National Park Service
U.S. Department of the Interior

Mediterranean Coast Network
Thousand Oaks, Ventura, & San Diego, California

Stream Water Quality Monitoring in the Mediterranean Coast Network (MEDN)

Santa Monica Mountains National Recreation Area

Version 1.0, January, 2008

Natural Resources Technical Report NPS/MEDN/NRTR—2008/00?

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Please cite this publication as:

Hibbs, B., J. L. Cameron, S. Hollinger,, & M. Merino, 2006. Stream Water Quality Monitoring in the Mediterranean Coast Network (MEDN), Version1.0. Natural Resources Technical Report NPS/MEDN/NRTR—2008/00?, 36 pp.

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LIST OF ACRONYMS AND ABBREVIATIONS USED

APHA	American Public Health Association
BU	Beneficial Use
CALM	Consolidated Assessment and Listing Methodology (EPA)
CHIS	Channel Island National Park
CABR	Cabrillo National Monument
COD	Chemical Oxygen Demand
CRM	Certified Reference Material
CCV	Continue Calibration Verification
CWA	Clean Water Act
END SP	Endangered Species
ELAP	Environmental Laboratory Accreditation Program
HUC	Hydrologic Unit Code
LARWQCB	Los Angeles Regional Water Quality Control Board
LOQ	Level of Quotations
LVMWD	Las Virgenes Municipal Water District
MEDN	Mediterranean Coast Network
MDL	Method Detection Limit
MQO	Measurement Quality Objective
MRT	Mountain Restoration Trust
MSD	Matrix Spike Duplicate
NAWQA	National Water Quality Assessment (USGS Program)
NFM	National Field Manual (USGS)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPSTORET	National Park Service version of EPA's STORET database
NPS	National Park Service
PQL	Practical Quantitation Limit
QAPP	Quality Assurance Project Plan
RCDSMM	Resource Conservation District of Santa Monica Mountains
RPD	Relative Percent Difference
RWRCB	Regional Water Resources Control Board
RWQCB	Regional Water Quality Control Board
SAMO	Santa Monica Mountains National Recreation Area
SCCWRP	Southern California Coastal Water Research Project
SOP	Standard Operating Procedure
SRM	Standard Reference Material
STORET	Storage and Retrieval (EPA's Water Quality database)
SWRCB	State Water Resources Control Board
TRL	Target Reporting Limit
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WMA	LARWRCB Watershed Management Area
WRD	Water Resources Division (National Park Service)

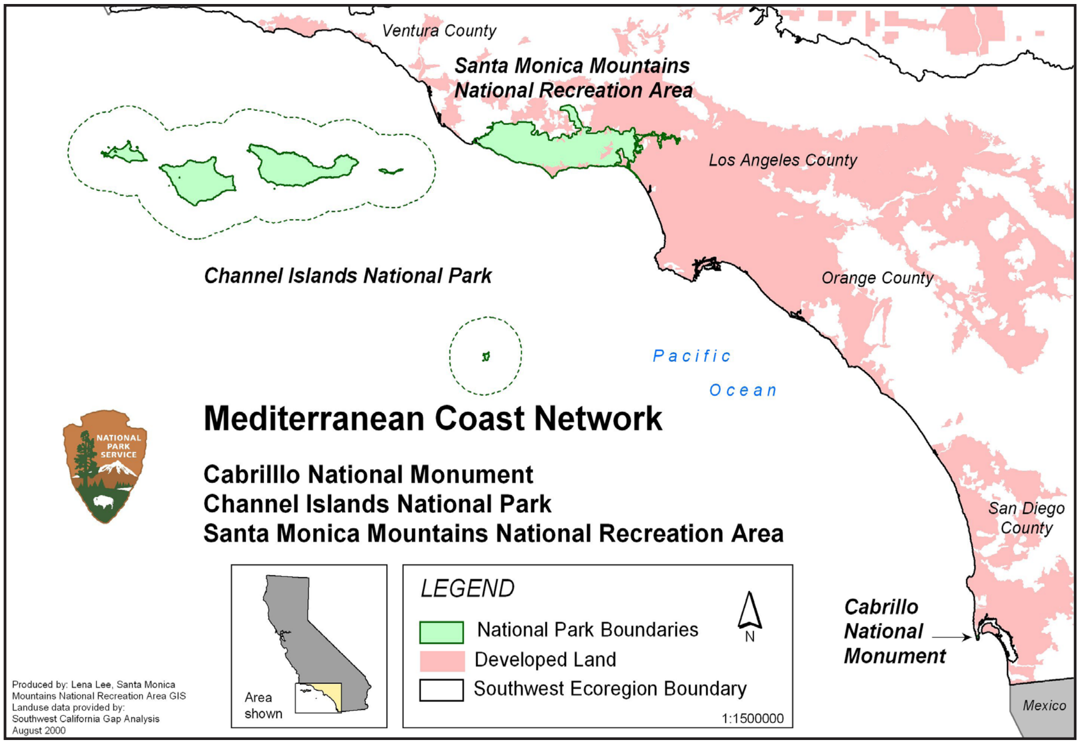


Figure 1.1. Santa Monica Mountains National Recreation Area, Channel Islands National Park, Cabrillo National Monument.

1.0 BACKGROUND AND OBJECTIVES

1.1 Introduction

The Mediterranean Coast Network (MEDN) includes three national park units: Santa Monica Mountains National Recreation Area (SAMO), Channel Islands National Park (CHIS), and Cabrillo National Monument (CABR) (Fig. 1.1). Within the Santa Monica Mountains and Channel Islands are numerous ephemeral, intermittent and perennial streams. While the protocol developed here is intended to be utilized for monitoring surface fresh water resources in SAMO and CHIS, this iteration of the protocol addresses water quality sampling in the Santa Monica Mountains only. Cabrillo National Monument contains only ephemeral stream channels, and biological surveys at CABR have found no organisms that require freshwater aquatic habitat for any of their life stages. Because of its lack of freshwater habitat resources, CABR is not included in this monitoring program.

A separate monitoring protocol is being developed for water quality of marine waters along the shores of CHIS and CABR. References to SAMO or the Santa Monica Mountains include the Simi Hills and much of the area in between the Santa Monica Mountains and the Simi Hills. Within the MEDN this area is called the Santa Monica Mountains Resource Management Zone (RMZ) (Figure 1.2).

The Santa Monica Mountains National Recreation Area and Channel Islands National Park lie within the U.S. Geological Survey (USGS) Water Resource Region 18, Subregion 1807. The Santa Monica Mountains and Channel Islands have many unique aquatic resources that are significant within an ecological and/or socioeconomic context. Aquatic resources in the two units include streams, estuaries, lagoons, lakes, reservoirs, freshwater and estuarine marshes, and springs.

The Santa Monica Mountains Resource Management Zone lies entirely within the regulatory boundary of the Los Angeles Region of the State Water Resources Control Board (Los Angeles Regional Water Quality Control Board; LARWQCB). Arroyo Sequit and all coastal streams farther east are included in LARWRCB's Santa Monica Bay Watershed Management Area. Coastal streams west of Arroyo Sequit are within the Ventura Coastal Streams Watershed Management Area (WMA). Small portions of the RMZ to the west and north of the Ventura Coastal Streams WMA lie within the Oxnard Plain WMA and the Calleguas-Conejo WMA. A small strip along the north

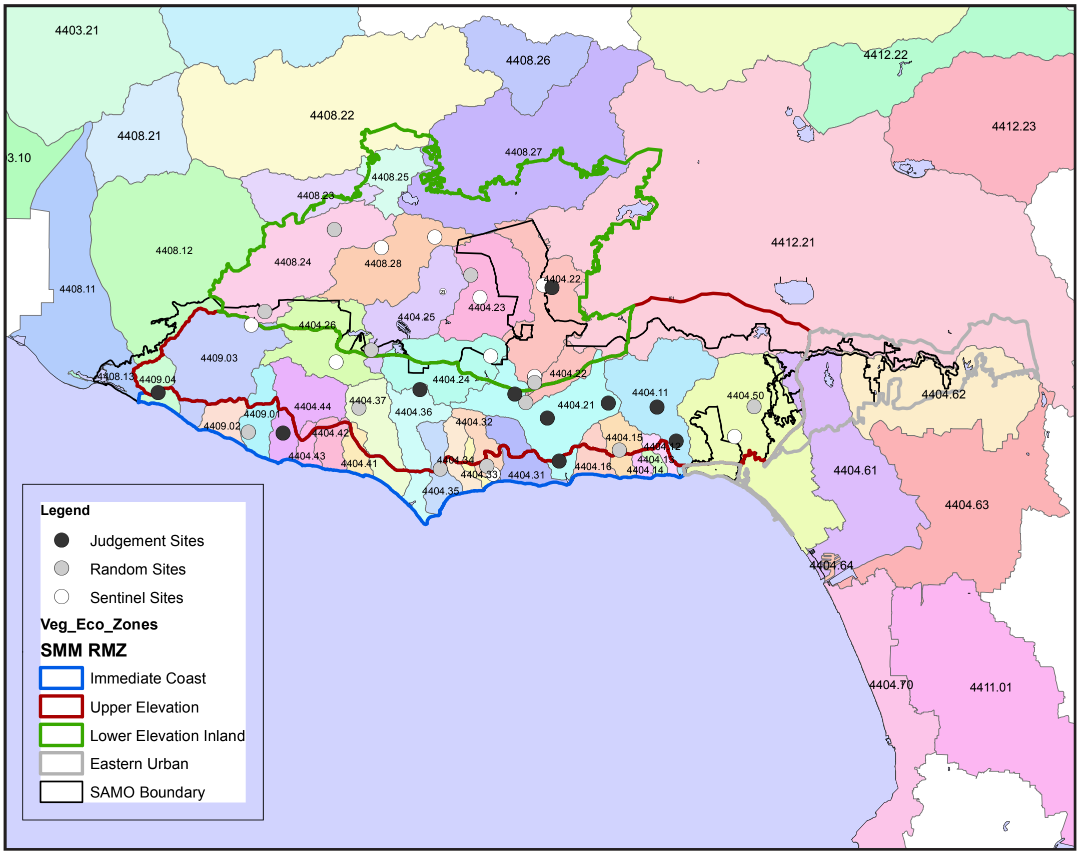


Figure 1.2: Sample locations within the Santa Monica Mountains RMZ. Watersheds are highlighted in different colors. Sub-watersheds are outlined and identified with their hydrological unit code (CalWater GIS database version 2.2).

slope of the Santa Monica Mountains is in the Los Angeles River WMA.

Streams on the mountains' north slope are quite small and are not proposed for monitoring in this protocol. A minimum of 31 stations are to be sampled three times a year. Stations are identified from within a suite of three sampling criteria: Ten amphibian monitoring sites are included as "sentinel" sampling sites. These sites carry over from a five year inventory of the distribution and abundance of aquatic amphibians in the Santa Monica Mountains. Twelve additional randomly selected amphibian monitoring sites from across the Santa Monica Mountains RMZ are also included. Finally nine sites were selected for monitoring based upon their state designated beneficial use, 303(d) impairments, TES habitat, or for their potential as reference streams (see Figure 1.2).

Three independent samples for laboratory analyses will be collected at each site during each visit. Additionally, three independent determinations of pH, water temperature, dissolved oxygen, and conductivity will be made at each visit to each site. These determinations will be made with hand held instrumentation and will be taken at ten meter intervals moving up stream from the primary sampling point. These three values are intended to add replication to the sampling program to allow for a better estimation of the precision in reading values and to account for potential micro-scale variability at the sampling location.

Watershed conditions within SAMO vary from relatively undisturbed to those with significant urban development. Terrain includes coastal plains, coastal mountains, deeply-incised canyons, and inland valleys. Large areas of wild land are protected as State Park and National Park open space. Cold Creek Preserve, managed by the Mountains Restoration Trust (MRT), is regarded as one of the most natural botanical areas in Southern California. Portions of or all of the communities of Los Angeles, Calabasas, Agoura Hills, Newbury Park, Malibu, and Thousand Oaks fall within the boundary of the Santa Monica Mountains NRA. Land use within SAMO and the larger RMZ includes agricultural, commercial (e.g., cattle, sheep, and goat ranching, equestrian operations, landscape plant nurseries), residential housing, natural open space (in public and private ownership), and state designated wilderness areas.

The Mediterranean climate of the

southern California region is characterized by cool wet winters and warm dry summers. Surface hydrologic systems in southern California are very flashy. Stream flows rise quickly in response to winter storms, then diminish rapidly when rainfall ceases. Between storm events, emerging groundwater and urban runoff generate relatively small base flows. Base flow discharge is typically subsurface in stream reaches with deep alluvial substrate. Stream channel processes are naturally quite dynamic due to active geologic processes associated with faulting, tectonic uplift, stream erosion, coastal erosion, and geomorphologic responses to rising sea levels since the close of the last glacial epoch.

Recent and continuing anthropogenic watershed alterations increase the complexity of the natural hydrologic systems. Impervious surfaces such as pavement and rooftops significantly reduce infiltration and increase storm runoff, altering natural stream-flow patterns. Streambeds and stream banks are altered when watershed disturbances increase the amount of sediment delivered to streams, dams block sediment movement within streams, or streams are channelized to prevent erosion and control flooding.

Imported water associated with urbanization significantly increases flow in Malibu Creek, its major tributaries, in Topanga Creek, and to a lesser extent in other streams with small numbers of upstream residences and businesses served by municipal water systems. As a result, many formerly intermittent or ephemerally flowing stream reaches exhibit perennial flow. While this altered flow has increased the available aquatic habitat in these streams, habitat quality is compromised by the poor quality of this runoff and the colonization of streams and riparian areas by several invasive species, most notably crayfish, bass, carp, sunfish, the giant reed *Arundo donax*, and the recent discovery of *Potamopyrgus antipodarum* (the New Zealand mudsnail).

Despite the presence of invasive species and water quality degradation from urban runoff, Malibu Creek and Topanga Creek both support small but robust populations of steelhead trout. Several efforts to improve watershed resources within SAMO are underway. There has been much effort to eradicate *Arundo donax*, one of southern California's most damaging invasive plants, from stream channels within SAMO. The Mountains Restoration Trust (MRT), in partnership with State Parks, the Resource Conservation District of the Santa Monica Mountains (RCDSMM), and volunteer groups are implementing a plan to remove large amounts of *Arundo* from Malibu Creek and Topanga Creek watersheds.

1.2 Aquatic Species of Concern

The combination of marine, brackish, and freshwater aquatic systems within the network parks support a variety of threatened and endangered species. Streams in the Santa Monica Mountains support three of the four southern-most existing populations of steelhead trout (*Oncorhynchus mykiss*) on the Pacific coast. Small populations of this Federal and State Endangered Species have survived continuously in Malibu Creek downstream from Rindge Dam and in Arroyo Sequit. Steelhead were historically documented upstream from Rindge Dam in Malibu Creek and several of its tributaries, but have not been observed since construction of the dam in the 1920's created a barrier to migration from the ocean. Steelhead also inhabited perennial reaches of numerous other streams in the Santa Monica Mountains including Solstice Creek and Topanga Creek, but had disappeared from those streams by the mid to late 1900's.

In the late 1990's, after an absence of almost twenty years, steelhead appeared and successfully spawned in Topanga Creek (RCD and Moffet & Nichol, 2002). Since then, steelhead have persisted and reproduced in Topanga Creek and their numbers have increased. Surveys conducted in 2004 documented almost two hundred steelhead in Topanga Creek, including young of the year, juveniles, and adults. Recent surveys found comparable numbers of steelhead in Malibu Creek. Steelhead are consistently seen in small numbers in Arroyo Sequit, where steelhead habitat was heavily impacted by a major wildfire in the early 1990's.

The tidewater goby (*Eucyclogobius newberryi*), a Federal and State Endangered Species, was reintroduced to Mugu Lagoon in the early 1990's. This species historically inhabited Malibu and Topanga lagoons, but disappeared from both in the mid-1900's.

After reintroduction to Malibu Lagoon *E. newberryi* established a thriving stable population, and in 2001 tidewater gobies were documented in Topanga Lagoon. It is likely that individuals swam down the coast from Malibu Lagoon, the nearest known source population, colonizing Topanga Lagoon which now also supports a reproducing population of tidewater gobies (RCD and Moffet & Nichol, 2002).

In 2001 the California red-legged frog (*Rana aurora draytonii*), thought to have been extirpated from streams in the Santa Monica Mountains, was discovered in a short isolated perennial reach of the East Fork of Las Virgenes Creek. This small population was found during planning surveys for a proposed residential development in the area. The frog's presence helped motivate the State of California to purchase land around the area for protection from development.

The southwest pond turtle (*Clemmys marmorata pallida*) which historically inhabited numerous streams in the Santa Monica Mountains has all but disappeared from much of the area. The only known thriving population of native pond turtles in the Santa Monica Mountains survives in the upper reaches of Old Topanga Canyon (Dagit, pers. comm.)

1.3 Beneficial Uses

Water bodies within the Santa Monica Mountains are regulated by the Los Angeles Regional Water Quality Control Board, part of the State Water Resources Control Board, an agency in the California Environmental Protection Agency. This board establishes management criteria for water bodies within the state of California. In its Quality Control Plan (also referred to as a "Basin Plan"), the LARWQCB has established beneficial use objectives for streams and rivers in Los Angeles and Ventura Counties, and has set numeric and narrative criteria to meet these surface water use objectives (California Regional Water Quality Control Board, 1995).

The primary water quality issues within the Santa Monica Mountains relate to whether or not streams are supporting the beneficial uses established by the LARWQCB. Table 1.1 identifies beneficial uses of streams proposed for monitoring in this protocol. Table 1.2 lists specific sample locations and the beneficial use objectives for the streams at those locations in the Santa Monica Mountains RMZ where monitoring is proposed. The numerous beneficial uses of surface waters in the Santa Monica Mountains are a testament to the significance of water resources within the mountains.

Table 1.1. Beneficial use acronyms included in this text and their definitions.

Acronym	Definition
AGR	Agricultural Supply
COLD	Cold Freshwater Habitat
FRESH	Freshwater Replenishment
GWR	Groundwater Recharge
MIGR	Fish Migration
MUN	Municipal Supply
RARE	Preservation of Rare and Endangered Species
REC1	Contact Water Recreation
REC2	Non-contact Water Recreation
SPWN	Fish Spawning
WARM	Warm Freshwater Habitat
WET	Wetland Habitat
WILD	Wildlife Habitat

Beneficial uses related to recreation (REC 1, REC 2), and wildlife habitat (COLD, MIGR, RARE, SPWN) are particularly important for Santa Monica Mountain streams. This list is somewhat outdated in that bureaucratic grindings have not yet caught up to the recent listing of southern steelhead trout as endangered by State and Federal agencies. This effectively adds the RARE use to several streams in the mountains. In addition, southern steelhead trout recently returned to Topanga Creek, which now also warrants a RARE designation.

The RWQCB defines REC 1 (contact recreation) as: "Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, and uses of natural hot springs." REC 2 (non-contact water recreation) is defined as: "Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where ingestion is reasonably possible. These uses include but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities" (California Regional Water Quality Control Board, 1995).

Table 1.2. Beneficial use objectives for water bodies in the SMM RMZ where water quality monitoring is proposed. Data are from the Basin Plan for the Coastal Watershed of Los Angeles and Ventura Counties, 1995; and Calleguas Creek Watershed Management Plan, 2004.

Stream Name:	Hydrological Unit Code	Beneficial Uses												
		MUN	GWR	AGR	FRSH	REC1	REC2	WARM	COLD	WILD	RARE	MIGR	SPWN	WET
Sentinel														
Big Sycamore Canyon	409.03	P	I			I	I	I	E	E		P	P	E
Carlisle Canyon	404.26	P	E			E	E	E		E				E
Erbes (Lower)	403.68†	P	E	E		E	E	E		E			E	
Lang Ranch (N)	403.68†	P	E	E		E	E	E		E				
Las Virgenes (N)	404.22	P				E	E	E	P	E	E	P	P	E
Las Virgenes (S)	404.22	P				E	E	E	P	E	E	P	P	E
Medea Creek (N)	404.23	I	I			E	E	E		E				E
Medea Creek (S)	404.23	I	I			E	E	E		E				E
Solstice Canyon	404.32	E				E	E	E		E		P	P	
Temescal Canyon	404.50	P				E		E		E	E			
Random (GRTS) Year 1														
Arroyo Conejo	403.64‡	P	I		I	I	I	I		E	E			
Carlisle Creek	404.25	P	E			E	E	E		E				E
Conejo Creek	403.64‡	P	I		I	I	I	I		E	E			
Las Flores	404.15	P				I	I	I		E				
Liberty Canyon	404.22	P				E	E		P	E	E	P	P	E
Little Sycamore	409.01	P				I	I	I		E	E		P	
Malibu Creek	404.21	P				E	E		E	E	E	E	E	E
Medea Creek	404.23	I	I			E	E	E		E				E
Ramirez	404.35	I				I	I	I		E			P	
Sullivan Canyon	404.50	P				I	I	I		E				
Solstice	404.32	E				E	E	E		E		P	P	
West Fork Trancas	404.37	E				E	E	E		E	E			
Random (GRTS) Year 2														
Bulldog Motorway	404.21	P				E	E		E	E	E	E	E	E
Cheesboro Creek	404.23	I	I			E	E	E		E				E
Circle X	404.44	P	I			E	E	E	E	E	E	E	E	E
Escondido Creek	404.34	I				I	I	I		E	E			
Las Flores	404.15	P				I	I	I		E				
Las Virgenes	404.22	P				E	E	E	P	E	E	P	P	E
Olson Road	403.64‡	P	I		I	I	I	I		E	E			
Rustic Creek	404.50	P				I	I	I		E				
Santa Ynez Canyon Trail	404.50	P				I	I	I		E				
Sostoma Trail	404.31	I				I	I	I		E		P	P	
Suttphur	404.11	P				I	I	E	E	E		P	I	
Triunfo	404.24	P				I	I	I		E				E
Random (GRTS) Year 3														
Arroyo Seguit	404.44	P	I			E	E	E	E	E	E	E	E	E
Cold Creek	404.21	P				E	E		E	E	E	E	E	E
Conejo Creek	403.64‡	P	I		I	I	I	I		E	E			
Malibu Creek (Crags Road)	404.21	P				E	E		E	E	E	E	E	E
Malibu Creek (Cross Creek)	404.21	P				E	E		E	E	E	E	E	E
Lady Face	404.23	I	I			E	E	E		E				E
Liberty Canyon	404.22	P				E	E	E	P	E	E	P	P	E
Malibu Creek State Park	404.21	P				E	E		E	E	E	E	E	E
Malibu Nature Preserve	404.43	P				I	I	E		E				
Topanga Creek (Summit Road)	404.11	P				I	I	E	E	E		P	I	
Topanga Creek (Topanga Blvd)	404.11	P				I	I	E	E	E		P	I	
Tuna Canyon	404.12	P				I	I	I	E	E				
Judgment														
Arroyo Sequit (Lower)	404.44	P	I			E	E	E	E	E	E	E	E	E
Cold Creek (Upper)	404.21	P				E	E		P	E	E		P	E
Cold Creek (Lower)	404.21	P				E	E		P	E	E		P	E
La Jolla Canyon	409.04	P	I			I	I	I	E	E		P	P	E
Las Virgenes Creek (East Fork)	404.22	P				E	E	E	P	E	E	P	P	E
Malibu Creek (Upper)	404.21	P				E	E		E	E	E	E	E	E
Malibu Creek (Lower)	404.21	P				E	E		E	E	E	E	E	E
Topanga Canyon (Upper)	404.11	P				I	I	E	E	E		P	I	
Topanga Canyon (Lower)	404.11	P				I	I	E	E	E		P	I	

† Designated as 408.28 in CalWater 2.2.
‡ Designated as 408.24 in CalWater 2.2.
E: Existing beneficial use.
P: Potential beneficial use.
I: Intermittent beneficial use.
For streams where no beneficial use designation has been determined, nearest down stream beneficial use is applied to the stream.

While most REC 1 use in the Santa Monica Mountains is limited to Malibu Creek and its tributaries, most other streams in the Santa Monica Mountains are too small to support significant recreational use. Hikers often cool off in mountain streams during the summer resulting in REC 1 classification for these streams. Virtually all streams in the Santa Monica Mountains provide important wildlife habitat. Many RARE (Preservation of rare and Endangered Species) designations exist for streams throughout the mountains (Table 1.2).

1.4 Water Quality Criteria

The RWQCB Basin Plan prescribes numerical and narrative objectives for local surface waters. These general objectives are used to determine whether water bodies are meeting specific beneficial use objectives.

1.4.1 TMDLs

The United States Environmental Protection Agency (EPA) Region 9 has established Total Daily Maximum Loads (TMDLs) for bacteria, nitrogen and phosphorous in the Malibu Creek Watershed.

Bacteria

The TMDLs for bacteria apply to the following segments of the Malibu Creek Watershed: Malibu Lagoon, Malibu Creek and five of its tributaries (Stokes Creek, Las Virgenes Creek, Palo Comado Creek, Medea Creek, and Lindero Creek). The beneficial uses REC1 and REC2 of these water bodies were found to be impaired due to high levels of coliform bacteria (Table 1.3).

In order to achieve the numeric targets in Table 1.4, the EPA allocated quantitative loads to each pollutant source category for fecal coliforms. Point sources were given load allocations and non-point sources were given waste load allocations. The sum of the allocations constitute the TMDL. These allocations are listed in Tables 1.5 and 1.6.

Table 1.3. Water bodies within the Malibu Creek watershed that are listed as impaired due to high fecal coliform counts (LARWQCB, 1996).

Waterbody	Extent impaired
Lindero Creek Reach 2 (above Lake Lindero)	4.8 miles
Lindero Creek Reach 1 (Medea Creek to Lake Lindero)	2.2 miles
Medea Creek Reach 2 (above confluence with Lindero Creek)	5.4 miles
Medea Creek Reach 1 (from Malibou Lake to confluence with Lindero Creek	3.0 miles
Palo Comado Creek	7.8 miles
Las Virgenes Creek	11.5 miles
Stokes Creek	5.3 miles
Malibu Creek	9.5 miles
Malibu Lagoon	13 acres

Nutrients

The TMDLs for nitrogen and phosphorus apply to following segments of the Malibu Creek Watershed: Malibu Lagoon, Malibu Creek, Lake Sherwood, Westlake Lake, Lake Lindero, Las Virgenes Creek, Lindero Creek, Medea Creek, and Malibou Lake. The TMDLs for nitrogen and phosphorus address the nutrient-related 303(d) impairments in these streams. These impairments were considered by EPA as impacting the beneficial uses of these streams. EPA set numeric targets for nitrogen and phosphorus (Table 1.7). Allocations were set to achieve the TMDL numeric targets. Other streams in Santa Monica Mountains do not yet have established TMDLs.

1.5 Significant Waters

Surface waters of the Santa Monica Mountains are significant for several reasons. As mentioned above, primary beneficial uses are recreation and wildlife habitat. Protected open space in the Santa Monica Mountains may be easily accessed by the millions of people who live in the Greater Los Angeles area. The mountains thus experience high recreational use. The SMM are also a common destination for numerous environmental education programs in urban schools, and places such as Malibu Creek State Park contribute significantly to the environmental education of students who otherwise would have very limited opportunities to experience and learn about natural systems.

While wildlife habitats in the Santa Monica Mountains are not necessarily unique. Regionally they are critical for the maintenance of many focal wildlife species. The Santa Monica Mountains include a number of relatively pristine contiguous coastal watersheds, and are at or near the southern boundary of many sensitive species' distributions. This is exemplified by the presence of three of the four southern-most steelhead trout populations on the west coast. Topanga Creek, the southern-

Table 1.4. TMDL numeric targets for bacteria.

Parameter	Geometeric Mean		Single Sample
Malibu Creek and Tributaries	Fecal	200	400
	E. coli	126	235
Malibu Lagoon	Total	1,000	10,000 or 1,000 if FC/TC > 0.1
	Fecal	200	400
	Enterococcus	35	104

Table 1.5. Dry season fecal coliform allocations (10^9 counts/6 months) by source category based on 1992-1995 data.

Source Category	Existing Load	% of Existing Load	Target Reduction (%)	Load Allocation
Point				
Tapia Discharge	12	0%	0	24
Nonpoint				
Runoff from residential lands	171,000	30%	6	160,740
Runoff from commercial areas	184,000	32%	6	172,960
Agriculture/Livestock	81	0%	50	41
Dry Weather Urban Runoff	2,610	0%	6	2,453
Septic Systems	105,000	18%	65	36,750
Effluent Irrigation/Sludge	2	0%	0	0
Background Nonpoint				
Birds	108,000	19%	0	108,000
Runoff from undeveloped lands	723	0%	0	723
Tidal	2,580	0%	0	2,580
Other	692	0%	0	692
Total TMDL	**574,700**	**100%**	**16%**	**484,961**

Table 1.6. Annual fecal coliform allocations (10^9 counts/6 months) by source category based on 1992-1995 data.

Source Category	Existing Load	% of Existing Load	Target Reduction (%)	Load Allocation
Point				
Tapia Discharge	59	0%	0	265
Nonpoint				
Runoff from residential lands	3,160,000	50%	69	979,600
Runoff from commercial areas	2,550,000	40%	69	790,500
Agriculture/Livestock	35,600	1%	50	17,800
Dry Weather Urban Runoff	5,220	0%	69	1,618
Septic Systems	246,000	4%	65	86,100
Effluent Irrigation/Sludge	21	0%	0	0
Background Nonpoint				
Birds	250,000	4%	0	250,000
Runoff from undeveloped lands	43,200	1%	0	43,200
Tidal	16,100	0%	0	16,100
Other	18	0%	0	18
Total TMDL	**6,306,218**	**100%**	**65%**	**2,185,201**

Table 1.7. TMDLs for nitrogen and phosphorus.

Season	Total Nitrogen	Total Phosphorus
Summer (April 15 - November 15)	27 lbs/day	2.7 lbs/day
Winter (November 16 - April 14)	8 mg/l	n/a

most relatively intact watershed in the Santa Monica Mountains, supports populations of numerous sensitive species including steelhead trout, tidewater gobies, California tree frogs, western toads, western pond turtles, and two-lined garter snakes (RCD and Moffet & Nichol, 2002). No stream farther south supports this large of an assemblage of sensitive species.

1.6 Clean Water Act Section 303d Impaired Waters

1.6.1 Santa Monica Mountains WMA

Several surface water bodies within the Santa Monica Mountains RMZ have been identified as impaired (Table 1.8) by the LARWQCB and in some cases, EPA. The Clean Water Act (CWA) requires states to identify water bodies that do not meet applicable water quality standards. In the Santa Monica Mountains, from Pt. Mugu to

Table 1.8. Streams listed as 303d impaired (shaded) that will be monitored from each of the three stream selection criteria within the SMM RMZ.

Data taken from the Ventura and Los Angeles counties Coastal Streams Basin Plan and the Calleguas Creek Watershed Management Plan, Phase I Report.

		Salts			Metal		Pesticides						Nutrients									
Stream Name:	Hydrological Unit Code	Chloride	TDS	Sulfates	Lead	Selenium	DDT	Chlordane	ChemA	Endosulfan	HCH	Toxaphene	Nitrogen	Ammonia	Nitrate/Nitrite	Algae	Organic Enrichment/ Low Dissolved Oxygen	Toxicity	Coliform	Sediment/Siltation	Trash	Scum/Foam
Sentinel																						
Big Sycamore Canyon	409.03																					
Carlisle Canyon	404.26																					
Erbes (Lower)	403.68†	✓	✓	✓			✓		✓	✓		✓	✓	✓	✓	✓		✓				
Lang Ranch (N)	403.68†	✓	✓	✓			✓		✓	✓		✓	✓	✓	✓	✓		✓				
Las Virgenes (N)	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Las Virgenes (S)	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Medea Creek (N)	404.23					✓							✓		✓	✓			✓	✓	✓	
Medea Creek (S)	404.23					✓							✓		✓	✓			✓	✓	✓	
Solstice Canyon	404.32																					
Temescal Canyon	404.50																					
Random (GRTS) Year 1																						
Arroyo Conejo	403.68†	✓	✓	✓			✓		✓	✓		✓	✓	✓	✓	✓		✓				
Carlisle Creek (Eleanor)	404.25																					
Conejo Creek	403.64‡		✓	✓			✓	✓						✓								
Las Flores	404.15																					
Liberty Canyon	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Little Sycamore	409.01																					
Malibu Creek	404.21					✓							✓		✓	✓			✓	✓	✓	
Medea Creek	404.23					✓							✓		✓	✓			✓	✓	✓	
Ramirez	404.35																					
Solstice	404.32																					
Sullivan Canyon	404.50																					
West Fork Trancas	404.37																					
Random (GRTS) Year 2																						
Bulldog Motorway	404.21					✓							✓		✓	✓			✓	✓	✓	
Cheeseboro Creek	404.23					✓							✓		✓	✓			✓	✓	✓	
Circle X	404.44																					
Escondido Creek	404.34																					
Las Flores	404.15																					
Las Virgenes	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Olson Road	403.64‡																					
Rustic Creek	404.50																					
Santa Ynez Canyon Trail	404.50																					
Sostoma Trail	404.31																					
Suttphur Creek	404.11				✓																	
Triunfo Creek	404.24																					
Random (GRTS) Year 3																						
Arroyo Sequit	404.44																					
Cold Creek	404.21					✓							✓		✓	✓			✓	✓	✓	
Conejo Creek	403.64‡																					
Malibu Creek (Crags Road)	404.21					✓							✓		✓	✓			✓	✓	✓	
Malibu Creek (Cross Creek)	404.21					✓							✓		✓	✓			✓	✓	✓	
Lady Face	404.23					✓							✓		✓	✓			✓	✓	✓	
Liberty Canyon	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Malibu Creek State Park	404.21					✓							✓		✓	✓			✓	✓	✓	
Mailbu Nature Preserve	404.43																					
Topanga Creek (Summit Road)	404.11				✓																	
Topanga Creek (Topanga Blvd)	404.11				✓																	
Tuna Canyon	404.12																					
Judgment																						
Arroyo Sequit (Lower)	404.44																					
Cold Creek (Upper)	404.21					✓							✓		✓	✓			✓	✓	✓	
Cold Creek (Lower)	404.21					✓							✓		✓	✓			✓	✓	✓	
La Jolla Canyon	409.04																					
Las Virgenes Creek (E Fork)	404.22					✓							✓		✓	✓	✓		✓	✓	✓	✓
Malibu Creek (Upper)	404.21					✓							✓		✓	✓			✓	✓	✓	
Malibu Creek (Lower)	404.21					✓							✓		✓	✓			✓	✓	✓	
Topanga Canyon (Upper)	404.11				✓																	
Topanga Canyon (Lower)	404.11				✓																	

† Designated as 408.28 in CalWater 2.2.
‡ Designated as 408.24 in CalWater 2.2.

Santa Monica Canyon, there are 9 streams, 4 lakes and 1 lagoon listed by the RWQCB as impaired. This list of water bodies (303d list) is compiled by the Regional Water Quality Control Board and is updated and revised every two years. The 303d impairments listed herein are in substantial agreement with those listed in the NPS Water Resources Division designated use and impairment database (www1.nrintra.npos.gov/wrd/dui/). Also see Table 1.9.

Table 1.9. Length of streams listed as 303(d) impaired in the Santa Monica Mountains by region (From NPS data files).

Region	Kilometers	Miles
Immediate Coast (Coastal Sage Scrub)	3.12	1.94
Lower Elevation Inland Santa Monica Mountains and Simi Hills (Chaparral)	146.00	90.72
Upper Elevation Santa Monica Mountains (Chaparral)	32.95	20.47

1.6.2 Calleguas Creek WMA

Conejo Creek borders the northwestern boundary of SAMO and is within the LARWRCB's Calleguas Creek WMA. The LARWRCB's website at http://www.waterboards.ca.gov/losangeles/html/programs/regional_program/wmi2004/Impaired%20Waters%20by%20Watershed/Calleguas%20Creek%20Watershed%20303d%20Waters.doc lists no impairments for Conejo Creek.

1.6.3 Ventura Coastal WMA

The LARWRCB's website at http://www.waterboards.ca.gov/losangeles/html/programs/regional_program/wmi2004/Impaired%20Waters%20by%20Watershed/Misc%20Ventura%20Coastal%20WMA%20303d%20Waters.doc lists no impairments for coastal streams in the Santa Monica Mountains within the Ventura Coast WMA

1.7 Water Quality Monitoring History

Malibu Creek and its major tributaries form the largest watershed in the Santa Monica Mountains and environs, and it is the largest stream entering the northern Santa Monica Bay. This watershed is also heavily urbanized and it's water quality is regulated and monitored by several local and state agencies. Including Heal the Bay (http://www.healthebay.org/), Los Angeles Department of Public Works (http://www.ladpw.org/), the Los Angeles Regional Water Quality Control Board, Santa Monica Bay WMA web page (http://www.waterboards.ca.gov/losangeles/html/programs/regional_program/ws_santamonica.html) and the Las Virgenes Municipal water District (all www sites accessed 7/3/2007).

1.8 Resource Management Objectives

The resource management objectives for this monitoring protocol include:

1. Maintain the quality of surface waters in the Santa Monica Mountains within the range of natural chemical and biological limits to meet applicable federal and state water quality criteria. *Justification: Waters that vary within their natural ranges can typically support healthy aquatic ecosystems and most beneficial uses.*

2. Advocate for the improvement in the quality of impaired waters within the SMM RMZ. *Justification: The NPS Government Performance and Reporting Act (GPRA) goal is 99.3% of streams and rivers managed by NPS will meet State and Federal water quality standards. Several water bodies within the Santa Monica Mountains are impaired or flow into an impaired water body. See Table 1.9 for kilometers (miles) of impaired stream within the Santa Monica Mountains.*

While improving quality of the water in the streams of the SMM is a resource management objective. The NPS cannot achieve this objective without the buy in of local stakeholders and cooperators. Documenting the condition and trends in condition in water quality can provide the evidence needed to initiate corrective action by stakeholders holding regulatory authority to instigate remedial actions when warranted.

3. Demonstrate high water quality where it exists, and advocate for remedial or mitigating actions when warranted. *Justification: There are numerous coastal streams within the Santa Monica Mountains that support listed species of concern. In addition, National Parks should be leading the way in advocating for the maintenance of good water quality regardless of beneficial uses (i.e., consideration should be given to water resources for their intrinsic value alone).*

1.9 Monitoring Questions

The monitoring questions addressed

directly or indirectly in this protocol include:

- What is the range of variation in water quality within the streams of the Santa Monica Mountains as related to season, landscape strata, beneficial use criteria, and breeding aquatic amphibians?
- What are the long-term trends in condition and range of variation in water quality parameters from streams of the Santa Monica Mountains?
- Is the water quality of Santa Monica Mountains streams in compliance (stable or improving) with designated beneficial uses, or is it trending toward impairment?
- Are specific management actions of local stakeholders and cooperators maintaining or improving water quality?
- What are the status and trends of water quality in 303d streams of management significance in the Santa Monica Mountains.
- What are the status and trends of water quality in amphibian monitoring streams in the Santa Monica Mountains.

Specific monitoring questions for each category of stream segment and specific parameters to be monitored are included in Table 2.1 in Section 2 (Sampling Design). These questions will be further refined in subsequent versions of this protocol to include details related to temporal and spatial variability. Questions may also be added or clarified during initial implementation of the protocol.

2.0 SAMPLING DESIGN

2.1 Background

Detecting ecologically or statistically significant changes or trends in the condition of an environmental parameter is dependent upon the adequacy of the sampling program designed to detect or document those changes (Cooprider, 2005; Irwin, 2004). The process of developing a rigorous sampling design requires incorporation of management objectives and associated monitoring questions in the planning process. Several methods for selecting water quality sampling locations are commonly used (EPA, 2002; Cooprider, 2005). These include:

- ***Census***: sample every water body in a watershed
- ***Judgmental***: target specific water bodies and locations based on proximity to known pollution sources or based on identified ecological concerns (e.g., declining species population or diversity).
- ***Random or probabilistic:*** select streams, stream reaches, or specific sampling locations using some randomization process.
- ***Rotating streams or basins:*** target a subset of streams and sub-basins on a rotating basis for coverage of all streams or basins over a specific number of years (e.g., 100 total streams monitored once every 5 years, with 20 streams sampled each year on a rotating basis).
- ***Fixed station:*** Monitor the same stations and sites on a continuous basis (e.g., U.S.G.S. fixed site monitoring at designated gage stations).
- ***Intensive survey:*** incorporate a large number of stations in a watershed or designated area for intensive monitoring during a specified period.

Two or more methods may be integrated in a monitoring program and used in conjunction with one another where appropriate.

2.2 Sampling Design for the Santa Monica Mountains

Agencies or other entities with interest in SAMO have typically used judgmental designs for short-term projects (e.g., RCD monitoring in Topanga Creek and sporadic university monitoring of SMM streams). Long-term monitoring programs are conducted in Malibu Creek and its tributaries by the Las Virgenes Municipal Water District (LVMWD) and Heal the Bay. These programs have received extensive peer review and their data are accepted by regulatory agencies including the RWQCB. Both programs utilize judgmental sample site selection.

Most streams in the SMM are relatively small. Access to potential sampling locations is limited by property ownership, distance from roads or trails, and terrain. Many streams in the SMM have short perennial reaches situated between long intermittent or ephemeral reaches. For these reasons, locating random sampling stations on streams in the SMM can be somewhat problematic.

In spite of this, monitoring objectives for water quality in the SMM suggest that a combination of judgmental and random design are appropriate for selecting monitoring sites (Table 2.1). While a suite of sampling stations were selected based on the judgement of program planners, a number of stations were selected randomly from landscape level strata to allow reliable extrapolation of water quality characteristics across the streams within these strata (see the MEDN aquatic amphibian monitoring protocol). See section 2.3.3 for a discussion of the methods for selecting random sampling locations.

2.3 Overview of Site Selection

Streams in the Santa Monica Mountains RMZ may be categorized as ephemeral, intermittent, wadeable/perennial, or high flow/storm stage. All streams in the mountains can experience storm related high flow at some time during the year. Due to steep topography and angular channels that confine flows, most creeks are not wadeable during storm events. However, streams and creeks may be sampled during storms in many locations with extension sampling devices, temporarily mounted auto-sampling probes, or via other specialized sampling devices.

The population of streams to be sampled in the SMM during the first three years will include wadeable/perennial, intermittent, and high flow/storm stage (first flush) sites. Overall program design will include sampling for three years from a watershed-wide network of creeks and streams from these categories.

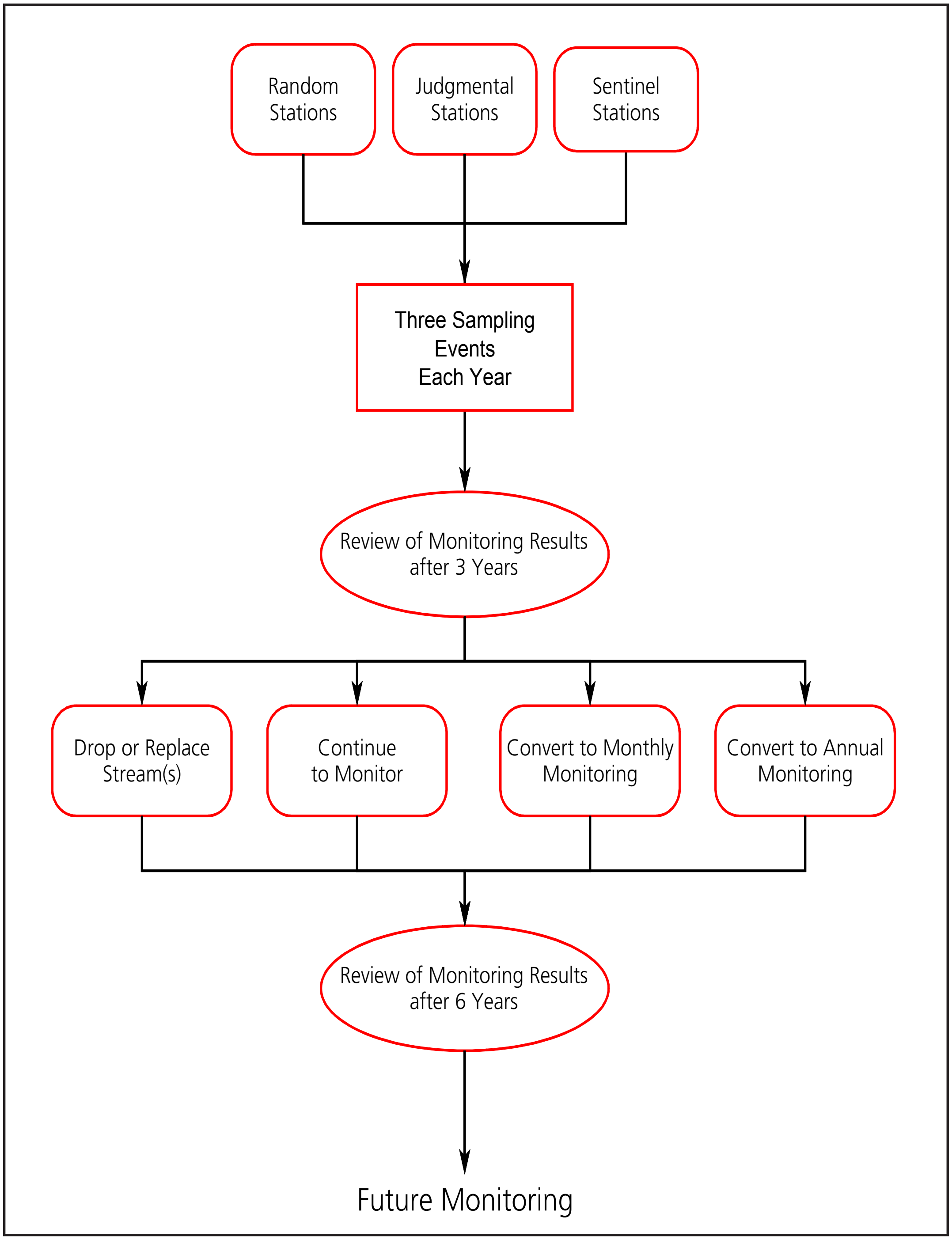
At the end of three years, a post-sampling audit will be done on all data to evaluate the effectiveness of sampling at a particular station to meet monitoring objectives (Figure 2.1). Subsequent program evaluations will be done after each

Table 2.1. Sampling design criteria based on monitoring questions modified from Cooprider, 2005.

Monitoring Question	Site/Sampling Location	Overall Sampling Design & Analysis
What are the ranges in variation of water quality parameters within the surface water resources of the SMM RMZ?	Random	Analyze data from randomly chosen upstream and/or control sites or reference streams; analyze annual, and seasonal data for each station and each group of stations in a stream or watershed.
What are long-term trends in water quality in SAMO surface water resources?	Random	Analyze data from randomly chosen sites in the upper, middle, and lower reaches. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed.
Does the water quality of SAMO surface waters meet beneficial use standards?	Random and Judgmental	Focus on sites known to be impaired; analyze data for each site for each group of stations (collectively) in a stream. Compare reference reach range with impacted reach range.
What are the pollution sources within the watersheds of the SMM RMZ?	Judgmental	Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed. Compare variability in reference reaches with variability in impaired reaches.
Are specific management actions reducing pollution loads?	Judgmental	Compare data from individual sites from one sampling event to another; also compare data from multiple sites within a stream. Analyze annual and seasonal data for each station and for each group of stations in a stream or watershed.

Levels of sampling design and associated degree of randomness:
Target stream (judgmental)
Site location (random or judgmental)
Habitat (pool/riffle, randomly chosen if possible)
Specific sampling spot within habitat (randomly chosen)

Figure 2.1. Flow of sampling activities from implementation of monitoring to protocol evaluation.



The plan specifies collecting data for 3 years at designated stations, followed by post-analysis audits to determine if and how to modify the plan after initial data is processed. The plan specifies additional post-audits at six-year intervals to evaluate and possibly modify the plan based on assessment of monitoring questions and goals.

addition six years (two complete cycles of the sample design) of monitoring (Figure 2.1).

Additional surface water bodies (e.g., ponds, wetlands, estuarine waters) may be added when protocols are updated, or as funding permits. Wetlands and marine/estuarine waters are valuable ecological and recreational waters within SAMO, but they are not included as target water bodies at this time since they were given a lower priority in the monitoring planning process (see the MEDN vital signs monitoring plan).

2.3.1 Sampling Limitations and Representativeness Issues

In addition to the site access limitations cited above there are other constraints to establishing a network of random sampling sites across a temporal sampling schedule. Several sites in the SMM require access from unpaved roads and trails that can be impassable following inclement weather. Muddy or damaged roads or trails can unpredictably limit access to sampling locations. Sites where access is over steep unstable slopes may occasionally present hazardous conditions for samplers during wet weather conditions. Normally, temporary restriction in access to a site can be remedied by sampling the site once the temporary constraint ameliorates or is removed, but this may involve staggering the sampling schedule in a less than ideal manner. In all cases, prudent judgments must be made to balance sampling needs against the safety of field personnel. Even in ideal weather conditions, sampling in the SMM involves risks from steep channel topography. Sampling personnel will not take unreasonable risks accessing sampling sites.

2.3.2 Selection of Target Streams

To avoid unnecessary duplication of effort and to reduce costs of this program, streams reaches already being monitored adequately by local stakeholders or other authorities are not proposed for inclusion in this program. Malibu Creek, the largest stream entirely within SAMO, is currently the subject of ongoing water quality monitoring programs conducted by the Las Virgenes Municipal Water District. Data from this monitoring are readily available to the MEDN.

The primary criteria for identifying sites from the population of streams in the SMM RMZ include streams that are part of the legacy amphibian monitoring program, stream size, annual flow pattern (perennial or intermittent), randomized geographic coverage, and investigator judgment based on pollution impacts or ecological importance. All of the larger streams in the SMM (>0.2 cfs during dry weather conditions) that could be sampled within the allotted budget and met access requirements were included in the population of streams from which monitoring sites were selected. Streams whose perennial reaches are entirely on private property are not included because of the uncertainty of long-term access.

While nearly all smaller streams (<0.05 cfs during dry weather conditions) are not proposed for inclusion in the sampling plan. East Fork Las Virgenes Creek, a headwater tributary to Malibu Creek, is an exception, and is included because it supports a population of the endangered, California red-legged frog (*Rana aurora draytonii*). The east fork drainage is entirely in public ownership, and it is not currently being monitored by any other stakeholder. The east fork is also valuable for monitoring as a reference stream because its drainage is one of the most natural and undisturbed in the Santa Monica Mountains.

2.3.3 Sampling Station Selection

The target population of stream stations for SAMO are identified as:

Sentinel Amphibian Monitoring

Ten stream monitoring stations that are part of an ongoing program monitoring stream use and breeding in four species of amphibians are included for water quality monitoring. Amphibian monitoring at these stations is part of an interagency program to monitor population dynamics of southern California amphibians. Selection of these ten stations was based upon the degree of urbanization within watersheds and the high likelihood of amphibian presence in the stream. These subjectively selected sampling locations are called “Sentinel” sites in the MEDN amphibian monitoring protocol. Each of these ten streams will me sampled three time a year. Three independent samples will be collected each visit at each of these sites for a total of 90 unique samples from sentinel streams each year.

Random Amphibian Monitoring

Thirty-six additional amphibian monitoring locations were selected using Generalized Random Tessellated Stratified (GRTS) survey design. Monitoring sites selected using GRTS are randomly chosen from a finite frame of possible sites and are spatially distributed across defined strata within the landscape frame. Sites were stratified according to vegetation and climate within the Santa Monica Mountains.

These sites are monitored following a rotating panel design with twelve sites sampled each year. All thirty-six sites will be sampled over three years. In the forth year, year-one sites are re-sampled and so on. These sites are called GRTS sites in the MEDN amphibian monitoring protocol. Each year twelve sites will be sampled three times with three independent samples taken at each visit. This results in 108 unique water quality samples from these twelve stations each year. See Figure 2.2 for a hierarchal representation of stream sampling types, timing of sampling, and number of samples to be collected at each sampling event.

Judgmental Stations

Judgement stations include stream reaches supporting endangered or threatened species; stream reaches impacted or potentially impacted by known or suspected pollutants (e.g., 303d impaired

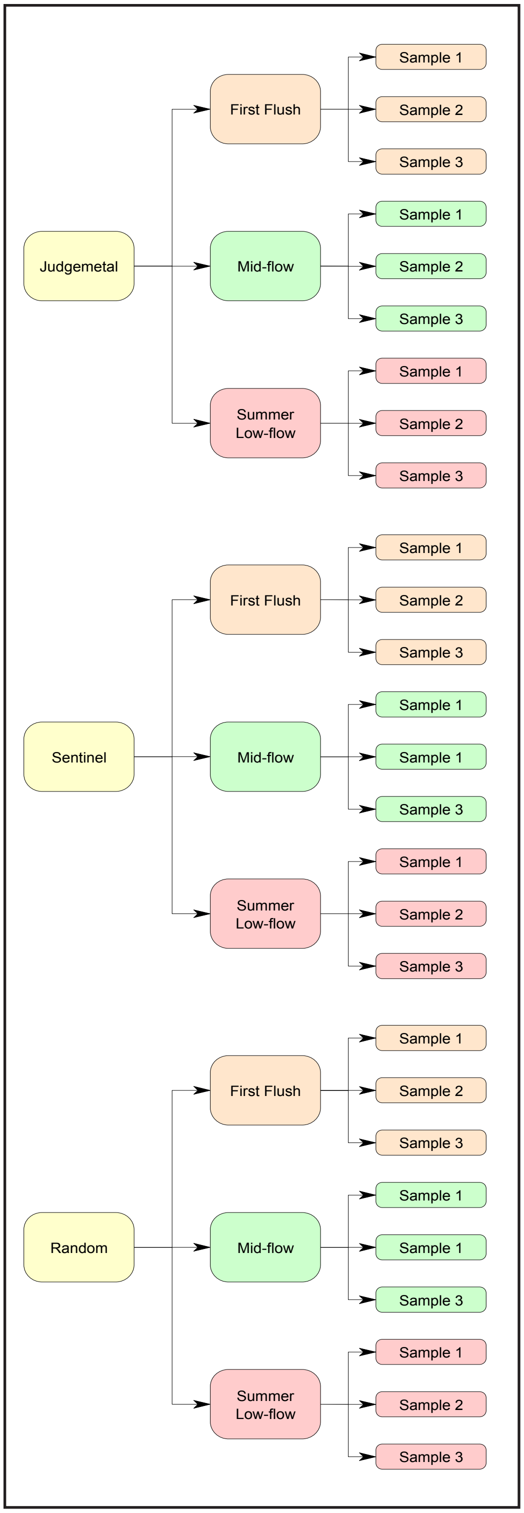


Figure 2.2. Hierarchy of propose sampling program for monitoring water quality in the Santa Monica Mountains.

A total of 31 stations will be visited 3 times a year with three independent samples taken at each visit. This gives a yearly total of 279 unique determination of the complete suite of data for the water quality parameters identified herein.

sites); or stream reference sites proposed for establishing background water quality at the watershed scale, or sites upstream of impaired stream reaches. Nine judgemental sampling station will be sampled three times each year with three independent samples collected during each sampling event. A total of 81 water quality samples will be collected and analyzed each year from judgemental stations.

Stream reaches subjectively selected were chosen based on the following criteria: 1) evidence or suspicion of contamination at a particular site (e.g., density of septic tanks, urban runoff sources, livestock and horse grazing areas), 2) human or aquatic health issue (e.g., recreational areas), 3) habitat for threatened and endangered species, 4) functionality as reference site monitoring, and 5) ongoing legacy amphibian monitoring.

The complete suite of sampling stations and temporal sampling frequency for those stations is presented in Table 2.2. This rotating panel design has all sentinel and judgemental stations being visited three times each year, supplemented by sampling at 12 of 36 randomly selected sites each year (see Figure 2.2).

Summarizing the above: ten sentinel amphibian monitoring sites, twelve random (GTRS) amphibian monitoring sites and nine judgemental stations will be sampled three times each year. Three independent samples will be collected and three independent series of *in situ* measurements will be made during each visit. These 93 unique water quality sampling events will result in 279 data points each year for each parameter monitored as outlined in Table 2.3 (see also Figure 2.2).

Streams Excluded From Monitoring

Streams subject to the following criteria or conditions were excluded from monitoring:

Ephemeral drainages:

Any stream that is not a wadeable or intermittent in flow is not included as a target stream. Within the SMM, ephemeral drainages are numerous, and most are small and unnamed. These drainages are usually tributary to targeted streams. First flush monitoring of targeted streams captures pollutants carried from ephemeral streams, but does not specifically identify the source of those pollutants.

Adequate monitoring by other entities:

Stream reaches consistently monitored by other entities (e.g., LVMWD) are not included in the monitoring program. Data from these monitoring efforts are available to the MEDN monitoring program, and the suite of water quality parameters monitored by these programs meets the needs and matches the quality of the MEDN monitoring program.

Table 2.2 Sampling frame for proposed water quality monitoring program in the Santa Monica Mountains.

Duplication in site names across groups is incidental. Site codes in the database are unique for these apparent duplicate sites.

Stream Name:	Sampling Years																	
	1			2			3			4			5			6		
Sampling Event	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Sentinel (10 Sites)																		
Big Sycamore Canyon	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Carlisle Canyon	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Erbes (Lower)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Lang Ranch (N)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Las Virgenes (N)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Las Virgenes (S)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Medea Creek (N)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Medea Creek (S)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Solstice Canyon	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Temescal Canyon	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Judgment (9 Sites)																		
Arroyo Sequit (Lower)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cold Creek (Upper)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cold Creek (Lower)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
La Jolla Canyon	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Las Virgenes Creek (East Fork)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Malibu Creek (Upper)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Malibu Creek (Lower)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Topanga Canyon (Upper)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Topanga Canyon (Lower)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Random (GRTS) Year 1 (12 Sites)																		
Arroyo Conejo	3	3	3							3	3	3						
Carlisle Creek	3	3	3							3	3	3						
Conejo Creek	3	3	3							3	3	3						
Las Flores	3	3	3							3	3	3						
Liberty Canyon	3	3	3							3	3	3						
Little Sycamore	3	3	3							3	3	3						
Malibu Creek	3	3	3							3	3	3						
Medea Creek	3	3	3							3	3	3						
Ramirez	3	3	3							3	3	3						
Sullivan Canyon	3	3	3							3	3	3						
Solstice	3	3	3							3	3	3						
West Fork Trancas	3	3	3							3	3	3						
Random (GRTS) Year 2 (12 Sites)																		
Bulldog Motorway				3	3	3							3	3	3			
Cheeseboro Creek				3	3	3							3	3	3			
Circle X				3	3	3							3	3	3			
Escondido Creek				3	3	3							3	3	3			
Las Flores				3	3	3							3	3	3			
La Virgenes				3	3	3							3	3	3			
Olson Road				3	3	3							3	3	3			
Rustic Creek				3	3	3							3	3	3			
Santa Ynez Canyon Trail				3	3	3							3	3	3			
Sostoma Trail				3	3	3							3	3	3			
Suttphur Creek				3	3	3							3	3	3			
Triunfo Creek				3	3	3							3	3	3			
Random (GRTS) Year 3 (12 Sites)																		
Arroyo Sequit							3	3	3							3	3	3
Cold Creek							3	3	3							3	3	3
Conejo Creek							3	3	3							3	3	3
Malibu Creek (Crags Road)							3	3	3							3	3	3
Malibu Creek (Cross Creek)							3	3	3							3	3	3
Lady Face							3	3	3							3	3	3
Liberty Canyon							3	3	3							3	3	3
Malibu Creek State Park							3	3	3							3	3	3
Mailbu Nature Preserve							3	3	3							3	3	3
Topanga Creek (Summit Road)							3	3	3							3	3	3
Topanga Creek (Topanga Blvd)							3	3	3							3	3	3
Tuna Canyon							3	3	3							3	3	3
Total Sites	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Total Samples per Event	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**
Total Samples per Year	**279**			**279**			**279**			**279**			**279**			**279**		

Limited Accessibility:

Streams located on or reachable only by crossing private property are not included in this program. Agreements for access, if obtained, could be rescinded if owner attitude or ownership changed.

2.3.4 Stratification and Selection of Random Stream Segments

Stream characteristics taken into consideration for including stratification of water quality stations for cross-comparison with other stations is based on categorization of streams into broad stream type (perennial, intermittent), topography,

Table 2.3. Target station types and parameters to be monitored.

Type Station	Parameters	Frequency	Personnel	Protocols
Randomized Stations	Index parameters, discharge, TSS, ammonia, nitrate, orthophosphate, & chloride.	Three times a year (including one storm event during the winter).	SAMO Technician & CSLA Physical Scientist.	National Field Manual (USGS, variously dated); Peck et al, (unpub. Draft); Rantz et al., 1992; Standard Methods, American Public Health Association, 2007.
Judgmental Stations	Index parameters, discharge, TSS, ammonia, nitrate, orthophosphate, & chloride.	Three times a year (including one storm event during the winter).	SAMO Technician & CSLA Physical Scientist.	National Field Manual (USGS, variously dated); Peck et al, (unpub. Draft); Rantz et al., 1992; Standard Methods, American Public Health Association, 2007.
Sentinel Amphibian Monitoring Stations	Index parameters, discharge, TSS, ammonia, nitrate, orthophosphate, & chloride.	Three times a year (including one storm event during the winter).	SAMO Technician & CSLA Physical Scientist.	National Field Manual National Field Manual (USGS, variously dated); Peck et al, (unpub. Draft); Rantz et al., 1992; Standard Methods, American Public Health Association, 2007.

Key to Table 2.3:

- Index parameters: D.O., specific conductance, pH, temperature (instantaneous).
- Discharge (instantaneous).
- Site Specific 303d Parameters (at limited designated stations); examples include selenium and lead.

stream morphology (straight, meandering, braided), dominant land use in watersheds, and vegetation (Cooprider, 2005). Stratification in the MEDN SMM protocol also divides sites into upstream, midstream, and downstream reaches. Selecting some sites randomly provides an opportunity to make inferences about water quality across the mountains generally.

Random selection of sampling stations was accomplished using GIS technology where a grid of 2.25 km^2 cells was laid over the SMM. A suite of cells containing USGS blue-line streams was selected using GRTS methodology. Random sites were stratified by habitat type and climate. Judgmental stations were selected from stream reaches supporting endangered or threatened species; or were impacted or potentially impacted by pollutants; or were sufficiently undisturbed that they were could serve as reference sites for establishing background water quality.

Visiting all water quality sampling sites will take up to four weeks each sampling event. Many sites represent inputs from all areas of the watershed (i.e., collector sites that include flows from all major tributaries) and are expected to be permanent long-term sites. Control or reference sites were located such that they addressed the concerns identified in the monitoring objectives.

Within each stream segment, specific sites will be selected and the type and number of habitats (e.g., riffle, run, pool) will be evaluated for sampling. Pools should be sampled because: (1) they are often the most contaminated, (2) they allow for sampling in intermittent streams where riffles/runs are absent part of the year, and (3) they are important fish habitat (Cooprider, 2005). Riffles should be sampled because they include transport, flow, and load–related concerns (e.g., sediment transport, fecal coliform load for TMDL monitoring) (Cooprider, 2005). Interstitial fluid downwelling and upwelling also occurs in riffles. Riffles are also important habitat for sub-benthic organisms and fish eggs.

2.4 Standard Protocols for Parameter Analysis

The EPA Operations Manual for Wadeable Streams (Lazorchak et al., 1998) and the National Field Manual (USGS, various dates; Wilde and others, 1998, 1999; 2003; 2004) protocols will be followed for field methods (Table 2.3). The National Field Manual will be followed for field sampling for all parameters except nutrients. The EPA wadeable stream protocol for water chemistry will be followed for nutrient sampling (Table 2.3). The USGS method described in Rantz et al., 1982) will be followed for stream discharge measurements.

Laboratory methods for nutrients, TSS, chloride, and site-specific 303d parameters will follow “Standard Methods” (American

Public Health Association, et al., 2007) or other laboratory procedures (e.g., ASTM). The QAPP of this plan (SOP No. 5) provides other details not covered in Table 2.3. The Sate of California Surface Water Ambient Monitoring Program (SWAMP) suggests specific analytical methods by number from both the EPA and Standards Methods but allows any method as long as it meets the sensitivity requirements of the SWAPM Target Reporting Limit (TRL) and are contained in 40CFR36 or the most current version of Standard Methods.

2.5 Data Comparability

Few long-term water quality sampling programs are in place in the SMM at this time. Long-term water quality monitoring programs by LVMWD and Heal The Bay are regulatory specific and use customized handling procedures for management and dissemination of data. Other water quality sampling programs in SAMO include short term issue-specific studies by NGOs and regulatory and non-regulatory agencies. Data collected in these studies are managed and disseminated through a variety of means and most are readily available to the MEDN.

2.6 Sampling Frequency and Replication

The schedule for sampling SMM streams is based on seasonal variations in hydrodynamic conditions (Figure 2.3). Sampling three times a year is specified for all streams. Winter "first flush" sampling will be done to collect overland flows that pickup pollutants accumulated on the surfaces of the catchments. Nearing the end of the wet season (mid-late spring), sampling will also be done when the regional aquifers and shallow perched zones have been recharged by infiltrating surface water. This is an important sampling period because perched water and groundwater may be laden with nutrients and other pollutants that eventually flow into local streams. This is also the time that local amphibians are returning to streams to reproduce and data from this sampling period are important covariates for the amphibian monitoring program. After abatement of the wet season, sampling will be done during the summer, when stream flows consist mainly of (1) groundwater seepage, and (2) urban runoff (in those catchments with urban landscapes). The conceptual models in Figure 2.3 show the importance of aquifer water levels and seasonally perched groundwater on the stream hydrologic budget.

At the end of three years, an audit of all data collected will be completed to determine if specific stations should be dropped from the program, converted to annual sampling, converted to quarterly sampling, or converted to monthly sampling (Figure 2.1). At the end of each additional six-year interval, results of analysis of the data will determine if additional modifications to the program should be made. Additional surface water bodies (e.g., ponds, wetlands, estuarine waters) may be added when protocols are updated, or as funding permits. Within all monitoring periods (seasonal, 3 year interim period, 6 year continuous) stations will continue to be evaluated to ensure that the sampling plan is addressing the monitoring objectives for water quality monitoring in the SMM.

3.0 Methods and Guidance

Field sampling and laboratory analyses will be performed according to the methods specified in Table 3.1. Laboratory analyses performed in-house will be performed according to the methods described in Standard Methods for the Examination of Water and Wastewater, 20th Edition. A Quality Assurance Project Plan (QAPP as SOP No. 3) and Standard Operating Procedures (SOP's) for all aspects of the sampling and analysis procedures required by this protocol are listed and summarized below. The QAPP and other SOP's are included as a separate document at the end of the narrative section.

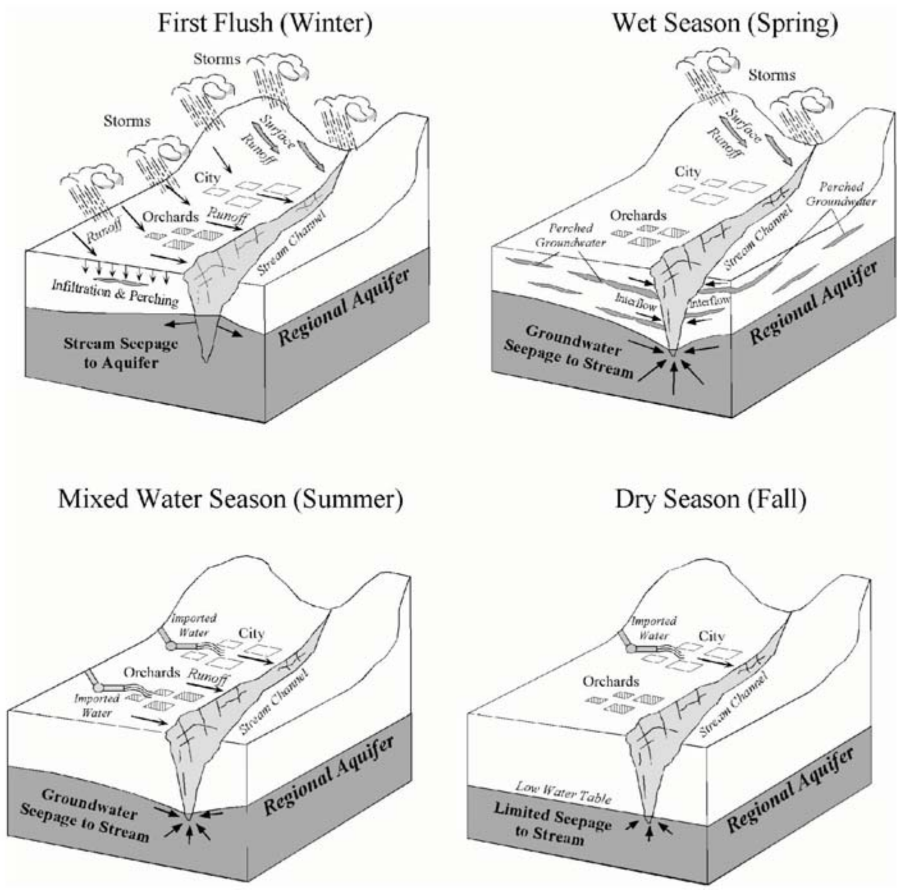
3.1 Standard Operating Procedures

Specific information and instructions for all aspects of the monitoring proposed here in are included in attached Standard Operating Procedures. A summary of the contents of each SOP are given below.

SOP - 1: Field Measurement of Core Water Quality Parameters

Conductivity, dissolved oxygen, pH and temperature will be monitored in situ with YSI handheld meters and probes. Instruments are calibrated in the laboratory prior to deployment according to manufacturers instructions. At each stream sampling location three independent

Figure 2.3. Conceptual models for seasonal hydrodynamic conditions in the Santa Monica Mountains.



Nearing the end of the wet season (mid-late spring), sampling will be done when the regional aquifers and shallow perched zones have been recharged from infiltrating surface water. This is an important sampling period because perched water and groundwater may be laden with nutrients and other pollutants that eventually flow into local streams. After abatement of the wet season, sampling will be done during the summer, when streamflows consist mainly of (1) groundwater seepage, and (2) urban runoff, in those catchments with urban landscapes. Finally, sampling will be done during the driest season (mid-late fall), when water tables have fallen and when irrigation of urban landscapes is much more limited. Several streams in SAMO will be dry by the fall sampling interval due to decaying groundwater levels.

measurements are taken and recorded (c.f. Figure 2.2). This is done by taking a full suite of measurements on all parameters at the sampling access point then proceeding upstream 10 meters and taking another suites of measurements. This is repeated again another 10 meters up stream.

At each of the three locations water samples are collected for laboratory analysis. Most field water samples will be collected via grab sampling in low density polyethylene bottles (LDPE) bottles. These bottles will be soaked and triple rinsed in deionized water and inspected prior to field use. All bottles will be triple rinsed with the water being sampled in the field prior to final filling. Field-filtered and unfiltered samples will be collected. Filtered samples will be obtained using 0.45 micrometer or smaller filters. Samples will be stored on ice until returned to the lab. Sample preservation with acid will be done in the field as required.

Specific sample container volumes, sample containers, preservatives, and field collection methods are presented in SOP No. 1.

Surface water samples will be taken several inches below the surface of the stream when depth of flow is less than 25 cm. This is the normal case for most conditions in the study areas. A bottle will be inverted and then re-inverted to allow the container to fill up. When depth of flow is greater than 25 cm, we will collect depth-integrated samples or discrete-depth (multiple vertical) samples depending on task requirements. Equal volumes will be collected at the various stream depths (e.g., top, bottom; or top, middle, bottom) and homogenized for depth-integrated samples.

SOP - 2: Measuring Stream Flow

Surface water discharge measurements will be made using a Marsh-McBirney portable flow meter and top-setting wading rods. The procedure is as follows:

Select a straight stream reach of

Table 3.1. Method number and method title – water samples.

Measurement	Method*	Method Title
Conductivity[1]	E 120.1	Conductance
Oxygen, dissolved[1]	SM 4500-O G	Membrane Electrode Method
pH[1]	SM 4500-H^+ B	pH Value
Temperature[1]	SM 2550-B	Temperature
TSS	SM 2540-D	Total Suspended Solids
Chloride[2]	SM 4110-B	Ion Chromatography with Chemical Suppression of Eluent Conductivity
Nitrate-N	SM 4110-B	Ion Chromatography with Chemical Suppression of Eluent Conductivity
Phosphate	SM 4110-B	Ion Chromatography with Chemical Suppression of Eluent Conductivity
Phosphorus	SM 4500-P B(5), E	Persulfate Digestion Method, Ascorbic Acid Method
Ammonia-N	SM4500-NH_3 D	Ammonia-Selective Electrode Method
Selenium	SM 3500-Se	Colorimetric Method
Lead	SM 3500-Pb	Dithizone Method
Chemical Oxygen Demand	SM 5200D	Closed Reflux, Colorimetric Method

[1] Field test
[2] Sulfate, Bromide, & Fluoride will also be reported as the analytical method provides those results at no additional cost.
*Method Sources:
SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition, published by American Public Health Association, American Water Works Association, and Water Pollution Control Federation.
E = EPA methods available on the CD-ROM "Methods and Guidance for Analysis of Water", version 2.0, June 1999, EPA821-C-99-004.

stream with a smooth shoreline and no obstructions such as water weeds. Extend a tape or non-stretch graduated line across the stream. Develop a water-depth profile at right angles to the direction of flow in the stream. This may be done by wading across the stream with a sounding rod and measuring the water depth at regular intervals. Divide the stream into a suitable number of segments such that the area of each may be readily measured and the flow rate within each is relatively constant. Enter the first segment and clamp the meter onto the vertical rod at a height equal to 0.6 the average depth of the stream within this segment. Take a velocity reading at the midpoint of the segment with the Marsh McBirney flowmeter. Two or more readings should be recorded at each point and the results averaged. Repeat previous two steps for each segment in the stream cross section (10 to 15 stations when stream width is less than 4 feet and 20 stations when stream width is greater than 4 feet). Compute the discharge for the first segment by multiplying the measured segment velocity by the cross-sectional area of the segment.

SOP - 3: Decontamination of Field Equipment

All field equipment that has come in contact with stream water, including field personnel clothing and footwear, must be cleaned and disinfected before being introduced into another stream in order to prevent the spread of fungus, disease, or non-native species. Sensitive sampling equipment (meter probes etc.) should be thoroughly cleaned with a laboratory wipe between sampling deployment from stream to stream.

Recent discovery of the New Zealand mudsnail (*Potamopyrgus antipodarum*) in the Malibu Creek watershed significantly increases the need for vigilance in cleaning of field equipment and personnel clothing to prevent the spread of this significant invasive mollusk.

New Zealand mud snails are very small, easily overlooked, and reproduce parthenogenetically (all individuals in the U.S. are female). They brood their young releasing extremely small juveniles that are essentially invisible to the unaided eye. A single juvenile transported to an uncontaminated stream could be enough to permanently alter the macroinvertebrate community of that stream.

SOP - 4: Monitoring-site Selection

Streams in the Santa Monica Mountains vary in terms of water availability, gradient, aspect, and urban influence. It is important that a variety of streams are monitored to capture the variation in stream water quality that might result from these factors. However, the number of streams and sampling locations along streams that can be visited annually is limited by personnel, the amount of data being collected, proposed frequency of visits to each stream, and seasonal availability of water.

Three categories of streams are to be sampled as part of the monitoring program. All streams sampling locations in the breeding amphibian monitoring program will be monitored for the full suite of parameters identified in this protocol. These include ten "Sentinel" stream sites that have been routinely sampled for breeding amphibians and core water quality parameters since 2000. Thirty-six additional randomly selected sampling locations for monitoring breeding amphibians are also included in the water quality monitoring program. Finally nine stations were selected for monitoring based on management considerations, such as 303d listing,

Table 3.2 Target reporting limits, container, required volume, preservative and holding time for various analytes in water samples.

Measurement	Reporting Units	Project TRL	Frequency of Duplicates	Container	Required Vol. (mL)	Preservative	Holding Time
Conductivity[1]	µS/cm	2.5	Single	P	N/A	Cool	28 d
Oxygen, dissolved[1]	mg/L	N/A	Single	N/A	N/A	N/A	N/A
pH[1]	Standard	N/A	Single	N/A	N/A	N/A	N/A
Temperature[1]	°C	N/A	Single	N/A	N/A	N/A	N/A
TSS	mg/L	0.05	1 in 20	P	1000	Cool	7 d
Chloride	mg/L	0.01	1 in 20	P	30	None req.[2]	28 d
Nitrate-N	mg/L	0.01	1 in 20	P	30	Field filter 0.4µ, cool	48 h
Phosphate-P	mg/L	0.01	1 in 20	P	30	Field filter 0.4µ, cool	48 h
Phosphorus	mg/L	0.05	1 in 20	P	150	H_2SO_4 pH < 2, cool	28 d
Total Nitrogen	mg/L	0.2	1 in 20	P	250	H_2SO_4 pH < 2, cool	28 d
Ammonia-N	mg/L	0.05	1 in 20	P	125	filter, H_2SO_4 pH < 2, cool	28 d

[1]Field measurement.
[2]Chloride may be analyzed with other anions and so will be stored cool.
Container: P = plastic, G = glass.
Preservative: Cool = stored at 4 +/- 2°C.

or because they are subject to unusual stressors such as upstream development or significant input from urban runoff that has permanently altered stream hydrology.

SOP - 5: Location of Sampling Stations

Instructions for preparing detailed maps with written driving instructions to each sampling site from SAMO park headquarters are included in this SOP. A route map, driving instructions, GPS coordinates, walking instructions to the final sampling location, and a photograph of the sampling site for each of the fifty-one water quality sampling sites are contained within an Access database located on the SAMO local area network. By selecting the stations to be visited in any given day field personnel can print out a single sheet of information for each site that provides instruction on how to find each specific sampling point.

Table 3.3. Bias of field parameters.

Parameter	Bias
pH	± 0.2 pH units
Conductivity	± 5% or ± 10 µmhos, whichever is greater
Dissolved Oxygen	± 5%
Temperature	± 0.5 °C

SOP - 6: Quality Assurance Project Plan

Included in the QAPP is information on project management, data generation and acquisition, project assessment and oversight, data validation, and quality assurance and quality control of all aspects of water quality sample collection and analysis.

Detailed instructions included:

1. Collection of field data (Conductance, Dissolved Oxygen, pH, & Temperature).
2. Gaging Stream flow.
3. Laboratory methods for determining total dissolved solids and turbidity.
4. Laboratory methods for Ion Chromatography and phosphorous, nitrogen, and ammonia analysis.
5. Sample chain of custody forms and stream flow determination sheets are also included.

Table 3.2 lists the target reporting limits for all parameters proposed for sampling and analysis. Information on bias in data from filed sampling meters is presented in Table 3.3 and overall data acceptability criteria are presented in Table 3.4.

SOP - 7: Data Analysis

Several analytical approaches may be taken to evaluate and interpret the data obtained from field and laboratory determination of water quality parameter values. Details of these analyses are presented in section 4 below and in SOP - 5 .

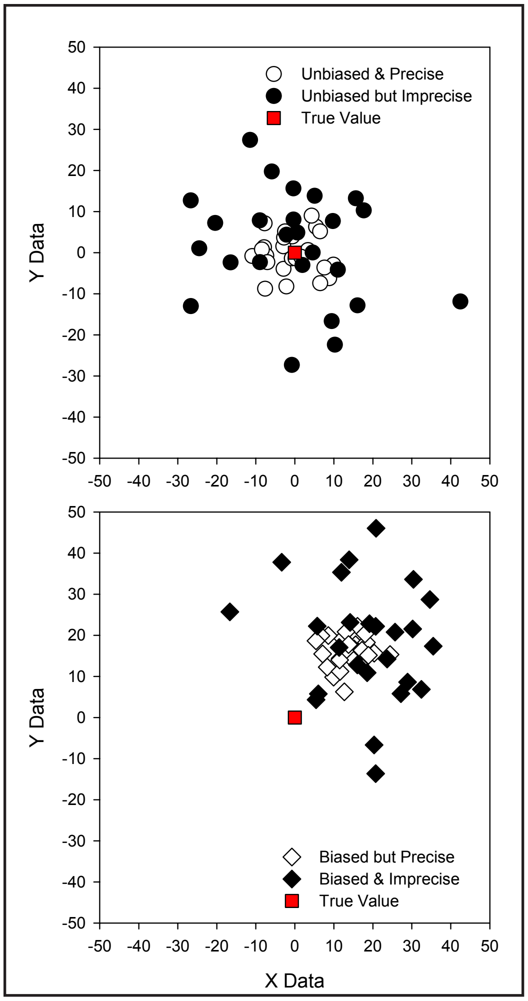
SOP - 8: Cumulative Bias & Sampling Precision

Key properties of a point estimator are the bias and precision of the estimator. Bias and precision provide an indication of the overall accuracy of the estimator (MacKenzie et al., 2006). Bias is the difference between the observed value of the estimator and the true value. Bias in a point estimator (data point) due to instrumentation may be inherent in the instrument or introduced by the observer using the instrument. Precision can be estimated by the degree of variability in the mean value of a point estimator. The lower the variability the more closely the mean is

Table 3.4. Data acceptability criteria.

Sample Type	Objective	Frequency of Analysis	Control Limits	Corrective Action
Calibration Standards (3-5 standards over the expected range of sample target analyte conc., with the lowest conc. Std at or near the Level of Quantitation).	Full calibration: Establish relationship between instrument response and target analyte conc.	Follow manufacturer's or procedures in specific analytical protocols. A min. 3 point calibration: Each set up, major disruption, and when routine calibration check exceeds specific control limits.	Linear regression, r>0.995.	Determine cause and take appropriate corrective action. Recalibrate and reanalyze all suspect samples or qualify all suspect data.
Calibration Check Standards (minimum of one midrange standard prepared independently from initial calibration standards).	Verify calibration.	After initial calibration or recalibration. Every 20 samples.	Recovery ± 20%	Determine cause and take appropriate corrective action. Recalibrate and reanalyze all suspect samples or qualify all suspect data.
Spiked matrix samples (analyte-free water samples to which known amounts of target analytes have been added; one spike for each target analyte at 1 -10 times the estimated MDL).	Establish or confirm MDL for analyte of interest.	Seven replicate analyses prior to use of method. Re-evaluation of MDL annually.	$\leq$ 0.314 TRL	Re-determine MDL or use a more sensitive method.
Bias and Precision Assessment				
Reference materials (SRMs or CRMs, covering the range of expected target analyte conc).	Assess method performance (initial method validation and routine bias assessment).	Method validation: As many as required to assess bias and precision of method before routine analysis of samples. Routine bias assessment: one (preferably blind) per 20 samples or one batch.	Measured value within 95% confidence intervals, if certified. Otherwise, Recovery ± 20% or	Determine cause and take appropriate corrective action. Recalibrate and reanalyze all suspect samples or qualify all suspect data.
Matrix spikes (field water samples to which known amounts of target analytes have been added: 1-5 times the concentration of analyte of interest or 10 times the MDL, whichever is higher).	Assess matrix effects and bias (%R) routinely.	One per 20 samples or one per batch, whichever is more frequent.	Recovery ± 20% or Control Limits based on 3x the standard deviation of laboratory's actual method recoveries.	If the Calibration Verifications are acceptable, qualify the data for the spiked sample or use another method or the method of standard addition.
Matrix Spike Duplicate (duplicate aliquot of matrix spike sample; 1-5 times the concentration of analyte of interest or 10 times the MDL, whichever is higher).	Assess method precision routinely	One duplicate per 20 samples or one per batch, whichever is more frequent; used if in most samples the analyte of interest is < the LOQ.	RPD <25% for duplicates.	MSD recovery: if the Calibration Verifications are acceptable, qualify the data for the spiked sample or use another method or the method of standard addition.
Laboratory Duplicate or MSD precision	Assess method precision	One duplicate per 20 samples or one per batch, whichever is more frequent.	RPD <25% for duplicates	Re-prepare and reanalyze the sample. Determine cause and take appropriate corrective action, such as, reanalysis of the batch.
Field Split	Assess shipping and method precision.	5% annual rate (5% of total number of field samples per analytical procedure per year, rounded up to nearest whole number).	RPD <25% for duplicates.	Determine cause and take appropriate corrective action. If the lab duplicate or MSD precision are acceptable qualify all suspect data.
Contamination Assessment				
Laboratory Blanks (method, processing, bottle, reagent).	Assess contamination from equipment, reagents, etc.	One method blank per sample preparation batch. At least one bottle blank per batch. One reagent blank before calibration, after calibration and after every 20 samples.	Blanks <MDL for target analyte.	Determine cause of problem (e.g., contaminated reagents, equipment), remove sources of contamination, and reanalyze all suspect samples or qualify all suspect data.
Field Method Blanks, Field Equipment Blanks.	Assess contamination from equipment, from air, from surrounding environment, etc.	Random performance evaluation during field audit; field blanks <MDL for analyte of interest. If acceptable performance, no field blanks required until next field audit. If non-acceptable, 5% field blanks must be conducted until next field audit.	Blanks <MDL for target analyte.	Determine cause of problem (e.g., equipment contamination, improper cleaning, exposure to airborne contaminants, etc.), remove sources of contamination, & reanalyze all suspect samples or qualify all suspect data.
General Provisions				
Acceptable Data Set: CCV Recoveries must be within control limits, & either SRM or Spiked Matrix recoveries must also be within control limits.				

Figure 3.1 Representation of the effects of bias and precision on data.



to the true value of the parameter. Precision in water quality observations is generally dependent upon the inherent sensitivity of the instrument or analytical procedure and may not be directly under the control of the observer except as care is given to follow calibration and instrument use procedures. The relationship between bias and precision is presented graphically in Figure 3.1.

With changes in program staff, equipment, and/or procedures it is important to quantify the effect that these changes may have on the overall integrity of the data to ensure that data comparability is maintained through the life of the monitoring program. This SOP addresses how bias in the data that might result from such change can be documented and mitigated to ensure that trends (or lack thereof) observed in the parameters monitored is real and not related to observer differences, sensor incompatibilities, or analytical methodology.

Instructions for documenting and recording bias once detected is included. Guidance for making adjustments in the data is provided.

Tracking and assigning cumulative bias insures that future users of the data are able to analyze and interpret the results in a meaningful manner accounting for the actual condition of parameters less any bias that might have been introduced or might accumulate due to changes in the process of collecting of the data.

SOP - 9: Data Management

The water quality component of the Natural Resource Challenge requires that networks archive all water quality data collected as part of the monitoring program in a STOrage and RETrieval (STORET) database maintained by the NPS Water Resources Division (WRD-STORET). Thus, all MEDN water quality monitoring data, regardless of which other databases it may reside in temporarily or permanently, will ultimately make its way to WRD-STORET.

The primary ‘working’ database for MEDN water quality data is “MEDN-water”. It is the main repository for water quality monitoring data, including all historic, current, and future data generated in MEDN units.

In section 4 below and this SOP specifics concerning data acquisition, verification, storage (databases), archiving and reporting are presented.

SOP - 10: Safety

Personnel and safety is of utmost importance in all aspects of water quality sampling and analysis. Procedures for performing sample collection (SOP -1) and analysis (SOP - 4) present guidance for safe and low risk process for collecting and analyzing water samples.

Specific safety issues that should be addressed during sampling include seasonal weather extremes, rattlesnake bite, and poison oak. SOP - 8 contains information on safe practices for each of these risks.

SOP - 11: Revision History & Control

Periodically it is important to make changes or edits to existing protocols. Any revisions that are made should first be brought up with the network coordinator and changes coordinated between the parks and partnering agencies. In this way, all data is consistent and usable to assess ecological or population changes between parks and partnering agencies.

At the top of each SOP there is a revision history log. It is important to fill out the history log for each SOP to document changes made to the protocols. Older versions of the SOP's should be archived or kept as an appendix to this document.

Each change of the SOP requires a new version number. Minor changes are recorded as decimal numbers (e.g. 1.0, 1.1, 1.2, etc.). A large modification of the protocols such as changes from a pitfall trapping methodology to a visual transect survey would be a change in the first number (e.g. 1.0, 2.0, 3.0).

SOP - 12: Personnel Requirements

A minimum of four individuals are needed to conduct water quality monitoring these may include but are not limited to the NPS project manager (network coordinator) who acts as project coordinator and COTR for administering task agreements with the university cooperator. The NPS project manager is responsible for all aspects of program cooperation, overseeing of data entry, data analysis and reporting.

The cooperating university provides a local project manager (faculty member). One or two field technicians supplied by the cooperator or NPS are also required. The technicians are responsible for field sampling of water quality and sample collection for laboratory analysis. The cooperator also provides a laboratory manager who oversees all laboratory analysis of water samples collected in the field and returned to the laboratory for analysis.

SOP - 13: Program Budget

Costs for completing planned water quality monitoring consist of several components:

1. Collection of field data and samples for laboratory analysis.
2. Laboratory analysis of water samples.
3. Data management and reporting at laboratory.
4. Data management, analysis, and reporting at network.
5. Expendable materials and supplies.

Of these elements 1, 2, 3, & 5 will accrue to the cooperator and are estimated to total nearly $54,000 per year. Element 4 is business as usual for the network and is accounted for in salary for the network data manager and the network coordinator as presented in the annual work plan for the network.

A more detailed breakdown of estimated monitoring costs is presented in SOP 13.

SOP - 14: Contact Information

The overall project manager for water quality monitoring in the MEDN is the network coordinator (Dr. Lane Cameron) who, working closely with a university cooperator (Dr. Barry Hibbs of California State University, Los Angeles at the moment), is the point contact for all aspects of water quality monitoring activity in the MEDN. Contact information for Drs. Cameron and Hibbs is listed in this SOP.

4.0 DATA HANDLING, ANALYSIS, AND REPORTING

4.1 Overview of Database Design

All field collected and laboratory generated data will be managed according to the MEDN Vital Signs Data Management Plan. Data must be submitted to the data manager as an MS Excel database with specified fields for each record or entered directly into NPSTORET. NPSTORET is an MS Access database developed by the NPS Water Resources Division for water quality data. It is designed to integrate with the Environmental Protection Agency's STORET database.

4.1.1 Excel database

All laboratory and field data entered into the Excel datasheet must include several required field columns including: collection location (site name, x-coordinate, y-coordinate, datum); laboratory identification number; date collected; time collected; data parameters; and reference to data source.

4.1.2 Access database

All data will reside on a master local version of the NPSTORET database. Information on the NPSTORET database may be obtained on the NPSTORET website (http://nrdata.nps.gov/programs/water/npstoret). Data submitted in

MS Excel will be uploaded to the local NPSTORET database using one of the built-in tools. Data submitted in NPSTORET will be merged with the master local version.

4.1.3 Data submissions

All data collected must be quality checked and verified before submission to the National Park Service. See Section 4.2 'Data Verification and Validation' for more information regarding quality control and assurance.

Submitted data will be appended or uploaded into the master local version of NPSTORET residing at the headquarters of Santa Monica Mountains NRA. This local database will house all records collected from the field and laboratory sampling or analysis. Submission of data to the national EPA STORET database occurs automatically once the data is in the NPSTORET database.

4.1.4 Database administration

<u>Data Maintenance</u>

Any editing of the archived data is accomplished jointly by the principal investigator and data manager. Changes to any record in the database are documented in the record itself and must include a description of pre- and post-edit changes.

<u>Version Control</u>

Prior to any major changes of a data set, a copy is stored with the appropriate version number to allow for tracking of changes over time. Versioning of archived data sets is handled by adding a three digit number to the file name. Each additional version is assigned a sequentially higher number. Frequent users of the data will be notified of the updates.

<u>Data Logs and Backups</u>

Backups of all datasets relating to this protocol will be carried out by the most appropriate method and as needed. This may include backing up related data and files to the main network server or copying to a CD/DVD-ROM. Maintaining a current backup of the data is essential for protecting data files from corruption or accidental deletion. Once a data set has passed QA/QC procedures specified in the protocol, a formal entry will be made into Dataset Catalog.

4.2 Data Verification and Validation

All field and laboratory data will be reviewed and verified according to the attached "Data Verification Procedure". The Project Quality Assurance Manager and the Project Director will jointly verify field and laboratory data packages for completeness, for factual content, and to insure it meets project specifications.

Specific instruction on data verification and validation are included in the attached QAPP (SOP No. 4).

4.3 Routine Data Summaries and Statistical Analyses to Detect Change

4.3.1 Characteristics of Water Quality Data

To analyze and understand the chemistry of natural and polluted waters, statistical correlations and associations between dissolved constituents and other environmental parameters (geologic substrate, climate, land use, human population) will be done on water quality data sets. Statistical correlations and analyses can present information in a form that allows cause-and-effect relationships to be detected or hypothesized. For example, a stream in a region may show a correlation between unusually high nitrate and chloride. A possible scenario that would produce such a correlation is that both constituents were derived from the same source, such as septic tank leachate into groundwater, and in turn, contaminated groundwater flowing into the stream. The deduction might be incorrect because the chloride may be sourced from a geologic formation and the nitrate might have an independent and anthropogenic source that is not related to chloride. If however, the spatial correlation of waters with high chloride and nitrate were in the vicinity of an unincorporated community with high density of septic tanks, the cause-and-effect correlation might be inferred, though not unequivocally proven. The purpose of statistical analysis therefore is to examine probable scenarios between chemical parameters, water quality trends, and correlations in water quality data sets.

For analysis of time series data, many common statistical methods assume that the data being analyzed have been drawn from a population of values with a normal distribution (Cooprider, 2005). Normally distributed data may be analyzed using several parametric approaches. Parametric regression analysis assumes that if a water-quality constituent is regressed with time, or any other independent variable, the resulting residuals are symmetrically distributed, forming a bell shaped (normal) curve. Unfortunately, the inherent variability of water quality data results in the loss of capability of a parametric test applied to water quality data sets. Water quality data often are not normally distributed (Schertz et al., 1991). For example, constituents such as suspended sediments, nutrients, bacteria, and common dissolved ions are often asymmetrically distributed (Schertz et al., 1991). Censored data (values defined as "less than" the laboratory reporting limit), outliers, and data sets with multiple laboratory reporting limits also diminish the power of parametric tests (Cooprider, 2005). This can be particularly acute for water quality parameters such as trace elements and pesticides that usually occur in very low concentrations.

Non-parametric tests are not constrained by the assumptions implicit for parametric tests and are more powerful than parametric tests for many water quality analyses (Neitzert, 2003). Non-parametric tests are also more easily applied to large numbers of data records examined in water quality investigations. For example, in the case of multiple-station trend studies, the large number of data values may prohibit individual checking to verify the assumptions of parametric tests because the process may be too time consuming (Schertz et al., 1991).

4.3.2 Spatial and Temporal Variability and Sampling Issues

Water quality data in a watershed or series of watersheds tends to be highly variable, both spatially and temporally. Spatial variability can be a function of transitions in geologic substrate, type of flow (e.g., perennial baseflow, urban loading), and point or non-point source inputs that remain relatively constant (wastewater discharge, atmospheric fallout at lower elevations). Random selection of some monitoring stations will allow inference of the spatial variability of water quality parameters across the landscapes of interest.

Temporal variability is caused by seasonal variations in water quality parameters that may reflect changes in biological function, sources of nutrients, or sources of sediment. All these may vary in response to seasonal differences in land use, such as agriculture, and climate (Schertz et al., 1991). The predominant source of water in a stream may also change seasonally and influence the concentration of water quality constituents. For example, the amount of groundwater seepage, rainfall, and imported water runoff (c.f. Figure 2.2) all can influence the seasonal variability of water quality.

A problem in assessing seasonal variations in water quality parameters occurs when water quality values used for trend analysis are collected too close in time (serial correlation). In such cases, water quality values used for trend assessment are collected so close in time that the values are not independent of one another (Schertz et al., 1991). To reduce effects of serial correlation, Ward et al. (1990) recommend reducing sampling frequency to once a quarter, unless looking for regulatory violations (Cooprider, 2005). Schertz et al. (1991) recommend that the number of averaged samples (or seasons) for use in non-parametric tests be restricted to 12 samples per year.

Concentrations of water quality parameters often vary with streamflow. For example, overland flow after a rain event may dilute a point source (e.g., wastewater discharge) that otherwise remains relatively constant. Other water quality constituents that contribute to the stream load from overland flow (e.g., suspended sediment) may increase as streamflow increases (Schertz et al., 1991). Groundwater baseflow containing nitrate, high salinity, and other water quality constituents is retarded during high streamflow as the hydraulic gradient is temporally reversed (Figure 2.2). Trend analysis is complicated by flow-related variability in water-quality data, which may be large compared to the magnitude of changes and trends in water quality resulting from anthropogenic factors in a watershed. Investigations of the effects of changes in human activities in a watershed should usually focus on tests for trends in flow-independent water quality concentrations (or flow-adjusted concentrations) in order to detect trends and change. Non-flow adjusted concentrations in water quality parameters should be examined when ambient water quality concentrations are of most interest (Schertz et al., 1991).

4.3.3 Censored Data

Censored data is water quality data reported as "less than" the laboratory reporting limit (Cooprider, 2005). For historical data sets and for data collected by other entities, censored data must be factored into the SAMO water quality analysis. Different entities use different laboratories, which will probably result in multiple laboratory reporting limits. Multiple laboratory reporting limits are likely to be found in data sets for some constituents due to: (1) changes in analytical procedures used by different laboratories or within laboratories; (2) changes in detection limits for a given method; and (3) sample dilution for analysis (Neitzer, 2003). With the possible exception of 3, these are not likely to be factors for water quality data collected under this protocol. These data will be analyzed using standard operating procedures and consistent methods of analysis. Other laboratory analyses will have to be screened and modified for censored data.

To calculate summary statistics, it will be necessary to select a single reporting level when multiple reporting levels exist for a particular constituent. To do this, the largest laboratory reporting limit that does not exceed at least one-half of the reported concentrations for that constituent can be selected as the study reporting level (Neitzert, 2003). All concentrations that are less than the study reporting level, no matter whether they were reported as "less than" in a laboratory report, or were actual concentrations, will be considered to be less than the study reporting level for analysis of summary statistics. In some summary statistics (e.g., boxplots), the study reporting level can be shown as a line across the boxplot for water quality data and the total number of samples with values below the study reporting level can be reported as a numerical value below the line for each site (Neitzer, 2003). For certain types of trend analysis and plots that require use of all data, the censored data may be assigned a concentration value of one-half the laboratory reporting limit (Neitzert, 2003).

In some cases, there may also be instances of reported data values greater than or equal to the upper detection limit (e.g., for some bacteria, data values are sometimes reported as "greater than" a most probable number). Data greater than the upper detection limit will be excluded from the calculation of statistics. If data fall between the MDL (method detection limit) and PQL (practical quantitation limit) they are considered "semi-quantitative" information and can be presented as a value greater than zero (Cooprider, 2005). The PQL is equal to the MDL multiplied by five (Cooprider, 2005). Censored data can be presented as less than or greater than the PQL in order to compare it to water quality criteria (Irwin, 2004).

The standard terminology used by the Los Angeles Regional Water Quality Control Board SWAMP program for data censoring limits is the Target Reporting Limits (TRL) of the analysis being performed. We will follow this precedent but for our internal analysis we will replace values below the TRl with a value equal to half the TRL.

4.3.4 Replicates

Replicates from the raw data sets should be averaged together and the single mean value used in their place for analysis, or the median value could be used if enough replicates are available (Cooprider, 2005). To estimate the variability in the measurement technique, the standard deviation or range of the replicates can be used (Stafford and Horne, 2004).

4.3.5 Data Analysis: Techniques and Issues

Several analytical approaches may be taken to evaluate and interpret the data obtained from field and laboratory determination of water quality parameter values. Water quality data from samples

Figure 4.1. Explanation of box and whiskers plot based on a single years pH data from the Malibu Creek outlet to Malibu Lagoon.

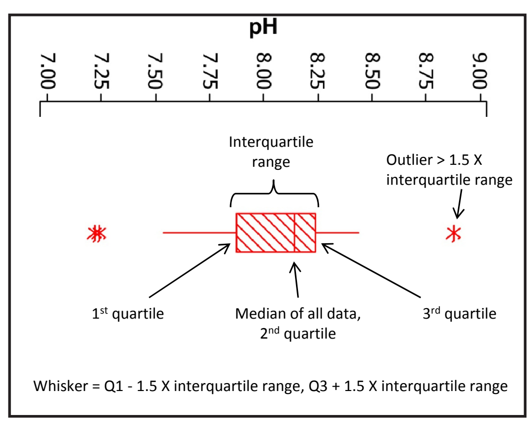
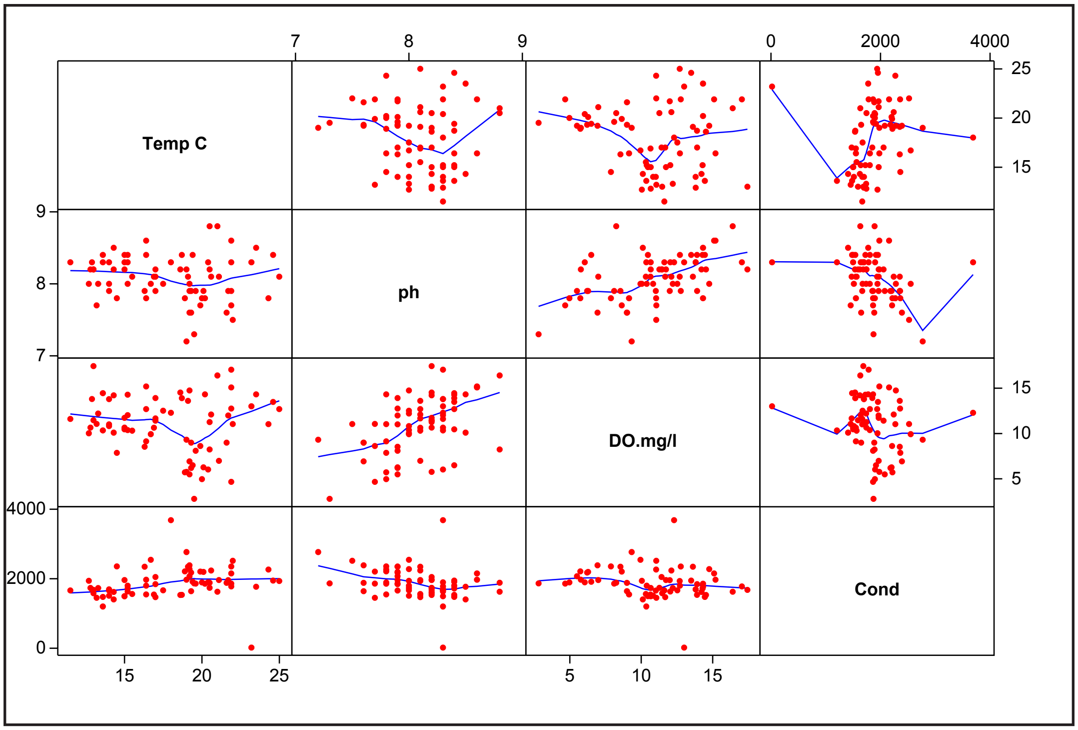


Figure 4.2 Bivariate matrix plot of selected water quality data from Malibu Creek outlet to Malibu lagoon. Locally weighted least squares (Lowess) smoothed line is also plotted.



collected at the Malibu Creek outlet to Malibu Lagoon (1999 through 2004) by Heal-the-Bay are used to present the results of analytical techniques proposed herein.

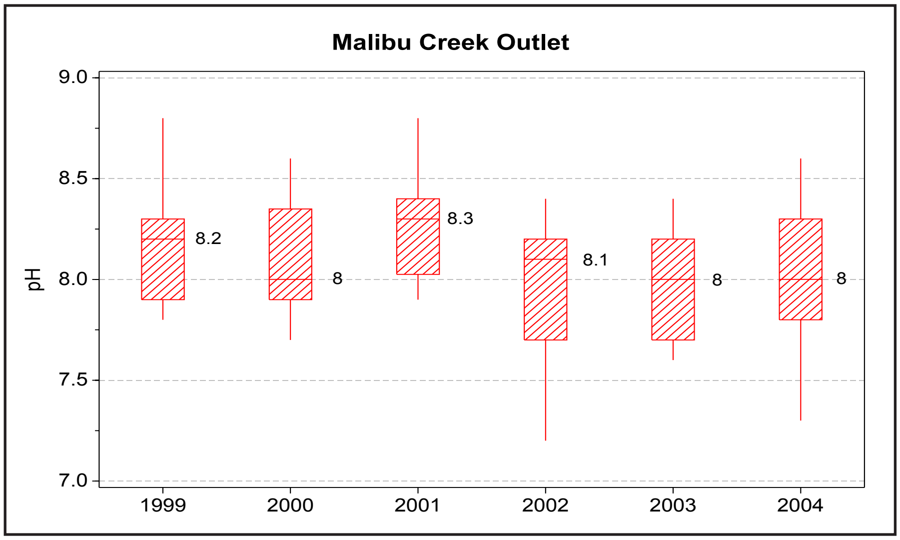
For each monitoring site, individual parameter data will be summarized seasonally and annually. Data from all stations within each landscape strata will also be summarized. Data can be compared with water quality standards by adding "water quality criteria line" or "action limit" on the graph that clearly shows which measurements fall above or below regulatory or management standards (Cooprider, 2005). At each station, data from other stations upstream and downstream of a suspected pollution source or tributary can be compared graphically as scatter plots and time series plots. Summary tables, histograms, and box and whisker plots. Box and whisker plots can be used to assess and compare sample distributions. The median (middle) value of the data is plotted. The box represents the intertilequartile range or the middle 50% of the data. 25% of the data values are less that the first quartile (Q1). 75% of the values are greater than the third quartile (Q3). The whisker extending from the top and/or bottom of the interquartile range box extends to the highest value in the upper range or lowest value in the lower range. Thes values are calculated as Upper Limit = Q3 + 1.5(Q3-Q1) and Lower Limit = Q3 - 1.5(Q3-Q1). Data points that are larger that 1.5 times the interquartile range (Q3-Q1) are plotted as outliers. (Figure 4.1 & c.f. 4.3).

Bivariate relationships between values of parameters may be graphically displayed using matrix plots of varying complexity (Figure 4.2) . Quantitative evaluations of the specific correlation among parameters may be obtained by correlation analysis. Correlation coefficients for all possible pairs of variables in a data set are calculated. Variables in the analysis may include individual comparisons between water quality parameters (chloride and nitrate; sodium and chloride) and between geologic and hydrologic variables (e.g., nitrate and stream discharge). Correlation coefficients represent numerically the extent to which two distinct water quality variables are statistically associated. Values of +1 indicate two variables are perfectly correlated whereas a value of 0 indicate the two variables are completely independent and have no correlation (Drever, 1997). Alternatively, a value of -1 indicates the parameters are negatively perfectly correlated. For example, an increase in stream flow in a hypothetical case that is matched by a perfectly linear decrease in

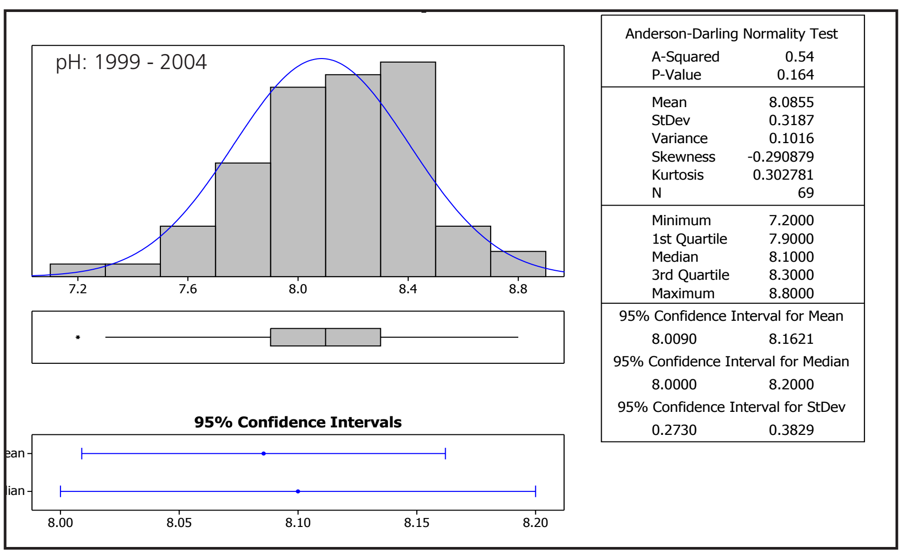
Table 4.1 Analysis of variance table for pH data from Malibu Creek Outlet.

Source	*df*	SS	MS	F	*p*
Year	5	0.7993	0.1599	1.65	0.160
Error	63	6.1062	0.0969		
Total	68	6.9055			

Figure 4.3. Example box and whisker plot, data summary, graphical summary for the entire pH data set from Malibu Creek at its outlet to Malibu Lagoon (Heal-the Bay).



Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
1999	15	8.1600	0.0722	0.2798	7.8	7.9	8.2	8.3	8.8
2000	11	8.0909	0.0899	0.2982	7.7	7.9	8.0	8.4	8.6
2001	12	8.2583	0.0753	0.2610	7.9	8.025	8.3	8.4	8.8
2002	9	7.9780	0.1290	0.3870	7.2	7.7	8.1	8.2	8.4
2003	11	7.9545	0.0846	0.2806	7.6	7.7	8.0	8.2	8.4
2004	11	8.0090	0.1120	0.3730	7.3	7.8	8.0	8.3	8.6



nitrate concentration will have a correlation coefficient of -1.

To determine if data can be modeled using parametric statistics, a graphical summarization performed in Minitab 15 of a given data set can provide visual and quantitative information on the degree of departure from normality (Anderson-Darling Normality Test), mean, variance, skewness, kurtosis, range, median, quartiles, and 95% confidence intervals for the mean, median, and standard deviation (Figure 4.3). A review of such an analysis provides a robust tool for assessing whether an observed process can reasonably be modeled by a normal distribution.

4.3.6 Analysis of Variance

For normally distributed data with equal variance collected from randomly selected stations, analysis of variance can be a powerful tool in assessing differences across spatial and temporal scales. As an example, pH data from the Malibu Creek outlet were grouped by year and analyzed by one-way analysis of variance using Minitab 15. Results of the analysis are presented in Table 4.1. Probability plots of the residuals and residuals plotted to fitted values can also provide indications of the normality of the data. Residual data that "hug" the probability plot line are a good indication that the data are distributed normally (Figure 4.4).

Table 4.2. Summary of Sample size and maximum detectable difference for specific levels of power, see Figure 4.6.

Power	Sample Size	Max Difference
0.4	9	0.30
	11	0.27
	13	0.25
	15	0.23
0.6	9	0.39
	11	0.35
	13	0.32
	15	0.30
0.8	9	0.50
	11	0.45
	13	0.41
	15	0.38

A plot of residuals values versus fitted values provides another graphical indication of normally distributed data if the points and distributed randomly above and below the mid-line ("0") (Figure 4.5).

Assumptions that parametric analyses that fail to reject the null hypotheses are correct are subject to challenge if there is no indication of the power of the test to detect a difference if it in fact exists. Statistical power is defined as the probability of accepting the null hypothesis when in fact it is true. The power of a particular test is dependent upon α (generally set at 0.05 or 0.1), the sample size, the magnitude of the effect that one desires to detect, and the variance of the data. While several statistical packages include elementary power calculators, determining power

Figure 4.4. Normal probability plot of residual values that "Hug" the diagonal line are an indication that the data are normally distributed.

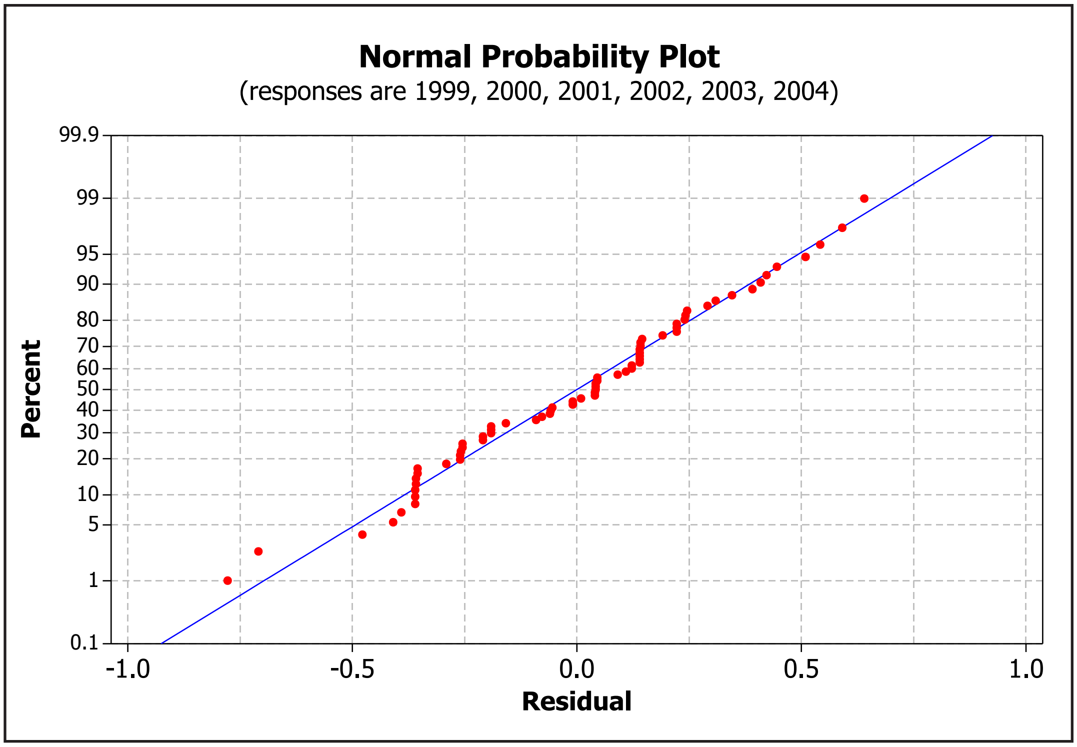
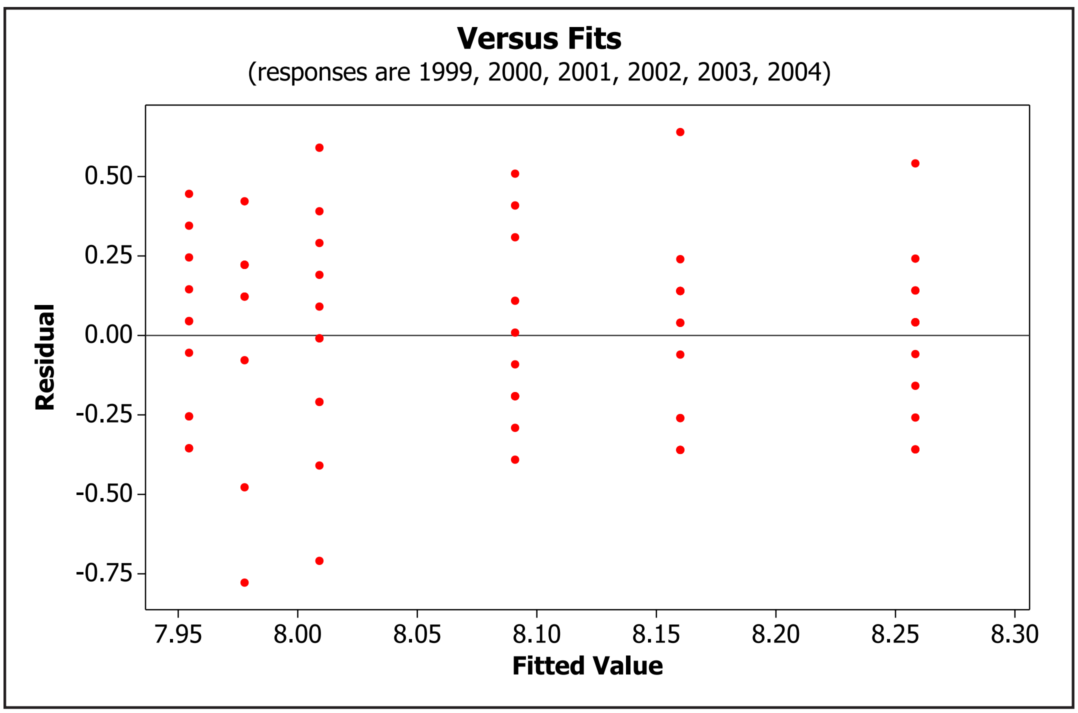


Figure 4.5. A plot of the residuals versus fitted values can also provide a graphical evaluation of whether or not the original data are normally distributed. Points randomly distributed above and below the "0" mid-line are an indication that the residuals are from normally distributed data.



for complicated mulit-factor analyses can be problematic. Bootstrap resampling methods can provide estimates of power nut of themselves are difficult to perform.

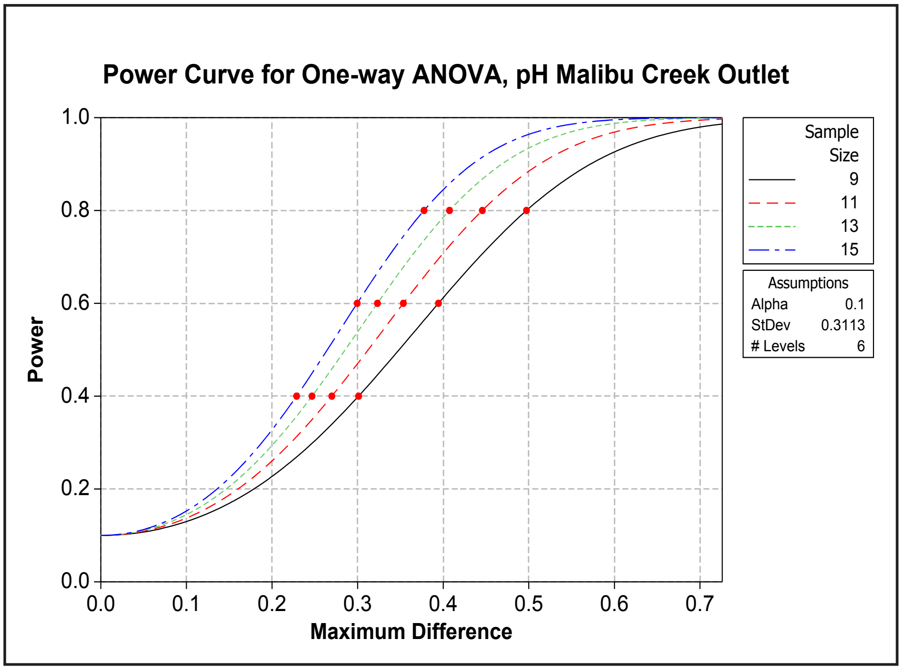
Within Minitab power may be readily calculated for one-way analyses of variance. Figure 4.6 displays power curves for sample sizes of 9, 11, 13, & 15, with a pooled standard deviation of 0.3113, and an α of 0.1 by the maximum detectable difference. These data are also summarized in Table 4.2.

4.3.7 Trend Analysis

Once normality or non-normality of data is determined (if possible), it will be necessary to determine if parametric or non-parametric statistics will be used to analyze trends in water quality data. For data sets collected over a minimum of 5 years, the program Estimate TREND (ESTREND) will be used. This computerized statistical and graphical program developed by the USGS (Schertz and others, 1991) uses three types of methods for trends in surface water quality data: (1) Seasonal Kendall test for

Figure 4.6 Power curves for analysis of variance of pH data from the Malibu Creek outlet to Malibu Lagoon.

Data were grouped by year for this example. Analysis and graphic produced in Minitab 15.



(effectively) uncensored data (i.e., censored observations < 5% of total observations); (2) Seasonal Kendall test for censored data; and (3) Tobit regression. Figure 4.7 shows decision rules for the selection of analysis method in ESTREND.

The Seasonal Kendall test for uncensored data is a non-parametric method used to analyze water quality data for both long-term and seasonal trends (Figure 4.7 and Table 4.3). The method is designed to remove variability in water-quality data caused by seasonality and flow variability (flow adjustment). It is used on water quality data with little or no censoring (less than five percent of the data record censored). Trend results for non-flow adjusted data are simultaneously computed in this procedure.

For water quality records with many observations censored at a single reporting limit, the Seasonal Kendall Test for censored data should be used (Figure 4.3 and Table 4.1). Variability caused by flow cannot be reliably removed from water quality records with a large number of censored values, so flow adjustment is not part of this particular trend analysis. Raw concentration data are used in this procedure. The method is not a preferred statistical model because it does not include flow adjustment, but it should be used when censored data is an important component of the data set.

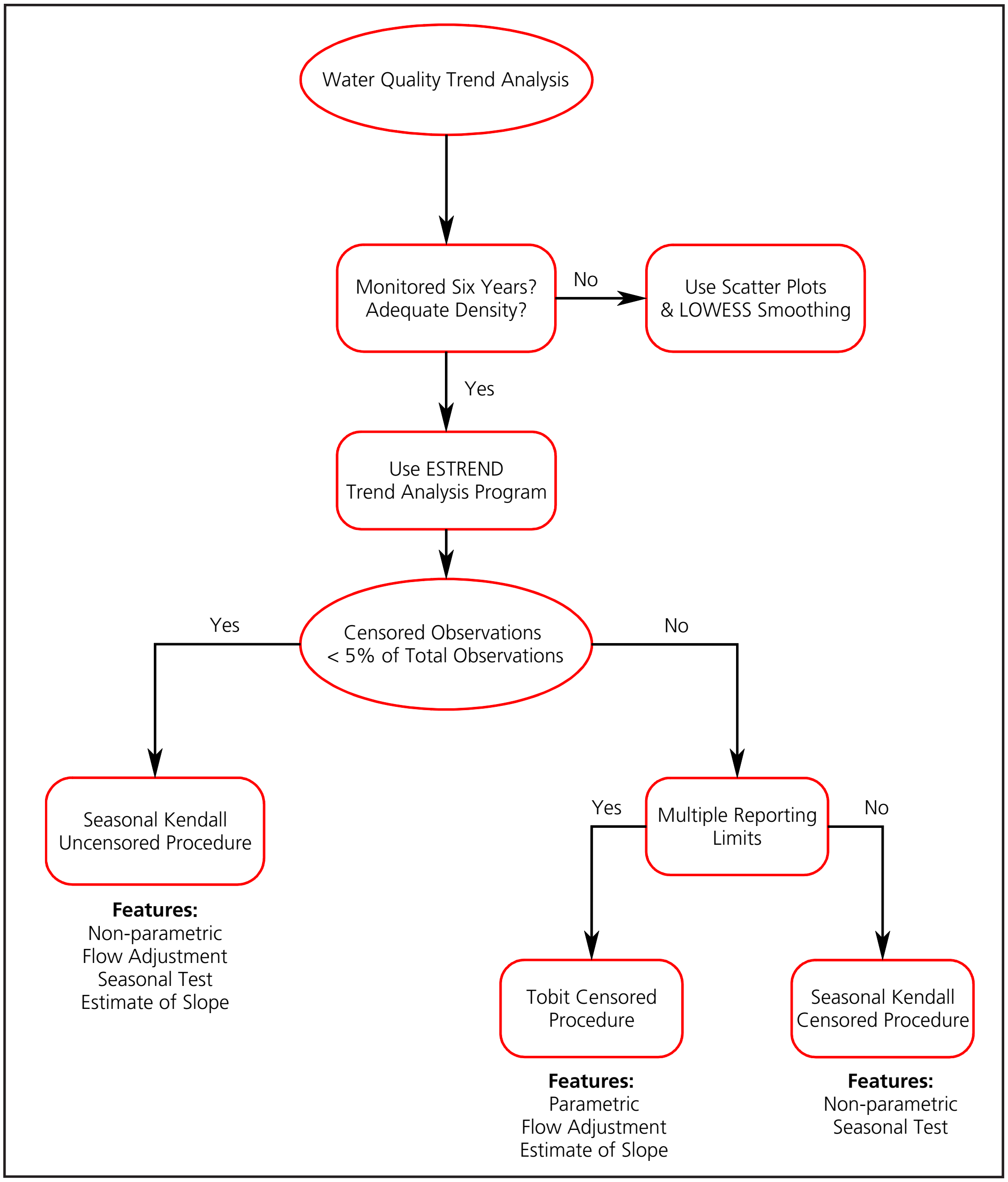
The Tobit parametric trend test should be used to analyze data sets containing values censored at multiple laboratory reporting limits (Figure 4.3 and Table 4.1). This method does not allow data to be flow adjusted. The Tobit trend procedure provides good results when the assumption of the test are satisfied (i.e., regression residuals approximately normally distributed). Careful scrutiny of the Tobit model analysis is recommended to check for the presence of outliers that would not satisfy the normality assumptions.

Criteria are established to evaluate whether a water-quality record has a large enough set of observations and density of data over a period of time to test for trend using the three test methods in ESTREND (Figure 4.3 and Table 4.1). Experience

Table 4.3. Criteria for trend analysis using ESTREND.

ESTREND Test Method	Criteria For Using Method
Seasonal Kendall Test for Uncensored Data	• The record must span a minimum of 5 years as determined by the difference in years between the beginning and ending observations. • The minimum number of observations in the record must be at least three times the number of designated annual seasons, and must be greater than or equal to 10. • A minimum percentage (as specified by the user) of the total possible number of seasonal water-quality values in the beginning and ending fifths of the record must be present in the record.
Seasonal Kendall Test for Censored Data	• The record must span a minimum of 5 years as determined by the difference in years between the beginning and ending observations. • The minimum number of detected observations in the record must be at least three times the number of designated annual seasons, and must be greater than or equal to 10. • A minimum of one observation per year must be present in the beginning and ending fifths of the record.
Tobit Test for Censored Data	• The record must span a minimum of 5 years as determined by the difference in years between the beginning and ending observations. • A minimum number of 10 detected observations must be present in the data record. • A minimum percentage (as specified by the user) of the total number of observations in the record must be detected observations. • A minimum of one observation per year must be present in the beginning and ending fifths of the record.
LOWESS Scatterplot Smoothing	• Use if the criteria above do not apply

Figure 4.7. Flow chart for selection of statistical method in USGS water quality trend analysis program ESTREND (modified from Schertz and others, 1991).



and knowledge of the generally accepted guideline for the application of the statistical tests are required of the user. For data sets with inadequate information for trend analysis with ESTREND, a substitute procedure will be used. Scatter plots and a smoothing line, created using the LOWESS (Locally Weighted Scatterplot Smoothing) method will be used to analyze short term trend (Cleveland, 1979) (Figure 4.3 and Table 4.1). Lowess is a nonparametric smoothing routine that generalizes the running means, and determines a predicted value at each point by fitting a weighted linear regression. This shows where the weights decrease with distance from the point of interest. LOWESS can detect slight changes in trend that may have occurred within a short period of time over the data series examined. The method does not use or correct for flow adjustment.

4.3.8 Monotonic and Step Trends

Tables 4.4 through 4.7 summarize recommendations for monotonic and step trend detection, depending on the type of data under analysis (from Cooprider, 2005; summarized from Hirsch and others, 1991). Monotonic trends are used for gradual changes in water quality data sets, and step trends are used before and after a significant change at a point in time. Monotonic trend testing is more commonly applied to general monitoring data unless there is a distinctive reason to test for a step trend (Cooprider, 2005). Step trend testing may be used after implementation of best management practice if there is expected to be a detectable change (Hirsch and others, 1991). The parameters classified as “mixed”

Table 4.4. Options for testing monotonic trends in uncensored water quality data.

Type	Not Flow Adjusted	Flow Adjusted
Fully parametric	Regressions of concentration on time and season	Regression of concentration on time, season, and flow
Mixed	Regression of deseasonalized concentration on time	Seasonal Kendall on residuals from regression of concentration on flow
Nonparametric	Seasonal Kendall	Seasonal Kendall on residuals from LOWESS of concentration on flow

Table 4.5. Options for testing step trends in uncensored water quality data.

Type	Not Flow Adjusted	Flow Adjusted
Fully parametric	Analysis of covariance of concentration on season and group (before and after)	Analysis of covariance concentration on season, flow and group
Mixed	Two-sample t test on deseasonalized concentration	Seasonal Rank Sum on residuals from regression of concentration on flow
Nonparametric	Seasonal Rank Sum	Seasonal Rank Sum on residuals from LOWESS of concentration on flow

Table 4.6. Options for testing for monotonic trends in censored water quality data.

Type	Not Flow Adjusted	Flow Adjusted
Fully parametric	TOBIT regression of concentration on time and season	TOBIT regression of concentration on time, season and flow
Nonparametric	Seasonal Kendall	no test available

Table 4.7. Options for testing for step trends in censored water quality data.

Type	Not Flow Adjusted	Flow Adjusted
Fully parametric	TOBIT analysis of covariance of concentration on season and group	TOBIT analysis of variance of concentration on season, flow and group
Nonparametric	Seasonal Rank Sum	no test available

have parametric and nonparametric components that can be executed in separate and successive statistical steps.

Many of the methods summarized in Tables 4.4 to 4.7 (e.g., Seasonal Kendall test for uncensored data, Seasonal Kendall Test for censored data, and Tobit parametric trend test) and their applications were described in Section 4.3.6 (Trend Analysis). Other methods include the Seasonal Rank Sum test (i.e., the Mann-Whitney "U" test) (Kirchner, 2003), performed for each season, with the Seasonal Rank Sum test statistic being the sum of the several test statistics (Cooprider, 2005). Simpler methods, such as regression analysis using linear and non-linear models may be performed by using a common statistical analysis and plotting program, such as Systat, Sigma Plot, MathLab, WQStat, R, or Minitab.

Trends in data over time can be assessed in Minitab and the data evaluate against linear, quadratic, exponential or S-curve

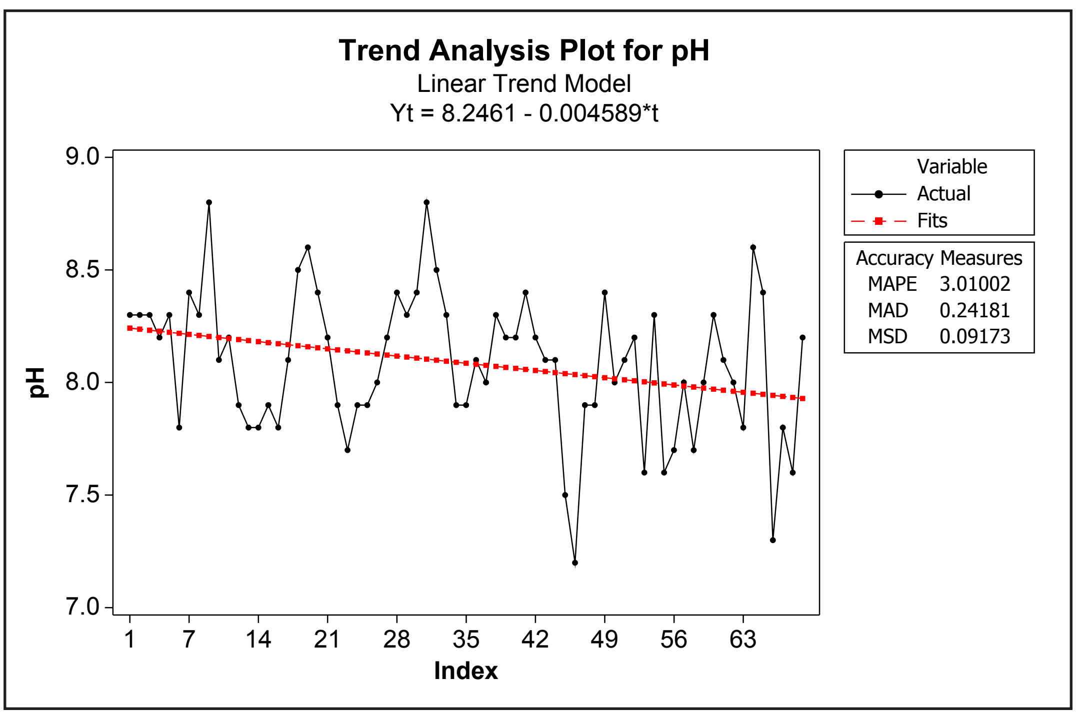


Figure 4.8. Time series trend analysis plot of pH data from Malibu Creek outlet.

models. Model fit is assessed through calculations of three measures of fit. MAPE is the Mean Absolute Percentage Error, it is a measure of the accuracy of fitted time series as a percentage. MAD is the Mean Absolute Deviation and is in the same units as original data. MDS or Mean Squared Deviation can be compared across different models. The better the fit the lower these values will be (Figure 4.8).

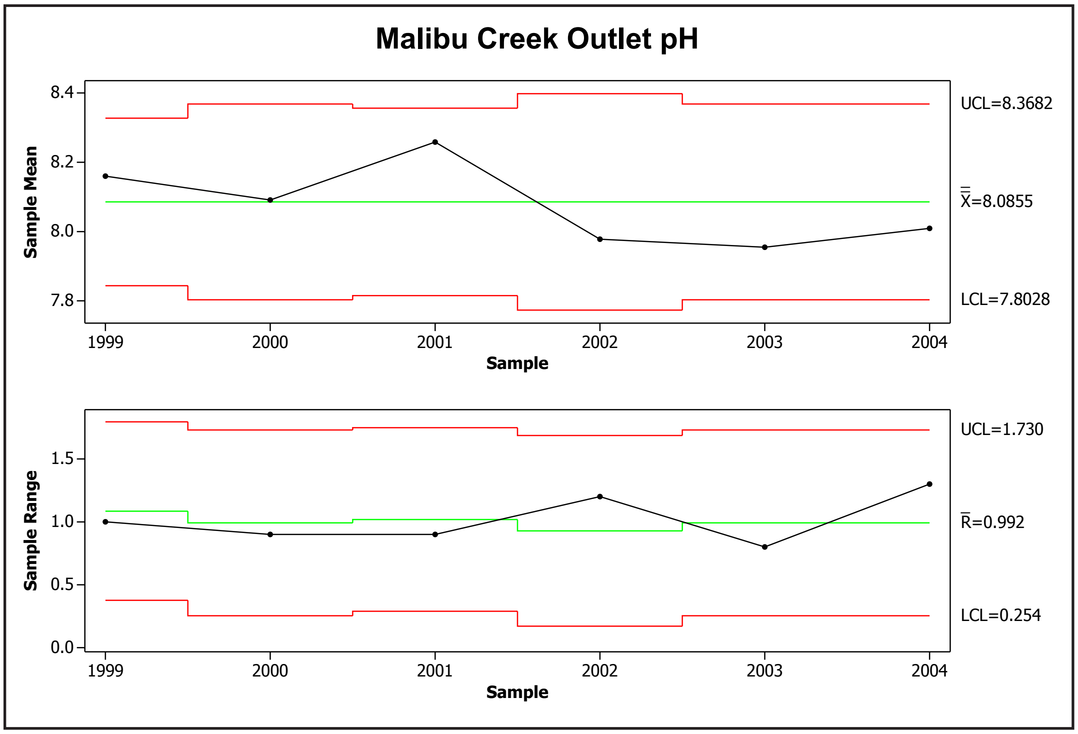


Figure 4.9. Control chart analysis of mean and range of values for pH from Malibu Creek outlet. This analysis indicates that no non-random variation in present in the data.

Stepwise changes in the control limits are a reflection of differences in sample size from one year to another.

4.3.9 Process Control Analysis

In an observable process or population there are potentially two sources of variability:

1. Natural Variability: The influence of natural (random and uncontrollable) stressors or influences, intrinsic and/or extrinsic, on the process, condition, or parameter of concern.
2. Assignable Variability: The influence of anthropogenic (non-random and controllable) stressors on the parameter of concern.

A process operating in the presence of assignable variability is said to be "out of control". The objective of statistical process control is to quickly detect the occurrence of assignable causes (non-random) sources of variation with the hope that management can implement measures to reduce the influence of assignable variability.

Control charts plot the mean value (or individual value) of a parameter with upper and lower control limits (generally 3σ). If all points fall within these limits and the distribution of points within the limits are random the parameter of interest is "in control". There is no non-random source of variation acting on the parameter (see Figure 4.9).

If one or more points fall outside the control limits or there is a repeating pattern to the data then the process is out of control and should be investigated for assignable cause variation.

4.3.10 Time Weighted Control Chart Analysis, Cumsum

The cumulative sum chart (CUMSUM) displays the cumulative sums of deviations of each value from the target value. CUMSUM charts may be either one sided or two sided. Out of control observations on two-sided charts are determined by placement of a V-mask over the data to identify the point where an out-of-control situation has developed. In the context of water quality monitoring out of control is translated as a situation where the status of a particular parameter has deviated beyond acceptable limits for management purposes.

4.3.11 Time Weighted Control Chart Analysis, EWMA

The Exponentially Weighted Moving Average chart (EWMA) incorporates information from all previous observations or groups of observations to detect any size shift in the process measured.

4.3.12 Reporting Schedule and Data Archiving

The SAMO Data Management Work Group is responsible for providing compatible water quality data in NPSTORET form to NPS on a quarterly basis. All summary statistics and graphs of each site will be compiled and provided electronically and in hard copy. Recommendations for revising the protocol (changing monitoring intervals and timing, moving/adding sites, changing parameters, etc.) at the appropriate intervals or in response to a change in watershed conditions will be described in a narrative rationalizing the action. An action list summarizing any revisions to the monitoring plan will be summarized in a table.

5.0 PERSONNEL REQUIREMENTS AND TRAINING

5.1 Roles and Responsibilities

The Water Quality Monitoring Program Leader will be a cooperating physical scientist (Cooperator) solicited from among the academic institutions party to the cooperative agreement with the Californian Ecosystems Study Unit. The Cooperator may enlist others to provide assistance but will be solely responsible for completing agreed duties. Duties will include fieldwork, lab analyses, and QA/QC measures for field collected data and laboratory analysis. The Network Monitoring Coordinator and Data Manager are primarily responsible for data management and analysis. Park staff at the park and regional level may provide assistance and guidance when necessary.

The Network Coordinator will coordinate with the Cooperator and with resource management staff at the parks to ensure monitoring goals are being met, to keep parks informed of monitoring activities, and to pursue funding opportunities.

5.2 Qualifications and Training

The Cooperator will have substantial expertise and credentials in the field of water quality analysis (e.g., practical experience demonstrated in work record, graduate degrees in water quality analysis, record of sustained publication and reporting). All assistants will be trained by the Cooperator, and their work will be reviewed by the Cooperator.

6.0 OPERATIONAL REQUIREMENTS

Yearly work schedules will include quarterly sampling and laboratory analysis will be accomplished for index parameters at all sites. The field crew will be capable of sampling an average of three or four sites per day. Thirty-two sites will be sampled in approximately four weeks. Lab work will begin when the first samples are brought in from the field and will continue for a period of time after fieldwork has been completed. Each quarterly sampling event, including fieldwork, lab work, and data analysis will be completed in approximately four weeks.

7.0 MEASURABLE OBJECTIVES

Specific measurable objectives of the water monitoring program in the SMM are to determine the condition and detect trends in condition of specific water quality parameters as identified in this protocol. While a multitude of methods exists to evaluate data to meet these objectives, two specific trends in condition will be evaluated. First levels of core parameters, nutrients and some additional measure of water quality as indicated will be collected in a manner that allows statistical analysis that can detect differences from one time period to another or over some time series based on stated levels of α, power, and desired detectable effect size for a given number of samples. Data may also be subjected to regression or trends analysis that can detect changes in condition through serial increases or decreases in value.

Additionally, trends in variation can be evaluated that can reveal the presence of stressor caused variation in the data. Stressor caused variation superimposed over natural variation is generally detected by the presence of non-random patterns in time series plots of mean values or by mean values in excess of prescribed limits. Specifics of these types of analyses are presented in section 4 of this narrative and in SOP No. 6. Limits of acceptable variation can be established from baseline or historic data, from data in the scientific literature, or by the conditions desired by management for a specific stream. As a starting point for comparative statistical analysis α will be set at 0.1, power at 0.8, effect size at 30% of the desired mean value for a given parameter, with a sample size of 3 replicates per sampling station per visit; the presence of non-random variation will be detected by the presence of non-random patterns in time series plots of mean values and specific values that exceed 3σ limits of the overall mean of desired mean value.

8.0 INFORMING MANAGEMENT

Once a significant departure from a desired condition in a specific water quality parameter or suite of parameters is detected, or an exceedance of a parameter or suite of parameters is noted, or a significant trend is detected that is leading to an unacceptable condition park resource managers will be notified and an effort will be made to determine possible causes and potential mitigating actions that can be taken. Care must be taken to note indications in the data that might provide indication of changes in water quality so that managers are not blind-sided by changes where early warning was evident. An example of such a situation might be in evaluating a graphic depicting an upward trend over time in say pH of a given stream. While the maximum data vale observed may not exceed impairment limits based on beneficial use designation clearly an upward trend should be evaluated to determine if in fact a situation exists where some management action should be taken.

Due to the nature of land ownership and source of surface waters within the SMM there is very little that NPS managers can do directly to ameliorate stressors to water quality that originate from or on non-NPS lands. Resource managers do participate with local and regional stakeholders on committees and councils for planning and mitigating the impacts of water quality stressors on the surface waters of the SMM. It is in these venues that managers can express concern for conditions that may be deteriorating or over exceedances in acceptable limits for specific parameters. When monitoring data reveal conditions that meet thresholds of concern to management this information can be presented to stakeholders with park managers acting as advocates for corrective action.

Park management may also comment on proposed development or proposals in land use changes within the boundaries of the park, recommending mitigation of activities that may negatively impact water quality in the surface waters of the park. Park management may also advise stakeholders with regulatory authority on the ongoing status of water quality as discovered through continuing monitoring. Managers may also engage the public through outreach and interpretative programs explaining the value of good water quality and identifying unacceptable conditions in park surface waters and possible methods to ameliorate such conditions.

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