U.S. Environmental Protection Agency Region 9

Malibu Creek & Lagoon TMDL for Sedimentation and Nutrients Impacting Benthic Community

TECHNICAL APPENDICES

December 2012

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Appendix A. Data Inventory

Table A-1. Spatial Datasets Assembled/Created for the Malibu Creek Watershed

Data Type	Source	Description	Date Accessed	Date Created/ Updated
polyline	http://www.horizon-systems.com/nhdplus/	Major waterways selected from NHDplus hydrography	Jan-10	Oct-08
polygon	Ventura County Watershed Protection District	Major waterbodies within the Malibu Creek watershed	Apr-08	
polygon	created by Tetra Tech	Watershed boundary created from subwatershed delineation		Sep-10
polygon	created by Tetra Tech	Subwatershed boundaries created from subwatershed delineation		Sep-10
point	http://waterdata.usgs.gov/nwis	USGS gages located within the Malibu Creek watershed (2 gages)	Nov-10	Nov-10
point	Kevin Jontz	All "Heal the Bay" BMI monitoring locations	Sep-10	Sep-10
point	Kevin Jontz	"Heal the Bay" BMI monitoring locations outside of Malibu Creek watershed	Sep-10	Sep-10
point	Kevin Jontz	"Heal the Bay" BMI monitoring locations within Malibu Creek watershed	Sep-10	Sep-10
point	Aquatic Bioassay, 2005	Bioassessment monitoring location for the MCWMP	Aug-10	Mar-05
grid	created by Tetra Tech	Mosaic of 10-meter DEMs obtained from NRCS Datagateway	Sep-10	Sep-10
polygon	created by Tetra Tech	CA Dept of Forestry and Fire Protection statewide fire history, clipped to watershed	Dec-09	Mar-08
polygon	created by Tetra Tech	Major recent fires extracted from the previous dataset	Dec-09	Mar-08
polygon	created by Tetra Tech	Hydrologic Soil Groups (SSURGO) clipped to watershed	Oct-10	Oct-10
polygon	created by Tetra Tech	1990 SCAG LULC clipped to watershed, aggregated, and then dissolved	Nov-07	Nov-07
polygon	created by Tetra Tech	2005 SCAG LULC clipped to watershed, aggregated, and then dissolved	Nov-07	Nov-07
polygon	created by Tetra Tech	Polygons created and dissolved from Landfire Existing Vegetation Type (EVT) dataset	Oct-10	Oct-10
polygon	created by Tetra Tech	Landfire EVT in 1990 SCAG's "undeveloped" areas	Oct-10	Oct-10
polygon	created by Tetra Tech	Landfire EVT in 2005 SCAG's "undeveloped" areas	Oct-10	Oct-10

Data Type	Source	Description	Date Accessed	Date Created/ Updated
polyline	Tele Atlas North America, Inc., ESRI	Major highways	Oct-06	Oct-06
polyline	Tele Atlas North America, Inc., ESRI	Major and minor highways	Oct-06	Oct-06
polygon	Los Angeles County Department of Public Works	Legal city boundaries within Los Angeles County	Mar-05	Apr-03
polygon	Ventura County Watershed Protection District	Legal city boundary of Thousand Oaks	Jan-09	

Table A-2. Water Quality Data Assembled for the Malibu Creek Watershed

Data Type	Source	Description	Dates
water quality	CEDEN	Water quality parameters including metals, and Lat/Long for 5 stations	2002-2006 for one station. 2003-2004 for 4 stations
water quality	Heal the Bay	Water quality parameter measurements, samples linked to event IDs and site numbers, lat/long not provided	11/7/1998- 6/6/2010
water quality	LADPW	2005-2006 Sampling (wet and dry) results for Malibu Creek at site# S02	2005 and 2006
water quality	LADPW	2006-2007 Sampling (wet and dry) results for Malibu Creek at site# S02	2006 and 2007
water quality	LADPW	Water quality for station S02 in Malibu Creek, includes data for surrounding stations	1995 - 2005
water quality	SCCWRP	Contains txt files of data & metadata	2003
water quality	SCCWRP	Contains txt files of data & metadata	1998
toxicology	SCCWRP	Contains txt files of data & metadata	1998
flow	MCLC	Presentation containing rainfall and flow data for Malibu Creek; max flows for specific days (2004, 2005; at F130R)	2004 and 2005
water quality	LADPW	2005-06 Summary of Water Quality Exceedances for Malibu Creek Mass Emission Station	2005 through 2006
water quality	LADPW	2006-07 Summary of Water Quality Exceedances for Malibu Creek Mass Emission Station	2006 through 2007
water quality	LADPW	Estimated Pollutant Loading; Malibu Creek (S02); Load (lbs)	2006 through 2007
water quality	LADPW	2007-08 Summary of Water Quality Exceedances for Malibu Creek Mass Emission Station	2007 through 2008

Data Type	Source	Description	Dates
water quality	LADPW	Malibu Creek @ Piuma Dry & Wet Weather Exceedance Summary; S02; 2009-10	2009 through 2010
water quality	LADPW	2009-10 Annual Report Mass Emission and Trib. Wet Weather Concentrations; S02	2009 through 2010
water quality	LADPW	2009-10 Annual Report Mass Emission and Trib. Dry Weather Concentrations; S02	2009 through 2010
Particle size	USEPA	Sediment grab sample particle size analysis at 5 sites	2010
Particle size	USEPA	Sediment grab sample particle size analysis at 5 sites (different from first 5 sites)	2010
Sediment chemistry	USEPA	Malibu Lagoon sediment samples analyzed for TKN, Nitrate, Nitrite, etc. for 3 different sample sites	2011
Particle Size	USEPA	Particle Size analysis and statistics for 3 different Sample IDs.	2011
Sediment chemistry	USEPA	Malibu Lagoon sediment samples analyzed for TKN, Nitrate, Nitrite, etc. for 5 different sample sites	2011
Sediment chemistry	USEPA	Particle Size analysis and statistics on 6 different Sample IDs	2011
Physical data	Heal the Bay	Contains 16 word documents with physical data for each site (SWAMP)	2009 and 2010 for all sites except CH6 (2010 only)
Water quality	Heal the Bay	Water quality data for 30 sites	1998-2010
Water quality	Heal the Bay	Water quality, flow, temperature, bacteria, and algae data for site HtB-1	1998-2010
Water quality	Heal the Bay	Water quality, flow, temperature, bacteria, and algae data for site HtB-12	2002-2010
Water quality	Heal the Bay	Water quality, flow, temperature, bacteria, and algae data for site HtB-15	2008-2010
Site Locations	LVMWD	Site descriptions, data type, and latitude/longitude of LA County Bioassessment Monitoring Sites. Note that not all sites are 2003-2009 but specifics are laid out by site in this file	2003-2009
Water quality	LACFCD	Physical water quality data for LACFCD Bioassessment Sites for 2009	2009
Water quality	LACFCD	Physical water quality data for LACFCD Bioassessment Sites for 2011 (even though named 2010 in title)	2011

Data Type	Source	Description	Dates
Water quality	LACFCD	Physical water quality data for LACFCD Bioassessment Sites for 2010	2010
Water quality	LACFCD	Physical and water quality data for 18 sites	2006
Water quality	LACFCD	Physical and water quality data for 18 sites	2007
Water quality	LACFCD	Physical and water quality data for 16 sites	2008
Water quality	LACFCD	Physical and water quality data for 16 sites	2003
Water quality	LACFCD	Physical and water quality data for 17 sites	2004
Water quality	LACFCD	Physical and water quality data for 18 sites	2005
Water quality	LADPW	2005-2009 Sampling (wet and dry) results for Malibu Creek at site# S02	2005-2009
Water quality and benthics	LADPW	2007-2008 sampling results, mass emissions and tributary sites	2007-2008
Water quality	LADPW	Wet weather concentrations and water quality at a large number of sites	2010-2011
Flow data	LADPW	Daily mean discharge for site F130: Malibu Creek Below Cold Creek	1979-1993
Physical data	MCWMP	Physical Site Data for 8 sites	2005
Physical Data	LVMWD	Physical habitat, bank stability, velocity, slope, width, riparian, etc. The period of record varies depending on the file in question, but all sampling dates are accounted for	2007-2011

Table A-3. Bioassessment Data Assembled for the Malibu Creek Watershed

Data Type	Source	Description	Dates
toxicology	CEDEN	Toxics data including survival (%), growth (mg/ind), and constituent concentrations	All samples recorded on 3/12/2003
IBI	Heal the Bay	Region 4 CDFG IBI (2000- 2001), LA County IBI (Oct-03 and Oct-04), and Ventura County IBI (2004/2005) scores	See description

Data Type	Source	Description	Dates
benthic	Heal the Bay	Taxonomic list of benthic macroinvertebrates sampled in Malibu Creek drainage basin in October 2000	October 2000
QA/QC	Heal the Bay	California Stream Bioassessment Procedure Biological and Physical Habitat Field Audit. QA/QC records	September 2005
benthic	Heal the Bay	Taxonomic list of benthic macroinvertebrates sampled in Malibu Creek drainage basin in October 2001	October 2001
benthic	Heal the Bay	Taxonomic list of benthic macroinvertebrates sampled in Malibu Creek drainage basin in April 2001	April 2001
benthic	Heal the Bay	Taxa list and abundance calculations for benthic macroinvertebrates sampled from the Malibu project, fall 2002	Fall 2002
benthic	Heal the Bay	Taxa list and abundance calculations for benthic macroinvertebrates sampled from the Malibu project, fall 2003	Fall 2003
benthic	Heal the Bay	Taxa list and abundance calculations for benthic macroinvertebrates sampled from the Malibu project, spring 2002	Spring 2002
benthic	Heal the Bay	Taxa list and abundance calculations for benthic macroinvertebrates sampled from the Malibu project, spring 2003	Spring 2003
IBI	Heal the Bay	IBI scores across 17 sites for Malibu Creek. Site IDs provided, but no lat/long	Winter 2005
benthic	Heal the Bay	Taxa list and abundance calculations for benthic macroinvertebrates sampled from the Malibu project, winter 2005	Winter 2005
benthic	Heal the Bay	Taxonomic list of benthic macroinvertebrates sampled in Malibu Creek drainage basin in May 2000	May 2000
site description	Heal the Bay	18 sites with lat/long and site location descriptions	N/A
IBI	Heal the Bay	Summary of IBI scores for all sampling events and sites in Malibu Creek watershed	Spring 2000-Spring 2009, w/o 2004 & 2007
benthic	Heal the Bay	Biol. metrics for the Malibu project, 2006	2006
benthic	Heal the Bay	Taxa list and abundance calculations for the Malibu project, 2006	2006

Data Type	Source	Description	Dates
benthic	Heal the Bay	Biol. metrics for benthic macroinvertebrates - Malibu project, 2008	2008
benthic	Heal the Bay	Taxa list and abundance calculations for Malibu project, 2008	2008
benthic	Heal the Bay	Biol. metrics for benthic macroinvertebrates - Malibu project, 2009	2009
benthic	Heal the Bay	Taxa list and abundance calculations for Malibu project, 2009	2009
IBI	Heal the Bay	IBI scores for 17 sites for Malibu Creek	2005
benthic	SCCWRP	Community measures at Bay and Estuary sites, benthic condition	unknown
benthic	SCCWRP	Contains txt files of data & metadata	2003
toxicology	SCCWRP	Contains txt files of data & metadata	2003
benthic	SCCWRP	Contains txt files of data & metadata	1998
toxicology	SCCWRP	Contains txt files of data & metadata	1998
toxicology	SCCWRP	A PDF document of sediment toxicity	2008
benthic	SCCWRP	9 PDF documents in this folder contain benthic data (Appendices A-G, etc.)	2008
Benthic	LVMWD	Benthic macroinvertebrate data	2006 – 2010
IBI	LVMWD	IBI scores corresponding to previous data set	2006 – 2011
benthic	LVMWD	Physical habitat scores	2007 - 2011
benthic	USEPA	Species Data at 8 different stations using various methods	2011
benthic	USEPA	Same document as “Malibu W atershed Data – Set 2.xls” but includes extra column for USEPA MALIBU 2011	2011
Benthic	USEPA	Species data, counts, percentages, indices, and richness for 5 different Malibu Creek sites (biological metrics calculated at 500ct.)	2011
Benthic	USEPA	Same species data as “Malibu_EPA_500ct_metrics.xls”, but biological metrics calculated at 600ct.	2011
Benthic	USEPA	Taxa list and abundance calculations for benthic macroinvertebrates, calculated at 600ct, LV2.	2011

Data Type	Source	Description	Dates
Benthic	Harrington	Biological metrics for 15 sites	2005
Benthic	Harrington	Biological metrics for 24 sites	2006
Benthic	Harrington	Biological metrics for 7 sites	2008
Benthic	Harrington	Biological metrics for 16 sites	2009
Benthic	Harrington	Biological metrics for 18 sites	2010
IBI	Harrington	IBI scores for 16 permanent and 13 special study sites in HTB Bioassessment Program	2000-2010
IBI and Benthic	Harrington	IBI scores and % New Zealand Mud Snail in sample (when present)	2000-2010
Benthic	Heal the Bay	Taxa Abundance	2006-2007
Benthic	LADPW	Bioassessment Monitoring Program in LA County Final Report	2006
Benthic	LADPW	Bioassessment Monitoring Program in LA County Final Report	2007
Benthic	LADPW	Bioassessment Monitoring Program in LA County Final Report	2008
Benthic	LADPW	Bioassessment Monitoring Program in LA County Final Report	2009
Benthic	LADPW	Bioassessment Monitoring Program in LA County Final Report	2010
benthic	Heal the Bay	Biological metrics for 12 sites	2011
Benthic	Heal the Bay	Taxa list and abundance calculation for Malibu Creek Project	2011
IBI	Heal the Bay	IBI scores for Heal the Bay Bioassessment Sites (16)	2000-2011
IBI	LADPW	Average IBI scores and lat/long for 4 LA County sites	2008
benthic	LACFCD	Taxonomic data for 20 sites	2006
Benthic	LACFCD	Taxonomic data for 20 sites	2007
Benthic	LACFCD	Taxonomic data for 18 sites	2008
Benthic	LACFCD	Taxonomic data for 23 sites	2009

Data Type	Source	Description	Dates
Benthic	LACFCD	Taxonomic data for 19 sites	2003
Benthic	LACFCD	Taxonomic data for 19 sites	2004
Benthic	LACFCD	Taxonomic data for 19 sites	2010
Benthic	LACFCD	Taxonomic data for 18 sites	2011
benthic	LACFCD	Taxonomic data for 17 sites	2005
benthic	LACFCD	2009 Bioassessment Monitoring Program in LA County	2009
IBI	LVMWD	LVMMWD Malibu and LA River Watersheds Bioassessment Monitoring Report	2006
IBI	LVMWD	LVMMWD Malibu and LA River Watersheds Bioassessment Monitoring Report	2007
IBI	LVMWD	LVMMWD Malibu and LA River Watersheds Bioassessment Monitoring Report	2008
IBI	LVMWD	LVMMWD Malibu and LA River Watersheds Bioassessment Monitoring Report	2009
IBI	LVMWD	LVMMWD Malibu and LA River Watersheds Bioassessment Monitoring Report	2010
benthic	LVMWD	Total abundance BMI results for the period of record	2006-2011
IBI	LVMWD	Adjusted IBI scores for 7 sites	2006-2011
benthic	MCWMP	Bioassessment Monitoring Report 2005	2005
benthic	MCWMP	Malibu Creek BMI Results	2005
benthic	LVMWD	The effect of water quality on BMI measures	2008

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Appendix B. Meteorology, Climate, and Fire History and Conditions

B.1 General Climate

The Malibu Creek watershed has a Mediterranean climate like other parts of the coastal region of southern California. The daily average air temperature ranges from 53 °F in January to 71 °F in July, and the annual average temperature is 61 °F (NRCS, 1995). Average winter temperatures have highs in the mid-60s and lows in the mid-40s (Abramson et al., 1998). Coastal fog is common in the morning during the summer months, but usually burns away by mid-day. During the summer, inland temperatures generally remain around 85 °F during the day, but may be 15 degrees cooler at the coast (Abramson et al., 1998; Jorgen, 1995).

Because of the mountainous topography, rainfall varies in different parts of the watershed. Figure B-1 shows the distribution of the long-term average annual rainfall in the watershed based on information from the Los Angeles County Flood Control District (Tetra Tech, 2002). The southern portion of the watershed is coastal mountains and has an average annual rainfall of 24 inches at the higher elevations (SCS, 1967; NRCS, 1995). The northern portion consists of inland basins with small hills and has a lower annual rainfall of 14 inches. The annual rainfall at the bottom of the watershed in Malibu is about 16 inches. Almost all of the rainfall occurs during the November to April wet season. The annual rainfall may vary from near zero during drought years to about five times the average annual precipitation during very wet years (NRCS, 1995). Measurable precipitation occurs on an average of about 35 days per year (Abramson et al., 1998).

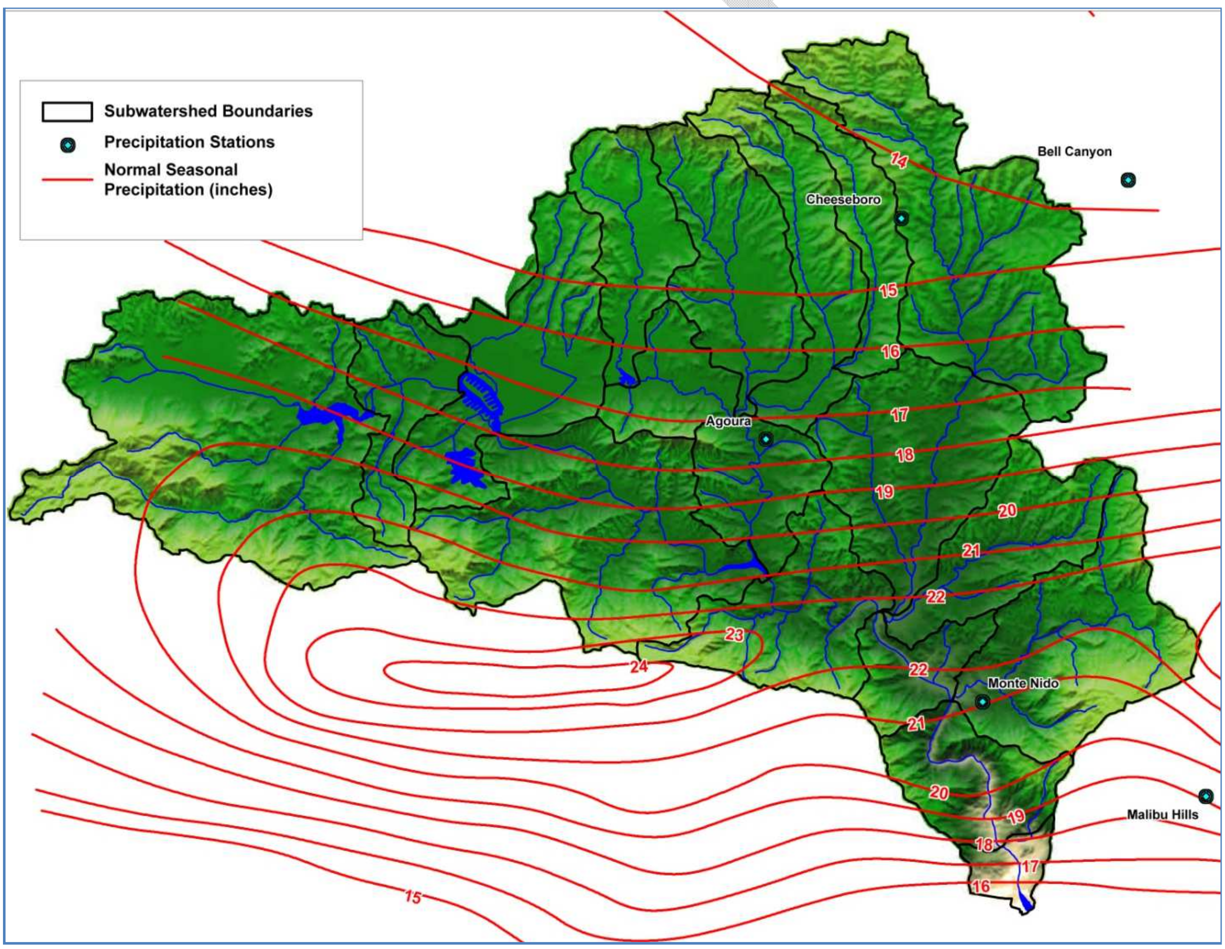

Figure B-1. Long-term Average Rainfall in the Malibu Creek Watershed (Tetra Tech, 2002)

The evaporation rate from open waters such as lakes is about 72 inches per year (NRCS, 1995). These rates vary seasonally with the weather, and range from a low of about 2 to 4 inches per month during January and February to a high of about 8 to 10 inches per month during the summer. Actual evapotranspiration rates vary with vegetation type and density of coverage. Estimated annual evapotranspiration rates in the Malibu Creek watershed are 23 to 24 inches for woodlands and orchards, 17 to 21 inches for chaparral and scrub, 8 inches for grasslands, 14 inches for cultivated areas, and 19 inches for developed areas (NRCS, 1995). The total annual evapotranspiration and evaporation in the watershed has been estimated at about 111,000 ac-ft, or 18.8 inches (NRCS, 1995).

Precipitation intensity in the watershed is strongly influenced by elevation and rainshadow effects. Maps of the 50-year 24-hour storm depth (LACDPW, 2006) show lower intensities at the coast and in the inland valleys, with maximum intensities (up to 10 inches in 24 hours) along the peak of the Santa Monica Mountains (Figure B-2).

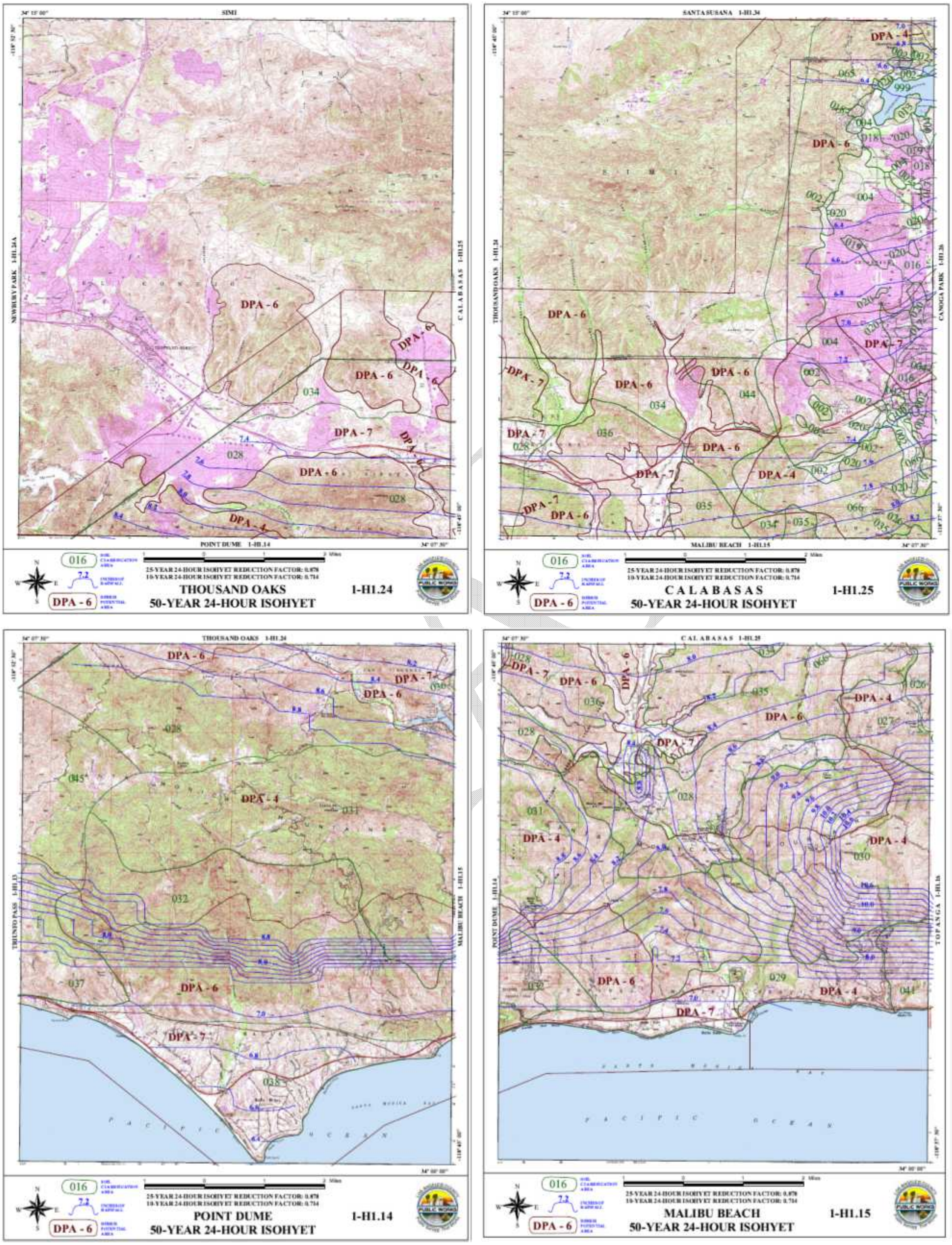

Figure B-2. 50-yr 24-hr Precipitation Depths for Malibu Creek Watershed

B.2 Temporal Trends

Climate is not constant from year to year. In addition to random variability and potential long-term trends (e.g., global climate warming), the climate of southern California is also influenced by strong decadal scale oscillations. It is typical to experience a series of very wet seasons followed by extremely dry seasons. This significantly influences sediment transport regimes and habitat condition. Further, biological condition observed in a given year may in part reflect timing relative to these longer-period cycles. Research on weather patterns in the watershed by Farnsworth and Warrick (2007) showed that stream flow discharges during the warm phases of the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) in southern California watersheds are two-fold higher compared to the cool phases.

Of particular note, in the late 1970s the PDO switched from a cold to a warm cycle (Figure B-3) which would result in more intense El Niños and a general pattern of increased rainfall (Mantua, 2009). Long-term trends in annual precipitation for Los Angeles County as summarized by the PRISM system (Daly et al., 2008) are shown in Figure B-4.

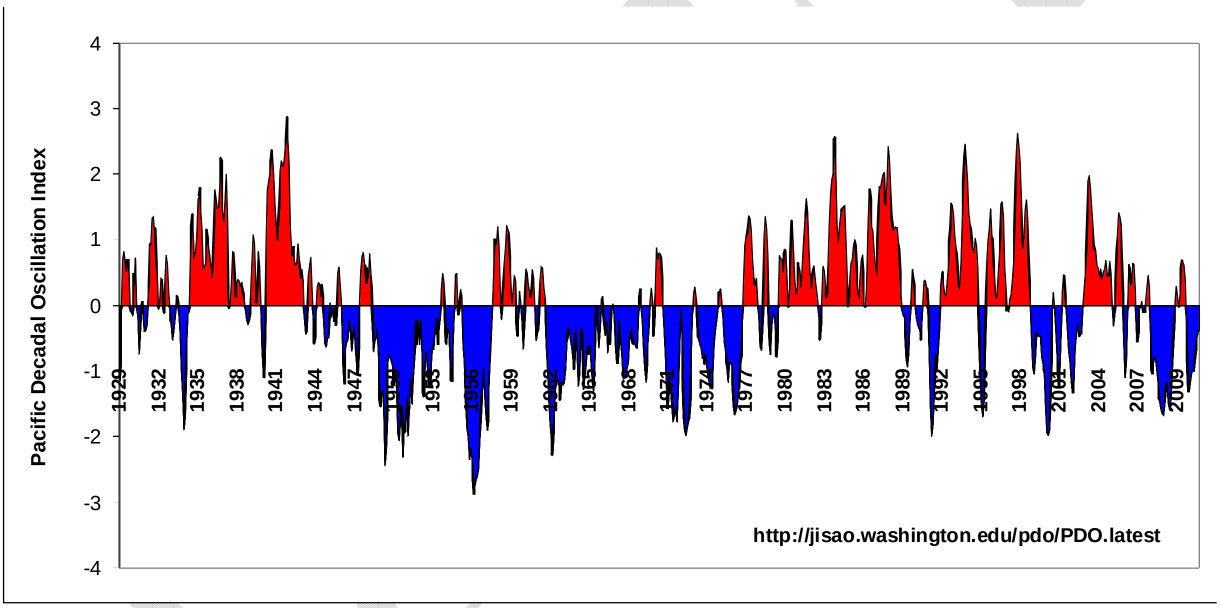

Figure B-3. Pacific Decadal Oscillation Index

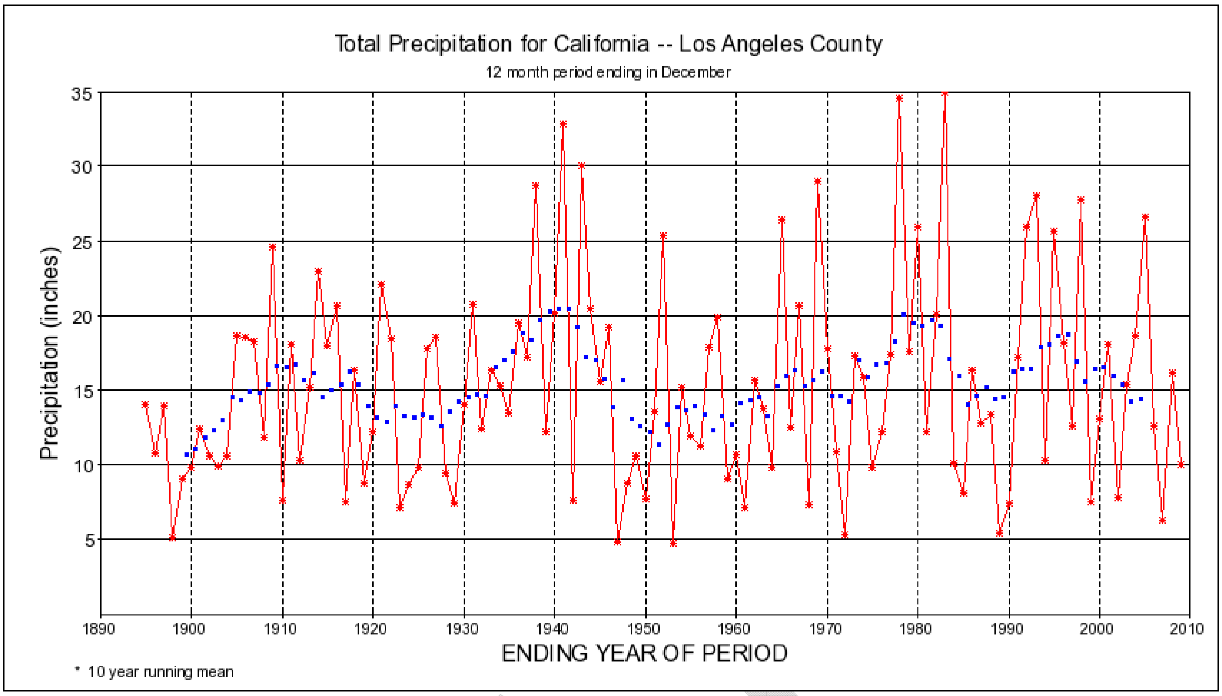

Figure B-4. PRISM Summary of Annual Precipitation for Los Angeles County

Note: Image from WestMap (http://www.cefa.dri.edu/Westmap/Westmap_home.php)

B.3 Fire History and Conditions

Major fires in the watershed were identified for each year from 1949 to the present as well as those affecting the proposed reference sites at LCH-18 and SC-14. These major fires are shown in Table B-1 and spatially in Figure B-5 through B-16 below.

Table B-1. Major Fire Events within Malibu Creek Watershed (1949 to 2009, >1,500 acres in year)

Year	Date	Fire Name	Fire Area in Watershed (acres)	Total Fire Area (acres)
1949	07/31/1949	REINDL NO. 78	2	231
	10/31/1949	SIMI HILLS	12,201	20,579
1956	12/27/1956	HUME FIRE	60	2,194
	12/28/1956	SHERWOOD/ZUMA	4,070	35,170
1958	11/28/1958		3,562	4,240
	12/02/1958		6,168	18,120
1967	10/15/1967	DEVONSHIRE-PARKER	7,606	23,094

Year	Date	Fire Name	Fire Area in Watershed (acres)	Total Fire Area (acres)
	10/16/1967	ROUND MEADOW FIRE	0	100
	10/30/1967	LATIGO FIRE	0[1]	2,869
1970	09/05/1970		12	12
	09/17/1970		47	47
	09/25/1970	CLAMPITT FIRE	13,448	115,537
	09/25/1970	WRIGHT FIRE	16,462	28,202
1978	07/03/1978		6	6
	08/09/1978		5	5
	09/22/1978		38	38
	10/23/1978	KANAN FIRE	10,562	25,589
1982	09/07/1982	HIGHLANDS FIRE	25	188
	10/08/1982	HALL	352	2,648
	10/09/1982	DAYTON CANYON FIRE	29,733	43,097
1985	06/30/1985	SHERWOOD FIRE	2,496	3,795
	07/12/1985	MULHOLLAND FIRE	66	66
	10/14/1985	PARK FIRE	156	156
	10/14/1985	DECKER FIRE	0[2]	6,567
	N/A	PIUMA	2,169	5,391
1993	09/27/1993	MALIBU FIRE 15 AC	14	14
	10/26/1993	GREEN MEADOWS	4,522	38,479
	10/28/1993	CHEESEBORO	845	845
	11/02/1993	OLD TOPANGA FIRE	4,927	16,468
1996	10/21/1996	CALABASAS FIRE	7,629	12,513
2005	09/28/2005	TOPANGA	9,748	23,396
2007	01/22/2007	FOOTHILL	55	56
	10/21/2007	CANYON	1,813	3,839

Year	Date	Fire Name	Fire Area in Watershed (acres)	Total Fire Area (acres)
	11/24/2007	CORRAL	19	4,708

Notes:

[1] Fire not in watershed but affected Reference Site HtB-SC-14

[2] Fire not in watershed but affected Reference Site HtB-LCH-18

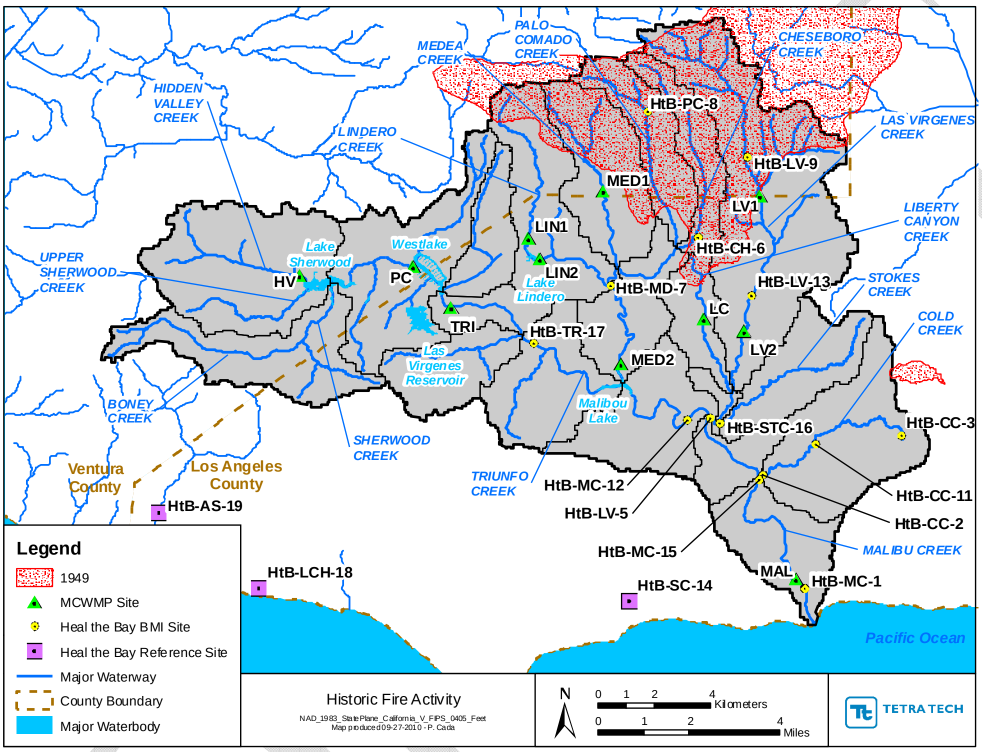

Figure B-5. Major Fire Activity Affecting Malibu Creek Watershed – 1949

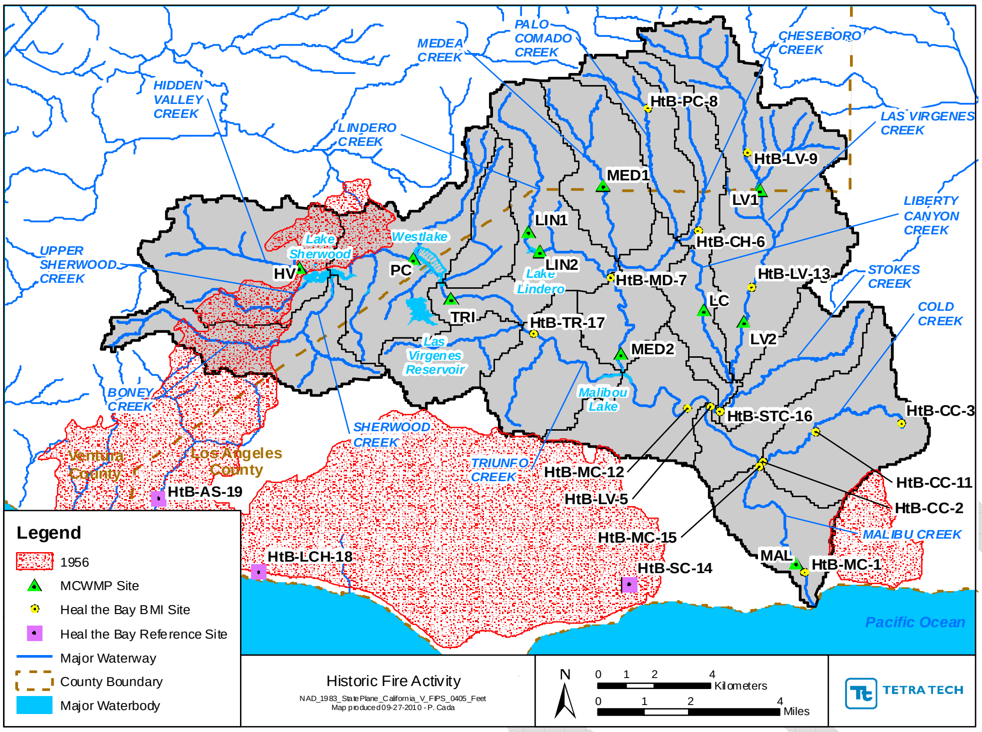

Figure B-6. Major Fire Activity Affecting Malibu Creek Watershed – 1956

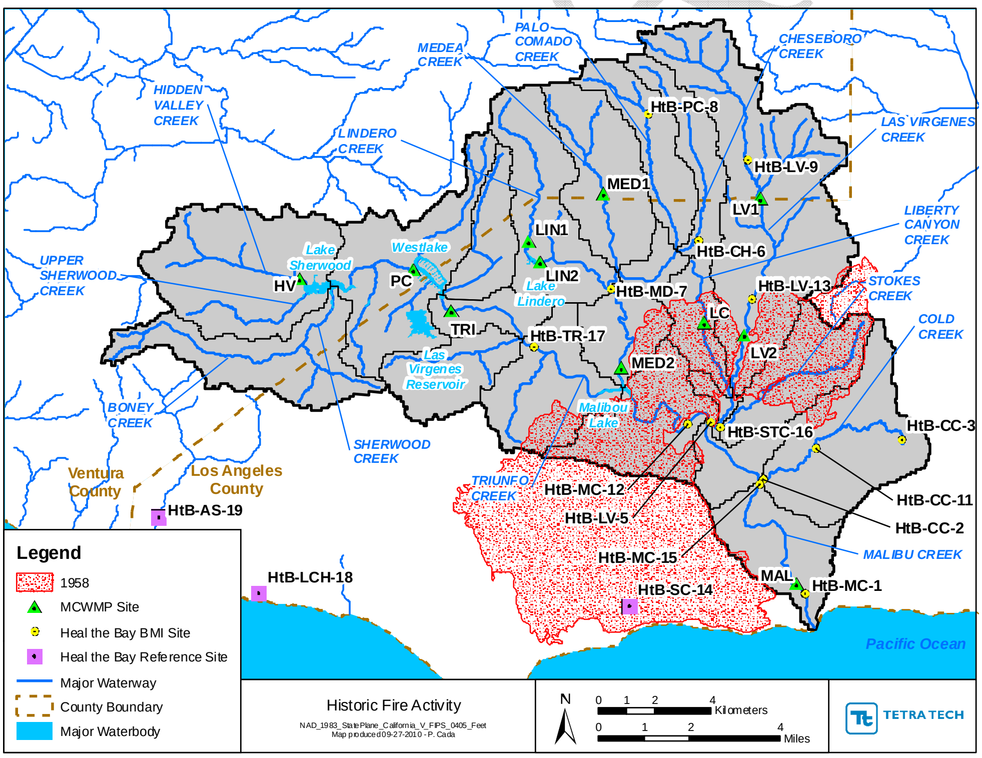

Figure B-7. Major Fire Activity Affecting Malibu Creek Watershed – 1958

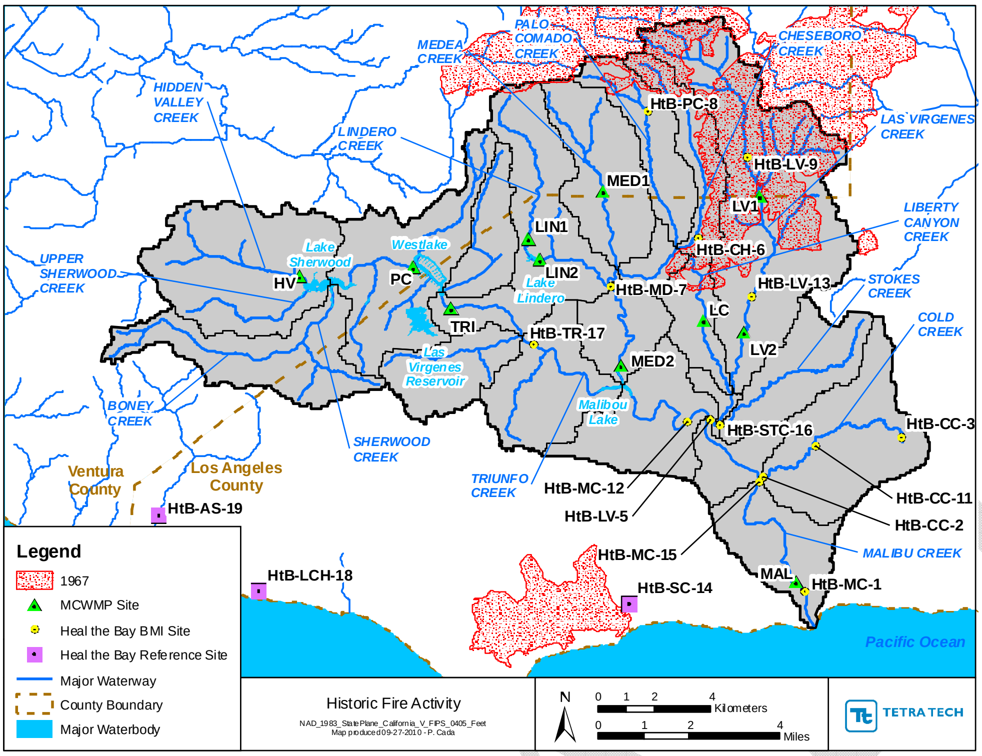

Figure B-8. Major Fire Activity Affecting Malibu Creek Watershed – 1967

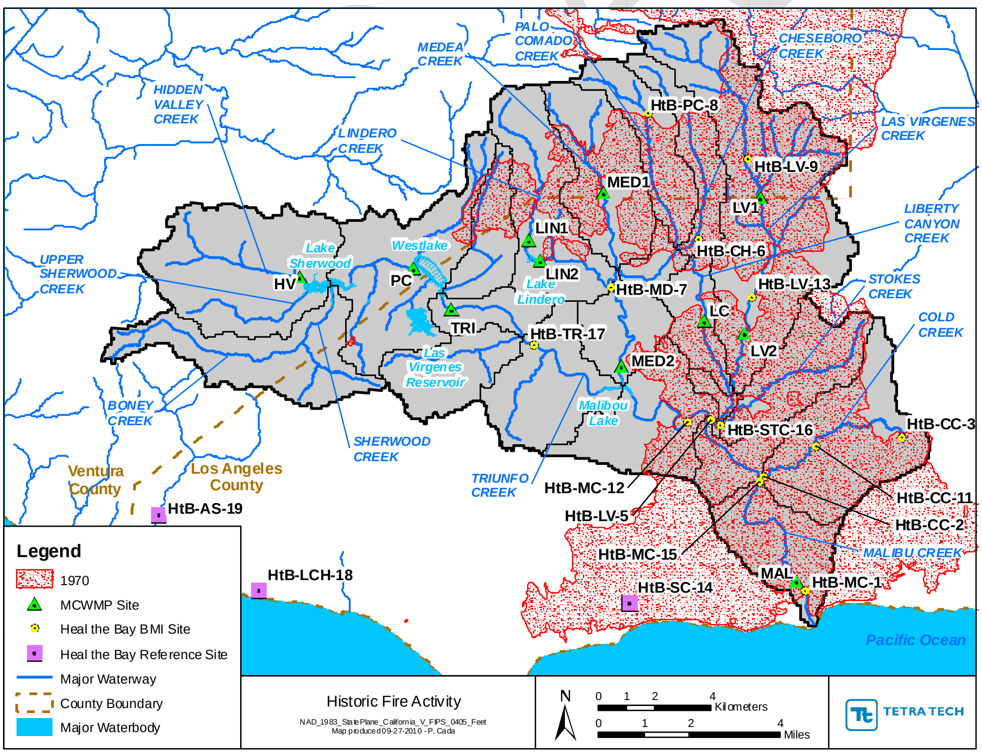

Figure B-9. Major Fire Activity Affecting Malibu Creek Watershed – 1970

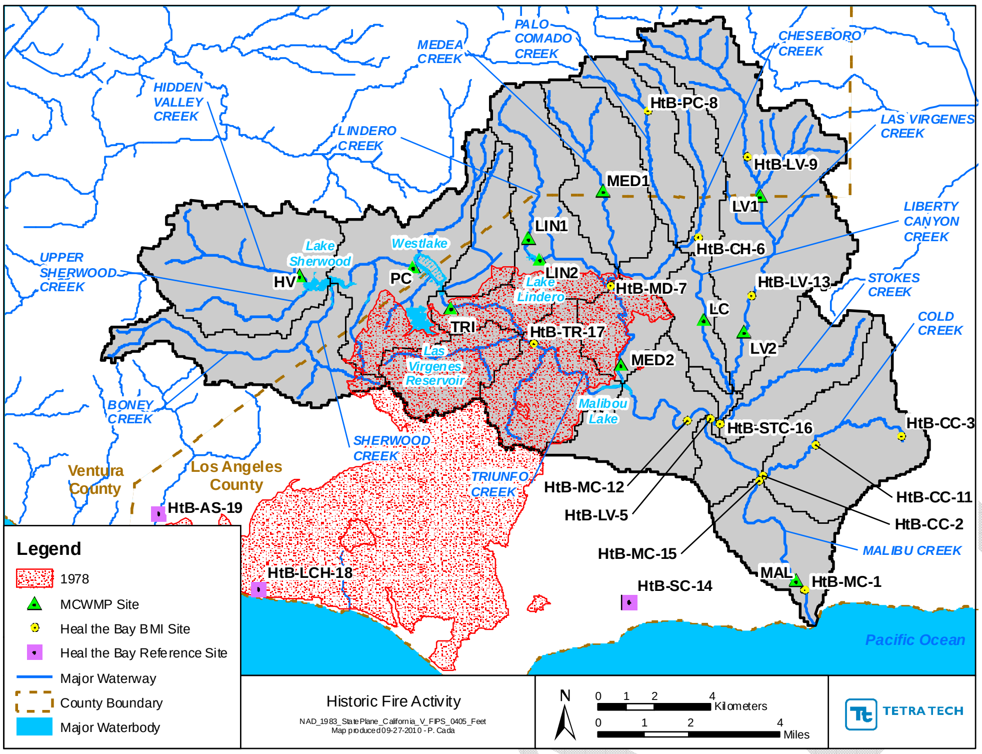

Figure B-10. Major Fire Activity Affecting Malibu Creek Watershed – 1978

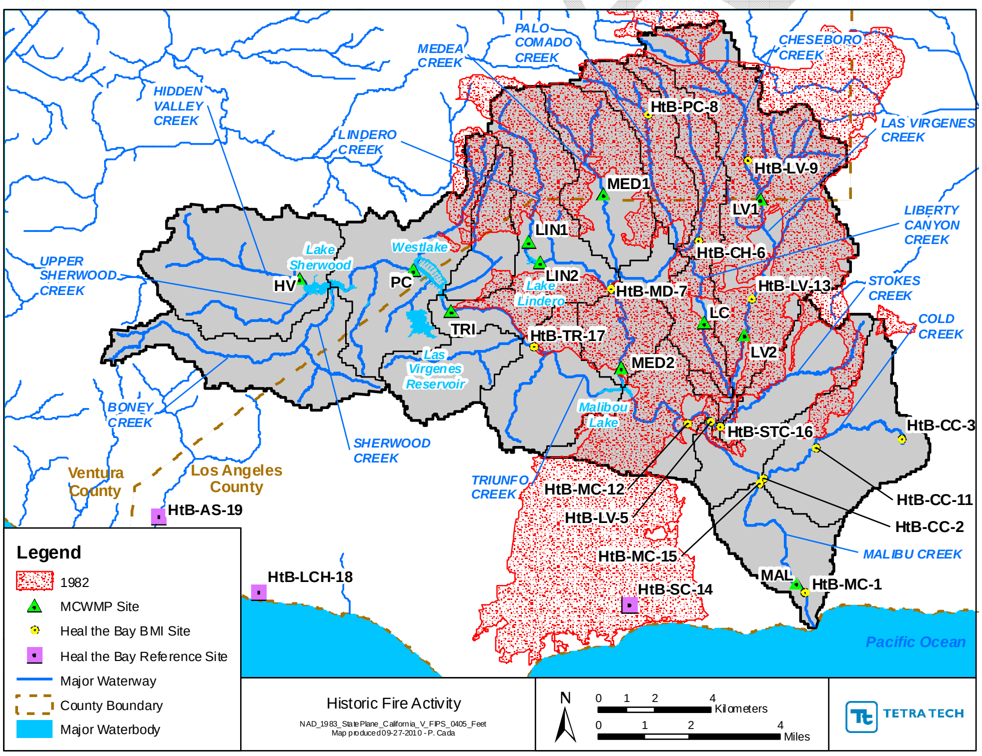

Figure B-11. Major Fire Activity Affecting Malibu Creek Watershed – 1982

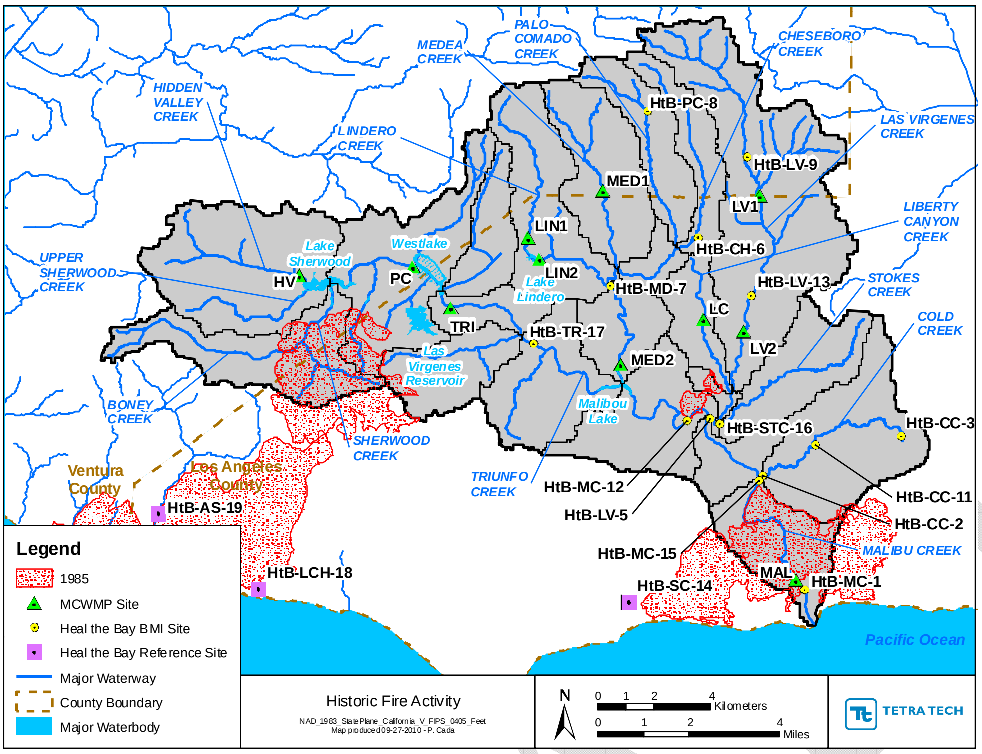

Figure B-12. Major Fire Activity Affecting Malibu Creek Watershed – 1985

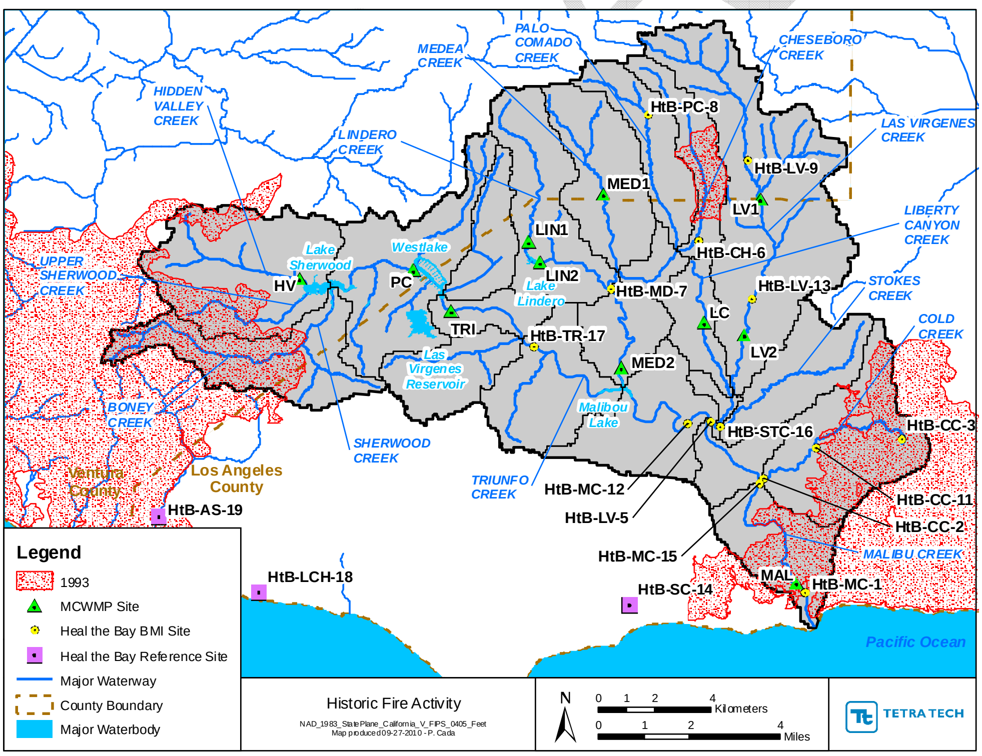

Figure B-13. Major Fire Activity Affecting Malibu Creek Watershed – 1993

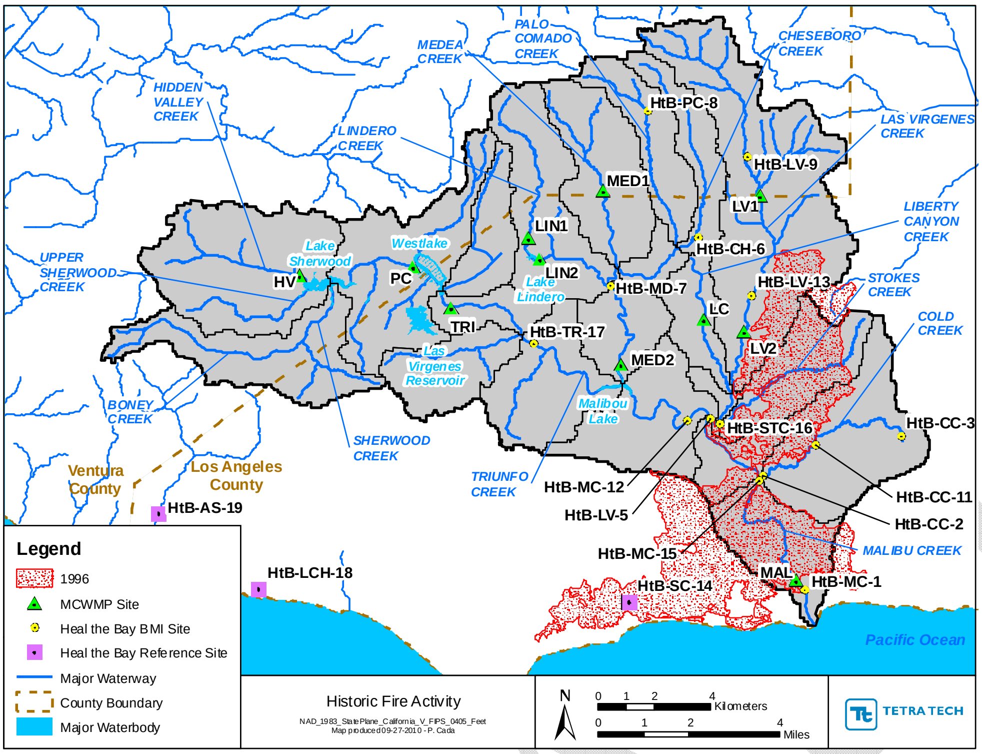

Figure B-14. Major Fire Activity Affecting Malibu Creek Watershed – 1996

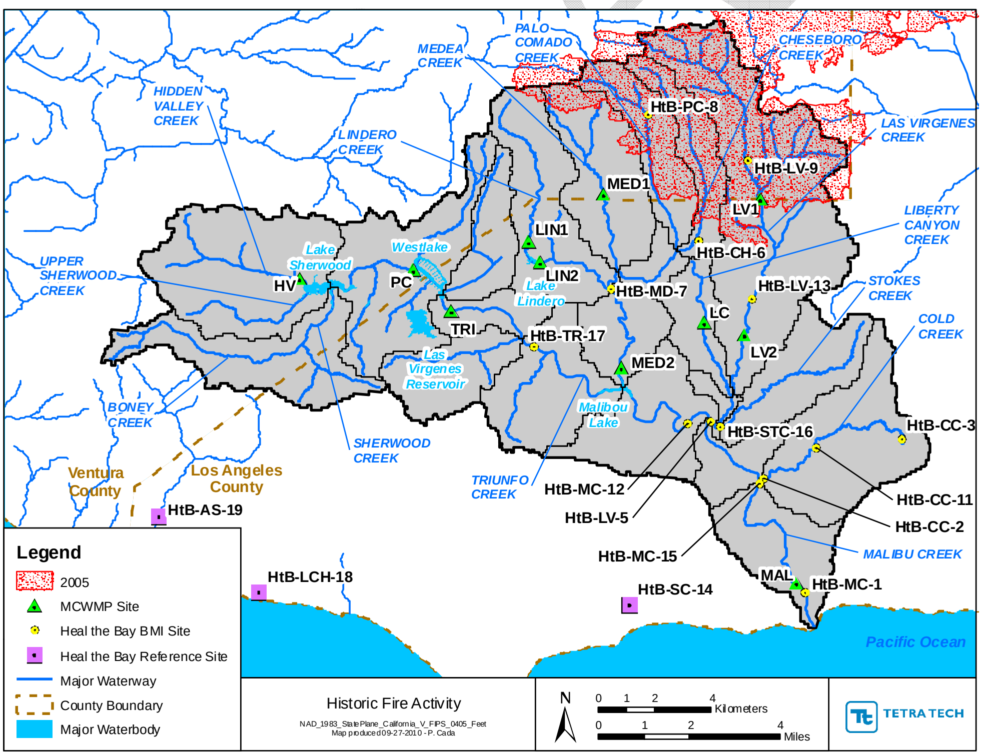

Figure B-15. Major Fire Activity Affecting Malibu Creek Watershed – 2005

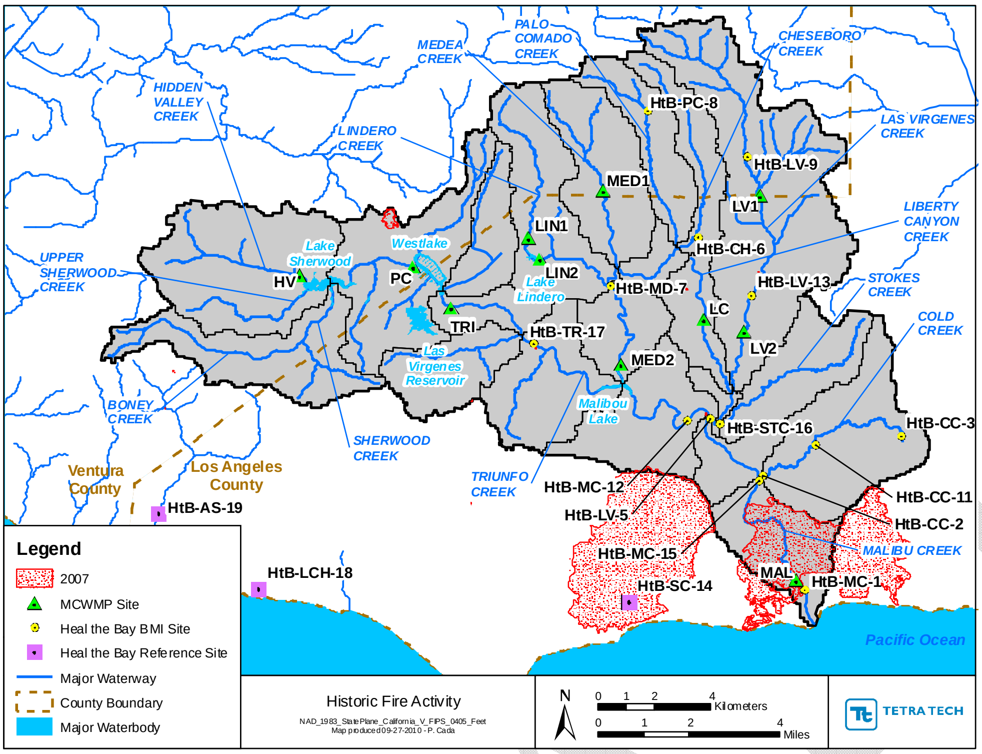

Figure B-16. Major Fire Activity Affecting Malibu Creek Watershed – 2007

Appendix C. IHA Reference Information

Specific ecosystem influences associated with each of the IHA parameter groups are shown in Table C-1 below.

Table C-C. Interpretation of IHA Flow Metrics (Nature Conservancy, 2007)

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influences
1. Magnitude of monthly water conditions	Mean or median value for each calendar month Subtotal 12 parameters	Habitat availability for aquatic organisms Soil moisture availability for plants Availability of water for terrestrial animals Availability of food/cover for fur-bearing mammals Reliability of water supplies for terrestrial animals Access by predators to nesting sites Influences water temperature, oxygen levels, photosynthesis in water column
2. Magnitude and duration of annual extreme water conditions	Annual minima – 1-day mean Annual minima – 3-day mean Annual minima – 7-day mean Annual minima – 30-day mean Annual minima – 90-day mean Annual maxima – 1-day mean Annual maxima – 3-day mean Annual maxima – 7-day mean Annual maxima – 30-day mean Annual maxima – 90-day mean Number of zero-flow days Base flow index: 7-day minimum flow/mean flow for year Subtotal 12 parameters	Balance of competitive, ruderal, and stress-tolerant organisms Creation of sites for plan colonization Structuring of aquatic ecosystems by abiotic vs. biotic factors Structuring of river channel morphology and physical habitat conditions Soil moisture stress in plants Dehydration in animals Anaerobic stress in plants Volume of nutrient exchanges between rivers and floodplains Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments Distributions of plant communities in lakes, ponds, floodplains Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
3. Timing of annual extreme water conditions	Julian date of each annual 1-day maximum Julian date of each annual 1-day minimum	Compatibility with life cycles of organisms Predictability/avoidability of stress for organisms Access to special habitats during reproduction or to avoid predation

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influences
	Subtotal 2 parameters	Spawning cues for migratory fish Evolution of life history strategies, behavioral mechanisms
4. Frequency and duration of high and low pulses	Number of low pulses within each water year Mean or median duration of low pulses Number of high pulses within each water year Mean or median duration of high pulses (days) Subtotal 4 parameters	Frequency and magnitude of soil moisture stress for plants Frequency and duration of anaerobic stress for plants Availability of floodplain habitats for aquatic organisms Nutrient and organic matter exchanges between river and floodplain Soil mineral availability Access for waterbirds to feeding, resting, reproduction sites Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
5. Rate and frequency of water condition changes	Rise rates: Mean or median of all positive differences between consecutive daily values Fall rates: Mean or median of all negative differences between consecutive daily values Number of hydrologic reversals Subtotal 3 parameters Grand Total: 33 parameters	Drought stress on plants (falling levels) Entrapment of organisms on islands, floodplains (rising levels) Desiccation stress on low-mobility streamedge (varial zone) organisms

The IHA guide to interpret EFC statistics is shown in Table C-2 below.

Table C-1. Interpretation of IHA Environmental Flow Components

EFC Type	Hydrologic Parameters	Ecosystem Influences
1. Monthly low flows	Mean or median values of low flows during each calendar month *Subtotal 12 parameters*	• Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)
2. Extreme low flows	Frequency of extreme low flows during each water year or season Mean or median values of extreme low flow event • Duration (days) • Peak flow (minimum flow during event) • Timing (Julian date of peak flow) *Subtotal 4 parameters*	• Enable recruitment of certain floodplain plant species • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
3. High flow pulses	Frequency of high flow pulses during each water year or season Mean or median values of high flow pulse event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters*	• Shape physical character of river channel, including pools, riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries
4. Small floods	Frequency of small floods during each water year or season Mean or median values of small	Applies to small and large floods: • Provide migration and spawning cures for fish

EFC Type	Hydrologic Parameters	Ecosystem Influences
	flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates Subtotal 6 parameters	• Trigger new phase in life cycle (i.e., insects) • Enable fish to spawn in floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain
5. Large floods	Frequency of large floods during each water year or season Mean or median values of large flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters* **Grand Total: 34 parameters**	Applies to small and large floods: • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

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Appendix D. O/E Analyses

D.1 Construction of an O/E Model

The predictive bioassessment approach used to create O/E models is based on the River InVertebrate Prediction And Classification System (RIVPACS) approach (Wright, 2000). RIVPACS, developed as one bioassessment model for Britain, and AUSRIVAS (AUStralian RIVer Assessment System) are methods of bioassessment that predict an expected invertebrate community in a stream based on physical features of the stream reach and surrounding landscape (Wright et al., 1984; Furse et al., 1984; Moss et al., 1987; Marchant et al., 1995; Wright, 1995; Davies, 2000; Simpson and Norris, 2000; Wright, 2000). These assessment models compare the observed number of invertebrate taxa at a test site to the number expected in the absence of human disturbance (Observed:Expected; O/E) and assess biological condition based on a significant departure from 1.0 (where the observed Observed = Expected). The observed number of taxa is found using standard sampling methods, whereas the expected number is predicted using a model based on reference (minimally/least disturbed) sites from across the sampling region. The approach is based on the concept that any site would most likely have those taxa commonly found at physically similar reference sites. In essence, one constructs a site-specific reference condition for each test site that is the most probable number of invertebrate taxa expected under reference conditions. The expected number of taxa is conceptually a weighted average of taxa frequencies in different groups of biologically similar reference sites, where the weights are the probability a site belongs in a particular group of reference sites based on its physical similarity to them; taxa frequencies from reference sites that are physically very similar to a test site are weighted most. The approach has been applied successfully in the UK and Australia and in several US states (Wright et al., 1993; Hawkins et al., 2000; Paul et al., 2002).

O/E-type model development proceeds in three main steps (Figure D-1): 1) a cluster analysis of reference sites to identify reference groups of similar taxonomic composition, 2) a predictive modeling step using physical variables to estimate the probability a test site belongs to each of the reference community groups created in step (1), and 3) the prediction of the number of taxa at test sites based on group membership probabilities (2) and the frequency of taxa occurrence in each reference group (1).

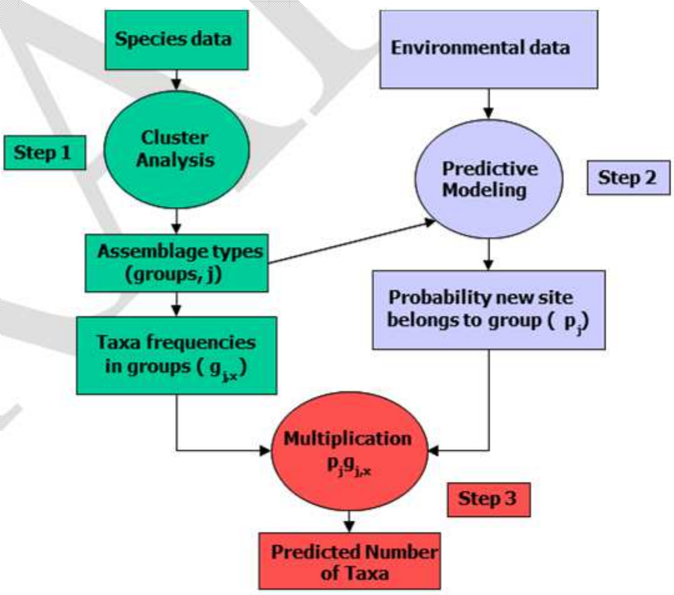

Figure D-1. Schematic showing the three main steps involved in building RIVPACS-type bioassessment models.

The modeling description above is generic to O/E models, but specific models use some variations in the choice of clustering algorithms, predictive modeling and predictors, and taxonomic resolution. The models used for the first O/E calculations in California were based on early O/E models (see Ode et al., 2008), but California is in the process of updating these with newer O/E models that are to be combined with hybrid IBI models to generate a new California Stream Condition Index for use in biological assessment. For this first generation model, however, California generated raw taxa count data from their samples and standardized the taxonomy by operational taxonomic units to resolve taxonomic ambiguities (e.g., samples with individuals identified to different taxonomic resolution, which need to be resolved for O/E modeling). Samples were rarefied to 300 individuals following removal of ambiguous individuals (Ode et al., 2008). California selected least disturbed reference sites (in accordance with Stoddard et al., 2006) from their database of sample data based on a variety of site and watershed characteristics (e.g., Ode et al., 2008). This reference site population was used to generate 3 California O/E models, one of which was applicable to the Malibu Creek Watershed (California Model 2 modified from that in Ode et al., 2008), but all three of which were developed using the process described above. California then used standard cluster analytical methods for Step 1, to generate reference assemblage groups for the O/E model applied here (see Ode et al., 2008). Once these cluster groups of reference sites were identified, frequencies of taxa found across reference sites were calculated ($g_{j,x}$ in Figure D-1 above). The next step (2) was building predictive models to predict the probability with which a new site belongs to one of the reference groups.

O/E predictive models are built using predictor variables considered relatively invariant to human disturbance (Wright et al., 1984; Hawkins et al., 2000; Wright, 2000). Using established biogeographic factors that are minimally affected by human activity, it is possible to predict the expected taxonomic composition for altered streams. If alterable variables were used (e.g., nutrient concentrations, conductivity, forest cover), it would be difficult to discriminate the natural gradient from that caused by human activity, and confident prediction of an expected community in the absence of human disturbance for a test site would be impossible. The final predictors used in the California O/E model used here were mean annual precipitation, watershed percent sedimentary geology, and longitude.

A variety of predictive modeling approaches exist. Traditionally, discriminant function models were used to predict group membership, but more recently, all subsets and random forest models have been used. The goal of predictive modeling is to generate a probability with which a site belongs to each of the reference cluster groups generated by the cluster analysis. This probability is generated using environmental predictor variables available for each site. Discriminant function analysis and random forests are techniques used when one has an existing grouping structure and wants to develop a model to predict the group membership of a new observation (Legendre and Legendre, 1998). In some applications, one only wants to know into which one group to assign a site. But in the O/E approach, the object is to generate the probability with which a new site belongs to each of the cluster groups. When a non-reference site has physical characteristics that resemble a mixture of a few different reference groups (e.g., along an ecotone), one would expect to find a mixture of the most common taxa found in each of those different groups. The degree of mixture is generated using probabilities derived from the predictive modeling.

As described, the actual goal of the predictive modeling is to generate the probability with which each site belongs to each reference group. The cluster analysis was used to break the continuous distribution of communities into discrete pieces and the predictive modeling uses the physical characteristics of those groups, in a sense, to place a site back along that continuous gradient. In discriminant analysis, the membership probabilities can be generated using the Mehalanobis distance. The Mehalanobis distance is a multivariate distance measure. It is the distance from any one site to the centroid (a multivariate average) of each of the different groups in multivariate space and is calculated as:

$$D^2 = \overline{d_j} V^{-1} \overline{d_j}'$$

where D^2 is the squared Mehalanobis distance, $\overline{d_j}$ is a vector of the distances of each predictor between a site and the mean predictor value for group j ($\overline{d_j}'$ is its transpose) and V^{-1} is the inverted covariance matrix of predictors. Other predictive methods use similar approaches.

The probability a site belongs in each group is derived from those distances – the closer a site is to one centroid, the higher the probability it belongs to that group. These probabilities can be calculated using the formula:

$$p_j = q_j / \sum_{j=1}^{k} q_j \ ,$$

where p_j is the probability a site belongs to group j (of k different groups). The value q_j is a weighted distance measure and is defined as:

$$q_j = n_j \times e^{\left(\frac{-d_j^{\,2}}{2}\right)},$$

where n_j is the number of sites in group j and d_j^2 is the squared Mehalanobis distance between the site score and each group mean discriminant function score (Moss et al., 1987). These probabilities are the important outcome of the discriminant function analysis approach to predictive modeling. These probabilities are combined with taxa frequencies in each group to predict the final taxonomic composition of a site.

The next calculation is to generate a set of per taxon capture probabilities (P_c). As mentioned all along, the predicted taxa list for a site is not only based on the taxa composition of the one reference group to which a site is most similar. If that were the case, one could simply find the group to which the site had the highest probability of belonging and compare the observed community to the average community composition of that one group. If all test sites looked exactly like only one reference group, this would be fine. But sites are often physically similar to several groups, since the groupings frequently reflect very subtle differences among reference sites (e.g., low gradient vs. high gradient reaches within one basin). Therefore, this approach predicts a mixture of taxa based on 1) which reference groups a site is most similar to and 2) which taxa are most frequently found in those groups. The P_c, therefore, is a weighted average expected taxon frequency for a site. It weights the per taxon frequencies in each reference group by the probability a site belongs to each of those groups. For example, common taxa from groups to which a site is most similar would have the highest probability of being captured.

In order to do this, the frequency of each taxon in each reference group needs to be calculated. This is done by calculating the frequency with which each taxon is found in each reference group; $g_{j,x}$ = proportion of reference sites in group j containing taxon x. This value is calculated for each taxon in the master taxa list (over all reference sites). In the end, each taxon has a frequency with which it occurs in each reference group. Many taxa from the master list are not found in every group; therefore, they will have a frequency of zero where they are absent; others are ubiquitous and have a value near 1.0 for every reference group.

Now that the probability of membership of any site in each reference group (p_j) from the predictive model and the frequency of every taxon x in each reference group ($g_{j,x}$) have been calculated, the probability of capturing (P_c) each taxon x at any site can be estimated using the equation:

$$P_{c,x} = \sum_{j=1}^{k} p_j \times g_{j,x}$$, for k reference groups.

Note that each probability of capturing a taxon is a continuous probability and not a discrete number. It is derived from the probability of group membership and the distribution of taxa frequencies. The expected number of taxa (E), then, is the sum of the capture probabilities of all the taxa at a site:

$$\mathrm{E} = \sum_{x=1}^{i} P_{c_x} \ .$$

This total can be the sum of all taxa, but it is common to only sum taxa with a capture probability greater than 0.01 (most taxa) or 0.5 (common taxa).

In standard O/E assessment models, E is then compared to the observed taxa richness (O) to generate and O/E score – or the percent of expected taxa found at a site. O/E scores are calculated for reference sites used to build the model, since model diagnostics are based on the distribution of O/E scores for reference sites and not on E alone.

There are a number of potential predictive models that can be developed using any set of predictors, and model selection is, obviously, critical. One option is to use stepwise discriminant analysis, but this can lead to locally solved and/or over-fit models. Another option is to explore the subset of all possible predictor combinations. An all-subsets routine was developed in the R programming language and can be used to identify best performing models (Van Sickle et al., 2006). The all-subsets program routine explores all possible predictor combinations and evaluates the 5 best models of each predictor order (1 predictor, 2 predictor, etc.) based on their discrimination of the reference groups using Wilks' lambda, a measure of model discrimination. The program also calculates an O/E score using observed data, and calculates a number of model diagnostics: the standard deviation of O/E among sites, the standard deviation of replicate sampling (a measure of the best possible model; Van Sickle et al., 2006), a null model O/E score (which calculates E as the average taxon frequency among all reference sites ignoring classification and discriminant models; Van Sickle et al., 2005), and evaluates the extent of model over-fitting by comparing re-substituted and cross-validated model classification efficiencies. Still other models may use a random forests modeling routine in classification mode to generate membership probability functions.

Whatever the modeling approach used, the outcome is a function that predicts the probability with which a site belongs to any of the reference groups (p_j) that is then combined with reference group taxa frequencies to predict the capture probability of each taxon, which are ultimately summed for a site to generate E, as explained above, which is combined with the observed number of the same taxa to calculate O/E.

D.2 The California Stream Condition Index: Future Bioassessment

For this analysis, USEPA relied on the previously established Southern California IBI, developed by California for the purposes of assessing biological condition, and a version of an early O/E model developed by California (Ode et al., 2008) and available on the Western Bioassessment Center webpage (http://www.cnr.usu.edu/wmc) to explore additional biological indicator tools. These were the two most comprehensive and applicable tools available to USEPA at the time.

USEPA is, however, aware that California is in the process of refining its bioassessment models and developing new tools to be used for evaluating biological condition and setting biological objectives. The new tools consists of a hybrid IBI and improved O/E model.

USEPA understands that the hybrid IBI consists of metrics calculated from invertebrate samples for which an expected value for any site is calculated based on physical variables. In much the same way an O/E model uses physical predictors to generate a continuous probability that a site belongs to a specific reference group, the hybrid IBI will use physical predictors to generate a model to predict the metric value for any site that should exist in the absence of disturbance. This prediction is built with least/minimally disturbed reference sites only. The score for that metric will then be based on comparison to the predicted value and metrics will be selected based on stressor responsiveness, as well as lack of redundancy with other metrics. The various metric scores will then combined as in a traditional metric, but then standardized to the reference site means to scale the score between 0-1, for comparability with O/E scores.

The improved O/E is simply intended to be an improvement on the various iterations of the O/E models that have been developing in California over the last 5 years. The final improved O/E will generate a score from 0-1 for any site.

The California Stream Condition Index (CSCI) score will then be the average of the two indices: the hybrid IBI and the O/E and will be between 0 and 1.

These models are apparently being finalized but are, at the time of this writing, not available for general application. USEPA, however, reserves the option to apply the new CSCI calculations to the Malibu Study samples when the models are available for use in analysis.

D.3 O/E Calculated Data

The O/E calculated results for Malibu are presented below in Table D-1.

Table D-1. Table of samples (Site_Date) with resulting O/E scores for two capture probability levels (p>0 and p>0.5), whether the model was in the experience of the model (Model Test = P), number of individuals modeled (ind.), and the IBI score.

Note: Individuals from disparate samples were rarefied to a basis of 300 individuals or less.

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
AS19_20011001	Arroyo Sequit	0.60	0.87	P	300	70
AS19_20020401	Arroyo Sequit	1.13	0.87	P	300	72
AS19_20021001	Arroyo Sequit	1.01	0.87	P	300	66
AS19_20030401	Arroyo Sequit	1.24	0.97	P	209	72
AS19_20031001	Arroyo Sequit	1.01	0.97	P	300	70
AS19_20050101	Arroyo Sequit	0.90	0.97	P	300	64
AS19_20060000	Arroyo Sequit	0.90	0.68	P	300	57
AS19_20080000	Arroyo Sequit	1.01	0.68	P	215	49
AS19_20090000	Arroyo Sequit	1.01	0.87	P	300	70
BMI_RWB_404S02920_20090512	Medea Creek Site 2920	0.34	0.21	P	300	22.1
BMI_RWB_404S06456_20090514	Topanga Creek Site 6456	1.04	0.72	P	300	46.4
BMI_RWB_404S11406_20090511	Malibu Creek Site 11406	0.44	0.39	P	300	29.2
BMI_RWB_404S16516_20090518	Medea Creek Site 16516	0.29	0.11	P	300	22.1
BMI_RWB_404S17266_20090519	Las Virgenes Creek Random Site 17266	0.37	0.32	P	300	36.4
BMI_RWB_404S17664_20090520	Las Virgenes Creek Site 17664	0.42	0.22	P	300	26.4
BMI_RWB_404S22464_20090519	Las Virgenes Creek Site 22464	0.21	0.11	P	300	22.1
BMI_RWB_MCM_404S03048_20090513	Lindero Canyon Site 3048	0.34	0.32	P	144	12.1

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
BMI_RWB_MCM_404S05992 _20090512	Medea Creek Site 5992	0.21	0.21	P	300	22.1
BMI_RWB_MCM_404S08040 _20090512	Santa Monica watershed unknown Site 8040	0.25	0.11	P	118	7.8
BMI_RWB_MCM_404S08616 _20090513	Malibu Creek Site 8616	0.23	0.10	P	300	12.1
BMI_RWB_MCM_404S08616 _20090513_DUP	Malibu Creek Site 8616	0.23	0.10	P	300	12.1
CC11_20001001	Cold Creek	0.23	0.19	P	30	46
CC11_20011001	Cold Creek	0.72	0.57	P	300	54
CC11_20020401	Cold Creek	1.10	0.57	P	300	49
CC11_20030401	Cold Creek	0.38	0.47	P	300	40
CC11_20060000	Cold Creek	0.76	0.76	P	300	47
CC11_20090000	Cold Creek	0.98	0.76	P	230	59
CC11A_20010401	Cold Creek	0.83	0.57	P	300	56
CC2_20010401	Cold Creek	0.82	0.68	P	300	46
CC2_20011001	Cold Creek	0.82	0.78	P	293	73
CC2_20020401	Cold Creek	0.98	0.78	P	300	53
CC2_20030401	Cold Creek	0.98	0.88	P	296	44
CC2_20050101	Cold Creek	0.74	0.88	P	300	27
CC2_20050101_DUP	Cold Creek	0.70	0.88	P	300	36
CC2_20060000	Cold Creek	0.82	0.78	P	215	31
CC2_20060000_DUP	Cold Creek	0.94	0.98	P	300	41
CC2_20090000	Cold Creek	0.78	0.68	P	300	27
CC3_20001001	Cold Creek	0.95	0.81	P	300	76
CC3_20010401	Cold Creek	0.91	0.61	P	300	92
CC3_20011001	Cold Creek	1.03	0.92	P	300	76
CC3_20020401	Cold Creek	1.16	0.81	P	300	83
CC3_20021001	Cold Creek	1.11	0.71	P	300	80
CC3_20030401	Cold Creek	1.28	0.71	P	300	84
CC3_20031001	Cold Creek	0.83	0.51	P	300	64
CC3_20050101	Cold Creek	0.70	0.71	P	300	60
CC3_20060000	Cold Creek	0.91	0.71	P	300	73
CC3_20080000	Cold Creek	0.83	0.51	P	300	74
CC3_20090000	Cold Creek	0.91	0.92	P	300	79
CC3_20090000_DUP	Cold Creek	1.32	0.92	P	231	81
CH6_20010401	Cheseboro Creek	0.71	0.54	P	300	59
CH6_20011001	Cheseboro Creek	0.63	0.43	P	300	57
CH6_20020401	Cheseboro Creek	0.67	0.75	P	300	64
CH6_20030401	Cheseboro Creek	0.59	0.54	P	300	49
CH6_20050101	Cheseboro Creek	0.63	0.54	P	285	54

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
CH6_20060000	Cheseboro Creek	0.50	0.54	P	300	43
HTB1_2000523	Malibu Creek	0.36	0.51	P	300	16
HTB10_2000523		0.50	0.58	P	300	57
HTB11_2000523	Cold Creek	0.68	0.57	P	300	54
HTB2_2000523	Cold Creek	0.90	0.88	P	263	36
HTB3_2000523	Cold Creek	0.99	0.71	P	300	80
HTB5_2000523	Las Virgenes Creek	0.39	0.59	P	300	29
HTB7_2000523	Medea Creek,	0.41	0.54	P	300	23
HTB8_2000523	Palo Comado	0.46	0.61	P	300	
HTB9_2000523	Las Virgenes Creek	0.55	0.54	P	300	
HV__MCWMP_20050401	Hidden Valley Creek	0.38	0.23	P	300	
LC18_20031001	Lachusa Creek	0.96	0.71	P	300	61
LC18_20090000	Lachusa Creek	1.04	0.71	P	300	57
LCC18_20030401	Lachusa Creek	1.08	0.71	P	300	54
LCH18_20011001	Lachusa Creek	1.08	0.71	P	300	73
LCH18_20020401	Lachusa Creek	1.20	0.92	P	300	72
LCH18_20021001	Lachusa Creek	1.12	0.82	P	300	76
LCH18_20050101	Lachusa Creek	0.92	0.71	P	300	54
LCH18_20060000	Lachusa Creek	0.60	0.61	P	300	11
LIN1__MCWMP_20050401	Lindero Creek	0.38	0.32	P	112	
LIN1__MCWMP_20051001	Lindero Creek	0.38	0.43	P	300	
LV1__20050401_MCWMP	Las Virgenes Creek	0.63	0.54	P	192	
LV1__MCWMP_20051001	Las Virgenes Creek	0.72	0.54	P	300	
LV13_20050101	Las Virgenes Creek	0.50	0.43	P	300	11
LV13_20060000	Las Virgenes Creek	0.46	0.43	P	300	19
LV13_20090000	Las Virgenes Creek	0.46	0.43	P	241	9
LV2__MCWMP_20051001	Las Virgenes Creek	0.25	0.32	P	300	
LV2_MCWMP_20050401	Las Virgenes Creek	0.46	0.43	P	241	
LV5_20001001	Las Virgenes Creek	0.51	0.68	P	300	34
LV5_20010401	Las Virgenes Creek	0.35	0.49	P	287	33
LV5_20050101	Las Virgenes Creek	0.55	0.68	P	300	17
LV5_20050101_DUP	Las Virgenes Creek	0.55	0.68	P	115	19
LV5_20060000	Las Virgenes Creek	0.43	0.59	P	300	14
LV5_20060000_DUP	Las Virgenes Creek	0.59	0.68	P	300	17
LV5_20090000	Las Virgenes Creek	0.55	0.59	P	300	26
LV5A_20010401	Las Virgenes Creek	0.31	0.39	P	300	21
LV9_20050101	Las Virgenes Creek	0.67	0.65	P	244	34
LV9_20060000	Las Virgenes Creek	0.84	0.65	P	300	34
LV9_20090000	Las Virgenes Creek	0.84	0.43	P	277	41

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
LVC13_20020401	Las Virgenes Creek	0.59	0.54	P	300	26
LVC13_20021001	Las Virgenes Creek	0.55	0.43	P	300	24
LVC13_20030401	Las Virgenes Creek	0.38	0.43	P	300	21
LVC13_20031001	Las Virgenes Creek	0.63	0.54	P	300	27
LVC5_20011001	Las Virgenes Creek	0.66	0.59	P	300	33
LVC5_20020401	Las Virgenes Creek	0.66	0.59	P	300	39
LVC5_20021001	Las Virgenes Creek	0.51	0.68	P	300	26
LVC5_20030401	Las Virgenes Creek	0.66	0.68	P	182	20
LVC5_20031001	Las Virgenes Creek	0.55	0.68	P	300	29
LVC5A_20011001	Las Virgenes Creek	0.66	0.59	P	300	
LVC5A2_20011001	Las Virgenes Creek	0.59	0.68	P	300	40
LVC9_20020401	Las Virgenes Creek	0.97	0.43	P	300	59
LVC9_20021001	Las Virgenes Creek	0.72	0.54	P	300	26
LVC9_20030401	Las Virgenes Creek	0.72	0.54	P	300	46
MAL__MCWMP_20051001	Malibu Creek	0.60	0.58	P	300	
MC1_20001001	Malibu Creek	0.68	0.61	P	300	24
MC1_20011001	Malibu Creek	0.72	0.72	P	300	39
MC1_20020401	Malibu Creek	0.64	0.61	P	300	19
MC1_20030401	Malibu Creek	0.60	0.72	P	300	26
MC1_20031001	Malibu Creek	0.56	0.51	P	300	23
MC1_20050101	Malibu Creek	0.60	0.82	P	300	26
MC1_20060000	Malibu Creek	0.76	0.72	P	300	26
MC1_20080000	Malibu Creek	0.40	0.31	P	300	21
MC1_20090000	Malibu Creek	0.68	0.72	P	135	30
MC1_20110614	Malibu Creek	0.80	0.92	P	300	
MC12_20001001	Malibu Creek	0.72	0.40	P	300	23
MC12_20020401	Malibu Creek	0.53	0.51	P	300	33
MC12_20021001	Malibu Creek	0.68	0.61	P	300	27
MC12_20030401	Malibu Creek	0.46	0.51	P	300	21
MC12_20031001	Malibu Creek	0.72	0.51	P	300	31
MC12_20050101	Malibu Creek	0.53	0.40	P	300	20
MC12_20060000	Malibu Creek	0.46	0.40	P	300	17
MC12_20090000	Malibu Creek	0.49	0.20	P	300	17
MC12A_20010401	Malibu Creek	0.38	0.40	P	300	20
MC12A_20011001	Malibu Creek	0.72	0.51	P	300	37
MC12B_20080000	Malibu Creek	0.61	0.40	P	300	
MC15_20020401	Malibu Creek	0.63	0.62	P	300	40
MC15_20021001	Malibu Creek	0.43	0.51	P	300	24
MC15_20030401	Malibu Creek	0.47	0.62	P	300	34

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
MC15_20031001	Malibu Creek	0.59	0.72	P	300	23
MC15_20060000	Malibu Creek	0.75	0.72	P	244	17
MC15_20090000	Malibu Creek	0.35	0.41	P	300	19
MC1B_20010401	Malibu Creek	0.36	0.41	P	300	26
MC9_20001001	Malibu Creek	0.63	0.72	P	300	33
MC9_20010401	Malibu Creek	0.47	0.62	P	300	24
MC9_20011001	Malibu Creek	0.75	0.72	P	300	43
MD7_20001001	Medea Creek,	0.41	0.54	P	300	26
MD7_20010401	Medea Creek,	0.37	0.43	P	300	19
MD7_20050101	Medea Creek,	0.37	0.43	P	300	14
MD7_20060000	Medea Creek,	0.49	0.32	P	242	16
MD7_20090000	Medea Creek,	0.16	0.11	P	300	19
MDC21_20060000		0.33	0.21	P	112	16
MDC7_20011001	Medea Creek,	0.74	0.64	P	300	34
MDC7_20020401	Medea Creek,	0.45	0.43	P	300	23
MDC7_20030401	Medea Creek,	0.53	0.54	P	300	9
MDC7_20031001	Medea Creek,	0.45	0.43	P	300	9
MED1__20050401_MCWMP	Medea Creek	0.38	0.54	P	300	
MED1__MCWMP_20051001	Medea Creek	0.25	0.21	P	300	
MED2__MCWMP_20050401	Medea Creek	0.24	0.21	P	300	
MED2__MCWMP_20051001	Medea Creek	0.28	0.21	P	300	
PC8_20050101	Palo Comado	0.84	0.71	P	204	40
R1_20060922	Malibu Creek	0.71	0.62	P	300	22.9
R1_20070425	Malibu Creek	0.47	0.62	P	300	8.6
R1_20080428	Malibu Creek	0.27	0.31	P	174	1.4
R1_20090422	Malibu Creek	0.43	0.51	P	300	18.6
R1_20100519	Malibu Creek	0.35	0.51	P	300	19
R11_20061025	Malibu Lagoon	0.08	0.00	P	300	
R11_20070424	Malibu Lagoon	0.28	0.20	P	300	
R11_20080428	Malibu Lagoon	0.12	0.00	P	300	
R11_20090423	Malibu Lagoon	0.16	0.10	P	39	
R11_20100518	Malibu Lagoon	0.20	0.00	P	300	
R13_20060921	Malibu Creek	0.79	0.62	P	300	25.7
R13_20070423	Malibu Creek	0.55	0.51	P	300	31.5
R13_20080428	Malibu Creek	0.35	0.41	P	300	11.4
R13_20090423	Malibu Creek	0.47	0.41	P	300	11.4
R13_20100519	Malibu Creek	0.43	0.21	P	241	27
R2_20060922	Malibu Creek	0.63	0.62	P	300	17.2
R2_20070425	Malibu Creek	0.59	0.72	P	300	15.7

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
R2_20080428	Malibu Creek	0.39	0.41	P	260	8.6
R2_20090422	Malibu Creek	0.35	0.51	P	213	14.3
R2_20100519	Malibu Creek	0.63	0.62	P	291	9
R3_20060921	Malibu Creek	0.64	0.58	P	300	20
R3_20070424	Malibu Creek	0.56	0.39	P	230	8.6
R3_20080428	Malibu Creek	0.48	0.29	P	214	14.3
R3_20090423	Malibu Creek	0.76	0.58	P	300	14.3
R3_20100518	Malibu Creek	0.68	0.58	P	300	13
R4_20060921	Malibu Creek	0.80	0.82	P	300	24.3
R4_20070424	Malibu Creek	0.40	0.41	P	300	5.7
R4_20080428	Malibu Creek	0.64	0.20	P	300	22.9
R4_20090423	Malibu Creek	0.52	0.41	P	300	11.4
R4_20100518	Malibu Creek	0.60	0.61	P	300	23
R7_20060922	Las Virgenes Creek	0.58	0.43	P	300	24.3
R7_20070424	Las Virgenes Creek	0.46	0.75	P	300	12.9
R7_20080428	Las Virgenes Creek	0.21	0.22	P	300	2.9
R7_20090423	Las Virgenes Creek	0.38	0.32	P	300	11.4
R7_20100520	Las Virgenes Creek	0.25	0.22	P	300	14
R9_20070425	Malibu Creek	0.74	0.88	P	300	12.9
R9_20080428	Malibu Creek	0.35	0.39	P	74	2.9
R9_20090422	Malibu Creek	0.35	0.39	P	200	5.7
R9_20100520	Malibu Creek	0.51	0.39	P	300	7
RL1_20060922	Malibu Creek	0.43	0.41	P	300	15.7
RL2_20060922	Malibu Creek	0.39	0.41	P	300	21.5
RL3_20060922	Malibu Creek	0.28	0.10	P	300	1.4
RL4_20060922	Malibu Creek	0.32	0.10	P	71	5.7
SC14_20011001	Solstice Creek	1.13	0.65	P	300	87
SC14_20020401	Solstice Creek	1.17	0.75	P	300	76
SC14_20021001	Solstice Creek	1.09	0.75	P	300	76
SC14_20030401	Solstice Creek	0.85	0.75	P	300	67
SC14_20031001	Solstice Creek	1.01	0.86	P	300	70
SC14_20050101	Solstice Creek	1.05	0.86	P	178	63
SC14_20060000	Solstice Creek	0.81	0.54	P	177	60
SC14_20090000	Solstice Creek	1.30	0.86	P	300	69
SK16_20050101	Stokes Creek	0.58	0.61	P	178	34
STC14_20080000	Stokes Creek	0.93	0.81	P	151	
STC16_20020401	Stokes Creek	0.54	0.61	P	300	34
STC16_20060000	Stokes Creek	0.69	0.61	P	300	51
TC17_20020401	Triunfo Creek	0.73	0.58	P	300	19

Site_Date	Stream	O/E (p>0)	O/E (p>0.5)	MODEL TEST	Ind.	IBI
TC17_20030401	Triunfo Creek	0.31	0.39	P	300	4
TR10_20010401	Triunfo Creek	0.46	0.68	P	300	19
TR17_20050101	Triunfo Creek	0.39	0.29	P	300	0
TR17_20060000	Triunfo Creek	0.77	0.58	P	289	20
TRI__20050401_MCWMP	Trifuno Creek	0.46	0.43	P	300	
TRI__MCWMP_20051001	Trifuno Creek	0.23	0.11	P	300	
WC15_20010401		0.50	0.41	P	244	
WCC10_20030401		0.69	0.49	P	300	51

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Appendix E. Relevant Studies

E.1 Inventory

A number of previous analyses have evaluated water quality stressors and impacts in Malibu Creek and Lagoon. An inventory of identified reports is provided in Table E-1 followed by summaries of a selected subset of key reports.

Table E-1. Previous Analyses of Water Quality and Use Support in Malibu Creek and Lagoon

Author, Date	Report Title	Report Description
Abramson and Grimmer (Heal the Bay), 2005	Fish Migration Barrier Severity and Steelhead Habitat Quality in the Malibu Creek Watershed	Report in which the severity of steelhead trout migration barriers in the Malibu Creek watershed were ranked. Study also rated pool habitat quality to be gained by the removal of each barrier and mapped a total of 201 potential barriers. Report concluded with a list of specific recommendations for removing barriers in the Malibu Creek watershed.
Ackerman et al., 2005	Evaluating HSPF in an arid, urbanized watershed	Paper presenting the findings of a study in which the predictive ability of Hydrologic Simulation Program-FORTRAN (HSPF) on hourly, daily, and annual time scales. Two arid southern California watersheds were selected for the study, one of which was the Malibu Creek watershed. The HSPF model was found to perform well for predicting flow on monthly or annual time scales and on daily time scales during wet weather conditions.
Ambrose and Orme, 2000	Lower Malibu Creek and Lagoon Resource Enhancement and Management	Summary of report is provided in text below.
Ambrose et al., 1995	Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek	Report summarizing a study performed by UCLA from July 1993 through April 1994. The goal of the study was to assess the effects of anthropogenic inputs into Malibu Creek and Lagoon on the physical, chemical and biological processes in the Creek and Lagoon.
Ambrose et al., 2003	Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties	Report detailing a study performed in 2001 to help identify land use factors influencing the abundance of macroalgae and benthic macroinvertebrates within three southern California coastal watersheds. Malibu Creek watershed was one of three watersheds selected for the study. Report presents methods, results, and a discussion of conclusions from the study.
Aquatic Bioassay, 2005	Malibu Creek Watershed Monitoring Program, Bioassessment Monitoring, Spring/Fall 2005	Summary of report is provided in text below.
Badgley et al., 2011	Quantifying environmental reservoir of fecal indicator bacteria associate with sediment and submerged aquatic vegetation	Presence of fecal indicator bacteria (FIB) is used to monitor fecal contamination. Many have also determined that FIB can persist in soils and sediments and is a major concern. Dominant concentrations of enterococci in the system were found in water or sediment (not submerged aquatic vegetation), pending site characteristics and water depth. Concentrations of contaminant vary as a function of depth, but at estuarine sites sediment contained the largest concentrations (rather than water or SAV). Authors suggest additional sampling

Author, Date	Report Title	Report Description
		(especially for TMDLs) to normalize matrix to surface area.
Bay et al., 1996.	Toxicity of Stormwater from Ballona and Malibu Creeks	Paper detailing a study performed to determine the magnitude and characteristics of toxicity in stormwater samples collected during storms in 1996 from Ballona and Malibu creeks. The magnitude of toxicity found in samples collected in Malibu Creek was usually lower than comparable samples from Ballona Creek. The study concluded that the relative toxicities observed for each creek were consistent with differences in land use between the two watersheds as the Malibu Creek watershed has a lower degree of development than the Ballona Creek watershed.
Bay et al., 2003	Temporal and spatial distributions of contaminants in sediments of Santa Monica Bay, California	Paper detailing a study in which sediment strata dated from 1890 to 1997 were sampled at 25 locations within the Santa Monica Bay. Samples were analyzed to examine the temporal and spatial patterns of sediments contaminated with metals, DDTs, PCBs, TOC, PAHs, and LABs. One sampling location was selected to target influence of stormwater runoff from Malibu Creek. Sediments sampled near Malibu Creek were found to contain low concentrations of both DDTs and PCBs.
Biggs and Price, 1987	A survey of filamentous algal proliferations in New Zealand rivers	In the first paper, in the series of algal proliferation studies, the authors describe the behavior of filamentous algae. Filamentous algae affect water quality, clogging, and aesthetic integrity, especially after long periods of low flow.
Biggs, 1990	Periphyton communities and their environments in New Zealand Rivers	Periphyton are most responsive to changes in habitat and are thus excellent indicators of water quality and invertebrate and aesthetic degradation. This paper illustrates how water conductivity, watershed variables, and temperate contribute to the behavior of periphyton communities.
Biggs, 2000	Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae	Paper describing models to predict effects of changes in nutrients on benthic algal biomass in different temperature streams and rivers. Biggs suggests that managing nutrient supply would decrease biomass accrual and reduce benthic algal growth in streams by both frequency and duration. Also indicates a relationship between algal dominance and increasing conductivity.
Brown and Bay, 2005	Organophosphorus pesticides in the Malibu Creek Watershed	Paper presenting a study performed to assess the persistence and magnitude of pesticides in three streams of the Malibu Creek watershed. Water column samples were collected from June 2002 to March 2003 to analyze organophosphorus pesticide contamination and toxicity to *Ceriodaphnia dubia*. Study concluded that the California Department of Fish and Game's acute criterion for organophosphorus pesticides was protective of *C. dubia* survival.

Author, Date	Report Title	Report Description
Busse et al., 2003	A Survey of Algae and Nutrients in the Malibu Creek Watershed	Report presents findings from surveys of algal biomass, cover, and composition conducted in streams within the Malibu Creek watershed in 2001 and 2002. Analyses were also performed to identify principal factors promoting excessive algal growth. Both algal biomass and nutrient concentrations were found to be much lower at undisturbed and rural sites compared to findings at developed sites; therefore, it was concluded that human development affects stream algal communities in the Malibu Creek basin.
Busse et al., 2006	Relationships among nutrients, algae, and land use in urbanized southern California streams	Paper presenting the findings of a study in which algal cover, algal biomass, and physical and chemical factors were surveyed in the Malibu Creek watershed. Nutrient diffuser substrate experiments were also conducted to determine which nutrient was limiting algal growth. Algal biomass was found to increase with urbanization as well as total nitrogen, total phosphorus, and benthic and total chlorophyll concentrations.
Callaway et al., 2009	Technical Memorandum #4, Nitrogen Loads from Wastewater Flowing to Malibu Lagoon are a Significant Source of Impairment to Aquatic Life	Report presents findings from a study performed to quantify cumulative nitrogen loads from onsite wastewater disposal systems in the Malibu Civic Center area to Malibu Lagoon. Results indicated wastewaters transported 30 to 35 lb/day of total nitrogen to the lagoon. All estimates were above TMDL targets established for restoration of the lagoon.
Greenstein et al., 2003	Toxicity assessment of sediment cores from Santa Monica Bay	Paper presenting a study in which sediment cores were sampled at 25 locations within the Santa Monica Bay in 1997 to assess levels of toxicity. Two sample locations were selected near the discharge of Malibu Creek to the bay. Report concluded that toxicity in sediments sampled at these locations was caused by something other than influence from Malibu Creek.
Hibbs and Ellis, 2009	Geologic and Anthropogenic Controls on Selenium and Nitrate Loading to Southern California Streams	Paper presents findings from a study in which selenium concentrations were measured in three watersheds in the Los Angeles Basin. Malibu Creek was found to have elevated selenium concentrations in dry weather surface flows as well as in shallow groundwater. Study also determined the relationship between measured nitrate and selenium concentrations.
Hibbs et al., 2012	Origin of stream flows at the Wildlands Urban Interface, Santa Monica Mountains, CA, U.S.A	Paper studies the transition from intermittent to perennial streams as a response to urbanization in the Santa Monica Mountains. Impairments derive from flow through the City of Calabasas (Nitrates, Selenium, and Organics). Saline signature of groundwater was found to be more responsible for surface water composition than urban runoff (specifically during dry weather conditions). Source flows and nutrient loading are a function of groundwater composition more than urbanization. Removal of riparian vegetation and deepening of channel may contribute more to the shift from intermittent to perennial flows, than specific change of environment.

Author, Date	Report Title	Report Description
Lai, C.P. 2009	Nitrogen mass loading for Malibu Lagoon and review summary of previous studies on mass loadings from OWDS to the Lagoon	A memorandum summarizing previous studies on impact of Nitrogen to Malibu Lagoon. The Stone Report used a groundwater flow model MODFLOW for solute transport analysis along Malibu Creek near Malibu Civic center. The report was then refined to model combination flows, resulting in slightly higher Nitrogen mass loads. Tetra Tech's TMDL modeling report results were also evaluated. From the 3 reports, Lai et al., conclude that the second model is best to determine Nitrogen mass loading to the Lagoon.
Las Virgenes Municipal Water District Tapia Water Reclamation Facility (LVMWD), 2006-2010	Bioassessment monitoring report for the Tapia Water Reclamation Facility	The report details the benthic macroinvertebrate community and metrics for the LVMWD at 8 sampling locations. It also the physica/habitat health and water chemistry of affected systems. Specific details are provided below.
Lim et al., 2006	Concentration, size distribution, and dry deposition rate of particle-associated metals in the Los Angeles region	Paper presenting the findings of a study in which daily average atmospheric concentrations and dry deposition fluxes of particulate metals were measured at 6 urban sites and 1 non-urban site in the Los Angeles region. Malibu Lagoon was identified as the non-urban site.
Los Angeles County Department of Public Works, 2006-2010 Los Angeles County Sanitation District, 1996	Bioassessment monitoring program in Los Angeles County Mineral leaching study Calabasas landfill	The report details the program which serves to assess biological integrity and to detect biological trends and responses to pollution in receiving waters throughout the County. To achieve these goals, the program focuses on the sampling and analysis of freshwater stream benthic macroinvertebrates (BMI). More detail of the report is provided in the section below. This study analyzes background water quality of groundwater from monitoring wells in landfills at the Calabasas landfill in upper Malibu Creek watershed. Rock and soil samples were analyzed for metal, chemical, TOC, pH and other results are presented in the results.
Luce and Abramson, 2005	Periphyton and Nutrients in Malibu Creek	Report summarizing a study performed to compare periphyton cover, nutrient concentrations, and canopy cover between nutrient-enriched and unenriched stream segments. Sites within Malibu Creek and adjacent coastal watersheds were selected and monitored from 1998 to 2002. Report proposed nutrient thresholds that may be useful for managing excess algal growth in Malibu Creek.
Manion, 1993	The Tidewater Goby - Reintroduction of a geographically isolated fish species into Malibu Lagoon: A watershed perspective	Report presenting the findings of a study performed to assess the success of reintroducing the tidewater goby (*Eucyclogobius newberryi*) to the Malibu Lagoon. An additional goal of the study was to describe the human-induced threats to biological diversity within the lagoon's watershed. Results demonstrated successful reintroduction of the tidewater goby and discussed recommendations to alleviate human-induced stressors to the lagoon.

Author, Date	Report Title	Report Description
Meyer et al., 1985	Chemistry and aquatic toxicity of raw oil shale cheachates from Piceance Basin, Colorado	Leachates were collected to analyze the composition from several depths in two surfaces, from raw oil shale. They found that alternate shale compositions produce variable leachate ionic concentrations. They also found that toxic mechanisms cannot always be prescribed to single toxicity values, since often the chemical mixture incorporates a variety of constituents.
Moeller et al., 2003	Elements in fish of Malibu Creek and Malibu Lagoon near Los Angeles, California	Paper presenting findings from a study performed to determine if past wastewater discharges increased metal pollutant loads in fish of Malibu Creek and Malibu Lagoon. In addition to the identification of wetland biota, the study included analyses of organic and inorganic chemicals and viruses. The study concluded that further sampling was necessary to prove effluent pollution.
Moffatt & Nichol, 2005	Malibu Lagoon Restoration Feasibility Study, Final Alternatives Analysis	Summary of report is provided in text below.
Mount et al., 1997	Statistical models to predict the toxicity of major ions to *ceriodaphnia dubia (C. dubia), daphnia magna (D. magna)* and *pimephales promelas* (fathead minnows)	Fresh water toxicity containing high total dissolved solids (TDS) can be dependent on the water's ionic composition. The authors aimed to provide a predictive tool which would attribute specific toxicity to particular ionic solutions using 3 test species. Initial application illustrates significant accuracy for the C.dubia, but overpredicted D.magna and fathead minnow toxicity.
Nezlin et al., 2005	Stormwater runoff plumes observed by SeaWiFS radiometer in the Southern California Bight	Paper detailing a study in which freshwater plumes found in the near-shore zone of the Southern California Bight were analyzed using reflectance data acquired from 1997 - 2003. Study determined the relationship between plume size and freshwater discharge. The Malibu Creek watershed was associated with one of the regions included in the study and findings indicated that watershed land-use, size, and elevation were influential factors regulating the relationship between rainstorms and plumes.
Pond et al., 2008	Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level macroinvertebrate bioassessment tools	The paper details impacts of surface coal mining in the Central Appalachian region and its influence on aquatic life. From the study, evidence illustrates that mining causes a shift in environmental conditions where it exists. The biological stream conditions are significantly altered due to mining activities. The benthic macroinvertebrate communities showed pronounced negative changes in richness, composition, tolerance, and diversity, under mining activities.
Randal Orton, 2012	Diatom as water quality indicators in Malibu Creek, presentation	Orton found that the diatom community is related to the water's high electrical conductance and sulfate concentration. Diatoms are particularly sensitive to the quantity and type of ions in water, which are particularly raised in Malibu Creek for SO4, Mg, PO4, and HCO3. They determined a new species named "fallacia" as potentially endemic to Malibu Cree. Presence of bicarbonate prevents the waters from being acidic, despite their composition.

Author, Date	Report Title	Report Description
Riley et al., 2005	Effects of Urbanization on the Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams	Paper presenting the findings of a study conducted from 2000 to 2002 in which the distribution and abundance of native amphibians and exotic predators was determined. Stream habitat and invertebrate communities were also characterized. Study included 35 streams north of Los Angeles - Lower Malibu Creek served as one of these streams.
Schiff and Bay, 2003	Impacts of stormwater discharges on the nearshore benthic environment of Santa Monica Bay	Paper presenting the findings of a study in which sediment samples collected offshore of Ballona and Malibu creeks were analyzed to examine the effects of stormwater discharges on the benthic marine environment of Santa Monica Bay. Report indicated that changes in sediment texture, organic content, and contamination were observed throughout a gradient of stormwater impact, but no alteration was observed in benthic communities.
Sikich et al.,	State of the Malibu Creek Watershed report: Trends in watershed health	An in depth report on the Malibu Creek watershed, including a complete bioassessment and monitoring, performed annually. A detailed summary is provided below.
Stein and Yoon, 2007	Assessment of water quality concentrations and loads from natural landscapes	The authors assess urban stormwater impacts downstream receiving waters. They found that specific impacts are dependent on time of build-up on land surface. Trace metal concentrations differ based on the point in hydrograph. Peak concentration took place just before peak flow hydrograph. Sections of the report describe particular trace metals, TSS, and FIB results. Authors surmise that geology is most influential in natural water quality. This necessitates an analysis of each geologic setting in order to determine its specific natural background levels of nutrients, algal cover, and biomass.
Sutula et al., 2004	Sediments as a nonpoint source of nutrients to Malibu Lagoon, California (USA), Technical Report #441	Report addressing the refinement of water quality objectives established in the 2003 TMDL for limiting seasonal and/or annual nutrient inputs from the Malibu Creek watershed to the Malibu Lagoon. Among the conclusions of the report is that particulate nitrogen and phosphorus deposited in the lagoon during the wet season provide a significant source of nutrients to the lagoon during the dry season through remobilization as dissolved inorganic nutrients.
Svejkovsky and Burton, 2001	Detection of Coastal Urban Stormwater and Sewage Runoff with Synthetic Aperture Radar Satellite Imagery	Paper detailing a study in which the utility of using Synthetic Aperture Radar (SAR) to discern polluted urban runoff plumes was tested. One sample area was the Santa Monica Bay where water is received from Malibu Creek and Ballona Creek watersheds. Ballona Creek plumes were found to have much less backscatter when compared to Malibu Creek plumes; this finding was attributed to the differences in land use and runoff contributions between the two watersheds.

Author, Date	Report Title	Report Description
US EPA Region 9, 2002	Total Maximum Daily Loads for Bacteria in the Malibu Creek Watershed	Document describes the Total Maximum Daily Loads (TMDLs) for coliform bacteria in the Malibu Creek watershed and summarizes the information used by the USEPA and the California Regional Water Quality Control Board to develop wasteload and load allocations for coliform bacteria. Report provides implementation recommendations by which the presented waste load allocations and load allocations may be achieved.
USEPA, 2003	Total Maximum Daily Loads for Nutrients, Malibu Creek Watershed	Summary of report is provided in text below.

E.2 Summary of Key Reports

(Ambrose and Orme, 2000): From 1997-1999, Robert F. Ambrose of UCLA and Antony Orme of the University of Arizona led a multidisciplinary investigation of lower Malibu Creek and Malibu Lagoon with funding from the California Coastal Conservancy. The stated purpose was “to understand better the natural system and human impacts on this system, and to develop strategies for the long-term management of the lower watershed.” The resulting massive report contains invaluable information on the system, written from a scientific, rather than regulatory perspective.

Chapter 1 of Ambrose and Orme contains a detailed history of the evolution and development of the creek and lagoon. A key geological control is the uplift of the Santa Monica Mountains, which has occurred at a rate of about 0.30 m/1,000 yrs. This uplift caused the incision of Malibu Canyon. During the last glacial maximum, when sea levels were lower, the canyon incised well out beyond the current shoreline. As sea levels have risen (at an ongoing rate of approximately 1.8 mm/yr) the submarine canyon has since filled back to create the modern estuarine lagoon. The form of the lagoon represents a dynamic balance between sea level rise and sediment supply. In general the system is aggrading.

Human disturbances play an important role in the current morphology of the system. From the 1860s through the 1920s, the watershed was dominated by ranching, increasing erosion rates. A railway was constructed across the mouth of the lagoon in 1908, which was transformed into the Pacific Coast Highway in 1929. The 1920s saw extensive wetland drainage and beach development. Rindge Dam was constructed upstream of the Lagoon in 1928, reducing sediment throughput, but was subject to such heavy sedimentation that it was 85 percent filled by 1949. Together, these factors resulted in aggradation which began to choke the Lagoon by increasing sediment import while reducing sediment export.

Conditions in the lagoon were likely reset by a large flood in 1938. In 1947-49 most of the lagoon was graded, and parts converted to truck farming. During the 1960s and 1970s a variety of building projects, including shopping centers and a civic center, impinged on the natural footprint of the lagoon, followed by a golf course in 1983 and extensive residential development. By the 1990s the authors conclude that the lagoon was severely constrained and “dysfunctional.”

Chapter 2 examines recent hydrology and morphodynamics of the system. Hydrological alterations are due to three major factors: urban growth in the watershed, altered fire regime, and physical constraints on the Lagoon opening. Under current conditions, the Lagoon cycles between closed and open forms in response to decadal oscillations in the flow regime. A major flood event in 1998 fully opened the Lagoon to the sea, resulting in deepening much of the lagoon by 0.5 to 1 m and increasing storage capacity by about 25 percent. However, these changes were soon reversed in the following season.

Under natural conditions, the barrier beach would be expected to close during the summer and breach during winter high flows. Human impacts have also shifted the temporal pattern of this sequence. Development in the upper watershed, including substantial use of imported water, has resulted in flows that are prolonged into the dry season. Coupled with reduced storage volume this introduces a tendency for the lagoon to overtop during summer, and summer mechanical breaching is regularly employed to alleviate flooding problems. In Chapter 8, perceived poor condition of the benthic invertebrate population in the lagoon is attributed to attenuated tidal flushing. It was unclear whether breaching of the beach is more or less common than under natural conditions, but the nature and timing of breaching has certainly changed. The combination of elevated freshwater flows and reduced volume of the estuarine prism has created a situation in which salinity in the lagoon is reduced.

(Aquatic Bioassay, 2005): While benthic bioinvertebrate samples have been regularly collected in Malibu Creek since 2000, the 2005 effort stands out because it was accompanied by a formal written report. Eight sites were sampled for this round, although only one (Malibu Creek above lagoon) was in the Malibu Creek mainstem. Bioassessment scores (SC IBI) at all sites were poor; however, at four of the sites (Malibu Creek above the lagoon, lower Las Virgenes, lower Medea, and Triunfo) the physical habitat was rated optimal or suboptimal. Therefore, it was concluded that for these four sites "stressors other than habitat conditions may have impacted these sites" – such as nutrients, metals, or organic pollutants. Also at issue was the invasive New Zealand mudsnail, which was dominant in Medea Creek, crowding out other species, and present in lesser numbers at other stations.

(Las Virgenes Municipal Water District Tapia Water Reclamation Facility (LVMWD) Bioassessment, 2006-2010): This report includes the results of bioassessment monitoring conducted for the Las Virgenes Municipal Water District (LVMWD) at eight sampling locations in the Malibu Creek Watershed during the spring of 2010. This report includes all of the physical, chemical, and biological data collected during the spring survey, photographic documentation of each site, QA/QC procedures and documentation followed by the metrics specified in the CSBP and Southern California Index of Biological Integrity (SoCal-IBI), along with interpretation of these results with comparisons between sample locations, and across years. A combined total of 5,161 BMIs were identified from 39 different taxa at the eight stations sampled during the spring 2010 survey. The majority of organisms collected at station R-11(Malibu Lagoon station) were Oligochaeta worms (64% of the total abundance). Physical habitat characteristics and water chemistry of Malibu Creek Watershed (along with other taxonomic information) are also presented within the report.

(Los Angeles Bioassessment Monitoring Program, 2006-2010): As part of the Los Angeles County monitoring program, bioassessment were conducted annually from 2006-2010. The study area includes 18 stream monitoring sites within the 5 watersheds of: San Gabriel, Los Angeles River, Dominguez Channel, Santa Monica Bay (including Malibu Creek and Ballona Creek), and the Santa Clara watershed. The report details sampling methods and describes county-wide results from previous studies. Key findings include the discovery of an overly abundant snail in Malibu Creek and tables of taxa and specific benthic communities in great detail.

(Malibu Creek Watershed Monitoring Program Bioassessment Monitoring, 2005): This report describes the bioassessment IBI results of 11 sampling sites. "Southern California Index of Biological Integrity (IBI) score provides a measure of the aquatic health of a stream reach and is calculated using a multi-metric technique that employs seven biological metrics that were each found to respond to a habitat and/or water quality impairment." The poor Malibu Creek scores indicate the watershed impaired. The physical/habitat characteristics were also assessed. This report also notes the prevalence of the New Zealand mudsnail, which is a significant and immediate environmental concern, but at present do not have methods for population control.

(Moffatt & Nichol, 2005): Following up on the technical basis provided by Ambrose and Orme, Mofatt & Nichol undertook a restoration feasibility study for Malibu Lagoon. This contains updated information, in particular, on sediment dynamics in the lagoon. They describe the lagoon as consisting of a main channel and three distinct western arms that are stagnant and cut off from the main channel at mean seal level (MSL). (Note, these arms were actually constructed for restoration purposes in 1983 – see Ambrose and Orme, 2000, p. 8-3). Substrate in the main channel was about 95 percent sand, while the western arms were about 45 percent sand and accreting. As noted by Ambrose and Orme, the lagoon experiences strong cycles of sedimentation: The 1997/98 El Niño year resulted in scour, while infilling occurred in 1998 through 2005. Moffatt & Nichol estimate the annual sedimentation rate for 1998-2004 as 0.76 in/yr as a lagoon-wide average, which has resulted in much of the sediment bed being perched above MSL. Fine sediment buildup in the western arms contributes to nutrient retention and recycling, increasing eutrophication impacts. Restoration alternatives included various techniques that might decrease trapping and increase expulsion of sediment from the lagoon.

(Sikich et al., 2012): The report provides a thorough description of the habitat, water quality, and biota within the Malibu Creek Watershed. Chapter 1 analyzes the current state of the watershed and identifies issues of concern; describing the water quality, biota, and stream health. The authors provide a detailed overview of the watershed, describing the sensitive habitats and species, and the improvement efforts in progress, as well as future needs. The watershed contains highly invasive species such as the New Zealand mudsnails, red swamp crayfish, bullfrogs, giant reed, periwinkle, and fennel which can displace local species. It also lies on the migration pathof endangered aquatic life. Chapter 2 speaks to the state of the habitat. Land cover is assessed. The assessment describe significant disturbance in the watershed, due to erosion, riparian habitat loss, and sedimentation. Areas with as low as 6.3% effective impervious areas display singificant biological degradation. Streambank modifications and stability are analyzed, including a sediment survey. From the gathered data, the authors provide a series of recommendations for development within and outside the Coastal Zone. Water quality is described in Chapter 3. Nutrients, algae, dissolved oxygen (DO),bacteria pollution, pH and other relevant parameters are addressed in detail.

The Tapia Water Reclamation Facility (Tapia) is the most prominent source of nutrients, and despite a decade of focused effort to reduce effluent concentrations, parameteres remain high. Furthermore, the concentrations of fecal coliform bacteria throughout the watershed are still high, despite intensive effort to reduce the concern. The report recomments targeted monitoring of Tapia's discharge and a centralized wastewater recycling plant in Malibu Civic Center to address these issues specifically. Chapter 4 details regional biota and biological integrity. Index of Biological Integrity (IBI), recommended by the US EPA, evaluates human impact on the "biotic condition of water bodies". Because different species respond differently to stressors, their presence, or lack there of, is an indicator of ecosytstem health. This chapter illustrates Malibu's integrity as well as identifying affecting stressors on the watershed, analyzed in large part by the Heal the Bay organization since 2000. The two major factors influencing the watershed's low biological integrity (via IBI scores) are water quality and high percent effective impervious area. Stormwater pollution from impervious areas has and will be addressed further by local ordinances implementing low impact development (LID) to reduce runoff and associated bacteria and nutrients. Stream health is described in Chapter 5. It presents a background to the status quo and describes the metric used to analyze water quality, biota, and physical habitat in order to assess comprehensive stream health called the Stream Health Index (SHI).

Due to prevalence of so many environmental stressors within the watershed, the impact of multiple and simulatenous effects is necessary. The report develops the SHI using existing data to reveal ecosystem health at particular locations. It utilizes water quality, biotic, and habitat data to formulate a single value from 0-27 (most degraded to least impacted). The report recommends action to actively protect and restore the health of the Malibu Creek watershed. The authors suggest maintaining an emphasis on stream and riparian buffer protection from development and "human encroachment" while maintaining restoration activities to improve the ecological health of the watershed. Sikich et al. advocate a programof stream andriparian habitat protection near the Santa Monica mountains; implementing LID practices of onsite water reclamation for new build and redevelopment; implementation of TMDLs and development of new where necessary; halting the spread of invasive species through comprehensive plans. These efforts would protect open space, reduce sediment and nutrient loads, and limit streambank hardening with BMPs and protective plans.

(**USEPA, 2003**): In 2003 USEPA Region 9 established nutrient TMDLs for the Malibu Creek watershed in accordance with Consent Decree requirements established in *Heal the Bay, Inc., et al. v. Browner*, approved on 22 March 1999. This addresses impairments in the Malibu Creek mainstem, Las Virgenes, Lindero, and Medea creeks, lakes Sherwood, Lindero, Malibou, and Westlake, and Malibu Lagoon. All but Malibu Lagoon were listed for algae, while the lagoon and all the lakes were listed for eutrophic conditions. A variety of other listings for scum/odors, ammonia, organic enrichment, and low dissolved oxygen were also associated with the nutrient impairments. The problem statement for the TMDL includes the following: "Excessive algae in the Malibu Creek watershed has resulted in several waterbodies not supporting their designated beneficial uses associated with aquatic life and recreation… Algal biomass can lead to impairment of swimming and wading activities. In addition, the proliferation of algae can result in loss of invertebrate taxa through habitat alteration (Biggs, 2000). Algal growth in some instances has produced algal mats…; these mats may result in eutrophic conditions where dissolved oxygen concentration is low (Briscoe et al., 2002), and negatively affect aquatic life in the waterbody (Ambrose and Orme, 2000)."

USEPA interpreted the narrative criteria for nutrients relative to Biggs (2000) recommendations of a threshold of 30 percent cover for 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. They found that algal problems were predominantly associated with summer low flow conditions, but that there was evidence of algal impairment in Malibu Creek throughout the year. Nutrient targets were then established for two seasons: During the summer (April 15 – November 15) Nitrate-plus-nitrite-N and total P targets are 1.0 and 0.1 mg/L respectively, while during the winter months (November 16 – April 14) the Nitrate-plus-nitrite-N target is 8 mg/L while no total P target is applied. It is important to note that there was considerable uncertainty as to what factors control algal abundances in Malibu Creek. Therefore, the summer nutrient targets are based primarily on a reference approach reflecting concentrations observed in "relatively undisturbed stream segments" on Upper Malibu Creek and Middle Malibu Creek. The winter target simply represents a 20 percent margin of safety adjustment on the existing 10 mg/L numeric objective provided in the basin plan. The nutrient TMDL document contains a detailed analysis of nutrient loading from nonpoint sources in the watershed in addition to the Tapia WRF.

The nutrient TMDL contains various sources of uncertainty. It was believed that the TMDL and allocations were conservative; however, it was not certain that nutrient-related impairment would be fully resolved as a result of the TMDL. The TMDL discussion notes (p. 44): "Studies are currently underway to improve our understanding of the relationship between nutrient levels in the watershed and algal growth. USEPA strongly recommends that these studies be completed and additional studies carried out if necessary to characterize the limiting factors that control algae growth in the Malibu Creek watershed… Based on results from these studies, the State should consider reviewing and, if necessary, revising the TMDLs, allocations, and/or implementation provisions."

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Appendix F. Nutrient Numeric Endpoints for TMDL Development: Malibu Watershed Case Study

Prepared by:

Tetra Tech, Inc.

January 2007, revised November 2012

In this analysis, the California nutrient numeric endpoints (NNE) tools were applied to three nutrient impaired streams and four lakes in the Malibu Creek watershed. Site-specific information on nutrient levels, physical conditions (e.g. stream temperature, light), and biological response for sites with different land uses and habitat conditions was used to develop site-specific nutrient targets. The analysis indicated that nutrient targets are variable among sites, depending on site characteristics. The results also suggest that the proposed TMDL target of 1 mg/L nitrate plus nitrite N may be too high to achieve desired algal densities in the streams and lakes of this watershed.

F.1 Introduction

Tetra Tech (2006), under contract to U.S. EPA Region IX and California State Water Resources Control Board, has developed a risk-based approach for estimating site-specific nutrient numeric endpoints (NNE) for California waters. In recognizing the limitation of using ambient nutrient concentrations alone in predicting the impairment in beneficial uses, the approach uses secondary indicators. Secondary indicators are defined as parameters that are related to nutrient concentrations, but are more directly linked to beneficial uses than nutrient levels alone, such as benthic algal density.

The CA NNE approach also incorporates risk cofactors other than nutrient concentrations and nutrient supply that affect algal productivity including: light availability, flow rate and variability, and biological community structure. The approach also recognizes that there is no scientific consensus on precise levels of nutrient concentrations or response variables that result in impairment of beneficial uses. Therefore, water bodies in California are classified into three categories, termed Beneficial Use Risk Categories (BURCs).

As part of the NNE process, Tetra Tech (2006) developed simplified scoping tools to estimate algal response to nutrient concentrations. USEPA Region 9 subsequently funded a series of case studies to evaluate the performance of the tools. Tetra Tech, under contract to USEPA, applied the NNE method to develop nutrient endpoints for selected California waterbodies requiring TMDLs. The purpose of these case studies was to demonstrate the NNE process and test and refine the tools. The case study reported here (Malibu Creek watershed) is one of the case studies under this task. The Malibu watershed NNE pilot study provides analyses for three creeks within the watershed including: Medea Creek; Las Virgenes Creek; and Malibu Creek. In addition the pilot study also includes four lakes within the Malibu watershed: Sherwood Lake; Westlake; Lindero Lake; and Malibou Lake.

F.1.1 Site

Malibu Creek watershed, located about 35 miles west of Los Angeles, California, drains an area of 109 square miles. The watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific coast at Santa Monica Bay (Bowie et al., 2002, Figure F-1). Several creeks and lakes are located in the upper portions of the watershed, and they ultimately drain into Malibu Creek at the downstream end of the watershed. The entire watershed lies within Level 3 subecoregion 6 (Southern and Central California Chaparral) within aggregate nutrient ecoregion 3 (Xeric West; USEPA, 2000a).

The watershed has seen urban development in recent decades, with a high degree of development occurring along portions of the main tributaries of Malibu Creek (Busse et al. 2006). Lower Malibu Creek also receives discharges from the Tapia waste-water treatment plant.

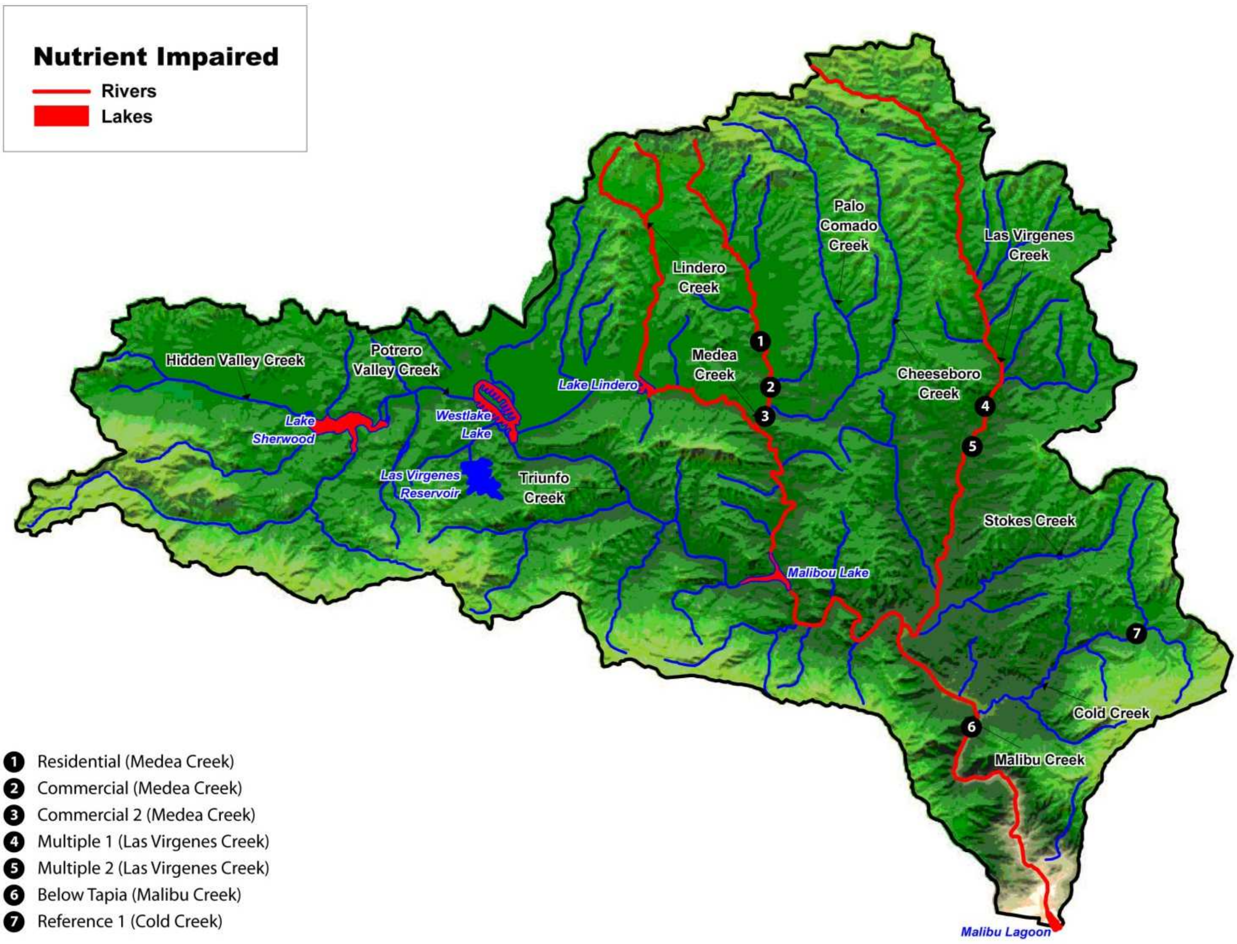

Figure F-1. Map of the Malibu Creek Watershed showing Nutrient-impaired Waterbodies in Red (Bowie et al., 2002).

Note: Also identified on this map are sampling locations near different land uses from Busse et al. 2003 that are discussed in Sections 2 and 3.

In 2003 USEPA Region 9 established nutrient TMDLs for the Malibu Creek watershed in accordance with Consent Decree requirements established in *Heal the Bay, Inc., et al. v. Browner*, approved on 22 March 1999. This addresses impairments in the Malibu Creek mainstem, Las Virgenes, Lindero, and Medea creeks, lakes Sherwood, Lindero, Malibou, and Westlake, and Malibu Lagoon. All but Malibu Lagoon were listed for algae, while the lagoon and all the lakes were listed for eutrophic conditions. A variety of other listings for scum/odors, ammonia, organic enrichment, and low dissolved oxygen were also associated with the nutrient impairments. The problem statement for the TMDL includes the following: "Excessive algae in the Malibu Creek watershed has resulted in several waterbodies not supporting their designated beneficial uses associated with aquatic life and recreation… Algal biomass can lead to impairment of swimming and wading activities. In addition, the proliferation of algae can result in loss of invertebrate taxa through habitat alteration (Biggs, 2000). Algal growth in some instances has produced algal mats…; these mats may result in eutrophic conditions where dissolved oxygen concentration is low (Briscoe et al., 2002), and negatively affect aquatic life in the waterbody (Ambrose and Orme, 2000)."

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F.1.2 Beneficial Uses and Impairment

The Malibu Creek watershed supports or potentially supports a total of 14 beneficial uses. Among them, 10 of 14 beneficial uses are sensitive to nutrient inputs and related effects, including: REC1 (Water contact recreation), REC2 (Non-contact Recreation), WARM (Warm freshwater habitat), COLD (Cold freshwater habitat), EST (Estuarine habitat), MAR (Marine habitat), WILD (Wildlife habitat), RARE (Preservation of rare and endangered species), MIGR (Migration of aquatic organisms), and SPWN (Spawning, reproduction, and/or early development). Recreational uses (REC1 and REC2) apply to all the listed water bodies. WARM is the existing use for all the impaired streams, except in Lower Medea Creek (reach 1) and Lindero Creek where WARM is an intermittent use.

Streams and lakes in the Malibu Creek watershed are susceptible to the cumulative effects of degradation in water quality because of continuing urban development. Marine sedimentary deposits in the watershed (Modelo formation) may also have elevated levels of nutrients. Data collected in the Malibu Creek watershed has shown elevated algal biomass and macroalgal cover in developed areas, attributed to increases in nutrient and light availability (Busse et al. 2006). Most of the water bodies in the Malibu Creek watershed have been listed under Section 303(d) for coliforms or algae/nutrient problems (Bowie et al. 2002; USEPA Region IX, Table F-1). Malibu Lagoon, Malibu Creek upstream of the lagoon, and several tributaries to Malibu Creek (Las Virgenes Creek, Medea Creek, and Lindero Creek) are major areas of concern. Streams that feed into Malibu Creek were listed under 303(d) for either coliforms, algae/nutrients, or both problems, including Las Virgenes Creek, Stokes Creek, Medea Creek, Lindero Creek, and Palo Comado Creek. In addition, four lakes in the watershed have been listed for eutrophication problems (algae, nutrients, ammonia, low DO): Malibou Lake, Lake Lindero, Westlake Lake, and Lake Sherwood.

Table F-1. Malibu Creek Watershed 303(d)-listed Waterbodies for Nutrients

Waterbody	Algae	Eutrophy	Scum/ Odors	Ammonia	Organic Enrichment	Dissolved Oxygen
Lake Sherwood (acres)	213	213		213	213	213
Westlake Lake (acres)	186	186		186	186	186
Lake Lindero (acres)	14	14	14		14	
Las Virgenes Creek (miles)	11.25		11.25			11.25
Lindero Creek (miles)	6.56		6.56			
Medea Creek (miles)	7.56					
Malibou Lake (acres)	69	69			69	69
Malibu Creek (miles)	8.43		8.43			
Malibu Lagoon (acres)		33				

Note: Streams = linear miles listed; lakes = acres listed; data from USEPA Region IX.

As of January 2007, the Los Angeles Regional Water Quality Control Board had established bacteria TMDLs for the Malibu Creek watershed. TMDLs for the algal/nutrient problems for the impaired water bodies in the watershed were under development.

F.1.3 Summary of the Existing Analysis

In 2002, Tetra Tech conducted nutrient and coliform modeling for the Malibu Creek watershed TMDL studies (Bowie et al. 2002). In the study, the watershed model HSPF was used to model pollutant loading and transformation in the watershed, streams and the Lagoon, and water quality model BATHTUB was used to model the eutrophication in the four lakes. Pollutant loadings from various sources were estimated.

In the summer of 2001 and 2002, a survey of nutrients and algae in the Malibu Creek Watershed was conducted by University of California, Santa Barbara, and Southern California Coastal Water Research Project members (Busse et al. 2003; Busse et al. 2006). In that study, algal biomass (both benthic and floating), nutrient levels (nitrogen and phosphorus), and physical conditions were surveyed in multiple streams with different surrounding land uses and habitat conditions in order to identify factors and land uses that promote excessive algal growth. High algal levels were found at sites with human influence. The study indicated nutrient and light availability significantly affect algal composition and total algal biomass. The study also indicated that at several locations algal growth is saturated by high nutrient levels and is not nutrient limited.

F.1.4 Scope of This Effort

As indicated in the study by Busse et al. (2003, 2006), although nutrient concentrations explained a large portion of variation in algal density across sites, other physical parameters such as shading and current speeds also affect to algal growth. Sites downstream of commercial land uses with moderate nutrient concentrations can exhibit high benthic algal density due to high temperature and lack of shading. The availability of site specific data on nutrient levels, algal density, and physical parameters provides a useful basis upon which to investigate the use of the CA NNE tools to develop site-specific nutrient concentration targets.

F.2 Data

F.2.1 Algal Response Data

In 2001 and 2002, algal biomass at different sites with a range of different land use patterns were surveyed by Busse et al. (2003, 2006). For the survey in 2002, benthic and floating algal density were measured separately and for each sampling site six sub-habitat types with different shading and flow conditions were surveyed. The 2002 survey locations also contained more sites with human influence. Also for the 2002 survey, more complete data were available for August 2002 than June 2002. Therefore for our analysis, we mostly rely on data obtained in August 2002.

For the survey in 2002, seven locations along the main tributaries (Las Virgenes Creek, Medea Creek) and Malibu Creek were included. The sites include one reference site containing open space, one site with a high density residential area, two commercial sites, two sites with multiple land uses, and one site below the Tapia treatment plant. These sites are shown in Figure 1. The two multiple land use sites on Las Virgenes Creek were influenced by both residential development and historical sludge injection fields.

Within each site, six sub-habitat types with different combination of shading and flow conditions including shaded pools, shaded runs, shaded riffles, sun pools, sun runs, and sun riffles were surveyed, if that sub-habitat type is available. For each sub-habitat type, three equally spaced cross-stream transects were established. Benthic algae were sampled at five evenly spaced locations along each transect. Chlorophyll *a* concentrations for benthic algae samples were averaged for each sub-habitat type. Besides chlorophyll *a*, ash free dry mass (AFDM) was also measured for each sample in the laboratory. Table F-2 lists algal response data in the August 2002 survey. The observed chlorophyll *a* was highly variable among different sites and sub-habitats. Commercial 1 sun run site showed the highest average benthic chlorophyll *a* concentrations of 969.2 mg/m^2. At two sites there was a significant mass of planktonic chlorophyll *a*. This was also reported on an areal basis for possible combination with the benthic chlorophyll *a* density. The chlorophyll *a* to AFDM ratio ranges from 1.2 to 11.9 among the different sites. As most of the sites have high ratios, high concentrations of benthic chlorophyll *a* can be associated with relatively low algal biomass.

Table F-2. Summary of Chlorophyll *a* and AFDM Data from the August 2002 Survey (Busse et al. 2003).

Creek	Land Use	Sub-Habitat	Benthic chlorophyll *a* (mg/m^2)	Benthic plus Planktonic chlorophyll *a* (mg/m^2)	Average Ash Free Dry Mass (g/m^2)	Chlorophyll *a* to AFDM ratio
Medea Creek	Residential 1	Sun Riffle	165.1	165.1	34.8	4.7
Medea Creek	Residential 1	Shade Riffle	50.0	50.0	10.7	4.7
Medea Creek	Commercial 1	Sun Run	969.2	969.2	210.3	4.6
Medea Creek	Commercial 1	Sun Riffle	110.9	110.9	44.9	2.5
Medea Creek	Commercial 2	Sun Pool	133.1	413.0	40.6	3.3

Creek	Land Use	Sub-Habitat	Benthic chlorophyll *a* (mg/m^2)	Benthic plus Planktonic chlorophyll *a* (mg/m^2)	Average Ash Free Dry Mass (g/ m^2)	Chlorophyll *a* to AFDM ratio
Medea Creek	Commercial 2	Sun Run	73	123.5	29.2	2.5
Medea Creek	Commercial 2	Sun Riffle	66.9	66.9	24.6	2.7
Las Virgenes	Multiple 1	Shade Run	383.9	383.9	45.7	8.4
Las Virgenes	Multiple 1	Shade Riffle	504.0	504.0	53.5	9.4
Las Virgenes	Multiple 2	Sun Run	102.6	102.6	85.3	1.2
Las Virgenes	Multiple 2	Shade Run	531.1	531.1	79.9	6.6
Las Virgenes	Multiple 2	Shade Riffle	255.9	255.9	21.5	11.9
Malibu Creek	Below Tapia	Shade Run	341	341	32.9	10.4
Malibu Creek	Below Tapia	Sun Riffle	230.3	230.3	40.4	5.7
Malibu Creek	Below Tapia	Shade Riffle	258.1	258.1	25.9	10.0

Note: AFDM data provided by L. Busse; not included in published report.

F.2.2 Chemical Water Quality Data

Water samples at each site were collected downstream of each transect. For each sample, ammonium (NH_4-N), nitrate (NO_3-N), soluble reactive phosphorus (SRP), total phosphorous (TP), and total nitrogen (TN) concentrations were measured. Table F-3 shows the nutrient concentrations obtained in the August 2002 survey. Nitrate concentrations were generally low (below 0.2 mg-N/L) for the residential and commercial sites, while multiple site 1 and 2 (sites with historical sludge injection) exhibit high nitrate concentrations of 2.8 and 3.8 mg/L, respectively. Total N ranged from 0.68 mg/L to 3.8 mg/L among sites. For Multiple 1 and Multiple 2 sites, measured average TN concentrations were less than the average NO_3-N concentrations.

Table F-3. Water Quality Data Obtained from August 2002 Survey (Busse et al. 2003).

Creek	Land Use	Sub-Habitat	NO_3-N (mg/L)	NH_4-N (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Medea Creek	Residential 1	Sun Riffle	0.018	0.043	0.686	0.123	0.186
Medea Creek	Residential 1	Shade Riffle	0.018	0.043	0.686	0.123	0.186
Medea Creek	Commercial 1	Sun Run	0.127	0.05	1.203	0.077	0.137
Medea Creek	Commercial 1	Sun Riffle	0.127	0.05	1.203	0.077	0.137
Medea Creek	Commercial 2	Sun Pool	0.072	0.063	1.418	0.053	0.087

Creek	Land Use	Sub-Habitat	NO_3-N (mg/L)	NH_4-N (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Medea Creek	Commercial 2	Sun Run	0.072	0.063	1.418	0.053	0.087
Medea Creek	Commercial 2	Sun Riffle	0.072	0.063	1.418	0.053	0.087
Medea Creek	Multiple 1	Shade Run	2.804	0.025	2.748/2.829*	0.268	0.296
Las Virgenes	Multiple 1	Shade Riffle	2.804	0.025	2.748/2.829*	0.268	0.296
Las Virgenes	Multiple 2	Sun Run	3.869	0.071	3.806/3.940*	0.301	0.326
Las Virgenes	Multiple 2	Shade Run	3.869	0.071	3.806/3.940*	0.301	0.326
Las Virgenes	Multiple 2	Shade Riffle	3.869	0.071	3.806/3.940*	0.301	0.326
Las Virgenes	Below Tapia	Shade Run	0	0.050	0.686	0.293	0.363
Malibu Creek	Below Tapia	Sun Riffle	0	0.050	0.686	0.293	0.363
Malibu Creek	Below Tapia	Shade Riffle	0	0.050	0.686	0.293	0.363

*TN values used in model as sum of NO_3-N and NH_4-N because reported TN values were less than NO_3-N.

The main source of water quality data for the four listed lakes is a study by UC Riverside for the Los Angeles Regional Water Quality Control Board in 1992-1993 (Lund et al., 1994). Water quality data were collected on a monthly basis at several depths for a one-year period from July 1992 to July 1993 (Table F-4). For the purpose of the analysis that follows, annual averages of these concentrations were used based on the finding that there was little consistent inter-seasonal change in concentration.

Table F-4. Nutrient Measurements in Malibu Creek Watershed Lakes by UC Riverside for 1992-1993 (Mean and Ranges; Lund et al. 1994)

Lake	NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	TN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Chlorophyll *a* (µg/L)
Sherwood	0.5 <0.1-1.2	0.8 <0.1-2.2	1.7 0.5-3.0	2.23 0.6-4.2	0.25 <0.1-0.5	0.25 <0.1-0.5	16 1-52
Westlake	0.3 <0.1-1.3	0.4 0.1-1.0	1.3 0.7-2.3	1.69 0.8-3.6	0.16 <0.1-0.3	0.16 <0.1-0.3	14 2-35
Lindero	0.4 <0.1-1.3	0.1 <0.1-0.5	1.1 <0.1-2.0	1.58 0.2-4.3	0.09 <0.1-0.2	0.13 <0.1-0.2	23 2-56
Malibou	0.5 <0.1-1.9	0.1 <0.1-0.3	1.2 <0.1-2.7	1.78 0.2-4.6	0.13 <0.1-0.3	0.14 <0.1-0.4	44 2-185

F.2.3 Physical Data

Table F-5 summarizes the observed physical conditions at the stream sites including velocity, percent open canopy, and water temperature for the selected locations surveyed in August 2002. Water velocities for the selected locations ranged from 0.02 to 0.36 m/s. Percent open canopy was around 90 percent for the selected sun sites and around 1-2% the shade sites, with only a few exceptions. Temperature was generally below or around 20 degrees, except at commercial site 1, where temperature was around 30 degrees.

Table F-5. Physical Conditions of Stream Sites in August 2002 Survey (Busse et al. 2003)

Creek	Land Use	Sub-habitat	Velocity (m/s)	% Open Canopy	Water Temperature (°C)
Medea Creek	Residential 1	Sun Riffle	0.28	90	23
Medea Creek	Residential 1	Shade Riffle	0.12	14.9	19.2
Medea Creek	Commercial 1	Sun Run	0.24	89.6	30.3
Medea Creek	Commercial 1	Sun Riffle	0.36	90.9	30.5
Medea Creek	Commercial 2	Sun Pool	0	74.5	28.6
Medea Creek	Commercial 2	Sun Run	0.18	91.1	18.1
Medea Creek	Commercial 2	Sun Riffle	0.23	88.9	20.8
Las Virgenes	Multiple 1	Shade Run	0.1	0.2	20.1
Las Virgenes	Multiple 1	Shade Riffle	0.13	0.2	20.2
Las Virgenes	Multiple 2	Sun Run	0.02	29.7	16.8
Las Virgenes	Multiple 2	Shade Run	0.09	1.6	16.6
Las Virgenes	Multiple 2	Shade Riffle	0.14	2.3	16.7
Malibu Creek	Below Tapia	Shade Run	0.04	0	19.4
Malibu Creek	Below Tapia	Sun Riffle	0.12	54.7	20
Malibu Creek	Below Tapia	Shade Riffle	0.2	1.8	19.6

Physical data for the lakes is summarized in Bowie et al. (2002).

F.3 NNE Tools Application - Streams

F.3.1 Parameter Specification

Depth and Velocity

Velocity for each stream location was measured during the survey and therefore was directly used in the analysis. For August 2002, the depth for surveyed streams is 15.2 (± 8.53) cm (L. Busse, personal communication). In our analyses we assumed a depth of 0.2 m.

Solar Radiation

Solar radiation was estimated for the summer period (June-August) based on the latitude, using the routine embedded in the Benthic Biomass Spreadsheet. Percent canopy openness measured during the survey was directly used in the analysis.

Light Extinction Coefficient

Light extinction coefficient can be calculated as a function of turbidity. An approximate linear relationship of light extinction to turbidity is expected in streams. Regression relationship (Walmsley et al. 1980), Ke (PAR) = 0.1T + 0.44, where Ke (PAR) is the extinction rate of photosynthetically active radiation (PAR, per meter) and T is nephelometric turbidity (NTU). Stream turbidity for Las Virgenes Creek, Medea Creek, and Malibu Creek below Tapia has been monitored by the Heal the Bay Stream team (http://www.healthebay.org/streamteam/). Turbidity for these streams during summer (July-September) generally ranges around 1 NTU. Based on the equation, the estimated light extinction coefficients for these streams are around 0.54 m^{-1}.

Days of Accrual

The days of accrual can be used to adjust maximum algal density based on the frequency of stream scouring events (see more detailed description in Tetra Tech, 2006). The days of accrual for Malibu Creek were examined from daily flow data of 1988-1998 from Los Angeles County Department of Public Works (LACDPW), using the count of hydrological events exceeding three times the median flow, yielding an estimate of 93.4 days. Daily flow data were not available for the Las Virgenes Creek and Medea Creek. Survey data from Busse et al. (2003) indicated stream velocity during summer and fall of 2001 and 2002 were generally below 0.35 m/s. Welch and Jacoby (2004) noted that significant scour usually does not begin until flow velocities reach about 0.7 m/s (2.3 ft/s). Therefore it is expected that during summer and fall no storm events will occur that will cause significant scour of benthic algae. A value of 100 was assumed for the days of accrual for all sites.

F.3.2 Model Results

The NNE Benthic Biomass Predictor tool provides a variety of empirical and simplified parametric methods to predict benthic algae response to ambient conditions. In this analysis, results from the steady-state approximations to the standard QUAL2K, revised QUAL2K, revised QUAL2K with accrual adjustment and Dodds et al. (2002, rev. 2006) methods are presented (Table F-6; see Tetra Tech, 2006, Appendix 3 for description of the methods). Generally, the tool was able to predict the observed maximum benthic chlorophyll *a* concentrations in various locations reasonably well. The Dodds et al. (2006) method, which is based on regression relationship of TN and TP, predicted the higher observed maximum chlorophyll *a* at sites with multiple land use (Las Virgenes Creek) and lower observed maximum chlorophyll *a* at residential land use site (Medea Creek). However without the consideration of physical parameters, the Dodds et al. (2006) method cannot predict the variability exhibited in different sub-habitat condition for the same land use. The parametric (QUAL2K-based) methods performed better in capturing the variation in observed maximum chlorophyll *a* among different sub-habitats. For example, for the residential 1 site (Medea Creek), the standard QUAL2K methods were able to predict the higher chlorophyll *a* concentrations under sun riffle sub-habitat and the lower chlorophyll *a* concentration under the shade riffle sub-habitat.

Table F-6. Observed and Predicted Maximum Benthic Chlorophyll *a* (mg/m^2)

Creek	Name/ Land use	Habitat	Standard QUAL2K	Revised QUAL2K	Revised QUAL2K with Accrual Adjustment	Dodds et al. 2002, 2006	Observed
Medea Creek	Residential 1	Sun Riffle	175	338	277	196	165
Medea Creek	Residential 1	Shade Riffle	85	165	135	196	50
Medea Creek	Commercial 1	Sun Run	307	419	343	221	969
Medea Creek	Commercial 1	Sun Riffle	312	426	349	221	111
Medea Creek	Commercial 2	Sun Pool	291	510	418	208	413*
Medea Creek	Commercial 2	Sun Run	116	203	166	208	123.5*
Medea Creek	Commercial 2	Sun Riffle	149	261	214	208	67
Las Virgenes	Multiple 1	Shade Run	626	679	556	362	384
Las Virgenes	Multiple 1	Shade Riffle	705	766	627	362	504
Las Virgenes	Multiple 2	Sun Run	85	104	86	417	103
Las Virgenes	Multiple 2	Shade Run	396	488	400	752	531
Las Virgenes	Multiple 2	Shade Riffle	719	887	727	417	256
Malibu Creek	Below Tapia	Shade Run	157	354	290	233	341
Malibu Creek	Below Tapia	Sun Riffle	125	282	231	233	230
Malibu Creek	Below Tapia	Shade Riffle	153	346	283	233	258

* Chlorophyll *a* density includes planktonic algae expressed on a mass per area basis.

The QUAL2K-based methods predict biomass as ash free dry mass (AFDM) and rely on a chlorophyll *a* to AFDM ratio to convert AFDM to chlorophyll *a*. For Malibu, site-specific chlorophyll *a* to AFDM ratios are available (Table F-2). With site-specific nutrient concentrations, physical conditions of canopy closure, stream temperature and current velocity as well as site-specific chlorophyll *a* to AFDM ratios, QUAL2K methods generally reproduced the variation in chlorophyll *a* concentrations well, although the methods under-predicted the maximum chlorophyll *a* at a few locations with extremely high chlorophyll *a* concentrations of over 700 mg/m^2 (e.g., shade run of Multiple 2 site, and sun run of Commercial 1). One possible cause is the estimation of nutrient concentrations from a single set of samples.

Overall, the QUAL2K-based methods provide more flexibility than the Dodds et al. (2002) method. The Revised QUAL2K with accrual adjustment results, without modification of the default parameters, performed reasonably well at reproducing the maximum benthic chlorophyll *a* densities. As shown in Figure F-2 the majority of the simulated maxima are close to or slightly greater than the observed concentrations, as expected. The major exception is the very high density reported for the Medea Creek Commercial 1 sun run site.

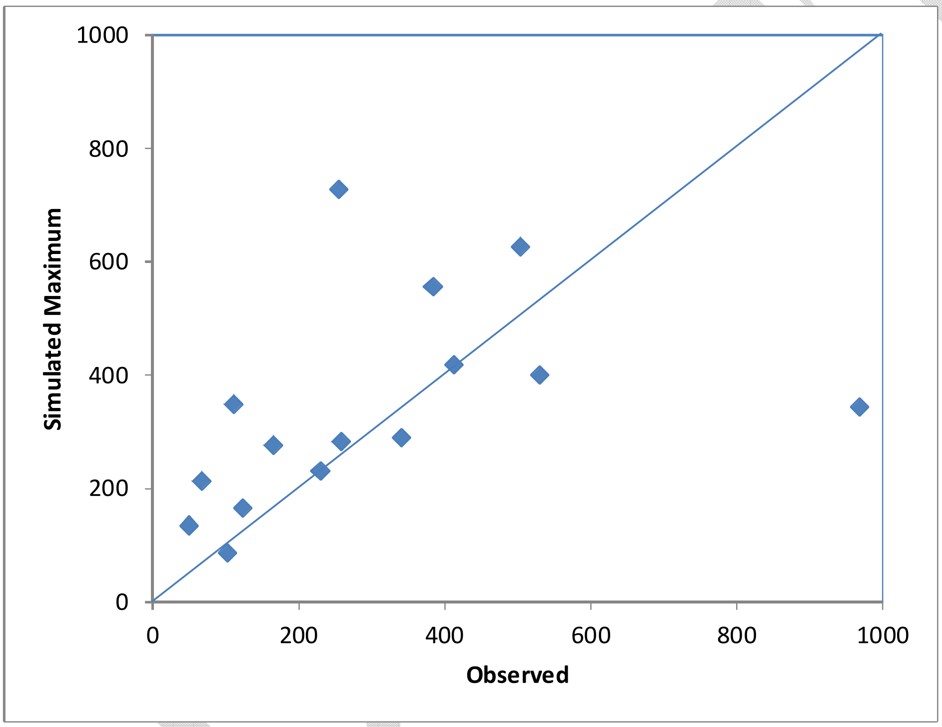

Figure F-2. Comparison of Observed and Simulated Maximum Benthic Chlorophyll *a* Densities (mg/m^2) using the Revised QUAL2Kw Method with Accrual Adjustment

F.3.3 Nutrient Targets

The NNE tool can be used to estimate nutrient targets to achieve a specified maximum algal density. Tetra Tech (2006) recommends a target maximum benthic chlorophyll *a* concentration of 100 mg/m^2 for the BURCI/II boundary (below which conditions may be deemed acceptable) and 150 mg/m^2 for the BURC II/III boundary (above which conditions are deemed unacceptable) for COLD and SPAWN uses. For WARM uses, Tetra Tech (2006) recommends a BURC I/II boundary of 150 mg/m^2 and a BURC II/III boundary of 200 mg/m^2. For Las Virgenes Creek, Medea Creek and Malibu Creek, COLD and SPAWN are the potential and existing uses. Proposed TMDL target for chlorophyll *a* in streams is also at150 mg/m2 for the Malibu Creek Watershed.

The tool was first used to predict target nutrient concentrations that would meet a maximum benthic chlorophyll *a* density of 150 mg/m^2 (BURC II/III for COLD uses and BURC I/II for WARM uses). The revised QUAL2K methods predict target concentrations for total N or total P, either one of which will achieve the target (Figure F-3; Table F-7). The standard QUAL2K method is based on inorganic nutrient concentrations, and the total nutrient limits shown in the table are those that would be required to at the existing average inorganic fraction of nutrient concentrations. The Dodds et al. (2002) methods is based on co-limitation of TN and TP, and the results shown in Table F-7 are the TN concentrations required to achieve the target density under current TP level and the TP concentrations required to achieve the target density at the existing average TN concentrations.

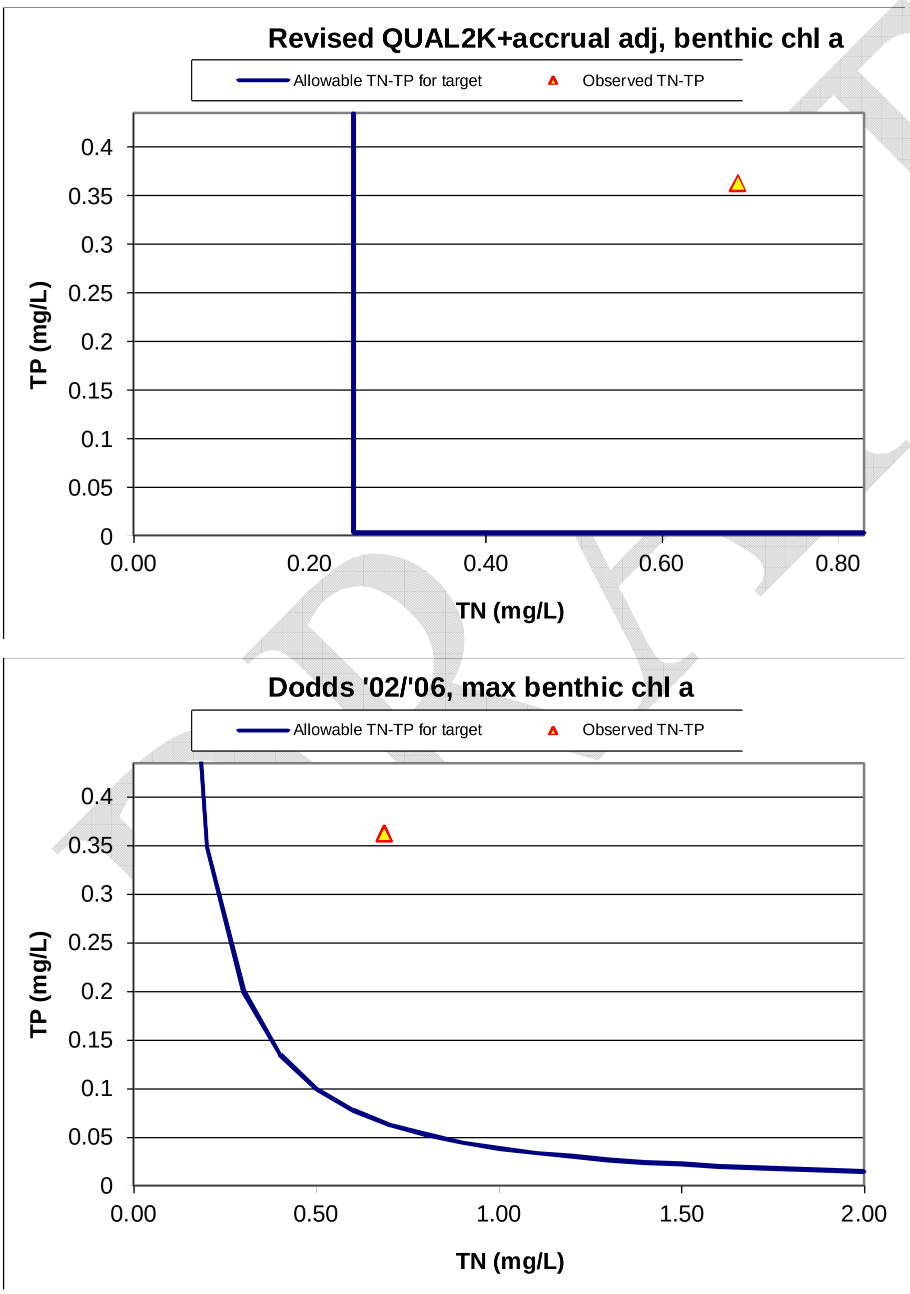

Figure F-3. Revised QUAL2K and Dodds et al. 2002 Tool Results for a Target Maximum of 150 mg/m2-Chlorophyll *a* at Malibu Creek below Tapia Shade Riffle Sub-habitat

Table F-7. Total Nitrogen and Total Phosphorus Targets (mg/L) to Achieve 150 mg/m^2 Maximum Benthic Chlorophyll *a*

Creek	Name/ Land Use	Habitat	Standard QUAL2K		Revised QUAL2K with Accrual Adjustment		Dodds et al. 2006	
			TN	TP	TN	TP	TN	TP
Medea Creek	Residential 1	Sun Riffle	0.57	0.0036	0.26	0.0033	0.32	0.0651
Medea Creek	Residential 1	Shade Riffle	1.56	0.0099	0.80	0.0185	0.32	0.0651
Medea Creek	Commercial 1	Sun Run	0.41	0.0050	0.32	0.0039	0.40	0.0303
Medea Creek	Commercial 1	Sun Riffle	0.40	0.0049	0.31	0.0038	0.40	0.0303
Medea Creek	Commercial 2	Sun pool	0.55	0.0041	0.27	0.0034	0.55	0.0242
Medea Creek	Commercial 2	Sun Run	2.29	0.0168	1.10	0.0260	0.55	0.0242
Medea Creek	Commercial 2	Sun Riffle	1.44	0.0105	0.79	0.0180	0.55	0.0242
Las Virgenes	Multiple 1	Shade Run	0.06	0.0030	0.31	0.0038	0.23	0.0094
Las Virgenes	Multiple 1	Shade Riffle	0.05	0.0026	0.26	0.0033	0.23	0.0094
Las Virgenes	Multiple 2	Sun Run	0.38	0.0194	NL	NL	0.21	0.0060
Las Virgenes	Multiple 2	Shade Run	0.11	0.0569	0.66	0.0155	0.04	0.0060
Las Virgenes	Multiple 2	Shade Riffle	0.05	0.0026	0.26	0.0033	0.21	0.0060
Malibu Creek	Below Tapia	Shade Run	0.65	0.0028	0.13	0.0022	0.19	0.0651
Malibu Creek	Below Tapia	Sun Riffle	0.87	0.0037	0.34	0.0041	0.19	0.0651
Malibu Creek	Below Tapia	Shade Riffle	0.67	0.0028	0.24	0.0031	0.19	0.0651

Note: The targets calculated by the Dodds method are for one nutrient with the other nutrient held constant and current levels; for the targets calculated by the QUAL2K-based methods control is predicted to be achieved if either the TN or TP target is met.

Predicted TN targets vary under different land uses and different habitat conditions (Table F-7). The predicted large variation in TN targets is in part a result of the highly variable light and temperature conditions observed among these sites. For the QUAL2K-based methods additional variability is introduced by the wide range of chlorophyll *a* to AFDM ratios. Estimated TN targets are mostly less than 1 mg/L, whereas the existing TMDL target is 1 mg/L of nitrate-N only. The analysis suggests that lower nutrient target values may be needed for sections of the streams with poor habitat integrity (loss of riparian zone) or high loading of nutrients as a result of human influence in the surrounding watersheds.

The QUAL2K-based methods (but not the Dodds method) produce targets of TN and TP that are *each* predicted to be sufficient to limit algal growth. Thus, it may be sufficient to achieve *either* the TN or TP target. The models also suggest that very low total phosphorus concentrations would be needed to achieve control of benthic algal growth by phosphorus alone (in many cases below 0.01 mg/L, Table F-7). As with nitrogen, the very low TP targets predicted by the QUAL2K-based methods are in large part due to the high chlorophyll *a* to AFDM ratios reported. Attaining the benthic algal density target based on control of total phosphorus alone might not be feasible at these low levels, as natural background phosphorus concentrations appear to be elevated, and reductions in total nitrogen may be the preferred management approach.

The Revised QUAL2K method appears to provide the most stable basis for setting targets. The Standard QUAL2K results are based on the observed relationship of inorganic nutrient to total nutrient concentrations, which are unlikely to be stable in time, while the Dodds method does not account for factors that influence light availability. In contrast, the Revised QUAL2K method is based on total nutrient concentrations and does

The availability of site-specific data allows the model to calculate site-specific nutrient targets based on nutrient levels and physical condition. The results suggest that appropriate targets vary widely among different land uses and sub-habitats, even for the same stream. For residential site sun riffle and shade riffle conditions, with similar ambient nutrient concentrations, the shade riffle sub-habitat has higher target TN and TP values due to the impact of physical condition (in this case shading). Canopy shading both limits light and reduces water temperature, resulting in the lower algal density that was observed (Table 2 and Table 3). As a result, higher nutrient targets are allowed for the shade riffle sub-habitat. The Commercial 1 site has high percentage of open canopy (90 % open canopy) and higher water temperature (over 30 deg C), which favor benthic algae growth and therefore the calculated nutrient targets for the site are low. For the Multiple 1 and Multiple 2 sites, high nutrient concentrations result in algae growth even under shade conditions. Therefore TN and TP values at these sites need to be reduced to very low levels in order to limit the algal growth. It is known that some diatoms are able to adapt to low light conditions. As indicated in Busse et al. (2003, 2006), the composition of algae vary among sites, with thick diatom and macroalgae dominating in more human influenced sites (Multiple sites, below Tapia). These sites also show higher chlorophyll *a* to AFDM ratios. Therefore, algal community structure is another factor influencing allowed nutrient targets. Overall, the lowest TN/TP target values were calculated at the Multiple 1 sites and the sites below Tapia.

USEPA (2000b) has suggested eco-regional nutrient criteria applicable to this area. Model results are compared to the USEPA statistical criteria and the summary of Region IX RTAG water quality monitoring in Table F-8. The range of targets derived from the CA NNE Scoping Tool for Malibu Creek cover the USEPA eco-regional criteria; however, the median target values derived using the Revised QUAL2K method are lower than the ecoregional criteria for both TN and TP. The median of the Revised QUAL2K TN targets falls between the lower quartile and median of the minimally impacted and unimpaired sites in the Region IX RTAG water quality monitoring data, but the median TP target is less than the lower quartile of these data – again suggesting that the TP targets may not be achievable. As was noted above, the low targets calculated for these sites are in part driven by the very high chlorophyll *a* to AFDM ratios.

Table F-8. Comparison of Model Results to USEPA Ecoregional Nutrient Criteria Recommendations and Region IX RTAG Water Quality Monitoring Data

Chemical	Stream Type	Proposed USEPA 304(a) Criterion – Level III ecoregion 6	Region IX RTAG Water Quality Monitoring Data (Tetra Tech, 2004)				
			Median	Average	Lower Quartile	Upper Quartile	No. of Data points
TN (mg/L)	Minimally Impacted		0.25	0.31	0.13	1.20	156
	Unimpaired		0.40	1.01	0.20	42.70	1425
	Impaired (nutrient)		0.7	1.06	0.40	11.00	868
	Impaired (other)		0.6	0.97	0.30	33.00	1486
	USEPA 304(a) (US EPA 2000b)	0.52					10
	CA NNE scoping tool	Revised QUAL2K median 0.31					
TP (mg/L)	Minimally Impacted		0.08	0.08	0.03	0.30	34
	Unimpaired		0.07	0.36	0.01	24.80	633
	Impaired (nutrient)		0.13	0.77	0.05	7.94	525
	Impaired (other)		0.07	0.34	0.03	45.10	1069
	USEPA 304(a) (US EPA 2000b)	0.03					23
	CA NNE scoping tool	Revised QUAL2K median 0.003					

F.3.4 Suggested Targets - Streams

The California NNE approach is a risk-based approach, with ultimate focus on supporting designated uses. The general NNE guidance and accompanying tools provided initial, scoping-level estimate of nutrient reduction targets that can be used as a starting point for a TMDL. The results may be superseded by detailed watershed models if these become available in future.

F.3.4.1 Response Targets

The California NNE approach (Tetra Tech, 2006) recommends setting response targets for benthic algal biomass in streams based on maximum density as mg/m^2 chlorophyll *a*. For the COLD and SPWN beneficial uses, the recommended BURC I/II boundary is 100 mg/m^2, while the BURC II/III boundary is 150 mg/m^2. Existing conditions in the Malibu Creek and its tributaries are clearly often above the BURC II/III boundary, indicating impairment of these uses. For Las Virgenes and Medea Creek, COLD and SPWN are not the existing uses but are potential uses. The WARM use boundary of 150 mg/m^2 for BURC I/II can be applied. Therefore a target maximum benthic chlorophyll *a* of 150 mg/m^2 should be appropriate response target for the Malibu Creek and its tributaries.

F.3.4.2 Nutrient Targets

As shown in Table F-7, application of the tool to Malibu Creek watershed using site specific data yields variable results in TN/TP target for various land uses and sub-habitat, suggesting the large influence of land use and habitat conditions on algal growth. Therefore suggesting a single target for a particular stream is difficult given the large influence of land use and physical condition on benthic algae growth and the high variability in observed benthic chlorophyll *a* concentrations and AFDM. One approach would be to implement the lowest calculated target value for each stream; however, this would likely over-credit the ability of the tool to derive targets. A more robust approach may be to examine the median target across multiple sites.

Application of the Revised QUAL2K method with accrual adjustment at the 150 mg/m^2 chlorophyll a target suggests median TN concentration goals of 0.32 mg/L for Medea Creek, 0.26 mg/L for Las Virgenes Creek, and 0.24 mg/L for Malibu Creek proper. The corresponding TP goals are 3.9, 3.6, and 3.1 µg/L – however, the method estimates that impairment can be addressed by meeting *either* the TN or TP target. The very low target concentrations are in part driven by high chlorophyll *a*-to-AFDM ratios; however, minimum targets obtained using Dodds' regression equation are similar, and it may simply be the case that the target chlorophyll *a* density of 150 mg/m^2 is not a realistic goal for this waterbody.

An alternative calculation was also undertaken with a chlorophyll *a* target of 200 mg/m^2. This is the general BURC II/III boundary for the WARM beneficial use stated in Tetra Tech (2006), and is greater than the BURC II/III boundary of 150 mg/m^2 for COLD and SPWN. Use of a higher target for Malibu is possibly justified on the basis of site-specific geology. The resulting targets increase by 50 to 100 percent relative to the targets derived for 150 mg/m^2 – but are still quite low relative to existing conditions (Table F-9).

Table F-9. Total Nitrogen and Total Phosphorus Targets (mg/L) to Achieve 150 mg/m^2 Maximum Benthic Chlorophyll *a*

Creek	Name/ Land Use	Habitat	Revised QUAL2K with Accrual Adjustment	
			TN	TP
Medea Creek	Residential 1	Sun Riffle	0.41	0.0047
Medea Creek	Residential 1	Shade Riffle	1.20	0.0275
Medea Creek	Commercial 1	Sun Run	0.51	0.0059
Medea Creek	Commercial 1	Sun Riffle	0.49	0.0057
Medea Creek	Commercial 2	Sun pool	0.43	0.0049
Medea Creek	Commercial 2	Sun Run	1.90	0.040
Medea Creek	Commercial 2	Sun Riffle	1.20	0.0275

Creek	Name/ Land Use	Habitat	Revised QUAL2K with Accrual Adjustment	
			TN	TP
Las Virgenes	Multiple 1	Shade Run	0.49	0.0057
Las Virgenes	Multiple 1	Shade Riffle	0.41	0.0047
Las Virgenes	Multiple 2	Sun Run	NL	NL
Las Virgenes	Multiple 2	Shade Run	1.00	0.0235
Las Virgenes	Multiple 2	Shade Riffle	0.41	0.0047
Malibu Creek	Below Tapia	Shade Run	0.38	0.0044
Malibu Creek	Below Tapia	Sun Riffle	0.54	0.013
Malibu Creek	Below Tapia	Shade Riffle	0.39	0.0045

F.3.5 Discussion of Stream Results

The Malibu case study raises a number of important methodological questions for the CA NNE:

1. ***Definition of "maximum" density***

Several of the scoping methods are designed to predict maximum benthic algal density. What is meant by "maximum"? Use of the maximum ties back to the work of Dodds et al. (2002). There, maximum appears to be intended to represent the maximum algal growth potential (in response to nutrient and light availability) in the absence of temporary reductions in density due to grazing, scour, and other factors. It is thus intended to be a temporal maximum. It is not intended to be a spatial maximum in the sense of representing the single rock or other substrate that has the greatest algal growth within a transect. In other words, it should be a temporal maximum and a spatial average: the (temporal) maximum (spatial) average density. The Malibu sampling effort intentionally selected the surfaces with maximum algal growth, and also occurred in the August period when density appeared to be at a maximum. Under these conditions, the NNE tool predictions should be compared to the transect spatial average densities, recognizing that these densities may in some cases be biased upward relative to the average density across a transect.

2. ***Ratio to Ash-Free Dry Mass (AFDM)***

Unlike the other case studies, the Malibu sampling measured AFDM. Some of the Malibu sites had very high chlorophyll *a*-to-AFDM ratios – expectially for sites dominated by shade-tolerant diatoms. On the other hand, the QUAL2Kw-based scoping tools were "tuned" to results from the cross-sectional studies of Dodds et al. (2002, 2006), based on an assumed constant (and low) chlorophyll *a*-to-AFDM ratio of 2.5. One question this raises is if chlorophyll *a* density is really the appropriate indicator of impairment. When the ratio to AFDM becomes very high, a high chlorophyll *a* density may be associated with only a moderate biomass density. One alternative might be to assume that the true target is an AFDM of 60 g/m^2 when the target chlorophyll *a* density is 150 mg/m^2 (applying the default ratio of 2.5). Interestingly, a majority of the sampling sites were not found to exceed a AFDM density of 60 g/m^2 (Table F-2). Alternative targets calculated to achieve this AFDM target are shown in Table F-10. These are much higher than the targets presented above for sites with a high chlorophyll *a*-to-AFDM ratio, but converge to the low numbers derived relative to the chlorophyll *a* targets for sites where the ratio is lower.

Table F-10. Alternative Targets from Revised QUAL2Kw (with Accrual Adjustment) based on Achieving AFDM of 60 g/m^2

Creek	Name/ Land Use	Habitat	Revised QUAL2K w Accrual Adjustment	
			TN	TP
Medea Creek	Residential 1	Sun Riffle	0.70	0.017
Medea Creek	Residential 1	Shade Riffle	2.30	0.048
Medea Creek	Commercial 1	Sun Run	0.32	0.004
Medea Creek	Commercial 1	Sun Riffle	0.31	0.004
Medea Creek	Commercial 2	Sun pool	0.43	0.005
Medea Creek	Commercial 2	Sun Run	1.10	0.026
Medea Creek	Commercial 2	Sun Riffle	0.89	0.020
Las Virgenes	Multiple 1	Shade Run	2.30	0.047
Las Virgenes	Multiple 1	Shade Riffle	2.20	0.046
Las Virgenes	Multiple 2	Sun Run	2.60	0.054
Las Virgenes	Multiple 2	Shade Run	3.98	2.030
Las Virgenes	Multiple 2	Shade Riffle	3.43	0.174
Malibu Creek	Below Tapia	Shade Run	2.50	0.051
Malibu Creek	Below Tapia	Sun Riffle	1.20	0.028
Malibu Creek	Below Tapia	Shade Riffle	2.40	0.050

3. Applicability to Diatoms

As discussed in the previous item, some Malibu sites were dominated by shade-tolerant diatoms, with very high chlorophyll *a* densities even under fully-shaded conditions. Indeed, increasing the ratio of chlorophyll *a* to mass is an adaptive response to low light. Busse et al. (2003, 2006) found essentially no correlation between chlorophyll *a* density and light availability. In addition to the issue of the chlorophyll *a*-to-AFDM ratio raised above, the work of Dodds et al. appears to be mainly focused on filamentous algae. Applicability to diatom-dominated communities may be open to question.

4. Planktonic Algae

Two Malibu sites had significant amount of planktonic algae present in addition to benthic algae. Both floating and attached algae are competing for the available nutrients and light. Properly, both should be considered in the estimation of total algal density. Busse et al. attempted to account for this by estimating the area density of planktonic chlorophyll *a* – enabling an additive analysis. However, the empirical methods established for benthic algae may not be appropriate to planktonic biomass.

5. Nutrient Concentration Variability

As is typical in many studies, measurements of algal density were accompanied by simultaneous measurements of nutrients. This introduces a potential temporal disconnect, as the algal density is an integrative measure of nutrient availability over the preceding days and weeks. If the contemporaneous measures of nutrient concentration are not representative of prior exposure, misleading results can be expected. An additional complicating factor in the Malibu watershed is that there is significant documented diurnal variability in nutrient concentrations (Gilbert, 2009).

These issues impede the ability of the tool to predict observed algal densities. They do not necessarily affect the ability of the tool to estimate target concentrations.

F. 4 NNE Tool Application - Lakes

Four lakes of the Malibu Creek watershed were listed for eutrophication problems (algae, nutrients, ammonia, low DO) – Malibou Lake, Lake Lindero, West Lake, and Lake Sherwood. All these lakes have existing or intermittent beneficial uses of REC1, REC2, WILD, and WARM. Among the four lakes, Malibou Lake has the highest observed chlorophyll *a* at 44 µg/L, exceeding the endpoint for REC2 and WARM uses.

F.4.1 BATHTUB Tool Application

The NNE BATHTUB spreadsheet tool was applied to all four lakes. The nitrogen and phosphorous loads to the lake as the required inputs to the spreadsheet tool were estimated as the total of loads coming from inflow tributaries and atmospheric deposition to lake surfaces. The predicted nutrient and chlorophyll *a* concentrations in the lakes compared well with the observed values (Table F-11). For Lake Sherwood, predicted and observed chlorophyll *a* concentrations are low, despite elevated nutrient concentrations, due to very high turbidity (Secchi depth of 0.4 m).

Table F-11. Predicted and Observed Nutrient and Chlorophyll *a* Concentrations in Lakes

Constituents	Sherwood		West Lake		Lindero		Malibou	
	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
Chlorophyll *a* (µg/L)	16	18.6	14	27.3	23	32.3	44	42.6
TP Concentration (mg/L)	0.25	0.46	0.16	0.21	0.13	0.17	0.14	0.17
TN Concentration (mg/L)	2.23	2.88	1.69	1.6	1.58	1.48	1.78	1.71

F.4.2 Suggested Targets - Lakes

The suggested nutrient numeric endpoints for planktonic algal biomass in lakes are 20 µg/L for REC1 and 25 µg/L for REC2 and WARM for BURC II/III boundary, and 10 µg/L for BURC I/II boundary. Here the tool was used to estimate TN/TP loadings and target TN/TP concentrations to meet a chlorophyll *a* target of 20 µg/L.

Table F-12 listed the predicted probability of exceeding the chlorophyll *a* target of 20 µg/L and the calculated TN loadings (under current TP loadings) and TP loadings (under current TN loadings) needed to meet the target. The target can be achieved by either reducing TN loadings or TP loadings. In the case of Lake Sherwood, current average concentrations are below the 20 µg/L target and algal growth is limited by light availability, so no reduction in nutrient load is needed to achieve the target.

Table F-12. Predicted Probability of Exceeding Chlorophyll *a* Target and Calculated TN/TP Loadings to Meet Targets

	Sherwood	West Lake	Lindero	Malibou
Probability of exceeding 20 µg/L under current loads	34.93%	71.59%	83.77%	95.30%
Calculated TN loading (kg/yr) to meet target at existing TP loading	light-limited	22,147	2,124	22,148
Calculated TP loading (kg/yr) to meet target at existing TN Loading	light-limited	1,734	147	1,334
TN at target (µg/L)	NA	967	771	557
TP at target (µg/L)	NA	76	55	34

For a chlorophyll *a* target of 20 µg/L, the BATHTUB-based tool predicted that the target will be exceeded 95 percent of the time in Malibou Lake. The predicted total nitrogen load to meet the target of 20 µg/L (if the total phosphorus load is held constant at 7,190 kg/yr) is about 22, 000 kg/yr, a 70% reduction from current load of 75390 kg/yr. The reduction in N load would result in an average predicted influent TN concentration of 0.59 mg/L and an in-lake TN concentration of 0.56 mg/L, both less than the proposed TMDL limit of 1 mg/L nitrate plus nitrite N. The chlorophyll *a* target can also be achieved by reducing total phosphorus load; however, this would require a reduction of more than 80 percent relative to existing load. The reduction of total P load would result in an influent total P concentration of 0.036, which is also lower than the proposed TMDL limit of 0.1 mg/L. The average TN and TP concentrations estimated to be consistent with the 20 µg/L target are less than the TMDL targets of 1 mg/L for nitrate plus nitrite N and 0.1 mg/L for total P, although there are substantial lake-to-lake differences that are reflective of their individual assimilative capabilities. The predicted targets for TN generally compare well to the median and average of unimpaired waters and are lower than the third quartile concentrations in RTAG monitoring data (Table F-13). Calculated total P targets were more consistent with the median and average of the unimpaired waters than total N targets. The 304(a) ecoregional recommendations for lakes have very limited data for Level III ecoregion 6; however, the aggregate recommendations for nutrient ecoregion 3 (USEPA, 2001) are 0.31 mg/L for total N and 0.017 mg/L for total P – in both cases lower than the targets derived using the BATHTUB tool.

Table F-13. Comparison of Model Results to RTAG Region IX Monitoring Data (Tetra Tech, 2004)

Chemical	Stream Type	Median	Average	First Quartile	Second Quartile	Third Quartile	Fourth Quartile	No of Data points
NO3 (mg/L)	Unimpaired	0.10	0.43	0.10	0.10	1.00	4.52	190
	Impaired (other)	0.70	1.88	0.23	0.70	2.60	15.81	28
TKN (mg/L)	Unimpaired	0.50	0.73	0.20	0.50	1.00	5.40	315
	Impaired (other)	0.50	0.96	0.30	0.50	0.80	9.40	107

Chemical	Stream Type	Median	Average	First Quartile	Second Quartile	Third Quartile	Fourth Quartile	No of Data points
TN (mg/L)	Unimpaired	0.60	1.16	0.30	0.60	2.00	9.92	
	Impaired (other)	1.20	2.84	0.53	1.20	3.40	25.21	
	CA NNE Scoping Tool	0.56 – 0.97						
TP (mg/L)	Unimpaired	0.03	0.08	0.03	0.03	0.08	3.00	252
	Impaired (other)	0.03	0.03	0.01	0.03	0.04	0.11	81
	CA NNE Scoping Tool	0.034 - 0.076						

F.5 Summary

The California NNE method and tools were successfully applied to the analysis of stream periphyton and lake planktonic algae in the Malibu Creek watershed. The standard and revised QUAL2K methods appeared to provide a reasonable fit to observed maximum periphyton density (as chlorophyll *a*). The application however suggested highly variable nutrient targets under different land uses and habitat conditions. Generally lower than 1 mg/L total nitrogen targets are required for stream segments with human influence in the surrounding watershed to achieve a maximum periphyton density of 150 mg/m^2. The four lakes also appear to require total nitrogen less than 1 mg/L.

The proposed nutrient TMDL for Malibu Creek watershed (USEPA Region IX) with a target nitrate-plus-nitrite nitrogen concentration limit of 1mg/L (and no limit on total nitrogen) and phosphorous limit of 0.1 mg/L is greater than the total nitrogen targets estimated for this watershed using the CA NNE tools. It is acknowledged that NNE tools provide a scoping-level analysis of nutrient targets, and should be superseded by a site-specific calibrated nutrient model where available.

The analysis for both stream and lake sites suggest that the TMDL criteria (USEPA Region IX, 2003) for the Malibu Creek watershed of 1 mg/L nitrate plus nitrite N and 0.1 mg/L total phosphorus (from April 15 to November 15) may not be adequate to support uses. As a postscript to this analysis it is noted that continued monitoring of Malibu Creek by Heal the Bay through 2010 has not revealed any excursions of the nitrate plus nitrite goal during the growing season since 2005. In contrast, phosphorus concentrations have remained high. The monitoring does not appear to show improvement in mat algal coverage, which continues to be greater than 60 percent in many samples.

F.6 References

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Appendix G. Hypothetical Linkage Analysis Example

To illustrate the linkage analysis process, this section presents a hypothetical example.

Babbling Brook recently experienced a series of fish kills. After the first fish kill, scientists investigated the stream and learned that the fish kills occurred downstream of a permitted point source discharge from a chemical manufacturing company. During the course of their investigation, biologists noted impaired fish communities, increased nutrient concentrations, toxic chemicals in the water column exceeding water quality criteria, and low dissolved oxygen. Fish collected from the site showed an unusually high number of deformities, fin erosion, lesions, tumors and anomalies. After collecting sufficient data, a linkage analysis was performed.

The candidate causes listed included the following:

1. Increased nutrients causing algal blooms and reduced DO
2. Point source discharges exceeding thermal permit limits and causing reduced DO
3. Point source discharges exceeding toxic chemical permit limits

Evidence from the case for candidate cause #1 included measurements of increased nutrients in Babbling Brook. The increased nutrient concentrations occurred both far upstream and downstream of the location of the fish kills. However, algal growth was observed to be very low, likely due to heavy canopy cover of the stream resulting in light limitation. Evidence from outside the case strongly supported a linkage between increased nutrients, algal blooms, and reduced dissolved oxygen—as long as light requirements also are met.

Evidence from the case for candidate cause #2 included water temperature measurements in the discharge plume, upstream, and downstream of the discharge. Coincident DO measurements were also available, and showed the expected relationship with temperature: lower DO occurred with higher water temperature. Temperature was lower and DO was higher upstream of the discharge compared with downstream, but temperature and DO returned to near upstream levels within approximately 100 meters of the discharge. Babbling Brook was categorized as a cold-water stream, with a DO criterion of not less than 6 mg/L. Continuous DO monitoring at several locations along the stream revealed that DO dipped to approximately 3 mg/L at the point of discharge. Evidence from outside the case shows that fish and other aquatic organisms frequently cannot survive DO levels less than 5 mg/L. On the other hand, evidence also shows that fish will avoid areas of low DO if possible.

Evidence from the case for candidate cause #3 included water column and sediment measurements of toxic chemicals in multiple locations along the stream, upstream and downstream of the discharge. The toxic chemicals were only detected downstream of the discharge. No water quality criteria are available for the toxic chemicals present, so no clear comparison to aquatic health-based criteria could be made. Evidence from outside the case, however, included laboratory studies of one of the chemicals, showing that the chemical caused a specific anomaly in test fish at low concentrations, and death at high concentrations. These anomalies were among the anomalies observed in fish from the stream. Fish surveys conducted prior to the chemical company’s existence made no mention of the specific anomaly.

Candidate cause #1 could be eliminated as a possible stressor, because the lack of algal growth in the stream shows unambiguously that the causal pathway is not complete.

Candidate cause #3 provided diagnostic evidence of at least one toxic chemical released from the point source discharge as a cause of fish community impairment. The anomaly demonstrated by laboratory fish to this chemical was very specific (no other chemicals were known to cause it). The same anomaly and the same chemical were observed in the stream, co-occurring in space. Additionally, the lack of observations of the anomaly prior to the chemical company discharging into the stream, and the occurrence of the anomaly later provided temporal evidence for causality.

Candidate cause #2 could not be eliminated as a causal factor. Evidence from the case indicated that co-occurrence and temporality were both compatible with thermal impacts being a causal factor, but the biological gradient was weak (fish could avoid the area of high temperature and low DO). Therefore, the evidence from the case was incomplete for the exposure pathway. Evidence from outside the case indicated that high temperature and low DO are plausible, but not specific causal factors for fish community impairment. Many cases exist in the literature for high temperature as a cause of fish community impairment, especially to cold-water streams, but there was no evidence for predictive performance. The consistency of evidence was that most evidence was consistent, and the inconsistencies could be explained by a credible mechanism: the evidence was coherent.

In this hypothetical case, the toxic chemical emerged as a primary stressor correlated with fish community impairment, with a high level of confidence. Thermal effects may also be associated with impairment in the stream.

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