediment and nutrient pollutant loads to the Lagoon. These biological threshold action levels are not WLAs, but action levels to inform the monitoring program requirements, assist with the assessment of performance towards meeting the TMDLs and water quality objectives, and ensure protection of beneficial uses in Malibu Lagoon.

## 10.4 CRITICAL CONDITIONS AND SEASONALITY

TMDLs must include consideration of critical conditions and seasonal variation to ensure protection of the designated uses of the waterbody at all times. For Malibu Creek and Lagoon there are multiple stressors related to biotic impairment that operate on different time lines. Thus, there is no single critical condition for this TMDL.

For sedimentation, the critical period is the winter and spring storm events that provide the majority of sediment transport through the creek and into the estuary.

Critical conditions for nutrient-impaired streams occur during the warm summer months when water temperatures are elevated and algal growth rates are high. In Malibu Creek this means that nutrient concentrations need to be controlled during the summer growing season. However, concentrations in the other seasons are also of concern because nutrient loading continues to load during the winter season, thus potentially creating critical conditions for excessive algae growth when temperature and light availability is sufficient to trigger algal growth year round. Furthermore, USEPA's analyses of benthic macroinvertebrate community's relationship to nutrient and sediment stressors demonstrate that these pollutant loads throughout the year can drastically harm the nutrient cycle and physical habitat necessary to support a healthy benthic macroinvertebrate community. In contrast, Malibu Lagoon is most sensitive to nutrient loads delivered during winter storms and stored within the estuary.

In sum, the biotic impairments in Malibu Creek and Lagoon do not have a single critical period, whether defined on hydrology or season. Instead, it will be important to control ambient nutrient concentrations under lower flow conditions (throughout the year) and nutrient and sediment loading during winter-spring high flow events.

## 10.5 MARGIN OF SAFETY

All TMDLs are required to include a Margin of Safety (MOS) to account for uncertainty in understanding the relationship between pollutant discharges and water quality impacts. The Margin of Safety may be provided explicitly through an unallocated reserve or implicitly through use of adequately conservative assumptions in the analysis.

For the Malibu TMDL an explicit MOS of 15 percent of loading capacity is assigned to the sedimentation target.

For this TMDL an implicit MOS is also used. The TMDL targets are believed to be conservative for several reasons. Most notably, the stressor identification process suggests that impaired benthic biota in both the stream and the estuary result from the combined effects of multiple stressors rather than from any single stressor. This TMDL sets targets for the critical pollutant stressors sources (nutrients, sedimentation) independently. Thus, achieving both the sedimentation and nutrient goals is likely to provide an implicit MOS.

In addition, we made conservative assumptions in translating the linkage between benthic macroinvertebrate and benthic community condition to the nutrient and sediment targets. Lastly, this TMDL established lowered concentration based allocations for TN and TP based on the more the conservative option.

For Malibu Lagoon, conservative assumptions were included when we set biological threshold action levels based on the expected benthic species richness from other southern California coastal lagoons.

## 10.6 DAILY LOAD EXPRESSIONS

As a result of the decision, *Friends of the Earth, Inc. v. EPA, et al*., No. 05-5015 (D.C. Cir. 2006), USEPA issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits* in November 2006 that recommended that all TMDLs and associated load allocations (LAs) and wasteload allocations (WLAs) include a daily time increment in conjunction with other temporal expressions (e.g., annual, seasonal) that may be necessary to implement the relevant water quality standards.

USEPA (2007) issued a draft guidance document entitled *Options for Expressing Daily Loads in TMDLs*. Following Option 2 in that guidance, USEPA is proposing a variable daily load expression. This option allows for variable expression that may be used when the applicable daily load value is determined as a function of a particular characteristic that affects loading or waterbody response, such as flow or season. In the Malibu Creek TMDL, the daily load for nutrients is first expressed as a daily average that is equal to the flow at the F-130 gage multiplied by the seasonal concentration target. The daily expression of the maximum load is defined, again consistent with USEPA (2007) as the 95$^{th}$ percentile flow (for the appropriate season ) at the F-130 gage times the seasonal concentration target.

For sedimentation, the TMDL is expressed first as an annual load (after considering the 15% MOS). This was converted into a daily average load by calculating the annual flow-weighted concentration (the annual load divided by the total annual flow) and then multiplying by the daily flow. The daily expression of the maximum load is then calculated as the 95$^{th}$ percentile flow (for the appropriate season) at the F-130 gage times the seasonal concentration target, converted to tons per day.

The resulting daily maximum load expressions are summarized in Table 10-5.

**Table 10-5. Daily Maximum Load Expressions at the F-130 Gage, Malibu Creek**

| 95th Percentile Flow (cfs) | Total N | | Total P | | Sedimentation | |
|---|---|---|---|---|---|---|
| | Concentration (mg/L) | Load (lbs/day) | Concentration (mg/L) | Load (lbs/day) | Concentration (mg/L) | Load (tons/day) |
| Summer (April 15 – November 15) | | | | | | |
| 32.21 | 0.65 | 113 | 0.1 | 17 | 172.1 | 14.9 |
| Winter (November 16 – April 14) | | | | | | |
| 215.43 | 1.0 | 1,162 | 0.2 | 232 | 172.1 | 100 |

(This page left intentionally blank).

# 11. Recommendations

Several programs are currently underway that will contribute towards implementation of these TMDLs. Some of these programs are described below along with suggested monitoring.

## 11.1 Recommendations for Implementation of Nutrient WLAs

We recommend the State implement the recommended WLAs in phases over time, using an adaptive management approach, in order to provide time to develop control strategies sufficient to implement the WLAs and to evaluate the efficacy of the interim allocations and other stressor control strategies (see Table 11-1). If the LARWQCB determines a longer phase-in period is warranted in the context of the nutrient TMDL revisions or review and revision of this TMDL, it may be appropriate to provide longer phase-in periods through NPDES permits and associated time schedule provisions.

**Table 11-1. Implementation Schedule Recommendations for Discharge-Specific Wasteload Allocations**

| TMDL Implementation Phases | TN Summer Season | TN Winter Season | TP Year Round |
|---|---|---|---|
| Current Nutrient WLAs | 1 mg/L | 8 mg/L | 0 lbs/day summer, no WLA set for winter |
| Phase 1 | 1 mg/L | 6/mg/L | 0.4 mg/L |
| Phase 2 | 1 mg/L | 4 mg/L | 0.1 mg/L *OR* 0.1 mg/L summer/0.2 mg/L winter |

We recommend that at the end of each phase, monitoring data of in-stream water TMDLs should be evaluated, and if the in-stream TMDLs are achieved, then the TMDL requirements are met. If the in-stream TMDLs are not achieved, then implementation should progress to the next phase of the TMDL. We expect that each phase could take up to between 1-2 permit cycles.

The allocations incorporate interim as well as final allocations to be phased in over time. While USEPA recommends incorporation of these interim and final allocations in NPDES permits based on the recommended schedules, we acknowledge that the State has the discretion to establish NPDES permit requirements that are different from those incorporated in this TMDL document as long as the State's permit implementation approaches are consistent with the assumptions and requirements of the approved TMDLs (40 CFR 122.44(d)(1)(vii)(B)). USEPA recommends evaluating attainment of both in-stream TMDLs and discharger specific allocations in concert with data for in-stream response indicators to evaluate the effectiveness of interim reductions and the need for further reductions. USEPA recommends conducting these evaluations on an annual basis, which would include seasonal average assessments of the allocations. If it is determined, based on weight of evidence evaluation, that implementation of interim allocations and associated implementation actions targeting other stressors of concern are sufficient to result in attainment of benthic community response indicators, the State should consider revising the TMDL allocations accordingly. By reviewing nutrient and response indicator data throughout the watershed, it will be possible for the State to regularly evaluate the effectiveness of different steps of nutrient reductions along with actions to reduce sediment loading and address other stressors of concern for benthic community health.

### 11.1.1 Recommendations for Monitoring

Permit monitoring and reporting requirements should include monitoring of each pollutant source, either separately or by joining a regional monitoring program. This is applicable to each identified point source. The monitoring program should consider the appropriate sites downstream to capture the representative watershed load and in-stream biological condition. This monitoring could be implemented via a coordinated monitoring effort between all entities (point source and non-point sources, where applicable) in the watershed. The monitoring requirements should identify the appropriate watershed or subwatershed representative site locations and include multiple sites downstream of representative source loads.

## 11.2 Recommendations for Sediment Load Allocations

With regards to the load allocations identified for the sediment loads, USEPA recognizes that sediment transport capacity from areas upstream of dams or lakes are distinct than the downstream areas. Although sediment transport capacity via a dam or lake takes place, there are uncertainties related to frequency of events (i.e., less), loads, and annual variability, particularly because the transport capacity is linked to the wet weather events. For these reasons, USEPA recommends sampling at a compliance point downstream of the lake or dam, to be determined by the LARWQCB, and that monitoring of the annual loads to be averaged over a three year period.

## 11.3 Malibu Lagoon Restoration Plan

Historically utilized as a dumping site, the Malibu Lagoon suffers from much malaise. Poor tidal flow and circulation in the west has decrease dissolved oxygen levels to near zero, threatening fish and wildlife, while harmful bacteria has flourished. Uncontrolled run-off water into the Lagoon and proliferation of foreign species threaten the livelihood of the native environment and the entire ecosystem.

To improve the Lagoon's diseased state, the Malibu Lagoon Restoration plan was accepted and approved, despite much heated debate. The approved plan will improve the function of the Lagoon by re-contouring the Western 12-acre section to lower bank slope grades and alter channels for improved hydrologic function and habitat diversity. The new public access trail will provide public educational information about the Lagoon and its improvements as well as the long-term monitoring plan.

In June 2012, Phase 1 of the 4-month project got underway (it is scheduled for completion by January 31, 2013). Since then, crews have removed more than 3,000 cubic yards of trash and debris from the Lagoon (Caskey, 2012). The wetlands and other construction pieces were completed by October 31, with current efforts dedicated to vegetation planting and aesthetic improvements.

As a result, USEPA believes that this restoration effort of the Lagoon should significantly improve the Lagoon conditions for the benthic community by providing improved habitat conditions. The Lagoon zones with anoxic conditions or limited tidal flushing are being corrected, in addition to removing debris and excess sediment that provided physical barrier for benthic community development.

The critical piece is to ensure that the sediment and nutrient loading from upstream sources are also reduced and addressed to ensure that both the in-Lagoon source and the Watershed sources are removed. Only by addressing both loads will the natural benthic community be able to flourish. Consequently, USEPA strongly recommends that the LARWQCB work with local stakeholders to identify effective and reasonable best management practices to control the watershed source.

## 11.4 California Statewide Biological Objectives

The SWRCB is currently developing biological objectives for freshwater streams and rivers in California. The SWRCB states that "biological objectives will help improve water quality in our streams and rivers by providing the narrative or numeric benchmarks that describe conditions necessary to protect aquatic life beneficial uses." The SWRCB utilized a Science Team of experts from the Department of Fish and Wildlife, SCCWRP, and the USGS to conduct the technical work necessary to support development of the State's biological objectives policy. This effort culminated in the development of the CSCI, which includes the O/E and pMMI scoring methods. The State Board is proposing the use of the CSCI tool as a primary tool to assess biological condition in the state. This provides a consistent scoring tool for all waterbodies in California. Currently, the tool and the relevant source documentation is available for review at http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml. SWRCB is still in the process of developing final numeric biological objectives. USEPA understands that the final numeric biological objectives will likely include the setting of probability based thresholds for the CSCI scores (K. Larsen and K. Schiff, personal communication). This TMDL is setting biological threshold action levels at between $5^{th}$-$10^{th}$ percentile. When the final SWRCB numeric biological objective policy is complete and adopted, USEPA recommends that the appropriate biological threshold be applied in Malibu Creek Watershed.

USEPA recommends that data used to ascertain compliance be conducted in accordance with bioassessment methods currently under development or established as guidance by USEPA or the SWRCB.

USEPA supports more extensive development of the CADDIS causal assessment with stakeholder participation in the future when applicable. This could be included in the Implementation Plan when detailed implementation actions, studies and best management practices are considered; this process will be successful only if state agencies and stakeholders can work collaboratively to build an improved assessment.

## 11.5 Onsite Wastewater Treatment Systems State Policy

Assembly Bill (AB) 885 required the SWRCB to develop septic system regulations that treat and dispose wastewater below ground. On June 19, 2012, the SWRCB adopted Resolution No. 2012-0032 (Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems [OWTS]). This policy will become effective upon adoption by the Office of Administrative Law and will require regulation and management of OWTS, based on a tiered approach (SWRCB, 2012).

The State's Implementation Plan should include monitoring and reporting of the OWTS activity. These may include conducting a sanitary survey to count, identify, map, and assess the condition of septic systems within 600 feet of Malibu Creek and its tributaries; identifying clusters of septic systems that do not utilize advanced treatment to monitor and better understand the septic sources. In addition, implementation measures may include advanced treatment for new and replaced systems within 600 feet of Malibu Creek and its tributaries. Other supplemental treatment requirements of the Septic Policy should be included in the Implementation Plan associated with this TMDL. Finally, the Implementation Plan should include a schedule that requires compliance with the load allocations as soon as practicable, given the watershed-specific circumstances.)

## 11.6 NNE State Policy

USEPA acknowledges that SWRCB is developing a statewide policy for NNE. When the State policy on NNE is complete and adopted, USEPA recommends that the appropriate nutrient endpoint measures be applied in Malibu Creek Watershed.

## 11.7 Rindge Dam Removal Project

During the public comment period, USEPA was informed that the Malibu Creek Ecosystem Restoration Project (Rindge Dam Removal Project) is scheduled to complete its feasibility assessment in the next year. If funding becomes available, the project should be implemented within the next ten years. This restoration project would remove Rindge Dam and up to 11 additional upstream barriers; these removal actions would allow protection and expansion of steelhead migration activity. Currently, the steelhead is found in only one of three streams within Santa Monica Mountains. Removal of the dam and the sediment impounded behind it will take many years. During this removal and post-removal period, sediment transport could increase temporarily during construction despite use of BMPs. Because this project would result in significant net benefits to the watershed and remove an identified impairment to fish migration, USEPA recommends the LARWQCB to consider the temporary impacts associated with the removal of Rindge Dam during the development of the Implementation Plan for this TMDL; the temporary impacts should be factored into the long-term implementation plan to restore the watershed and support the protection of the designated beneficial uses. If appropriate, the State may need to reconsider the TMDL and consider any potential effects on the benthic macroinvertebrate community following the removal of the Dam.

## 11.8 Recommendations for Monterey/Modelo Formation Areas

Based on elevated phosphorus levels observed from the existing data set and those areas draining only the Monterey/Modelo Formation lead, USEPA is recommending additional monitoring of the specific sites in the Monterey/Modelo Formation. The following data should be investigated: 1) additional data and information provided to illustrate seasonal TP concentrations correlated to limited algal coverage data, which must be below the benthic algal coverage numeric criteria; and (2) delineation of and verification that sub areas in the Watershed that can be appropriately distinguished between those areas draining the Monterey/Modelo Formation and those sub areas draining from Non- Monterey/Modelo Formation.

# 12. References


2NDNATURE. 2008. Malibu Lagoon Restoration Monitoring Plan (MLRMP) Baseline Conditions Report. Report Submitted to Resource Conservation District of the Santa Monica Mountains. March 31, 2008.

2NDNATURE. 2010. Malibu Lagoon restoration monitoring plan (MLRMP) baseline conditions report. Report Submitted to Resource Conservation District of the Santa Monica Mountains. 70 pp.

Abramson, M., C. Padick, E.T. Schueman, G.O. Taylor, J. Olson, J. Safford, K. Starman, and J. Woodward. 1998. The Malibu Creek Watershed: A Framework for Monitoring, Enhancement and Action. Prepared for Heal the Bay and The California State Coastal Conservancy. The 606 Studio, Graduate Department of Landscape Architecture, California State Polytechnic University, Pomona, CA.

Abramson, M. and M. Grimmer. 2005. Fish Migration Barrier Severity and Steelhead Habitat Quality in the Malibu Creek Watershed. Produced for California State Coastal Conservancy and California Department of Parks and Recreation by Heal the Bay.

Abramson, M. 2009. Tracking the invasion of the New Zealand mudsnail, *Potamopyrgus antipodarum*, in the Santa Monica Mountains. *Urban Coast*, 1: 21-27

Abramson, M., J. Topel, and H. Burdick. 2009. New Zealand Mudsnail Surveys July 2006-April 2009, Santa Monica Mountains. Santa Monica Bay Restoration Commission, Santa Monica Baykeeper, Santa Monica, CA.

Ackerman, D., K.C. Schiff, and S.B. Weisberg. 2005. Evaluating HSPF in an arid, urbanized watershed. *Journal of the American Water Resources Association*, 41: 477-486.

Allan, J. D. 1995. *Stream Ecology*. Chapman and Hall, London.

Ambrose, R.F., I.H. Suffet, and S.S. Que Hee. 1995. Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek. Las Virgenes Municipal Water District, Calabasas, CA.

Ambrose, R.F. and A.R. Orme. 2000. Lower Malibu Creek and Lagoon Resource Enhancement and Management. Report to the California Coastal Conservancy. University of California, Los Angeles.

Ambrose, R.F., S.F. Lee, and S.P. Bergquist. 2003. Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties. Regional Water Quality Control Board, Los Angeles, CA.

Anderson, B.A., J. Hunt, B. Phillips, J. Newman, R. Tjeerdema, C.J. Wilson, G. Kapahi, R.A. Sapudar, M. Stephenson, M. Puckett, R. Fairey, J. Oakden, M. Lyons, and S. Birosik. 1998. Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Los Angeles Region. California State Water Resources Control Board, Division of Water Quality, Bay Protection and Toxic Cleanup Program.

Aquatic Bioassay. 2005. Malibu Creek Watershed Monitoring Program, Bioassessment Monitoring, Spring/Fall 2005. Aquatic Bioassay & Consulting Laboratories, Ventura, CA.

Aquatic Bioassay. 2010. Las Virgenes Municipal Water District, Tapia Water Reclamation Facility. Spring 2009 Bioassessment Monitoring Report (NPDES CA0056014). Submitted to Las Virgenes Municipal Water District by Aquatic Bioassay and Consulting Laboratories, Ventura, CA.

Armitage, P. D. 1995. Faunal community change in response to flow manipulation. Pages 59-78 in D. M. Harper and A. J. D. Ferguson (eds.), The Ecological Basis for River Management. John Wiley and Sons, Chichester.

Badgley, B.D., Thomas, F.I.M., and Harwood, V.J. 2011. Quantifying environmental reservoirs of fecal indicator bacteria associated with sediment and submerged aquatic vegetation. *Environmental Microbiology,* 13(4):932-942.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Bay, S., D. Greenstein, A. Jirik, and A. Zellers. 1996. Toxicity of stormwater from Ballona and Malibu Creeks. *SCCWRP Annual Report*, 1996: 96-104.

Bay, S.M., D. Lapota, J. Anderson, J. Armstrong, T. Mikel, A.W. Jirik, and S. Asato. 2000. Southern California Bight 1998 Regional Monitoring Program: IV, Sediment Toxicity. Southern California Coastal Water Research Project, Westminster, CA.

Bay, S.M., E.Y. Zeng, T.D. Lorenson, K. Tran, and C. Alexander. 2003. Temporal and spatial distributions of contaminants in sediments of Santa Monica Bay, California. *Marine Environmental Research,* 56:255-276.

Bay, S.M., T. Mikel, K. Schiff, S. Mathison, B. Hester, D. Young, and D. Greenstein. 2005. Southern California Bight 2003 Regional Monitoring Program: I. Sediment Toxicity. Southern California Coastal Water Research Project, Westminster, CA.

Bay, S.M., D.J. Greenstein, M. Jacobe, C. Barton, K. Sakamoto, D. Young, K.J. Ritter, and K.C. Schiff. 2011. Southern California Bight 2008 Regional Monitoring Program, I: Sediment Toxicity. Southern California Coastal Water Research Project, Costa Mesa, CA.

Benson, A.J. and R.M. Kipp. 2008. *Potamopyrgus antipodarum*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL . http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1008. Revision Date: 1/22/2008.

Biggs, B.J.F. 1987. A survey of filamentous algal proliferations in New Zealand rivers. *New Zealand Journal of Marine and freshwater Research,* 21:175-191.

Biggs, B.J.F. 1990. Periphyton communities and their environments in New Zealand rivers. *New Zealand Journal of Marine and freshwater Research,* 24:367-386.

Biggs, B.J.F. 2000a. New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams. New Zealand Ministry of Environment. http://www.mfe.govt.nz/publications/water/nz-periphyton-guide-jun00.pdf.

Biggs, B.J.F. 2000b. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. *Journal of the North American Benthological Society*, 19(1): 17-31.

Blackburn, M. and C. Mazzacano. 2012. Using Aquatic Macroinvertebrates as Indicators of Stream Flow Duration. The Xerces Society for Invertebrate Conservation: Portland, OR. 17 pp. Available online at http://www.xerces.org/wp-content/uploads/2009/03/Streamflow_duration_indicators_IDWA_2012_Final_06072012.pdf.

Bowie, G., K. Hancock, J. Maehr, S. Cliffen, C.Chung, C. Creager, S. Liu, L. Richards. 2002. Nutrient and Coliform Modeling for the Malibu Creek Watershed TMDL Studies. Prepared for U.S. EPA Region IX and Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc., Lafayette, CA.

Brandt, S.A. 2000. Classification of geomorphological effects downstream of dams. Catena 40:375-401.

Briscoe, E., K. Kramer, S. Luce, M. Abramson, and K. Schiff. 2002. Pre-dawn Dissolved Oxygen Levels in the Malibu Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board by the Southern California Coastal Water Research Project and Heal the Bay.

Brown, J.S. and S.M. Bay. 2005. Organophosphorus pesticides in the Malibu Creek watershed. *SCCWRP Annual Report,* 2003-04: 94-102.

Busse, L., J. Simpson, S. Cooper, K. Kamer, and E. Stein. 2003. A Survey of Algae and Nutrients in the Malibu Creek Watershed. Technical Report 412. Southern California Coastal Water Research Project, Westminster, CA.

Busse, L.B., J.C. Simpson, and S.D. Cooper. 2006. Relationships among nutrients, algae, and land use in urbanized southern California streams. *Canadian Journal of Fisheries and Aquatic Sciences*, 63(2): 2621-2638.

Byron, E. and T. DuPuis. 2002. Establishing relationships between nutrients and algae "impairment" in streams: The challenge of nutrient TMDLs. *Proceedings of the Water Environment Federation, Watershed 2002:* 1145-1157.

California Geological Survey. 2009. Preliminary Geologic Map of the Los Angeles 30' x 60' Quadrangle. California: A Digital Database. California Geological Survey, Preliminary Geologic Map, version 12/22/09, scale 1:100,000.

Callaway, T., O. Gonzalez, and C.P. Lai. 2009. Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life. Technical Memorandum #4, Final Technical Staff Report, Evidence in Support of an Amendment to the Water Quality Control Plan for the Caskey, Melissa. "Malibu Lagoon project nearing completion." The Malibu Times. November 28, 2012. http://www.malibutimes.com/news/article_f088d428-398f-11e2-a2e1-0019bb2963f4.html

Caraco, D., J. Zielinski, and R. Claytor. 1998. Nutrient Loading From Conventional and Innovative Site Development. Chesapeake Research Consortium, Center for Watershed Protection. Ellicott City, MD.

CDFG (California Department of Fish and Game). 2012. Invasive Species Program: New Zealand mudsnail. Accessed on November 14, 2012. http://www.dfg.ca.gov/invasives/mudsnail/Mudsnail_FAQ.html

CDM. 2008. Malibu Creek Watershed Monitoring Program: Task 12 Report. Prepared for City of Calabasas by Camp Dresser & McKee, Inc., Los Angeles, CA. http://www.cityofcalabasas.com/environmental/pdf/MCWMP/MCWMPReport032408.pdf

Clarke, R.T., J.F. Wright, and M.T. Furse. 2003. RIVPACS models for predicting the expected macroinvertebrate fauna and assessing the ecological quality of rivers. *Ecological Modeling*, 160:219-233.

Caskey, Melissa. "Malibu Lagoon project nearing completion." The Malibu Times. November 28, 2012. http://www.malibutimes.com/news/article_f088d428-398f-11e2-a2e1-0019bb2963f4.html

Coats, R., M. Larsen, A. Heyvaert, J. Thomas, M. Luck, and J. Reuter. 2008. Nutrient and sediment production, watershed characteristics, and land use in the Tahoe Basin, California-Nevada. *Journal of the American Water Resources Association* 44(3):754-770.

Cohen, A. C., D.E. Peterson, and R. F. Maddocks. 2007. Ostracoda. pp. 417-446, In: J. T. Carlton, ed., *The Light & Smith Manual: Intertidal Invertebrates from Central California to Oregon*. Fourth Edition. University of California Press, Berkeley and Los Angeles.

Cuffney, T., R. Brightbill, J. May, and I. Waite. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. *Ecological Applications,* 20(5):1384-1401.

CWP (Center for Watershed Protection). 1999. *The Impacts of Imperviousness*. Center for Watershed Protection, Ellicott City, MD.

Daly, C., M. Halbleib, J.I. Smith, W.P. Gibson, M.K. Doggett, G.H. Taylor, J. Curtis, and P.A. Pasteris. 2008. Physiographically-sensitive mapping of temperature and precipitation across the conterminous United States. *International Journal of Climatology*, DOI: 10.1002/joc.1688.

deBruyn, A.M.H. and P.H. Chapman. 2007. Selenium toxicity to invertebrates: Will proposed thresholds for toxicity to fish and birds also protect their prey? *Environmental Science and Technology*, 2007, 41 (5): 1766–1770.

Dodds, W.K., V.H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: A case study of the Clark Fork River. *Water Research*, 31(7): 1738-1750.

Dodds, W.K. and E.B. Welch. 2000. Establishing nutrient criteria in streams. *Journal of the North American Benthological Society*, 19(1): 186-196.

Dodds, W.K., V.H. Smith, and K. Lohman. 2002. Nitrogen and phosphorus relationships to benthic algal biomass in temperate streams. *Canadian Journal of Fisheries and Aquatic Sciences,* 59: 865-874.

Dodds, W.K., V.H. Smith, and K. Lohman. 2006. Erratum: Nitrogen and phosphorus relationships to benthic algal biomass in temperate streams. *Canadian Journal of Fisheries and Aquatic Sciences*, 63: 2290-1191.

Dorgelo, J. 1987. Density fluctuations in populations (1982-1986) and biological observations of *Potamopyrgus jenkinsi* in two trophically differing lakes. *Hydrobiological Bulletin*, 21: 95-110.

Dudgeon, D. 1994. The functional significance of selection of particles by aquatic animals during building behaviour. Pages 289-312 in R. S. Wotton (ed.), *The Biology of Particles in Aquatic Systems*, 2nd ed. Lewis Publishers, London.

Ecological Studies of the Sacramento-San Joaquin Estuary; Part 1,: Zooplankton, Zoobenthos, and Fishes of San Pablo and Suisun Bays, Zooplankton and Zoobenthos of the Delta. California, Dept. of Fish and Game Delta Fish and Wildlife Protection Study. 1966. 133 p. California Sacramento : State of California, The Resources Agency, Dept. of Fish and Game.

Espinosa-Perez, M.C. and Hendrickx, M.E. 2002. Distribution and ecology of isopods (Crustacea: Peracarida: Isopoda) of the Pacific Coast of Mexico. *Modern Approaches to the Study of Crustacea*, pp. 95-195.

Farnsworth, K.L. and J.A. Warrick. 2007. Sources, Dispersal, and Fate of Fine Sediment Supplied to Coastal California. Scientific Investigations Report 2007-5754. U.S. Geological Survey, Reston, VA.

Feminella, J. W., and C. P. Hawkins. 1995. Interactions between stream herbivores and periphyton: a quantitative analysis of past experiments. *Journal of the North American Benthological Society,* 14:465–509.

Ferren, W.R., Jr.; P.L. Fiedler, R.A. Leidy, K.D. Lafferty, and L.A.K. Mertes,. 1996. Wetlands of California, part II: A method for their classification and description. *Madroño*, 43: 125-182.

Foltz, S. 2009. Storm-water ponds saupport *Corisella incripta*, a new aquatic hemipteran species record for Wisconsin (Corixidae). *Entomological News*, 120(3), 338-340pp.

Gentile, S.M., Gentile, J.H., Walker, J., and Heltshe, J.F. 1982. Chronic effects of cadmium on two species of mysid shrimp: *Mysidopsis bahia* and *Mysidopsis bigelowi*. *Hydrobiologia,* 93(1-2):195-204.

Gilbert, R.M. 2009. A Multi-method Approach for the Characterization of Urban Stream Quality and Algal Dynamics. A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Environmental Health Sciences, University of California, Los Angeles.

Gilmore, S. 2002. *Benthic Macro-Invertebrate Population Difference Between Sand and Cobble Substrates in the Arroyo Seco Watershed.* California State University, Monterey Bay, Earth Systems Science and Policy, The Watershed Institute, Central Coast Watershed Studies: Monterey, CA. 12 pp.

Glare, T.R. and O'Callaghan, M. 1998. *Report for the Ministry of Health: Environmental and Health Impacts of* Bacillus thurniensis israelensis. Biocontrol & Biodiversity, Grasslands Division, AgResearch, Lincoln:New Zealand. 58 pp.

Goepel, C., K. Hoeberling, F. Keto, R. Pardo, J. Palmquist, M. Traverso, and A. Yoon. 2012. Potential Extent of Vineyard Development in the Santa Monica Mountain National Recreation Area. Institute of the Environment & Sustainability, UCLA Environment 180 – Senior Practicum. June 2012.

Greenstein, D.J., S.M. Bay, A.W. Jirik, J.S. Brown, and C. Alexander. 2003. Toxicity assessment of sediment cores from Santa Monica Bay, California. *Marine Environmental Research,* 56(1-2):277-297.

Gresswell, R. E. 1999. Fire and aquatic ecosystems in forested biomes of North America. *Transactions of the American Fisheries Society,* 128: 193-221.

Harrington, J.M. 2003. California Stream Bioassessment Procedures. California Dept. of Fish and Game, Water Pollution Control Laboratory, Rancho Cordova, CA.

Harrison, E. T., R. H. Norris, and S. N. Wilkinson. 2007. The impact of fine sediment accumulation on benthic macroinvertebrates: implications for river management. In: Wilson, A. L., Dehaan, R. L., Watts, R. J., Page, K. J., Bowmer, K. H., and Curtis, A. (Eds.) Proceedings of the 5th Australian Stream Management Conference. Australian rivers: making a difference. Charles Stuart University, Thurgoona, New South Wales.

Heal the Bay. 2011. http://sites.healthebay.org/news/2006/06_08_nzmudsnail/default.asp).

Herbst, D. B. 1986. Comparative studies of the population ecology and life history patterns of an alkaline salt lake insect: *Ephydra (Hydropyrus) hians* Say (Diptera: Ephydridae). Ph.D. dissertation, Oregon State University, Corvallis. 206 pp.

Herbst, D.B. 1990a. Distribution and abundance of the alkali fly (*Ephydra hians* Say) at Mono Lake, California (USA) in relation to physical habitat. *Hydrobiologia,* 197:193-205.

Hibbs, A.J. and B.S. Ellis. 2009. Geologic and anthropogenic controls on selenium and nitrate loading to southern California streams. American Geophysical Union, Fall Meeting 2009, abstract #H23B-0933.

Hibbs, B., Hu, W., Ridgway, R.2012. Origins of stream flows at the Wildlands-Urban interface, Santa Monica Mountains, California, U.S.A. *Environmental & Engineering Geoscience*, 17(4): 20.

Holloway, J.M. and R.A. Dahlgren. 2002. Nitrogen in rock: Occurrences and biogeochemical implications. *Global Biogeochemical Cycles*, 16(4), 1118, doi:10.1029/2002GB001862.

IDNR. 2009. Water Quality Standards Review: Chloride, Sulfate and Total Dissolved Solids. Iowa Department of Natural Resources. http://www.iowadnr.gov/water/standards/files/ws_review.pdf.

Isham, B. 2005. Freshwater stream invertebrates: Response to water quality impairment and physical habitat alteration. Technical Paper #0508. StormCon 2005, Orlando, FL.

Izbicki, J.A., P.W. Swarzenski, C.A. Burton, L.C. Van DeWerfhorst, P.A. Holden, and E.A. Dubinsky. 2012. Sources of fecal indicator bacteria to groundwater, Malibu Lagoon and the nearshore ocean, Malibu, California, USA. *Annals of Environmental Science*, 6: 35-86.

Jones & Stokes. 2006. Malibu Lagoon Restoration and Enhancement Plan Final EIR. March 2006 Los Angeles, CA.

Jorgen, R. 1995. *Mountains to Ocean: A Guide to the Santa Monica Mountains National Recreation Area*. Southwest Parks and Monuments Association, Tucson, AZ.

Josselyn, M. 1983. The ecology of San Francisco bay tidal marshes: a community profile. U.S. Fish and Wildlife Service, Division of Biological Services, Washington D.C. FWS/OBS-83/23. 102 pp.

Kapustka L.A., W.H. Clements, L. Ziccardi, P.R. Paquin, M. Sprenger, and D. Wall. 2004. Issue Paper on the Ecological Effects of Metals. U.S. Environmental Protection Agency, Risk Assessment Forum.

Kerans, B.L., M.F. Dybdahl, M.M. Gangloff, and J.E. Jannot. 2005. *Potamopyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone Ecosystem. *Journal of the North American Benthological Society*. 24(1):123-138.

LACDPW. 2006. Hydrology Manual. Los Angeles County Department of Public Works, Los Angeles, CA.

LACDPW. 2010. Los Angeles County 2009-2010 Annual Stormwater Monitoring Report. Los Angeles County Department of Public Works, Los Angeles, CA. http://dpw.lacounty.gov/wmd/NPDES/2009-10tc.cfm.

Lafferty, K. 2005. Assessing Estuarine Biota in Southern California. USDA Forest Service General Technical Report. PSW-GTR-195.

Lai, C.P. 2009. Nitrogen Mass Loading for Malibu Lagoon and Review Summary of Previous Studies on Mass Loadings from OWDS to the Lagoon. California Regional Water Quality Control Board, Los Angeles Region, Los Angeles, CA.

Lim, J.H., L.D. Sabin, K.C. Schiff, and K.D. Stolzenbach. 2006. Concentration, size distribution, and dry deposition rate of particle-associated metals in the Los Angeles region. *Atmospheric Environment,* 40(40):7810-7823.

Lin, C.J. 2002. Effects of Landscape Modification on Stream Ecology and Structure in a Mixed-Use Watershed in Mediterranean Southern California. Doctoral Thesis, University of California, Los Angeles.

Lin, C.J., Quan-Fang Ye and I.H. Suffet. 1995. The effect of a Topanga Canyon Wildfire on the Eutrophic State of Malibu Lagoon, CA. In Ambrose, R.F., I.H. Suffet and S.S. Que Hee 1995. Enhanced environmental monitoring program at Malibu Lagoon and Malibu Creek. Report to the Las Virgenes Municipal Water District. pp. A1.

Los Angeles Board. 1994. 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, Los Angeles, CA.

Los Angeles Board. 2002. Malibu Creek Watershed Draft Fact Sheets, 2002 303(d) List of Impaired Waterbodies. California Regional Water Quality Control Board, Los Angeles Region, Los Angeles, CA.

Los Angeles Board. 2005a. Amendment to the Water Quality Control Plan – Los Angeles Region with Respect to the Early Life Stage Implementation Provision of the Inland Surface Water Ammonia Objectives for Freshwaters. California Regional Water Quality Control Board, Los Angeles Region, Los Angeles, CA. Accessed February 2011. http://63.199.216.6/larwqcb_new/bpa/docs/2005-014/2005-014_RB_BPA.pdf.

Los Angeles Board. 2005b. Fact Sheet, Waste Discharge Requirements for Las Virgenes Municipal Water District (Tapia Water Reclamation Facility). NPDES No. CA0056014, Public Notice No.: 05-047. California Regional Water Quality Control Board, Los Angeles Region, Los Angeles, CA.

Los Angeles Board. 2005c. Total Maximum Daily Load for Nutrients in Malibu Creek and Lagoon. Staff Presentation to the Regional Board on November 4, 2004 (posted 03/09/05). California Regional Water Quality Control Board, Los Angeles Region, Los Angeles, CA. http://www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/bpa_34_New_td.shtml

Los Angeles County. 2010. Bioassessment Monitoring Program in Los Angeles County, Final Report. Prepared for Los Angeles County Flood Control District Watershed Management Division, Alhambra, CA.

Los Angeles County Sanitation District. 1996. Mineral leaching study Calabasas landfill. Los Angeles, CA.

Los Angeles County West Vector & Vector-Borne Disease Control District. N.D. Mosquito Control Program. Available at www.lawestvector.org/mosquito_control.htm. Accessed on 17 April 2013.

Ligon, F. K., Dietrich, W. E., and Trush, W. J., 1995, Downstream ecological effects of dams. BioScience. Vol. 45, pp. 183-192.

Longing, S.D. 2006. *Ecological Studies of Benthic Macroinvertebrates for Determining Sedimentation Impacts in Chattahoochee National Forest Streams.* [Ph.D. Dissertation.] Virginia Polytechnic Institute and State University: Blacksburg, VA. 172 pp.

Luce, S.L.M. 2003. Urbanization and Aquatic Ecosystem Health in Malibu Creek, California: Impacts on Periphyton, Benthic Macroinvertebrates, and Environmental Policy. A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Environmental Science and Engineering, University of California, Los Angeles, CA.

Luce, S. and M. Abramson. 2005. Periphyton and Nutrients in Malibu Creek: A Heal the Bay Report. http://sites.healthebay.org/assets/pdfdocs/mcwstudies/Periphyton_and_Nutrients_2005.pdf. Accessed January 24, 2011.

Lund, L.J. M.A. Anderson, and C. Armhein. 1994. Evaluation of Water Quality for Selected Lakes in the Los Angeles Hydrologic Basin. Dept. of Soil and Environment Sciences, University of California, Riverside. For California Regional Water Quality Control Board, Los Angeles Region.

LVMWD. 2010. Bioassessment Monitoring Report for the Tapia Water Reclamation Facility. Prepared for Las Virgenes Municipal Water District, Calabasas, CA.

LVMWD. 2011. Water Quality in the Malibu Creek Watershed, 1971 – 2010. Report #2475.00. Submitted by the Joint Powers Authority of the Las Virgenes Municipal Water District and the Triunfo Sanitation District to the Los Angeles Regional Water Quality Control Board in compliance with Order No. R4-2010-0165.

MacDonald, K.B. 1969. Quantitative Studies of Salt Marsh Mollusc Faunas from the North American Pacific Coast. Ecological Monographs 39:33–60.

Manion, S. 1993. The Tidewater Goby (*Eucyclogobius newberryi*), Reintroduction of a Geographically Isolated Fish Species into Malibu Lagoon: A Watershed Perspective. Final Report to California Department of Parks and Recreation. Prepared for Topanga-Las Virgenes Resource Conservation District, Topanga, CA.

Mantua, N. 2009. The Pacific Decadal Oscillation. Joint Institute for the Study of the Atmosphere and Oceans, Climate Impacts Group, University of Washington, Seattle, WA. http://www.atmos.washington.edu/~mantua/REPORTS/PDO/PDO_egec.htm. Accessed August 4, 2009.

Mazor, R. 2013. Personal Communications by email and telephone with A. Roseberry-Lincoln of Tetra Tech between 11 February and 02 May 2013.

Mazor, R.D., K. Schiff, K. Ritter, A. Rehn, and P. Ode. 2010. Bioassessment tools in novel habitats: An evaluation of indices and sampling methods in low-gradient streams in California. *Environmental Monitoring and Assessment*, 167: 91-104.

McDonald Morrissey Associates, Inc. 2010. Groundwater Flow Modeling Report, City of Malibu, Malibu, California. Contained within Stone Environmental (2010).

MCWMP. 2005. Malibu Creek Watershed Monitoring Program, Bioassessment Monitoring Report. Prepared for the City of Calabasas, Environmental Services Division, Calabasas, CA.

Meigs, A., N. Brozovic, and M.L. Johnson. 1999. Steady, balanced rates of uplift and erosion of the Santa Monica Mountains, California. *Basin Research*, 11: 59-73.

Merkel & Associates. 2009. Batiquitos Lagoon Long-term Biological Monitoring Program Final Report. M&A Doc. No. 96-057-01-F. Prepared for City of Carlsbad Planning Department and Port of Los Angeles, Environmental Management Division. San Diego, CA.

Merritt, R. W., K. W. Cummins, and M. B. Berg (eds). 2007. An Introduction to the Aquatic Insects of North America (4th ed.). Kendall/Hunt Publ. Co., Dubuque, IA

Meyer, J.S., Sanches, D.A., Brookman, J.A., McWhorter, D.B., and Bergamn, H.L. 1985. Chemistry and aquatic toxicity of raw oil shale leachates from Piceance Basin, Colorado. *Environmental Toxicology and Chemistry,* 4: 559-572.

Meyer-Peter, E. and R. Muller. 1948. Formulas for bedload transport. Proceedings of the Second Congress, IAHR, Stockholm, pp. 39-64.

Meyers, M. R., M. Anghera, and R. F. Ambrose. 2001. Assessment of Southern California Wetland Porewater Toxicity Using the Sea Urchin 72-Hour Development Test. Unpublished.

Minshall, G.W. 2002. Responses of stream benthic macroinvertebrates to fire. Forest Ecology and Management 178:155-161.

Moeller, A., S.D. MacNeil, R.F. Ambrose, and S.S. Que Hee. 2003. Elements in fish of Malibu Creek and Malibu Lagoon near Los Angeles, California. *Marine Pollution Bulletin,* 46:424-429.

Moffatt & Nichol. 2005. Malibu Lagoon Restoration Feasibility Study, Final Alternatives Analysis. Prepared by Moffatt & Nichol in association with Heal the Bay for California State Coastal Conservancy and California State Parks.

Moss, D., M.T. Furse, J.F. Wright, and P.D. Armitage. 1987. The prediction of the macroinvertebrate fauna of unpolluted running-water sites in Great Britain using environmental data. *Freshwater Biology*, 17:41-52.

Mount, D.R., Gulley, D.D., Hockett, J.R., Garrison,T.L., and Evans, J.M. 1997. Statistical models to predict the toxicity of major ions to *ceriodaphnia dubia, daphia magna, and pimephales promelas* (fathead minnows). *Environmental Toxicology and Chemistry,* 16(10):2009-2019.

Naiman, R.J. and R.E. Bilby, eds. 1998. *River Ecology and Management: Lessons from the Pacific Coastal Region*. Springer-Verlag, New York.

NRCS. 1995. Malibu Creek Watershed Natural Resources Plan, Los Angeles and Ventura Counties, California. USDA National Resources Conservation Service, Davis, CA. for Topanga-Las Virgenes Resource Conservation District.

Nature Conservancy. 2007. Indicators of Hydrologic Alteration, Version 7, User's Manual. The Nature Conservancy, Arlington, VA.

Neary, D. G.; Ryan, K. C.; DeBano, L. F., eds. 2005. (revised 2008). Wildland Fire in Ecosystems: Effects of Fire on Soils and Water. Gen. Tech. Rep. RMRS-GTR-42-vol.4. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Nezlin, N.P., P.M. DiGiacomo, E.D. Stein, and D. Ackerman. 2005. Stormwater runoff plumes observed by SeaWiFS radiometer in the Southern California Bight. *Remote Sensing of Environment,* 98:494-510.

NOAA/EPA. National Oceanic and Atmospheric Administration and Environmental Protection Agency. 1988. Strategic Assessment of Near Coastal Waters, Chapter 3, Susceptibility and Concentration Status of Northeast Estuaries to Nutrient Discharges. NOA A: Washington, D.C.

Nordby, C.S. and Covin, J. 1988. Physical-chemical and Biological Monitoring of Los Peñasquitos. Los Peñasquitos Lagoon Foundation. Cardiff, CA.

Nordby, C.S. and Zedler, J. B. 1991. Responses of fish and macrobenthic assemblages to hydrologic disturbances at Tijuana Estuary and Los Peñasquitos Lagoon, California. *Estuaries*, 14(1): 80-93.

Ode, P.R., A.C. Rehn, and J.T. May. 2005. A quantitative tool for assessing the integrity of southern coastal California streams. *Environmental Management*, 35(4): 493-504.

Orton, R. 2012. Diatoms as water quality indicators in Malibu Creek. Presentation to the Malibu Creek Watershed Technical Advisory Committee, July 2012.

Owen, B. 1998. Runoff Analysis for the Malibu Creek Watershed. Prepared as an appendix to Abramson (1998), A Framework for Monitoring and Enhancement of the Malibu Creek Watershed. Available online at http://www.owenswatershedplanning.com/Malibu/malibu.pdf, accessed 5/15/13.

Paul, M.J. and J.L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333-365.

Peterson, C.H. 1977. Competitive organization of the soft bottom macrobenthic communities of southern California lagoons. *Mar. Biol.* 43(4)343-360.

Poff N.L., Allan J.D., Bain M.B., et al. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47: 769–84.

Pond, G.J., Passmore, M.E., Borsuk, F.A., Reynolds, L., and Rose, C.J. 2008. Downstream effects of mountaintop coal mining: comparing biological conditions using family – and genus-level macroinvertebrate bioassessment tools. *Journal of the North American Benthological Society,* 27(3):717-737.

Preston, S.D., V.J. Bierman Jr., and S.E. Silliman. 1989. An evaluation of methods for the estimation of tributary mass loads. *Water Resources Research*, 25(6): 1379-1389.

Questa. 2005. Malibu Civic Center Integrated Water Quality Management Feasibility Study. Prepared for City of Malibu by Questa Engineering Corporation.

Quinn, J. M., A. B. Cooper, M. J. Stroud, and G. P. Burrell. 1997. Shade effects on stream periphyton and invertebrates: An experiment in streamside channels. *New Zealand Journal of Marine and Freshwater Research*, 31(5):665-683.

Ranasinghe, J.A., S.B. Weisberg, R.W. Smith, D.E. Montagne, B. Thompson, J.M. Oakden, D.D. Huff, D.B. Cadien, R.G. Velarde, and K.J. Ritter. 2009. Calibration and evaluation of five indicators of benthic community condition in two California bay and estuary habitats. *Marine Pollution Bulletin*, 59: 5-13.

Ranasinghe, J.A., K.C. Schiff, D.E. Montagne, T.K. Mikel, D.B. Cadien, R.G. Velarde, and C.A. Brantley. 2010. Benthic macrofaunal community condition in the Southern California Bight, 1994-2003. *Marine Pollution Bulletin*, 60(6): 827-833.

Riley, S.P.D., G.T. Busteed, L.B. Kats, T.L. Vandergon, L.F.S. Lee, R.G. Dagit, J.L. Kerby, R.N. Fisher, and R.M. Sauvajot. 2005. Effects of Urbanization on the distribution and abundance of amphibians and invasive species in southern California streams. *Conservation Biology,* 19(6):1894-1907.

Roby, K. B. and D. L. Azuma. 1995. Changes in a reach of a northern California stream following wildfire. *Environmental Management,* 19(4):591-600.

Rowe, C. L., W. A. Hopkins, J. D. Congdon. 2002. Ecotoxicological implications of aquatic disposal of coal combustion residues in the United States: a review. *Environmental Monitoring and Assessment*, 80:207-276.

Roy, A.H., A.D. Rosemond, M.J. Paul, D.S. Leigh, and J.B. Wallace. 2003. Stream macroinvertebrate response to catchment urbanization (Georgia, USA). *Freshwater Biology,* 48:329–346.

Sandoval, C.P. and K.D. Lafferty. Invertebrate communities. In Coastal Wetland Resources: Santa Barbara County Mainland. R.F. Ambrose ed. Final Report to the County of Santa Barbara.

Schiff, K.C. and S.M. Bay. 2003. Impacts of stormwater discharges on the nearshore benthic environment of Santa Monica Bay. *Marine Environmental Research,* 56(1-2):225-243.

SCS. 1985. Urban Hydrology for Small Watersheds. Technical Release 55. U.S. Soil Conservation Service, Washington, DC.

Shifting Baselines (The Shifting Baselines Ocean Media Project). 2011. The Facts about the Malibu Lagoon Restoration. http://www.youtube.com/watch?v=Fede_M_TBKI.

Sikich, S., K. Pease, S. Diringer, M. Abramson, M. Gold, and S. Luce. 2012. State of the Malibu Watershed Report: Trends in Watershed Health. Heal the Bay, Santa Monica, CA.

Skaggs, R. W., M. A. Brevé, and J. W. Gilliam. 1994. Hydrologic and water quality impacts of agricultural drainage. *Critical Reviews in Environmental Science and Technology,* 24(1):1-32.

Smith, R.W., J.A. Ranasinghe, S.B. Weisberg, D.E. Montagne, D.B. Cadien, T.K. Mikel, R.G. Velarde, and A. Dalkey. 2003. Extending the Southern California Benthic Response Index to Assess Benthic Condition in Bays. Technical Report #410. Southern California Coastal Water Research Project, Westminster, CA.

Spindler, P. 2004. *Stream Channel Morphology and Benthic Macroinvertebrate Community Associations in the San Pedro River and Verde River Basins of Arizona, 1999-2002.* Open File Report 04-01. Arizona Department of Environmental Quality, Water Quality Division, Hydrologic Support and Assessment Section, Surface Water Monitoring and Standards Unit: Phoenix, AZ. 32 pp.

Stein, E.D. and V.K. Yoon. 2007. Assessment of Water Quality Concentrations and Loads from Natural Landscapes. Technical Report No. 500. Southern California Coastal Water Research Project, Costa Mesa, CA.

Stone Environmental. 2004. Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, California. Prepared for Santa Monica Bay Restoration Commission. Stone Environmental, Inc., Montpelier, VT.

Stone Environmental. 2010. Hydrology Study of the Cumulative Impacts for the Civic Center Area, Malibu, California. Stone Environmental, Inc., Montpelier, VT.

Strayer D. L. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology*, 55(Suppl. 1): 152-174.

Sutula, M., K. Kamer, and J. Cable. 2004. Sediments as a Non-point Source of Nutrients to Malibu Lagoon, California (USA). Technical Report #441. Prepared for Los Angeles Regional Water Quality Control Board.

Svejkovsky, J., and J. Burton. 2001. Detection of coastal urban stormwater and sewage runoff with synthetic aperture radar satellite imagery. *Eos, Transactions, American Geophysical Union,* 82(50):621, 624-625, 630.

SWRCB (State Water Resources Control Board). 1972. Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California.

California State Water Resources Control Board. Accessed February 2011. http://www.waterboards.ca.gov/water_issues/programs/ocean/docs/wqplans/thermpln.pdf

SWRCB (State Water Resources Control Board). 2010. 2010 CWA Section 303(d) List of Water Quality Limited Sections. California Regional Water Quality Control Board, Sacramento, CA. http://www.waterboards.ca.gov/rwqcb4/water_issues/programs/303d_list.shtml

SWRCB (State Water Resources Control Board). 2012. OWTS Policy: Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems. June 19, 2012. http://www.waterboards.ca.gov/water_issues/programs/owts/docs/owts_policy_06192012.pdf

Talley, T.S. and L.A. Levin. 1999. Macrofaunal succession and community structure in *Salicornia* marshes of southern California. *Estuaries, Coastal, and Shelf Science.* 49:713-731.

Tetra Tech. 2002. Nutrient and Coliform Modeling for the Malibu Creek Watershed TMDL Studies. Prepared for USEPA Region 9 and Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc., Lafayette, CA.

Tetra Tech. 2004. Progress Report: Development of Nutrient Criteria in California 2003-2004. Prepared for U.S. EPA Region IX under Task Order 2004-38. Lafayette, CA.

Tetra Tech. 2006. Technical Approach to Develop Nutrient Numeric Endpoints for California. Prepared for USEPA Region IX and California State Water Resources Control Board by Tetra Tech, Inc., Lafayette, CA.

Topanga-Las Virgenes Resource Conservation District. 1995. Natural Resources Plan: Malibu Creek Watershed, Los Angeles and Ventura Counties, California

Topanga - Las Virgenes Resource Conservation District, for LA County Dept. of Beaches and Harbors and California Dept. of Parks and Recreation. 1989. Manion, B.S. & J.H. Dillingham eds. Malibu Lagoon: A Baseline Ecological Survey.

Trim, H., for the Santa Monica Bay Restoration Project. 1994. Review of Monitoring and Response Protocol for the Malibu Creek Watershed.

Trimble , S.W. 1997. Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed. Science 278: 1442-1444.

UCSB (University of California, Santa Barbara, Marine Science Institute, Riparian Invasive Research Laboratory). 2012. New Zealand mudsnail: impacts on stream's ecosystem. Accessed on November 14, 2012. http://rivrlab.msi.ucsb.edu/NZMS/impact.php

USEPA (United States Environmental Protection Agency). 1985. Summary of Revisions to Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (50 FR 30792, July 29, 1985).

USEPA (United States Environmental Protection Agency). 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. EPA 440/4-91-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (United States Environmental Protection Agency). 1999. 1999 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-R-99-014. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA (United States Environmental Protection Agency). 2000a. 40 CFR Part 131 Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule. http://www.epa.gov/fedrgstr/EPA-WATER/2000/May/Day-18/w11106.pdf.

USEPA (United States Environmental Protection Agency). 2000b. Stressor Identification Guidance Document. EPA-822-B-00-025. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA (United States Environmental Protection Agency). 2000c. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. EPA-822-B-00-02. U.S. Environmental Protection Agency, Washington, DC.

USEPA (United States Environmental Protection Agency). 2000d. Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion III. EPA 822-B-00-016. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA (United States Environmental Protection Agency). 2000e. Guidance for Developing TMDLs in California. January 7, 2000. Available at: http://www.epa.gov/region9/water/tmdl/303d-pdf/caguidefinal.pdf

USEPA. 2001. Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Lakes and Reservoirs in Nutrient Ecoregion III. EPA 822-B-01-008. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA (United States Environmental Protection Agency). 2002. Total Maximum Daily Loads for Bacteria in the Malibu Creek Watershed. U.S. Environmental Protection Agency, Region 9, San Francisco, CA. http://www.epa.gov/region9/water/tmdl/malibu/final_bacteria.pdf.

USEPA (United States Environmental Protection Agency). 2003. Total Maximum Daily Loads for Nutrients Malibu Creek Watershed. U.S. Environmental Protection Agency, Region 9, San Francisco, CA. http://www.epa.gov/region9/water/tmdl/malibu/final_nutrients.pdf.

USEPA (United States Environmental Protection Agency). 2007. Options for Expressing Daily Loads in TMDLs. U.S. Environmental Protection Agency Office of Wetlands, Oceans & Watersheds, June 22, 2007 Draft.

USEPA (United States Environmental Protection Agency). 2008. Municipal Nutrient Removal Technologies Reference Document. EPA832-R-08-006. U.S. Environmental Protection Agency, Office of Wastewater Management, Municipal Support Division, Municipal Technology Branch, Washington, D.C.

USEPA (United States Environmental Protection Agency). 2012. *Causal Analysis/Diagnosis Decision Information System (CADDIS)*. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. Accessed November 13, 2012. http://www.epa.gov/caddis.

USEPA, Pesticides and Toxic Substances. 1991. R.E.D. FACTS: Methoprene. 738-F-91-104. USEPA: Washington, DC. 6 pp.

Walmsley, R.D., M. Butty, H. Van Der Piepen, and D. Grobler. 1980. Light penetration and the interrelationships between optical parameters in a turbid subtropical impoundment. Hydrobiologia, 70: 145-157.

Walsh, C.J., A.K. Sharpe, P.F. Breen, and J.A. Sonneman. 2001. Effects of urbanization on streams of the Melbourne region, Victoria, Australia: I. Benthic macroinvertebrate communities. *Freshwater Biology*, 46: 535-551.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, and R.P. Morgan II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. *Journal of the North American Benthological Society*, 24:706–723.

Walsh, C.J., K.A. Waller, J. Gehling, and R. MacNally. 2007. Riverine invertebrate assemblages are degraded more by catchment urbanisation than by riparian deforestation. *Freshwater Biology* 52:574-587.

Warrick, J.A. and L.A.K. Mertes. 2009. Sediment yield from the tectonically active semiarid Western Transverse Ranges of California. *Geological Society of America Bulletin*, 121: 1054-1070.

Welch, E. B. and J.M. Jacoby. 2004. Pollutant Effects in Freshwater, Applied Limnology, 3rd Edition. Spon Press, London.

Wenger, S.J., A.H. Roy, C.R.Jackson, E.S. Bernhardt, T.L. Carter, S. Filoso, C.A. Gibson, W.C. Hession, S.S. Kaushal, E. Martí, J.L. Meyer, M.A. Palmer, M.J. Paul, A.H. Purcell, A. Ramírez, A.D. Rosemond, K.A. Scholfield, E.B. Sudduth, and C.J. Walsh. 2009. Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. *Journal of the National Benthological Society*. 28(4):1080–1098.

Weston. 2009. 2009 Bioassessment Monitoring Program in Los Angeles County, Final Report. Prepared for Los Angeles County Flood Control District by Weston Solutions, Inc., Carlsbad, CA.

Weston. 2011. 2010 Bioassessment Monitoring Program in Los Angeles County, Final Report. Prepared for Los Angeles County Flood Control District by Weston Solutions, Inc., Alhambra, CA.

Williams G.D, Desmond J.S. Restoring assemblages of invertebrates and fishes. In: Zedler J.B, editor. Handbook for Restoring Tidal Wetlands. Boca Raton, FL: CRC Press LLC; 2001. p. 235-269. 439 pp.

Wohl, E. and S. Rathburn. 2003. Mitigation of sediment hazards downstream from reservoirs. International Journal of Sediment Research 18:97-106.

Woolfolk, A. and Labadie, Q. 2012. The significance of pickleweed-dominated tidal salt marsh in Elkhorn Slough, California. Elkhorn Slough Technical Report Series 2012:4.

Wong, M. and G. Parker. 2006. Re-analysis and correction of bedload relation of Meyer-Peter and Muller using their own database. *J. Hydr. Eng., ASCE*, 132(11): 1159-1168.

Wood, P.J. and P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. *Environmental Management*, 21(2): 203–217.

Wright, J.F. 1995. Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology*, 20:181-197.

Yoder, C., R. Miltner, and D. White. 1999. Assessing the aquatic life designated uses in urban and suburban watersheds. In *Proceedings of the National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments*, Chicago, IL, pp. 16–28. A. Everson, S. Minamayer, J. Dye, P. Heimbrock and J. Wilson. eds. EPA/625/R-99/002.

Yuan, L. 2010. Estimating the effects of excess nutrients on stream invertebrates from observational data. *Ecological Applications,* 20(1):110-125.

Zedler, J.B.; C.S. Nordby; and B.E. Kus. 1992. The ecology of Tijuana Estuary: a National Estuarine Research Reserve. Washington DC: NOAA Office of Coastal Resource Management, Sanctuaries and Research Division.

(This page left intentionally blank.)