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Calleguas Creek Watershed Metals and Selenium TMDL

Draft Final Technical Report

Submitted to Los Angeles Regional Water Quality Control Board
and the United States Environmental Protection Agency

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on Behalf of the Calleguas Creek Watershed Management Plan

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ACR	Acute-to-Chronic Ratio
Ag	Silver
allowable load	amount of constituent in receiving water beyond which impairment occurs
ambient source	environmental source(s) of metals and selenium in the watershed, such as natural soil concentrations, atmospheric deposition, and natural groundwater seepage
ASBS	Area of Special Biological Significance
BAF	Bioaccumulation Factor
background load	discharges from undeveloped open space due to ambient sources and/or natural groundwater seepage (agricultural and urban ambient sources not included)
BMP	Best Management Practice
$CaCO_3$	Calcium Carbonate
CARB	California Air Resources Board
CCC	Criterion Continuous Concentration (chronic)
CCDP	Conejo Creek Diversion Project
CCW	Calleguas Creek Watershed
CCWTMP	Calleguas Creek Watershed TMDL Monitoring Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic feet per second (flow rate)
CMC	Criterion Maximum Concentration (acute)
COC	Chemical of Concern (US Navy, Point Mugu)
COPC	Chemical of Potential Concern (US Navy, Point Mugu)
COPEC	Chemical of Potential Ecological Concern (US Navy, Point Mugu)
CTR	California Toxics Rule (40 CFR Part 131)
Cu	Copper
CURBA	California Urban and Biodiversity Analysis
CWA	Clean Water Act
DPR	California Department of Pesticide Regulation
EDL	Elevated Data Level
EMC	Event Mean Concentration
ERL	Effects Range Low
ERM	Effects Range Median
FACR	Final Acute-to-Chronic Ratio
GIS	Geographic Information System
Hg	Mercury
HSPF	Hydrologic Simulation Program Fortran
K_D	Partition Coefficient
LA	Load Allocation
LARWQCB	Los Angeles Regional Water Quality Control Board

LC	Loading Capacity
LC50	Concentration at which 50% of test organisms are killed
loading capacity	amount of constituent in receiving water beyond which impairment occurs
LWA	Larry Walker Associates
MCL	Maximum Contaminant Level
MeHg	Methylmercury
MLMSM	Mugu Lagoon Metals and Selenium Model
MOS	Margin of Safety
MRDS	Mineral Resource Data System
MS4	Municipal Separate Storm Sewer System
NAWS	Naval Air Weapons Station
ND	Not Detected, Non Detect
Ni	Nickel
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PAN	Pesticide Action Network
Pb	Lead
PCH	Pacific Coast Highway
POTW	Publicly Owned Treatment Works
PPB	Parts Per Billion
PPM	Parts Per Million
PUR	Pesticide Use Report (from DPR)
Q	Flow
RGHg	Reactive Gaseous Mercury
RI/FS	Remedial Investigation and Feasibility Study
ROS	Regression on Order Statistics
RWQCB	Regional Water Quality Control Board
Se	Selenium
SOAR	Save Open Space and Agricultural Resources
SQuiRTs	Screening Quick Reference Tables (sediment guidelines produced by NOAA)
SSO	Site Specific Objective
SSURGO	Soil Survey Geographic (SSURGO) Database, NRCS
SVOC	Semi-Volatile Organic Compound
SWRCB	State Water Resources Control Board
TEL	Threshold Effects Level
TIE	Toxicity Identification Evaluation
TL	Trophic Level
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VCWPD	Ventura County Watershed Protection District
V_{dep}	Deposition Velocity

VFCD	Ventura Flood Control District
WER	Water-Effect Ratio
WLA	Waste Load Allocation
WQA	Water Quality Assessment
WQC	Water Quality Criteria
WQCP	Water Quality Control Plant
WQO	Water Quality Objective
WWTP	Wastewater Treatment Plant
Zn	Zinc

1 INTRODUCTION

The Calleguas Creek Watershed Metals and Selenium Total Maximum Daily Load (TMDL) document presents the required elements for addressing impairments to Calleguas Creek and its tributaries caused by metals and selenium. The TMDL determines the causes of these impairments, allowable loadings for the various sources, and measures required to remove these impairments.

Three of fourteen reaches in the Calleguas Creek Watershed (CCW), in southern Ventura County, are identified on the 2002 Clean Water Act Section 303(d) list of water-quality limited segments as impaired due to elevated levels of metals and selenium in water. The 303(d) listings, which were approved by the State Water Resources Control Board in February 2003, require the development of TMDLs to establish the maximum amount of pollutants a water body can receive without exceeding water quality standards. The CCW reaches identified as impaired on the 2002 303(d) list are presented below in Table 1.

The Clean Water Act requires development of TMDLs to restore impaired water bodies, and the Porter-Cologne Water Quality Act requires that an Implementation Plan be developed to achieve water quality objectives. This document fulfills these statutory requirements and serves as the basis for amending the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to achieve water quality standards in Calleguas Creek for metals and selenium. The CCW Metals and Selenium TMDL addresses the requirements prescribed by Section 303(d) of the Clean Water Act (40 CFR 130.2 and 130.7) and USEPA guidance (USEPA, 1991).

Larry Walker Associates provided the analysis to determine the TMDL for metals and selenium in the CCW under contract to the Calleguas Creek Watershed Management Plan Steering Committee (Steering Committee) with support from the California Regional Water Quality Control Board, Los Angeles Region (Regional Board or LARWQCB), and the United States Environmental Protection Agency, Region 9 (USEPA).

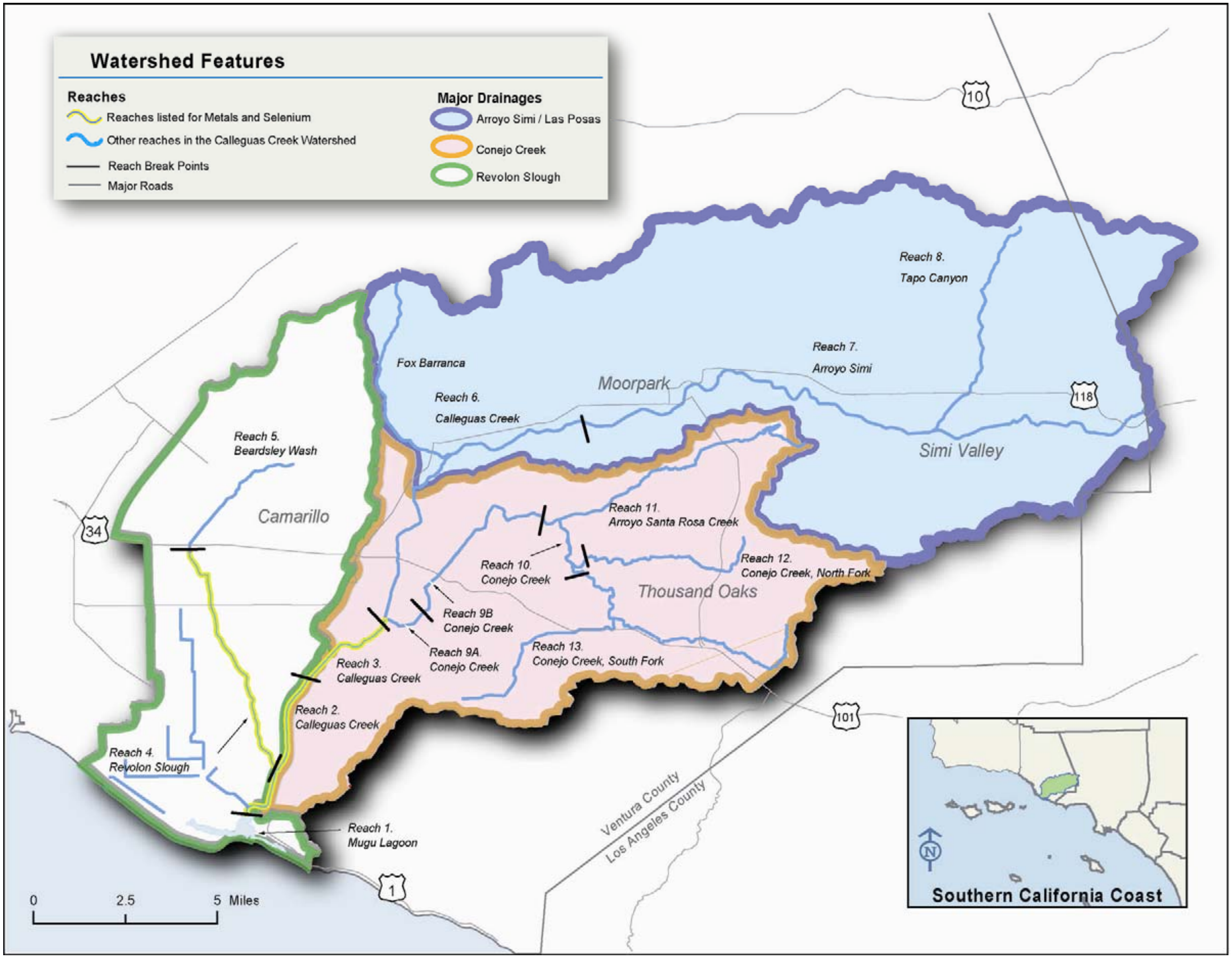


Figure 1. Map of Calleguas Creek Watershed, showing reaches impaired by metals and/or selenium.

Table 1. 2002 303(d) Listings for Metals and Selenium in the CCW

Reach	Total Copper	Dissolved Copper	Total Mercury	Total Nickel	Total Selenium	Total Zinc
1 – Mugu Lagoon	x	---	x	x	---	x
2 – Calleguas Creek, Lower	---	x	---	---	---	---
4 – Revolon Slough	---	---	---	---	x	---

x = reach listed as impaired for this metal

1.1 Regulatory Background

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

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in USEPA guidance (USEPA, 1991). A TMDL is defined as the “sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background” (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the loading capacity) is not exceeded. TMDLs are required to account for seasonal variations, and must include a margin of safety to address uncertainty in the analysis. The individual TMDL elements are defined below in Section 1.3, along with corresponding sections containing detailed descriptions of the analyses supporting each element.

States must develop water quality management plans to implement TMDLs (40 CFR 130.6). The USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. If the USEPA disapproves a TMDL submitted by a state, USEPA is required to establish a TMDL for that water body. The Regional Board identified over 700 water body-pollutant combinations in the Los Angeles Region where TMDLs are required (LARWQCB, 2003). A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. The consent decree combined water body pollutant combinations in the Los Angeles Region into 92 TMDL analytical units. In accordance with the consent decree, the analyses performed for TMDL development are summarized herein and the TMDLs address waterbodies with metals and selenium listings in analytical unit 6. According to the consent decree, TMDLs addressing analytical unit 6, must be approved or established by USEPA by March 2007.

As part of the 2002 listing process, a number of the analytical unit 6 metals and selenium listings from the 1998 list were delisted and one metal listing was added (Table 2). All of the 2002 delistings were for tissue-based metals and selenium listings. The original tissue listings from 1996 were based on Elevated Data Levels (EDLs) which are no longer considered a valid mechanism for listing a waterbody as impaired. As stated in the 1998 listing process, EDLs are "not to be used for listing unless a human risk assessment has been completed" (LARWQCB, 2003). In 2002, the listings included on the 303(d) list based on EDLs were removed from the list. As stated in the Consent Decree, paragraph 8 under Measuring Compliance with

TMDL deadlines, “EPA is under no obligation to establish TMDLs for any pairing of a WQLS and a pollutant that EPA determines . . . does not require a TMDL or which has been removed after the Effective Date from an EPA approved California Section 303(d) list”. Thus, the listings in analytical unit 6 under the Consent Decree that were delisted in 2002 do not require a TMDL and are considered as meeting the requirements of the Consent Decree. Therefore, although this TMDL only discusses the listings present on the 2002 list, it addresses all of the listings in analytical unit 6 based on the fact that the additional listings were delisted in 2002.

In addition to the federal and state regulations described above, the Regional Board enacted Resolution No. 97-10, *Support for Watershed Management in the Calleguas Creek Watershed* on April 7, 1997. Resolution 97-10 recognized watershed management as an innovative, cost-effective strategy for the protection of water quality. Resolution 97-10 also recognized that the Calleguas Creek Municipal Water District and the Publicly Owned Treatment Works (POTWs) in the Calleguas Creek watershed had worked cooperatively with the Regional Board to develop an integrated watershed-wide monitoring program. The Calleguas Watershed Management Plan has been active since 1996 in the development of a watershed management plan for the Calleguas Creek watershed and has proactively worked with the Regional Board and the USEPA to develop TMDLs in the watershed.

Table 2. Consent Decree Listings for Metals and Selenium in the CCW

	Reach	Total Copper	Dissolved Copper	Total Mercury	Total Nickel	Total Selenium	Total Zinc	Cadmium (Tissue)	Chromium (Tissue)	Nickel (Tissue)	Silver (Tissue)	Selenium (Tissue)	Zinc (Tissue)
1	Mugu Lagoon	x	--	x	x	--	x	--	--	--	--	--	--
2	Calleguas Creek, Lower	--	x[2]	--	--	--	--	--	--	--	--	--	--
4	Revolon Slough	--	--	--	--	x	--	--	--	--	--	--	--
1	Conejo Creek	--	--	--	--	--	--	x[1]	x[1]	x[1]	x[1]	--	--
2	Conejo Creek	--	--	--	--	--	--	x[1]	x[1]	x[1]	x[1]	--	--
3	Conejo Creek	--	--	--	--	--	--	x[1]	x[1]	x[1]	x[1]	--	--
1	Arroyo Simi	--	--	--	--	--	--	--	x[1]	x[1]	x[1]	x[1]	x[1]

x = reach listed as impaired for this metal
1=reach delisted in 2002. The Consent Decree outlines specific actions required by EPA to address the 1998 listings that were delisted in 2002.
2=reach listed in 2002

1.2 Calleguas Creek TMDL Stakeholder Participation Process

The Calleguas Creek Watershed Management Plan has been active since 1996. In 2001, the group began discussions with the Regional Board and USEPA to provide assistance in the development of the TMDLs for the watershed. In December 2002, the group developed TMDL work plans for most constituents on the 2002 303(d) list. The Metals TMDL Work Plan, developed with input from the LARWQCB and USEPA, forms the basis of all of the work conducted to develop this TMDL. USEPA Region IX approved the Metals TMDL Work Plan in October 2003.

The purpose of the watershed group assisting with the development of the TMDLs was to incorporate local expertise and reach a broad group of stakeholders to develop implementation plans to resolve the water quality problems within the watershed. Stakeholders include representatives of cities, counties, water districts, sanitation districts, private property owners, agricultural organizations, and environmental groups with interests in the watershed.

A high level of stakeholder involvement has occurred throughout the TMDL development process. There have been no interventions from outside groups, and much of the work has been performed or paid for by members of local government agencies and USEPA grant funding.

1.3 Elements of a TMDL

Individual elements of the CCW Metals and Selenium TMDL are presented as sections in this document, as described below.

- Problem Statement - Section 2: Explanation of environmental setting, beneficial uses, and the basis for listings addressed through this TMDL.
- Current Conditions – Section 3: Summarizes current conditions in water, as well as providing an evaluation of fish tissue concentrations where available.
- Numeric Targets – Section 4: Presents appropriate numeric targets that will result in the attainment of water quality objectives as well as the basis for selection of targets.
- Source Analysis - Section 5 and Section 6: Presents an inventory of the sources of the pollutants of concern.
- Linkage Analysis - Section 7 and Section 8: Analysis developed to describe the relationship between the input of the pollutants of concern and the subsequent environmental response with regard to listings.
- TMDL and Allocations – Section 9 and Section 10: Identifies the TMDL allocations for point sources (waste load allocations) and non-point sources (load allocations) that will result in the attainment of water quality objectives.
- Margin of Safety-Section 11: Describes the basis for the margin of safety included in the allocations.
- Future Growth – Section 12: Estimates likely economic and population growth, and the effects of that growth upon water supply and water quality
- Implementation Plan - Section 13: Describes the strategy for implementing the TMDL and achieving water quality objectives, as well as a brief overview of the strategy for monitoring the effects of implementation actions.
- Nickel Site-Specific Objective-Section14: Describes the proposed nickel SSO and the associated allocations should the SSO become effective.

2 PROBLEM STATEMENT

This section provides the context and background for the CCW Metals and Selenium TMDL. The environmental setting provides an overview of the hydrology, climate, and anthropogenic influences in the CCW. In addition, this section includes an overview of water quality standards applicable to the watershed and reviews data used to develop the 1996, 1998, and 2002 303(d) listings.

2.1 Environmental Setting

Calleguas Creek and its tributaries are located in southeast Ventura County and a small portion of western Los Angeles County. Calleguas Creek drains an area of approximately 343 square miles from the Santa Susana Pass in the east to Mugu Lagoon in the southwest. The main surface water system drains from the mountains in the northeast part of the watershed toward the southwest where it flows through the Oxnard Plain before emptying into the Pacific Ocean through Mugu Lagoon. The watershed, which is elongated along an east-west axis, is about thirty miles long and fourteen miles wide. The Santa Susana Mountains, South Mountain, and Oak Ridge form the northern boundary of the watershed; the southern boundary is formed by the Simi Hills and Santa Monica Mountains.

Land uses in the Calleguas Creek watershed include agriculture, high and low density residential, commercial, industrial, open space, and a Naval Air Base located around Mugu Lagoon. The watershed includes the cities of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Most of the agriculture is located in the middle and lower watershed with the major urban areas (Thousand Oaks and Simi Valley) located in the upper watershed. The current land use in the watershed is approximately 26% agriculture, 24% urban, and 50% open space. Patches of high quality riparian habitat are present along the length of Calleguas Creek and its tributaries.

Climate and Hydrology

The climate in the watershed is typical of the southern California coastal region. Summers are relatively warm and dry and winters are mild and wet. Eighty-five percent of the rainfall occurs between November and March with most of the precipitation occurring during just a few major storms. Annual rainfall in Ventura County averages 15 inches and varies from 13 inches on the Oxnard Plain to a maximum of 20 inches in the higher elevations (USDA, 1995). Storm events concentrated in the wet-weather months produce runoff usually ranging in duration from one-half day to several days. Discharge during runoff from storm events is commonly 10 to 100 times greater than at other times. Storm events and the resulting high stream flows are highly seasonal, grouped heavily in the months of November through February, with an occasional major storm as early as September and as late as April. Rainfall is rare in other months, and major storm flows historically have not been observed outside the wet-weather season.

Surface Waters

The main surface water system drains from the mountains toward the southwest, where it flows through the Oxnard Plain before emptying to the Pacific Ocean through Mugu Lagoon. Dry weather surface water flow in the Calleguas Creek watershed is primarily composed of groundwater, municipal wastewater, urban non-storm water discharges, and agricultural runoff. In the upper reaches of the watershed, upstream of any wastewater discharges, groundwater discharge from shallow surface aquifers provides a constant base flow. Additionally, urban non-stormwater runoff and groundwater extraction for construction dewatering or remediation of contaminated aquifers contribute to the base flow. Stream flow in the upper portion of the watershed is minimal, except during and immediately after rainfall. Flow in Calleguas Creek is described as “storm-peaking” and is typical of smaller watersheds in coastal southern California. “Storm-peaking” refers to peak discharges limited to a wet weather season and concentrated into a few days after short-term, discrete storm events, when flow commonly is two to three orders of magnitude greater than non-storm flow (Duke, 2001).

The Calleguas Creek Watershed is generally characterized by three major subwatersheds: Arroyo Simi/Las Posas in the northeast, Conejo Creek in the south, and Revolon Slough in the west. Additionally, the lower watershed including Mugu Lagoon is also drained by several minor agricultural drains in the Oxnard plain. Subwatersheds of the CCW are depicted in Figure 1 along with reach names and boundary locations used in the 2002 listing process and the CCW Metals and Selenium TMDL. The three major subwatersheds are described below in more detail.

Arroyo Simi / Arroyo Las Posas

The northern portion of the watershed is drained by the Arroyo Simi and Arroyo Las Posas. The northern part of the watershed system originates in the Simi Valley and surrounding foothills. The surface flow comes from the headwaters of the Arroyo Simi at Santa Susanna pass (upper parts of Reach 7) and Tapo Canyon (Reach 8). Arroyo Simi and Arroyo Las Posas flow through the cities of Simi Valley and Moorpark and join with Calleguas Creek, upstream from the City of Camarillo. Upstream of Simi Valley, the creek is unlined and passes through open space and recreational areas. Through the City of Simi Valley, the Arroyo Simi flows through concrete lined or rip-rapped channels. Between Simi Valley and Moorpark, a distance of approximately 7 miles, the creek is unlined and without rip-rap forming high quality natural creek and riparian habitats. From the edge of Moorpark to Hitch Boulevard, the creek is once again rip-rapped on the sides with a soft bottom throughout most of the channel, but in some areas, such as under bridges, the bottom is covered with concrete and rip-rap. The Arroyo Simi essentially becomes the Arroyo Las Posas at Hitch Blvd. Downstream of Hitch Boulevard, Arroyo Las Posas passes through agricultural fields and orchards in a primarily natural channel. Although the Arroyo Las Posas channel joins with Calleguas Creek near Camarillo, surface flow is typically not present in this portion of the channel due to evaporation and groundwater recharge upstream of Seminary Road.

Two POTWs discharge in the subwatershed. The Simi Valley Water Quality Control Plant (WQCP) discharges to the Arroyo Simi on the western edge of the City of Simi Valley. The Moorpark Wastewater Treatment Plant (WWTP) discharges primarily to percolation ponds near the Arroyo Las Posas downstream of Hitch Boulevard. Direct discharges to the Arroyo Las Posas from the Moorpark WWTP only occur during extremely wet periods.

Conejo Creek Subwatershed

Conejo Creek and its tributaries (Arroyo Conejo and Arroyo Santa Rosa) drain the southern portion of the watershed. Flow in the southern portion of the watershed originates in the City of Thousand Oaks and flows through the east side of the City of Camarillo before joining Calleguas Creek upstream of California State University Channel Islands (CSUCI). The subwatershed supports significant residential and agricultural land uses. The streams and channels of the Conejo Creek subwatershed are described below, in order from uppermost to lower.

Arroyo Conejo

The Arroyo Conejo runs through Thousand Oaks and has three branches, the main fork, the north fork, and the south fork. The main fork of the Arroyo Conejo runs underground for most of its length, with the portions that are above ground flowing through concrete lined channels until the creek enters Hill Canyon on the western side of Thousand Oaks at the confluence with the South Fork of the Arroyo Conejo. The South Fork runs through the southern and western portions of Thousand Oaks. For most of its length, the South Fork flows underground or through concrete lined channels. The North Fork of the Arroyo Conejo runs through Thousand Oaks upstream of the Hill Canyon Wastewater Treatment Plant (WWTP). The channel is concrete lined for the portion that runs through the city, but becomes unlined when it nears the treatment plant. The Hill Canyon WWTP discharges to the North Fork of the Arroyo Conejo on the western edge of the City of Thousand Oaks. The main fork and the south fork join together about a mile upstream of the treatment plant. The joined flow (usually called the south fork at this point) and the north fork converge approximately 0.4 miles downstream of the Hill Canyon WWTP. The Arroyo Conejo then flows in a natural channel through a primarily open space area until it merges with the Arroyo Santa Rosa to form Conejo Creek at the confluence.

Arroyo Santa Rosa

Arroyo Santa Rosa runs on the northern edge of the City of Thousand Oaks and through agricultural land in the Santa Rosa Valley. Arroyo Santa Rosa is a natural channel for most of its length with portions of riprap and concrete lining along the sides and bottom of the channel in the vicinity of homes (such as near Las Posas Road). Prior to 1999, a wastewater treatment plant (Olsen Road) discharged to Arroyo Santa Rosa and maintained a constant surface flow in the reach. Since 1999, the POTW has not discharged and the channel is dry during non-storm events.

Conejo Creek

Arroyo Conejo and Arroyo Santa Rosa converge at the base of Hill Canyon to form Conejo Creek, which flows downstream approximately 7.5 miles through the City of Camarillo to its confluence with Calleguas Creek. Just downstream of Camarillo, the Camarillo Sanitary District Water Reclamation Plant discharges to Conejo Creek. Conejo Creek provides the majority of the flow in Calleguas Creek. For most of the length of the Conejo and Calleguas Creeks, the sides of the channel are rip rapped and the bottom is unlined.

Calleguas Creek

Calleguas Creek runs along the eastern side of Oxnard Plain to Mugu Lagoon. From the headwaters in the hills north of Camarillo to the confluence with the Arroyo Las Posas through to the confluence with Conejo Creek, Calleguas Creek is typically dry due to rapid infiltration and evaporation. During wet weather storm events, the stretch of Calleguas Creek provides a conduit for transporting storm flows from the upper CCW to the Pacific Ocean. The Camrosa WRP is located near California State University, Channel Islands. The Camrosa WRP only discharges to the creek during extreme storm events. Calleguas Creek is tidally influenced from Mugu Lagoon to approximately Potrero Road.

Revolon Slough Subwatershed

Revolon Slough drains the agricultural land in the western portion of the watershed (Oxnard Plain). The slough does not pass through any urban areas, but does receive drainage from tributaries which drain urban areas. Revolon Slough starts as Beardsley Wash in the hills north of Camarillo. The wash is a rip rapped channel for most of its length and combines with Revolon Slough at Central Avenue in Camarillo. The slough is concrete lined just upstream of Central Avenue and remains lined for approximately 4 miles to Wood Road. From there, the slough is soft bottomed with rip-rapped sides. The lower mile to mile and a half of the slough to above Las Posas Road appears to be tidally influenced by inflows from Mugu Lagoon. Revolon Slough flows into Mugu Lagoon in a channel that runs parallel to Calleguas Creek. The flows from

Revolon Slough and Calleguas Creek only converge in the lagoon. In addition to Revolon Slough, a number of agricultural drains (Oxnard Drain, Mugu Drain, and Duck Pond Drain) serve as conveyances for agricultural and industrial drainage water to the Calleguas Creek estuary and Mugu Lagoon.

Mugu Lagoon

Mugu Lagoon, an estuary at the mouth of Calleguas Creek, supports a diverse wildlife population including migratory birds and endangered species; and is an area of special biological significance (ASBS). The Point Mugu Naval Air Weapons Station directly impacts Mugu Lagoon as do the substantial agricultural activities in the Oxnard Plain. The lagoon consists of approximately 287 acres of open water, 128 acres of tidal flats, 40 acres of tidal creeks, 944 acres of tidal marsh and 77 acres of salt pan (California Resources Agency, 1997). The Lagoon is comprised of a central basin which receives the flow from Revolon Slough and Calleguas Creek, and two arms (eastern and western) that receive some drainage from agricultural and industrial drains. In addition, multiple drainage ditches drain into the lagoon. Two of these ditches, Oxnard drainage ditches 2 and 3, discharge urban and agricultural runoff originating beyond the Naval Station's boundaries into the central and western portion of the lagoon. The remaining ditches discharge urban and industrial runoff originating on the Station.

The salinity in the lagoon is generally between 31 and 33 parts per thousand (ppt) (Granade, 2001). The central basin of the lagoon has a maximum tidal range of approximately -1.1 to 7 feet (as compared to mean sea level) with smaller ranges in the eastern and western arms of the lagoon. The western arm of the lagoon receives less tidal volume because of a bridge culvert that restricts the flows in that area. The velocity of water traveling through the narrow mouth of the lagoon is approximately 5-6 knots, which is a high velocity for a lagoon (Grigorian, 2001). The mouth of the lagoon never closes, apparently as a result of a large canyon present at the mouth of Calleguas Creek. The canyon prevents ocean sand from building up to a high enough level to close the mouth and likely accounts for the high velocities in the lagoon (Grigorian, 2001).

Groundwater

Groundwater features of the watershed are dominated by the Fox Canyon Aquifer System, which is linked to the neighboring Santa Clara River Watershed. The Fox Canyon Aquifer System is a series of deep, confined aquifers. The deep aquifers today receive little or no recharge from the watershed. The water quality in these aquifers is very high. However, because there is little recharge to these aquifers they suffer from overdraft. Major groundwater basins within the watershed include the Simi Basin, East Las Posas, West Las Posas, South Las Posas, Pleasant Valley, and Arroyo Santa Rosa Basins. Significant aquifers within the watershed include the Epworth Gravels, the Fox Canyon aquifer, and the Grimes Canyon aquifer in order from shallowest to deepest. In addition, the top 350 feet of sediments within the Pleasant Valley Basin are often referred to as the "Upper Zone", and are thought by some to be equivalent to the Hueneme aquifer zone that is a more well-defined and recognized layer to the west of the Pleasant Valley Basin.

Shallower, unconfined aquifers are located in the valleys of the watershed. In the upper sub-watersheds of Simi Valley and Conejo Valley, groundwater collects in the lower areas and overflows into the down-gradient valleys. The Tierra Rejada, Santa Rosa and South Las Posas valley basins are larger than the upper valley basins and are the most significant unconfined basins on the watershed. Areas of perched and unconfined groundwater are also present along the base of the Santa Monica Mountains, and overlying areas of the southeastern Oxnard Plain in the Pleasant Valley.

Water rights have not been adjudicated in many of these basins, and groundwater production is not comprehensively controlled or maintained. However, groundwater extractions are regulated in the Oxnard Plain, Pleasant Valley Basin and the Las Posas Basin by the Fox Canyon Groundwater Management Agency. In some basins, groundwater is being over-drafted and as a result Pleasant Valley has experienced subsidence. In other basins, such as the South Las Posas Basin, groundwater storage has increased significantly in the last several decades.

Anthropogenic Alterations

Historically, the Oxnard Plain served as the flood plain for Calleguas Creek. Starting in the 1850's, agriculture began to be practiced extensively in the watershed. By 1889, a straight channel from the area near the present day location of Highway 101 to the Conejo Creek confluence had been created for Calleguas Creek. In the 1920's, levees were built to channelize flow directly into Mugu Lagoon (USDA, NRCS, 1995). Increased agricultural and urban land uses in the watershed resulted in continued channelization of the creek to the current channel system. Historically, Calleguas Creek was an ephemeral creek flowing only during the wet season. The cities of Simi Valley, Moorpark, Camarillo, and Thousand Oaks experienced rapid residential and commercial development beginning in the 1960s. In the early 70's, State Water Project supplies began being delivered to the watershed. In 1957, the Camarillo Water Reclamation Plant came online, followed by the Hill Canyon WWTP in Thousand Oaks in 1961. Increasing volumes of discharges from these POTWs eventually caused the Conejo/Calleguas system to become a perennial stream by 1972 (SWRCB, 1997). When the Simi Valley Water Quality Control Facility began discharging in the early 1970's, the Arroyo Simi/Arroyo Las Posas became a perennial stream that gradually flowed further downstream and currently reaches Seminary Road in Camarillo. However, surface flows from the Arroyo Simi/Arroyo Las Posas do not connect with surface flows in the Conejo Creek/Calleguas system, except during and immediately following large storm events.

Sedimentation

Agricultural development and urbanization have brought about significant changes in the watershed such as increased runoff and freshwater flows, accelerated erosion and sedimentation and transport of agricultural chemicals and urban pollutants. Previous to the channelization of lower Calleguas Creek, sediment was deposited largely in a vast estuarine network that meandered across the Oxnard Plain. Numerous drop structures, channel bed stabilizers, dams, and debris basins have since been constructed to compensate for the loss of flood plain. Extensive urban development, farmland conversion, and the resulting redevelopment of orchards onto steeper slopes have changed the hydrology of the area and led to accelerated erosion rates. Accelerated erosion rates have contributed to flooding and sedimentation of the Oxnard Plain and Mugu Lagoon (USDA, NRCS, 1995).

Flow Diversion Project

The Conejo Creek Diversion Project (CCDP) in the Calleguas Creek watershed diverts the majority of flow in Conejo Creek to agricultural uses in the Pleasant Valley area. The diversion project is located approximately 7 miles downstream from the Hill Canyon Wastewater Treatment Plant (WWTP). The water rights application allows the diversion of an amount equal to Hill Canyon's effluent minus 4 cfs for in-stream uses and channel losses. An additional amount of water equal to the flow contributed by use of imported water in the region (estimated at 4 cfs) may be diverted when at least 6 cfs of water will remain in the stream downstream of the diversion point (SWRCB, 1997). Natural flows due to precipitation will not be diverted. As a result of this project, flows in the lower reach of Conejo Creek have been reduced to less than half of the previous creek flows. Projects similar to the CCDP may be developed as part of the overall Watershed Management Plan for Calleguas Creek to address water resource, water quality, or flooding/erosion concerns. As such, TMDLs must be developed in a manner that considers the impacts of changing flows in the watershed and does not result in restrictions on the necessary use of the water for other purposes.

Reach Designations

Table 3 summarizes the reach descriptions of Calleguas Creek used in this TMDL and the correlation between these reaches with the 303(d) and consent decree listed reaches. These reach designations provide greater detail than the designations in the current Basin Plan, and were developed by the Regional Board for TMDL purposes. The reach revisions may provide an appropriate analytical tool for future analyses in the watershed. At this time, though, the reach revisions are not regulatory and do not alter water quality objectives for the reaches in the existing Basin Plan.

Table 3. Description of CCW Reaches on 2002 303(d) List.

Reach Names for Metals and Selenium TMDL	Reach Names as Listed in 303(d) List and Consent Decree	Geographic Description	Notes: Hydrology, land uses, etc.
1 Mugu Lagoon	Mugu Lagoon	Lagoon fed by Calleguas Creek	Estuarine; brackish, contiguous with Pacific Ocean
2 Calleguas Creek South	Calleguas Creek Reach 1 and Reach 2 (Estuary to Potrero Rd.)	Downstream (south) of Potrero Rd	Tidal influence; concrete lined; tile drains; Oxnard Plain
4 Revolon Slough	Revolon Slough Main Branch	Revolon Slough from confluence with Calleguas Creek to Central Ave	Concrete lined; tile drains; Oxnard Plain; tidal influence

Additional reaches discussed in the analysis of watershed conditions are described below.

Reach Names	Reach Names as Listed in 303(d) List and Consent Decree	Geographic Description	Notes: Hydrology, land uses, etc.
3 Calleguas Creek North	Calleguas Creek Reach 3 (Potrero to Somis Rd.)	Potrero Rd. upstream to confluence Conejo Creek	Concrete lined; no tidal influence; Agriculture tile drains; Pleasant Valley Basin. Camrosa WRP discharges to percolation ponds.
5 Beardsley Channel	Beardsley Channel	Revolon Slough upstream of Central Ave.	Concrete lined ; tile drains; Oxnard Plain
6 Arroyo Las Posas	Arroyo Las Posas Reach 1 and Reach 2 (Lewis Somis Rd. to Moorpark Fwy (23))	Confluence with Calleguas Creek to Hitch Road	Ventura Co. POTW discharge at Moorpark to percolation ponds; discharges enter shallow aquifer; dry at Calleguas confluence
7 Arroyo Simi	Arroyo Simi Reach 1 and Reach 2 (Moorpark Fwy (23) to Headwaters)	End of Arroyo Las Posas (Hitch Rd) to headwaters in Simi Valley.	Simi Valley WQCP discharge; discharges from shallow aquifers; pumped GW; GW discharges from shallow aquifers.
8 Tapo Canyon	Tapo Canyon Reach 1 and Reach 2	Confluence w/ Arroyo Simi up Tapo Cyn to headwaters	Origin near gravel mine, used by nursery, ends in residences.
9A Conejo Creek	Conejo Creek Reach 1 (Confl with Calleguas Creek to Santa Rosa Rd.)	Extends from the confluence with Arroyo Santa Rosa downstream to the Camrosa Diversion	Camarillo WWTP discharge; Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Groundwater and surface water used for agriculture.
9B Conejo Creek	Conejo Creek Reach 1 and Reach2 (Confl with Calleguas Creek to Tho. Oaks city limit)	Extends from Camrosa Diversion to confluence with Calleguas Creek.	Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Camarillo WWTP discharges to percolation ponds near downstream end.
10 Hill Canyon reach of Conejo Creek	Conejo Creek Reach 2 and Reach 3 (Santa Rosa Rd. to Lynn Rd.)	Confluence w/ Arroyo Santa Rosa to confluence w/ N. Fork; and N. Fork to just above Hill Canyon WWTP	Hill Canyon WWTP; stream receives N. Fork Conejo Creek surface water.
11 Arroyo Santa Rosa	Arroyo Santa Rosa	Confluence w/Conejo Creek to headwaters	Olsen Rd. WRP; dry before Calleguas Ck confluence except during storm flow.
12 North Fork Conejo Creek	Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	Confluence w/Conejo Creek to headwaters	
13 Arroyo Conejo (S.Fork Conejo Cr)	Conejo Creek Reach 4 (Above Lynn Rd.)	Confluence w/ N. Fork to headwaters - two channels	City of Thousand Oaks; pumped/treated GW

2.2 Water Quality Standards

Federal law requires states to adopt water quality standards, which are defined as the designated beneficial uses of a water segment and the water quality criteria necessary to support those uses (33

U.S.C. §1313). California implements the federal water quality standard requirements by providing for the reasonable protection of designated beneficial uses through the adoption of water quality objectives (CA Water Code §13241). Water quality objectives (WQOs) may be numeric values or narrative statements. For inland surface waters in the Los Angeles Region, beneficial uses and numeric/narrative objectives are identified in the Basin Plan and additional numeric objectives for toxic pollutants are contained in the California Toxics Rule as adopted by the U.S. EPA (40 CFR 131.38). In addition, federal regulation requires states to adopt a statewide antidegradation policy that protects high quality waters and the level of water quality necessary to maintain and protect existing uses.

2.3 Beneficial Uses

The Basin Plan defines 21 types of beneficial uses for water bodies in the Calleguas Creek Watershed, which are rated for each reach as existing, potential or intermittent (Table 4). The federally-defined beneficial uses (and the Los Angeles Region Basin Plan equivalents) that could potentially be impaired by metals and selenium in the CCW include: MUN, GWR, REC-1, REC-2, WARM, COLD, EST, MAR, WILD, BIOL, RARE, MIGR, SPWN, COMM, SHELL, WET. The designated beneficial uses for reaches identified as impaired due to elevated levels of metals and selenium in the CCW are listed in Table 4 and briefly described below.

Table 4. Beneficial Uses Associated With Impaired Reaches in the Calleguas Creek Watershed.

Waterbody	MUN	IND	PROC	AGR	GWR	FRSH	NAV	REC1	REC2	COMM	WARM	COLD	EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	SHELL	WET
Mugu Lagoon							E	P	E	E			E	E	E	E	E	E	E	E	E
Lower Calleguas Creek	P*			E	E	E		E	E		E	E			E		E				E
Revolon Slough	P*	P		E	E			E	E		E				E						E

P = potential beneficial use
E = existing beneficial use
* = MUN designations are designated under State Board Regulation No. 88-63 and Regional Board Regulation No. 89-03. Some designations may be considered for exemptions at a later date.

Water Supply (MUN, GWR)

Municipal and domestic supply (MUN) includes use of water for community, military, or individual water supply systems including, drinking water supply. Groundwater recharge (GWR) includes use of water to recharge groundwater for future extraction, maintenance of water quality, or halting saltwater intrusion into freshwater aquifers.

Habitat-Related Uses (WARM, COLD, EST, WET, MAR, WILD, BIOL, RARE, MIGR, SPWN)

Several habitat-related beneficial uses are designated for the CCW. These uses include warm and cold freshwater habitats; estuarine, wetland and marine habitats; wildlife habitat; biological habitats (including Areas of Special Biological Significance); habitats that support rare, threatened, or endangered species; habitats that support migration of aquatic organisms; and habitats that support spawning, reproduction, and/or early development of fish.

Human Consumption of Aquatic Organisms (COMM, SHELL)

Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Recreational Uses (REC-1, REC-2)

Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2) are defined as uses of water for recreational activities involving body contact and proximity to water. Some of these activities include swimming and fishing, and where the ingestion of water is reasonably possible.

2.4 Water Quality Objectives

Basin Plan Objectives

The Basin Plan contains the following narrative and numeric water quality objectives (WQOs) applicable to the listed metals and selenium and their related effects:

Regional Narrative Objectives for Inland Surface Waters

- Bioaccumulation – Toxic pollutants shall not be present at levels that will bioaccumulate in aquatic life to levels which are harmful to aquatic life or human health.
- Chemical Constituents – Surface waters shall not contain concentrations of chemical constituents in amounts that adversely affect any designated beneficial use. Water designated for use as MUN shall not contain concentrations of chemical constituents in excess of the limits specified in Title 22 of the California Code of Regulations.
- Toxicity - All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal or aquatic life. Effluent limits for specific toxicants can be established by the Regional Board to control toxicity identified under Toxicity Identification Evaluations (TIEs).

Regional Narrative Objective for Wetlands

- Habitat - Existing habitats and associated populations of wetlands fauna and flora shall be maintained by: protecting food supplies for fish and wildlife.

Regional Narrative Objective for Groundwater

- Chemical Constituents - Groundwaters shall not contain concentrations of chemical constituents in amounts that adversely affect any designated beneficial use. Groundwater designated for use as MUN shall not contain concentrations of chemical constituents in excess of the limits specified in Title 22 of the California Code of Regulations.

Regional Numeric Objectives

The Basin Plan maximum contaminant levels (MCL) for inorganic chemicals, where the MUN beneficial use is applied, include the following Title 22 drinking water standards Table 5.

Table 5. Basin Plan Maximum Contaminant Levels for Metals and Selenium, Title 22 Drinking Water Standards.

Metal	MCL (ug/L)
Copper	1,000[1]
Mercury	2
Nickel	100
Selenium	50
Zinc	5,000[1]

[1] Copper and zinc have secondary MCLs only, because these constituents are not public health concerns, rather they may adversely affect the taste, odor or appearance of drinking water.

California Toxics Rule (CTR) Water Quality Criteria

CTR numeric criteria for priority toxic pollutants are promulgated for the protection of aquatic life and human health. The aquatic life criteria include one-hour average (acute) and four-day average (chronic) concentrations of these chemicals to which aquatic life can be exposed without harmful effect. The human health criteria are typically applied as 30-day average concentrations for consumption of organisms and water or consumption of organisms only. The CTR criteria for the listed metals and selenium are shown in Table 6.

Table 6. California Toxics Rule Water Quality Criteria for Listed Metals and Selenium

		Freshwater (ug/L)		Saltwater (ug/L)		Human Health for consumption of:	
Compound	CAS #	Criterion Maximum Conc	Criterion Continuous Conc.	Criterion Maximum Conc	Criterion Continuous Conc.	Water & Organisms (ug/L)	Organisms Only (ug/L)
Copper	7440508	13 b,c,d,f	9.0 b,c,d,f	4.8 c,d	3.1 c,d	1,300	---
Mercury	7439976	---	---	---	---	0.050 a	0.051 a
Nickel	7440020	470 b,c,d,f	52 b,c,d,f	74 c,d	8.2 c,d	610 a	4600 a
Selenium	7782492	---	5.0 e	290 c,d	71 c,d	---	---
Zinc	7440666	120 b,c,d,f	120 b,c,d,f	90 c,d	81 c,d	---	---

a. Criteria revised to reflect the Agency q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of October 1, 1996. The fish tissue bioconcentration factor (BCF) from the 1980 documents was retained in each case.
b. Freshwater aquatic life criteria for metals are expressed as a function of total hardness (mg/L) in the water body. Values displayed above in the matrix correspond to a total hardness of 100 mg/L. Criteria will increase or decrease as site-specific hardness increases or decreases.
c. Criteria for these metals are expressed as a function of the water-effect ratio, WER.
d. These freshwater and saltwater criteria for metals are expressed in terms of the dissolved fraction of the metal in the water column.
e. This criterion is expressed in the total recoverable form.
f. This criterion has been recalculated pursuant to the 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA–820-B–96–001, September 1996. See also Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA–80–B–95–004, March 1995.

2.5 Antidegradation

The state's Antidegradation Policy is contained in State Board Resolution 68-16, Statement of Policy with Respect to Maintaining High Quality Water in California. The Antidegradation Policy states that water quality in surface and ground waters of California must be maintained unless it is demonstrated that a change will be consistent with the maximum benefit of the people of the state, not unreasonably affect present and anticipated beneficial use of such water, and not result in water quality less than that prescribed in water quality plans and policies. In addition to meeting state Antidegradation Policy, any actions that may result in a reduction of water quality of a water of the United States are subject to the federal Antidegradation Policy provisions contained in 40 CFR 131.12, which allows for the reduction in water quality as long as existing beneficial uses are maintained and that the lowering of water quality is necessary to accommodate economic and social development in the area.

2.6 Basis For Listings

The basis for development of the 303(d) listings for metals and selenium in the CCW stems from Water Quality Assessments (WQAs) in 1996, 1998 and 2002 conducted by Regional Board staff with the majority of metals and selenium listings first appearing on the 1996 303(d) list. The listings for total copper, mercury, nickel and zinc in Reach 1 were based on studies conducted by the United States Navy, Point Mugu. The dissolved copper listing in Reach 2 was based on data from the Calleguas Creek Characterization Study (LWA, 1999). The total selenium listing in Reach 4 was based on data collected by the Los Angeles Regional Water Quality Control Board (RWQCB) and the Ventura County Flood Control District (VCFCD) in 1990 – 1993.

2.7 303(d) Listing Data

The original recommendations for listing total copper, mercury, nickel, zinc, and selenium in Mugu Lagoon were presented in the 1996 WQA and were based on data collected by the US Navy. However, no information is available on when or where the Navy data were collected. As the original listing was made in 1996 the only Navy data that would have been available to review for the listing cycle were data collected during a 1994 study. The 1994 study collected samples in and around the lagoon. Table 7 presents a summary of data collected by sample source. The sample source indicates the type of waterbody from which samples were collected. Drainage ditch and tidal creek sample sources represent ditches and creeks that discharge to the lagoon. Additionally, the Navy collected samples upstream of the lagoon in Lower Calleguas Creek (Reach 2) and Revolon Slough (Reach 4).

Table 7. Sample Sources for 1996 Mugu Lagoon Metals Listings.

Sample Source	Number of Samples Collected
Reach 2	2
Reach 4	2
Drainage Ditches discharging to Reach 1	27
Tidal Creeks discharging to Reach 1	13
Reach 1 proper (Receiving Water)	5
Ditches, tidal creeks, and Reach 1 proper	45
All Data	49

Summaries of the water column data used to develop 303(d) listings in the CCW are shown in Table 8. All 49 data records are presented in Table 8 as it is unclear which data formed the basis of the 1996 listings.

Table 8. Calleguas Creek Watershed, Data Summary for 303(d) Water Column Listings[1]

Reach	Constituent	Year Listed	Impaired Use Listed	n	Range (ug/L)	Median [2] (ug/L)	Criterion[3] (ug/L)	% Exceedances
1	Total Copper	1996	Aquatic Life	49	<0.5 – 0.5	0.5	2.9	0%
1	Total Mercury	1996	Aquatic Life	49	<0.1 – 0.1	0.1	0.025	6%
1	Total Nickel	1996	Aquatic Life	49	<5 – 10.9	5	8.3	16%
1	Total Zinc	1996	Aquatic Life	49	<5 – 65.6	5	58	2%
4	Total Selenium	1998	Aquatic Life	7	<1 – 11	1	5	29%
2	Dissolved Copper	2002	Aquatic Life	4	2.3 – 5.3	3.75	3.1	75%

1. All results are listed in units of μg/L.

2 For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

3 Criteria listed are those that were in effect when the original listing were made in 1996. Total Copper, Mercury, Nickel, Selenium Criteria taken from the National Toxics Rule (NTR). Total Zinc is from the “EPA Water Quality Criteria for Zinc, 1986.”

3 CURRENT CONDITIONS

Since the mid-1990's various studies have been conducted to assess water and fish tissue quality in the CCW. Portions of the data collected through these studies were incorporated into the 1996, 1998, and 2002 Water Quality Assessments (WQAs) to identify exceedances of water quality objectives. The portion of the available data that formed the basis of the listings was presented in the Problem Statement section. The purpose of the Current Conditions section is to present the most temporally relevant monitoring data, some of which may not have been included in any WQAs completed thus far. Available water quality data are presented below for each reach of the CCW.

3.1 Data Used in Current Conditions Section – Water and Tissue

Receiving water quality data have been gathered through a variety of monitoring programs and incorporated in the CCW Database (LWA, 2005). Table 9 presents the studies and associated data type available for development of the Current Conditions section.

Table 9. Summary Table of Data Sources Used to Develop Metals and Selenium TMDL Current Conditions Section .

Data Source[1]	Begin Date	End Date	Water Data
Camarillo Wastewater Treatment Plant NPDES Monitoring (City of Camarillo, 1997-2004)	7/01	8/04	X
Camrosa WWRF NPDES Monitoring (Camrosa Municipal Water District, 1996-2005)	7/01	9/02	X
Calleguas Creek Characterization Study – CCCS (LWA, 2000)	8/98	5/99	X
Calleguas Creek Watershed TMDL Work Plan Monitoring Plans (LWA, 2004)	8/03	10/04	X
Hill Canyon Wastewater Treatment Plant NPDES Monitoring (City of Thousand Oaks, 1997-2004)	1/02	12/04	X
Moorpark Wastewater Treatment Plant NPDES Monitoring (City of Moorpark, 2001-2002)	7/01	12/02	X
United States Navy (personal communication, Granade)	6/98	1/05	X
Los Angeles Regional Water Quality Control Board Database	6/96	6/97	X
Simi Valley Wastewater Treatment Plant NPDES Monitoring (City of Simi Valley, 1997-2004)	7/01	4/05	X
Ventura County Watershed Protection District (VCWPD, 1996-2004)	1/98	1/05	X

1 Complete references for these studies are provided in the References section of this report when available.

Monitoring of water quality during 2003-2004 (referred to as TMDL Work Plan monitoring) was a preliminary stage in the development of the CCW Metals and Selenium TMDL. The purpose of TMDL Work Plan monitoring was to augment previously collected data for the CCW, which contained a high proportion of non-detected values due to use of methods with high detection limits. Analysis of TMDL Work Plan samples used methods with lower detection limits than previously existing data. These data significantly improve understanding of current conditions in the CCW and also improve the capability for data analysis and modeling.

Development of Summary Statistics

The data set used to develop summary statistics for the Metals and Selenium TMDL contains many non-detect values. There are three procedures to handle non-detect values: 1) simple substitution, 2) distributional, and 3) robust methods. A full discussion of these procedures can be found in *Statistical Methods in Water Resources* (Helsel and Hirsch, 1992).

While the simple substitution method is widely used, there is no theoretical basis for its use. Data used in the Metals and Selenium TMDL development were collected over time and by different programs, so there are a variety of non-detected levels. Many of the non-detect levels are comparable to the maximum measured values. Additionally, one-half of the higher non-detect levels is often greater than the median of the data sets. Thus, simple substitution is not used in the data analysis for this TMDL.

Distributional methods force both measured data and non-detects to follow an assumed distribution type. So long as the data follow the assumed distribution, unbiased estimates of summary statistics can be calculated, however, if the data do not exactly follow the assumed distribution, there will be a bias to summary statistics.

Robust methods use the measured data to estimate an assumed distribution that is then used to fill-in the non-detect values. The filled-in non-detect values are only used to estimate summary statistics and are not considered estimates of specific samples. Robust methods use measured values and filled-in non-detect values to calculate summary statistics. Robust methods are not as sensitive to the choice of assumed distribution as the distributional method, and summary statistics can be directly calculated using filled-in values. Because the non-detect data are filled-in after the distribution is calculated, multiple non-detect levels are easily handled by the method. The robust method of regression-on-order statistics (ROS) is used in the data analysis for the Metals and Selenium TMDL to provide a statistically defensible analytical procedure and to protect against potential errors of a distributional method. A complete discussion of the ROS method is included in Helsel and Hirsch (1992).

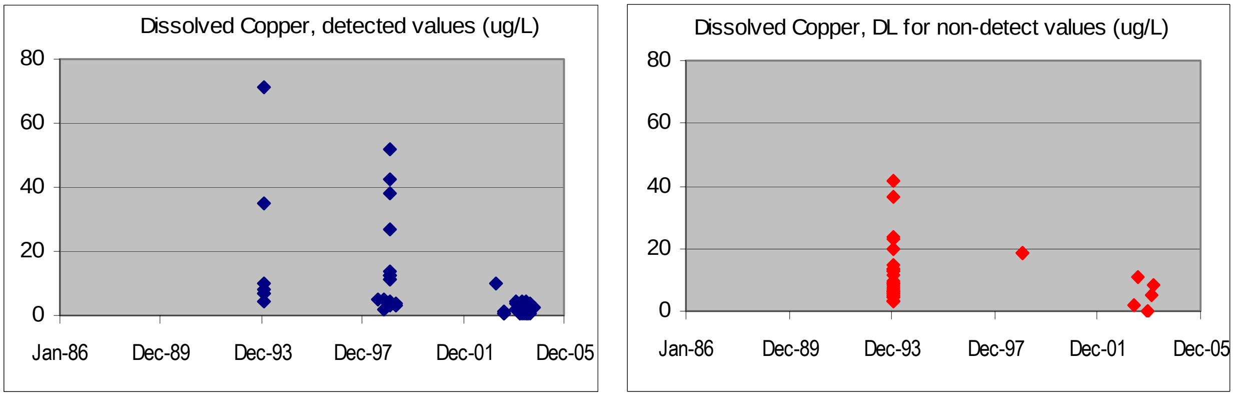
ROS is used to incorporate non-detect information in the analyses performed for the Metals and Selenium TMDL. A log-normal distribution is flexible in shape, providing reasonable approximations to data which are nearly symmetric (normally distributed) as well as positively-skewed distributions (Helsel and Hirch, 1992). The log-normal distribution is widely used in practice to represent environmental data [California State Implementation Plan (SWRCB, 2000) and USEPA's Technical Support Document (1991)]. ROS utilizes the measured data (uncensored) in an analysis to estimate the log-normal distribution of the concentrations (Helsel, 1988, 1990). The initial step of the ROS method is to calculate probability-plotting positions (i.e. z-scores or standard deviates) for each data point (censored and uncensored) based on the ordering of all data. A least-squares regression is performed to fit a regression of the log-transformed measured values to their probability plotting positions, thereby defining the best fit log-normal distribution to the data. The censored data (non-detects) are assigned values based on their probability plotting positions and the calculated distribution (Helsel, 1990; Shumway, 2002). Summary statistics are then calculated based on the uncensored data points and the filled-in censored values. Criteria for sufficient data to use the ROS method are: 1) at least 20% and preferably 50% detected data and 2) at least three unique detected values. Instances of insufficient detected data are marked in the summary statistics tables.

The ROS method was used to generate summary statistics for the current conditions analysis. For comparison of the data to water quality objectives, each individual data point was compared to the objective to obtain the percent exceedance.

Because of limited available data, grab and composite samples are treated in the analysis as equivalent and equally representative of the sampled water. Additionally, estimated and qualified data are used as normal detected values. Both uses of the data may introduce uncertainty into the analysis, as grab samples may not be equivalent to composite samples and may not be representative of the targeted source type, and estimated values, while being a better estimate of the true value than the reporting limit, may not accurately reflect the true value in the water.

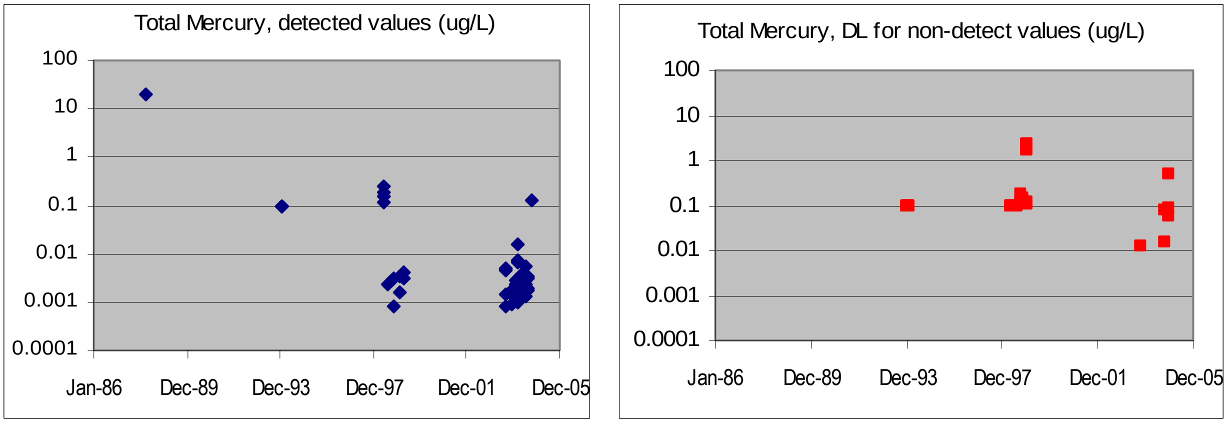
Concentration of Metals and Selenium Verses Time in Mugu Lagoon

Concentrations of metals and selenium in water over time are presented below in Figure 2 - Figure 6 for Reach 1, Mugu Lagoon. Although concentrations in other reaches over time are not shown, they are implicitly considered because Mugu Lagoon is the ultimate terminus for all reaches in the watershed. In each figure, detected values are plotted on the left and the detection limit or qualified value for non-detect results is plotted on the right. Although a general trend of decreasing concentration over time seems present for all constituents other than selenium, the certainty of this apparent trend is somewhat reduced by the large number of non-detect results (shown on the right, in each figure below).


Dissolved Copper, detected values (ug/L)

Dissolved Copper, DL for non-detect values (ug/L)

Figure 2. Concentration of Dissolved Copper in Water in Mugu Lagoon Over Time.


Total Mercury, detected values (ug/L)

Total Mercury, DL for non-detect values (ug/L)

Figure 3. Concentration of Total Mercury in Water in Mugu Lagoon Over Time.

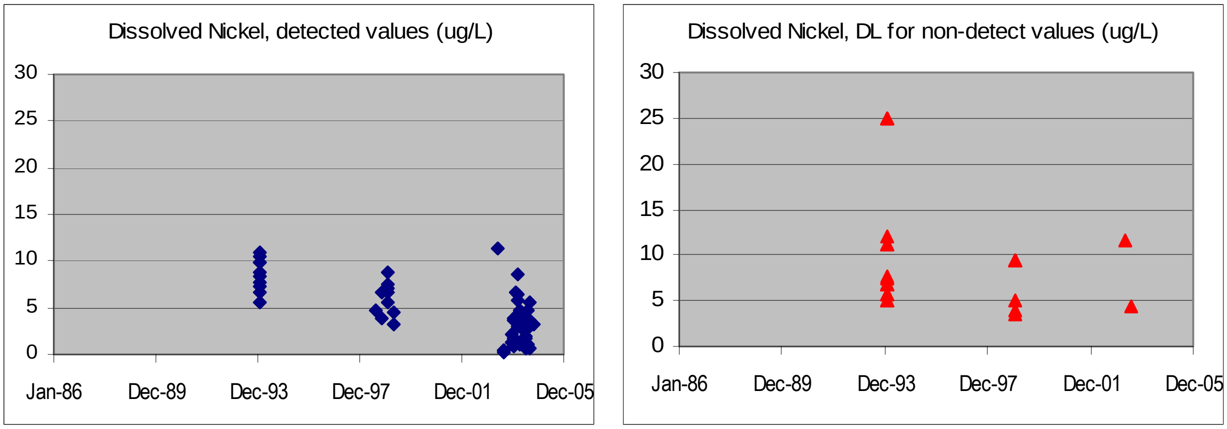


Figure 4. Concentration of Dissolved Nickel in Water in Mugu Lagoon Over Time.

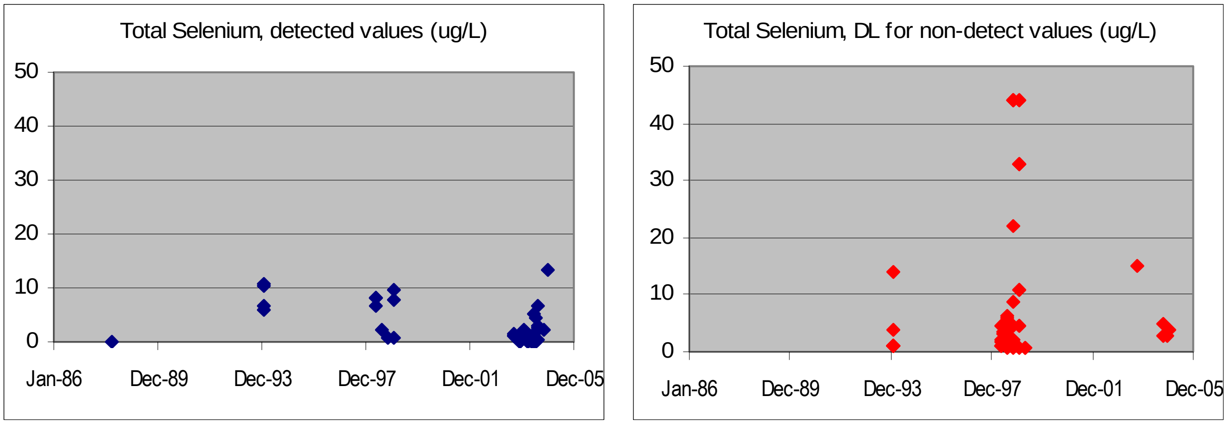


Figure 5. Concentration of Total Selenium in Water in Mugu Lagoon Over Time.

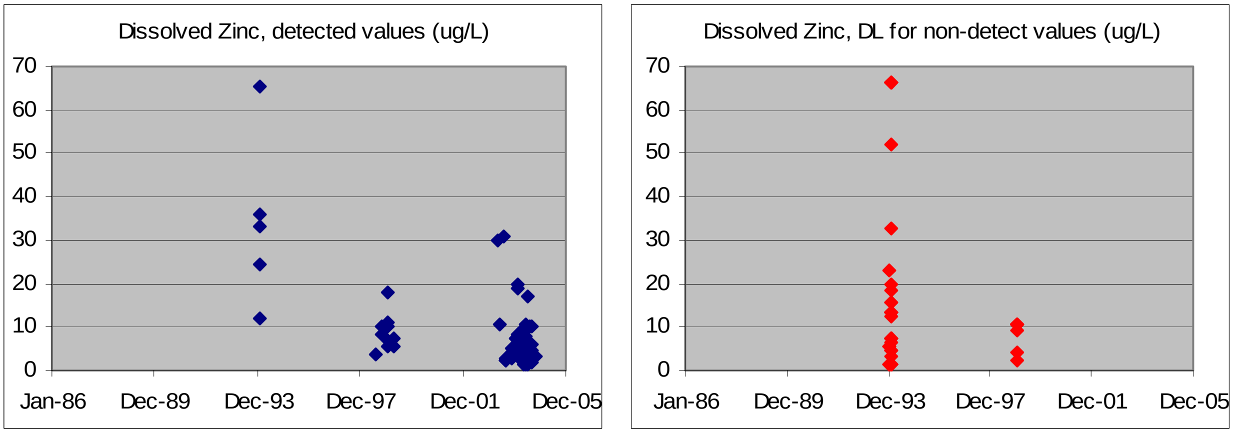


Figure 6. Concentration of Dissolved Zinc in Water in Mugu Lagoon Over Time.

3.2 Current Conditions Data by Reach - Water Column Concentrations

The current condition summary statistics tables presented for each reach consider only more recent data collected between 1996 and 2005. This time frame is selected for analysis to represent conditions after the initial 303(d) listings for metals and selenium in the CCW which occurred in 1996. Water chemistry data collected from receiving waters in the CCW and compiled in the CCW Database (LWA, 2005) were used to develop the current conditions summary statistics. Receiving water samples are selected as most appropriate for inclusion in the tables presented below because 303(d) listings, which drive the TMDL process, consider only receiving water samples. To determine if current data suggest a continuing impairment, data were compared to numeric targets presented in the Numeric Targets section. In order to provide a conservative evaluation of current conditions, all current conditions data were compared to the lower of the acute or chronic criteria for each constituent; and only the non-WER numeric target for copper was used (since adoption of the WER has not yet occurred).

Calleguas Creek Reach 1 (Mugu Lagoon)

Mugu Lagoon is on the 2002 303(d) list for total copper, total mercury, total nickel, and total zinc. In addition, water quality data have indicated the presence of selenium. Table 10 presents relevant summary statistics for water quality data collected in Reach 1.

Table 10. Summary Statistics for Relevant Water Quality Data in Reach 1 (ug/L)

Constituent	n	% Detected	Criteria Used	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [1]
Dissolved Copper	47	85%	3.1	2.1	1.8	1.5	10.3	28%
Total Mercury	46	87%	0.051	0.01	0.02	0.002	0.13	2%
Dissolved Nickel	47	96%	8.2	3.0	2.3	2.2	11.4	4%
Total Selenium	48	85%	71	1.4	2.2	0.55	13.4	0%
Dissolved Zinc	47	100%	81	7.5	6.7	5.5	31	0%

1 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

Spatial Distribution of Monitoring Data for Mugu Lagoon

Because a majority of the 303(d) listings for metals and selenium in the Calleguas Creek Watershed are for Mugu Lagoon, and because samples have been collected from many locations throughout the lagoon, the available water quality data were plotted spatially to examine how concentrations vary throughout the lagoon (Figure 7 - Figure 11). When multiple samples have been collected at a given site and when a sufficient number of detected values are included in the results to allow for valid statistical analysis, a mean concentration is shown. When only a single sample has been collected which contained a detected concentration of the analyte, the single detected value is shown. Sample sites where multiple samples were collected but very few detected values resulted are not shown in these maps. Data included in these maps are from both receiving water samples and non-receiving water samples (e.g. tributaries, drains, tidal creeks).

In general, concentrations of metals and selenium in Calleguas Creek tend to decrease as water flows toward the mouth of the lagoon. Slightly elevated concentrations often occur in samples collected from the mouth of the lagoon (01_MOUTH), for reasons which are not understood at this time. Samples from sites located more inland on the Navy Base generally have the highest concentrations of copper and nickel (see section 6.3 Sources General, Soils subsection).

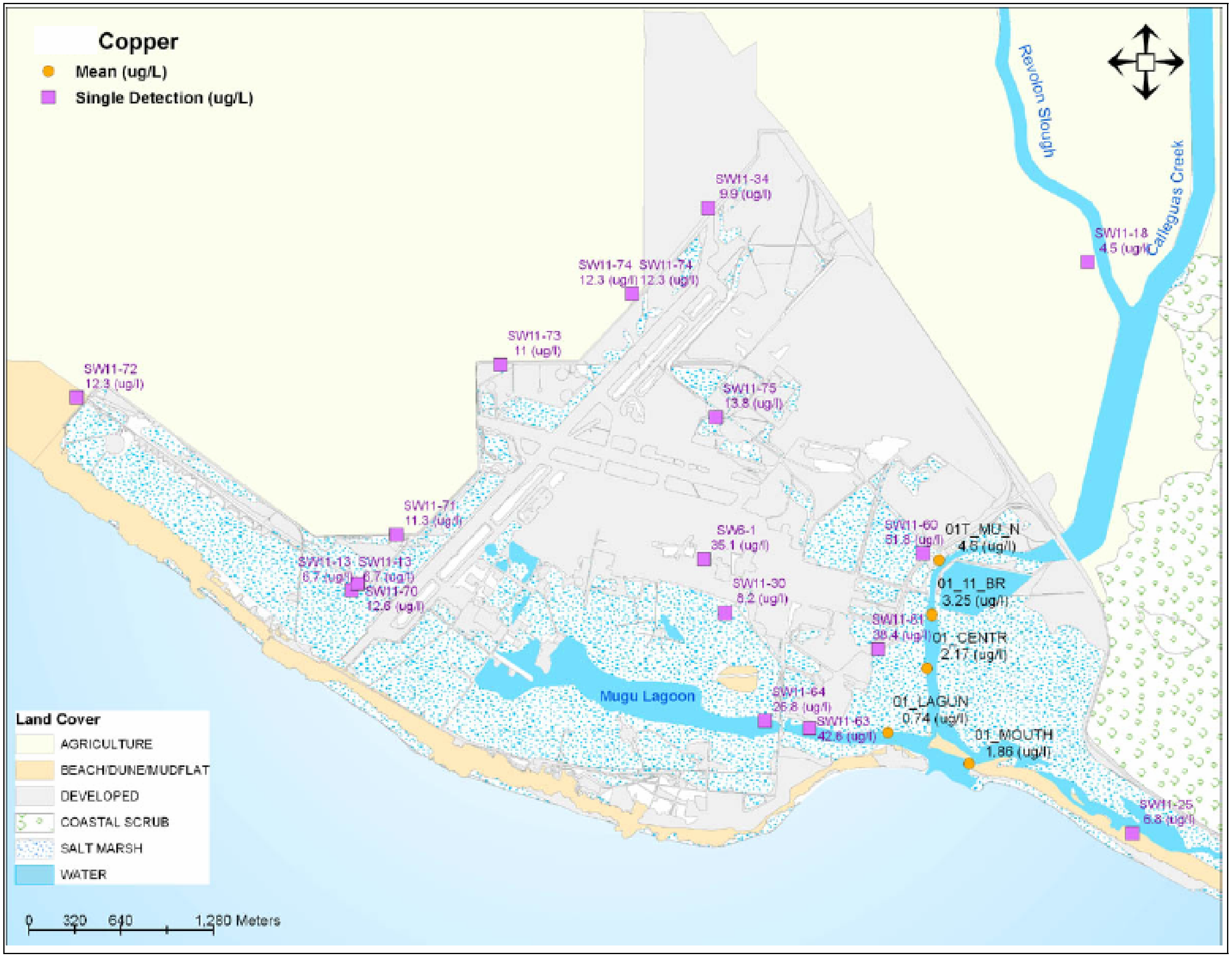


Figure 7. Map Showing Monitoring Results for Dissolved Copper in Water collected from Mugu Lagoon and Surrounding Area.

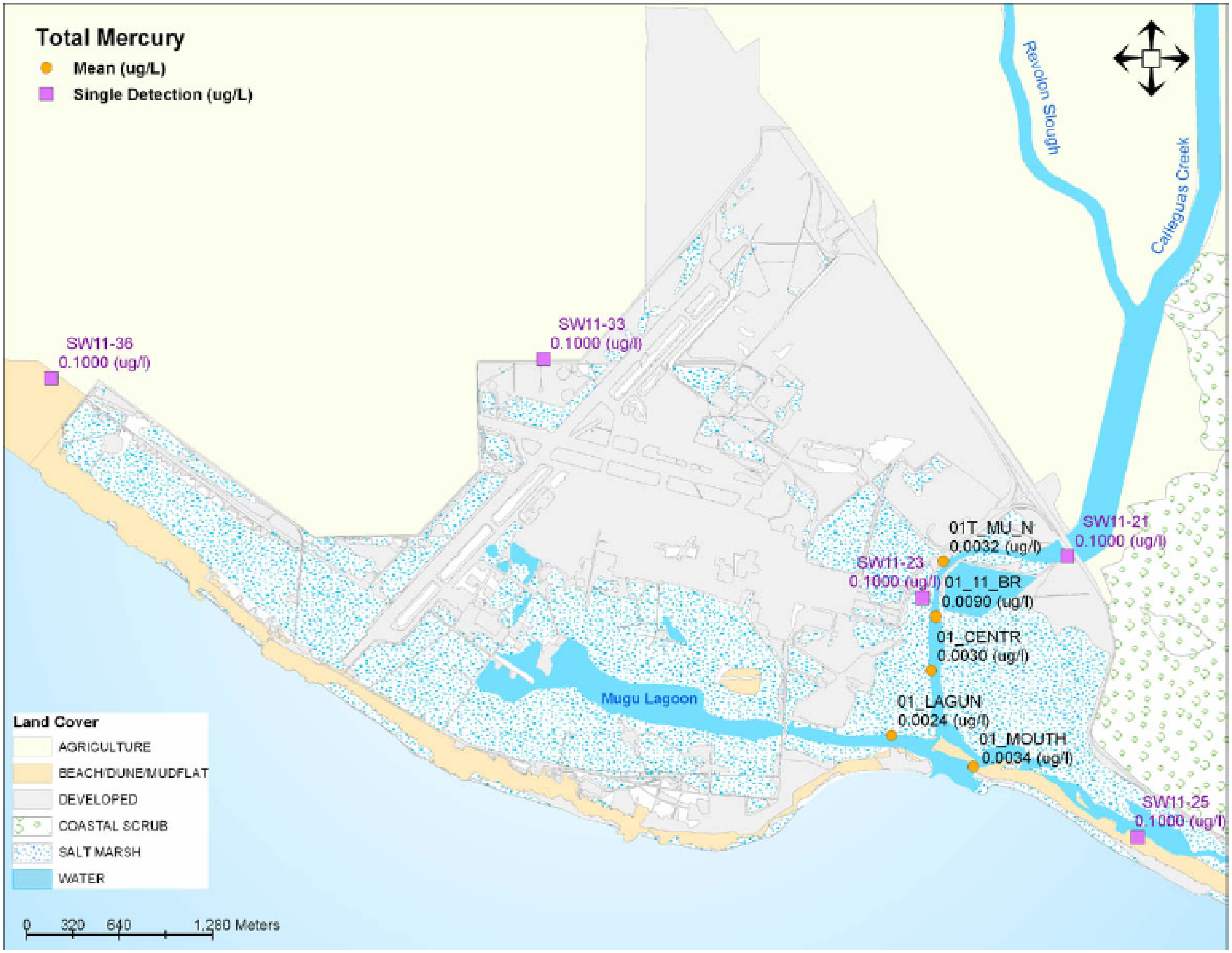


Figure 8. Map Showing Monitoring Results for Total Mercury in Water collected from Mugu Lagoon and Surrounding Area.

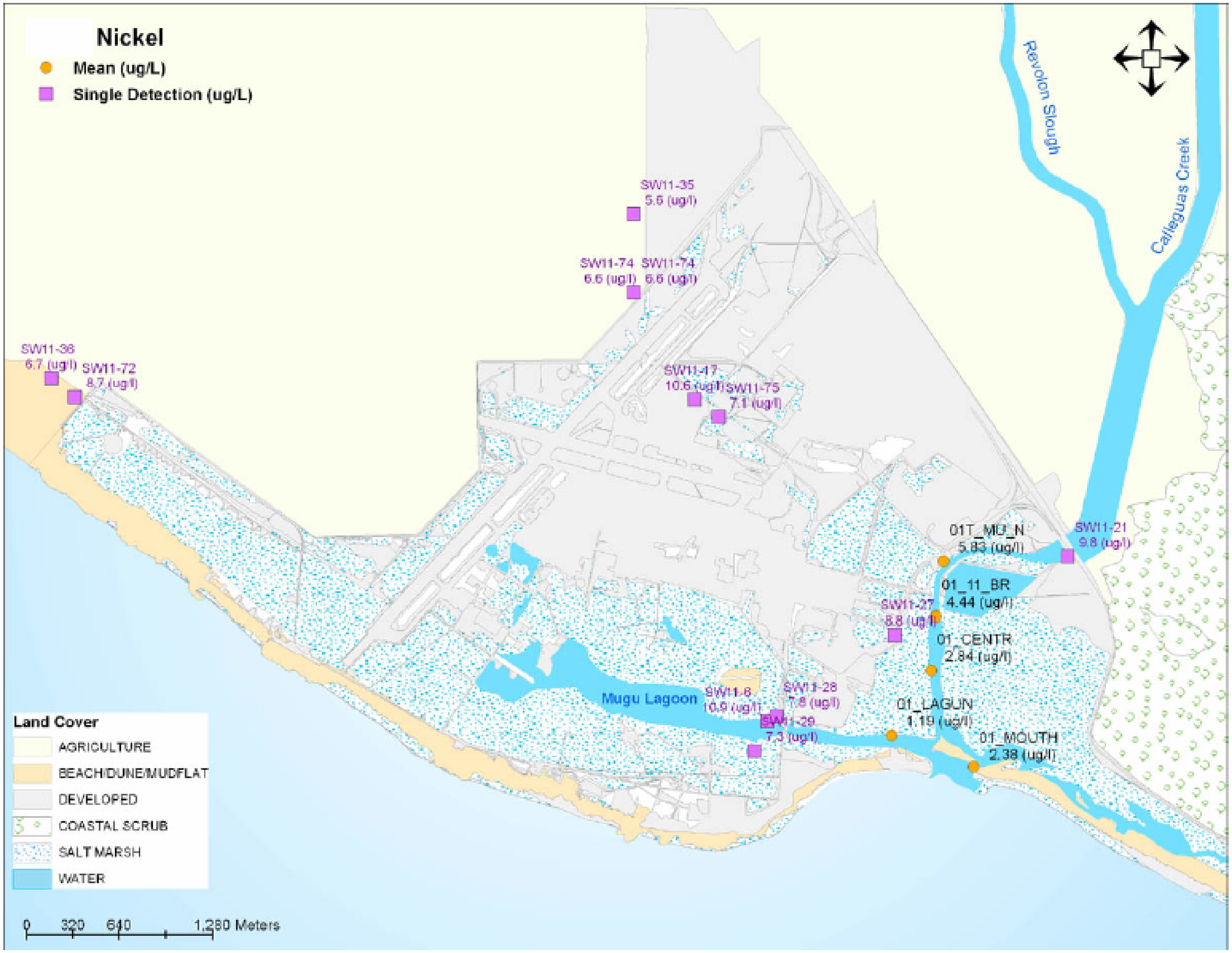


Figure 9. Map Showing Monitoring Results for Dissolved Nickel in Water collected from Mugu Lagoon and Surrounding Area.

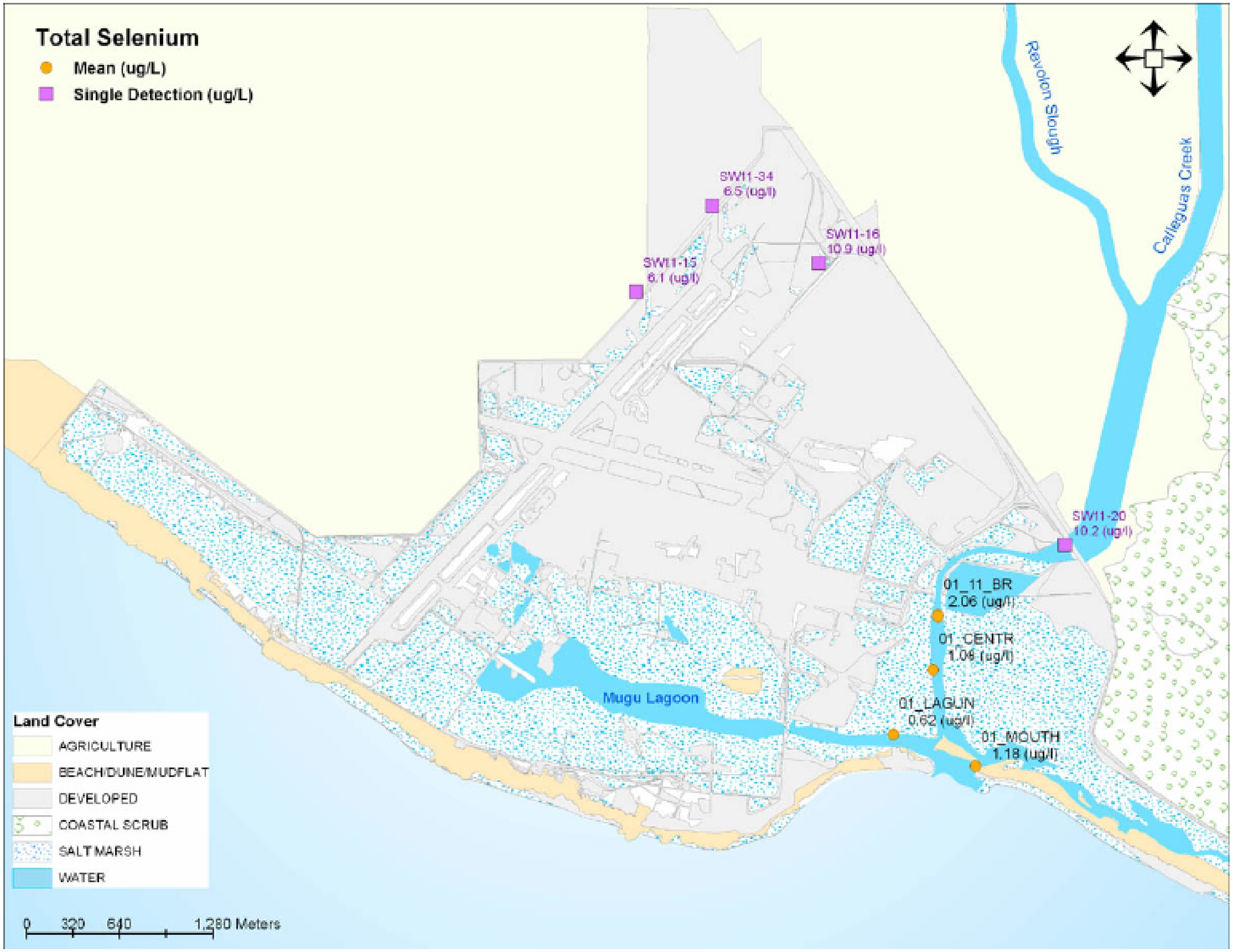


Figure 10. Map Showing Monitoring Results for Total Selenium in Water collected from Mugu Lagoon and Surrounding Area.

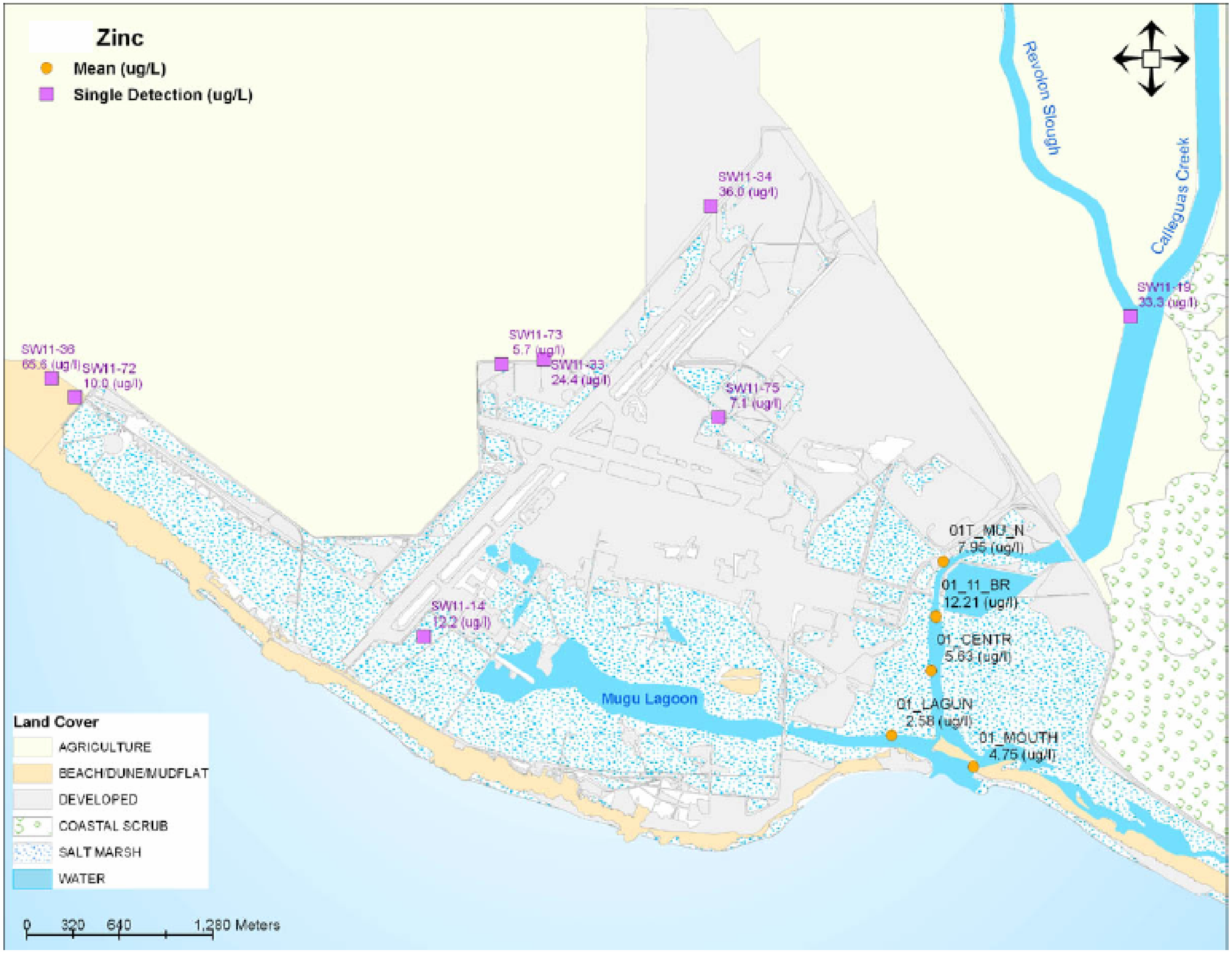


Figure 11. Map Showing Monitoring Results for Dissolved Zinc in Water collected from Mugu Lagoon and Surrounding Area.

Calleguas Creek Reach 2 (Calleguas Creek South)

Calleguas Creek South is listed on the 2002 303(d) list for dissolved copper. In addition, water quality data have indicated the presence of mercury, nickel, selenium, and zinc; as shown below in Table 11.

Table 11. Summary Statistics for Relevant Water Quality Data in Reach 2 (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper	19	79%	3.1	3.8	1.4	3.6	8.67	47%
Total Mercury	23	74%	0.051	0.05	0.158	0.005	0.700	13%
Dissolved Nickel	19	100%	8.2	8.3	4.1	7.6	22.2	47%
Total Selenium	24	58%	5	3.3	3.5	2.1	13.6	25%
Dissolved Zinc	19	100%	81	14.8	6.8	13.2	30.1	0%

1 The lower of freshwater and saltwater criteria were used per the CTR requirement that the lower of the two criteria apply in waterbodies with salinities between 1 and 10 ppt.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

Calleguas Creek Reach 3 (Calleguas Creek)

Calleguas Creek is not listed on the 2002 303(d) list for metals and selenium. Table 12 presents relevant summary statistics for water quality data for metals and selenium collected in Reach 3.

Table 12. Summary Statistics for Relevant Water Quality Data in Reach 3 (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	38	100%	25.9	5.9	6.2	4.6	35	3%
Total Mercury	55	82%	0.051	0.042	0.08	0.008	0.435	22%
Dissolved Nickel [3]	38	100%	149	6.7	2.3	6.4	17.9	0%
Total Selenium	58	72%	5	2.8	3.3	1.98	22	3%
Dissolved Zinc [4]	38	95%	214	18.2	10.2	15.8	60	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (346 mg/L).

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (204 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

Of the 12 exceedances of the total mercury water quality criteria, 11 occurred during wet weather events.

Calleguas Creek Reach 4 (Revolon Slough)

Revolon Slough is on the 2002 303(d) list for total selenium. In addition, water quality data have indicated the presence of mercury, nickel, selenium, and zinc. Table 13 presents relevant summary statistics for water quality data. The 6% exceedance shown for zinc would not qualify for a 303(d) listing according to SWRCB guidance on the number of allowable exceedances per number of samples analyzed (SWRCB, Sept 2004); and thus is not considered indicative of an impairment.

Table 13. Summary Statistics for Relevant Water Quality Data in Reach 4 (ug/L)

Constituent	n	% Detected	Criteria Used[1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[2]
Dissolved Copper	33	94%	3.1	8.41	8.98	5.72	44	76%
Total Mercury	34	74%	0.051	0.043	0.070	0.008	0.282	29%
Dissolved Nickel	33	100%	8.2	7.52	3.97	6.42	17	42%
Total Selenium	50	80%	5	10.50	12.2	4.79	44.3	50%
Dissolved Zinc	33	100%	81	28.57	74.8	10.80	429	6%

1 The lower of freshwater and saltwater criteria were used per the CTR requirement that the lower of the two criteria apply in waterbodies with salinities between 1 and 10 ppt.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

Calleguas Creek Reach 5 (Beardsley Channel)

Beardsley Channel is not on the 2002 303(d) list for metals or selenium. Only total selenium data are available for considering impairments in water in Reach 5. Table 14 presents relevant summary statistics for water quality data for selenium in Reach 5.

Table 14. Summary Statistics for Relevant Water Quality Data in Reach 5 (ug/L)

Constituent	n	% Detected	Criteria Used	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria
Total Selenium	8	100%	5	29.1	19.5	19.1	64.6	88%

Calleguas Creek Reach 6 (Arroyo Las Posas)

Arroyo Las Posas is not on the 2002 303(d) list for metals and selenium. Only total selenium data are available for considering impairments in water in Reach 6 (Table 15).

Table 15. Summary Statistics for Relevant Water Quality Data in Reach 6 (ug/L)

Constituent	n	% Detected	Criteria Used	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1]
Total Selenium	4	50%	5	NA	NA	NA	6.9	25%

1 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

NA Insufficient detected data to develop summary statistics

Calleguas Creek Reach 7 (Arroyo Simi)

The Arroyo Simi is not on the 2002 303(d) list for metals and selenium. Table 16 presents relevant summary statistics for water quality data collected in Reach 7 for metals and selenium.

Table 16. Summary Statistics for Relevant Water Quality Data in Reach 7 (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	12	100%	29.3	2.2	0.76	2.1	3.7	0%
Total Mercury	61	34%	0.051	0.016	0.030	0.005	0.200	7%
Dissolved Nickel [3]	12	100%	168	3.7	1.6	3.1	6.4	0%
Total Selenium	105	85%	5	8.5	6.98	5.8	25	61%
Dissolved Zinc [4]	12	100%	240	7.6	5.7	5.5	19	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets were calculated using a hardness value of 400 mg/L because the median hardness for Reach 7 is over 400 mg/L. Per the CTR, the maximum hardness that can be used to calculate criteria is 400 mg/L.

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (233 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

Calleguas Creek Reach 8 (Tapo Canyon)

Tapo Canyon is not listed on the 2002 303(d) list for metals and selenium. No metals and selenium data are available for this reach.

Calleguas Creek Reach 9A (Conejo Creek)

Conejo Creek is not on the 2002 303(d) list for metals and selenium. Table 17 presents relevant summary statistics for water quality data for metals and selenium collected in Reach 9A.

Table 17. Summary Statistics for Relevant Water Quality Data in Reach 9A (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	4	100%	27.9	2.5	0.72	2.4	2.9	0%
Total Mercury	10	40%	0.051	0.004	0.0004	0.004	0.005	0%
Dissolved Nickel [3]	4	100%	160	3.8	0.69	3.8	4.6	0%
Total Selenium	10	20%	5	NA	NA	NA	2.4	0%
Dissolved Zinc [4]	4	100%	324	20.3	10.2	18.5	34	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (378 mg/L).

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (332 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

NA Insufficient detected data to develop summary statistics

Calleguas Creek Reach 9B (Conejo Creek Main Stem)

The Conejo Creek Main Stem is not on the 2002 303(d) list for metals and selenium. Table 18 presents relevant summary statistics for water quality data collected in Reach 9B for metals and selenium.

Table 18. Summary Statistics for Relevant Water Quality Data in Reach 9B (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	4	100%	27.9	1.8	0.25	1.8	2.1	0%
Total Mercury	23	87%	0.051	0.005	0.013	0.003	0.063	4%
Dissolved Nickel [3]	4	100%	160	3.9	0.66	3.8	4.8	0%
Total Selenium	23	83%	5	1.9	0.56	1.9	3.0	0%
Dissolved Zinc [4]	4	100%	324	18.3	7.80	17	28	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (378 mg/L).

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (332 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

Calleguas Creek Reach 10 (Hill Canyon Reach of Conejo Creek)

Hill Canyon is not listed on the 2002 303(d) list for metals and selenium. Table 19 presents summary statistics for relevant water quality data.

Table 19. Summary Statistics for Relevant Water Quality Data in Reach 10 (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	4	100%	27.9	2.5	1.2	2.2	4.1	0%
Total Mercury	21	57%	0.051	0.011	0.014	0.006	0.060	5%
Dissolved Nickel [3]	4	100%	160	4.7	4.2	3.7	11	0%
Total Selenium	10	10%	5	NA	NA	NA	2.0	0%
Dissolved Zinc [4]	4	100%	324	16	3.2	16	21	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (378 mg/L).

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (332 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

NA Insufficient detected data to develop summary statistics

Calleguas Creek Reach 11 (Arroyo Santa Rosa)

The Arroyo Santa Rosa is not on the 2002 303(d) list for metals and selenium. However, since the closure of the Olsen Road Water Reclamation Plant in 2002 there is no flow in this reach except during wet weather conditions that cause sufficient runoff to generate flow. No wet weather metals and selenium data are available for this reach; as such no data analysis was conducted for this reach.

Calleguas Creek Reach 12 (North Fork Conejo Creek)

The North Fork of the Conejo Creek is not on the 2002 303(d) list for metals and selenium. Table 20 presents relevant summary statistics for water quality data for metals and selenium collected in Reach 12.

Table 20. Summary Statistics for Relevant Water Quality Data in Reach 12 (ug/L)

Constituent	n	% Detected	Criteria Used	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [1]
Total Mercury	38	45%	0.051	0.013	0.014	0.007	0.06	3%
Total Selenium	27	70%	5	4.7	7.5	2.4	27	11%

1 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

Calleguas Creek Reach 13 (South Fork Conejo Creek)

The South Fork of the Conejo Creek is not on the 2002 303(d) list for metals and selenium. Table 21 presents relevant summary statistics for water quality data for metals and selenium collected in Reach 13.

Table 21. Summary Statistics for Relevant Water Quality Data in Reach 13 (ug/L)

Constituent	n	% Detected	Criteria Used [1]	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria [2]
Dissolved Copper [3]	4	100%	27.9	NA	NA	NA	1.5	0%
Total Mercury	4	100%	0.051	0.003	0.002	0.003	0.006	0%
Dissolved Nickel [3]	4	100%	160	2.60	1.34	2.4	4.5	0%
Total Selenium	4	100%	5	NA	NA	NA	1.4	0%
Dissolved Zinc [4]	4	100%	324	6.2	3.8	5.3	11	0%

1 Targets for dissolved copper, nickel, and zinc were calculated based on hardness during dry and wet weather. Acute targets apply during wet weather and chronic targets apply during dry weather. The lower of dry and wet weather targets are used for comparison to all data.

2 Only detected values that exceed criteria are used in calculation of "% Above Criteria." The actual number of exceedances could be higher because not all samples were tested at detection limits below numeric targets.

3 Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (378 mg/L).

4 Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (332 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

NA Insufficient detected data to develop summary statistics

3.3 Assessment of Zinc Impairment

The SWRCB 2004 report titled: *Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List* provided guidance on using the collected data to determine if each of the listed metals and selenium continue to cause an impairment in a listed reach. Using the current data as a basis, the tables presented in this section indicate a percent above criteria. According to the 303(d) listing policy (SWRCB 2004) the allowable percent above criteria for delisting purposes varies between six and eight percent based on the sample size.

Based on the results presented in the Current Conditions section, impairments due to zinc in the watershed are not occurring. Consequently, additional analysis will not be presented for zinc in the TMDL. Targets will be assigned and monitoring for zinc will continue to ensure the targets are not exceeded, but load allocations and waste load allocations will not be developed at this time. The implementation section includes an action to pursue delisting for zinc based on the SWRCB 2004 policy.

3.4 Sediment Data

Although there are no sediment listings for metals or selenium in the CCW, a brief summary of current sediment data is presented to provide additional understanding of watershed conditions. Almost all sediment data collected in the CCW and analyzed for metals and selenium has been collected from locations in the lower part of the watershed. The greatest number of samples have been collected from reach 1 (Mugu Lagoon), with many also collected from reaches 2 and 4 (Revolon and Lower Calleguas), and a very few from Reach 7 (Arroyo Simi). These data are shown below in Table 22.

Table 22. Sediment Concentrations in the Lower CCW (mg/Kg) - 1996 to 2005.[1]

Constituent	Cu	Ni	Se	Hg
N	97	96	88	84
% Detected	100%	100%	72%	48%
Mean	12.51	15.10	0.75	0.03
Median	8.50	11.60	0.56	0.02
Standard Deviation	11.20	11.85	0.46	0.04
Minimum	0.02	0.06	0.20	0.01
Maximum	49.48	51.82	2.71	0.16

1 Data collected from receiving water and mudflats is shown here, since tidal influence usually inundates sampling sites in these two categories at least once per day.

4 NUMERIC TARGETS

Numeric targets identify specific goals for the Metals and Selenium TMDL which equate to attainment of water quality standards and provide the basis for data analysis and final TMDL allocations. Multiple numeric targets are often employed when there is uncertainty that a single numeric target is sufficient to ensure protection of designated beneficial uses. The 2002 303(d) list for the Calleguas Creek Watershed contains listings for metals and selenium in the water column. Dissolved CTR water criteria are selected as numeric targets for copper, nickel, and zinc; while total CTR water criteria are applied for mercury and selenium. Additionally, fish tissue targets are designated for mercury and bird egg targets are designated for mercury and selenium. Finally, alternative numeric targets for copper and nickel in sediment have been designated as triggers for sediment toxicity testing.

Achievement of the water, tissue, and bird egg targets named above will adequately protect benthic and aquatic organisms, wildlife, and human health from potentially harmful effects associated with metals and selenium. Numeric targets are presented in Table 23 and Table 24, and explained in detail further below.

Table 23. Water Quality Targets for Copper, Nickel, Zinc and Selenium.

	Dry Weather (Chronic) Water Quality Targets [1] (ug/L)				Wet Weather (Acute) Water Quality Targets [1] (ug/L)			
Reach	Dissolved Copper	Dissolved Nickel	Total Selenium	Dissolved Zinc	Dissolved Copper	Dissolved Nickel	Total Selenium	Dissolved Zinc
Mugu [2]	3.1 * WER [6]	8.2	71	81	4.8 * WER [7]	74	290	90
Calleguas Reach 2 [3]	3.1 * WER [6]	8.2	5	81	4.8 * WER [7]	74	290	90
Calleguas Reach 3	25.9 [4]	149 [4]	5	338 [4]	26.3 [5]	856 [5]	N/A	214 [5]
Revolon/Beardsley subwatershed [3]	3.1 * WER [6]	8.2	5	81	4.8 * WER [7]	74	290	90
Conejo subwatershed	27.9 [8]	160 [8]	5	365 [8]	41.6 [9]	1292 [9]	N/A	324 [9]
Arroyo Simi/Las Posas Subwatershed	29.3 [10]	168 [10]	5	382[10]	29.8 [11]	958 [11]	N/A	240 [11]

[1] Water quality criteria for protection of aquatic life.

[2] Saltwater criteria apply to Mugu Lagoon.

[3] The more stringent of the freshwater or saltwater CTR criteria apply to these reaches. For copper, nickel and zinc, the more stringent criterion is the saltwater criterion. For selenium, the more stringent chronic criterion is the freshwater criterion and the more stringent acute criterion is the saltwater criterion.

[4] Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (346 mg/L).

[5] Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (204 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

[6] A WER of 2.13 has been proposed for Mugu Lagoon and Revolon Slough and a WER of 4.06 has been proposed for Lower Calleguas. The final WER will be set equal to that which is adopted by the RWQCB.

[7] A WER of 2.13 has been proposed for Mugu Lagoon and Revolon Slough and a WER of 4.06 has been proposed for Lower Calleguas the final WER will be set equal to that which is adopted by the RWQCB.

[8] Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (378 mg/L).

[9] Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (332 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

[10] Dry Weather (Chronic) Freshwater Targets are calculated using the 50th percentile hardness calculated from all dry weather freshwater hardness data in the subwatershed (400 mg/L).

[11] Wet Weather (Acute) Freshwater Targets are calculated using the 50th percentile hardness calculated from all wet weather freshwater hardness data in the subwatershed (233 mg/L). Wet weather targets apply when the flows in the stream exceed the 86th percentile flow rate for each reach.

“N/A” indicates a target is not available for this constituent (the CTR did not define a criterion for freshwater CMC).

Table 24. Mercury Targets and Selenium Bird Egg Target

Media	Mercury	Selenium
Fish Tissue (Human Health)	0.3 mg/kg wet weight [1]	
Fish Tissue (Wildlife)	TL3 < 50 mm = 0.03 mg/kg wet weight [2] TL3 50-150 mm = 0.05 mg/kg wet weight [3] TL3 150-350 mm = 0.1 mg/kg wet weight [3]	
Bird Egg (Wildlife)	less than 0.5 mg/kg wet weight [4]	6.0 ug/g [6]
Water Column	0.051 ug/L [5]	(See table above)

[1] USEPA, 2001. “Water Quality Criterion for the Protection of Human Health: Methylmercury”. The 0.3 ppm concentration in fish tissue is based on a total fish and shellfish consumption-weighted rate of 17.5 grams of fish/day.

[2] USFWS, 2003. “Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California.” The 0.03 ppm fish tissue concentration is specifically intended to protect the California Least Tern, which consumes almost exclusively TL3 fish less than 5cm in size.

[3] USFWS, 2005. “Derivation of Numeric Targets for Methylmercury in the Development of a Total Maximum Daily Load for the Guadalupe River Watershed.” The 0.05 ppm target for TL3 fish 50-150 is considered protective for Great Blue Heron and Belted Kingfisher. The 0.1 ppm target for TL3 fish 150-350 mm is considered protective for Common Merganser.

[4] SFRWQCB, 2004. “Mercury in San Francisco Bay Total Maximum Daily Load (TMDL) Proposed Basin Plan Amendment and Staff Report.” Because available information suggests the bird egg mercury concentration at which no adverse effects would occur is below 0.5 ppm, a bird egg target of less than 0.5 ppm mercury (wet weight) *where no observable adverse effects occur* is proposed. This target is proposed in addition to the fish tissue targets shown above, to help ensure protection of wildlife.

[5] CTR 30-day average water quality criterion for the protection of human health (organisms only).

[6] Skorupa, 1998; as cited in USFWS Biological Opinion, March 2000.

In addition to the targets presented above, alternative sediment targets for Mugu Lagoon have been identified to protect benthic organisms from sediment toxicity due to metals. The alternative sediment targets are based on screening levels endorsed by NOAA (Buchman 1999). The chosen targets are the effects range-low (ERLs) values combined with evidence of sediment toxicity due to metals.

Table 25. Alternative Sediment Targets for Copper and Nickel

Constituent	Target (mg/kg) [1]
Copper	34 mg/kg (in combination with sediment toxicity due to copper)
Nickel	20.9 mg,kg (in combination with sediment toxicity due to nickel)

1 The Toxicity TMDL for the Calleguas Creek watershed defines a target for sediment toxicity. The target is based on the definition of a toxic sediment sample as defined by the September 2004 Water Quality Control Policy For Developing California’s Clean Water Act Section 303(d) List (SWRCB). Exceedances of the ERL in conjunction with exceedances of the sediment toxicity target and confirmation that the toxicity is due to the associated metal will trigger implementation actions to address benthic sediment impacts due to copper and/or nickel.

If exceedances of the sediment target in Mugu Lagoon are found to occur primarily as a result of natural soil concentrations, such exceedances will not trigger action unless additional sources are identified which exceed the sediment target as a result of anthropogenic activities.

4.1 Water Column Targets

California Toxics Rule (CTR) aquatic life criteria for water are selected as numeric targets for protection of freshwater and marine life from aquatic toxicity for dissolved copper, nickel and zinc; and for total mercury and selenium. Both the 4-day average chronic criterion (Criterion Continuous Concentration, or CCC) and 1-hour average acute criterion (Criterion Maximum Concentration, or CMC) for each constituent are included as targets for the TMDL. CTR aquatic life criteria are not developed for mercury, so 30-day average CTR human health criteria (organisms only) are applied instead.

The Basin Plan and CTR state that the salinity characteristics (i.e., freshwater versus saltwater) of the receiving water shall be considered in determining the applicable water quality criteria (WQC). Freshwater criteria shall apply to discharges to waters with salinities equal to or less than 1 ppt at least 95 percent of the time. Saltwater criteria shall apply to discharges to waters with salinities equal to or greater than 10 ppt at least 95 percent of the time in a normal water year. For discharges to waters with salinities in between these two categories, or tidally influenced fresh waters that support estuarine beneficial uses, the criteria shall be the lower of the saltwater or freshwater criteria (freshwater criteria are calculated based on ambient hardness) for each substance. The latter of these scenarios applies to the lower reaches of the CCW due to tidal influence and in Revolon Slough above the tidal influence as a result of high salinity discharges from groundwater and agriculture.

For copper and nickel, consideration of site-specific factors that could lead to adjustments of the water column targets are discussed in this TMDL and presented in detail as Appendix A (Copper Water-Effects Ratio) and Appendix B (Nickel Recalculation SSO). Currently, the proposed WER for copper is scheduled to be considered for approval on the same time schedule as the TMDL. For copper, the proposed WER can be adopted in conjunction with the TMDL and go into effect if/when approved by the State and EPA Region 9. However, changes to the CTR nickel target will require de-promulgation of the current criteria. The schedule for de-promulgation cannot currently be set. It is likely that the TMDL will be adopted and approved prior to the nickel SSO becoming effective. Therefore, the discussion of the proposed nickel SSO and the impacts on the TMDL is included as a separate section (Section 14, Nickel SSO). At the time of approval of the nickel SSO, the targets, allocations and implementation actions discussed in Section 14 will go into effect.

Copper Water Effects Ratio

Bioavailability and toxicity of copper are dependent on site-specific factors such as pH, hardness, suspended solids, dissolved oxygen (i.e., redox state), dissolved carbon compounds, salinity, and other constituents. Because of the potential for location specific differences in water character used to determine the national aquatic-life criterion, USEPA has provided guidance concerning three procedures that may be used to convert a national criterion into a site-specific criterion [USEPA, 1994]. One of these, the Indicator Species procedure, is based on the assumption that characteristics of ambient water may influence the bioavailability and toxicity of a pollutant. Toxicity in site water and laboratory water is determined in concurrent toxicity tests using either resident species or acceptable sensitive non-resident species, which can be used as surrogates for the resident species. The ratio of the ambient to the laboratory water toxicity values, deemed a water-effects ratio (WER), can be used to convert a national concentration criterion for a pollutant to a site-specific concentration criterion.

The California Toxics Rule (CTR) defines the chronic criterion for dissolved copper as 3.1 µg/L for marine water, *multiplied by a Water Effects Ratio or WER* (40 CFR 131.38 (b) and (c)(4)(i) and (iii)). The default value for the WER is 1.0 unless a WER has been developed using methods as set forth in USEPA's WER guidance [USEPA, 1994]. EPA has, in effect, streamlined SSOs for trace metals given adopted wording in the CTR.

Appropriate samples were collected in Reach 1 & 2 to perform WER tests. Since Reach 2 is tidally influenced, both freshwater and saltwater species toxicity tests were performed. The most conservative of these approaches (i.e., the lowest WER) was used for calculating the numeric targets. Because saltwater species are more sensitive to copper then freshwater species, the saltwater species toxicity results were carried forward and used to determine the WER. The complete results of the WER testing were submitted to the LARWQCB, SWRCB, and EPA in September of 2005; and are included as part of Appendix A.

4.2 Fish Tissue Targets

Fish tissue targets are designated to protect humans and wildlife from consumption of fish and other aquatic organisms contaminated by mercury. Since mercury is a bioaccumulative pollutant, it is important to consider how concentrations of this constituent may affect humans and other species living, breeding, and/or feeding within the watershed.

Protection of Human Health

In 2001, USEPA adopted new criteria for mercury based on the methods described in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (USEPA, 2000). The following excerpt from the USEPA criteria document describes the reasoning for switching from an ambient water criteria to a fish tissue criteria for mercury.

> "Traditionally, EPA has established recommended 304(a) criteria to protect human health as ambient concentrations in water. For those pollutants that bioaccumulate, such as methylmercury, exposure through the food pathway is estimated by using a bioaccumulation factor (BAF). However, following review of available data and recommendations made by external peer reviewers [U.S. EPA, 2000c], EPA determined that it is more appropriate to base the methylmercury criterion on a fish tissue residue concentration than on an ambient water concentration." [USEPA, 2001]

The 2001 USEPA mercury target of 0.3 mg/kg for protection of human health is for methylmercury (US EPA, 20010). Approximately 90-95% of mercury that accumulates in fish tissue occurs in the form of methylmercury. For the purposes of this TMDL, total mercury content will be compared to the methylmercury criteria.

Protection of Wildlife

The fish tissue targets designated in this TMDL for protection of wildlife are based on methodology developed by the US Fish & Wildlife Service and numeric targets developed for the San Francisco Bay Mercury TMDL and the Guadalupe River Watershed Mercury TMDL (using the USFWS methodology). Those TMDLs are developed in locales comparable to the CCW - coastal or semi-coastal watersheds in California - which are inhabited by similar sensitive species. The specific targets selected for this TMDL and presented above in Table 24 are protective of the CCW species which are most sensitive to the effects of mercury, including: California Least Tern, Light Footed Clapper Rail, Snowy Plover, Bald Eagle, and

Great Blue Heron.

The methodology developed by US Fish and Wildlife was initially intended to determine whether the fish tissue concentration of 0.3 mg/kg of methylmercury, for protection of human health, is also protective of federally listed wildlife species in California (USFWS, 2003). The methodology uses a series of calculations and numerous parameters (e.g., dietary composition, food ingestion rates, body weights, bioaccumulation factors, food chain multipliers, transfer coefficients) to specify acceptable daily exposure to methylmercury at which no adverse effects to various wildlife species are expected; also referred to as wildlife value (WV).

Some concern has been expressed (Tetra Tech, 2005) regarding the validity of the USFWS methodology for estimating acceptable methylmercury exposure for wildlife. One of the main issues of concern is the use of national average bioaccumulation factors (BAFs) in calculating trophic transfer coefficients; because BAFs are known to vary by orders of magnitude among different waterbodies. All of the fish tissue targets selected for protection of wildlife for this TMDL were developed without the use of these trophic transfer coefficients. The WV for California least terns developed by USFWS and the WVs developed for the Guadalupe TMDL (other than for osprey) all were for wildlife species feeding exclusively or primarily on prey from a single trophic level; thus no trophic level transfer coefficient was necessary. The Tetra Tech review also considered the methylmercury reference dose calculated by the USFWS, and concluded "although based on a relatively old study on mallards dating back to 1979, [the reference dose] is generally defensible and not contradicted by more recent studies, including a recent study on loons." Other concerns were expressed relating to the way in which uncertainty values and food chain multipliers employed in the USFWS methodology may affect final results.

The fish tissue targets presented in this TMDL for protection of wildlife are based on currently available information and may be revised if more site-specific information is generated for the watershed.

4.3 Bird Egg Targets

Since mercury and selenium are bioaccumulative pollutants, they have the greatest effect on species higher up in the food web. Animals such as piscivorous birds which feed primarily or exclusively on fish and other aquatic organisms are especially at risk from the potentially harmful effects of these constituents. Since mercury and selenium are known to cause reproductive failure and other developmental effects, bird egg concentration targets are one of the most direct means by which to measure impacts from these constituents. The bird egg targets selected for this TMDL and presented above in Table 24 add an appropriate additional measure of protectiveness beyond that provided by the use of water column and fish tissue targets.

The bird egg targets presented in this TMDL for protection of wildlife are based on currently available information and may be revised if more site-specific information is generated for the watershed. Consistent with the recent policy direction of the SWRCB to the San Francisco RWQCB relating to the mercury egg concentration target designated for the San Francisco Bay Mercury TMDL, it should be clarified that the bird egg target for mercury in the CCW is a monitoring target only, as it represents a Lowest Observable Effect Level, not a No Observable Effect Level. Protection of wildlife also relies upon the mercury targets for fish tissue according to size class and trophic level, which are shown above in Table 24.

4.4 Sediment Targets

Sediment quality guidelines for copper and nickel published by the National Oceanic and Atmospheric Administration (NOAA) in their Screening Quick Reference Tables (SQuiRTs) (Buchman, 1999) as advisory values are used in this TMDL, in conjunction with observed sediment toxicity due to copper and/or nickel, as numeric targets for marine sediment. NOAA included the following caveat in the introductory comments to the SQuiRTs: "These tables are intended for preliminary screening purposes only; they do not represent NOAA policy and do not constitute criteria or clean-up levels. NOAA does not endorse their use for any other purposes." Since these sediment guidelines are not adopted sediment quality criteria, they are used as alternative numeric targets to help ensure that the TMDL allocations based on compliance with CTR criteria are protective of benthic sediments in Mugu Lagoon.

Stakeholders involved in the development of the TMDL accepted the targets above as a compromise based on the use of the targets as a trigger to initiate toxicity evaluations and in recognition that the State Board is developing sediment quality guidelines that will be incorporated into this TMDL when adopted. Exceedance of the ERLs in combination with sediment toxicity that has been identified as being caused by copper and/or nickel will trigger additional investigations into the sources of copper and/or nickel toxicity in Mugu Lagoon as discussed in the Implementation Plan.

The CCW Toxicity TMDL did not identify any metals as causing toxicity in water or sediment. Any unidentified toxicity, which may result from metals, is addressed in this TMDL by selection of the sediment numeric targets in conjunction with the sediment toxicity targets.

Multiple sediment screening values are included in the SQuiRTs "to help portray the entire spectrum of concentrations which have been associated with various probabilities of adverse biological effects." The specific numeric values selected from the SQuiRTs tables as numeric targets are the Effects Range Low (ERL) values for marine sediment. The ERL sediment guidelines are intended to represent the concentration at which no effects are observed.

4.5 Alternatives Considered

Alternatives considered during the process of selecting numeric targets for the CCW Metals and Selenium TMDL are discussed below.

USEPA Draft Selenium Criteria

In 2004, USEPA developed draft criteria for selenium. The new criteria include both an acute and chronic toxicity criteria for freshwater where only a chronic toxicity value was previously available. For acute toxicity, a 24-hour water column concentration is proposed. For chronic toxicity, a fish tissue criterion is proposed. Although these criteria have not been adopted, they are believed by USEPA to represent the best science available about the toxicity of selenium.

5 SOURCE ASSESSMENT – PROCESSES AND CYCLING

Initial steps in the development of a TMDL include assessing sources and then linking the loads from those sources to concentrations in various environmental compartments. Conceptual models of environmental cycling are presented below for copper, mercury, nickel, and selenium; as well as the linkages between sources, pathways, and reservoirs for each constituent.

5.1 Copper Transport and Transformation

Once discharged to a water body, copper can be transformed and transported in a number of ways. Copper in receiving waters of the CCW is either transported through the lower watershed and Mugu Lagoon to the ocean or enters groundwater basins in areas where surface water recharge occurs. Copper can also be associated with sediments and the transport and fate of the sediment-associated copper is linked to the sediment transport in the watershed. Copper deposited in sediments can reenter the water column through resuspension and dissolution, erosion of buried sediments, and benthic flux of dissolved copper. Resuspension and dissolution occur as a function of the movement of water over and within sediments (Gee and Bruland, 2002; Flegal et al., 1991). Benthic flux (sometimes referred to as internal recycling) represents the net transport of dissolved chemical species between the water column and the underlying sediment. This transport is affected by redox reactions, complexation, sorption, and other chemical processes (Topping et al, 2001). Copper can also be stored in watershed biota. The fate, transport and storage of copper in each of the various compartments (water, sediment, biota) are affected by environmental cycling in the watershed. The conceptual model of environmental cycling and fate for copper in the CCW is depicted in Figure 12.

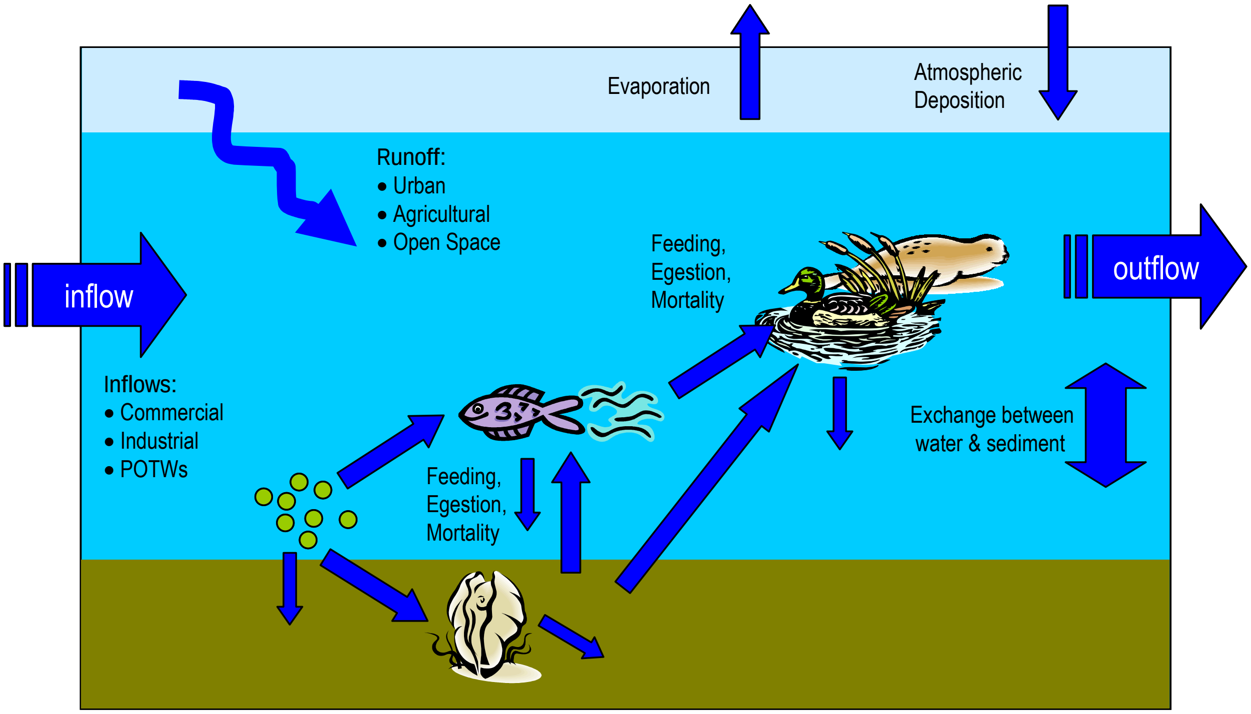


Figure 12. Environmental Cycling of Copper.

Copper cycling is important in the CCW because it plays a major role in both the fate and toxicity of the metal loads entering the lagoon. The conceptual model of cycling involves chemical speciation of copper and the chemical, physical, and biological processes that influence their fate, concentrations, and interactions between chemical forms. The species considered are the free metal ions; inorganic complexes with chlorides, hydroxides, carbonates, and sulfates; organic complexes with strong and weak ligands; adsorbed forms and other particulate forms. Speciation is very important since only free metal ions and labile inorganic complexes are bioavailable and potentially toxic. It is important to understand the processes that control the transformations between different chemical forms of the metals, since these will determine the speciation and concentrations of the metals as loads or internal cycling processes change over time.

Copper partitions between the dissolved and particulate phase in the watershed. Processes of sorption and desorption impact this partitioning. The ratio of particulate to dissolved concentration at equilibrium is referred to as the partition coefficient (K_d). This coefficient depends on metal chemistry and site-specific factors, including salinity, suspended solids, and dissolved organic carbon (Romkens et al. 1999; Weng et al., 2002l Ciffro et al., 2002).

Dissolved copper exists as inorganic complexes, organic complexes, colloids and free cationic species. The ionic form of copper is most toxic to aquatic organisms, as it is the form which most readily diffuses across cell membranes. The complexation of dissolved copper has a direct effect on copper toxicity. This can have a direct effect on water quality management decisions such as evaluation of a copper water effect ratio. Sedlak et al. 9(1997) and Bedsworth and Sedlak (1999) found that most of the copper and nickel released by South San Francisco Bay POTWs was dissolved, but strongly complexed by organic molecules, and therefore not present in toxic amounts. This has been confirmed by more recent speciation assessments in receiving waters of South San Francisco Bay (Buck and Bruland, 2005). If this is also true of Calleguas Creek POTWs, it might be predicted that the water effect ratio for copper would be higher during the low-flow conditions. On the other hand, other factors, such as higher concentrations of naturally occurring humic substances, can cause wet-weather water effect ratios to be higher. This is a preliminary finding of the copper water effect ratio study in the Los Angeles River (Larry Walker Associates, 2005), although it has not been confirmed.

Complexation and sorption are the main processes that control copper speciation. Inorganic complexation reactions are fast, and can be considered as equilibrium processes. Salinity variations have the largest effect on these reactions, since salinity determines the concentrations of the inorganic ligands that complex with the metals. Organic complexation and sorption reactions are slower, and are considered to be kinetically limited. These kinetic relationships make the organic complexes and sorbed species unavailable for uptake, as well as influencing their fate and transport in the watershed.

Organisms influence the biogeochemical cycling of copper through uptake and excretion processes, incorporation into biological tissues, production of organic detrital material containing the metals, and subsequent metals release during decomposition and mineralization. Uptake removes dissolved metals from the water column and incorporates them in the biota, while excretion returns metals back to the water in soluble forms. However, this biological processing can change the form and bioavailability of the metals. Free metal ions and weak inorganic complexes are the forms that are most readily assimilated from the water, while excreted forms may be complexed with organic ligands that are much less available for uptake. In addition, phytoplankton excrete cellular exudates that chelate copper ions, effectively reducing copper bioavailability and toxicity.

Particulate organic detrital copper is produced through food web processing. Following accumulation of the metal in the biota, processes such as phytoplankton settling, plankton mortality, and egestion generate organic detrital metals that settle and deposit the metals in the sediments. These metals are released as soluble forms to the water column and sediment pore waters as the organic material decomposes. Solubilization of metals by benthic animals feeding on phytoplankton and detritus could also be an important process, as could benthic bioturbation/irrigation effects on sediment release.

Accumulation of copper in the aquatic food web depends on uptake from two routes of exposure; water and food. Accumulation can be calculated from the metal uptake rates from water; metal assimilation efficiencies from food; metal elimination rates from the organisms; organism growth rates, consumption rates, and dietary preferences; and metal concentrations in food items. The uptake and elimination rates must account for the effects of metal regulation by the organisms, at least for copper. Copper does not bioaccumulate in organisms to a significant degree.

As with water, the toxicity of sediment-associated copper to benthic organisms depends on site-specific factors. In particular, the molar ratio of leachable copper to acid-volatile sulfides is a much better predictor of copper toxicity than the copper concentration alone (Ankley et al., 1993; Besser et al., 1996; Casas and Crecelius, 1994). Acid-volatile sulfides form complexes with copper that inhibit organismal uptake. When the ratio of leachable copper to available sulfide exceeds 1, there is not enough sulfide to complex all the available copper, and toxicity ensues. This kind of basic science concept will be important in the development of site-specific sediment quality objectives.

Due to the lack of data on the different forms of copper, the TMDL analysis only discusses dissolved and total recoverable copper. Dissolved copper is used as a conservative representation of the bioavailable form of copper. We know from basic principles of aquatic chemistry that >99% of all dissolved copper is expected to be present as organic complexes (Morel and Hering, 1993). As site-specific toxicity data is developed to support a water effect ratio, ancillary measurements of organic carbon and other parameters that can be used in chemical speciation models will help provide mechanistic explanations for empirical observations of copper toxicity. Future adaptive implementation studies may also include assessments of copper speciation.

5.2 Mercury Transport and Transformation

Critical elements needed to understand the behavior of mercury in the environment are *speciation* (the molecular ions, molecules and atoms which form compounds or "forms" with diverse properties), *transformations* (biological and geochemical reactions in the major compartments), and *ecosystem flux* (cycling of the various mercury forms between compartments). The conceptual model of environmental cycling and fate for mercury in the CCW is depicted in Figure 13. The principal pathways of mercury in the CCW include historic and new sources of mercury bound to sediment, water movement within the watershed transporting mercury-laden sediment, (depositing some in wetlands, mudflats, and sloughs, where conditions favor methyl mercury formation), small aquatic organisms (such as plankton) taking in methylmercury and passing it up through the food web to higher organisms, and wildlife and birds at the top of the food web consuming mercury in fish and other aquatic organisms (e.g., clams, snails, crabs, and worms). A more detailed discussion of these pathways follows.

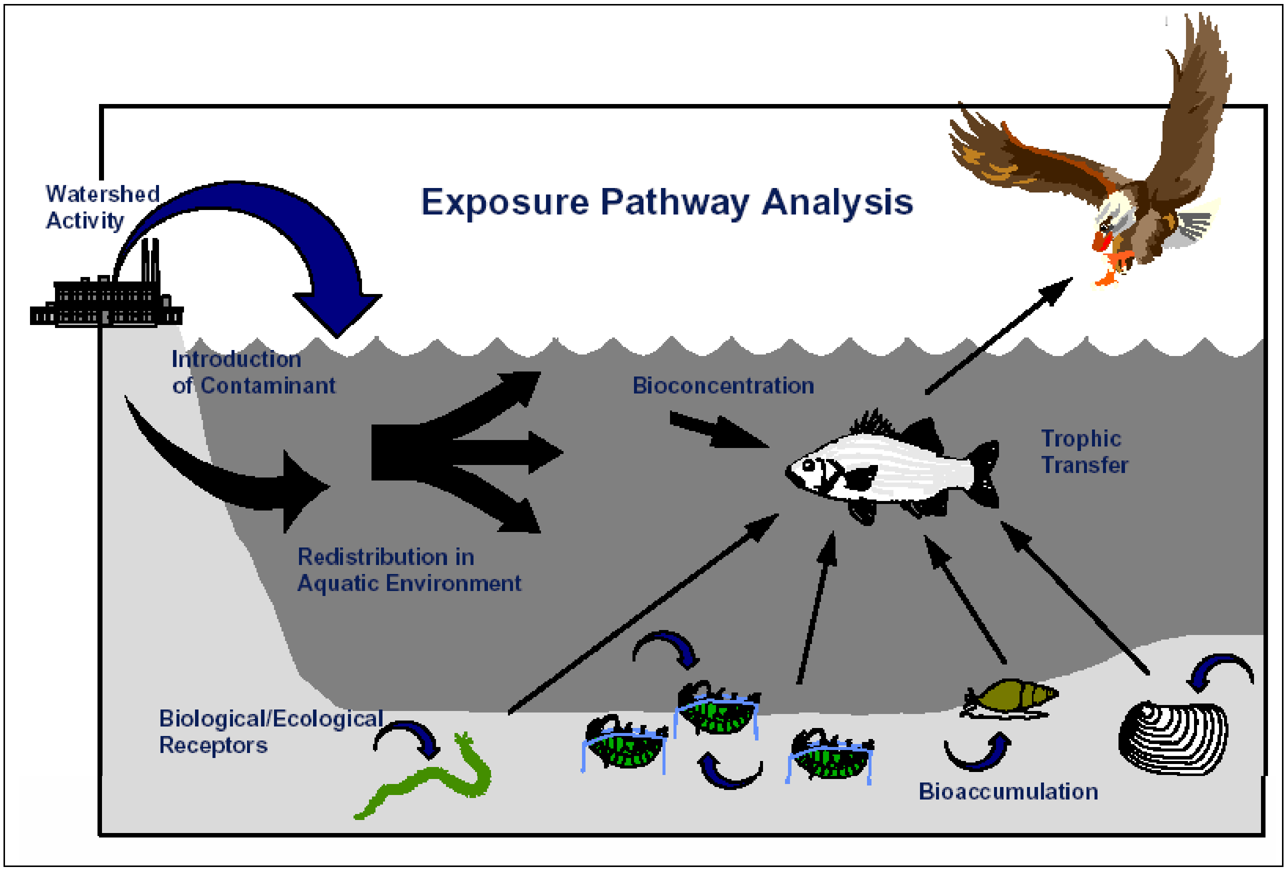


Figure 13. General Mercury Pathways (interpreted from RWQCB, 2004).

Speciation

Chemical speciation of mercury plays an important role in the transformation and transport of mercury in the aquatic environment because the different forms of mercury react and interact differently. The important mercury compounds (comprised of various forms or species of mercury) are described in more detail in Table 26.

Table 26. Chemistry and Significance of Mercury Species in Natural Waters (DTMC/SRWP, 2002).

Mercury Species		Key Characteristics	Importance to Mercury Cycling
Hg^0	Elemental Mercury (aka, quicksilver)	Liquid at room temperature but highly volatile dissolves little into water.	Most prevalent form fluxing into atmosphere, oxidizes to Hg^{+2} in sunlight, found in mercury and gold mining areas and higher in industrialized and populated areas, most prevalent form in atmosphere (>95%) and can be transported globally.
Hg(II)	Divalent mercury (aka, inorganic mercury)	Most readily methylated, adsorbs to solids.	Highest proportion of wet and dry atmospheric deposition occurs in this form, reduces to Hg^0 by natural processes in air and water.
CH_3Hg^+/ MeHg	Methylmercury	A form of divalent mercury, soluble in water.	Dominant form in organisms and most readily biomagnifies, adsorbs to solids, highly toxic to humans and wildlife, generally low proportion (0.1%-5%) of total mercury in oxygenated water but can be the dominant specie under anoxic conditions.
HgS(s)	Cinnabar (aka, inert or inorganic mercury)	A form of divalent mercury, solid.	Non-reactive, and relatively unavailable and non-toxic to biota, found in natural ores and sediments and in mercury mining waste piles.

Dimethylmercury is not included in Table 26, as it is typically undetectable in fresh or brackish surface waters and near detection limits in marine environments (Wiener et al., 2002, as cited in DTMC/SRWP, 2002). Therefore, it is assumed that dimethylmercury is insignificant in the CCW.

Important factors controlling mercury speciation include temperature, organic and inorganic ligands concentrations, redox potential, salinity (chloride concentration), pH, sunlight, sulfate concentration, microbial assemblages, and mercury concentration (Benoit et al., 1999; Gilmour, 1995; Keating et al., 1997, as cited in DTMC/SRWP, 2002). Subtle changes in these factors can cause reactions that drastically change its speciation over both short and long time scales (hours to years). In the CCW, the same factors are all potentially important in determining mercury speciation.

Transformation / Flux

Mercury moves (also said to "cycle" or "flux") from one compartment into another based on various factors. The important fluxes include:

- Exchanges between the atmosphere and the water column,
- Exchanges between the water column and the "active" sediment bed, and
- Biological accumulation (exchange between the sediment or water column and biota).

Vaporous elemental mercury in the atmosphere may be oxidized to other forms that can fall as precipitation on water or soil surfaces. Divalent mercury released to the atmosphere may fall as wet or dry deposition relatively near its source. The atmosphere may also be a sink for mercury that evaporates from surface waters. Diffusive loss to the atmosphere, or volatilization, can represent a significant loss of mercury from marine ecosystems (Rolfhus and Fitzgerald, 2001, as cited in DTMC/SRWP, 2002).

Much of the total mercury load in rivers is bound to sediment (Horowitz, 1995, as cited in DTMC/SRWP, 2002). The active sediment bed plays a key role in any aquatic mercury model. Suspended sediments, with mercury bound to them, are deposited to and eroded from the sediment bed. Depending upon natural concentrations of the various mercury species, the suspended sediments lost or gained to the water column become a source or sink for mercury. Once deposited, sediments coalesce to form an unconsolidated layer of variable, but often shallow (less than 10 cm), depth. This "active" layer of sediments may undergo continual bioturbation, or mixing by organisms, so that sediments and mercury are distributed evenly throughout.

Within the sediment bed, biotic and abiotic reactions result in methylation, demethylation, and reduction, just as in the water column. However, because of varying environmental conditions, the rate of these reactions can vary dramatically from those in the water column. Mass transfer between each mercury species in the sediment bed may be modeled in a manner analogous to that of water column reactions. Mercury tends to bind to smaller size sediments, colloids and clays. These particles tend to move with water more than heavier sediment particles such as gravels and sand.

Diffusion occurs when the activity level of a molecule varies across a boundary or interface. Mercury concentrations often differ widely across the sediment-water interface of natural aquatic systems and this differential creates a strong tendency for diffusion across the sediment-water interface. Dispersion is a process analogous to diffusion, but involves mixing at larger scales due to erosion and ambient turbulence. The combined result of these processes is dispersion of mercury into the near-bed domain and subsequent diffusion or dispersion of this re-suspended and re-dissolved mercury upward and throughout the water column.

Erosion or resuspension of bed material due to bed shears in excess of a critical shear of erosion cause the re-entrainment of mercury-laden particulates into the water column. This re-entrainment is assumed to involve transfer of a representative volume of sediment bed, so that all mercury within that volume, dissolved and bound, re-enters the overlying water.

Bioaccumulation

Bioaccumulation refers to the net incorporation of mercury in an organism from its environment and food sources; plus the magnification of methylmercury in each successively higher level in the food chain. Bioaccumulation is of particular concern in ecosystem management because it can lead to long-term accumulation and food-chain magnification of mercury. Concentrations of total mercury in water or sediments are not always well correlated with mercury fish tissue concentrations (Gilmour, 1995, as cited in DTMC/SRWP, 2002). However, mercury is known to biomagnify in aquatic food chains with top predators often having a million times more mercury (by weight) than the water they live in (Wiener and Spry, 1995, as cited in DTMC/SRWP, 2002).

Over 90% of mercury found in fish is in the form of methylmercury (Bloom, 1992, as cited in DTMC/SRWP, 2002), a form that typically accounts for only a small fraction of total mercury. The process of bioaccumulation is complex, principally involving diffusion of mercury into phytoplankton and sorption onto detritus, followed by consumption of organisms or detritus. The ratio of methyl to total mercury tends to be greater in higher trophic levels (Lasorsa and Allen-Gil, 1995, as cited in DTMC/SRWP, 2002). Methylmercury has a high affinity for sulfur-containing proteins. In the environment, tissue concentrations of mercury increase at each successively higher level in the food chain (trophic level) because consumers tend to retain protein preferentially over other components. Predators magnify the protein concentration in their prey by eating the portions (e.g. muscle, fat) of the prey which accumulate methylmercury (Mason et al., 1995, as cited in RWQCB, 2000).

Studies have shown that mercury uptake from prey species outweighs uptake from water as the primary source of mercury accumulation in fish tissue (Keating et al., 1997, as cited in DTMC/SRWP, 2002). Ambient concentrations of mercury in water are typically not of direct danger to fish, wildlife, or humans because animals exposed only to mercury in the water could not metabolize enough of the toxicant to cause poisoning. Instead, the danger to fish, wildlife, and humans is in consumption of contaminated food, and the key to mercury accumulation in food is methylmercury.

Sulfate-reducing bacteria, which typically live in the upper 5 cm of anoxic sediments, convert inorganic mercury to methylmercury as a by-product of their normal respiration (Matilainen, 1995, as cited in RWQCB, 2000). To methylate mercury, the bacteria first have to take it up across their cell membranes. This requires mercury to be in a form than can cross the membrane. Dissolved, neutrally charged complexes of mercury cross cell membranes most readily (Gilmour et al., 1992, as cited in RWQCB, 2000). Dissolved, neutral complexes of inorganic mercury (Hg^{2+}) and sulfide (S^{2-}) have been implicated as important links to methylmercury production. The involvement of sulfate reducing bacteria and the role of sulfide complexes explains why mercury methylation rates are highest in wetlands, marshes, and suboxic sediments (Krabbenhoft et al., 1999; Zilliouz et al., 1993; Benoit et al., 1999a; Benoit et al., 1999b, as cited in RWQCB, 2000). Methylation rates increase with increasing sulfate supply, to a point. At higher sulfate concentrations salinities, increased sulfide production rates tend to decrease mercury availability to methylating bacteria, resulting in a “bell-shaped” distribution of methylation rates across a sulfate gradient.

The trophic transfer of mercury begins at the bottom of the food chain and branches out to higher trophic levels. Primary producers, phytoplankton or attached algae, adsorb and retain (accumulate) dissolved methylmercury at concentrations 100 times greater than in water. Zooplankton and herbivores feed on phytoplankton, accumulating methylmercury to concentrations of about 10 times those found in their food. Small fish feed on zooplankton and may accumulate mercury to concentrations 100 times those in zooplankton. In this scheme, mercury concentrations are magnified two orders of magnitude (100x) across one trophic level to small fish, but five orders of magnitude (100,000 times) from dissolved mercury to small fish. Larger fish may feed on a combination of foods from lower trophic levels, with a diet of both zooplankton and smaller fish, and thereby consume a mixed dose of mercury. Finally, in higher trophic levels, mercury may be magnified as much as six orders of magnitude (1,000,000x) from aqueous concentrations; depending on site-specific conditions and local food web characteristics.

The concentration of dissolved methylmercury in ambient waters depends on the *net* methylation rate, that is, the balance between methylation rates and demethylation rates. Demethylation can occur through photo-ablation (destruction by light) and by bacterial respiration. Bacteria demethylate methylmercury as either a detoxification mechanism (mer-degradation) or a source of carbon (oxidative demethylation). In the former pathway, elemental mercury (Hg^0) is produced, in the latter, the end product is Hg^{2+}. It is important to understand the microbial demethylation pathway in order to assess mercury fate and transport. The mer-degradation pathway provides a gaseous escape for Hg^0, while oxidative demethylation results in Hg^{2+}, which remains in the waterbody and can be converted back to methylmercury. In the absence of specific, mechanistic information, net methylmercury production rates can be estimated from methylmercury concentrations. The ratio of methylmercury to total mercury is a useful indicator of ecosystems with high methylation efficiencies. In watersheds across the United States, methylmercury to total mercury ratios higher than 5% are associated with enhanced mercury bioaccumulation at the highest trophic levels (Krabbenhoft et al., 1999, as cited in RWQCB, 2000).

The susceptibility to methylation, or *bioavailability*, depends on the chemical form of mercury in the source and the biogeochemistry of the receiving water. Neutral complexes of dissolved inorganic mercury are the link to methylating bacteria (Benoit et al., 1999), so sources of dissolved mercury may be more readily methylated than particulate sources. However, mercury can desorb from particles, enhancing its availability, and dissolved mercury can be complexed by organic ligands or form charged complexes, decreasing its bioavailability (Figure 14).

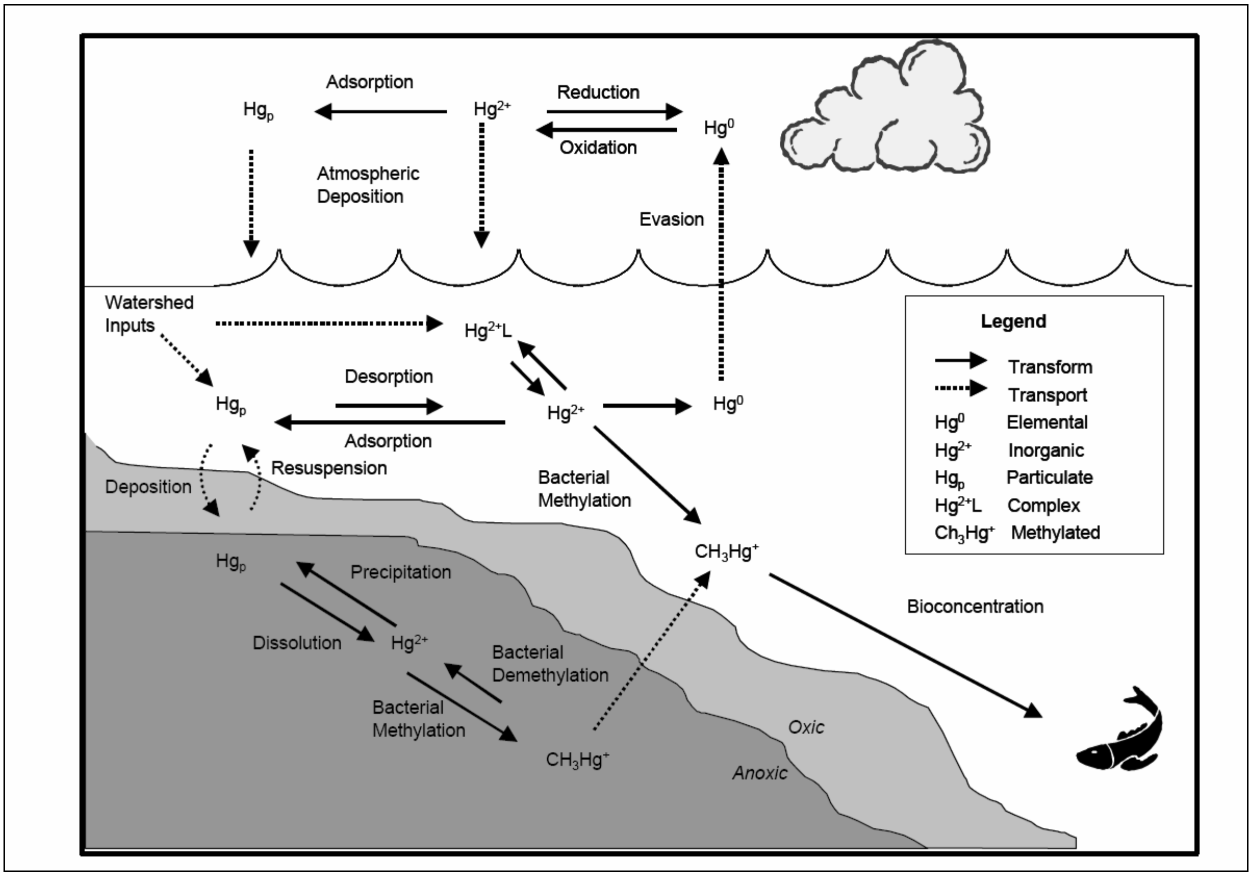


Figure 14. The Complex Biogeochemical Cycling of Mercury (RWQCB, 2000).

Mobilization of Mercury

Total mercury concentrations typically peak following precipitation and increased river flows of the early wet season, and then decrease steadily through the remainder of the wet season (DTMC/SRWP, 2002). In general, this pattern is consistent with the seasonal mobilization of fine-grained particulates in river sediments and runoff (and associated mercury) deposited during the dry season and during lower flows. This pattern is less distinct for total mercury concentrations in the agricultural drainage-dominated waters and in smaller tributaries.

Episodic (storm-driven) fluxes of mercury may be significant in the overall impact of mercury in the watershed. While relatively steady-state loads (such as groundwater or wastewater dischargers) add a relatively constant amount of mercury, storms produce spikes that are important in terms of the total mass loading of a bioaccumulative substance. Rainfall runoff can be modeled explicitly, accounting for seasonal and spatial rainfall variability, to estimate runoff contributions from discrete areas within a watershed.

Tidal influences can drive a mixture of ocean and river water up into the lower portions of the Calleguas Creek watershed (such as Revolon Slough and Lower Calleguas Creek); thereby creating a continually changing aquatic environment. These complicated flow patterns have implications for the movement and distribution of mercury. Wetlands are believed to be locations of enhanced methylation that may promote increased mercury concentrations in target species.

5.3 Nickel Transport and Transformation

Nickel enters the CCW through point and nonpoint source discharges, and is present either in the form of colloidal or dissolved species, or associated with particulate material. Dissolved species consist of the free ion, inorganic complexes, and organic complexes. The particulate form of nickel is either: adsorbed to upland sediments that erode and are transported in stream channels, adsorbed to solids that are discharged in wastewater, embedded in the matrix of soil particles at natural concentrations, or associated with other minor anthropogenically related sources. Once nickel enters local water bodies, its chemical form changes as a result of the different variables that control speciation, such as pH, dissolved organic carbon concentrations, redox potential, salinity, affinity of metal for particulates, and biologically related processes. The conceptual model of environmental cycling and fate for nickel is depicted in Figure 15.

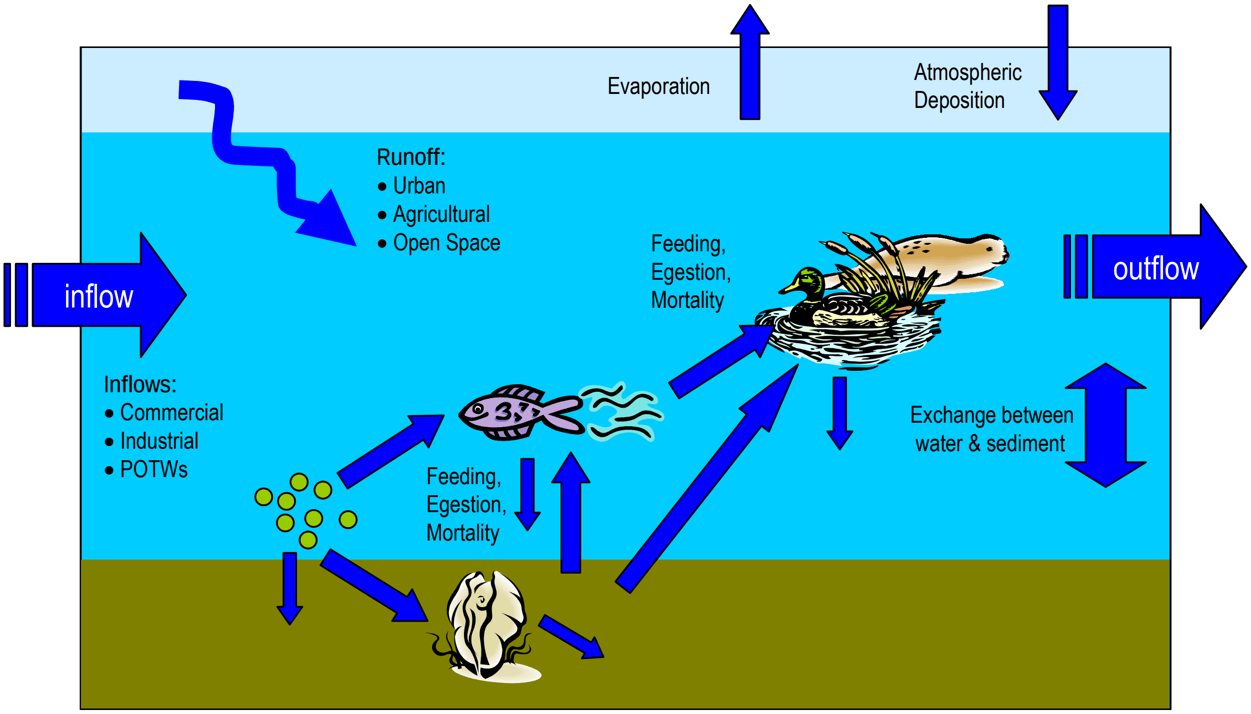


Figure 15. Environmental Cycling of Nickel.

Nickel has a number of possible fates in the watershed. Nickel cycling plays a major role in both the fate and toxicity of the metal loads that enter the CCW. Uptake, accumulation, and toxicity vary with the chemical forms of nickel, since only some species are bioavailable for uptake. Chemical speciation also influences fate and transport processes, since dissolved nickel can be complexed with organic ligands, and since only free ions are adsorbed to inorganic suspended particles. The adsorptive/desorptive exchange between dissolved nickel and suspended particles may be an important source of dissolved nickel during resuspension events. Cycling between the water and sediments is very important, since sediments contain much of the historical loads of nickel. The species considered are the free metal ions; inorganic complexes with chlorides, hydroxides, carbonates, and sulfates; organic complexes with strong and weak ligands; and adsorbed forms and other particulate forms (Tetra Tech, 1999).

Speciation is very important since only free metal ions and labile inorganic complexes are available for uptake. Therefore, these are also the forms that determine toxicity. However, only a small fraction of the total nickel in the water column occurs in these forms. Much of the dissolved nickel is typically complexed with organic ligands, and particulate forms also represent a significant fraction of the total metal concentrations. Complexation and adsorption are the main processes that control nickel speciation. Adsorption processes are believed to depend on free metal ion concentrations.

Nickel partitions between the dissolved and particulate phase in the watershed. Processes of sorption and desorption impact this partitioning. The ratio of adsorption to desorption is referred to as the partition coefficient (K_d). This coefficient depends on metal chemistry and site-specific factors, including salinity, suspended solids, and dissolved organic carbon. Inorganic complexation reactions are fast, and can be considered as equilibrium processes. Salinity variations have the largest effect on these reactions, since that determines the concentrations of the inorganic ligands that complex with the metals. Organic complexation reactions depend on the relative concentrations of organic ligands and dissolved metals.

Sediment processes are important in the speciation and cycling of nickel. The redox conditions are lower in the sediments, producing different chemical reactions than occur in the water column. Soluble fluxes between the water column and sediments are low compared to other sources of the metals. However, sediment resuspension and desorption may release large quantities of dissolved nickel to the water column, making this a major source of dissolved metals.

Aquatic organisms influence the biogeochemical cycling of nickel through uptake and excretion processes, incorporation into biological tissues, and production of organic detrital material containing nickel. Uptake removes dissolved nickel from the water column and incorporates it in the biota, while excretion returns nickel back to the water in soluble form. However, this biological processing can change the form and bioavailability of nickel. Free metal ions and weak complexes with inorganic species are the forms that are most readily assimilated from the water, while excreted forms may be complexed with organic ligands that are much less available for uptake. Following accumulation of the metals in the biota, processes such as phytoplankton settling, plankton mortality, and egestion generate organic detrital metals that settle and deposit the metals in the sediments. These metals are released as soluble forms to the water column and sediment porewaters as the organic material decomposes. One of the most important biological components of the nickel biogeochemical cycle is processing by the phytoplankton. Phytoplankton form the base of the food web and phytoplankton accumulation of metals is the major route of entry into the rest of the food web (Tetra Tech, 1999).

Only free metal ions and labile inorganic metal complexes are available for uptake, since metals complexed to strong organic ligands or adsorbed to suspended particles cannot cross the cell membrane. Water quality factors such as pH, alkalinity, hardness, dissolved organic matter, and suspended particulates influence the speciation and therefore uptake of the metals. Competition with other metals can inhibit nickel uptake, as well as the uptake of other nutrient metals. This occurs through both competition for uptake sites on the cell membrane, as well as through intracellular sites that control membrane transport rates of nickel.

Accumulation of nickel in aquatic food webs depends on uptake from two routes of exposure; water and food. For the primary producers and bacteria, water is the only source of uptake, while for aquatic animals, food and water are both potentially important. For birds and marine mammals, food is the primary source of uptake, although dermal exposure to water also occurs. The accumulation of metals from water depends on the relative rates of uptake, elimination, and growth dilution. Accumulation of nickel from food depends on consumption rates, nickel concentrations in foods, and assimilation efficiencies of the metals during digestion and passage through the gut. Food chain magnification is not important for nickel, although uptake from food may still be a major source of uptake and accumulation (Tetra Tech, 1999).

Due to the lack of data on the different forms of nickel, the TMDL analysis only discusses dissolved and total recoverable nickel. Dissolved nickel is used as a conservative representation of the bioavailable form of nickel.

5.4 Selenium Transport and Transformation

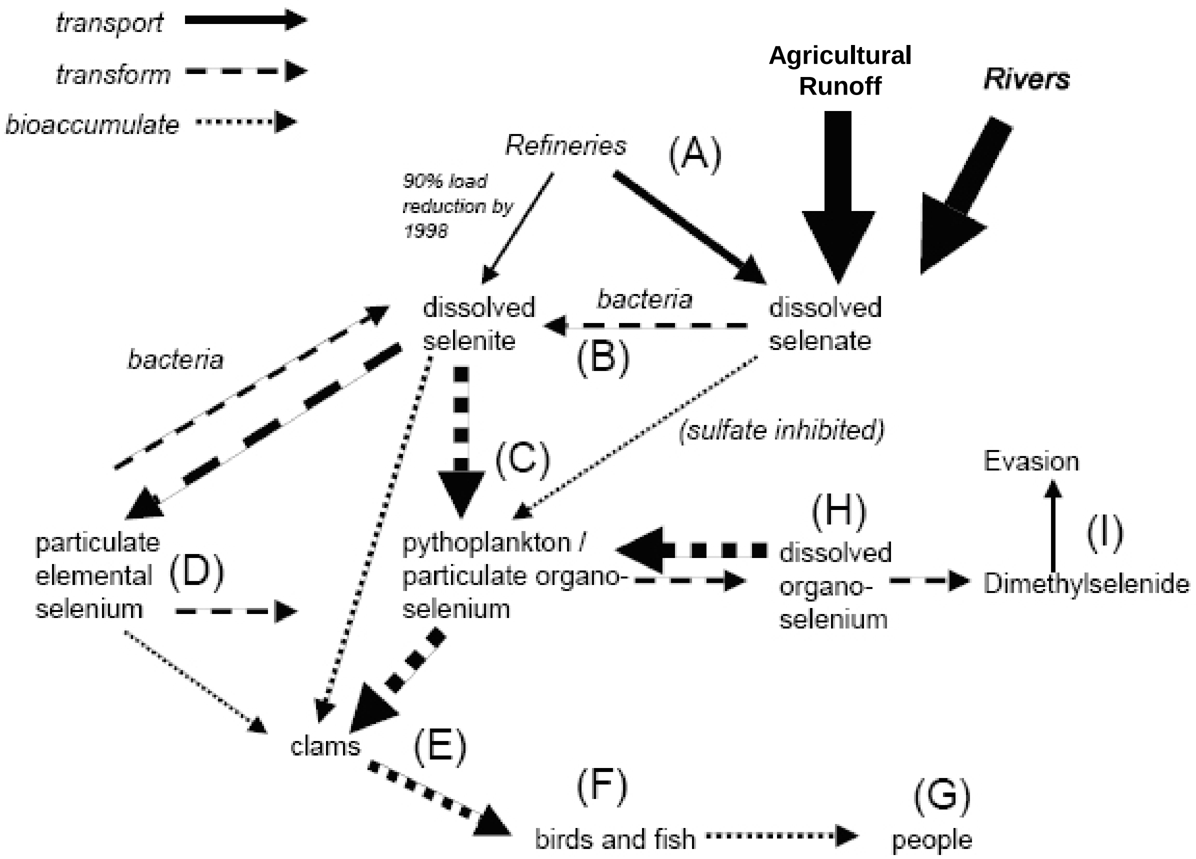
Selenium occurs in several different chemical forms, or *species* (Table 27). Chemical properties of and transformations between selenium species play important roles controlling the fate and effects of selenium in aquatic ecosystems (Abu-Saba and Ogle, 2005). The basic mechanism of selenium toxicity is by mimicking sulfur in important proteins (Oremland, 1994, as cited in Abu-Saba and Ogle, 2005) which destroys the ability to function. The selenium analogue of sulfate, selenate, is thermodynamically favored in oxygenated waters. Reduction in sediments from selenate to selenite, organoselenium, and elemental selenium is the process that led to bird deaths and deformities in Kesterson Reservoir (Ogle, 1988; Ohlendorf, 2002, as cited in Abu-Saba & Ogle, 2005).

The conceptual model of transformation and transportation of selenium in the CCW integrates information on sources of selenium loading to the watershed, the chemical characteristics of selenium, the linkages between these, and the resultant cycling and bioaccumulation of selenium (Figure 16).

Table 27. Chemistry and Significance of Selenium Species in Natural Waters.

Oxidation State	Selenium Species	Key Characteristics	Importance to Selenium Cycling
Se^{+6}	Selenate (SeO_4^{2-})	Extremely soluble with a very low affinity for sorption to particulates. Thermodynamically most stable in oxic waters.	Principal form in minerals (e.g., marine shales), therefore dominant species in leached agricultural drainwaters. Very low bioaccumulation and/or biotransformation by algae. Uptake is inhibited by sulfate.
Se^{+4}	Selenite (SeO_3^{2-})	Extremely soluble with a much greater affinity for sorption to particulates than selenate. Thermodynamically less stable in oxic waters, but still common due to very slow oxidation rate.	Principal form of concern as it accumulates in phytoplankton ~10-fold more readily than selenate; Uptake is not inhibited by sulfate.
Se^0	Elemental Selenium	Insoluble precipitate, formed primarily from dissimilatory reduction of selenite in anoxic sediments.	Removal pathway from waterbodies; conversion to particulate organoselenium is important bioaccumulation pathway for benthic invertebrates.
Se^{-2}	Inorganic selenide (Se^{2-})	Highly reactive, forms insoluble precipitates with metals analogous to sulfide; Se2-often co-occurs with inorganic sulfide ores (e.g., cinnabar)	Formation of highly insoluble HgSe (cinnabar analogue) may explain mechanism of Hg detoxification by Se.
	Cellular (aka, particulate) Organoselenium	Selenium that has been incorporated into phytoplankton/higher organisms. Selenium substitutes for sulfur in amino acids (e.g. selenomethionine)	Particulate organoselenium is major bioaccumulation pathway for benthic invertebrates (particularly for bivalves like *Potamocorbula*)
	Dissolved Organoselenium (aka, organoselenide)	Dissolved organic compounds (e.g. selenomethionine) released from decaying cellular tissues.	Regenerative pool of selenium with uncertain bioavailability?
	Dimethylselenide, Dimethydiselenide	Methylated selenium is produced by microbes, plants, and animals.	Provides gaseous escape from sediments and surface waters into the atmosphere.

Source: Summarized from Maier, 1988; Luoma and Presser, 2000; Maier, 1993; Baines et al., 2001; Cutter, 1989; Ogle, 1996; Hansen, 1998; Luoma et al., 1992, as cited in Abu-Saba & Ogle, 2005.



(A) Selenium from Revolon Slough and Lower Calleguas Creek is predominantly selenate. Refineries discharge both selenate and selenite.
(B) Selenate is reduced to selenite by bacteria and the return to selenate by oxidation is slow, so selenite concentrations can persist in oxygenated waters.
(C) Selenate uptake is also slowed down by increasing sulfate concentrations (Williams, 1994; Ogle, 1996, as cited in Abu-Saba & Ogle, 2005), whereas selenite accumulation is more constant over varying sulfate concentrations (Bailey et al., 1995, as cited in Abu-Saba & Ogle, 2005). Uptake by phytoplankton (algae) is a concern because algae convert dissolved selenium to particulate organoselenium.
(D) Selenium in particles can be both organoselenium from accumulation at the base of the food chain and elemental selenium from bacterial reduction of selenate and selenite (Oremland, 1994, as cited in Abu-Saba & Ogle, 2005).
(E) Particulate selenium is the link to tissue concentrations of benthic invertebrates like clams and mussels.
(F) Birds and fish then eat the benthic invertebrates and accumulate selenium.
(G) People then eat the birds and fish and are exposed to selenium that has accumulated in muscle and tissue.
(H) Plankton, bacteria, and other detrital particulate matter decompose to form a pool of dissolved organoselenium.
(I) Dissolved organoselenium can be re-assimilated into the food chain (Baines et al., 2001, as cited in Abu-Saba & Ogle, 2005), or converted to dimethylselenide, which can *evade* (i.e. escape to the atmosphere by forming micro-bubbles and being stirred by the wind). Algae, some animals and vascular plants can produce gaseous dimethylselenide (Maier, 1988, as cited in Abu-Saba & Ogle, 2005).

Figure 16. Graphical Summary of Selenium Biogeochemical Cycling. Arrow size indicates relative importance of a process, but not exactly scaled to rate constants (Abu-Saba & Ogle, 2005).

Unlike microbes and algae, the primary source for selenium bioaccumulation by consumer organisms is via the food chain. At the lower trophic levels, this consists primarily of ingestion of particulate materials (i.e., microbes, algae, detritus, as well as abiotic particulate materials).

Particulate selenium can be found in any of the oxidation states discussed in Table 27:

1. organic selenides (e.g., cellular selenium, such as bacteria and algae),
2. elemental selenium, or
3. adsorbed or co-precipitated selenite of selenate.

Organic selenium comprises a large part of the particulate fraction (averaging ~45% of the total), with varying amounts of elemental selenium and adsorbed selenite. Because elemental selenium is generally only formed in anoxic sediments, it can be assumed that re-suspended sediments are the source of a large amount of the suspended particulates (Doblin et al., 2005, as cited in Abu-Saba & Ogle, 2005).

Sediment-Water Interchange of Selenium

In other parts of California, studies using stable isotope ratios to discern sources of selenium to sediments concluded that the reduction of selenium from the overlying water is not a significant mechanism for incorporation of selenium into the sediments (Johnson et al., 2000, as cited in Abu-Saba & Ogle, 2005). This is consistent with recent sediment and sediment porewater studies that indicate that while there is a very small flux of inorganic selenium into sediments and a very small flux of organic selenium out of sediments, the net flux of total selenium between the water column and sediments is relatively negligible (Meseck, 2002, as cited in Abu-Saba & Ogle, 2005).

Volatilization of Selenium

Under appropriate conditions, microbes (bacteria and fungi), algae and plants can form dimethylselenide and dimethyldiselenide which can be volatilized and released to the atmosphere (Ansede and Yoch, 1997, as cited in Abu-Saba & Ogle, 2005).

Selenium Cycling and Bioaccumulation

Unlike mercury which is found almost exclusively in sediments, selenium has a relatively low, variable partition coefficient (K_d between 100 and 10,000), and about 70% of total selenium in the water column is dissolved. That means it needs to be modeled in two compartments: dissolved and particulate. The fact that most of the water column selenium is in the dissolved phase means water selenium inventories can be removed more quickly by flushing. This flushing is reflected in the recent findings that the 90% reduction in refinery loads of selenite was accompanied by a rapid response in the water column concentrations of dissolved selenium (Cutter and Cutter, 2004, as cited in Abu-Saba & Ogle, 2005). However, the sediment selenium inventory will almost certainly have a longer response time relative to the water inventory.

While dissolved selenium species can cause direct toxicity to aquatic organisms, the lethal threshold concentrations (e.g., LC50 values) are typically much higher than the waterborne concentrations seen in all but the most contaminated of ecosystems. However, the reproductive and other health impairments that can result from bioaccumulation of selenium up through the food chain can be a toxicity issue of concern. Surface waters and effluent discharges that enter the CCW can convey selenium into the waters in a variety of the forms listed in Table 27.

Depending upon residence time within the waterways, much of the selenium entering creeks may be flushed out to the ocean without ever being taken up by or even interacting with the watershed's biota. For instance, selenate is much less readily taken up by fungi, bacteria, and algae than is selenite; during high flow, it might well be that much of the selenate that enters the watershed may pass through to the ocean without ever entering the bioaccumulation process.

Traditional consideration of bioaccumulation begins with the dissolved contaminant being taken up by primary producers (e.g. algae or phytoplankton) as the "base" of the food chain. However, it is important to note that microbial uptake (by fungi and bacteria) can often be just as, or an even more important first step in the eventual bioaccumulation by consumer organisms. Moreover, it is the bacteria, fungi, and algae that will perform the most critical selenium biotransformation step: the reduction of selenite and selenate and incorporation of the reduced selenides into seleno-amino acids, particularly *selenomethionine*, an analog to the essential amino acid methionine (due to its chemical similarity, the selenium is 'mistakenly' used in place of sulfur in the synthesis of this compound). Methionine is an essential amino acid, meaning it cannot be produced by higher-level consumer organisms, who rely upon the synthesis by the lower organisms and subsequent trophic uptake to provide this biologically necessary compound (Robinson et al., 1978; Kim et al., 1992, as cited in Abu-Saba & Ogle, 2005) and who have developed specialized cellular mechanisms to facilitate its uptake and accumulation. Studies have demonstrated that it is this food-borne selenomethionine that is the major cause of much of the observed reproductive problems in fish and waterfowl (Woock et al., 1987; Heinz et al., 1989; Coyle et al., 1993, as cited in Abu-Saba & Ogle, 2005).

Microbial & Algal Uptake and Transformation of Selenium

Studies have indicated that selenite uptake by marine bacteria is rapid with the selenium being biotransformed into selenoamino acids and proteins within 10 minutes of exposure (Foda et al., 1983, as cited in Abu-Saba & Ogle, 2005), suggesting that bacteria may be an important vector in the bioaccumulation of organoselenides by bivalves, ducks, and fish. Furthermore, while selenite was readily taken up by bacteria and incorporated into amino acids and proteins, selenate was not (Foda et al. 1983, as cited in Abu-Saba & Ogle, 2005), suggesting significant differences in the cycling, fate, and effects of selenite vs. selenate.

Estuarine/marine fungi are important in organic matter processing and as a food source in detrital particles. Uptake experiments have indicated that while an aquatic fungus was able to take up and reduce selenite, it could not reduce selenate (Brown and Smith, 1979, as cited in Abu-Saba & Ogle, 2005), again suggesting that selenate is less able to be reduced and incorporated in organoselenides.

There have been a number of studies with a wide variety of algae, which again have indicated that selenite is readily taken up and accumulated whereas the uptake of selenate is much more limited (Wheeler et al., 1982; Wrench and Measures, 1982; Lindstrom, 1983; Apte et al., 1986; Harrison et al., 1988; Vandermeulen and Foda, 1988; Hu et al., 1996, as cited in Abu-Saba & Ogle, 2005). Loadings of selenate and selenite can both push phytoplankton uptake towards higher selenium levels, it's just that selenite has a greater effect, pound for pound.

Studies with the marine algae *Tetraselmis tetrahele* and *Dunaliella minuta* reported that selenite was readily biotransformed into seleno-amino acids (Wrench, 1978, as cited in Abu-Saba & Ogle, 2005); similar results have also been reported for many other marine algal species (Wrench and Campbell, 1981; Bottino et al., 1984; Vandermeulen and Foda, 1988; Boisson et al., 1995, as cited in Abu-Saba & Ogle, 2005). While much (if not most) of this biotransformed organoselenium is retained within the cellular tissues and eventually ingested by consumer organisms, studies have indicated that live and dead algae will release organoselenides back into the water (Vandermeulen and Foda, 1988; Fisher and Wente, 1993; Besser et al., 1994; Hu et al., 1996, as cited in Abu-Saba & Ogle, 2005); whether or not these released organoselenides re-enter the food chain is uncertain as there are conflicting reports regarding their apparent bioavailability and uptake (Cutter and Bruland, 1984; Cutter and Cutter, 1998; Baines et al., 2001, as cited in Abu-Saba & Ogle, 2005).

Selenium Bioaccumulation by Invertebrates.

It has long been recognized that assimilation of ingested selenium (i.e., from the diet) is the primary mechanism for bioaccumulation of selenium by invertebrates (Fowler and Benayoun, 1976; Sanders and Gilmour, 1994; Zhang et al., 1990; Luoma et al., 1992; Wang et al., 1996; Ogle, 1996; Wang and Fisher, 1999, as cited in Abu-Saba & Ogle, 2005).

Selenium Bioaccumulation by Zooplankton.

Traditional analysis of food chain bioaccumulation by invertebrates would focus upon the transfer from phytoplankton to zooplankton. However, although efficient at assimilating selenium, zooplankton do not appear to accumulate selenium to concentrations much higher than present in their microbial/algal diet (Baines et al., 2002, as cited in Abu-Saba & Ogle, 2005) perhaps due to their relatively high excretion rate of the assimilated selenium (Wang and Fisher, 1998; Xu et al., 2001, as cited in Abu-Saba & Ogle, 2005). Recent studies of selenium in San Francisco Bay zooplankton reported that the zooplankton tissue concentrations were generally similar to those found in other “uncontaminated “ systems and generally without any spatial trends in the Bay (Purkerson et al., 2003, as cited in Abu-Saba & Ogle, 2005).

Selenium Bioaccumulation by Bivalves.

Bivalves have been shown to exhibit extremely high assimilation rates for ingested (i.e., “particulate”) selenium (Zhang et al. 1990; Luoma et al. 1992; Wang et al. 1995; Reinfelder et al. 1998, as cited in Abu-Saba & Ogle, 2005) with relatively negligible absorption efficiency of dissolved selenium from water (Luoma et al., 1992; Reinfelder et al., 1997; Wang, 2001, as cited in Abu-Saba & Ogle, 2005). However, unlike zooplankton, the bivalves have been observed to accumulate the ingested selenium to concentrations markedly higher than present in the microbial/algal diet (Reinfelder et al., 1998, as cited in Abu-Saba & Ogle, 2005), in part due to their high assimilation rates of the cytosolic selenium, but also to their relatively low excretion rates (Reinfelder et al., 1997; Schlekat et al., 2000, as cited in Abu-Saba & Ogle, 2005). Suspended particulate selenium is the primary source of selenium bioaccumulated by bivalves.

Selenium Bioaccumulation by Fish and Waterfowl.

Given that benthic bivalve tissue selenium concentrations can be elevated, it is not surprising that the higher trophic level organisms that eat these bivalves will, in turn, exhibit elevated tissue selenium concentrations. In contrast, fish that feed primarily upon the planktonic food chain (i.e., such as juvenile striped bass feeding on zooplankton and other water column organisms) do not exhibit similarly elevated tissue selenium concentrations (Baines et al., 2002; Schlekat et al., 2002; Purkerson et al., 2003; Stewart et al., 2004, as cited in Abu-Saba & Ogle, 2005).

Although total selenium is used for the remaining analysis of selenium in the TMDL (due to lack of available data on other forms), examination of the different forms of selenium and their impacts on the beneficial uses in the watershed may be incorporated during implementation to evaluate site-specific selenium impacts.

6 SOURCE ASSESSMENT – DATA, PATHWAYS, SOURCES

Initial steps in the development of a TMDL include assessing sources and then linking the loads from those sources to concentrations in environmental compartments. A generalized conceptual model of the processes and environmental cycling of copper, mercury, nickel, and selenium is presented in the previous section; and the linkage between sources and pathways is presented in this section. Available information from the literature and watershed specific data useful for assessing sources are also presented. Finally, likely sources of copper, mercury, nickel, and selenium specific to the Calleguas Creek Watershed are examined.

6.1 Estimated Loading Contributions by Land Use Type

Runoff data categorized according to land use (land-use runoff data) and data from point source discharges (discharge data) are available from several sources, as shown in Table 28. This information is used to gain understanding about the relative contributions of metals and selenium from various pathways and sources.

Table 28. Summary of Land-Use Runoff and Discharge Data.

Data Source	Begin Date	End Date	Urban Land Use Sites	Agricultural Land Use Sites	Groundwater Discharge	POTW
205(J) Non Point Source Study	Nov-98	May-99	x	x		
Ventura County WPD	Feb-92	--	x	x		
Calleguas Creek Characterization Study(LWA, 1999)	Aug-98	May-99	x	x	x	x
Camrosa WRF	Dec-95	Dec-02				x
Camarillo WRP	Aug-98	--				x
Hill Canyon WWTP	Feb-94	--				x
Moorpark WWTP	Sep-97	--				x
Olsen Road WRP	Aug-93	May-99				x
Simi Valley WQCP	Dec-93	--				x
TMDL Work Plan Monitoring (LWA, 2004a)	Feb-04	Aug-04	x			

Estimated loading of metals and selenium in water, generated by the HSPF model described in the Linkage Analysis section using the land use data described above, are summarized below in Table 29 - Table 34. Average annual flow for each water year (October-Sept) is shown below in Figure 17. The contributions from groundwater and from POTWs tend to represent a larger proportion of the total load during years of lower annual flow, and a smaller proportion during years of higher annual flow (since these two sources are less affected than other sources by precipitation).

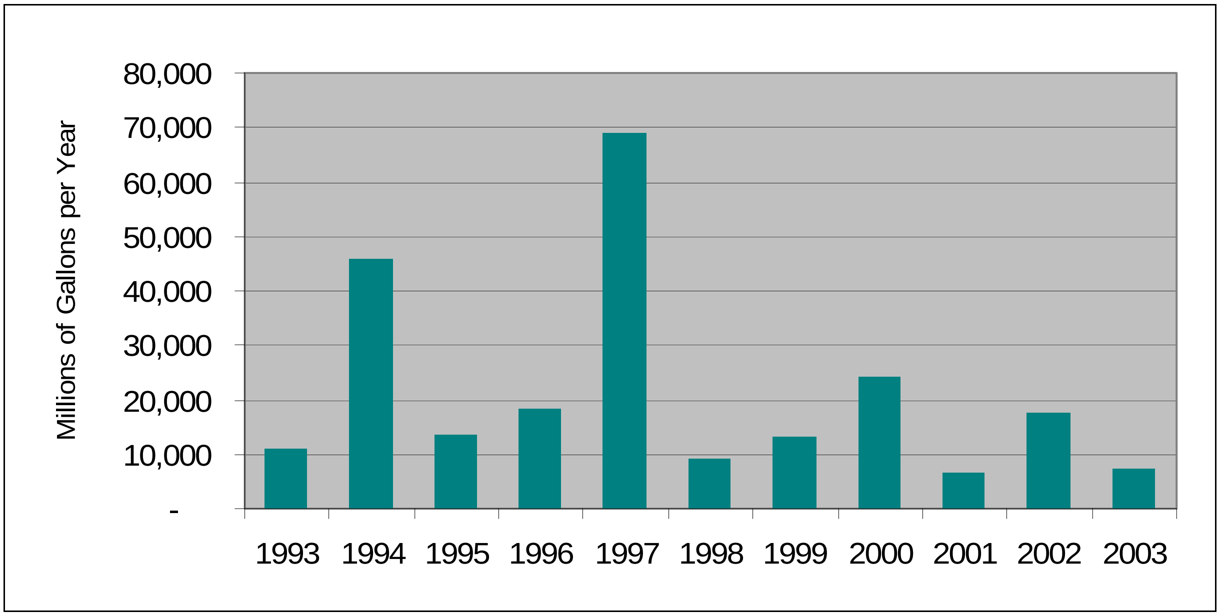


Figure 17. Annual Flow in the CCW, 1993-2003.

In the loading estimate tables presented below, the category ‘Urban’ is calculated as the sum of the following: residential, commercial, and industrial areas; plus runoff which lands on impervious surfaces and flows directly to drain systems (i.e. driveways and roads are included, but rooftops are not because most water landing on a rooftop usually runs off into the yard). The category ‘Groundwater’ represents seepage/exfiltration of groundwater into surface waters in the watershed. The category ‘Simi Well’ is based on monitoring data from five dewatering wells in Simi Valley, which discharge pumped groundwater to the storm drain system for the purpose of lowering the local water table. Although runoff from ‘Open Space’ has not been monitored explicitly, one monitoring site drains a lightly developed portion of Tapo Canyon which is considered representative of undeveloped open space.

Table 29. Estimated Total Copper Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	3,247	2,009	172	494	40	11	5,971
1994	68,316	210,502	313	508	37	13,355	293,033
1995	4,456	4,713	201	485	37	130	10,022
1996	7,372	26,077	215	489	38	138	34,329
1997	151,112	423,949	329	575	38	75,892	651,895
1998	1,933	252	156	469	28	2	2,841
1999	5,834	9,361	161	522	37	85	16,000
2000	24,147	55,460	210	521	33	839	81,208
2001	2,285	406	135	542	34	7	3,409
2002	23,579	37,529	174	540	35	496	62,353
2003	8,786	9,631	120	537	34	164	19,273
average	27,370	70,899	199	516	36	8,284	107,303
% of Total	26%	66%	0%	0%	0%	8%	100%

Table 30. Estimated Dissolved Copper Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	5	1.22	171.54	493.67	39.75	0.05	711.13
1994	84	72.3	312.94	508.12	37.41	47.08	1061.71
1995	8	3.01	201.19	485.15	36.72	0.69	734.52
1996	19	15.87	215.32	489.36	37.77	1.08	777.94
1997	124	104.45	329.39	574.64	37.86	116.02	1285.97
1998	2	0.12	155.81	468.89	28.45	0.01	655.29
1999	15	6.41	160.87	522.36	37.34	0.45	742.35
2000	47	29.53	209.88	520.5	32.76	5.98	845.27
2001	1	0.31	134.63	541.71	34.02	0.01	712.02
2002	42	17.16	173.81	539.86	34.98	3.19	811.28
2003	11	4.75	120.17	537.06	33.79	0.44	706.73
average	32	23	199	516	36	16	822
% of Total	4%	3%	24%	63%	4%	2%	100%

Table 31. Estimated Total Nickel Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	758	2,643	645	264	239	7	4,555
1994	38,621	223,913	1,688	267	212	7,150	271,844
1995	1,373	5,103	769	259	135	79	7,718
1996	2,990	35,141	1,008	262	197	92	39,691
1997	89,694	440,709	1,888	300	176	47,731	580,505
1998	181	301	535	268	130	1	1,416
1999	2,253	12,214	575	277	172	59	15,549
2000	12,575	66,986	962	288	143	605	81,559
2001	848	453	485	282	111	6	2,187
2002	12,802	48,225	860	293	317	354	62,853
2003	4,905	9,856	469	290	195	130	15,845
average	15,182	76,868	899	277	184	5,110	98,520
% of Total	15%	78%	1%	0%	0%	5%	100%

Table 32. Estimated Dissolved Nickel Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	41	3.955	645.049	263.775	239.225	0.252	1192.902
1994	2,248	1420.281	1687.98	266.541	211.985	512.042	6346.472
1995	85	13.147	768.906	259.267	135.029	5.136	1266.986
1996	461	136.14	1008.432	261.944	196.611	7.102	2070.758
1997	4,004	3015.696	1888.453	300.48	176.495	2214.111	11598.908
1998	8	0.359	534.662	267.948	129.597	0.038	940.736
1999	175	24.404	574.763	276.523	172.37	3.678	1226.967
2000	919	360.281	962.077	287.555	143.063	48.483	2720.278
2001	8	0.972	485.448	282.438	111.433	0.083	888.731
2002	692	78.178	860.422	293.237	317.327	19.915	2260.859
2003	89	12.18	468.813	289.961	194.562	3.002	1057.069
average	794	461	899	277	184	256	2,870
% of Total	28%	16%	31%	10%	6%	9%	100%

Table 33. Estimated Total Mercury Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	7.9	7.0	0.021	1.2	0.012	0.3	16.5
1994	31.5	47.3	0.047	1.2	0.012	77.1	157.2
1995	9.1	8.8	0.025	1.2	0.012	2.1	21.2
1996	12.3	12.7	0.030	1.2	0.012	4.6	30.9
1997	43.0	76.1	0.058	1.4	0.012	199.4	319.9
1998	6.0	2.4	0.022	1.3	0.011	0.1	9.8
1999	18.0	16.0	0.023	1.3	0.012	2.6	37.9
2000	23.7	26.1	0.035	1.4	0.012	20.9	72.2
2001	5.3	2.8	0.018	1.4	0.012	0.1	9.6
2002	28.4	25.5	0.029	1.4	0.012	18.0	73.3
2003	11.7	11.3	0.017	1.4	0.012	2.4	26.7
Average	17.9	21.5	0.030	1.3	0.012	29.8	70.5
% of Total	25%	30%	0%	2%	0%	42%	100%

Table 34. Estimated Total Selenium Loading in CCW by Land Use Type (Lbs/Yr).

Year	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
1993	139.1	46.41	833.01	75.42	10.45	0.20	1,104.61
1994	1469.0	4,380.27	1,698.52	72.12	10.17	269.14	7,899.16
1995	176.1	114.81	1,030.06	69.35	10.11	2.80	1,403.14
1996	257.1	629.42	1,077.66	72.50	9.98	3.21	2,049.86
1997	3039.1	9,799.03	1,927.81	81.53	10.29	1,492.08	16,349.38
1998	92.8	6.70	858.60	73.88	7.84	0.04	1,039.85
1999	212.2	236.61	844.18	74.69	10.07	1.83	1,379.62
2000	595.2	1,338.73	1,143.29	76.56	8.96	22.57	3,185.18
2001	83.5	12.63	669.00	76.07	9.17	0.14	850.54
2002	607.5	786.59	924.57	78.67	9.27	11.12	2,417.79
2003	229.3	178.52	622.86	76.32	9.24	3.20	1,119.44
Average	627.3	1,593.6	1,057.2	75.2	9.6	164.2	3,527.1
% of Total	18%	45%	30%	2%	0%	5%	100%

6.2 Pathways

This section discusses the pathways by which metals and selenium move from various sources to receiving waters. The pathways considered here include urban and agricultural runoff, NPDES discharges, groundwater discharges, erosion/sediment transport, and atmospheric deposition. Throughout the source assessment a distinction is made between pathways and sources in order to better understand the relationship between conveyance mechanisms and actual sources. However, the assignment of allocations will be primarily to the pathways discussed in this section. The source information is provided to help in the implementation of control strategies to reduce contributions through these pathways. Pathways are described below, and individual sources contributing to these pathways are discussed in later sections.

The distinction between sources and pathways is important because ambient sources of metals and selenium (such as natural soil concentrations, atmospheric deposition, and groundwater seepage) contribute to the loading discharged from each land use shown in the tables above. Thus, the load of a given constituent carried in runoff from an agricultural, urban, or open space area can result from anthropogenic and/or non-anthropogenic sources.

Agricultural Runoff

As indicated in the tables presented above, runoff from agricultural land can be an important source of metals and selenium to surface waters in the CCW. Sources potentially contributing to this pathway include use of pesticides/fertilizers, natural soil concentrations, groundwater, imported water, and aerial deposition, and imported water.

Urban Runoff

Runoff from urban land areas such as residential, industrial/commercial, and impervious surfaces is most significant in the case of copper (especially from impervious surfaces, i.e. brake pad residues). Sources potentially contributing to this pathway include: natural soil concentrations, pesticides/fertilizers, aerial deposition, automobiles, architectural materials, use of commercial products, and imported water.

Open Space Runoff

Runoff from undeveloped open space is an important source of metals and selenium for those constituents where natural soil concentrations and atmospheric deposition represent significant contributions to the total loading. This is most true in the case of mercury.

Groundwater Seepage and Dewatering

Mobilization of groundwater by natural seepage and human activity is a potentially important source of metals and selenium, depending on whether dissolved or total concentrations are considered. Groundwater is a major contributor for selenium, and may be a relevant factor for copper and/or nickel. The primary source suspected to contribute to this pathway is natural soil concentrations.

NPDES Discharges

Three major, nine minor, and ten general NPDES permits are issued in the CCW (Table 35). About fifty industrial stormwater permits (Table 36) and about one hundred and fifty construction stormwater permittees are also issued at the present time. Some of these permitted discharges may contribute metals and selenium to receiving waters by way of discharged water and/or sediment. Of the various NPDES dischargers in the watershed, only POTWs are specifically included in the tables presented above. Loadings from other NPDES dischargers are inherently included in the urban runoff, open space, or commercial/industrial categories. Sources potentially contributing to this pathway include pesticides/fertilizers, architectural materials, industrial/commercial processes, use of commercial products, and imported water.

Table 35. Major, Minor, and General NPDES Permittees in the CCW.

Permit Type	Receiving Water	Discharger	Facility
Major	Conejo Creek	Camarillo Sanitary District	Camarillo WRP, NPDES
	Arroyo Simi	Simi Valley, City Of	Simi Valley WWTP, NPDES
	Arroyo Conejo	Thousand Oaks City Of DPW	Hill Canyon WWTP, NPDES
	All	Municipal Separate Storm Sewer Systems	Stormwater NPDES permit
Minor	Calleguas Creek	Camrosa Water District	Camrosa WRP, NPDES
	Arroyo Simi	Cemex, Inc	Cemex, Inc
	Arroyo Conejo	Conexant Systems, Inc.	Tank Leak-Hillcrest Facility
	Arroyo Conejo	Emery Worldwide	Pti Technologies
	Calleguas Creek	Exxon Mobil Refining Supply Co.	RAS#7-8712
	Arroyo Conejo	Teleflex Inc.	The Talley Site, Newbury Park
	Arroyo Santa Rosa	Thousand Oaks City Of DPW	Olsen Road WWRP, NPDES
	Calleguas Creek	Tosco Corp.	Tosco Gasoline Service Station
	Arroyo Las Posas	Ventura Co Water Works Dist.	Moorpark WWTP
General	Arroyo Conejo	Exxon Mobil Oil Corporation	Tank Leak-Mobil Ss#11-H7a
	Calleguas Creek	Naval Base, Point Mugu	Tank Leak-Navy Exchange Gas St
	Arroyo Conejo	Unocal Corp.	Former Unocal Station #4687
	Arroyo Conejo	Ventura County Fire Dept.	Ventura County Fire Station#30
	Arroyo Las Posas	Calleguas Municipal Water Dist	Grimes Canyon Road Wellfiel
	Arroyo Las Posas	Calleguas Municipal Water Dist	Grimes Canyon Wellfield #2
	Arroyo Las Posas	Calleguas Municipal Water Dist	Well Nos. ASR-17 and ASR-18
	Arroyo Simi	Calleguas Municipal Water Dist	Fairview Pump Station
	Arroyo Simi	Calleguas Municipal Water Dist	Calleguas Conduit North Branch
	Arroyo Conejo	Thousand Oaks City Of DPW	City of Thousand Oaks

Table 36. Industrial Stormwater NPDES Permittees in the CCW.

RECEIVING WATER NAME	FACILITY SITE NAME	FACILITY CITY	FACILITY SITE LOCATION
ARROYO SIMI	SIMI AUTO WRECKING	SIMI VALLEY	900 WEST LOS ANGELES AVE
ARROYO CONEJO	BAXTER HEALTHCARE HYLAND	THOUSAND OAKS	1700 RANCHO CONEJO BLVD
ARROYO CONEJO	HILL CANYON TREATMENT PLANT	CAMARILLO	9600 SANTA ROSA RD.
ARROYO CONEJO	UPS - CAWES	NEWBURY PARK	1501 RANCHO CONEJO RD
ARROYO CONEJO S. BRANCH	PARKER SYMETRICS	NEWBURY PARK	3353 OLD CONEJO ROAD
ARROYO CREEK	FLUID INK TECHNOLOGY , INC	MOORPARK	5360 NORTH COMMERCE ST
ARROYO LAS POSAS	MOORPARK WWTP	MOORPARK	9550 LOS ANGELES AVE.
ARROYO LAS POSAS	SIMI VALLEY	SIMI VALLEY	5596 BENNETT ROAD
ARROYO SIMI	ANDERSON RUBBISH DISPOSAL	SIMI VALLEY	4590 INDUSTRIAL STREET
ARROYO SIMI	CITY CONCRETE PRODUCTS	SIMI VALLEY	360 WEST LOS ANGELES AVE
ARROYO SIMI	GI INDUSTRIES	SIMI VALLEY	195 W. LOS ANGELES AVENUE
ARROYO SIMI	NATIONAL READY MIXED CONCRETE	MOORPARK	13950 LOS ANGELES AVE
ARROYO SIMI	OLOUGHLIN & COMPANY	SIMI VALLEY	1371 KUEHNER DR
ARROYO SIMI	POLYTAINER INC	SIMI VALLEY	2220 SHASTA WAY
ARROYO SIMI	PS EMC WEST LLC	MOORPARK	14370 WHITE SAGE RD STE 100
ARROYO SIMI	SIMI VALLEY LANDFILL	SIMI VALLEY	2801 MADERA RD
ARROYO SIMI	SIMI VALLEY RECYCLING CENTER	SIMI VALLEY	400 WEST LOS ANGELES AVE
ARROYO SIMI	SPECIAL DEVICES, INC	MOORPARK	14370 WHITE SAGE RD
ARROYO SIMI	TANNER AND SHENKEL TRUCK FAC	SIMI VALLEY	1750 TAPO STREET
ARROYO SIMI	VIKING ELECTRONICS INC	MOORPARK	5455 ENDEAVOUR CT
ARROYO SIMI FLOOD CONTROL	PRE-CON PRODUCTS	SIMI VALLEY	240 W. LOS ANGELES AVE
ARROYO TAPO CANYON	TAPO ROCK AND SAND	SIMI VALLEY	5023 TAPO CANYON ROAD
CALLEGUAS	IMATION CORP	CAMARILLO	350 S LEWIS RD
CALLEGUAS CREEK	CAMARILLO AIRPORT, VENTURA COUNTY	CAMARILLO	295 DURLEY AVENUE
CALLEGUAS CREEK	CAMROSA WATER RECLAMATION FAC	CAMARILLO	1900 LEWIS RD
CALLEGUAS CREEK	MOORPARK	MOORPARK	750 E. LOS ANGELES AVE
CALLEGUAS CREEK	WEYERHAEUSER CO	CAMARILLO	2000 PLEASANT VALLEY RD
CALLEGUAS CREEK PACIFIC	CONSOLIDATED FREIGHTWAYS OXN	CAMARILLO	355 S DAWSON DR
CONEJO CREEK	MAINTENANCE & OPERATIONS	NEWBURY PARK	310 E KELLY RD
CONEJO CREEK	NEWBURY PARK-MEDTRANS	NEWBURY PARK	1090 LAWRENCE DR STE 106-107
CONEJO CREEK	SIEMENS SOLAR IND	CAMARILLO	4650 ADOHR LN.
CONEJO CREEK	THOUSAND OAKS TRANS	THOUSAND OAKS	2323 MOORPARK RD.
CONEJO CREEK	VITESSE SEMICONDUCTOR CORP.	CAMARILLO	741 CALLE PLANO
CONEJO CREEK & CALLEGUAS	CONEXANT SYSTEMS INC	NEWBURY PARK	2427 WEST HILLCREST DR
GRABBER CANYON DRAINAGE	SOUTHDOWN INC MOORPARK FAC	MOORPARK	9035 ROSELAND AVE
PACIFIC OCEAN	CONSOLIDATED FREIGHTWAYS SIM	SIMI VALLEY	91 WEST EASY STREET
CONEJO CREEK	GC INTERNATIONAL	CAMARILLO	4671 CALLE CARGA
PACIFIC OCEAN	KAVLICO CORP	MOORPARK	14501 LOS ANGELES AVE
PACIFIC OCEAN	POINT MUGU SITE	POINT MUGU	311 MAIN RD STE 1 CODE N45V
PACIFIC OCEAN	STANDARD ABRASIVES INC	SIMI VALLEY	4201 GUARDIAN STREET
REVLON SLOUGH	PROCTER & GAMBLE PAPER CO	OXNARD	800 NORTH RICE AVENUE
REVLON SLOUGH	VIKING FREIGHT INC	OXNARD	3501 STURGIS RD
REVOLON SLOUGH	DEL NORTE REG RECY & TRNS STN	OXNARD	111 S. DEL NORTE BLVD
CALLEGUAS CREEK	SEMTECH CORP	CAMARILLO	200 FLYNN ROAD
SIMI VALLEY ARROYO	SCHLUMBERGER TECHNOLOGIES	SIMI VALLEY	85 MORELAND ROAD
TRIPAS & L. TRIPAS CANYONS	SIMI VALLEY OPERATIONS	SIMI VALLEY	5131 TAPO CANYON ROAD
WESTLAKE LAKE	TERADYNE INC B5	THOUSAND OAKS	3500 WILLOW LANE
CALLEGUAS CREEK	PARKER HANNIFIN	CAMARILLO	3800 CALLE TECATE
CALLEGUAS CREEK	PLEASANT VALLEY SCHOOL DISTRICT	CAMARILLO	600 TEMPLE
CALLEGUAS CREEK	SHINE N PRETTY	CAMARILLO	456 CONSTITUTION
CALLEGUAS CREEK	IMATION	CAMARILLO	350 S. LEWIS
CALLEGUAS CREEK	ROADRUNNER SHUTTLE	CAMARILLO	537 CONSTITUTION
CALLEGUAS CREEK	CAMARILLO RECYCLING	CAMARILLO	532 DAWSON DR.
CONEJO CREEK	PACIFIC ROCK	CAMARILLO	1000 PANCHO RD.
REVOLON SLOUGH	7UP RC BOTTLING CO. OF S. CALIFORNIA	CAMARILLO	166 N. AVIADOR

Groundwater Discharges

Loading of metals and selenium from groundwater associated with exfiltration / passive seepage varies significantly among constituents (dewatering of groundwater is considered separately, as a NPDES discharge). For total mercury and total copper the contribution seems negligible. In the case of dissolved copper and total selenium, groundwater discharge may represent a important contribution to the overall loading. Natural soil concentrations are the most likely primary source responsible for groundwater concentrations; although use of pesticides, fertilizers and other commercial products as well as industrial/commercial processes may also contribute.

Erosion and Sediment Transport

The contribution from erosion and sediment transport is not explicitly captured in the data summary tables presented above. However, these processes are associated with runoff from all land uses and also some NPDES discharges. Sources potentially contributing metals and selenium to this pathway include natural concentrations in soil, mining/extraction activities, pesticides/fertilizers, and aerial deposition.

Atmospheric Deposition

Deposition from the atmosphere is often a significant source of heavy metals and other toxic trace elements to waterbodies (Landis and Keeler 2002). Atmospheric deposition is measured as the sum of wet and dry deposition. Wet deposition occurs as contaminants in both the particulate and gaseous phase are scavenged in the atmosphere by water droplets, which are deposited to land and water during rain and snow events.

Unlike wet deposition which is episodic, dry deposition is continuous. Contaminants bound to particles in the atmosphere, also known as aerosols, settle and dry deposit to land and water. The frequency of dry deposition depends upon the concentration and size of aerosols; meteorological factors such as relative humidity, wind speed, and atmospheric stability; and the characteristics of the intercepting surface (Caffrey and Ondov 1998). To rigorously determine dry deposition of trace elements from the atmosphere requires more information than is provided in most data sets. Therefore, the assumption of a relatively stable environment is often made so that the dominant factor controlling the frequency of deposition of particulate matter is aerosol size. Small aerosols are buoyant and generally have small mass such that deposition is predominantly controlled by Brownian Diffusion. Therefore, the velocity of deposition of small particles is relatively slow. In contrast, large aerosols are more strongly affected by other environmental factors such that deposition velocities are greater than for small aerosols.

Estimates of both wet and dry deposition of metals and selenium to the Calleguas Creek Watershed are presented below in Table 37 and the methodologies used to develop the estimates are discussed below. Because dry deposition of mercury in the gaseous phase represents a significant source of the metal to surfaces (Laurier et al. 2003), an estimate of this source was included. Note that these estimates represent total deposition to the watershed; and are not representative of the amount of metals and selenium actually reaching receiving waters.

Table 37. Estimates of the annual flux and mass of trace elements deposited to the Calleguas Creek watershed via wet and dry deposition.

Constituent	Dry Deposition Flux ($\mu g/m^2$ yr)	Mass Dry Deposited to Watershed (Kg/yr)	Wet Deposition Flux ($\mu g/m^2$ yr)	Mass Wet Deposited to Watershed (Kg/yr)	Total Deposition Flux ($\mu g/m^2$)yr	Mass Deposited to Watershed (Kg/yr)	Mass Deposited to Watershed (Lbs/Yr)
Copper	990	881	403	359	1393	1240	2734
Mercury	646	575	19	17	665	592	1305
Nickel	558	497	155	138	713	635	1400
Selenium	20	18	320	285	340	303	668

Dry Deposition

Estimates of dry deposition of copper, mercury, nickel, and selenium to the Calleguas Creek watershed were calculated given atmospheric concentration data taken from the California Air Resources Board (CARB), utilizing typical values for deposition velocities taken from the literature based upon particle size. To determine the mass of contaminants entering the watershed from the atmosphere through dry deposition annually, the following calculations were performed:

$F = C * V_{dep}$ *where F is the Flux of the contaminant* ($\mu g / m^2$ *yr); C is the concentration of contaminant in the atmosphere* ($\mu g / m^3$)*; and* V_{dep} *is the Deposition Velocity (m/yr)*

$M = F * A$ *where M is the mass of contaminant annually deposited to the watershed (Kg/yr) and A is the Area of the watershed (m2)*

Daily particulate concentrations (µg m-3) of each contaminant were determined for the years 1992 through 1996 (most current dataset available) by CARB at three Southern California sites: North Long Beach, Azusa and Riverside. Since dry deposition of aerosols is strongly size dependent, CARB monitors atmospheric aerosols concentrations via a dichotomous sampler which measures two size fractions separately, fine (0 to 2.5 µm) and coarse (2.5 to 10 µm). Deposition velocities based on those size fractions were used to estimate fluxes and deposition of the contaminants to the watershed. It is important to note that aerosols greater than 10µm do exist in relatively small concentrations. However, because of their large size, these particles generally deposit quickly and near their source. Though this method of dry deposition estimation is commonly used and should be reflective of the average deposition across the watershed, it does not take the >10µm size fraction into account, and therefore may not fully account for localized hot spots.

Typical values for deposition velocities (Vdep) were obtained from the literature, and used in the calculation of the flux of particulate copper, mercury, nickel, and selenium to the watershed. Since the amount of dry deposition is highly dependent on the size of the aerosol, two values for deposition velocity were used for each trace element; a typical minimum value was applied to the fine fraction, and a value more representative of a medium size aerosol was applied to the coarse fraction. Where possible, these values were obtained from studies conducted in Southern California, in the State of California, or coastal cities. These values are shown in Table 38.

Table 38. Values for dry deposition velocities for trace elements in coarse and fine size fractions.

Constituent	V_{dep} Coarse (cm/s)	V_{dep} Fine (cm/s)
Copper	0.26 [a]	0.033 [a]
Mercury	0.20 [b]	0.100 [c]
Nickel	0.41 [a]	0.180 [a]
Selenium	0.10 [d]	0.005 [d]

a. Sabin et al. (2004); b. Hoff et al. (1996); c. Lindberg and Stratton (1998); d. Haygarth et al. (1994)

Dry deposition of mercury in the gaseous phase, particularly as reactive gaseous mercury (RGHg), contributes significantly to atmospheric sources of mercury to land and water (Lindberg and Stratton 1998; Mason et al. 2001; Laurier et al. 2003). It was determined by Poissant et al. (2004) that 90% of dry deposition of mercury to the St. Francois wetlands was due to RGHg. Because dry deposition of mercury is comprised of particulate Hg and the two gaseous phases, RGHg, and elemental Hg, and deposition of elemental Hg was found to be negligible, dry deposition of RHG in this case was 9 times greater than deposition of the particulate phase. This finding is supported by two other studies in which dry deposition of RGHg was found to be 5 to 10 times greater than that of particulate Hg (Shia et al. 1999; Bullock Jr. et al. 2000). For the estimates included here, it was assumed that dry deposition of gaseous mercury was 5 times greater than the dry deposition of particulate mercury.

Estimates of atmospheric deposition to the watershed were calculated assuming a watershed area of approximately 220,000 acres; including the areas of Arroyo Simi, Las Posas, Conejo Creek, Calleguas Creek, Revolon Slough and Mugu Lagoon.

The estimates of annual dry deposition fluxes to the Calleguas Creek watershed compare well to values found in the literature. In general, they are slightly lower than values for more industrialized areas. For example, it was estimated that 990 µg/m2 yr of copper is dry deposited to the Calleguas Creek watershed annually versus 1300 to 3650 µg/m2 yr calculated for the Great Lakes, including Lake Michigan near Chicago (Paode et al. 1998; Sweet et al. 1998). Similarly for selenium, it was estimated that 20 µg/m2 yr enters the watershed via dry deposition versus the Great Lakes where 52 to 95 µg/m2 yr was determined (Sweet et al. 1998), though values as low as 8 µg/m2 yr have been found in Southern Lake Michigan (Caffrey and Ondov 1998). Dry deposition of nickel to the watershed is comparable to values for the Great Lakes; 320 to 570 µg/m2 yr (Caffrey and Ondov 1998; Paode et al. 1998; Sweet et al. 1998).

It should be noted that estimates for the watershed are significantly less than calculations performed at a Los Angeles coastal site by the Southern California Coastal Water Research Project where measured daily fluxes suggest that 8669 µg/m2 yr of copper and 2154 µg/m2 yr of nickel are dry deposited. This area is highly urbanized however (Sabin et al. 2004). Comparison of dry deposition of mercury is difficult as few studies consider gaseous deposition.

Wet Deposition

Estimates of wet deposition of copper, mercury, nickel, and selenium to the Calleguas Creek watershed were calculated using typical concentrations in precipitation obtained from the literature and measurements of rainfall to the watershed area for the years from 1903 through 2004. Rainfall data was acquired from

Ventura County Watershed Protection District. Wet deposition to the watershed was calculated using the following equations:

$F = C * H_{rain}$ *where F is the flux of the contaminant ($\mu g / m^2 yr$); C is the concentration of the contaminant in precipitation ($\mu g/m^3$); and H_{rain} is the average height of rain annually (m/yr)*

$M = F * A$ *where M is the mass of contaminant annually deposited to the watershed (Kg/yr) and A is the area of the watershed (m2)*

Values for all the trace elements other than mercury were obtained from sites near the watershed. Specifically they are coastal sites along the Los Angeles River watershed (Sabin et al, 2004). Because no values for mercury in precipitation could be found near the watershed, the median value was chosen from a study conducted by Mason et al. (1997) at a rural site on the Chesapeake Bay which has periodic urban/industrialized air-shed influence. The trace element concentration in precipitation values used to calculate wet deposition in the Calleguas Creek watershed are shown in Table 39.

Monitoring of precipitation at sites in the watershed has been ongoing since 1903. An average annual precipitation height (e.g. inches of rain) was determined from this dataset and applied to the above calculations with an approximate watershed area of 220,000 acres to estimate wet deposition of copper, mercury, nickel, and selenium.

It is estimated that approximately 94% of the atmospheric deposition of selenium, 40% of copper and 30% of nickel occurs in the aqueous phase. In contrast only 3% of Hg is wet deposited, reflecting the high rate of dry deposition of the gaseous phase.

Table 39. Trace Element Concentrations in Precipitation Used to Estimate Wet Deposition in the CCW.

Constituent	Concentration in Precipitation (µg/L)
Copper	0.87 [a]
Mercury	0.04 [b]
Nickel	0.33 [a]
Selenium	0.69 [a]

a. Sabin et al. (2004); b. Mason et al. (1997)

Pathways - Summary / Conclusions

Pathways by which metals and selenium move from various sources to receiving waters include runoff from land surfaces (agricultural, urban, open space), NPDES discharges, groundwater exfiltration/discharges, erosion and associated sediment transport, and atmospheric deposition. Throughout the source assessment, a distinction is made between pathways and sources in order to better understand the relationship between conveyance mechanisms and actual sources. Agricultural runoff represents an important contribution for all of the constituents included in this source analysis (in the case of selenium this is due primarily to the use of groundwater for irrigation). The significance of POTWs, urban runoff, groundwater, runoff from open space, and other factors varies by constituent.

6.3 Sources (General)

This section describes general sources which contribute metals and/or selenium to receiving waters of the Calleguas Creek Watershed. Following this section, sources specific to each constituent are discussed.

Imported Water / Water Supply

Imported water used in the CCW is eventually received by POTWs or used for agricultural irrigation, landscaping, washing cars, and other purposes that result in runoff into receiving waters or infiltration of groundwater. Drinking water and irrigation water are imported to the watershed from the State Water Project and the Freeman Diversion, respectively. The State Water Project pumps water from the San Francisco Bay Delta which originates in northern and central California, including the Central Valley. Water from the mountains in Northern and Central California may contain metals and selenium resulting from mining activities and/or ambient sources. The Central Valley is cultivated extensively and a range of pesticides have been used there which may include copper and historically mercury.

The detection limits used to measure concentrations of metals and selenium in the imported water are high and result in non-detected values for copper, nickel mercury and selenium. To estimate the possible contribution from imported water, monitoring data from stations at the mouths of the Sacramento and San Joaquin Rivers (the major tributaries to the Delta) are presented. The actual quality of the imported water may vary from the data presented below as a result of treatment at drinking water treatment facilities. A summary of monitoring results from samples collected during 1998-2000 is presented below, in Table 40.

Since imported water eventually finds its way into POTW effluent, agricultural runoff, urban runoff, and/or groundwater; this potential source is implicitly considered when land-use runoff and discharge data are examined for urban runoff, POTWs, and groundwater.

It should be noted that the constituent concentrations in the water supply do not necessarily reflect the concentrations in domestic water. Treatment and purification can remove some constituents, whereas other factors, such as corrosion of copper piping, can increase them. Selenium in the source water is likely dissolved, thus very little is removed during purification. While copper concentrations in other water supply systems have been shown to be 5-6 g/L , studies of domestic water show that copper piping can increase copper in water. A report by Murphy (1993) confirms that non-corrosive water can have approximately 30 g/L copper, whereas corrosive water can have as much as 600 g/L.

Table 40. Concentration of Metals and Selenium in Sacramento and San Joaquin Rivers (1998-2000).[1]

Sample	Cu		Hg		MeHg		Ni		Se		Zn	
Date	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Result	MDL
02/04/1998	6.721	0.002	0.0189	0.0001			11.77	0.00	0.183	0.020	16.430	0.007
02/04/1998	4.118	0.002	0.0096	0.0001			5.17	0.00	0.197	0.020	7.570	0.007
04/16/1998	3.103	0.004	0.0006	0.0001			3.69	0.00		0.020	4.801	0.008
04/16/1998	2.468	0.004	0.0049	0.0001			2.99	0.00	0.430	0.020	3.269	0.008
07/29/1998	2.808	0.009	0.0052	0.0001			2.90	0.00	0.160	0.020	4.788	0.032
07/29/1998	2.104	0.009	0.0021	0.0001			1.77	0.00	0.190	0.020	3.390	0.032
02/10/1999	2.903	0.037	0.0046	0.0001	0.1140	0.0040	5.33	0.02	0.087	0.020	3.134	0.006
02/10/1999	2.979	0.037	0.0056	0.0001	0.1460	0.0040	5.28	0.02	0.127	0.020	3.931	0.006
04/21/1999	3.059	0.001	0.0035	0.0001	0.0480	0.0030	3.67	0.00	0.099	0.020	3.773	0.001
04/21/1999	2.940	0.001	0.0067	0.0001			3.03	0.00	0.064	0.020	3.250	0.001
07/21/1999	3.842	0.027	0.0100	0.0001	0.0790	0.0030	5.11	0.01	0.104	0.030	5.802	0.002
07/21/1999	4.143	0.027	0.0084	0.0001	0.0630	0.0030	5.16	0.01	0.123	0.030	5.837	0.002
02/09/2000	3.334	0.031	0.0022	0.0000	0.2800	0.0040	2.99	0.00	0.115	0.030	4.310	0.039
02/09/2000	3.066	0.031	0.0067	0.0000	0.0640	0.0040	2.31	0.00	0.128	0.030	2.932	0.039
07/19/2000	3.396	0.014		0.0000	0.0430	0.0050	5.34	0.01	0.104	0.030	5.531	0.015
07/19/2000	2.941	0.014		0.0000	0.0640	0.0050	3.44	0.01	0.099	0.030	3.997	0.015
02/14/2001	4.613	0.002	0.0017	0.0000		0.0050	6.50	0.03		0.030	7.022	0.014
02/14/2001	4.811	0.002	0.0058	0.0000		0.0050	6.73	0.03	0.136	0.030	7.055	0.014
08/07/2001	3.300	0.002	0.0108	0.0000	0.3315	0.0200	4.75	0.03	0.110	0.030	4.710	0.014
08/07/2001	2.625	0.002	0.0050	0.0000	0.1853	0.0200	2.25	0.03	0.115	0.030	2.225	0.014
07/30/2002	3.215	0.010	0.0049	0.0000		0.0001	4.07	0.05	0.133	0.030	3.979	0.011
07/30/2002	3.121	0.010	0.0055	0.0000		0.0001	3.81	0.05	0.105	0.030	3.724	0.011
08/15/2003	3.376	0.039	0.0058	0.0007	0.0828	0.0239	3.88	0.08	0.063	0.030	4.906	0.047
08/15/2003	2.625	0.039	0.0033	0.0007	0.0560	0.0189	2.52	0.08		0.030	2.705	0.047
average =	3.400	0.015	0.006	0.0001	0.120	0.008	4.353	0.019	0.137	0.026	4.961	0.016

[1] All data for Water Column Total (Unfiltered). All units are ug/L. Source: San Francisco Estuary Institute, Regional Monitoring Program, www.SFEI.org.

Soil Concentrations - Metals and Selenium

Many soils within the watershed naturally contain measurable concentrations of metals and/or selenium. Since these natural concentrations are often correlated with specific soil types, an examination of soil composition throughout the watershed is essential to the source assessment.

An estimate of metals and selenium content in soils of the CCW is presented below, followed by a summary of soils data from Naval Air Weapons Station, Point Mugu.

Concentrations in CCW Soils

Soil types occurring in the CCW are shown in Figure 18, based on the Soil Survey Geographic (SSURGO) database from the Natural Resources Conservation Service (NRCS). A study completed in March of 1996 for the Kearney Foundation of Soil Science, at the University of California's Agriculture and Natural Resources Division, evaluated concentrations of 46 trace and major elements in 50 benchmark soils selected from throughout the state (Bradford et al, 1996). In combination, these two resources provide the capability to estimate the natural concentrations of metals and selenium in CCW soils.

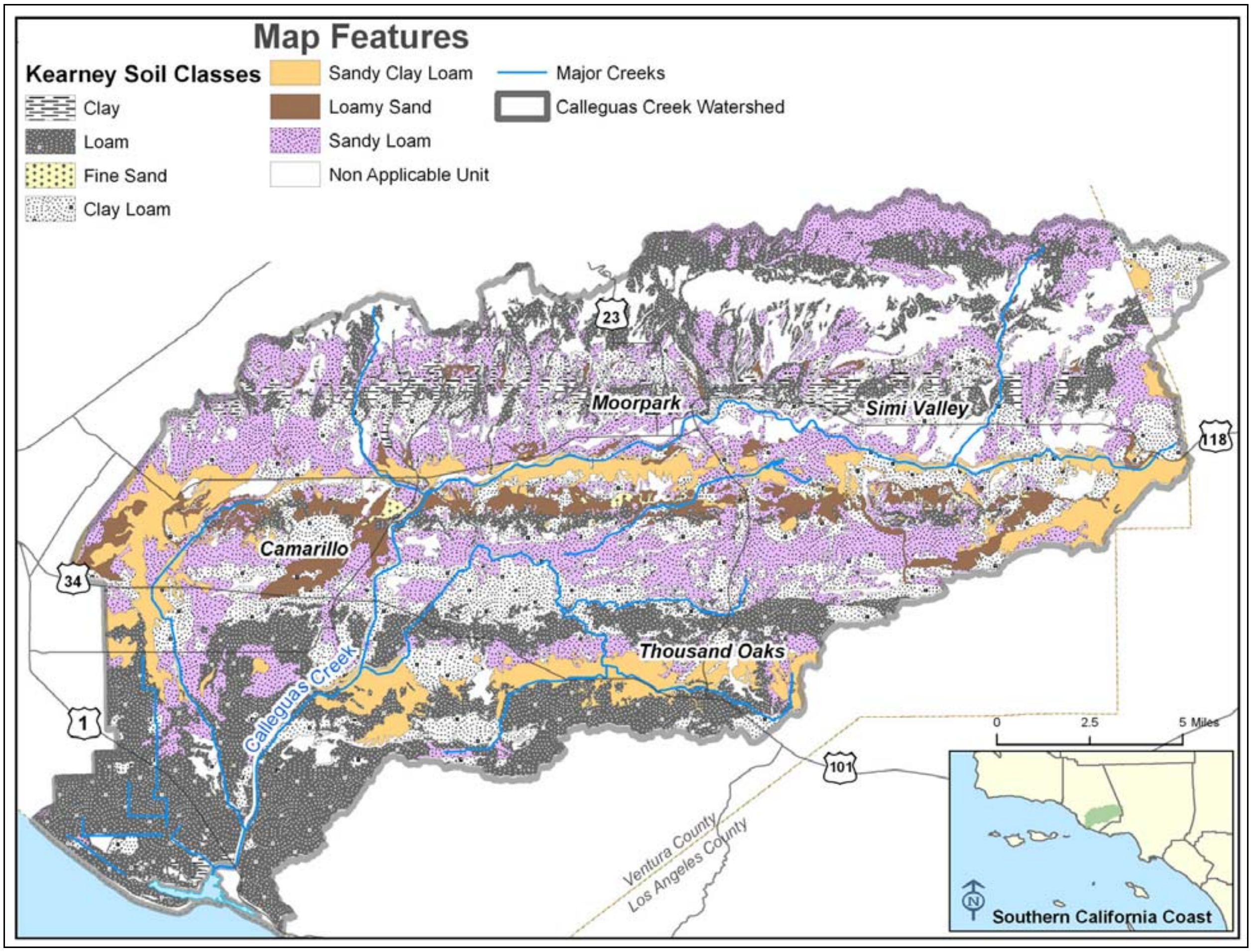


Figure 18. Surface Soils of the CCW - Eight Generalized Soil Classes (Natural Resources Conservation Service, Soil Survey Geographic (SSURGO) Database).

For the purpose of this source assessment, the 50 benchmark soils evaluated in the Kearny study are aggregated into eight general soil classes (e.g. clay, loam, sand, etc) with an average concentration of metals and selenium calculated for each. GIS analysis of the SSURGO soils layer, based on the same eight classes, provides the total acres of each soil type in the CCW. Individual soils from Kearney and/or SSURGO not identified as falling into one of the eight selected categories are designated as 'unidentified.'

The average concentrations and acreage calculations for each soil type are presented in Table 41, along with a watershed-wide average natural soil concentration for each TMDL constituent. The watershed-wide concentration is calculated as the weighted average concentration, according to the number of acres for each soil type. The average soil concentrations predicted for mercury and nickel are actually higher than the Effects Range Low (ERL) sediment guideline value, suggesting that natural soil concentrations may cause exceedances of the sediment guideline.

Three soil types shown below in Table 41 (clay, clay loam, and sandy clay loam) are noticeably higher in concentrations of both copper and nickel, relative to the other soil types. This may provide information useful for implementing the load allocations for these two constituents, if areas containing primarily these soil types can be targeted for erosion control measures.

Table 41. Acreages and natural concentrations for soil types found in the CCW, based on GIS analysis and Kearny benchmark soil concentrations.

Soil Type	Acres in CCW	% of All Acres in CCW	% of Identified Acres	Cu (mg/Kg)	Hg (mg/Kg)	Ni (mg/Kg)	Se (mg/Kg)
clay	4,458	2.0%	2.6%	34.50	0.32	139.00	0.10
clay loam	44,720	20.4%	26.4%	36.44	0.31	70.37	0.07
fine sand	1,498	0.7%	0.9%	14.05	0.10	24.50	0.08
Loam	63,780	29.1%	37.6%	15.09	0.25	20.50	0.03
loamy sand	4,466	2.0%	2.6%	22.05	0.22	56.50	0.02
sandy clay loam	6,829	3.1%	4.0%	96.40	0.27	51.00	0.02
sandy loam	43,838	20.0%	25.8%	21.33	0.18	31.67	0.04
unidentified	49,751	23%	NA	--	--	--	--
Sum	219,339	100%	100%	NA	NA	NA	NA
Average [1]	NA	NA	NA	26.29	0.25	41.86	0.04
ERL [2]	NA	NA	NA	34.0	0.15	20.9	--

[1] Average concentrations shown here are weighted based on '% of Identified Acres' for each soil type.

[2] SQuiRTs sediment guidelines from NOAA, effects range low (ERL) values.

Concentrations for each soil type presented above are used in combination with soil erosion estimates generated by an erosion model to predict loading of metals and selenium resulting from natural soil concentrations.

Sediment erosion was modeled for surface and rill/sheet erosion, but did not include in-stream channel erosion. The sediment erosion modeling was comprised of two GIS based models: (1) RUSLE: a gross sediment delivery model, and (2) SEDMOD: a sediment delivery ratio model that provided the final result of net sediment delivery to streams in tons/acre/year. The final sediment delivery figures reflect an average hydrologic regime as the models were developed, in part, on long term rainfall data.

The Revised Universal Soil Loss Equation, commonly known as RUSLE, is a sheet and rill erosion model developed and used by the U.S. Dept. of Agriculture's Natural Resource Conservation Service. RUSLE determines the potential sediment loss in terms of tons per acre per year. In GIS, this unit is calculated within 30m square blocks of the watershed by multiplying the following RUSLE parameters:

1. R factor: Rainfall intensity factor (R factor spatial dataset) based on long term precipitation data
2. K Factor: Soil loss factor (SSURGO soil survey)
3. C Factor: Land cover management coefficient (SCAG land use)
4. LS Factor: Product of slope steepness factor and slope length factor (DEM)

$$E = R * K * C * LS$$

Where E [tons/acre/year] is average soil loss, R [inches/year] is the rainfall intensity factor, K [tons per acre per unit] is the soil loss factor, C [dimensionless] is the land cover factor, and LS [dimensionless] is the topographic factor.

RUSLE provides a gross estimation of surface sediment erosion to streams, and does not account for factors that may reduce sediment erosion, such as deposition areas.

SEDMOD (Spatially explicit delivery model for sediment and associated non-point source pollutants) (Fraser et. al., 1998) is a GIS model of a Sediment Delivery Ratio (SDR). An SDR is defined as a correction factor for gross surface sediment erosion models. The SEDMOD model is composed very similar to the RUSLE model; Six major factors compose the SEDMOD model which are multiplied together: flow-path slope gradient, flow-path slope shape, flow-path surface roughness (Manning's coefficient), stream proximity, soil texture, and overland flow index. As these many of these factors require a considerable amount of time to produce in ArcView GIS, a simplified version of SEDMOD was created using surface roughness and soil texture factors. The final SEDMOD product was normalized to a 1-100% scale.

Once the RUSLE and SEDMOD models were completed, their results were multiplied together to produce a net sediment delivery streams in tons/acre/year. In order to arrive at tons/year, the net sediment delivery values for each 30m grid cell were multiplied by 0.2224 acres (acreage of 30 square meters). The resulting net sediment delivery in tons/year was them summarized within the SSURGO soil units for each of the five sub-watersheds. The end result of the GIS erosion modeling was a table of SSURGO soil units and their Kearney soil counterparts (clay, sandy loam, etc.) with equivalent net sediment delivery in tons/year. These figures were then calculated with the corresponding trace metal concentrations to arrive at total metal loads from natural soils in lbs/year for each watershed (see Table 43).

Table 42. Estimated Loads of Metals and Selenium to Receiving Waters in the CCW from Natural Soil Concentrations

Subwatershed	Square Miles	Load from All Land Use Types (lbs/year)				Load from Agricultural Land Only (lbs/year)			
		Copper	Mercury	Nickel	Selenium	Copper	Mercury	Nickel	Selenium
Arroyo Simi	129	1,814	19.43	2,841	3.18	194	1.97	295	0.36
Las Posas	34	2,399	16.57	2,647	2.42	1,464	13.43	2,185	2.47
Conejo	73	824	9.15	1,402	1.50	70	0.48	82	0.08
Calleguas Creek	27	183	1.71	257	0.26	30	0.26	44	0.04
Revolon Slough	62	884	7.11	1,141	1.16	694	5.14	861	0.88
Mugu Lagoon	19	2	0.02	3	0.00	0	0.00	0	0.00
Total	344	6,106	53.99	8,292	8.53	2,453	21.28	3,467	3.84

The natural soils loading data demonstrates that natural concentrations of metals and selenium in soils could contribute a significant portion of the loading for all of the metals in the watershed. The loading from these soils is implicitly included in loading from agricultural and urban areas and may account for a majority of the contribution from these land uses for mercury.

Concentrations in Soils from NAWS, Point Mugu

Soils from the Naval Air Weapons Station (NAWS) Point Mugu have been evaluated for concentrations of various metals and selenium as part of the Phase I Remedial Investigation required by CERCLA (United States Navy, 1998). Soils data referred to as 'background soils' were collected and screened to represent natural concentrations. Additional soils data referred to as 'site soils' were collected to examine the content of soils located at eight sites designated for cleanup or other mitigation measures as part of CERCLA requirements (described in the NAWS Point Mugu subsection). Soils data for constituents relevant to this

TMDL are summarized in Table 43. The 'site' soils are noticeably higher than the 'background' soils for copper and nickel, which suggests past activities at NAWS Point Mugu as possible sources of copper and nickel. The 'site' soils and 'background' soils data are more similar in the case of mercury and selenium.

Table 43. Background Soils Data Set - NAWS Point Mugu (mg/Kg).

Constituent	Copper	Mercury	Nickel	Selenium
n	98	98	98	98
% Detected	63%	4%	81%	21%
Minimum	2.40	0.07	3.20	0.20
Mean	13.60	0.07	17.90	0.30
Median	6.20	0.07	7.40	0.20
Maximum	79.70	0.28	128.00	1.50
ERL	34.0	0.15	20.9	--

Table 44. Site Soils Data Set - NAWS Point Mugu (mg/Kg).

Constituent	Copper	Mercury	Nickel	Selenium
n	727	502	502	488
% Det.	83%	11%	90%	23%
Minimum	0.59	0.06	1.70	0.24
Mean	41.90	0.09	46.10	0.39
Median	14.00	0.06	17.90	0.24
Maximum	8590.00	4.00	5480.00	2.60
ERL	34.0	0.15	20.9	--

Mining/Extraction

A range of mining and extraction activities have occurred within the CCW over the years. Active and inactive mining/extraction sites are shown in Figure 19, based on information provided by USGS and the California Department of Conservation. The transport of contaminated sediment and water from mines and petroleum wells located within the watershed may affect water quality in downstream reaches. A discussion specific to the potential effects of mining/extraction activities for each constituent is included in later sections of the Source Assessment.

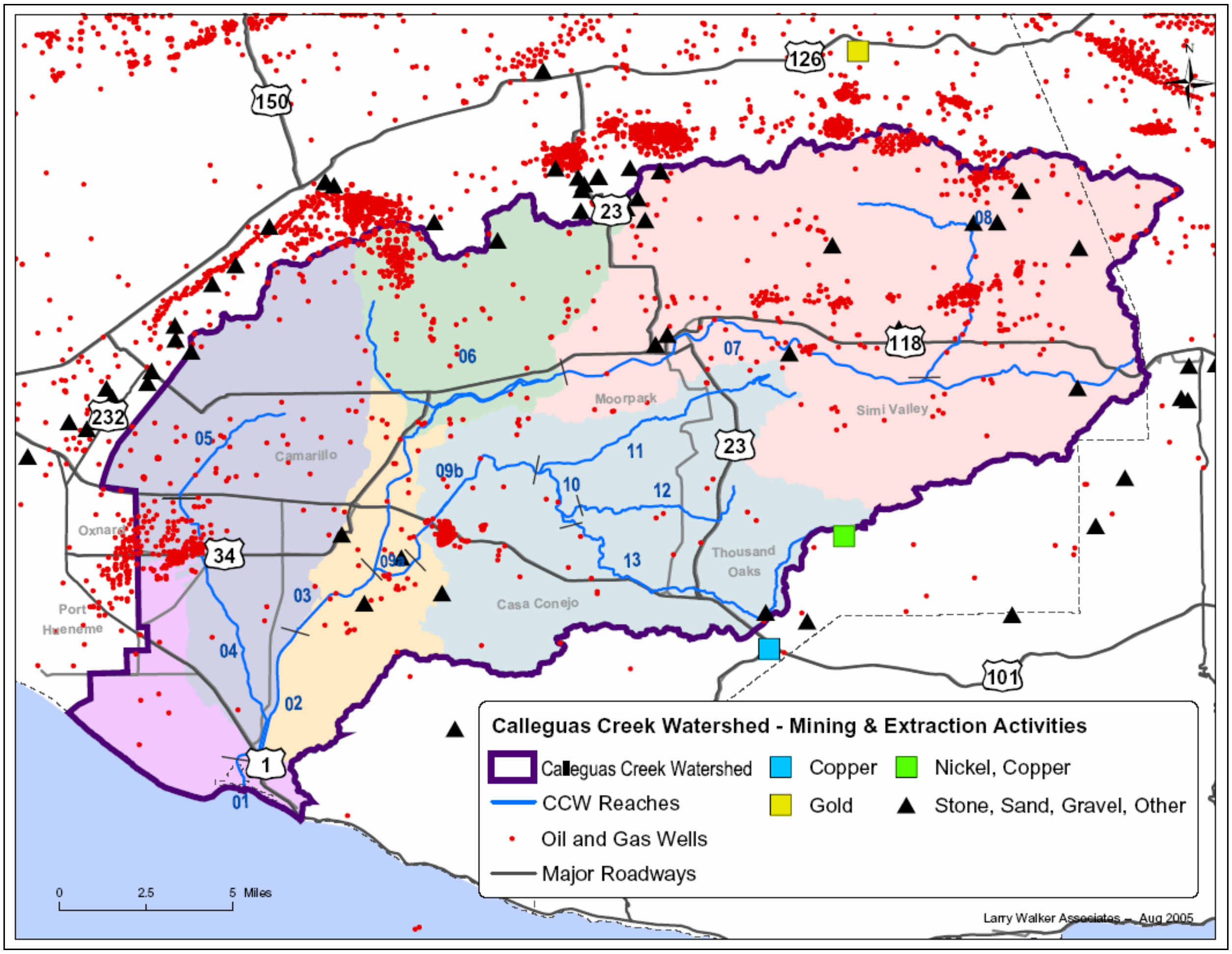


Figure 19. Active and Inactive Mining/Extraction Sites in the Calleguas Creek Watershed (USGS Mineral Resources Data System (MRDS) and California Department of Conservation Division of Oil, Gas, and Geothermal Resources).

Groundwater

Loading of metals and selenium resulting from groundwater (i.e. exfiltration and passive seepage… not including dewatering, which is considered as a NPDES discharge) varies significantly between constituents. For total mercury and total copper the contribution seems negligible. In the case of dissolved copper and selenium, groundwater discharge may represent about a quarter to a third of the total. Metals and selenium occurring naturally in watershed soils are the most likely cause of groundwater concentrations; although use of pesticides, fertilizers and other commercial products as well as industrial/commercial processes may also contribute.

Monitoring of Selected Groundwater Well Sites

In response to stakeholder input, concentrations of metals and selenium in six CCW groundwater dewatering wells were investigated in December 2005 (Figure 20). Concentrations varied significantly between the six wells (Table 45). For instance, Well-1 had a high total copper concentration of 102 ug/L, relative to nearby Well-5 which had a total copper concentration of 2.85 ug/L. Similarly, Well 1 had a total selenium concentration of 3.74 ug/L, while the Well 5 concentration was 23.1 ug/L.

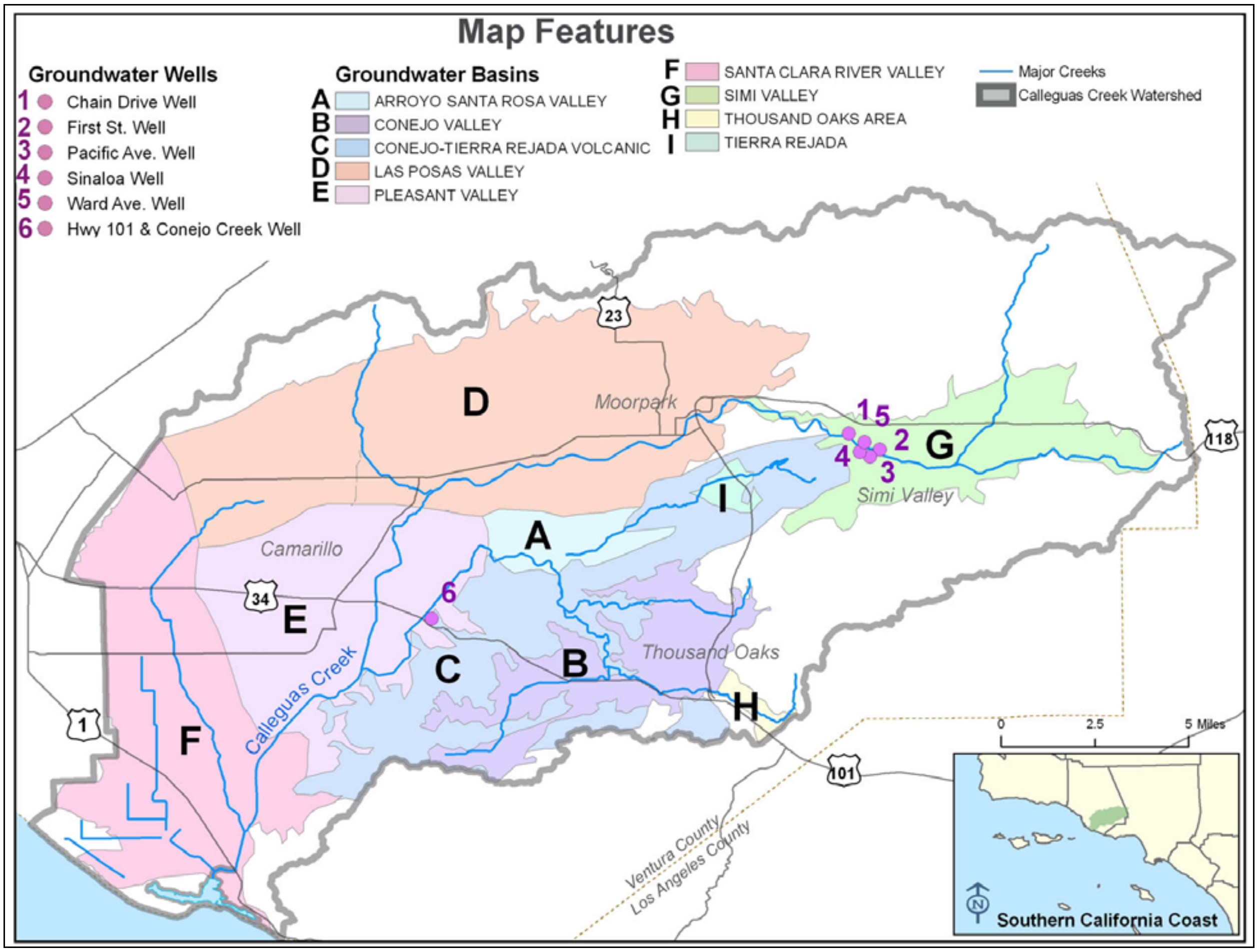


Figure 20. Monitoring of Selected Groundwater Dewatering Well Sites during December of 2005.

Metals and selenium from groundwater dewatering wells could transport into receiving waters as a result of discharges from dewatering operations or through seepage of water into the creeks. It is apparent that some wells contain much higher concentrations of metals and selenium then other wells and further investigations are necessary to determine how the metals and selenium from these wells are entering the stream. Possible solutions may include taking certain wells off-line or treatment before disposal.

Table 45. Concentration of Total Metals & Selenium in Selected CCW Groundwater Dewatering Wells.

Sample ID*		Depth (feet)	Flow (gpm)	Total Cu (ug/L)	Total Ni (ug/L)	Total Se (ug/L)	Total Hg (ng/L)
1	Chain Drive Well	na	na	102	36.0	3.74	1.84
2	First St. Well	97.8	523.6	3.57	0.67	29.6	3.43
3	Pacific Ave. Well	99.4	191.2	1.79	1.26	54.8	0.83
4	Sinaloa Well	99.6	142	3.88	1.13	3.64	0.17
5	Ward Ave. Well	109.8	300	2.85	0.80	23.1	0.65
6	Hwy 101 & Conejo Creek	na	na	3.20	1.06	3.35	0.58

*All samples collected on 12/21/05

Debris Basins

In February of 2004, sediment collected from seven debris basins within the CCW was analyzed for the concentration of metals and other constituents (Table 46). Sediments were sieved into <63um and 63um – 2mm fractions. All of the samples contained detectable concentrations of copper, nickel, and selenium. Mercury was only detected in one sample from Reach 6.

Table 46. Concentration of Metals and Selenium (ug/dry g) Detected in Sediment Collected from Debris Basins on February 21st, 2004.

Sample Name [1]	Fraction	Copper	Mercury	Nickel	Selenium
5D_DB3-13	63µm-2mm	10.00	ND	6.21	0.22
	<63µm	60.20	ND	17.10	0.64
6D_DB3-15	63µm-2mm	9.42	ND	8.68	1.15
	<63µm	62.40	ND	35.40	2.16
6D_DB3-01	63µm-2mm	2.52	ND	3.68	0.26
	<63µm	155.00	0.03	40.40	1.28
7D_DB3-17	63µm-2mm	4.77	ND	3.11	0.10
	<63µm	63.40	ND	19.70	0.66
7D_DB3-09	63µm-2mm	6.91	ND	3.39	0.07
	<63µm	46.20	ND	19.50	0.60
11D_DB3-05	63µm-2mm	35.7	ND	76.70	1.21
	<63µm	34.0	ND	96.90	0.78
NOAA Sediment Guidelines (SQuiRTs) 3	Marine ERL	34	0.15	20.9	NA

[1] The prefix of each sample name indicates the reach to which the debris basin discharges (i.e., 5D_DB3-13 = reach 5).

[2] Bolded values indicate sample concentrations which exceed sediment guideline values from NOAA (SQuiRTs)

[3] Note: NOAA's sediment guidelines included in the Screening Quick Reference Tables (SQuiRTs) are presented with the following disclaimer: "These tables are intended for preliminary screening purposes only: they do not represent official NOAA policy and do not constitute criteria of clean-up levels. NOAA does not endorse their use for any other purposes."

Contaminated sediments from debris basins could find their way into receiving waters of the CCW via several possible scenarios, including: mobilization of the sediments due to wind or water currents, use of sediment from the debris basins for fill dirt or landscaping, or accidental spills during transport for proper disposal. Based on a comparison of the metals and selenium concentrations from debris basin samples and NOAA's sediment guidelines (ERLs), a need may exist to evaluate current methods for disposing of these sediments.

Naval Air Weapons Station Point Mugu

Despite the significant amount of information contained in various reports generated by the United States Navy for Naval Air Weapons Station (NAWS) Point Mugu, the amount of metals and selenium being contributed to Mugu Lagoon by anthropogenic and natural sources in and around the Navy base is somewhat unclear. As shown earlier in Figure 7 - Figure 11, water column concentrations in the lagoon tend to decrease in sample sites successively closer to the mouth of the lagoon; yet sites around the lagoon are generally higher than in-lagoon concentrations. It is possible that soils and/or contamination at NAWS Point Mugu may contribute loads of metals and selenium to the lagoon, which are diluted by the effects of tidal flushing. The two primary reports generated by the Navy which were reviewed for this TMDL are listed below.

- *Naval Air Weapons Station Point Mugu, California - Phase I Remedial Investigation Technical Memorandum, Volume I - Chapters 1 - 13. Draft Final*. (United States Navy, 1998)
- *Ecological Risk Assessment Addendum for Installation Restoration Program Sites 5 and 11 Naval Air Station Point Mugu Naval Base Ventura County, California* (United States Navy, 2005). October 2005

The Department of the Navy, Southwest Division, Naval Facilities Engineering Command conducted a remedial investigation and feasibility study (RI/FS) for eight sites at Naval Air Weapons Station (NAWS) Point Mugu, shown in Figure 21. The RI/FS was conducted in accordance with USEPA's guidance for conducting a RI/FS under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Each of the eight RI sites has a different operational history, environmental condition, type and degree of contamination, and potential exposure pathways and receptors. Each of the eight RI/FS sites have been evaluated through physical and analytical data collected during field investigation, site inspection (SI), and other investigation phases. These investigations have included geophysical surveys; collection of soil, sediment, surface water, and groundwater data; evaluation of hydrological surface water conditions; collection of ecological data; and conducting tidal influence studies at most sites.

The IR program is primarily intended to clean up past hazardous waste disposal or spill areas that endanger public health, welfare, or the environment and may include such contaminants as polychlorinated biphenyls (PCB), inorganic chemicals, petroleum oil and lubricants, pesticides, paints and solvents, and limited ordnance products. The Navy's IR program follows a process developed by the U.S. Environmental Protection Agency (EPA) to identify, assess, and remediate hazardous waste sites. This process is identified in the National Oil and Hazardous Substances Contingency Plan (NCP) and consists of three main activities:

- Preliminary. assessment (PA) and site inspection (SI)
- Remedial investigation (RI) and feasibility study (FS)
- Remedial design (RD) and remedial action (RA)

As part of the RI program, constituents of concern (COCs) were designated in the 1998 report and constituent of potential ecological concern (COPECs) designated in the 2005 report. Most of the concerns for Navy's RI were related to substances other than metals and selenium. A summary of the metals and selenium COCs and COPECs (only) is included below in Table 47.

Table 47. Summary of Metals and Selenium COCs and COPECs for NAWS Point Mugu.

Site Name	COCs (Remedial Investigation Report) 1	COPECs (Eco Risk Addendum, for R/I Report) 2
Site 1 - Lagoon Landfill	--	--
Site 2 - Old Shops Area	--	--
Site 4 - Public Works Storage Yard	--	--
Site 5 - Old 6 Area Shops	Ecological COCs in soil, for: copper, nickel, zinc	copper, nickel, selenium, zinc
Site 6 - Building 311 Yard	--	--
Site 8 - Runway Landfill	--	--
Site 9 - Main Base Fire Training Area	--	--
Site 11 - Mugu Lagoon & Drainage Ditches	--	nickel, selenium, zinc

1 Constituents of Potential Concern, either related to human health or ecological concerns.

2 Constituents of Potential Ecological Concern

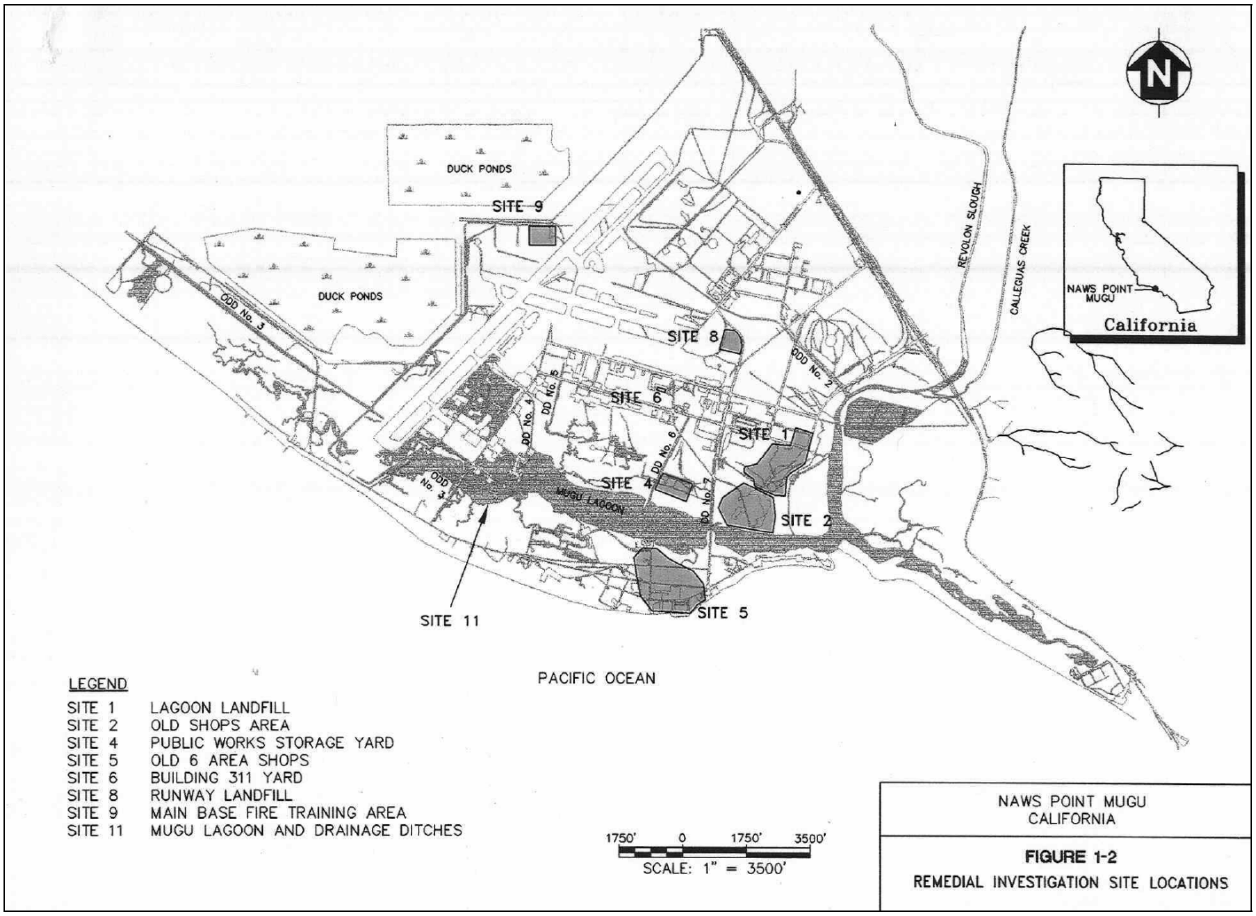


Figure 21. Remedial Investigation Sites at Naval Air Weapons Station (NAWS) Point Mugu (United States Navy, 1998).

Site 1 - Lagoon Landfill

The Lagoon Landfill has been inactive since the mid-1970s and was historically used for disposal of solid waste and dredge materials. Erosion has been observed along the eastern landfill margin during the Remedial Investigation (RI) activities. In this area, the integrity of the landfill has been compromised by tidal action and stream flow from Calleguas Creek, thereby exposing solid wastes and posing a threat of release of both wastes and landfill soils into the adjacent Mugu Lagoon ecosystem. Chemicals with human health risk values exceeding 1 x 10^{6} included semi-volatile organic chemicals (SVOC) and polychlorinated biphenyls (PCB). None of the detected chemical concentrations were above EPA action levels for soil.

Site 2 - Old Shops Area

As a public works vehicle maintenance facility, Site 2 is mainly a developed area. The site is bounded on the east and south by mudflats and tidal marsh areas associated with Mugu Lagoon. Surface water from the southern and eastern portions of the site flows toward outfalls that discharge to the lagoon mudflats. Surface water runoff from the northern and western portions of the site flows east to marsh areas located between Dump Road and South Mugu Road. No obvious erosion channels are present on the site surface. Human health risks were calculated for both the current and future industrial scenario and the future residential scenario. The only human health soil chemical of concern (COC) identified was Aroclor 1260. For the ecological risk assessment, most detected soil contaminants were at very low concentrations and at low frequencies. No soil COCs for ecological receptors were identified at Site 2.

Site 4 - Public Works Storage Yard

A removal action was conducted at the Public Works Storage Yard to remove high concentrations of PCBs and heavy metals in soils. Site 4 was previously used for storage of construction materials and was the site of some facility maintenance activities. Human health cancer risks posed by site soils were determined to be potentially significant (greater than 1 x 10 "4) for the future wildlife manager due to soil concentrations of PCBs. The ecological risk assessment determined that PCBs at Site 4 could pose significant risk to ecological receptors as well, including those with direct exposure to the site and those exposed to contaminants potentially migrating into adjacent wetlands. The removal action included the excavation of surface soils in the northeastern portion of the site to remove PCBs, the excavation of surface soils in the western portion of the site to remove metals, and excavation of sediments directly adjacent to the site to remove PCBs. The area was then restored to a natural habitat by constructing two bird breeding and nesting islands. PCBs were not detected following the removal action at Site 4, therefore, no COCs exist for the soil at Site 4.

Site 5 - Old Area Shops

The southern and northwestern portions of Site 5 are developed areas, while the northern half of the site is comprised of tidally influenced marsh areas, creek channels, and intertidal mudflats. A tidal creek, which originates in Mugu Lagoon, cuts through the northern half of the site. Site 5 is located on a sand spit which separates Mugu Lagoon from the Pacific Ocean. Surface water flows from the site through channels and marsh areas to the lagoon. Runoff from the southern portion of the site is directed to outfalls that discharge to the marsh areas on the northern portion of the site, and eventually to Mugu Lagoon. The only chemical at Site 5 associated with human health risks greater than 1 x 10^{-6} is benzo(a)pyrene. The ecological risk assessment identified potential risks to ecological receptors from heavy metals in soils and from pesticides in the sediments adjacent to the site. Nickel and chromium were identified as COCs for ecological receptors in surface water at Site 5. However, these constituents exceeded EPA national ambient water quality criteria by only a small margin.

In response to preliminary RI sampling results, an emergency removal action was conducted at Site 5 from June 21, 1994, through June 24, 1994. Analytical data from soil samples collected during the RI at Site 5 indicated that concentrations of chromium, cadmium, copper, nickel, and silver exceeded total threshold limit concentrations (TTLC), as listed in the California Code of Regulations (CCR), Title 22, Section 66261.24.

Site 6 - Building 311 Yard

Site 6 is a small unpaved area immediately south of Building 311 which was historically used for waste disposal. Surface water flows to the southeast across the site. A surface swale in the southeastern portion of the site provides a route for surface drainage. Drainage from this area leads to Drainage Ditch No. 6, which discharges to Mugu Lagoon. The ecological risk assessment determined that Site 6 does not provide significant wildlife habitat and therefore poses little or no risk to ecological receptors. In addition, most contaminants were detected at very low concentrations and at low frequencies.

Site 8 - Runway Landfill

Site 8 is a grassy area located at the northeastern end of Runway 9-27. The site is located in a topographic depression, and surface water collects on the site from surrounding areas. Surface water at Site 8 flows toward Drainage Ditch No. 2 to the north, which discharges to Mugu Lagoon. Human health risks were calculated for current and future industrial workers. Recommendations regarding future action at Site 8 are based on the industrial exposure scenario. There were no potential human health cancer risks greater than 1x 10 -6 at Site 8. Ecological exposure is not expected to be significant at Site 8 since the site primarily consists of disturbed areas and mowed areas that do not provide significant habitat.

Site 9 - Main Base Fire Training Area

Site 9 consists of an old, 40-foot diameter, unlined circular burn pit. A new fire ring is located to the west of the site but is not considered part of the site since it is still active. Surface water flows into a series of drainage ditches and culverts that drain into ODD No. 3, which ultimately discharges into Mugu Lagoon. The Ventura County Game Preserve and Point Mugu Game Preserve duck ponds are located north of Site 9 and the base boundary. DDT, PCBs, dioxins, and furans had risk values higher than 1 x 10 -6. Potential human health cancer risks (between 1 x 10 -6 and 1 x 104) are posed by site COCs for ingestion of and dermal contact with soil for the industrial worker. Site 9 primarily consists of disturbed areas that are sparsely vegetated or paved. As such, it does not provide significant habitat. Toxicity testing conducted on soils collected from the area generally corroborate this finding. In addition, the chemicals at Site 9 were detected at very low concentrations relative to ecological effects criteria.

Site 11 - Mugu Lagoon And Drainage Ditches

Mugu Lagoon consists of a central basin and two main arms of the open-water lagoon, tidal creeks and streams, tidal marsh, intertidal mudflat, and drainage ditches. Site 11 is located along the southern part of the base between the beach and the air field industrial area and receives fresh water inflows from Revolon Slough and Calleguas Creek from the north. Runoff from the Santa Monica Mountains and wetlands flows into the eastern portion of the lagoon. At low tide, a large portion of the site is exposed, and is inundated during high tides. The lagoon, including subtidal and intertidal areas, covers over 1,300 acres and is about 3.5 miles long and about 0.5 mile at its widest. Surface water runoff from the base flows through the storm drain system and ultimately discharges to the lagoon. In addition, all runoff and discharges in the Calleguas Creek watershed eventually flow to Mugu Lagoon.

The only chemical with human health risk values that exceeded 1 x 10-6is benzo(a)pyrene. No estimated hazards exceed the hazard quotient of 1.0 for sediment and surface water at Site 11. Therefore, there were no COCs identified based on non-carcinogenic health effects. The ecological risk assessment determined, based on additional sediment samples collected in 1997, that the sediment chemical concentrations in the lagoon closely reflect concentrations present in reference areas. In addition, the exposure analysis that evaluated the character of the benthic community and toxicity testing conducted for sediments throughout the lagoon generally indicated that no significant impacts have occurred. Further, examination of the character of the benthic community revealed conditions that would be expected in an intertidal area subject to sedimentation, tidal fluctuations, and freshwater inputs.

Navy Soils Monitoring Data

Summary statistics for metals and selenium in soils analyzed by the Navy are presented earlier in the Sources (General) section, Natural Soil Concentrations subsection (Table 43 and Table 44).

Boeing / Rocketdyne – Santa Ana Field Lab

According to a recent article in the Los Angeles Times (Griggs, 2005), a federal grand jury is investigating water pollution from the Santa Susana Field Laboratory near Simi Valley, which is owned by Boeing. A grand jury demanded documents relating to storm-water and wastewater discharges from the 2,900-acre hilltop site, where nuclear and rocket testing has been conducted for more than 55 years. State water regulators ordered Boeing to stop allowing discharges that exceed federally allowable levels and to clean up the sources of contamination. The Regional Water Quality Control Board notified Boeing in March and October of 2005 that in nearly 50 instances, it allowed too much contaminant, including chromium, mercury, dioxins and chlorine, to flow from its property.

Runoff from the lab flows into 12 creeks and rivers, including Bell Creek, a tributary of the Los Angeles River, and the Arroyo Simi, Calleguas Creek and Mugu Lagoon in Ventura County. The field lab used to be owned by Rocketdyne, which became a subsidiary of Boeing, but in February 2005, Boeing sold the rocket-manufacturing business and the name to United Technologies. The lab was not part of that sale.

Sources (General) - Summary / Conclusions

Based on the information presented above, the imported water supply, naturally occurring concentrations of metals in soils, Point Mugu NAWS, and groundwater have the potential to be important sources of metals and selenium to receiving waters.

6.4 Sources - Copper

Copper finds its way into receiving waters through industrial and POTW discharges, urban and agricultural runoff, erosion and sediment transport, groundwater discharges, and atmospheric deposition. Sources potentially contributing to the concentrations discharged through these pathways include: automobile brake pads, corrosion of copper pipes, architectural copper, copper-containing pesticides, industrial copper use, vehicle fluid leaks, natural concentrations in soil, and water supply (TDC, 2004).

Sources and pathways through which copper is transported to the stream are illustrated in Figure 22, copper concentrations over time according to land use type are shown in Figure 23, loading contributions according to land use type are presented in Table 48, and HSPF modeling results indicating cumulative loading versus flow are presented in Figure 24. The HSPF model is described in the Linkage Analysis section.

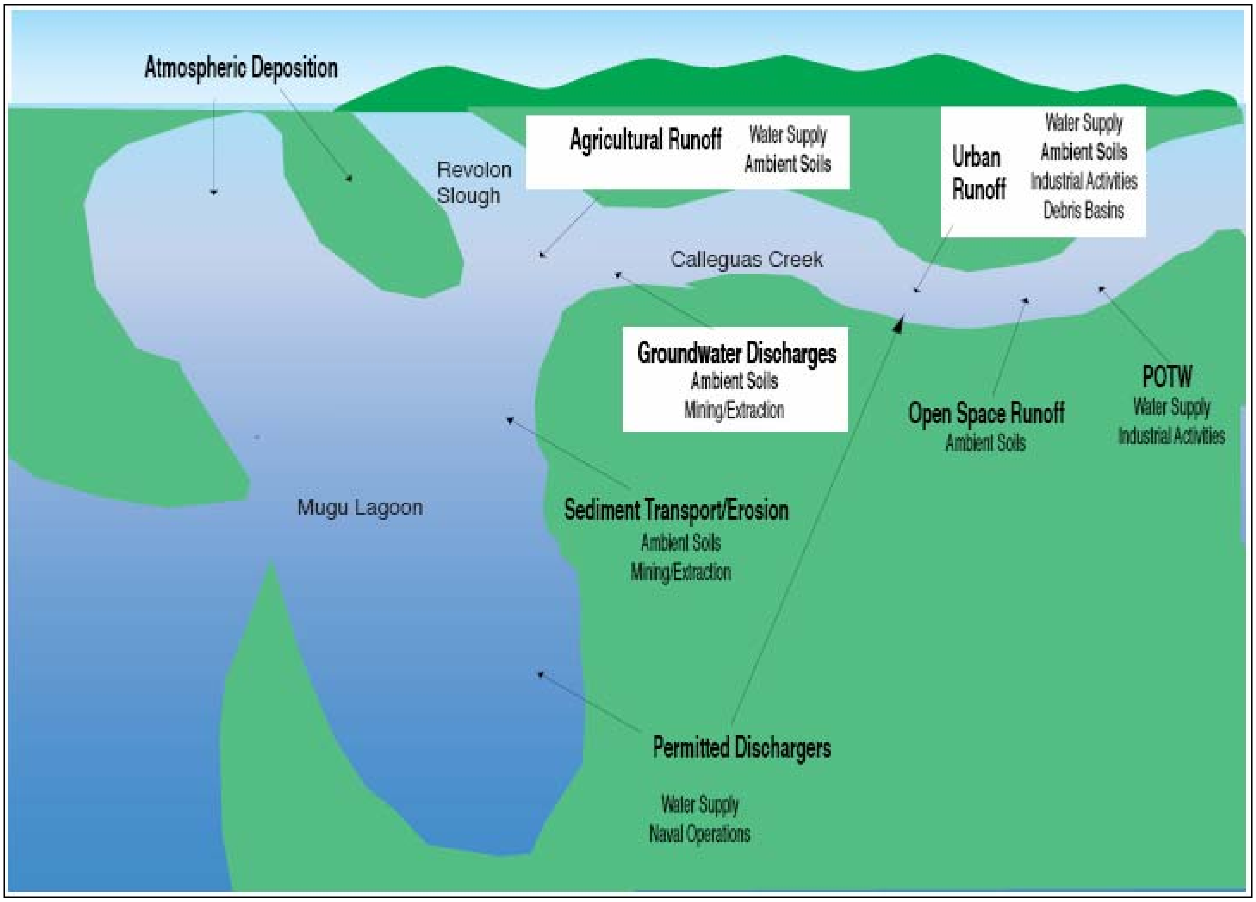


Figure 22. Copper sources and pathways. Most significant sources indicated by white boxes.

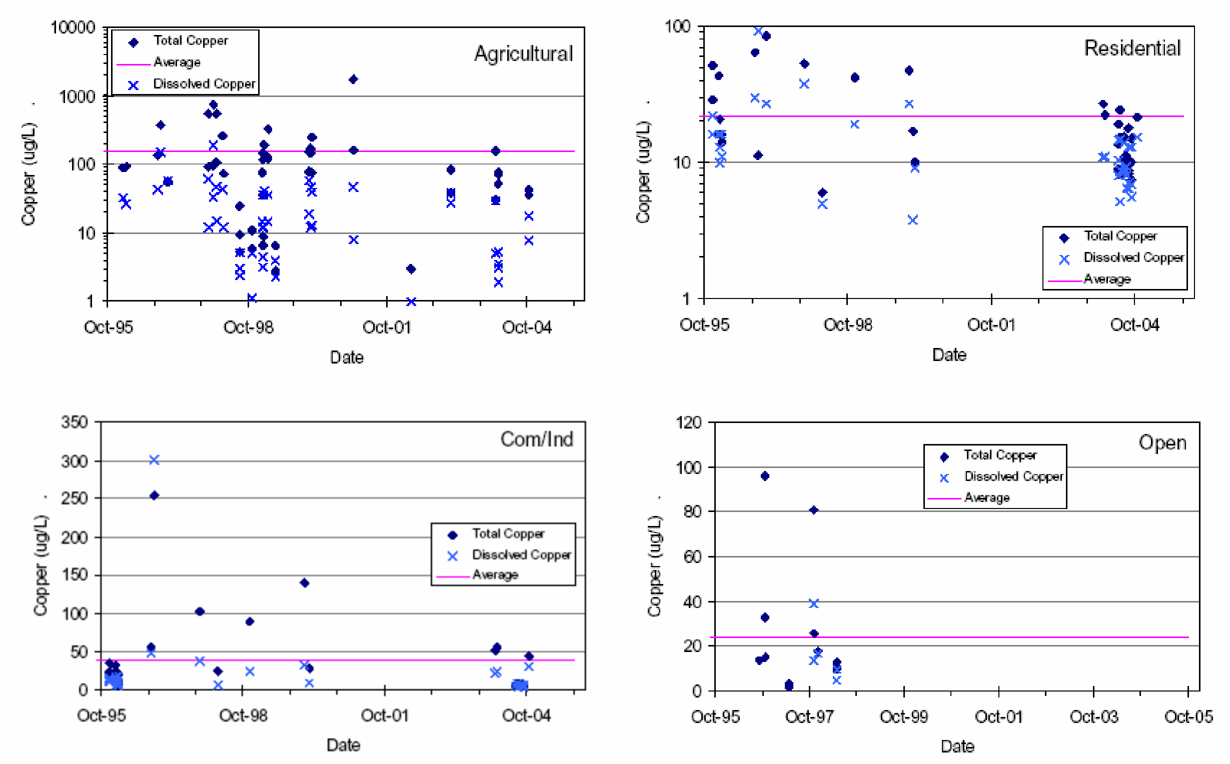


Figure 23. Copper in runoff by land use category, using data from CCW and adjacent watersheds (ug/L).

Table 48. Estimated Total Copper Loading in the CCW by Land Use Type (Lbs/Yr). [1]

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average [2]	27,370	70,899	199	516	36	8,284	107,303
Percent of Total	26%	66%	0%	0%	0%	8%	100%

1 According to HSPF modeling described in the Linkage Analysis section.
2 Load calculated as annual average for the water years 1994-2004

Table 49. Estimated Dissolved Copper Loading in the CCW by Land Use Type (Lbs/Yr). [1]

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average [2]	32	23	199	516	36	16	822
Percent of Total	4%	3%	24%	63%	4%	2%	100%

1 According to HSPF modeling described in the Linkage Analysis section.
2 Load calculated as annual average for the water years 1994-2004

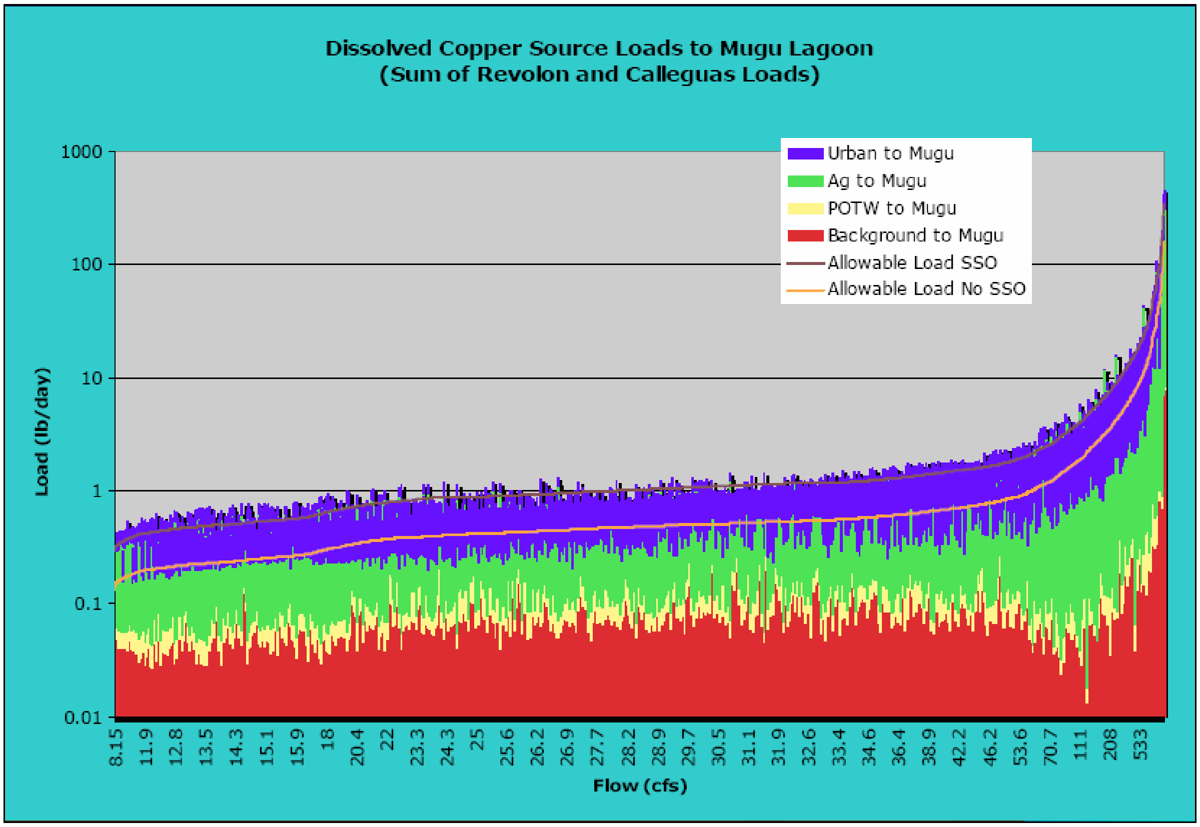


Figure 24. Dissolved copper source loads to Mugu Lagoon, based on HSPF modeling results.

Brake Pads

Dust from disc brake pad wear is estimated to contribute approximately 35 percent of the total copper loading to the San Francisco Bay (Armstrong, 1994). Brake pads are likely a significant source of copper in the CCW as well. GIS analysis of road and intersection density was performed using Census 2000 Tiger/Line data, in an attempt to identify areas of high automobile brake usage within the watershed. The steps used to create the resulting map (Figure 25) are presented below:

1. selected 'paved', 'neighborhood' and 'highway' roads from the 2000 Census Tiger Line shapefile (discarded connectors, jeep trails, on/off ramps);
2. calculated road density within 1km circles for 100m grid cells using the 'line density' function.
3. produced a point shapefile of road intersections of shapefile created in step 1. Assigned a weight of 1 to these intersections and converted to 100m raster;
4. using a raster calculator, combined the road density with the road intersections to create a product that emphasizes road intersections in addition to relative road density;
5. assigned a 0-4 ranking scale; and
6. compared road lines and intersections with final raster layer.

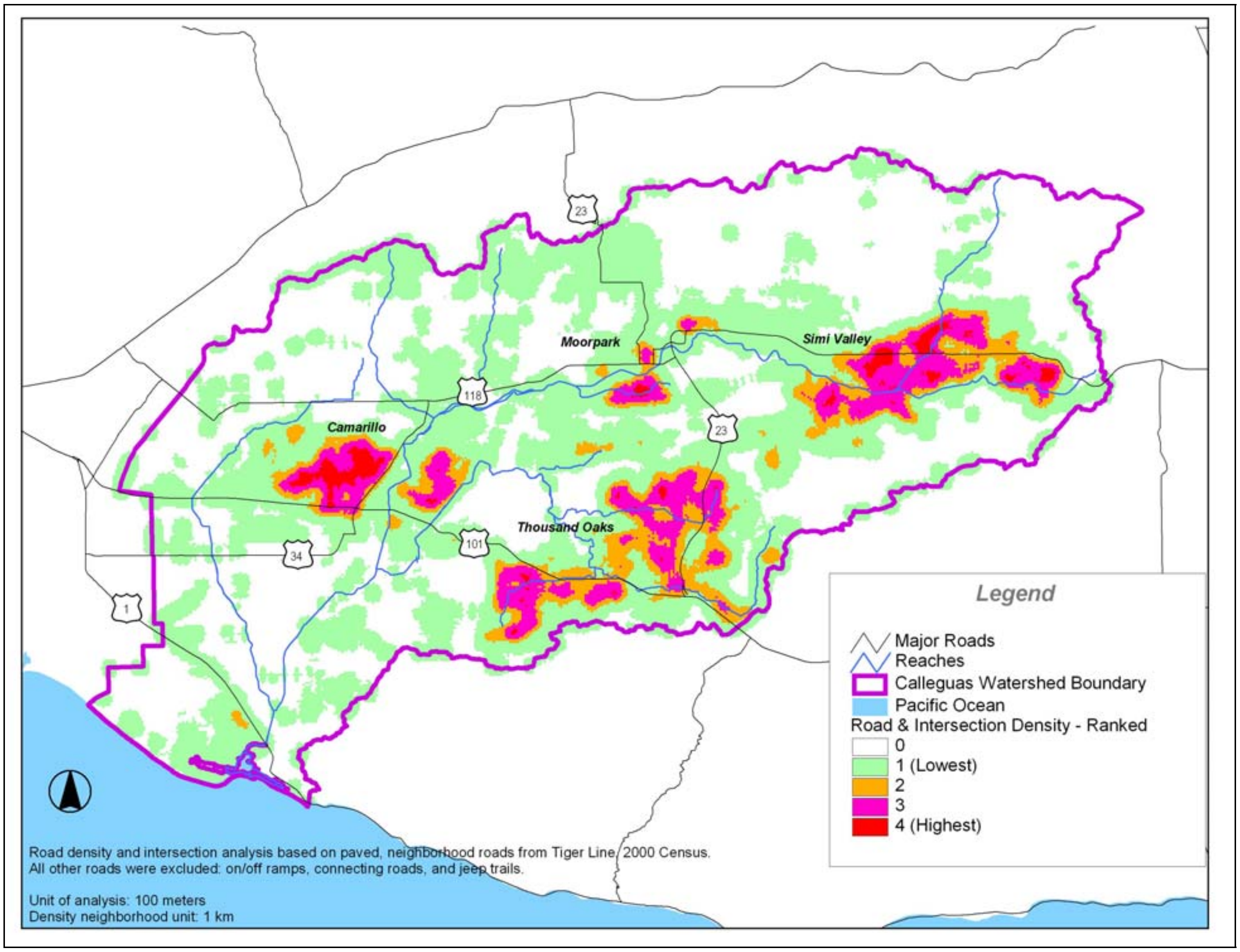


Figure 25. Predicted Areas of High Automobile Brake Usage, Calculated According to Road Density and Intersection Density (Census 2000 Tiger/Line Data).

In a more detailed future analysis, weighting of each hectare could include consideration of traffic volume and road gradient/slope. Although Caltrans traffic volume data of average annual daily traffic for 2004 is only available for major routes (indicated by black lines on the map above), an assumption of lesser traffic volume rates for other road classes might yield reasonable useful results. Additionally, future analysis could utilize the loading estimate methodology developed in the San Francisco Bay Area by the Santa Clara Valley Nonpoint Source Pollution Control Program (Armstrong, 1994) to predict loading of copper to receiving waters in the CCW resulting from brake pad wear.

Agricultural Uses of Copper

Growers in the Calleguas Creek Watershed use copper in a number of ways. Pesticide Use Report (PUR) Data from the California Department of Pesticide Regulation (DPR) indicate copper is an ingredient in 26 pesticides used by growers in Ventura County(Table 50), including three of the top 50 most used pesticides in the county (Table 51). A product called Copper-53, containing 53% ‘copper sulphate (basic)’, is commonly applied to citrus trees in the watershed for control of a blight known as brown rot which is caused by Phytophthora fungi. Copper sulfate and hydrated lime are applied to tree trunks in orchards/groves to inhibit snails; and copper is often applied directly to trees where local soils contain concentrations of copper sub-optimal for growth (McIntyre, pers. comm., 2005).

Table 50. Pesticides Containing Copper Used in California (Department of Pesticide Regulation PUR data, from PAN website, www.pesticideinfo.org)

Chemical Name	CAS #	Use Type	Chemical Class
Copper (from triethanolamine complex)	82027-59-6	Algaecide	Inorganic-Copper
Copper ethanolamine complex	14215-52-2	Algaecide	Inorganic-Copper
EDTA, copper complex	12276-01-6	Algaecide	Inorganic-Copper
Copper sulfate (pentahydrate)	**7758-99-8**	**Algaecide, Fungicide, Insecticide, Water Treatment, Molluscicide**	**Inorganic-Copper**
Copper bronze powder		Antifoulant	Inorganic-Copper
Copper	7440-50-8	Fungicide	Inorganic-Copper
Copper ammonium carbonate	33113-08-5	Fungicide	Inorganic-Copper
Copper ammonium complex	16828-95-8	Fungicide	Inorganic-Copper
Copper octanoate	20543-04-8	Fungicide	Inorganic-Copper
Copper oxychloride	1332-40-7	Fungicide	Inorganic-Copper
Copper oxychloride (Cu2Cl(OH)3)	1332-65-6	Fungicide	Inorganic-Copper
Copper oxychloride sulfate	8012-69-9	Fungicide	Inorganic-Copper
Copper salts of fatty and rosin acids	9007-39-0	Fungicide	Inorganic-Copper
Cupric gluconate	527-09-3	Fungicide	Inorganic-Copper
Cuprous chloride (Cu2Cl2)	7758-89-6	Fungicide	Inorganic-Copper
Copper carbonate, basic	12069-69-1	Fungicide, Algaecide, Insecticide	Inorganic-Copper
Copper sulfate (anhydrous)	7758-98-7	Fungicide, Algaecide, Molluscicide	Inorganic-Copper
Copper sulfate (basic)	**1344-73-6, 1332-14-5**	**Fungicide, Algaecide, Molluscicide**	**Inorganic-Copper**
Copper oxide (ic)	1317-38-0	Fungicide, Insecticide	Inorganic-Copper
Copper oxide (ous)	1317-39-1	Fungicide, Insecticide	Inorganic-Copper
Copper 8-quinolinoleate	10380-28-6	Fungicide, Microbiocide	Inorganic-Copper, Quinoline
Copper hydroxide	**20427-59-2**	**Fungicide, Microbiocide, Nematicide**	**Inorganic-Copper**
Copper ethylenediamine complex	13426-91-0	Herbicide	Inorganic-Copper
Cuprous thiocyanate	1111-67-7	Microbiocide	Inorganic-Copper
Copper naphthenate	1338-02-9	Wood Preservative, Insecticide, Fungicide, Dog and Cat Repellent	Inorganic-Copper
Copper silicate	1344-72-5	(use type not listed)	Inorganic-Copper

Table 51. Pesticides Containing Copper Which are Among the 50 Most Used Pesticides in Ventura County during 2003, by Total Pounds Applied (Department of Pesticide Regulation PUR data, from PAN website, www.pesticideinfo.org).

Rank	Chemical Name (CA Chem Code)	Chemical Class	Gross Pounds	Application Rate Pounds/acre treated	Acres Treated
15	Copper sulfate (basic) (162) Uses: Fungicide, Algaecide, Molluscicide	Inorganic-Copper	45,706	5.51	8,258
18	Copper hydroxide (151) Uses: Fungicide, Microbiocide, Nematicide	Inorganic-Copper	25,929	1.31	19,707
37	Copper sulfate (pentahydrate) (161) Uses: Algaecide, Fungicide, Insecticide, Water Treatment, Molluscicide	Inorganic-Copper	8,421	23.9	278.6

PUR data set contains a great deal of information about how, when, and where various pesticides are used. An example of the potential use of these data is offered below, using 'Copper Sulfate (Basic)' as an example. Similar analysis could be completed for each of the copper containing chemicals listed above. Table 52 shows the amount of 'Copper Sulfate (Basic)' used for various purposes in the Calleguas Creek Watershed, using the township-range information contained in the PUR database to select those records which are within the watershed. Figure 26 shows the total pounds of 'Copper Sulfate (Basic)' applied from 1998-2002 in each township-range square within the watershed.

Table 52. Total Pounds of 'Copper Sulfate (Basic)' Use Reported for Various Purposes within the Calleguas Creek Watershed from 1998-2002 (Department of Pesticide Regulation PUR data, 1998-2002).

Purpose of Application	Lbs per Use Type	% of Total
Lemon	127,645	97.9%
N-Grnhs Flower	8	0.0%
Broccoli	925	0.7%
Beet	59	0.0%
Carrot	356	0.3%
Sugarbeet, Unspecified	582	0.4%
Orange	399	0.3%
N-Grnhs Plants In Containers	2	0.0%
N-Outdr Plants In Containers	37	0.0%
N-Outdr Flower	3	0.0%
Celery	324	0.2%
Total =	130,340	100.0%

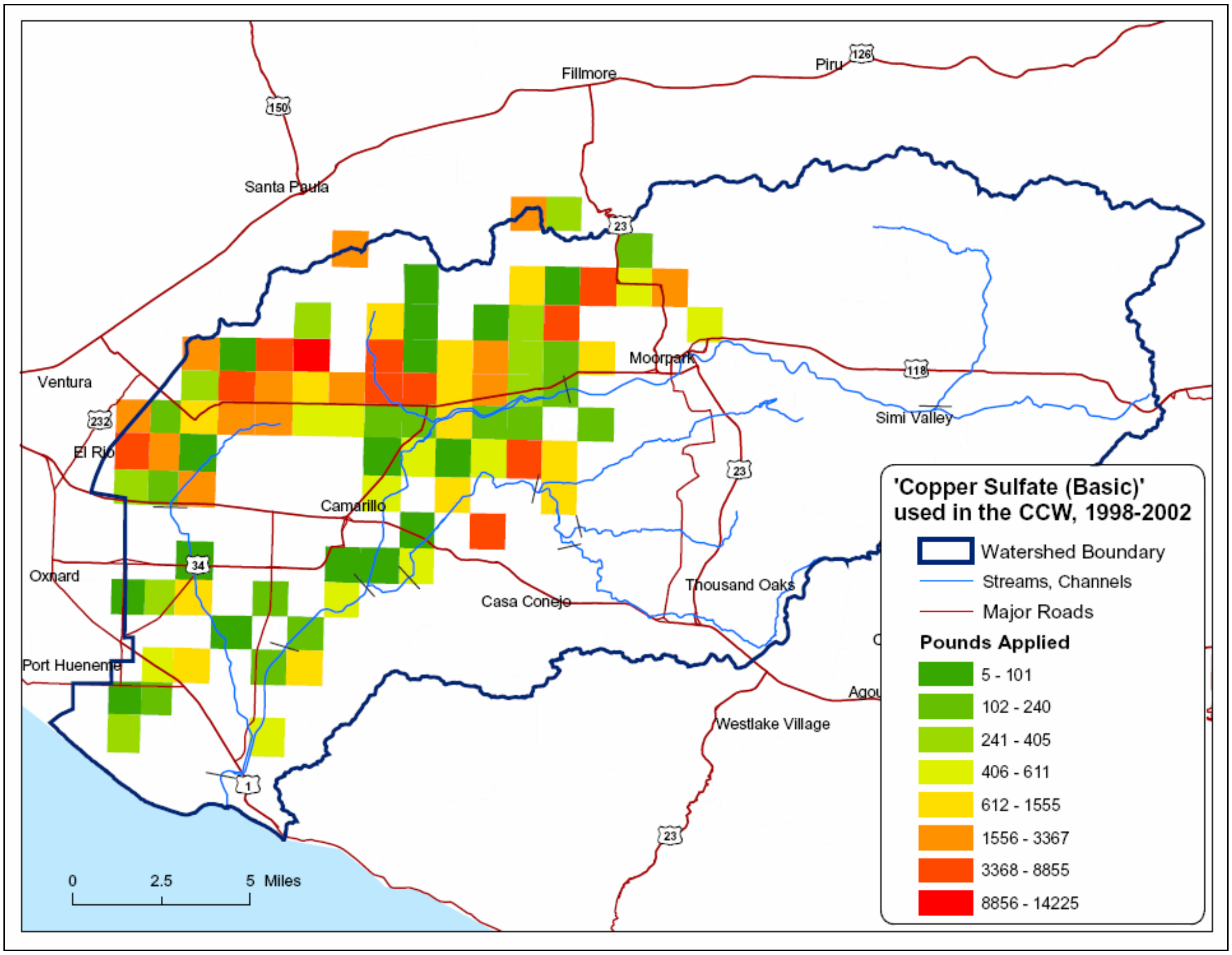


Figure 26. Total Reported Use of 'Copper Sulfate (Basic)' in the Calleguas Creek Watershed from 1998-2002 (California Department of Pesticide Regulation).

Copper Algaecides

A study of copper released from non-brake sources in the San Francisco Bay Area identified copper-containing algaecides as a significant source in that region (Sinclair, 2005). These algaecides are typically used for a variety of applications, including:

- maintenance of rights of way, public health, and recreational facilities (e.g. parks);
- pools, spas, and fountains;
- agricultural uses of algaecides in water areas.

In that study, copper from algaecides was estimated to account for slightly less than half of all copper released to surface waters and storm drains (not counting contributions from brake pads or ambient sources), No quantitative analysis of the contribution from copper algaecides to receiving waters of the CCW has been completed. The Ventura County Watershed Protection District does not use copper-containing algaecides to maintain rights of way or for other purposes. No agricultural uses of algaecides in water areas have been identified.

Corrosion of Copper Pipes

It is a generally known and widely accepted fact that corrosion of copper piping is a common source of copper to POTWs. The Palo Alto Regional Water Quality Control Plant (RWQCP) completed a study which found that approximately 71% of the copper discharged from the RWQCP comes from corrosion of copper pipes and cooling equipment in homes and businesses. It is likely corrosion of copper pipes also represents a significant source of copper to POTWs in the CCW.

Architectural Copper

Roofing sheets, roofing tiles, flashing strips, gutters, downspouts, cupolas, vents, handrails, light fixtures and signs are available in copper. Owners and architects choose this metal for its appearance, constructability, fire resistance, and longevity. The initial cost of copper is significantly more than other materials with shorter lifespans. However, the overall life cycle cost of copper can be less than other roofing materials requiring more frequent replacement (Palo Alto Regional Water Quality Control Plant, 2000).

A copper roof on a new 230 sqm (2,500 sqft) home initially corrodes at a rate of approximately 1.2 kg (2.5 lbs) per year. About 20% of this amount dissolves and washes off the roof when it rains. The rest stays on the roof. Copper releases from all roofs in the Palo Alto RWQCP service area is believed to be something on the order of 136 kg (300 lbs) per year. This dissolved copper release is about 20% of the total copper load measured in local creeks. Use of coated steel roofs or rainwater treatment units would reduce these copper releases (Palo Alto Regional Water Quality Control Plant, 2000).

A study of copper released from non-brake sources in the San Francisco Bay Area found that copper leaching from pressure-treated lumber is an additional source of architectural copper (Sinclair, 2005). That study estimated releases from pressure-treated lumber to account for about one third of copper released to permeable surfaces in the San Francisco Bay Area (not counting contributions from brake pads or ambient sources). No quantitative analysis of copper releases from treated lumber specific to the CCW has been completed.

Soil Concentrations - Copper

Natural concentrations of copper in soils of the CCW and also specific to the Naval Air Weapons Station Point Mugu are discussed in detail in the Sources (General) section, Soil Concentrations subsection. Estimated natural soil loadings of total copper presented in that section represent about 6% of the average annual loading of total copper. During wet years, the proportion of the load from soil concentrations could be more significant.

6.5 Sources - Mercury

Mercury reaches receiving waters through industrial and POTW discharges, urban and agricultural runoff, erosion and sediment transport, atmospheric deposition, and perhaps to some degree from groundwater. Sources potentially contributing to the concentrations discharged through these pathways include: natural concentrations in soils, water supply (imported and/or groundwater), industrial activity, mining/extraction, consumer products containing mercury, and possibly residues from past use of agricultural chemicals containing mercury.

Loading contribution by land use type is presented in Table 53, and the sources and pathways through which mercury is transported to the stream are illustrated in Figure 27.

Sources and pathways through which mercury is transported to the stream are illustrated in Figure 27, mercury concentrations over time according to land use type are shown in Figure 28, loading contributions according to land use type are presented in Table 53, and HSPF modeling results indicating cumulative loading versus flow are presented in Figure 29. The HSPF model is described in the Linkage Analysis section.

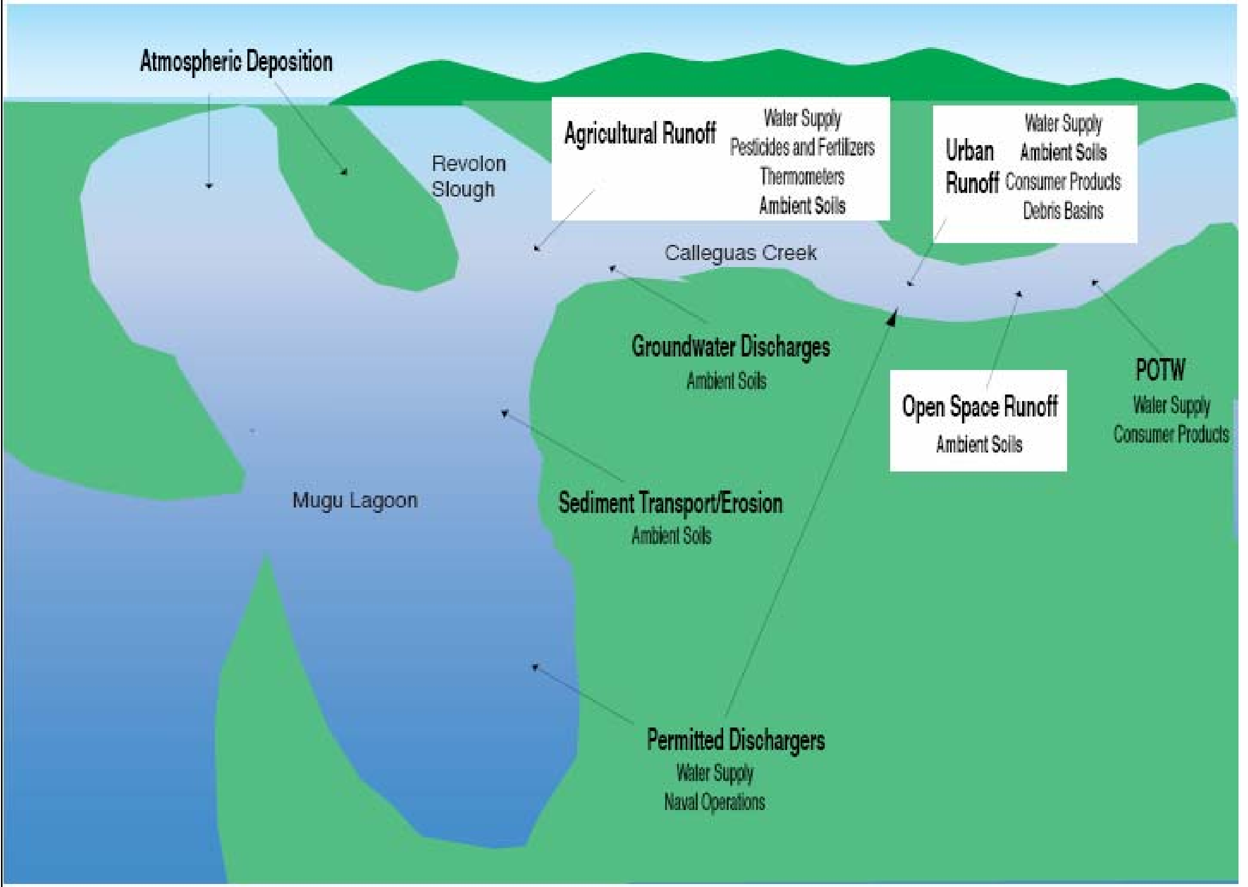


Figure 27. Mercury sources and pathways. Most significant sources indicated by white boxes.

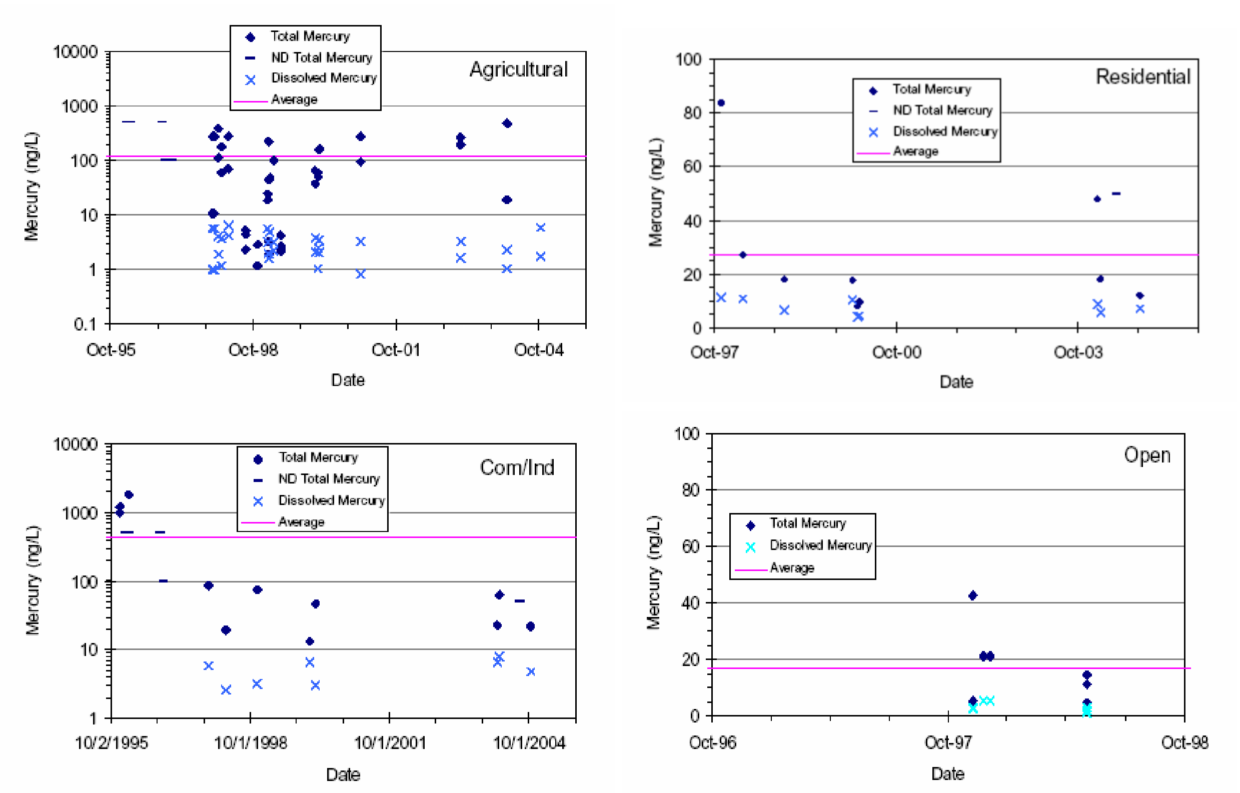


Figure 28. Mercury in runoff by land use category, using data from CCW and adjacent watersheds (ug/L).

Table 53. Estimated Total Mercury Loading in the CCW by Land Use Type (Lbs/Yr).

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average [2]	17.9	21.5	0.030	1.3	0.012	29.8	70.5
Percent of Total	25%	30%	0%	2%	0%	42%	100%

1 According to HSPF modeling described in the Linkage Analysis section.

2 Load calculated as annual average for the water years 1994-2004

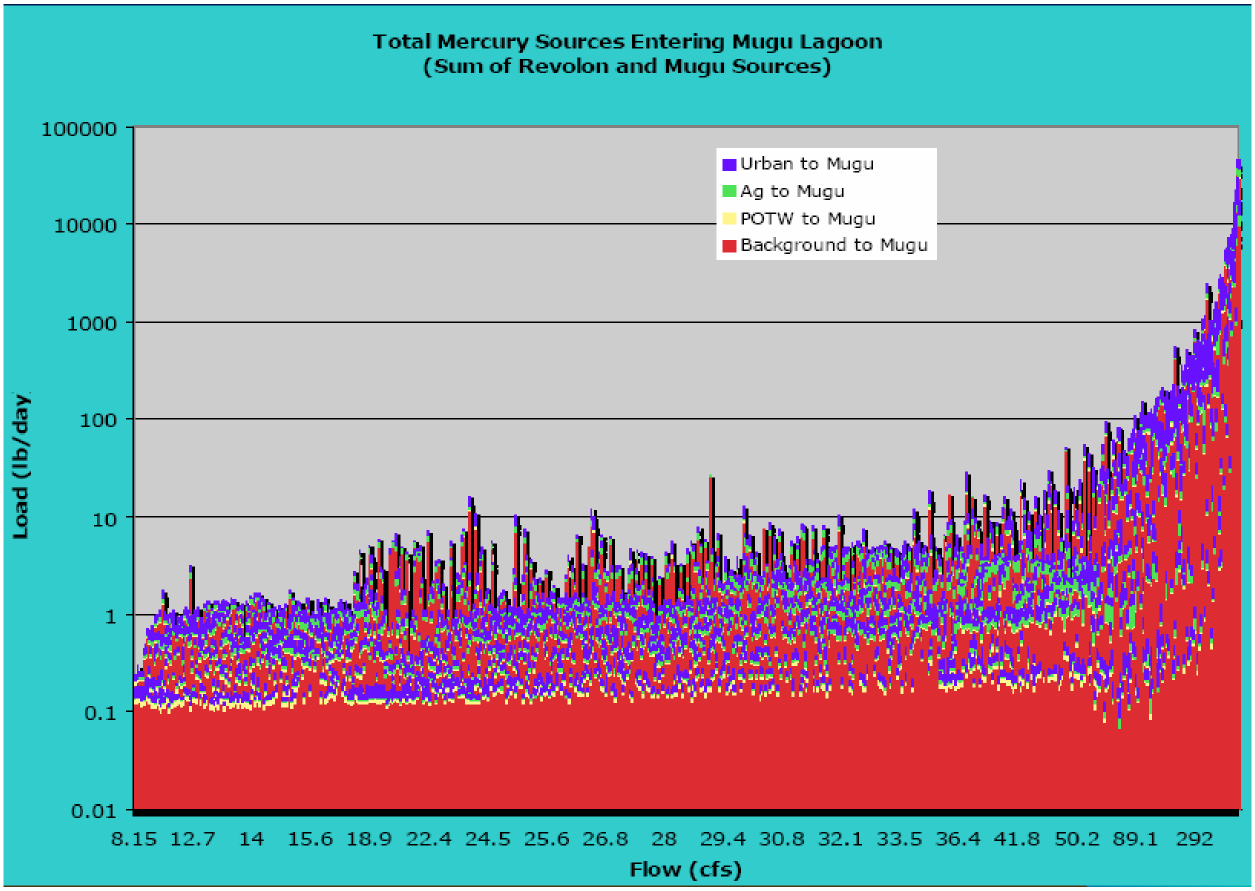


Figure 29. Total mercury source loads to Mugu Lagoon, based on HSPF modeling results.

Historically, mercury has been used to extract gold in mining operations, and in the production of munitions, electronics, health care and conventional goods, and commercial products. Additionally, mercury was used in agricultural chemicals as a fungicide, mildewcide, or pesticide. Many of the sources of mercury seen today are legacies of past uses (SFBRWQCB, 2004).

Studies in the San Francisco Bay (SFBRWQCB, 2004) found the following distribution for sources of mercury (Table 54). Similar sources are possibly present in the CCW, although a key difference is that San Francisco Bay receives very a large amount of runoff from historical gold and other mining areas. Additionally, the size and character of the drainage areas contributing to SF Bay and Mugu are rather different.

Table 54. Sources and Losses Distribution for Mercury in San Francisco Bay (SFBRWQCB, 2004).

Sources	% Contribution	Losses	% Contribution
Watershed Runoff	43%	Transport through Mouth of Bay	80%
Bed Erosion	38%	Evaporation	11%
Urban Stormwater Runoff	13%	Dredging/Disposal	9%
Atmospheric Deposition	2%		
Non Urban Stormwater Runoff	2%		
Wastewater	2%		

Soil Concentrations - Mercury

Natural concentrations of mercury in soils of the CCW and also specific to the Naval Air Weapons Station Point Mugu are discussed in detail in the Sources (General) section, Soil Concentrations. Estimated natural soil loadings of mercury presented in that section represent about 76% of the average annual loading of mercury. During wet years, the proportion of the load from soil concentrations could be even higher. Therefore, mercury concentrations in natural soils make up a significant portion of the loading to the receiving waters.

Pesticide Use

Widespread use of mercury for agricultural uses, either as a spray on crops or as a seed preservative, was halted in 1976, when the US EPA banned most pesticide uses of mercury. Exceptions were initially made for fungicidal uses in paints and outdoor fabrics. However, use in paints was discontinued in 1991 under the Federal Insecticide, Fungicide and Rodenticide Act. Since most uses of mercury in pesticide have been discontinued for thirty years and all uses banned for almost ten years, it is unlikely that past uses of mercury significantly contribute to current agricultural runoff. However, mercury-containing chemicals may still be present in the form of old stocks.

There are over 150 trade and chemical names of pesticides used in the past that contain mercury (Wisconsin DNR, 1997). The Pesticide Action Network (PAN) website (www.pesticideinfo.org) lists almost one hundred pesticides containing mercury which were used in the past. Data from the Department of Pesticide Regulation and from the EPA include lists of products containing mercury and information regarding whether they are in active use or were cancelled, but does not provide use information. Conversely, a list of pesticides containing mercury is available, but the brand names are given, for which there are several different pesticides, not necessarily containing mercury. Since there are hundreds of these listings, analysis of this information is not possible within the scope of this TMDL. However, as mentioned above, the discontinued use of mercury for agricultural purposes almost 30 years ago probably makes that information inconsequential.

Consumer Products

Mercury has properties that have led to its use in many different products and industrial sectors. It conducts electricity, forms alloys with other metals and expands in response to changes in temperature and pressure. Some mercury compounds act as preservatives, and are used in medicines and other products. While some manufacturers have reduced or eliminated their use of mercury in products, there are still many existing items in the marketplace that contain mercury. The following list represents some of the major consumer items found to contain mercury: batteries, dental amalgam, fluorescent lamps, necklaces and other jewelry, paint, thermometers, and thermostats.

Batteries

Mercury prevents internal discharge and gassing in batteries. Since 1994, federal law has limited the amount of mercury added to button cell batteries, and has prohibited intentional addition of mercury to standard household batteries (dry-cell sizes A, AA, C, D, etc.).

Dental Amalgam

The silver fillings used by dentists contains a mixture of metals such as silver, copper, tin, and mercury.

Fluorescent Lamps

Mercury is used in the long fluorescent, compact fluorescent, and high-intensity discharge (HID) lamps. Visible light is produced when the mercury in the lamp is electrically energized.

Necklaces and Other Jewelry

There are some necklaces imported from Mexico that contain a glass pendant that contains mercury. The mercury-containing pendants can come in various shapes such as hearts, bottles, balls, saber teeth, and chili peppers.

Paint

Mercury was used as a preservative in indoor and exterior paint until its use was discontinued in 1991. Many water-based paints (even interior paints) used mercury as a fungicide.

Thermostats

Mercury is used in thermostats, a type of switch that is used to control temperature changes in heating and air conditioning systems.

Thermometers

Mercury is used in glass thermometers because mercury is sensitive to changes in temperature. A mercury thermometer can be easily identified by the presence of silver liquid. Thermometers may contribute mercury to POTWs owing to consumer breakage and disposal. Additionally, agricultural use of mercury thermometers could contribute mercury to receiving waters via runoff.

An internet search of orchard thermometers currently sold by supply companies indicates thermometers currently being sold are alcohol based; not mercury thermometers. However, it is reported (Ben Faber of UC Cooperative Extension, pers. communication to S.Rothenberg, 2005) that mercury thermometers are currently used to detect frost by citrus and avocado growers. If an estimated 2 thermometers were used on every 50 acres of orchards (26,250 acres total), about 1,000 mercury thermometers might be in use in the CCW at any given time.

Legislation to restrict mercury use in consumer products and in other applications has been introduced at the Federal level as well as in many states throughout the country. Legislation has been proposed that prohibits the sale or supply of mercury fever thermometers (except by prescription), novelty items and automobile switches as well as prohibiting purchases of mercury by schools (LWA, 2002). Additionally, many cities throughout California offer thermometer exchange programs which allow residents to turn in a mercury thermometer in exchange for a digital thermometer, or a coupon for a discounted digital thermometer.

Summary / Conclusions

Primary pathways of mercury seem to be runoff from agricultural land, residential areas, and open space. Available data are not yet sufficient for determining proportional contributions from the sources contributing to these runoff pathways. It is suspected that natural soil concentrations, atmospheric deposition, and possibly residues from past use of pesticides containing mercury are primarily responsible.

6.6 Sources – Nickel

Nickel can find its way into receiving waters through industrial and POTW discharges, urban runoff, erosion and sediment transport, and atmospheric deposition. Nickel is released into the atmosphere and wastewater by industries that make or use nickel, nickel alloys, or nickel compounds. Sources potentially contributing to the concentrations discharged through these pathways include: automobile related industries (dealers, car washes, and mechanic shops), motor oil, manufacturing sector that produce nickel alloy products, and natural concentrations in soil.

Sources and pathways through which nickel is transported to the stream are illustrated in Figure 30, nickel concentrations over time according to land use type are shown in Figure 31, loading contributions according to land use type are presented in Table 55, and HSPF modeling results indicating cumulative loading versus flow are presented in Figure 32. The HSPF model is described in the Linkage Analysis section.

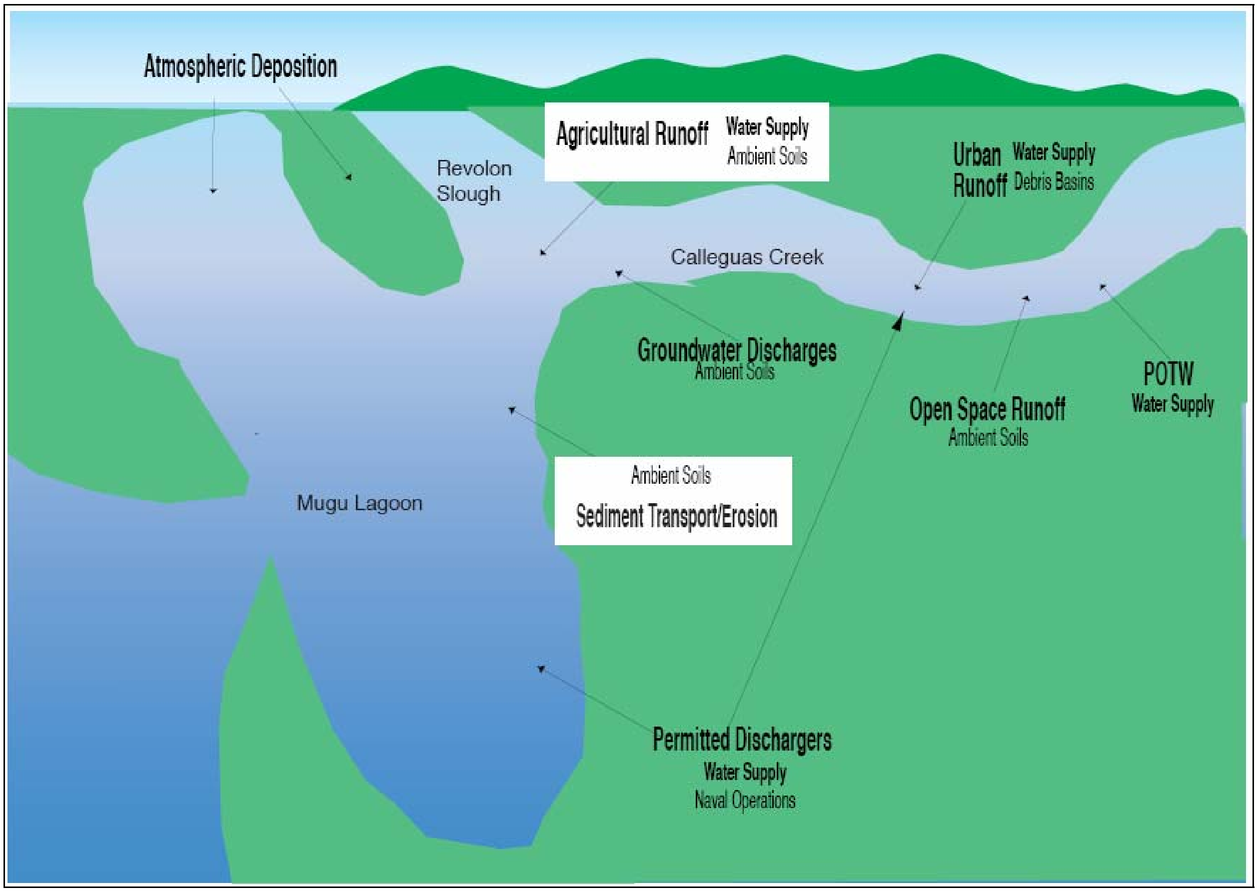


Figure 30. Nickel sources and pathways. Most significant sources indicated by white boxes.

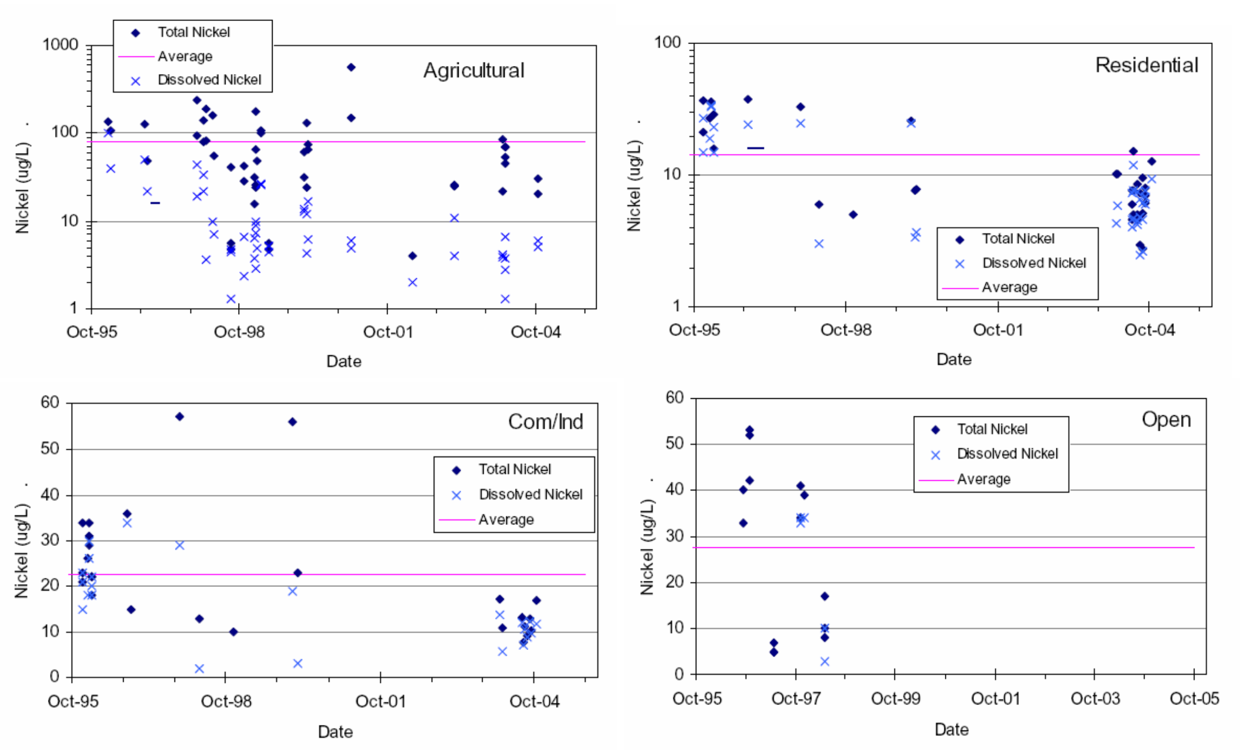


Figure 31. Nickel in runoff by land use category, using data from CCW and adjacent watersheds (ug/L).

Table 55. Estimated Total Nickel Loading in the CCW by Land Use Type (Lbs/Yr).

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average [2]	15,182	76,868	899	277	184	5,110	98,520
Percent of Total	15%	78%	1%	0%	0%	5%	100%

1 According to HSPF modeling described in the Linkage Analysis section.
2 Load calculated as annual average for the water years 1994-2004

Table 56. Estimated Dissolved Nickel Loading in the CCW by Land Use Type (Lbs/Yr).

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average [2]	794	461	899	277	184	256	2,870
Percent of Total	28%	16%	31%	10%	6%	9%	100%

1 According to HSPF modeling described in the Linkage Analysis section.
2 Load calculated as annual average for the water years 1994-2004

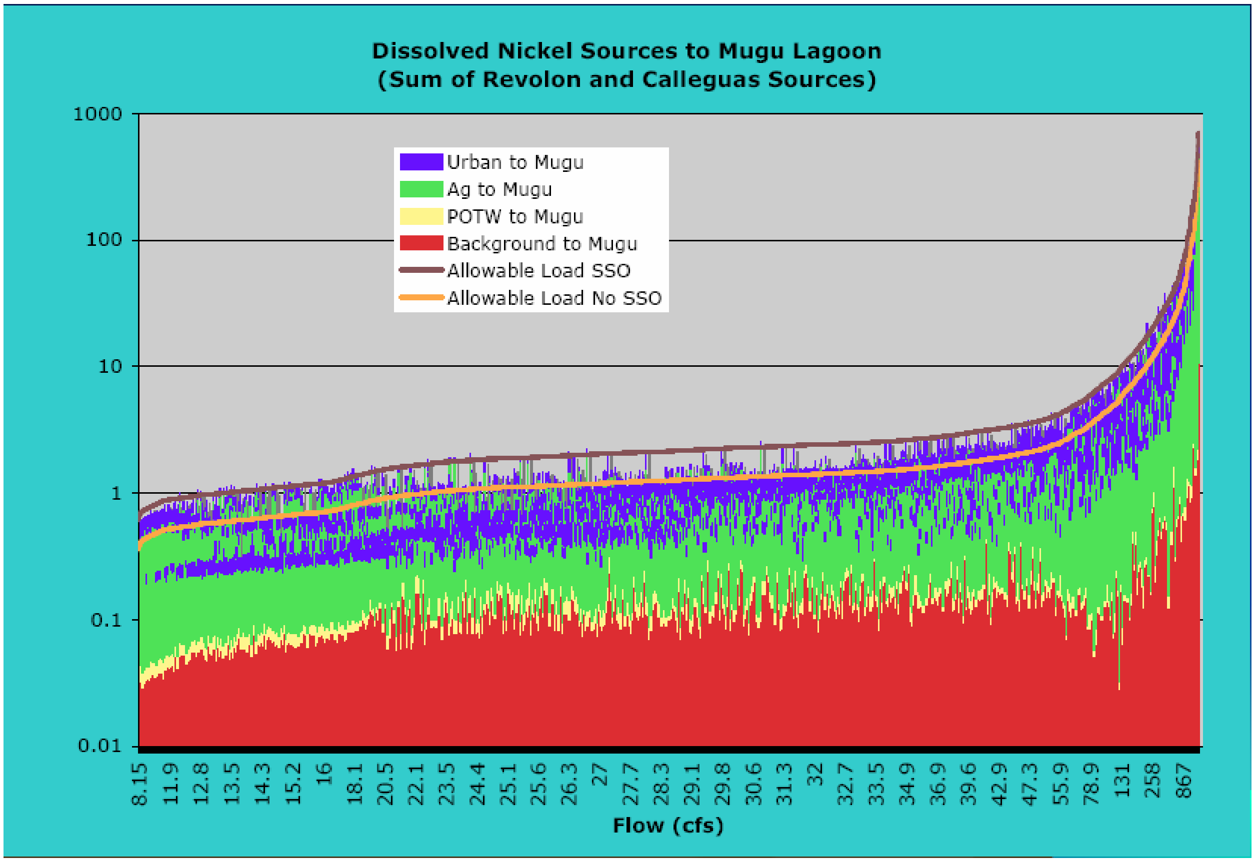


Figure 32. Dissolved nickel source loads to Mugu Lagoon, based on HSPF modeling results.

Pure nickel is a hard, silvery-white metal, which has properties that make it very desirable for combining with other metals (iron, copper, chromium, and zinc) to form alloys. Alloys uses range from metal coins and jewelry to industrial parts such as valves and heat exchangers. Most commonly, nickel is used to make stainless steel. In addition, compounds that consist of nickel combined with other elements such as chlorine, sulfur, and oxygen are water soluble. Nickel compounds are used for nickel plating, to color ceramics, batteries, and catalysts that increase the rate of chemical reactions .

Soil Concentrations - Nickel

Nickel is the 24th most abundant element. Nickel combined with other elements occurs naturally in the earth's crust. It is found in virtually all types of soil. In the environment, it is primarily found combined with oxygen or sulfur as oxides or sulfides. Nickel is also found in meteorites and on the ocean floor in lumps of minerals called sea floor nodules.

Natural concentrations of nickel in soils of the CCW and also specific to the Naval Air Weapons Station Point Mugu are discussed in detail in the Sources (General) section, Soil Concentrations subsection. Estimated natural soil loadings of total nickel presented in that section represent about 10% of the average annual loading of total nickel. During wet years, the proportion of the load from soil concentrations could be more significant.

Pesticide Use

There are currently no known documented uses of nickel in pesticide products for urban or agricultural purposes in the CCW. Although some uses may have occurred in the past, none are currently indicated as registered for use by the EPA, Table 57.

Table 57. Pesticides Containing Nickel, Potentially Used in the Past in the CCW (www.pesticideinfo.org).

Chemical Name	Use Type	Chemical Class	U.S. EPA Registered
Alkyl*-1-(2-amin…	Microbiocide	Inorganic-Nickel, Imidazoline	No
Maneb and nickel sulfate hexahydrate	Fungicide	Dithiocarbamate, Inorganic-Nickel	No
Nickel		Inorganic-Nickel	No
Nickel and nickel compounds	Fungicide	Inorganic-Nickel	No
Nickel Chloride		Inorganic-Nickel	No
Nickel diethyl hexyl acid phosphate complex		Inorganic-Nickel	No
Nickel sulfate (anhydrous)	Fungicide	Inorganic-Nickel	No
Nickel sulfate hexahydrate	Fungicide	Inorganic-Nickel	No

Consumer Products

Nickel readily combines with other metals to form alloys with properties that include corrosion resistance, strength, and special magnetic and electronic properties. It is commonly used in electronics and specialist engineering for plating, special truck bodies, spark plugs, gears, etc. Nickel-based alloys are used in producing spark plugs, diesel valves, thermostats, turbochargers wheels and casings. More recently, nickel is used in rechargeable batteries in the forms of Nickel-Cadmium (NiCd) and Nickel- metal Hybrids (NiMH) for many uses including EV and hybrid cars. It is estimated that the automotive sector accounts for approximately 7-8% of new nickel use (approximately 90,000 tons) each year. Other potential sources of nickel include: car dealers, car washes, machine shops, miscellaneous equipment rental, vehicle repair, vehicle service facilities, electroplaters, hospitals, soap manufacturing, and used motor oil.

Summary of Nickel Sources in the CCW

Based on monitoring and modeling results, it appears that a majority of the nickel found in the CCW is from agricultural areas and groundwater. The primary suspected source is natural concentrations in local soils, which travel to receiving waters via erosion and sediment transport processes.

6.7 Sources - Selenium

Selenium makes its way into receiving waters through groundwater discharges, industrial and POTW discharges, urban and agricultural runoff, erosion and sediment transport, and atmospheric deposition. Sources potentially contributing to the concentrations discharged through these pathways include: natural concentrations in local groundwater and soils, industrial activities, mining/extraction activities, and water supply.

Sources and pathways through which selenium is transported to the stream are illustrated in Figure 33, selenium concentrations over time according to land use type are shown in Figure 34, loading contributions according to land use type are presented in Table 58, and HSPF modeling results indicating cumulative loading versus flow are presented in Figure 35. The HSPF model is described in the Linkage Analysis section.

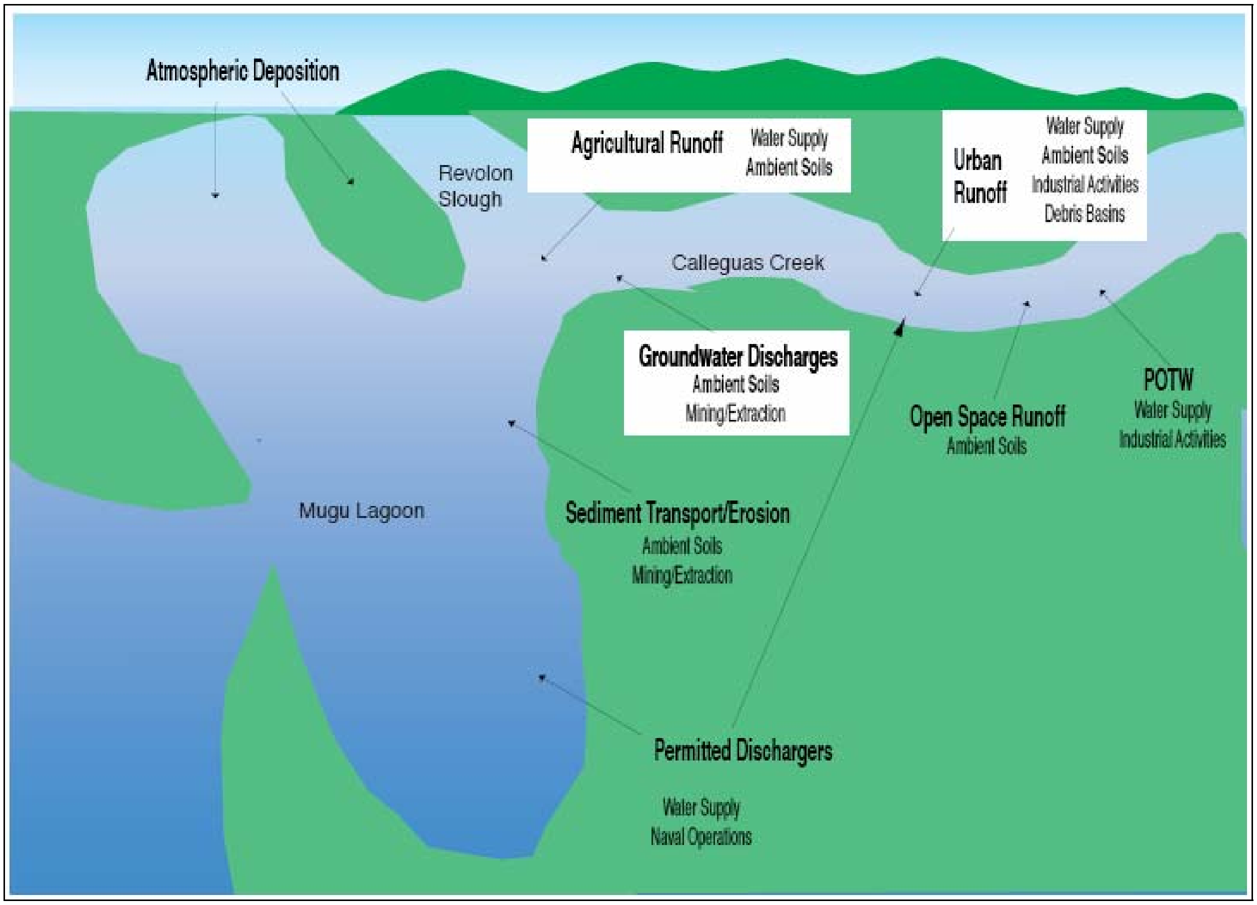


Figure 33. Selenium sources and pathways. Most significant sources indicated by white boxes.

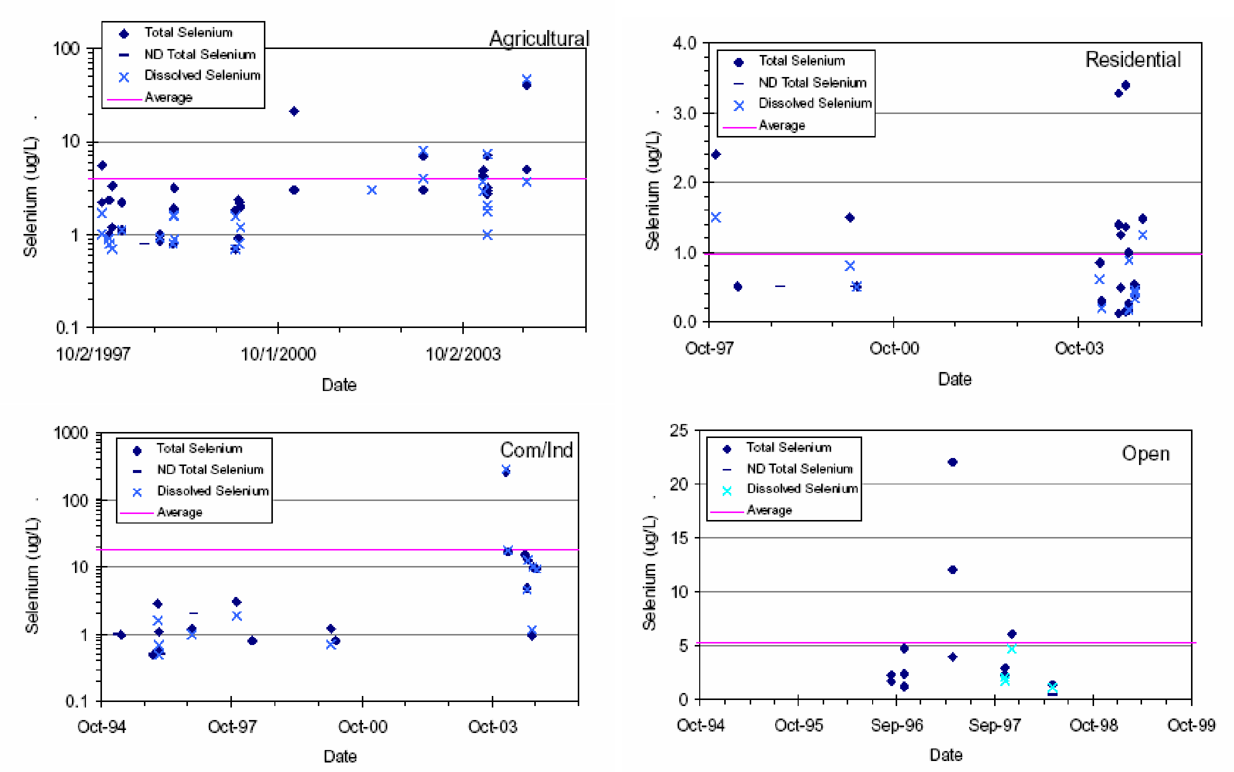


Figure 34. Selenium in runoff by land use category, using data from CCW and adjacent watersheds (ug/L).

Table 58. Estimated Total Selenium Loading in the CCW by Land Use Type (Lbs/Yr).

Land Use	Urban	Ag	Groundwater	POTW	Simi Wells	Open Space	Total
Annual Average 2	627.3	1,593.6	1,057.2	75.2	9.6	164.2	3,527.1
Percent of Total	18%	45%	30%	2%	0%	5%	100%

1 According to HSPF modeling described in the Linkage Analysis section.

2 Load calculated as annual average for the water years 1994-2004

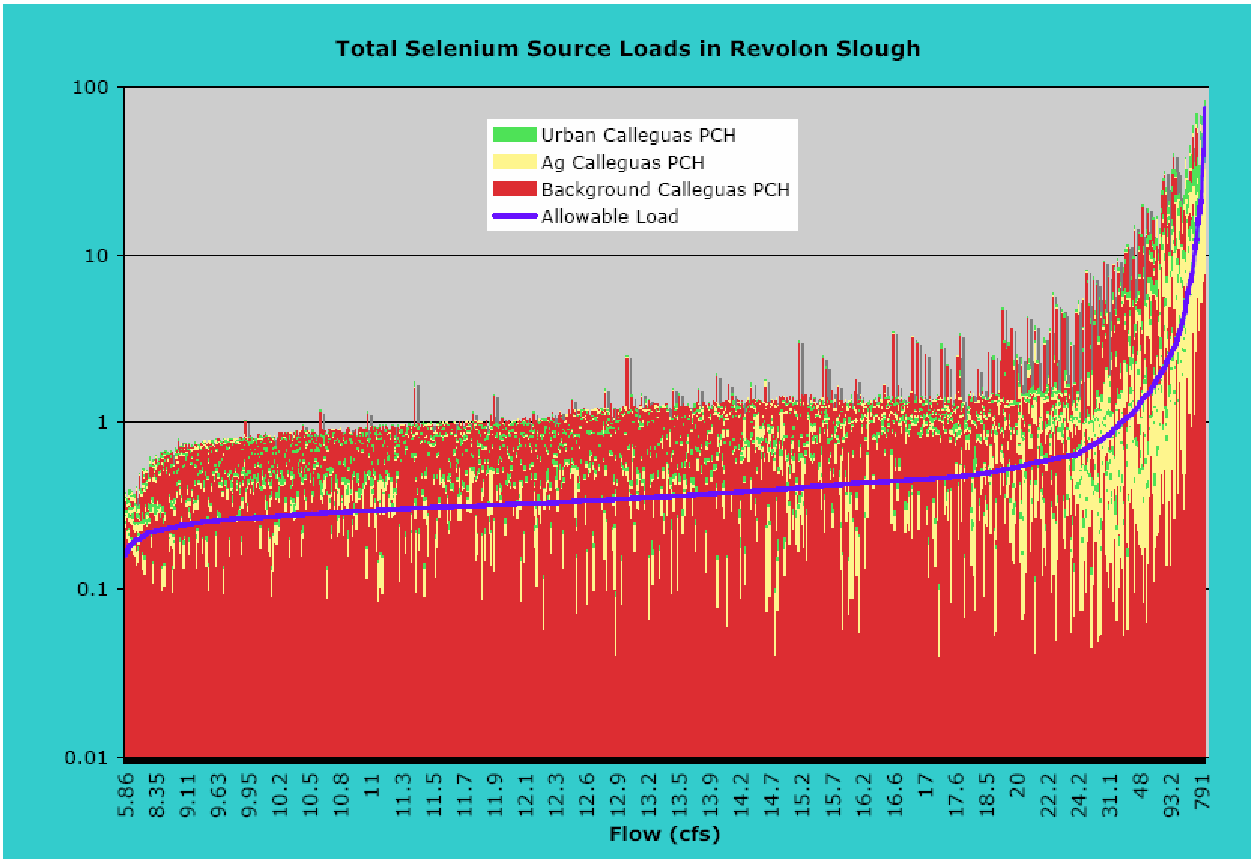


Figure 35. Total selenium source loads to Mugu Lagoon, based on HSPF modeling results.

Groundwater

See description of groundwater, presented above in the Sources (General) subsection.

Soil Concentrations - Selenium

Groundwater sometimes contains elevated concentrations of selenium due to weathering/leaching from rocks and soils. Selenium can be concentrated through irrigation practices in areas with seleniferous soils such as those composed of marine shale. Selenium occurs in the sulfide deposits of Cu, Pb, Hg, Ag, Zn and can be released during the mining and smelting of these ores. Marine shales are formed by sedimentary accumulation and mineralization of marine particulate matter, including phytoplankton (Presser, 1994). Agricultural drainage may remobilize selenium by leaching it from soils that are enriched in marine shales, and as a result of long-term irrigation practices, seleniferous salts can build up (Luoma and Presser, 2000).

According to the Soil Survey Geographic (SSURGO) Database from NRCS, Ventura County contains several soil types which include shale (Figure 36). Most of the land containing shaly soils is located in the eastern half of the watershed, generally situated at higher elevations.

Natural concentrations of selenium in soils of the CCW and also specific to Naval Air Weapons Station Point Mugu are discussed in detail in the Sources (General) section, Soil Concentrations subsection.

Estimated natural soil loadings of total selenium presented in that section represent less than 1% of the average annual loading of total selenium. During wet years, the proportion of the load from soil concentrations could be more significant.

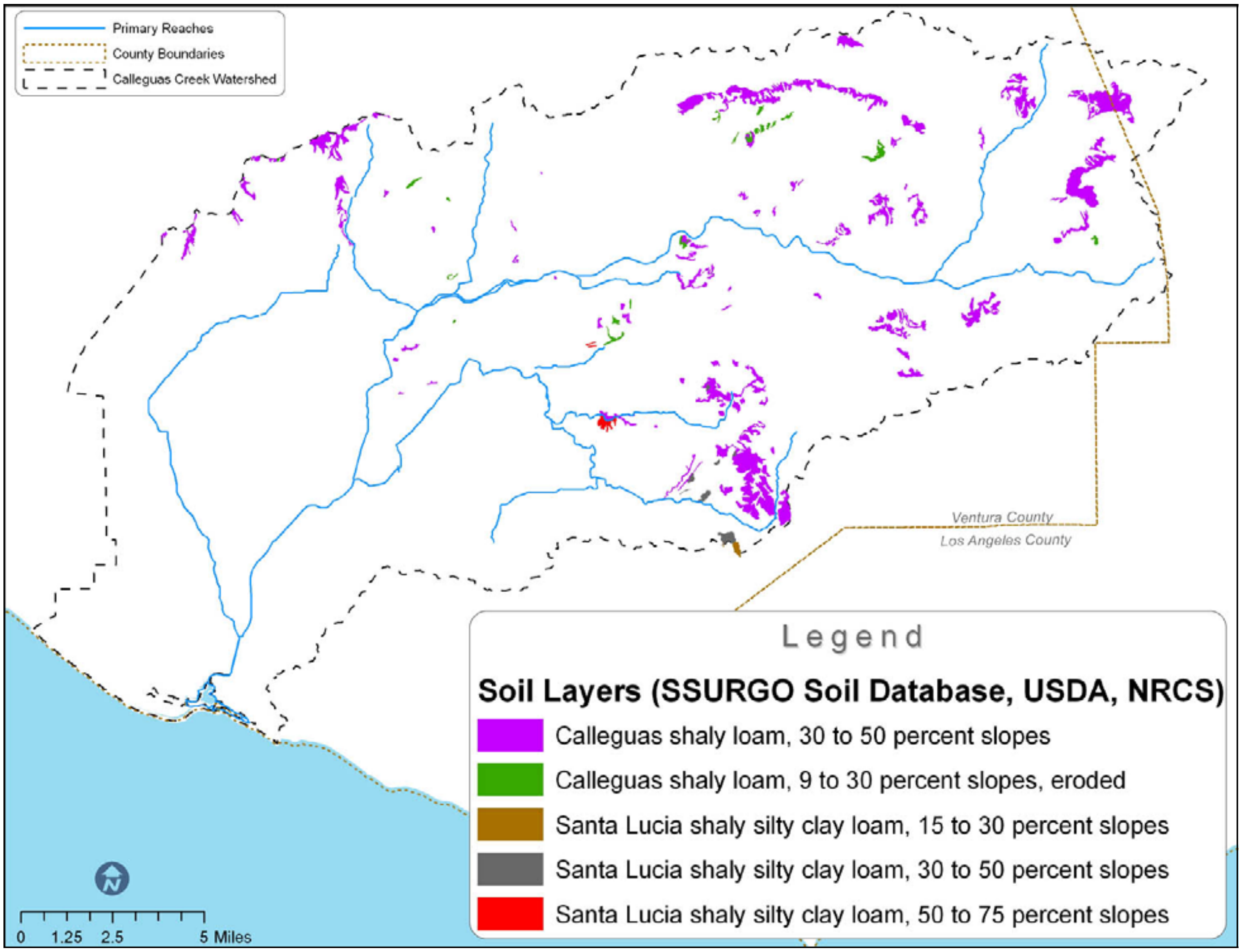


Figure 36. Shaly Surface Soils in the Calleguas Creek Watershed (Natural Resources Conservation Service, Soil Survey Geographic (SSURGO) Database).

Another common method for assessing the presence of selenium in soils is to look for the presence of certain plant species which require high selenium levels in order to thrive, known as indicator species. A few of the most widely known indicator plants include: various species of Astragalus, prince's plume, some woody asters, Atriplex sp. (saltbush), Sideranthus sp., Machaeranthera sp. (tansy asters), Grindelia sp. (gumweed). The following statewide plant and vegetation spatial-databases were examined, and no occurrences/listings of selenium indicator plants were found:

- CNDDB (CDFG) - T&E species occurrence database - checked within Calleguas watershed (only Astragalus was A. Brauntonii).
- CalVeg - linked with Ca. WHR (CDFG) species and did not find any listings for selected plants.
- Channel Island Chapter of the Ca. Native Plant Society. No listing for selected plants.

Mining, Oil Extraction and Refining

Selenium is present in coal, crude oil, and oil shale (Lemly 1997). The same biogeochemical processes that make selenium a bioaccumulation concern explain how selenium made its way into crude oil and marine shales. Oil refineries and agricultural drainage have a common source for selenium, which is the bioaccumulation of selenium by phytoplankton, plants, and animals, along with mineralization and fossilization over geologic timescales and human remobilization. Thus, selenium occurs naturally in coal and fuel oil and is emitted in flue gas and in fly ash during combustion (US EPA, 2004). Selenium that has accumulated in fossil fuels is remobilized in the process of refining and cracking crude oils. Additionally, selenium may naturally occur in areas that are associated with oil production and be released into the groundwater through natural processes not associated with mining and oil extraction. Mining and oil extraction activities may mobilize selenium into the environment or natural discharges of selenium may be correlated to areas where mining and oil extraction occur because of the geology of the area.

A map of inactive and current mining/extraction sites in the CCW is presented above in the Sources (General) section, Figure 19. Many of the mines shown in that figure are not currently active.

Selenium is not released in any significant quantity into by-products, air or water, during oil separation from oil shale. The majority of selenium remains in the spent shale (Shendrikar and Faudel 1978). However, rain can leach selenium from coal and oil-shale mining, preparation and storage sites, where it may enter down-gradient streams and reservoirs through precipitation runoff (Jones 1990). Most (if not all) oil extraction in Southern California is not from oil shale however, but from other sedimentary deposits where crude oil is pumped directly from the ground from drilled wells.

In October of 2000, the EPA's Office of Compliance released a Profile of the Oil and Gas Extraction Industry (EPA 2000). Review of this document suggests several potential sources of selenium contamination during oil and gas extraction. However, the document indicates that these sources are controlled and that disposal is monitored. A brief description follows.

The primary byproduct of oil extraction is water. Most of this water is extracted from the well concurrent with the oil. The concentrations of inorganics, including selenium, in this water can be high depending upon the geochemistry of the region. Most often this water is injected underground for one of two purposes. The first is disposal, accounting for 37% of the use or disposal of extraction water. The second involves the reuse of this water to enhance the recovery of oil in the extraction process. In 57% of cases, oil associated water is injected underground for oil recovery enhancement. In both cases, prior to injection the water is checked to determine if it fails NPDES requirements (including EPA water quality criteria). If NPDES requirements are not met, the water is treated as waste. An alternative disposal method is to use the water for agricultural irrigation, in which case the water is treated and monitored for water quality standards prior to use.

There are also solid byproducts of oil extraction, such as the waste rock produced during drilling. There are several methods of disposal. Often this waste is stored in a dirt covered pit onsite, once the liquid fraction has been removed. Depending upon the geology of the region, some states require the use of a liner. In some cases a mixture of cement, fly ash (from coal-fired utility boilers, often high in selenium concentration) and lime or cement kiln dust is added to the contents of the pit (the liquids are not necessarily removed). The contents then solidify, immobilizing the heavy metal components. Approximately 10% of the time the solid waste is spread over land. Due to obvious groundwater contamination concerns, the solids are first checked for heavy metal and other contaminant concentrations and then are continually monitored for pH, chlorides and hydrocarbons. Finally, offsite commercial disposal consists of approximately 15% of the disposal of solid wastes in oil gas extraction.

Oil and gas extraction facilities are not required by the Engineering Planning and Community Right-to-Know Act to report to the Toxics Release Inventory. Therefore, no specific information regarding Southern California facilities is available.

Industrial Activities

Although information in the literature suggest oil and gas extraction processes potentially release selenium to the surrounding natural environment; much of the focus on oil and gas activities is on processes involved in refining crude oil, which is known as a risk for selenium contamination. No crude oil refineries currently operate in the CCW have been identified.

Source Tracking

During selenium speciation testing performed in one area of the Calleguas Creek Watershed (Revolon Slough and Beardsley Wash), it was found that the majority of total selenium (80-100%) was selenate (+6) and a small fraction (<10%) was selenite (+4) (Figure 37). The various forms of selenium and their roles in cycling, fate and transport are described earlier in the Source Assessment Processes and Cycling section.

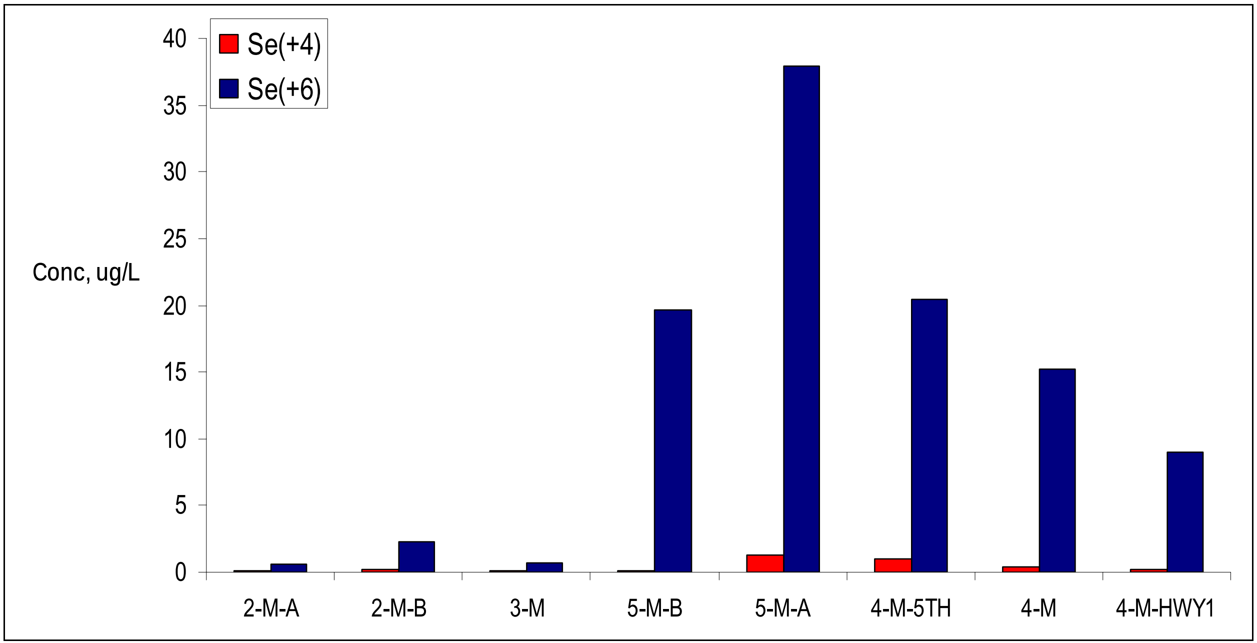


Figure 37. Results of Selenium Speciation Testing.

Source investigation testing in the Revolon Slough and Beardsley Wash reaches pointed toward the agricultural drain in Beardsley Wash as the main contributor of selenium (34.1 ug/L) compared to 11.6 ug/L from the channel that flows through the lemon orchards, and 0.94 ug/L from the channel that comes from residential/golf course area (Figure 38). It is important to note that the agricultural drain in Beardsley Wash represents a pathway, which likely results primarily from sources such as groundwater, imported water, and/or natural concentrations in the soil; rather than from agricultural use of fertilizers or pesticides.

Another factor potentially worthy of consideration relating to the selenium source study, is the presence of a large number of oil and/or gas wells in the vicinity of the sampling area.

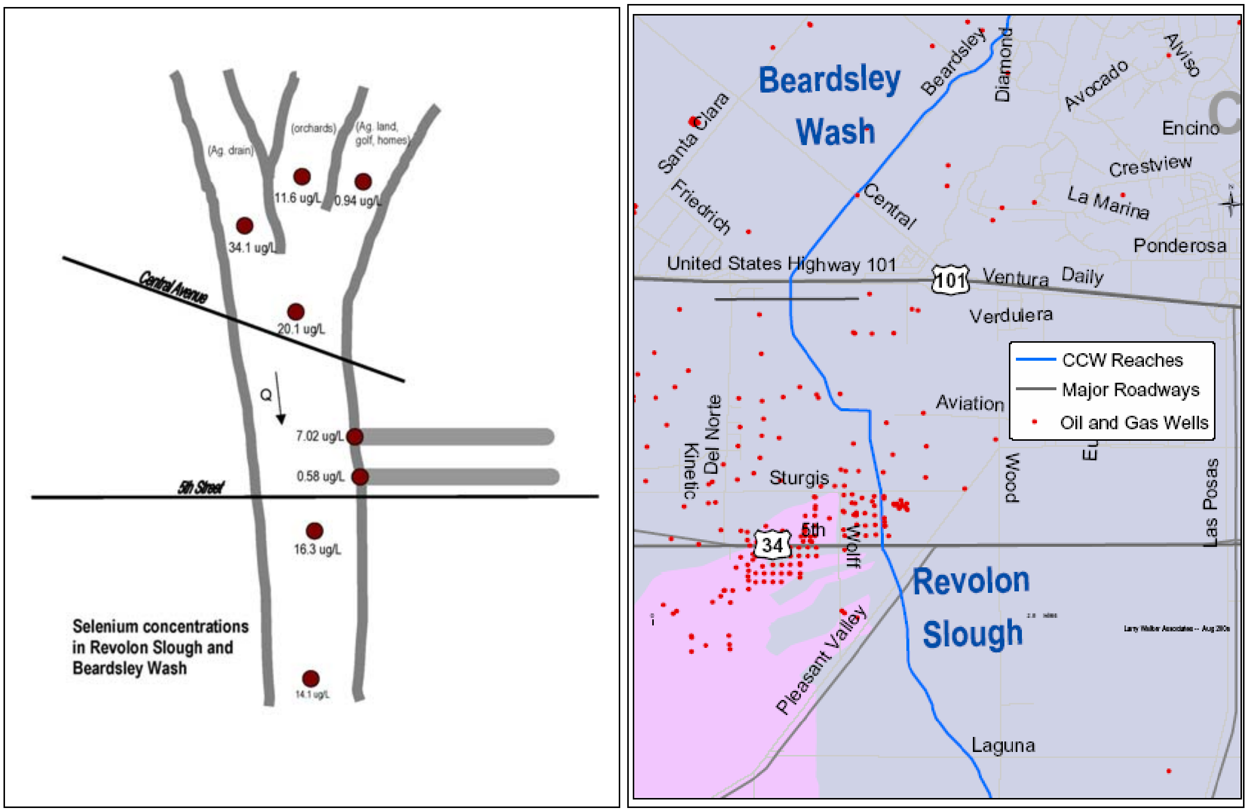


Figure 38. Selenium Source Investigation Monitoring Results (left) and Map Showing Oil and Gas Wells in Monitoring Area (right). Note that 5th street and Hwy 34 are the same road in this area.

Summary / Conclusions

Natural soil concentrations are the primary source of selenium identified in the CCW as a likely contributor to groundwater and agricultural discharges. Past and current mining/extraction activities may also contribute.

7 LINKAGE ANALYSIS – COPPER, NICKEL, AND SELENIUM

Achievement of the numeric targets proposed for the copper, nickel, and selenium TMDLs is linked to controlling sources of these constituents in the watershed. This section demonstrates how actions taken to control the sources of copper, nickel, and selenium will ensure attainment of water quality standards. A brief description of modeling used to support the linkage analysis and for developing allocations is included here, and detailed explanations of all modeling are provided in Appendix C (Linkage Analysis HSPF Modeling Report), Appendix D (HSPF Modeling Calibration Report), and Appendix E (Mugu Lagoon Model Report).

7.1 Relationship Between Sources, Targets, and Allocations - Cu, Ni, Se

Copper, nickel, and selenium discharge to receiving waters from a variety of natural and anthropogenic sources, as described in the Source Analysis section. These constituents exist in receiving waters in both the dissolved and particulate form.

Copper and nickel in receiving waters can cause toxicity to aquatic organisms. The free ionic form of these metals are the most bioavailable and cause the majority of toxicity to aquatic organisms. Measurement of the free ionic fraction is not a standard analysis. In a practical sense, the bioavailable form, and therefore the potential for impairment, is best represented by the dissolved fraction of the constituent in the water column (USEPA, 1993). Thus, numeric targets selected for the copper, and nickel TMDLs are for dissolved concentrations.

In contrast, the primary route of exposure of concern for selenium is through contamination of the food web. While most selenium exists as dissolved species, such as selenate and selenite, particulate forms of organoselenium are key linkages to accumulation in filter feeders. Therefore, the existing water quality objective for selenium (5 ppb), and the water column numeric target of this TMDL, is based on total recoverable concentrations.

Although dissolved concentrations are the primary concern for copper and nickel; waste load allocations and load allocations are assigned according to the total loads of these constituents in water. Allocations are expressed as total loads for several reasons:

1. NPDES permits require loads expressed in the total form;
2. to address concerns that copper and nickel associated with the particulate portion may transfer or re-partition into the dissolved portion and thereby increase aquatic toxicity.
3. to address concerns that pollutant-laden suspended sediments carried into Mugu Lagoon might settle out and then cause toxicity to benthic organisms in the lagoon.

For copper and nickel, total allocations are set by first determining dissolved loads necessary to achieve numeric targets during critical conditions and then calculating the total loads associated with each dissolved load and critical condition. For selenium, total loads are calculated directly based on total recoverable targets. Modeling described below is used to determine dissolved and total loads necessary to achieve water quality standards.

7.2 HSPF Hydrologic and Water Quality Model - Cu, Ni, Se

USEPA's Hydrologic Simulation Program Fortran (HSPF) model provides the foundation for development of the TMDLs for copper, nickel, and selenium. By simulating both hydrology and water quality, the model is able to generate estimates of loading, movement, and the effects of reduced pollutant discharges upon receiving waters. The model is driven by meteorological inputs and the corresponding responses of the land surface and subsurface processes. In order to achieve the full range of functionality described here, a hydrologic HSPF model developed to represent conditions in the Calleguas Creek Watershed (Aqua Terra, 2005) was modified to provide enhanced water quality analysis capabilities. Additional water quality parameters added to the model include: temperature, total suspended solids (TSS), hardness, chloride, total and dissolved copper, total and dissolved nickel, and total and dissolved selenium.

The HSPF application used for this TMDL to evaluate conditions in the CCW provides a sound model for watershed management analyses. Calibration and validation results demonstrate a good to very good representation of the observed hydrologic data, based on a wide range of graphical and statistical comparisons and measures of model performance. Calibration of the model includes consideration of up to eight stream gage locations throughout the watershed for annual runoff, daily and monthly streamflow, flow duration and frequency, water balance components, and hourly storm hydrographs (Aqua Terra, 2005) Since water quality data are much more limited than data of receiving water flowrates, model calculations for water quality may not match water quality data as well as the hydrologic model output matches actual flow values. However, calibration of water quality modeling results suggest the model is sufficient to accurately reflect the relative loading of constituents from sources present in the watershed and to provide decision support for the CCW Metals and Selenium TMDL. A detailed explanation of the HSPF model is provided in Appendix C and Appendix D.

Initial Partition Coefficients Used in Model and Relationship to TSS

Copper, nickel, and selenium are modeled as both particulate and dissolved phase in surface waters, and as dissolved phase in groundwater baseflow and interflow. Total concentrations are calculated as the sum of the dissolved and particulate concentrations. In order to model the particulate phase, the partition coefficient is required by the model. An estimate of the partition coefficient (K_D) is determined by rearranging the partition equation into the form of a regression equation with a zero intercept, as shown below in Equation 1 - Equation 2.

Equation 1

$$C_d = \frac{C_T}{1 + \frac{K_D * TSS}{10^6}}$$

Equation 2

$$\frac{C_T}{C_d} - 1 = \frac{K_D}{10^6} * TSS$$

Equation 3

$$K_D = \left[\frac{C_T}{C_d} - 1 \right] * \frac{10^6}{TSS}$$

Where:		
	C_d	dissolved concentration
	C_T	total concentration
	TSS	total suspended solids
	KD	partition coefficient

Receiving water data from the watershed are used to estimate the partition coefficient (K_D). Calculated K_D values for the CCW are shown below in Figure 39 - Figure 41 as a plot of C_T/Cd-1 versus TSS. Per Equation 3, the slope of the regression line in each figure indicates the best-fit value for K_D which is used as an initial estimate in the model for copper (5600 L/Kg), nickel (5400 L/Kg), and selenium (420 L/Kg).

As indicated in Equation 3 and the figures below, K_D varies with TSS as well as the total and dissolved concentration of copper, nickel, and selenium. Thus, use of the best-fit value described above as an initial estimated K_D for each critical condition appropriately accounts for the relationship between K_D and TSS.

Other points which are key to understanding operation of the model involve mass transfer rates and setting of initial conditions. The mass transfer rate is set fast enough not to affect model results; equilibrium is maintained over a one day averaged time step. Since the first several years of simulation are not considered (to allow for model spin-up), the initial conditions specified in the model have little effect on results.

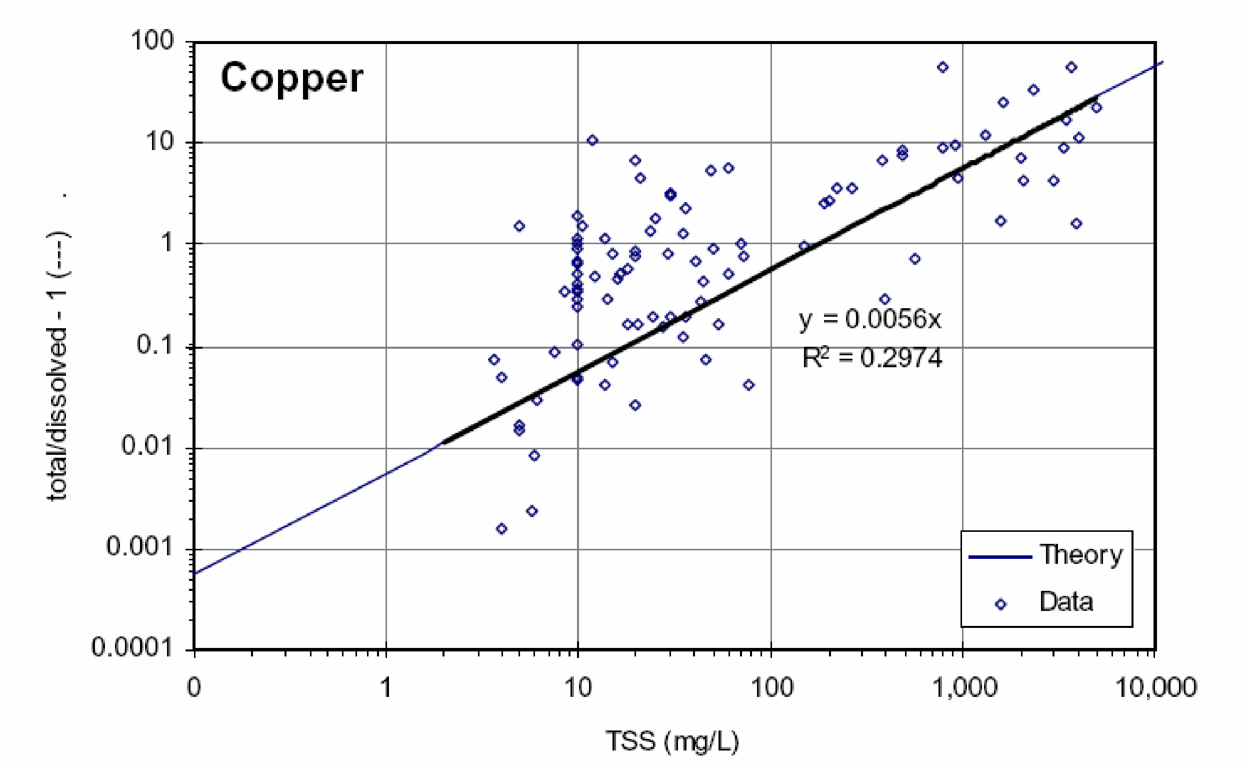


Figure 39. Copper K_D values for the CCW, and best-fit K_D used for modeling of copper in the CCW (5,600 L/kg).

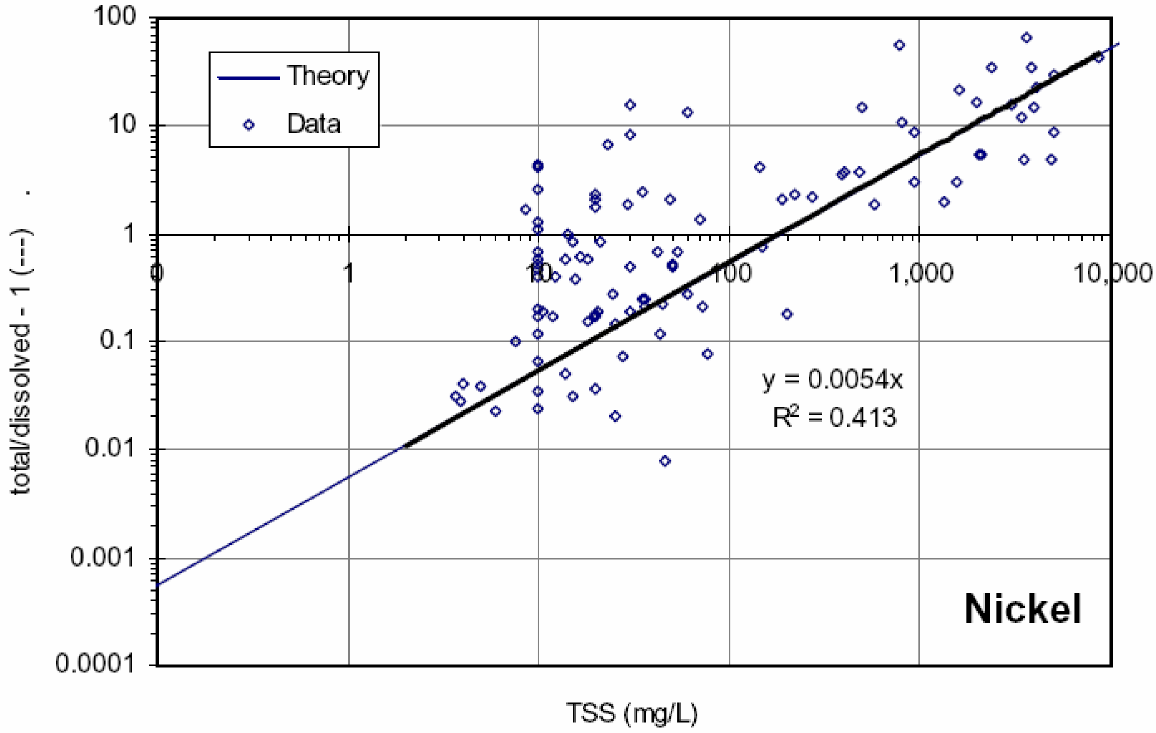


Figure 40. Nickel K_D values for the CCW, and best-fit K_D used for modeling of nickel in the CCW (5,400 L/kg).

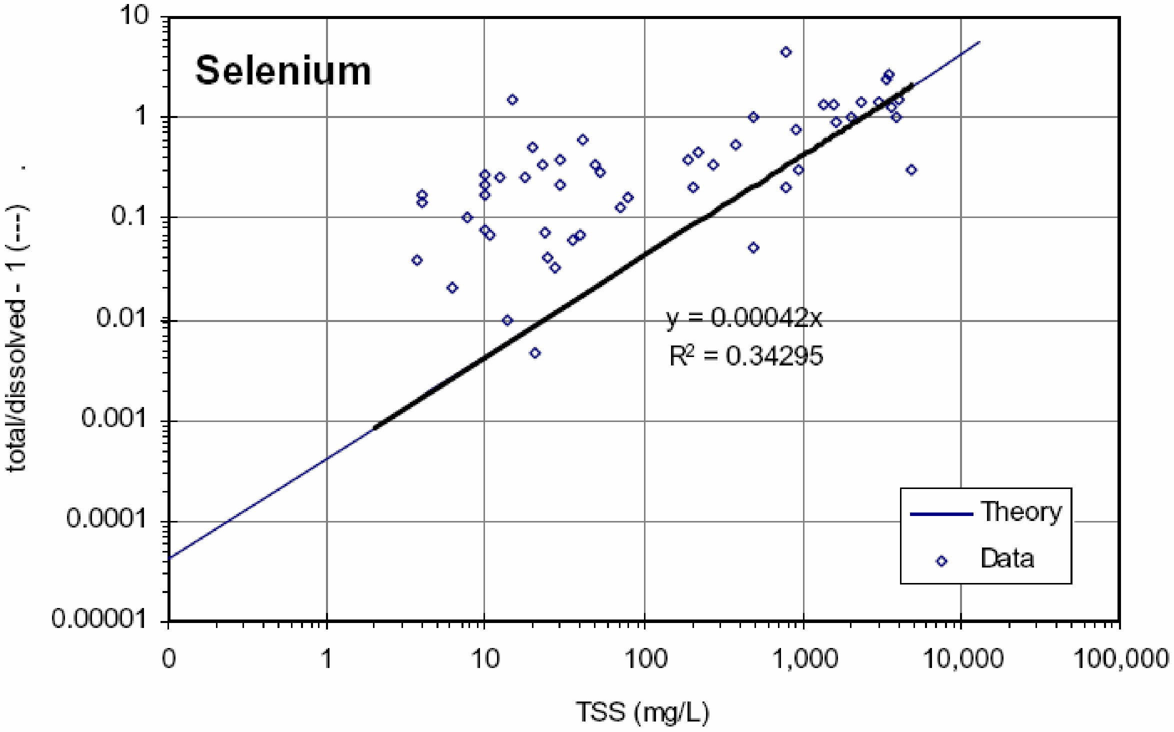


Figure 41. Selenium K_D values for the CCW, and best-fit K_D used for modeling of selenium in the CCW (420 L/kg).

7.3 Translating Requisite Dissolved Loads to Equivalent Total Loads - Cu, Ni

As explained earlier, dissolved loads of copper and nickel estimated to result in achievement of numeric targets are translated into equivalent total loads. EPA guidance on translators (USEPA, 1996), describes three acceptable methods for translating dissolved loads into equivalent total loads:

> "The translator is the fraction of total recoverable metal in the downstream water that is dissolved; that is, the dissolved metal concentration divided by the total recoverable metal concentration. The translator may take one of three forms. (1) It may be assumed to be equivalent to the criteria conversion factors. (2) It may be developed directly as the ratio of dissolved to total recoverable metal. (3) Or it may be developed through the use of a partition coefficient that is functionally related to the number of metal binding sites on the adsorbent in the water column (i.e., concentrations of TSS, TOC, or humic substances)."

The TMDLs for copper and nickel in the CCW were developed using the partition coefficient equation to translate allowable dissolved loads into equivalent total loads. EPA guidance notes the strength of this approach:

> "Use of the partition coefficient may provide advantages over the dissolved fraction when using dynamic simulation for waste load allocation (WLA) or the total maximum daily load (TMDL) calculation and permit limit determination because Kp [the soil water partition coefficient, K_D] allows for greater mechanistic representation of the effects that changing environmental variable have on fD [fraction of total recoverable metal that is dissolved].

Since a translator is effectively the dissolved metal concentration divided by the total recoverable metal concentration, the partition coefficient equation utilized by the HSPF model provides the ability to translate dissolved concentrations and loads to total concentrations and loads for any set of temporal, spatial, and flow conditions. The manner in which total and dissolved concentrations are accounted for in the partition equation is represented above in Equation 1 - Equation 3, and also below in Equation 4.

Equation 4

$$C_T = C_d * \left[\frac{K_D * TSS}{10^6} + 1 \right]$$

7.4 Potential Effects of Suspended Sediment Loads Into Mugu Lagoon

During development of the TMDLs for copper and nickel, and selenium, concerns were expressed that pollutant-laden suspended sediments carried into Mugu Lagoon might settle out and then either re-partition into the dissolved phase or cause toxicity to benthic organisms. In order to address these concerns, a simple 'bathtub' model is used to examine the relationship between loads entering the lagoon and conditions in the lagoon.

Mugu Lagoon Metals and Selenium Model

A simplistic 'bathtub' model is used to investigate the way in which total, dissolved, and benthic sediment concentrations of metals and selenium respond to loading from the Calleguas Creek Watershed. Through conservative simplifying assumptions, equations describing water flow, sediment flux, and constituent fate and transport are reduced to a form suitable for implementing in a spreadsheet model, referred to as the Mugu Lagoon Metals and Selenium Model (MLMSM). Operation of the MLMSM and results from the model are described briefly below, and a detailed description included as Appendix E.

Operation of Mugu Lagoon Metals and Selenium Model

The MLMSM is developed from the fundamental principle of mass balance. The entire lagoon is modeled of as one complete-mix system. Tidal influences are not considered, and the lagoon is modeled as a constant volume. Since the tidal exchange of the lagoon would serve to dilute concentrations of metals and selenium, neglecting the exchange provides an implicit margin of safety to the model calculations. The principle of mass balance is presented below in Equation 5.

Equation 5.
$$\text{Accumulation} = \text{Inflow} - \text{Outflow} + \text{Generation} - \text{Degradation}$$

The concentration of a dissolved constituent is affected by the inflow and outflow of the constituent, adsorption onto suspended particles, and adsorption onto benthic sediment. The particulate content of a constituent is affected by the inflow and outflow of the constituent, settling of suspended material from the water column, and desorption to the dissolved phase. The benthic particulate content of a constituent is effected by the settling of water column particle associated constituent, and transfer with the dissolved water column phase.

Suspended solids are modeled by accounting for the inflow and outflow of TSS to and from the lagoon, and assuming a set percentage of the material deposits in the lagoon. No resuspension of the solids is included in the model. The lagoon bottom is considered an infinite sink for settled particles. A fixed-depth active sediment layer is specified in the model, and as new solids settle to the bottom of the lagoon they displace benthic sediments from the active layer.

Results - Mugu Lagoon Metals and Selenium Model

Results from the MLMSM are presented below in Figure 42 - Figure 47, showing in-lagoon concentrations of copper, nickel, and selenium versus time for total and dissolved concentrations in water and also for concentrations in sediment.

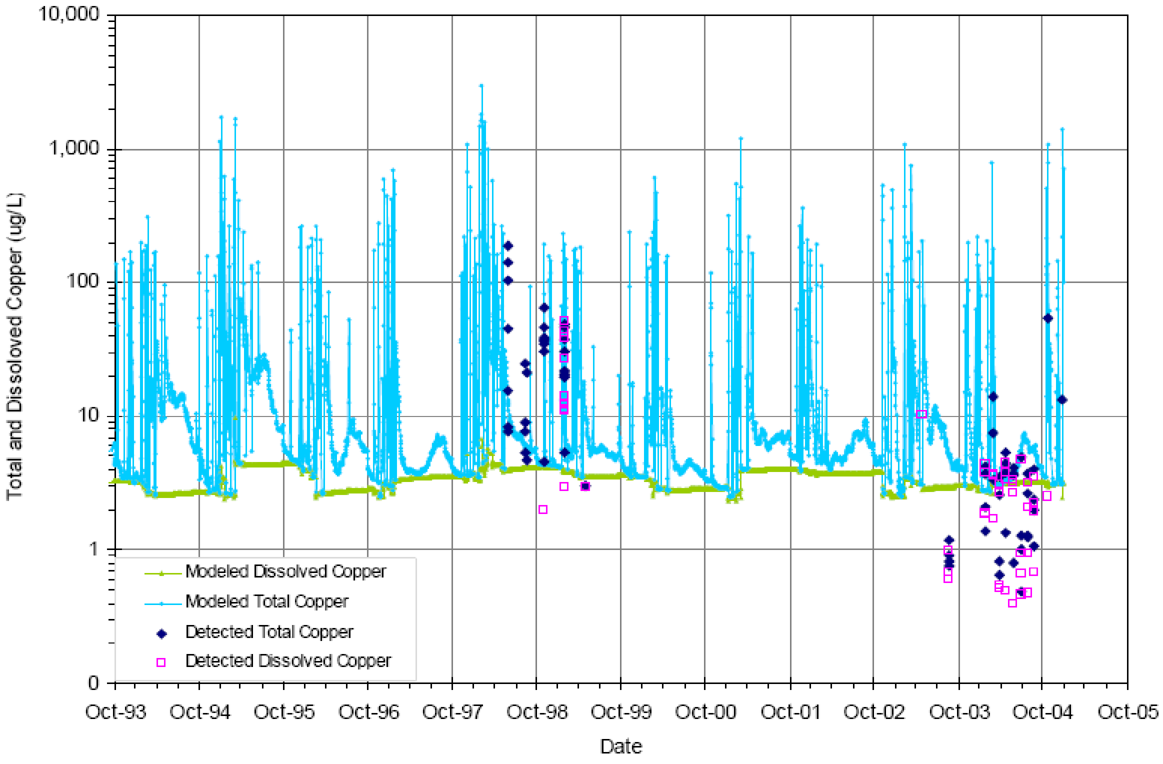


Figure 42. Time series of Total and Dissolved Copper from MLMSM Output and Measured Data.

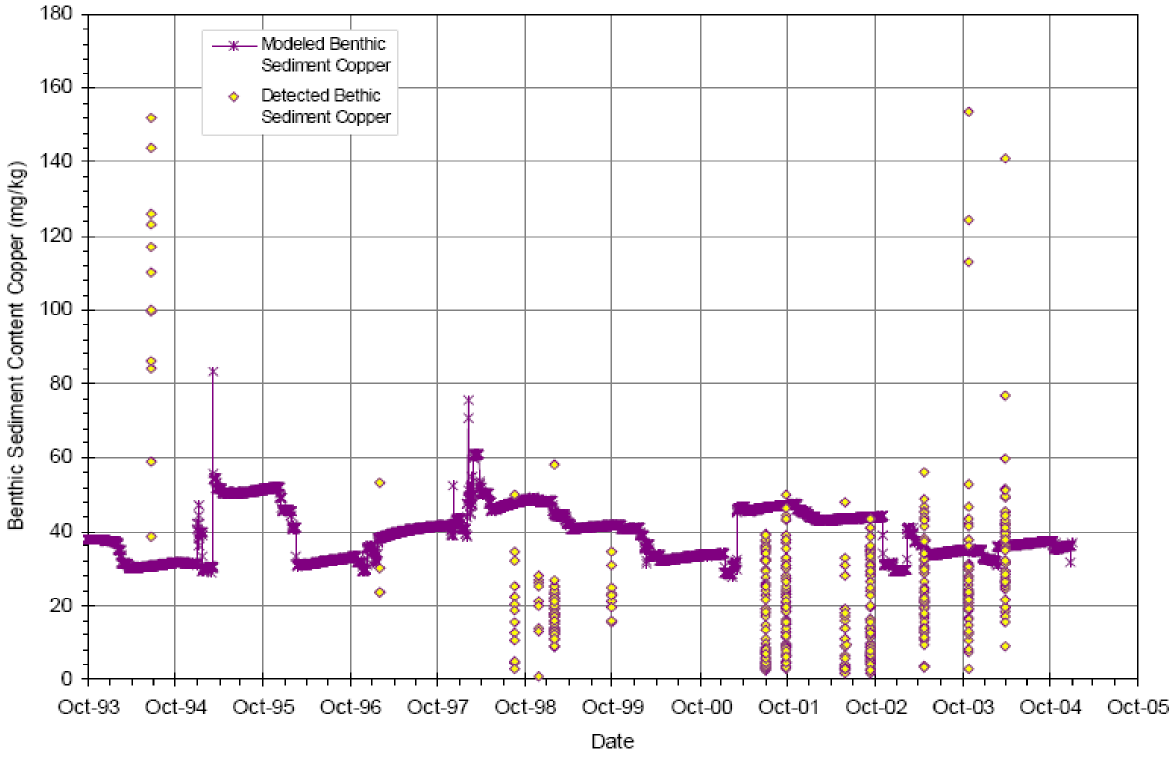


Figure 43. Benthic Sediment Copper Content from MLMSM Output and Measured Data.

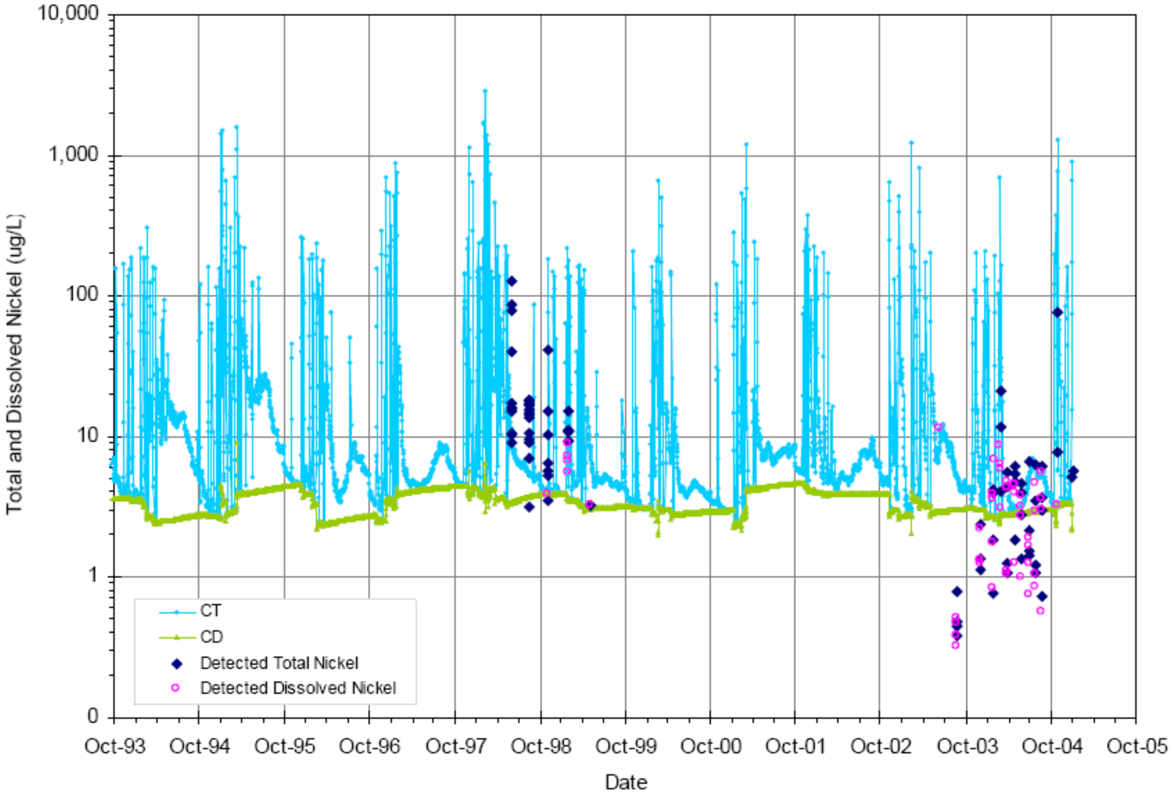


Figure 44. Time series of Total and Dissolved Nickel from MLMSM Output and Measured Data.

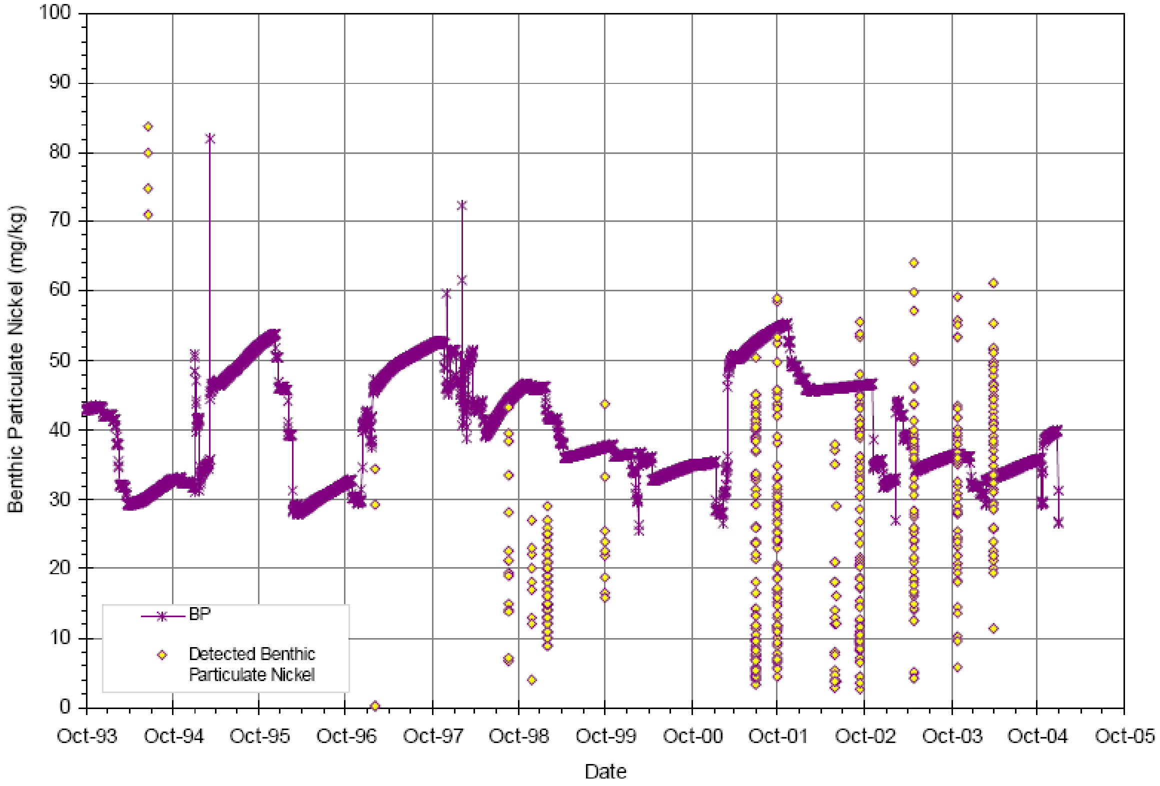


Figure 45. Benthic Sediment Nickel Content from MLMSM Output and Measured Data.

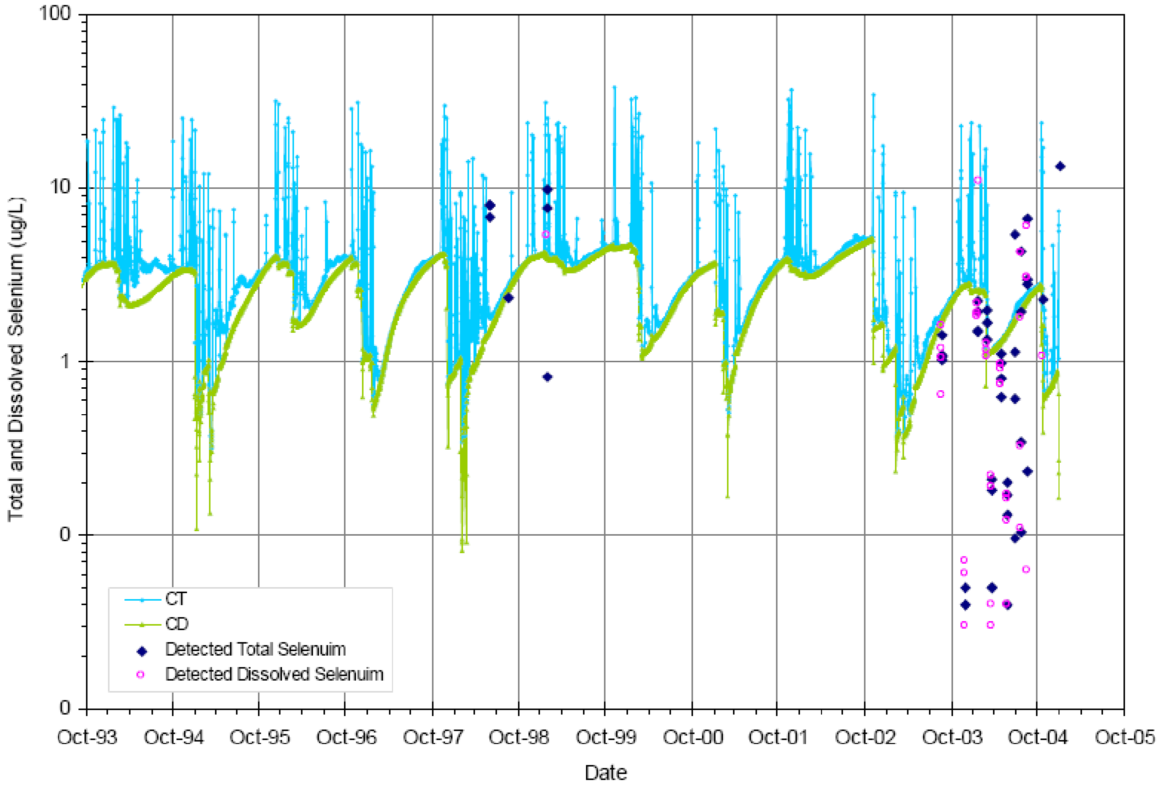


Figure 46. Time series of Total and Dissolved Selenium from MLMSM Output and Measured Data.

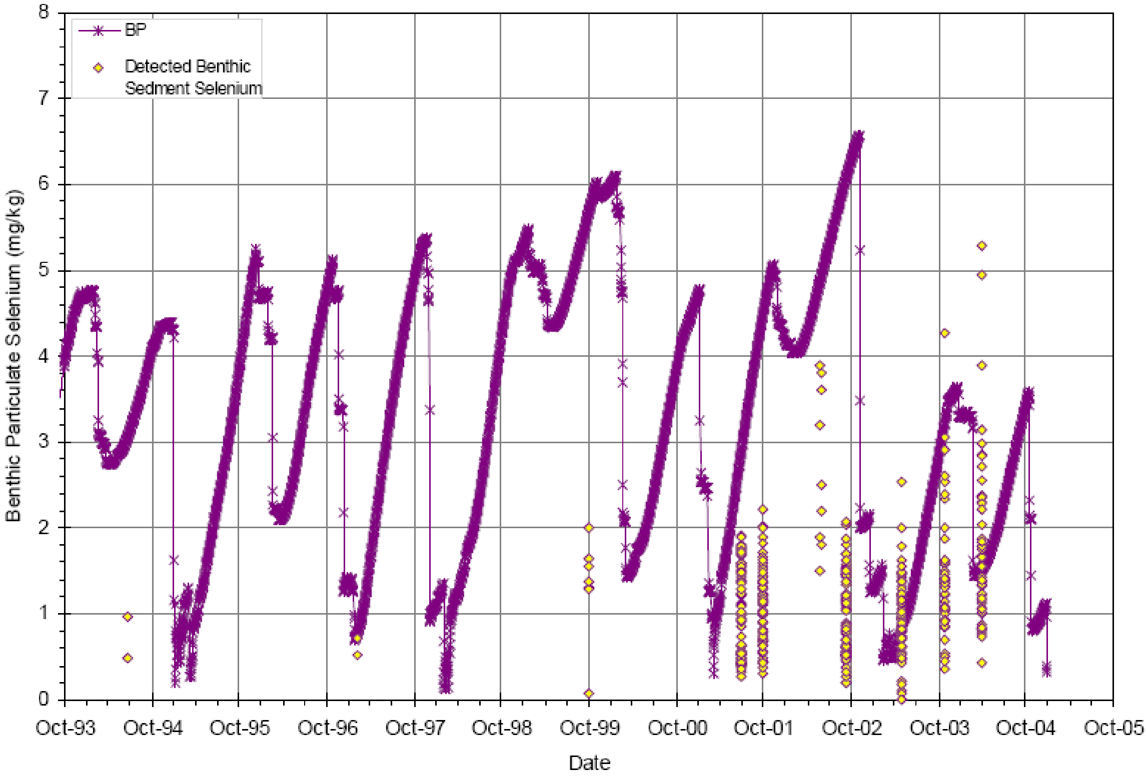


Figure 47. Benthic Sediment Selenium Content from MLMSM Output and Measured Data.

Discussion of MLMSM Results – Total Loads and Dissolved Concentrations

The MLMSM results offer insight into the relationship between dissolved metals concentrations in the lagoon and total loads entering the lagoon from sources throughout the watershed. In the model, benthic particulate concentrations for each constituent are affected by settling of pollutant-laden suspended sediment, transfer to the dissolved water column phase, and adsorption from the dissolved water column.

During development of the CCW Metals and Selenium TMDL, concerns were expressed that pollutant-laden suspended sediment entering Mugu Lagoon might settle out and later re-partition into the dissolved phase. Results from the MLMSM suggest a correlation between dissolved metals concentrations and benthic sediment content. Although the apparent relationship may result in part from the calculation method used for these two parameters, it is well understood that transfer occurs between the dissolved and particulate phases. What is not clearly understood, is whether accumulation of settled out particulate matter causes measurable increases in dissolved concentrations, independent of and relative to other factors.

Discussion of MLMSM Results – Total Loads and Benthic Toxicity

The Mugu Lagoon Metals and Selenium Model provides a way to assess the potential for pollutant-laden suspended sediments settling out in the lagoon to cause benthic toxicity. Under most conditions, output from the model does not indicate a correlation between high total metals concentrations and concentrations of copper, nickel, or selenium in benthic sediments.

Model results show sediment concentrations spikes concurrent with the two periods of highest total concentrations of copper and nickel in water (during the heavy precipitation winters of 1994-1995 and 1997-1998), but these elevated sediment concentrations exist only briefly. Since total concentrations of copper, nickel, and selenium in water and benthic sediment concentrations are not generally correlated temporally, there is no clear basis for concluding total loads in water are directly linked to benthic toxicity.

There are no 303(d) listings exist in the CCW for toxicity caused by metals or selenium. The Calleguas Creek Watershed Toxicity TMDL Implementation Plan includes measures to address any unidentified toxicity occurring in the CCW.

7.5 Achievement of Numeric Targets in Reaches Addressed by Allocation Process

After calculating existing loads and loading capacity for copper, nickel, and selenium and then allocating the loading capacity to point and non-point sources (see TMDL & Allocations section for details), the HSPF model is used to verify the allocation process and ensure targets are met under conditions defined in the TMDL and Allocations section. For nickel and selenium, this means target conditions will be met only in the listed reaches; for mercury and copper allocations are designed to meet target conditions in all reaches (see TMDL & Allocations section for details). Table 59 shows the percentage of individual days in ten years of HSPF modeling where allocations resulted in attainment of numeric target concentrations.

Table 59. Results from HSPF Modeling of Allocated Loads vs. Attainment of Targets for Copper, Nickel, and Selenium.

Dissolved **Copper Wet Weather** Concentrations vs. CTR Acute with WER			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
100.0%	100.0%	100.0%	100.0%
Dissolved **Copper Dry Weather** Concentrations vs. CTR Chronic with WER			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
97.8%	100.0%	100.0%	99.6%
Dissolved **Nickel Wet Weather** Concentrations vs. CTR Acute			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
NA (100%)[1]	NA (100%)[1]	NA (100%)[1]	NA (100%)[1]
Dissolved **Nickel Dry Weather** Concentrations vs. CTR Chronic			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
NA[2]	NA[2]	NA[2]	NA[2]
Total **Selenium Wet Weather** Concentrations vs. CTR Acute			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
NA (100%)[1]	NA (100%)[1]	NA (100%)[1]	NA (100%)[1]
Total **Selenium Dry Weather** Concentrations vs. CTR Chronic			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
99.1%	NA[3]	NA[3]	99.9%

1 This analysis is not relevant for nickel or selenium because no reductions/allocations are necessary during wet weather conditions (i.e., current concentrations are below target levels)

2 Dry weather allocations for nickel were developed based on the percent reduction necessary for the listed reach (Mugu Lagoon) to meet the CTR, rather than using the HSPF model, as explained in the TMDL and Allocations section

3 Selenium is only included on the 303(d) list for Revolon Slough, thus the allocation approach only addresses that reach.

Although attainment of the water quality numeric target for selenium is predicted when allocations are met, achieving the allocations will not be possible without reductions in background loads and/or other ambient sources (i.e. the values shown above are calculated based on reductions in all sources, including background loads). Special studies included in the implementation plan will determine the potential for standards actions or other regulatory actions such as natural background exclusion or site specific objectives to address any background loads which preclude achievement of allocations.

8 LINKAGE ANALYSIS – MERCURY

Achievement of numeric targets proposed for the mercury TMDL is linked to controlling sources of mercury in the watershed. This section demonstrates how actions taken to control the sources mercury will ensure attainment of water quality standards. A brief description of modeling used to support the linkage analysis is included here, and a detailed explanation is provided in Appendix C (Linkage Analysis HSPF Modeling Report), Appendix D (HSPF Modeling Calibration Report), and Appendix E (Mugu Lagoon Model Report)..

Linkage analysis for mercury is handled separately from that for copper, nickel, and selenium because of the unique properties and environmental behavior of mercury. Mercury is more strongly associated with particulate matter than the other constituents. Also, potential impacts from mercury are associated with bioaccumulation in the food web over monthly to annual timescales (while copper and nickel concerns are primarily related to toxicity over timescales of hours to days).

8.1 Relationship Between Sources, Targets, and Allocations

Discharges of mercury to receiving waters occur from multiple sources, as described in the Source Analysis section. The majority of mercury content discharged into receiving waters is associated with the particulate phase, although a small amount is also present in the dissolved phase.

The primary threat posed by mercury is reproductive and neurological impairment for aquatic organisms, wildlife, and humans resulting from bioaccumulation of mercury in the food web. Thus, numeric targets selected for the mercury TMDL include the CTR water criterion for protection of human health, fish tissue targets for protection of human health and wildlife, and bird egg targets for protection of wildlife.

Although numeric targets are designated for mercury in water, fish tissue, and bird eggs; allocations are assigned as loads of mercury in suspended sediment. Allocations are expressed as suspended sediment loads for several reasons:

1. mercury in water preferentially associates with particulate matter; and most of the particulate-associated mercury load is carried as washload (i.e. suspended sediment) rather than bedload;
2. areas in the watershed, such as tidal marshes and creeks, where high rates of methylation occur are more reachable by suspended sediment than by transport of bedload sediment;
3. assigning allocations as loads of mercury in suspended sediment offers flexibility to achieve necessary reductions, by reducing particulate associated mercury concentrations, TSS, or both;
4. due to interactions between bottom sediment and suspended sediment, suspended sediment allocation loads will also bring about improvements in benthic mercury concentrations;
5. allocations designated according to sediment loads are most directly applicable to the various sources of mercury in the watershed; and
6. tissue concentrations are not practical for allocating loads to sources, and current lab methods are better able to quantify mercury in sediment than in water.

Suspended sediment allocations are set according to the percent reduction required for achievement of numeric targets for water and fish tissue. Modeling described below is then used to estimate current loads and calculate allowable loads based on the required percent reduction to meet numeric targets.

8.2 HSPF Hydrologic and Water Quality Model

HSPF modeling described in the linkage analysis section for copper, nickel, and selenium is also employed for evaluation of mercury. A brief explanation of how the model operates is included in the linkage analysis section for copper, nickel, and selenium; and a detailed explanation of the HSPF model is provided in Appendix C and Appendix D.

Initial Partition Coefficient Used in Model and Relationship to TSS

Mercury is modeled as both particulate and dissolved phase in surface waters, and as dissolved phase in groundwater baseflow and interflow. Total concentrations are calculated as the sum of the dissolved and particulate concentrations. In order to model the particulate phase, an initial partition coefficient (K_D) is required by the model. As explained in the linkage analysis for copper, nickel, and selenium, an estimate of the K_D is determined by rearranging the partition equation into the form of a regression equation with a zero intercept (see Equation 1 - Equation 3, in that section).

Receiving water data from the watershed are used to estimate K_D. Figure 48 shows K_D values calculated for the CCW as a plot of C_T/Cd-1 versus TSS. Per Equation 3, the slope of the regression line in the figure indicates the best-fit value for K_D which is used as an initial estimate in the model for mercury (32,300 L/kg). Note this value is significantly higher than the K_D values for copper (5,600 L/Kg), nickel (5,400 L/Kg), and selenium (420 L/Kg); which reflects the strong affinity for particulate matter exhibited by mercury.

As indicated earlier in Equation 3 and below in Figure 50, K_D varies with TSS as well as the total and dissolved concentration of mercury. Thus, use of the best-fit value described above as an initial estimated K_D for each critical condition appropriately accounts for the relationship between K_D and TSS.

Other points which are key to understanding operation of the model involve mass transfer rates and setting of initial conditions. The mass transfer rate is set fast enough not to affect model results; equilibrium is maintained over a one day averaged time step. Since the first several years of simulation are not considered to allow for model spin-up, the initial conditions specified in the model have little effect on results.

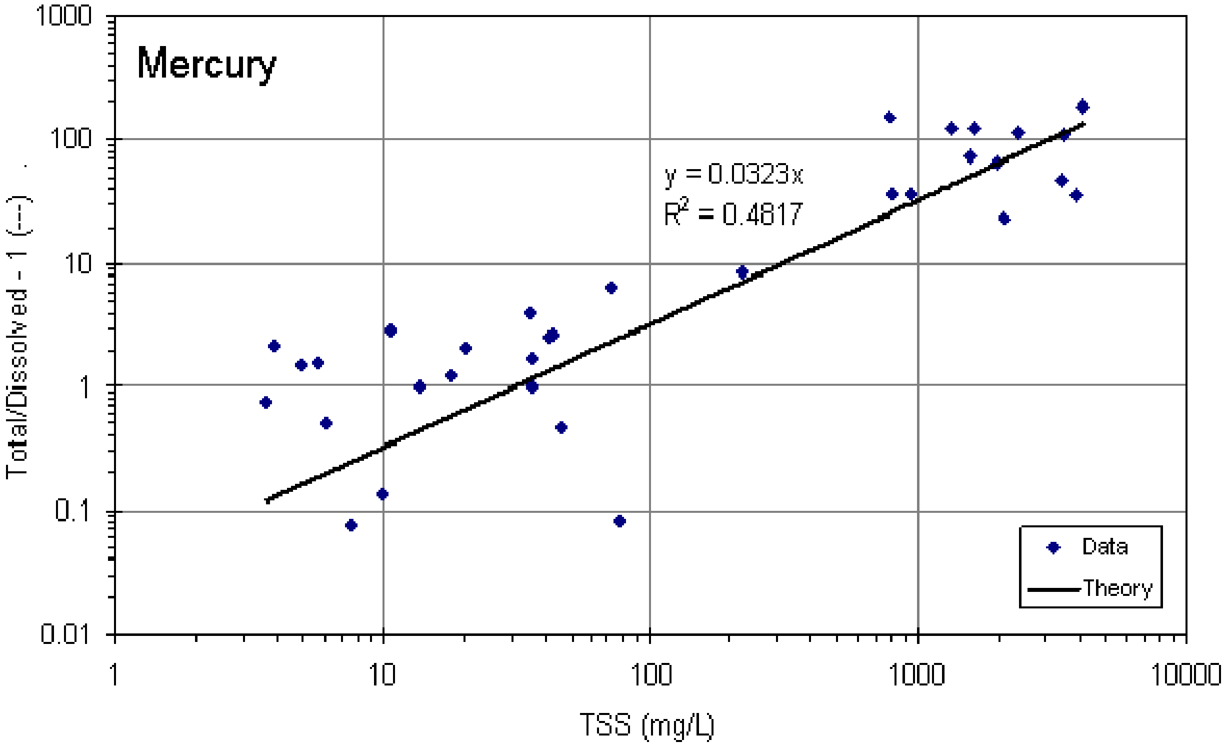


Figure 48. Mercury K_D values for the CCW, and best-fit K_D used for modeling of copper in the CCW (32,300 L/kg).

8.3 Linkages Between Tissue, Water, and Suspended Sediment

As explained in the Source Analysis section (Mercury Fate and Transport subsection) the primary concern for mercury is associated with bioaccumulation in the food web. The process of bioaccumulation involves the following four basic factors:

1. Most mercury in the water column binds to sediment;
2. Water movement transports mercury-laden sediment; depositing some in wetlands, mudflats, and sloughs, where conditions favor methylmercury formation;
3. Small aquatic organisms such as plankton and benthic invertebrates take in methylmercury and pass it up through the food web to higher organisms, such as fish;
4. Humans and wildlife such as birds consume mercury in fish and other aquatic organisms, which biomagnifies at each successively higher level in the food chain.

Development of the mercury TMDL relies upon the following linkages, which are directly associated with factors contributing to bioaccumulation:

- mercury concentrations in tissue are related to mercury content in suspended sediment;
- mercury concentrations in water are a function of mercury content in suspended sediment;
- reducing loads of mercury in suspended sediment will result in reduced concentrations in fish tissue and the water column

- mercury concentrations in suspended sediment and the active layer of benthic sediment are comparable due to continuous interaction and mixing; and thus reducing loads of mercury in suspended sediment will result in reduced benthic sediment concentrations
- mercury loads in suspended sediment are a function of mercury concentrations and TSS.

Mercury Concentrations in Tissue are Related to Mercury Content in Suspended Sediment

Mercury in water is transported with sediment, some of which reaches areas favorable for methylmercury production. Methylmercury production, or methylation, is the conversion of inorganic mercury to organic methylmercury. Methylation at any particular site is strongly influenced by total mercury in local surface sediment (Rudd et al. 1983, as cited in the San Francisco Bay Mercury TMDL). Local surface sediment is in turn highly influenced by settled out suspended solids, especially in high methylation areas such as wetlands and tidal marshes (where bedload transport of sediment is a lesser factor).

Methylmercury is the form of mercury available for accumulation within the food web. Lower trophic level aquatic organisms take up methylmercury from food, water, and sediment; and higher organisms acquire methylmercury primarily through food ingestion (Rudd et al. 1983; Morel et al. 1998). Many wildlife and bird species obtain almost all of their diet from Mugu Lagoon and/or surrounding areas in the CCW, and the lagoon is both the feeding and nesting ground for numerous birds, mammals, and other animals.

Since mercury content in suspended sediment is linked to methylmercury production, and methylmercury production is linked to accumulation of mercury in the food web, reducing loads of mercury in suspended sediment is expected to result in reduced concentrations of mercury in tissues of aquatic organisms, wildlife, and humans that live in and/or consume food from Mugu Lagoon or other areas of the CCW.

Mercury Concentrations in Fish Tissue

Development of the mercury TMDL considers reductions required to meet fish tissue and water column numeric target concentrations. However, a comparison of fish tissue targets and available data results in some uncertainty about the percent reduction necessary for achievement of numeric target concentrations (Table 60). The only CCW reach listed for mercury is Reach 1, Mugu Lagoon. Yet, most fish tissue data were collected from freshwater reaches located upstream in the watershed; and very few fish tissue samples for TL3-TL4 have been collected from Mugu Lagoon (no samples were collected from Mugu Lagoon for TL-2 fish). None of the watershed-wide mean or median concentrations exceed numeric targets. The only TL3 sample collected from Mugu Lagoon, a Shiner perch, did not exceed the numeric target for its size class. Six of eight Smoothhound shark samples collected from Mugu Lagoon exceeded the numeric target for TL4.

Table 60. Attainment of fish tissue targets in CCW and Mugu Lagoon. [1]

Trophic Level	Target	n	n^{ML}	n > tgt	Mean	%-Red.	Median	%-Red.
TL3 (< 5cm)	0.03	4	0	0	0.025	0%	0.030	0%
TL3 (5-15cm)	0.05	32	1	5	0.035	0%	0.026	0%
TL3 (5-15cm) ^{ML} Shiner Perch	0.05	1	1	0	0.030 [2]	0%	0.030 [2]	0%
TL3 (15-35cm)	0.1	10	0	0	0.021	0%	0.020	0%
TL4	0.3	37	8	10	0.167	0%	0.069	0%
TL4 ^{ML} - All S.H. Shark [3]	0.3	8	8	6	0.517	72%	0.550	83%

[1] Although the 303d listing for mercury is for Reach 1, most of the percent reductions included in this table are calculated using tissue data from samples collected throughout the CCW, in order to provide a meaningful sample size.

[2] individual value, rather than an average or median (n = 1).

[3] Smoothhound Shark is the only TL4 species which has been collected from Mugu Lagoon. Smoothound shark lengths in Mugu Lagoon (min 29cm, max 80cm, avg 69cm). Common adult length 100cm or more (116-161cm).

ML - Mugu Lagoon

Effects of Food Web Relationships Upon Bioaccumulation

While the amount of methylmercury in a water body influences the rate at which methylmercury enters the food web, the structure of the food web's predator-prey relationships determines the efficiency of transfer among organisms (Morel et al. 1998). In order to better predict the expected relationship between mercury concentrations in fish tissue and concentrations in suspended sediments, it is important to further develop a food web model such as the one shown in Figure 49.

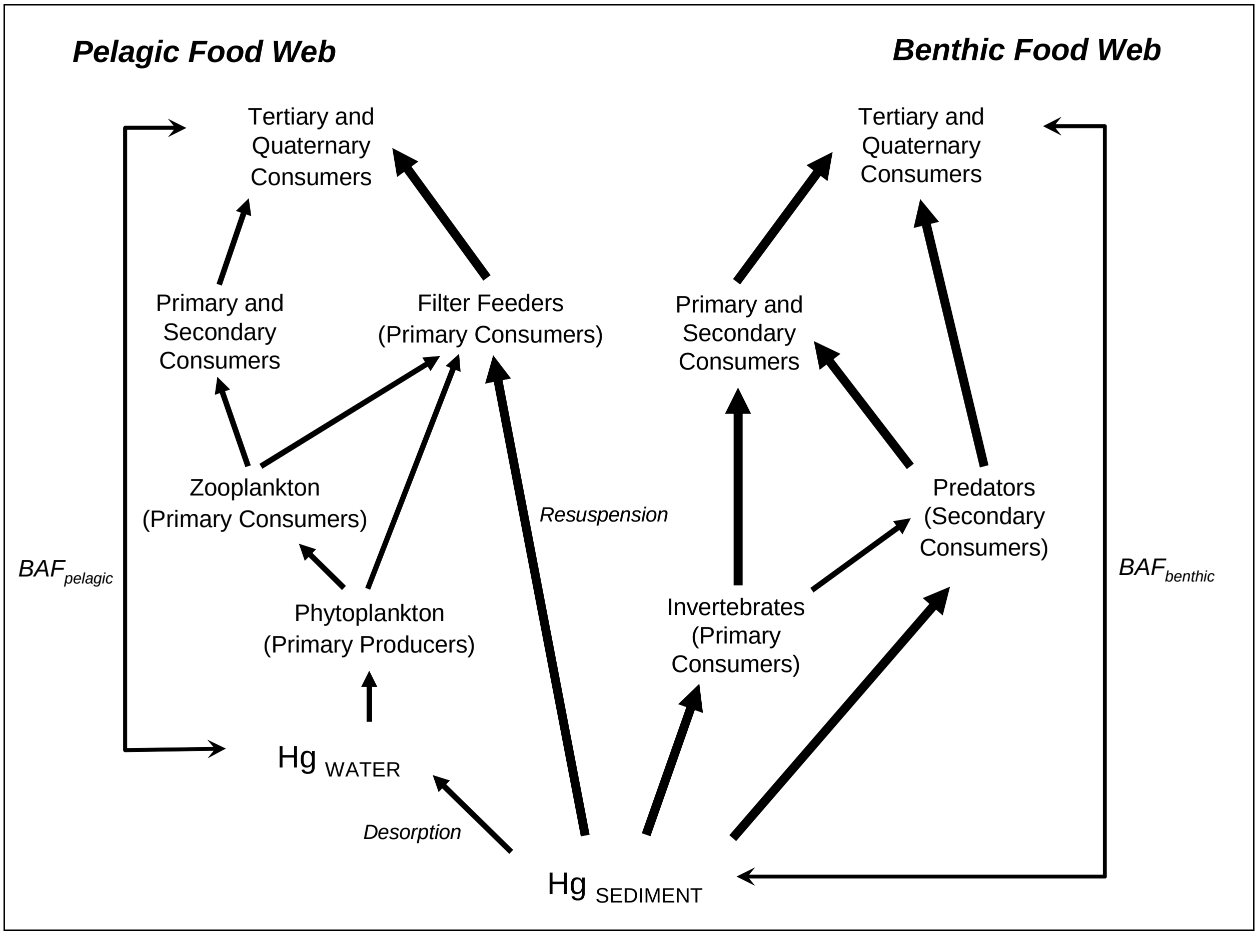


Figure 49. Basic food web model for CCW aquatic organisms, freshwater and marine.

An assessment of all organisms present in the food web for the CCW has not been completed, but preliminary monitoring information is available. With incomplete information on the food web and mercury bioaccumulation processes in the CCW and Mugu Lagoon, a proportional relationship between suspended sediment mercury concentrations and fish tissue concentrations is assumed. Development of a detailed food web model and population of the model with matched predator-prey-sediment data could verify or refute that assumption, and should be completed in the future.

Mercury Concentrations in Water are Related to Mercury Content in Suspended Sediment

The primary water quality objective that drives the mercury TMDL is the CTR human health criterion of 0.050 ug/L. Exceedance of this objective in receiving waters is the basis for listing Mugu Lagoon as impaired due to mercury. Exceedances are consistently associated with elevated concentrations of total suspended solids (Figure 50).

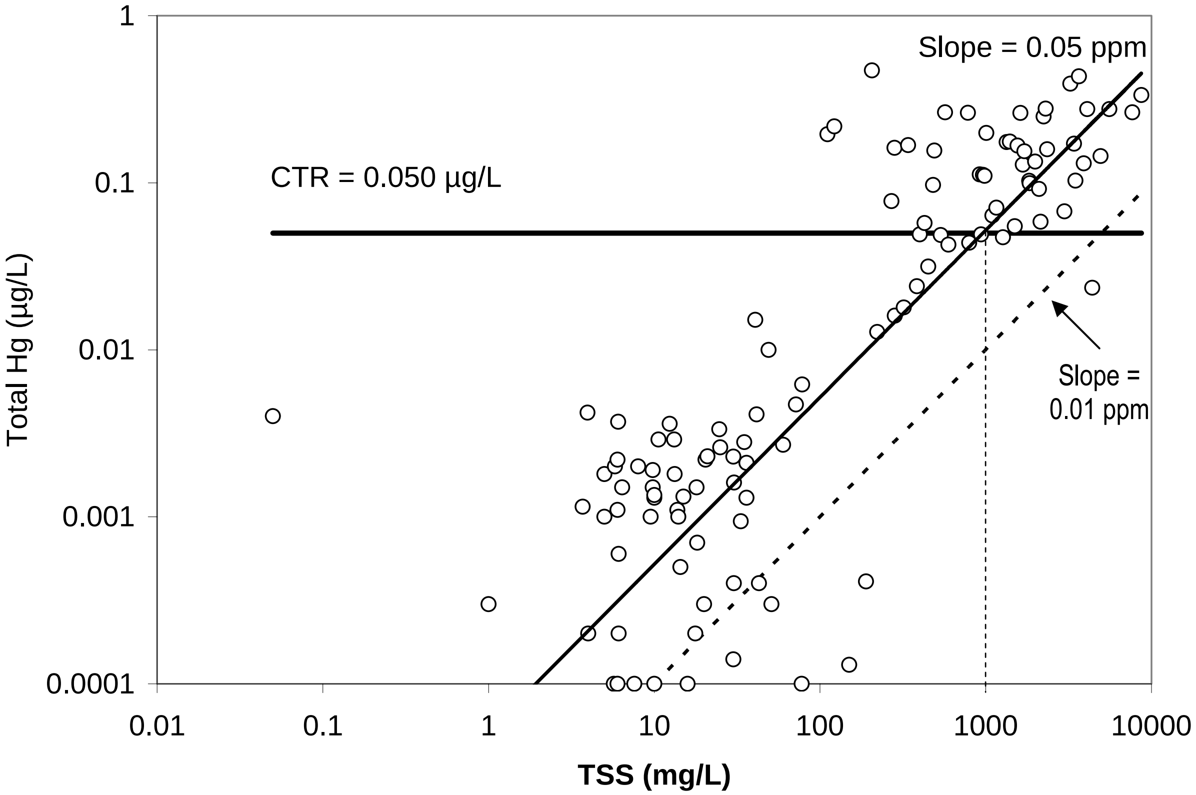


Figure 50: Relationship between total mercury in the water column and total suspended solids (TSS). Note that the slope of the best fit line (solid diagonal) forced through zero gives an estimate of the average or typical mercury concentration on suspended sediment in Calleguas Creek, 0.05 ppm. To attain the CTR Water Quality Objective of 0.050 µg/L (solid horizontal line), either TSS must be maintained below 1000 mg/L (vertical dashed line) or suspended sediment mercury content must be brought down to as low as 0.01 ppm (diagonal dashed line).

As shown in Figure 50, two factors drive exceedances of the numeric target for water: average mercury concentration in suspended sediments and TSS. The slope of the line in Figure 50 indicates an average suspended sediment concentration of 0.05 ppm (slope = 0.05 ug/L * L/1000mg = 0.05 ug/g). If TSS in the CCW is maintained at or below 1000 mg/L, then attainment of 0.05 ppm mercury in suspended sediments will ensure attainment of the CTR water quality objective of 0.05 µg/L. If attainment of 1000 mg/L TSS is not attainable, suspended sediment mercury concentrations may need to be lowered to 0.01 ppm to ensure attainment of the CTR water quality objective; as indicated by the dotted diagonal line in Figure 50. In more simple terms, attainment of the water quality objective requires either less suspended sediment in receiving waters of the CCW, or cleaner suspended sediment (i.e., lower mercury concentrations), or both.

Thus, the load corresponding to attainment of the CTR water quality objective can be calculated as a reduction of mercury concentrations in sediments, or a reduction in TSS loads. Since the HSPF model has been developed for contemporary sediment transport scenarios, it is more straightforward to calculate the mercury load if TSS concentrations are assumed to remain unchanged over time. Assuming unchanged TSS over time has the same effect as setting a suspended sediment mercury concentration target of 0.01 ppm. Regardless of which method is used to calculate the TMDL, attainment of allocated loads can result either from BMPs to reduce the average concentration of mercury in suspended sediments, BMPs to reduce TSS in the creek, or both.

Mercury Concentrations in Water

Development of the mercury TMDL considers percent reductions required to meet fish tissue and water column numeric target concentrations. HSPF model results summarized below in Table 61 indicate a 79.5% reduction (bolded in table below) is required for maximum 30-day average total mercury concentrations in water to reach attainment of the CTR 0.050 ug/L criteria at all times. Observed data plotted in Figure 50 suggest mercury concentrations frequently exceed 0.050 ug/L when TSS is equal to or greater than 1000 mg/L.

Table 61. HSPF modeled Maximum 30-day Average Concentrations of Mercury in Water for Mugu Lagoon for the years 1993 – 2003 (each year begins in October and ends in September of the following year).

Year	Max 30day Concentration (ng/L)			Max 30day %-Reduction		
	Mugu Lagoon 1	Revolon Slough 2	Lower Calleguas Creek 2	Mugu Lagoon 1	Revolon Slough 2	Lower Calleguas Creek 2
1993	49	75	70	-1%	33%	29%
1994	138	135	161	64%	63%	69%
1995	63	107	93	21%	53%	46%
1996	120	132	139	58%	62%	64%
1997	178	99	239	72%	50%	79%
1998	25	55	64	-101%	9%	22%
1999	123	244	164	59%	79%	70%
2000	133	154	159	63%	68%	69%
2001	49	55	105	-3%	10%	53%
2002	90	111	108	44%	55%	54%
2003	82	142	143	39%	65%	65%

1 values presented for Mugu Lagoon are modeled concentrations in the lagoon.

2 values presented for Revolon Slough and Calleguas Creek are modeled concentrations at/near the discharge point into Mugu Lagoon.

Mercury Concentrations in Bird Eggs

At this point in time, no data are known to exist for concentrations of mercury in bird eggs from Mugu Lagoon or the elsewhere in the CCW. Although bird eggs have not been analyzed for metals and selenium, collection of bird eggs from in and around Mugu Lagoon has occurred in the past and is planned for the future. Thus, the opportunity exists for future analysis of mercury concentrations in bird eggs and comparison to the numeric target. Resident birds, rather than migratory birds, should be monitored.

Percent Reduction for Mercury in Suspended Sediment

The mercury TMDL is developed with consideration of percent reductions required to meet fish tissue, water column, and bird egg numeric target concentrations. However, the final/overall percent reduction designated as representative of necessary reductions in fish tissue and water column concentrations is set as the percent reduction necessary to meet the CTR water quality objective (80%), for the following reasons:

1. the watershed-wide data set for fish tissue is not found to exceed numeric targets for mercury;

2. very few fish tissue data are available from Mugu Lagoon itself;
3. tissue concentrations only exceed numeric targets in one scenario (TL4, sharks in Mugu Lagoon, eight samples) and the necessary percent reduction is approximately equal to the percent reduction necessary for water concentrations;
4. no data are presently available to indicate concentrations of mercury in bird eggs in the CCW or Mugu Lagoon.

Although allocations for mercury are developed based primarily on the percent reduction required for water concentrations, fish tissue targets serve as one of the most important endpoints for measuring success of the TMDL Implementation Plan.

8.4 Mercury Methylation and Bioaccumulation

It should be recognized that this TMDL relies upon a simple loads-linkage analysis to plan for attainment of the CTR numeric water quality objective. Managing mercury concentrations in fish is a more complicated problem. Figure 51 shows a conceptual model for the main factors that need to be considered if additional monitoring reveals that mercury concentrations in fish threaten beneficial uses such as fishing and wildlife habitat.

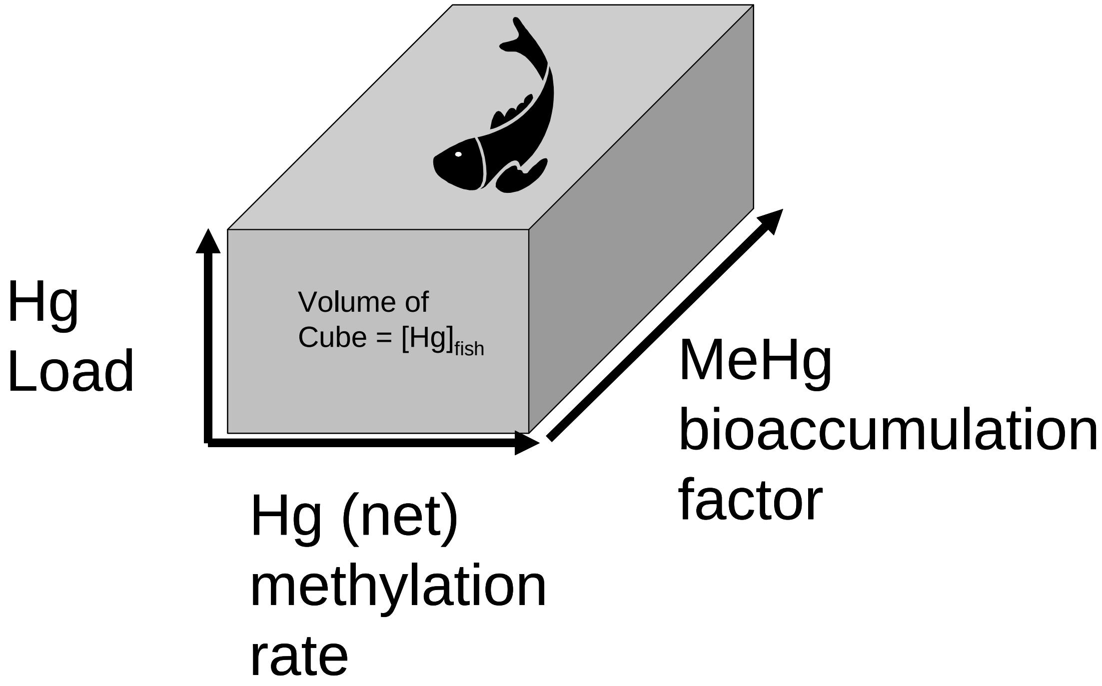


Figure 51: Conceptual model for management of mercury concentrations in a waterbody.

The concentration of mercury in a fish is represented in Figure 51 as the volume of a cube. Three things affect the volume of the box: mercury load rates into the waterbody (height), the net methylation rate of those mercury loads (width), and the overall bioaccumulation factor of methylmercury in the aquatic ecosystem (depth). We can't control the bioaccumulation factor, it is what it is, and is mostly a function of the food web complexity. The bioaccumulation factor does need to be known or assumed order to predict or estimate how the other two factors, loads and methylation, affect mercury concentrations in fish.

If the depth of the box, the bioaccumulation factor, is fixed, then the only management options are to reduce loads and / or reduce methylation rates. It is unknown whether there are options to reduce methylation. Net methylation rates increase when dissolved oxygen goes down (Figure 52) in other waterbodies. This makes sense, because it is sulfate reducing bacteria that methylate mercury, and they thrive under low oxygen conditions. It is unclear whether Calleguas Creek, Mugu Lagoon or its adjacent sloughs have low DO, or whether that is a controllable water quality factor. There are also other factors that affect net mercury methylation rates.

Another way to look at the box in Figure 51 is that certain areas may be more prone to methylation than others, and therefore require relatively greater load reductions. However, this TMDL as presented is calling for an 80% mercury load reduction already in order to attain the CTR water quality objective. Progress should be made towards implementing that load reduction, concurrent with developing any new information to determine whether fish tissue concentrations exceed numeric targets and whether that triggers additional actions.

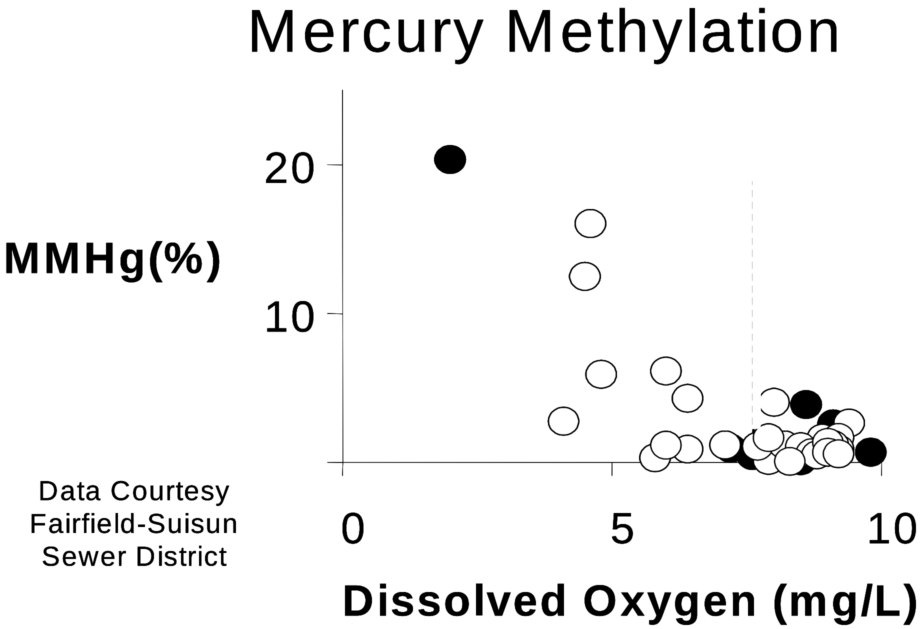


Figure 52: Plot of the percent of mercury in the water column that is methylmercury (MMHg(%)) vs. dissolved oxygen in sloughs draining into San Francisco Bay. Note that the % methylmercury, which is an indicator for net methylation rates, increases four-fold when dissolved oxygen drops below 5 mg/L. Data Courtesy Fairfield Suisun Sewer District. Methylmercury analysis by Rob Mason, Chesapeake Biological Laboratories. Figure as cited in Grovhoug et al (2003).

8.5 Achievement of Numeric Targets in Reaches Addressed by Allocation Process

After calculating existing loads and loading capacity for mercury and then allocating the loading capacity to point and non-point sources (see TMDL & Allocations section for details), the HSPF model is used to verify that achieving allocations will result in attainment of numeric target concentrations. Table 63 shows the percentage of individual days in ten years of HSPF modeling where allocations resulted in attainment of numeric target concentrations.

Table 62. Results from HSPF Modeling of Allocated Loads vs. Attainment of Targets for Copper, Nickel, and Selenium.

Total Mercury 30-day Average Concentrations vs. CTR Human Health			
Revolon, PCH	Calleguas, PCH	Calleguas, Potrero	Revolon, Wood
100.00%	99.61%	99.61%	100.00%

Although attainment of the water quality numeric target is predicted when allocations are met, achieving the allocations will not be possible without major reductions in background loads and/or other ambient sources (i.e. the values shown above are calculated based on reductions in all sources, including background loads). Special studies included in the implementation plan will determine the potential for standards actions or other regulatory actions such as natural background exclusion or site specific objectives to address the large background loads of mercury which will likely prove challenging to control.

9 TMDL & ALLOCATIONS FOR COPPER, NICKEL, AND SELENIUM

Allocations for copper, nickel, and selenium are developed using a different approach from those for mercury because concerns about copper, nickel, and selenium are primarily associated with the dissolved portion in the water column, while mercury is almost completely associated with particulate matter. In many TMDLs, the chosen allocation approach is to assign the numeric targets as concentration-based allocations or the numeric targets multiplied by the discharge flow as the allocations. For this TMDL, different allocation approaches were chosen. However, in all cases, the loading capacity is defined as the numeric target multiplied by the in-stream flow rate. The allocation approach section explains how the loading capacity (which is based on the numeric target) is divided among the various dischargers. The following two paragraphs discuss reasons for the use of approaches other than “numeric target * flow” for copper, nickel, and selenium.

Copper and Nickel

Freshwater water column targets for copper and nickel are less stringent than saltwater water column targets. Freshwater targets are not exceeded in the freshwater reaches. Freshwater streams with higher loading capacities, due to the less stringent freshwater targets, flow downstream into reaches where saltwater criteria apply and loading capacities are lower (Mugu, Revolon, Lower Calleguas). Therefore, assigning allocations based on the freshwater target * flow for discharges to freshwater reaches would not result in reductions being required for the freshwater reaches, and would not result in the achievement of the saltwater targets in the lower reaches. Assigning the saltwater target * flow as allocations for all upstream dischargers would result in compliance with the saltwater target. However, not all discharges into the freshwater reaches make it to the reaches where saltwater criteria apply (due to sections of dry streambed, diversions, and other factors). To assign allocations based on the freshwater load which actually flows to the saltwater reaches and to account for any dilution or removal of loads that may occur between the discharge and the portion of the watershed to which the saltwater criteria apply, the allocation approach discussed later in this section was developed.

Selenium

Discharges to Revolon Slough of selenium come primarily from agriculture, urban runoff, and groundwater discharges. Unlike POTWs, none of these sources have a single point discharge into the stream for which flow and concentration can be quantified and a discharge load developed. Therefore, group in-stream allocations have been the approach taken to allocate loads for these sources in Region 4. The selenium allocation approach defines an instream allocation for all of these sources that is equal to the numeric target multiplied by the in-stream flow rate. The division of the in-stream load by source was accomplished using modeling information because sufficient flow information were not available to divide the allocations by multiplying the numeric target by the discharge flow rate.

The following subsections are included in Section 9:

9.1	Approach - Copper, Nickel, and Selenium TMDL & Allocations
9.2	Critical Conditions & Seasonal Variation
9.3	Loading Capacity
9.4	Comparison of Current Loads and Loading Capacity
9.5	Allocations
9.6	Impacts of Loading from Ambient Sources

The loading capacity (LC) for each reach in the CCW serves as the allowable total maximum daily load of each constituent in the reach. Loading capacity is dependant on in-stream flows and as such is variable. However, by defining a critical condition in the reach, the LC can be calculated as the product of the in-stream flow rate at the defined critical condition, the applicable numeric target, and a margin of safety. The loading capacity is calculated according to Equation 6:

Equation 6. $$TMDL = LC = Q * C_{NT} * MOS * f$$

Where:

LC = Loading Capacity (lbs/day)
Q = In-stream Flow at Critical Condition (cubic feet per second)
C_{NT} = Numeric Target Concentration (ug/L)
MOS = Margin of Safety
f = Conversion factor of 0.00539 [(pounds/day)/(ug/L * cfs)]

The LC is allocated to a set of waste load allocations (WLAs) accounting for all identified point sources, a set of load allocations (LAs) accounting for all identified non-point sources, and a background load (BL) accounting for ambient sources not related to human activities; as shown in Equation 7:

Equation 7. $$TMDL = LC = WLAs + LAs + BL$$

Allocations to the sources are established to result in the attainment of numeric targets. WLAs and LAs are allocated for copper, nickel, and selenium for the following reasons:

- Copper: Copper is on the 303(d) list for Mugu Lagoon and Calleguas Creek Reach 2. Review of current conditions data, as compared to the numeric targets, indicates that exceedances of the targets are currently occurring in Mugu Lagoon, Calleguas Creek Reach 2, and Revolon Slough.
- Selenium: Selenium is on the 303(d) list for Revolon Slough and the current conditions analysis indicates that exceedances of the targets are currently occurring in Calleguas Creek, Revolon Slough, Beardsley Wash and Arroyo Simi/Las Posas.
- Nickel: Nickel is on the 303(d) list for Mugu Lagoon and the current conditions analysis indicates exceedances of the targets are currently occurring in Calleguas Creek and Revolon Slough.

WLAs and LAs are not developed for zinc because examination of available data indicates exceedances of water quality objectives are not currently occurring. Although allocations are not developed for zinc, CTR numeric targets still apply. Monitoring for zinc will continue and WLAs and LAs will be developed in the future if concentrations increase above numeric targets.

Allocations for selenium have only been developed for the listed reach (Revolon Slough) although the analysis recognizes exceedances of the selenium targets may exist in other portions of the watershed.

As discussed in the source analysis section, ambient sources (such as natural soil concentrations, natural groundwater seepage, and atmospheric deposition) contribute significantly to the loading of metals and selenium in the CCW. The impacts of loading from ambient sources are discussed for copper, nickel, and selenium at the end of this section (Section 9).

9.2 Approach - Copper, Nickel, and Selenium TMDLs & Allocations

The TMDLs for copper and nickel are calculated based on dissolved water column targets. However, to address the potential for conversion of total metals present in discharges into dissolved metals in the receiving water, total allocations are developed which will result in attainment of the dissolved targets.

The process used to calculate total recoverable allocations necessary for achieving dissolved targets uses partition coefficients from the HSPF model to calculate allocations. USEPA has developed guidance for developing a total recoverable permit limit from a dissolved criterion (USEPA, 1996). The guidance also includes some information on calculating total recoverable WLAs and TMDLs based on dissolved targets. On page 19, the guidance states:

> “A partition coefficient may be derived as a function of TSS and other factors such as pH, salinity, etc. The partition coefficient is the ratio of the particulate-sorbed and dissolved metal species multiplied by the adsorbent concentration. Use of the partition coefficient may provide advantages over the dissolved fraction when using dynamic simulation for Waste Load Allocation (WLA) or the Total Maximum Daily Load (TMDL) calculations and permit determinations because K_D allows for greater mechanistic representation of the effects that changing environmental variables have on the f_D [dissolved fraction].”

The partition coefficient used in the HSPF model is developed based on site-specific data and is used to calculate the total concentration equivalent to each requisite dissolved concentration. Using the partition coefficient and TSS, the model simulates both dissolved and total concentrations. The ratio between dissolved and total recoverable concentrations in the model output (i.e. a translator) is defined by the linear partitioning model and therefore equal to Equation 8:

Equation 8.

$$Cu_{dis}/Cu_{tot}=1/\{1+K_D(TSS)(10^{-6})\}$$

This “translator” is used to convert the dissolved critical condition loads to total recoverable critical condition loads and used as a basis for developing total recoverable allocations for the sources. Additional explanation of the partition coefficient equation, the translator, and initial K_D values used in the HSPF model is included in the Linkage Analysis section for copper, nickel, and selenium.

The processes used to develop critical conditions and allocations for copper, nickel and selenium are shown in Figure 53 - Figure 55.

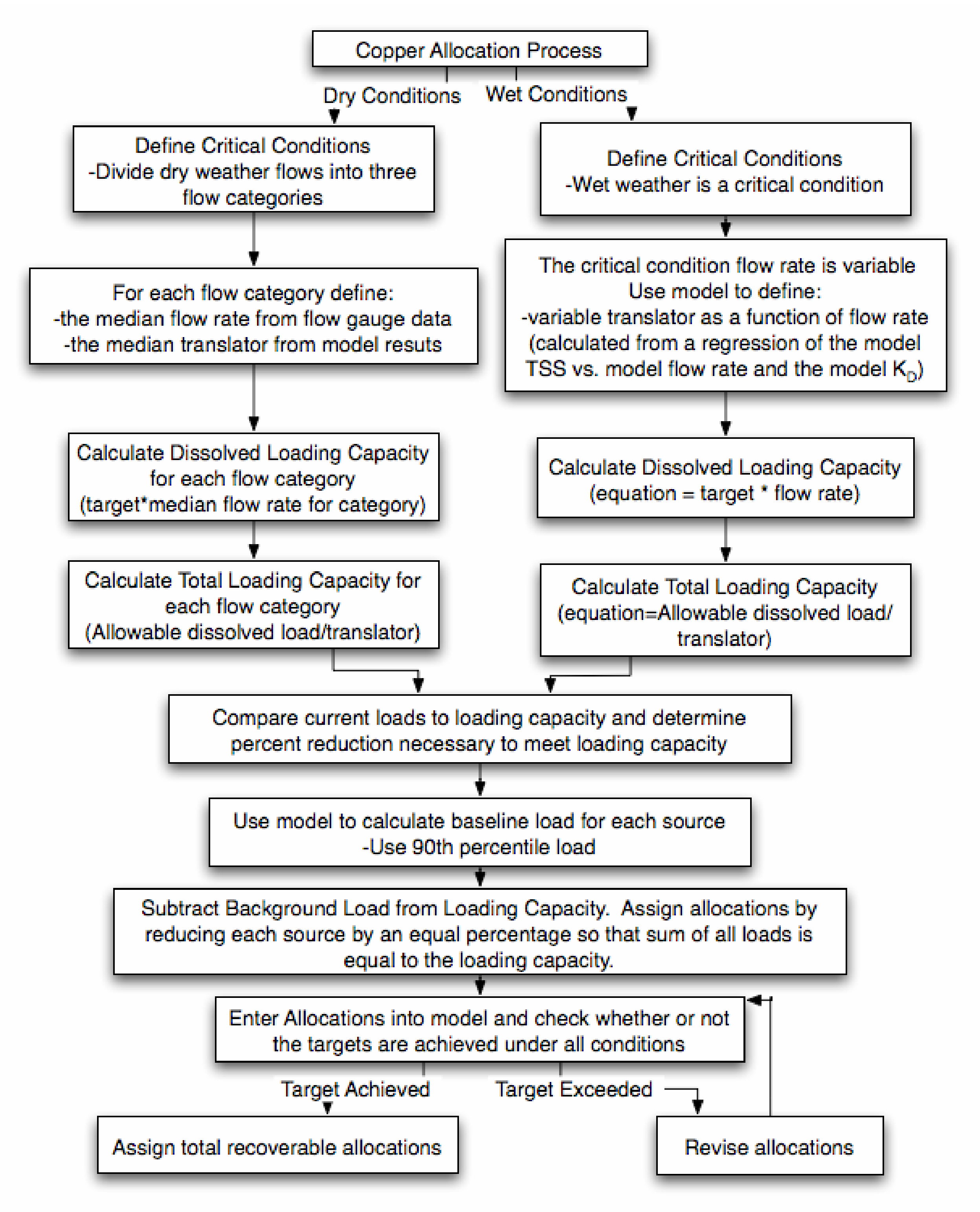


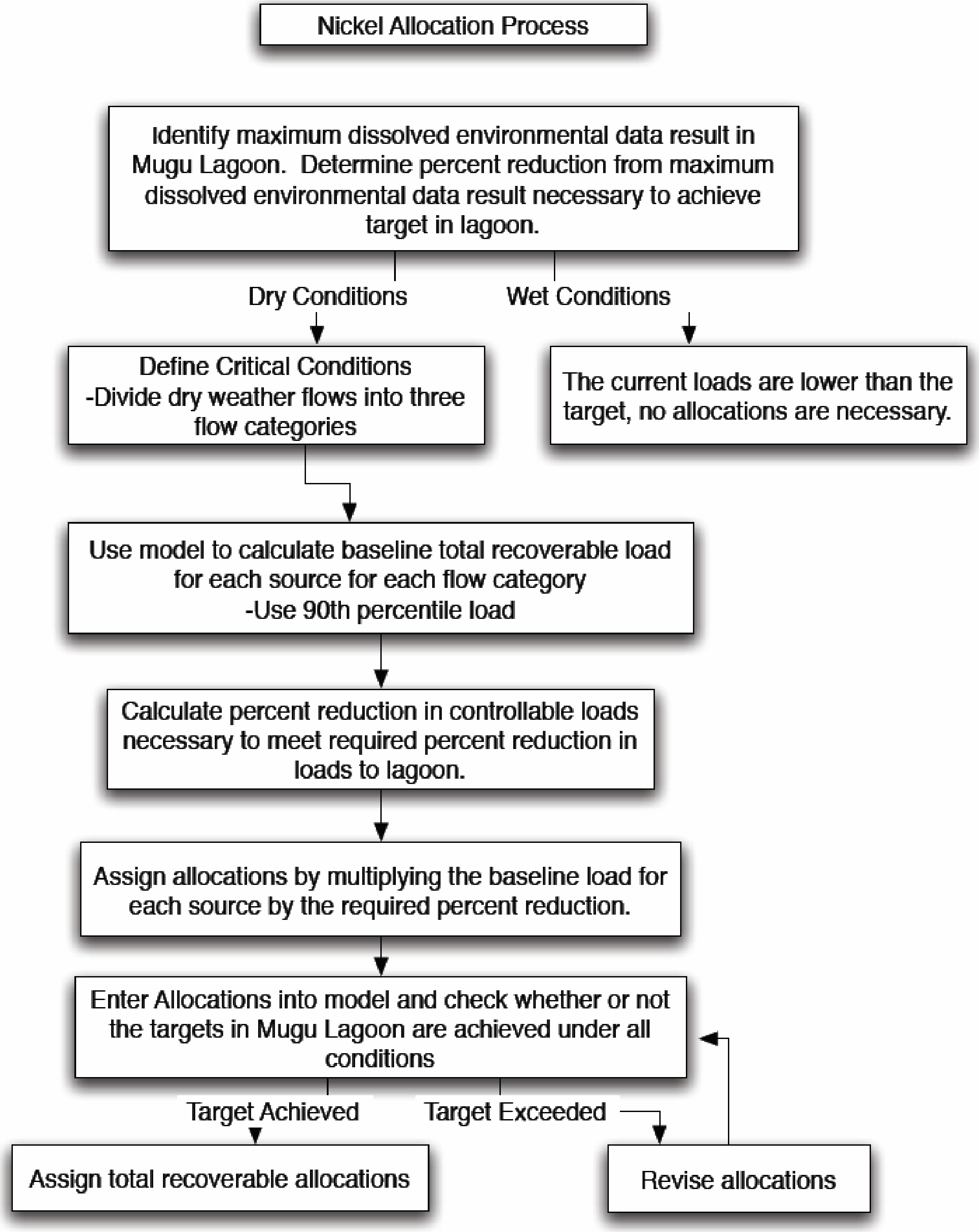
Figure 53. Copper Allocation Development Process

Copper Allocation Approach

For dry weather, the critical condition translator was developed by dividing the modeled total recoverable concentration by the modeled dissolved concentration for results in the three flow categories. The median translator for each flow category was defined as the translator for the flow category.

For wet weather, a relationship between TSS and flow was defined for Revolon Slough and Calleguas using modeled TSS and flow results. The translator was defined for wet weather using the linear partitioning equation with the TSS concentration replaced by an equation representing the relationship between TSS and flow rate. Using this method, the total recoverable allowable load during wet weather is only a function of flow. This relationship will be used as the default value for calculating the translator during wet weather. However, if data on TSS and/or dissolved and total metals are available, the calculated translator specific to that monitoring event can be used in lieu of the relationship for determining compliance with the allocations. Additionally, the TSS and flow relationship will be reevaluated based on monitoring results gathered as part of the TMDL implementation.

As discussed in the targets section, a copper WER has been submitted to the LARWQCB for consideration. The TMDL provides allocations corresponding to the CTR targets and the targets derived from the proposed WER (in case the WER is not adopted and approved simultaneously). Final WLAs and LAs will be set based on the WER which is adopted by LARWQCB.



If a SSO for nickel becomes effective, the process used to develop the copper allocations will be used to develop nickel allocations. These allocations are shown in Section 14.

Figure 54. Nickel Allocation Development Process

Nickel Allocation Approach

The allocation process for nickel described above in Figure 54 is based on the method required to achieve numeric target conditions in the listed reach (Mugu Lagoon). Modeling data suggests additional reductions may be necessary to meet the CTR targets in Lower Calleguas Creek and Revolon Slough, but neither of these reaches are listed for nickel.

As discussed in the targets section, information has been developed for a SSO for nickel in Lower Calleguas Creek, Revolon Slough and Mugu Lagoon. However, adoption and approval of the SSO will likely not occur concurrently with this TMDL. Therefore, allocations will be based on achievement of targets in the listed reach until the time at which SSOs are adopted or additional monitoring determines that impairments are not occurring in these reaches after implementation of the TMDL.

In the event the SSOs is approved by the State and USEPA, the allocations developed to address Lower Calleguas Creek and Revolon Slough which are included in the Nickel SSO section of this document (Section 14) will become the effective allocations for this TMDL. The process used to develop allocations with the SSO as the target is the same as the process used to develop the copper allocations.

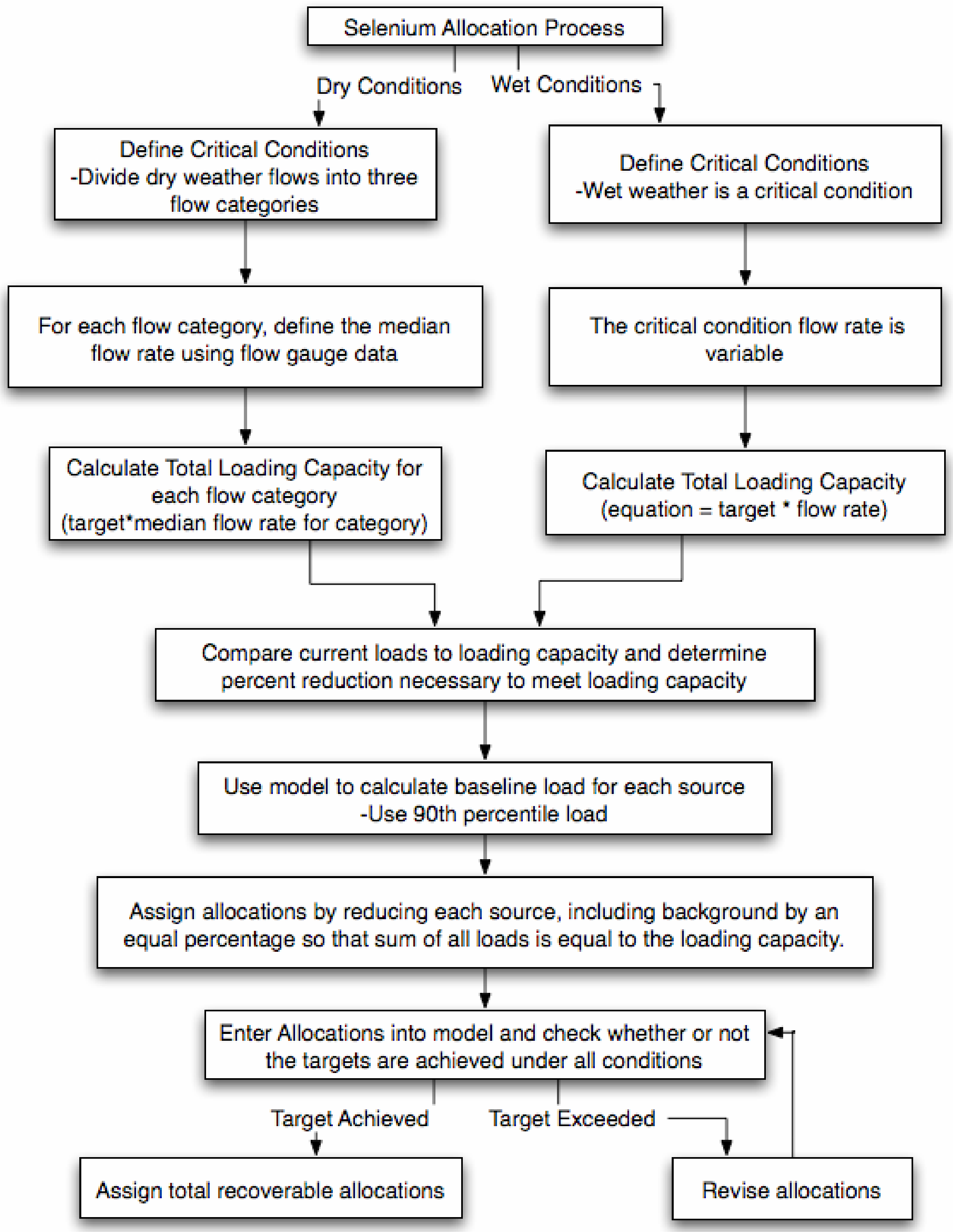


Figure 55. Selenium Allocation Development Process

Selenium Allocation Approach

The basic process used to develop allocations for selenium is the same as the process used to develop the copper allocations, with the key exception that no translator is necessary (since targets and allocations are both for total selenium).

Approach for Minor NPDES Dischargers

Sufficient information for calculating load allocations for minor NPDES dischargers is not available. Because these sources are likely to be minor contributors to the loads, they are assigned concentration-based allocations according to the reach into which they discharge.

Alternatives Considered

Four alternatives to the process described above for determining and allocating loads for copper, nickel and selenium were considered to meet in-stream numeric targets:

1. Develop a constant translator for converting between dissolved targets and total loads (copper and nickel only)
2. Allocate load reductions to discharges based on an individual discharge's current proportion of the loading during critical conditions.
3. Allocate load reductions to discharges based on the ability of the discharge to meet the allocation.
4. Set WLAs and LAs equal to the numeric target.

Alternative 1 does not account for the large variability in the discharge of total metals that can occur without causing dissolved concentrations and toxicity in the water column to increase. Because of the large amount of open space and agricultural lands in the watershed, sediment discharges containing metals can be significant during storm events without causing an impact on the bioavailable portion of the metals in the stream and sediment. Using a constant translator during wet weather may require significant reductions in discharges without a corresponding reduction in impacts. Additionally, using the modeled translator results in the ability to account for in-stream sediment impacts on the water column that are not accounted for when using a constant translator.

Alternative 2 would allocate load reductions and ultimately WLAs and LAs based on each discharger's current proportion of in-stream loading during critical conditions. During dry weather, POTWs are responsible for a more significant portion of the loading and in wet weather agriculture and urban runoff are more significant. Using this method would require varying the allocations not only based on flow rate and a variable translator (as shown above), but also as a function of the loading from each source during the given condition. This added complexity was not deemed to be reasonable for this TMDL.

To implement Alternative 3, highly detailed information on the effectiveness of BMPs for agriculture and urban runoff is required to determine the most cost-effective method for allocating the loads. Although such information on BMPs is being developed for this watershed, it is not available at the present time, and thus implementing this allocation method was not possible at this time.

Alternative 4 would set WLAs and LAs equal to the numeric targets set forth in the Numeric Targets section. For copper and nickel, the targets become lower at the interface of the saltwater and the freshwater in the lower reaches of the waterbody. These lower targets drive the allowable load at those points, but upstream of those areas, the allowable load is larger due to the higher freshwater objectives. Upstream of the saltwater/freshwater interface, some of the discharged load is diverted for reclaimed water use, seeps into the groundwater or is diluted by other sources of water. Consequently, the load that reaches the lower portion of the watershed is not equal to the load that was discharged. Therefore, applying the saltwater target to the discharges would be overly conservative and applying the freshwater targets to the discharges may not be protective. To address the concern that saltwater targets applied upstream would be overly conservative and still use this allocation approach, dilution factors could be determined for the upstream dischargers and allocations calculated based on the dilution factors and the numeric targets. However, the calculation of dilution factors would involve many of the same complexities as the chosen allocation method and would likely result in similar allocations. By using the model results, dilution is inherently considered in the chosen allocation approach. The chosen allocation method accounts for the impacts of the discharges on the lower reaches in assigning the allocations.

9.3 Critical Conditions and Seasonal Variation - Copper, Nickel, and Selenium

Seasonal variation is addressed by developing separate targets and allocations for dry and wet weather conditions. As described below, critical conditions during wet and dry weather are addressed separately and account for seasonal variation.

Critical Conditions

For this TMDL, wet weather and dry weather critical conditions were defined for each constituent. The critical conditions were developed by using the model results to calculate the maximum observed 4-day average dry weather concentration and the associated flow condition. Wet weather as a whole was defined as a critical condition.

Acute criteria are compared to the calculated daily concentrations from the HSPF model, and chronic criteria are compared to a rolling 4-day arithmetic average of the calculated concentrations. The HSPF model estimates in-stream concentrations of dissolved and total copper, dissolved and total nickel, total selenium and total mercury for conditions existing between 10/1/93 and 12/31/04 in the CCW. The in-stream flow duration curves generated by the HSPF model are plotted in Figure 56. By inspection, a “knee” is present in each of the flow duration curves occurring at approximately the 86th percentile flow rate. The “knee” corresponds to precipitation driven runoff representing an estimate of the maximum non-storm flow rate. The 86th percentile flows are used to distinguish dry weather from wet weather critical conditions and flowrates. Below the 86th percentile flow rate, the dry weather allocations will apply. Above the 86th percentile flow rate, the wet weather allocations will apply. The 86th percentile flow rate is 21.6 for Revolon at PCH and 29.7 for Calleguas at PCH.

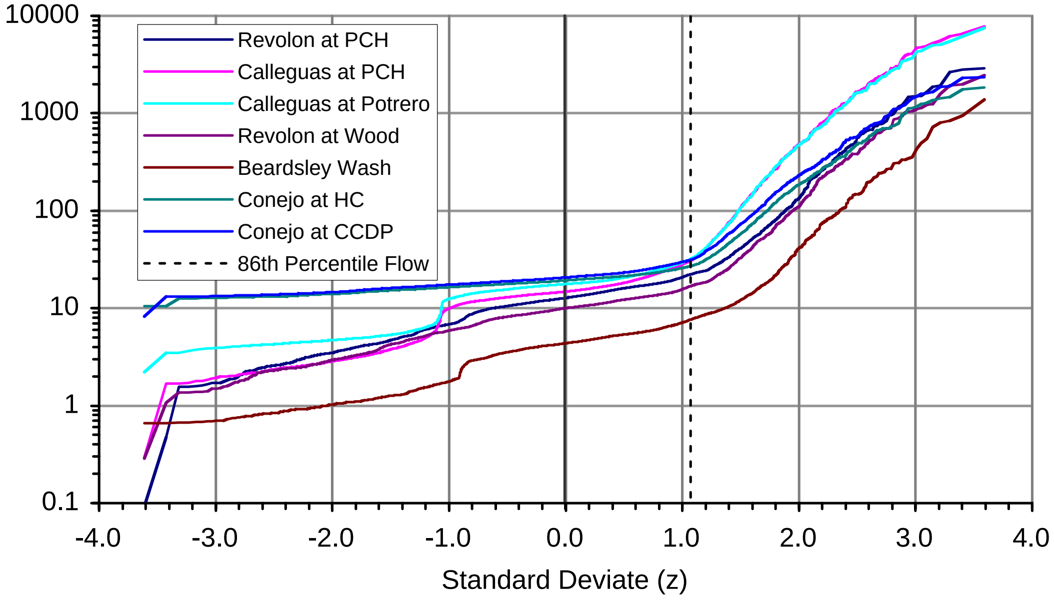


Figure 56. Flow duration curves for in-stream flowrates for each subwatershed in the CCW

For dry weather, the allowable load for each flow category was calculated using Equation 6 with the flow rate for each category equal to Q and chronic numeric targets equal to C_{NT} for in-stream flowrates less than the 86th percentile flow (non-storm conditions) and acute numeric targets equal to C_{NT} for flows above the 86th percentile flow (storm flow conditions).

To define the dry weather flow categories, the model results were reviewed to determine the flow conditions that resulted in the highest dissolved copper and nickel concentrations and total selenium concentrations during dry weather. The flow conditions associated with maximum modeled concentrations are considered the critical conditions for the constituent. Table 63 summarizes the flow rates associated with the maximum modeled copper, nickel and selenium concentrations.

Table 63. Calculated In-Stream Flowrates at Dry Weather Critical Conditions

Constituent	Revolon Critical Condition Flow (cfs)	Calleguas Critical Condition Flow (cfs)
Copper	21.2	3.26[1]
Nickel	13.1	13.5
Selenium	19.3	29.5

1. Flow rate after diversion. Loads calculated based on flow rate with diversion.

As shown in the table above, the dry weather critical condition flow rate is typically an elevated flow rate that occurs after a storm event, except for copper in Calleguas Creek. The allocations in this TMDL are being assigned as loads, so the elevated flow rates result in loads that may not be protective under lower flow conditions. Therefore, rather than just assign loads based on the critical condition flow rates, flow categories were developed and used to define the loading capacity and allocations. Within each flow category, the median flow rate was used to establish the loading capacity. The flow categories were established based on flow rates that resulted in similar concentrations. For example, elevated copper concentrations in Calleguas Creek occur to approximately 5 cfs and then the concentrations are slightly lower until after storm events. Therefore, the flow categories were divided at 5 cfs for low flow and 21 cfs to represent elevated flows after storm events. Table 64 shows the flow categories and associated median flow rates used to develop the loading capacity.

Table 64. Dry Weather In-Stream Flow rate Categories and Associated Median Flowrates.

Flow Category	Revolon Flows in Category (cfs)	Revolon Median Flow for Category (cfs)	Calleguas Flows in Category (cfs)	Calleguas Median Flow for Category (cfs)
Low	0-10.0	7	0-5.0	3
Average	10.0-17.0	12	5.0-21	14
Elevated	17.0-22.0	19	21-30	24

For Revolon Slough, the loading capacities were calculated using the median flowrates listed in the table above. However, for Calleguas the flowrates shown in the table above do not account for the diversion of water in Conejo Creek and recharge of groundwater that remove loads from the stream upstream of Calleguas Creek. Therefore, the flowrates used to calculate the loading capacities and allocations are based on the flow rate at the Conejo Creek Diversion plus the Camarillo Sanitary District Water Reclamation Plant flow associated with the flows shown in Table 64.

9.4 Loading Capacity - Copper, Nickel, and Selenium

Using the approach shown in Figure 53 - Figure 55, total recoverable loading capacities are defined for dry and wet weather. As discussed in the targets section, a WER for copper is being proposed as part of this TMDL. Because the copper WER is not yet effective, this TMDL includes the loading capacity and allocations for both targets with and without a copper WER . The following tables summarize the calculation of dry weather total loading capacity.

Table 65. Dry Weather Dissolved and Total Recoverable Loading Capacity with CTR as Targets

	Constituent	Dissolved Target (ug/L)	Critical Condition Flow (cfs)	Critical Condition Dissolved Load (lb/day)	Critical Condition Translator	Critical Condition Total Load (lb/day)
Calleguas	Low Flow (Dry)					
	Copper	3.1	20.0	0.33	0.83	0.40
	Nickel	8.2	20.0	0.88	0.80	1.10
	Average Flow (Dry)					
	Copper	3.1	23.0	0.38	0.86	0.45
	Nickel	8.2	23.0	1.02	0.85	1.20
	Elevated Flow (Dry)					
	Copper	3.1	28.0	0.47	0.63	0.74
	Nickel	8.2	28.0	1.24	0.70	1.77
Revolon	Low Flow (Dry)					
	Selenium	5	7			0.19
	Copper	3.1	7.0	0.12	0.96	0.12
	Nickel	8.2	7.0	0.31	0.97	0.32
	Average Flow (Dry)					
	Selenium	5	12			0.32
	Copper	3.1	12.0	0.20	0.85	0.24
	Nickel	8.2	12.0	0.53	0.87	0.61
	Elevated Flow (Dry)					
	Selenium	5	19			0.51
	Copper	3.1	19.0	0.32	0.57	0.56
	Nickel	8.2	19.0	0.84	0.63	1.34

Table 66. Dry Weather Dissolved and Total Recoverable Loading Capacity Including Copper WER 1

Reach	Constituent	Dissolved Target (ug/L)	Critical Condition Flow (cfs)	Critical Condition Dissolved Load (lb/day)	Critical Condition Translator	Critical Condition Total Load (lb/day)
Calleguas	Low Flow (Dry)					
	Copper	12.6	20.0	1.36	0.83	1.63
	Nickel	8.2	20.0	0.88	0.80	1.10
	Average Flow (Dry)					
	Copper	12.6	23.0	1.56	0.86	1.82
	Nickel	8.2	23.0	1.02	0.85	1.20
	Elevated Flow (Dry)					
	Copper	12.6	28.0	1.90	0.63	3.02
	Nickel	8.2	28.0	1.24	0.70	1.77
Revolon	Low Flow (Dry)					
	Selenium	5	7			0.19
	Copper	6.6	7.0	0.25	0.96	0.26
	Nickel	8.2	7.0	0.31	0.97	0.32
	Average Flow (Dry)					
	Selenium	5	12.0			0.32
	Copper	6.6	12.0	0.43	0.85	0.51
	Nickel	8.2	12.0	0.53	0.87	0.61
	Elevated Flow (Dry)					
	Selenium	5	19.0			0.51
	Copper	6.6	19.0	0.68	0.57	1.19
	Nickel	8.2	19.0	0.84	0.63	1.34

The wet weather loading capacity is calculated based on the flow rate during a storm. The loading capacity for wet weather is calculated by multiplying the acute numeric target by the daily storm volume and dividing by the translator equation ($Cu_{dis}/Cu_{tot}=1/\{1+K_D(TSS)(10^{-6})\}$). For each reach, a regression equation between TSS and flow was developed. This equation was substituted into the translator equation for TSS so that the translator equation became a function of flow. The following table summarizes the wet weather load duration curve equations written out to show the target, daily storm volume and translator equations and conversion information.

Table 67. Wet Weather Critical Condition Dissolved and Total Recoverable Loading Capacity with CTR as Targets

	Allocation	Dissolved Acute Target (ug/L)	Critical Condition Wet Weather Total Load Duration Curve Equation (lb/day)
Calleguas	Copper	4.8	(4.8*Q)*(1+0.0054(6.4Q+197.5))*C
	Nickel	74	(74*Q)*(1+0.0027(6.4Q+197.5))*C
Revolon	Copper	4.8	(4.8*Q)*(1+0.0024(27.8+75.9))*C
	Nickel	74	(74*Q)*(1+0.0019(27.8+75.9))*C
	Total Selenium	290	290*Q*C

Q Daily storm volume
C Conversion from ug/L multiplied by cfs to lb/day

Table 68. Wet Weather Critical Condition Dissolved and Total Recoverable Loading Capacity including Copper WER

	Allocation	Dissolved Acute Target (ug/L)	Critical Condition Wet Weather Total Load Duration Curve Equation (lb/day)
Calleguas	Copper	19.5	(19.5*Q)*(1+0.0054(6.4Q+197.5))*C
	Nickel	74	(74*Q)*(1+0.0027(6.4Q+197.5))*C
Revolon	Copper	10.2	(10.2*Q)*(1+0.0024(27.8+75.9))*C
	Nickel	74	(74*Q)*(1+0.0019(27.8+75.9))*C
	Total Selenium	290	290*Q*C

Use of the equation shown above to represent TSS is necessary for creating a load which is dependent on only one variable (flow) and for developing a default allocation curve in situations where environmental data are not available. However, this method does not characterize the translator as well as using actual TSS or translator measurements in the receiving water collected during wet weather events.

9.5 Comparison of Current Loads and Loading Capacity for Copper, Nickel, and Selenium

Table 69 presents estimated current dry weather total copper, nickel and selenium loads; total loading capacities for Calleguas during the critical condition; and the percent reduction in current total dry weather loads necessary to meet the loading capacities. The current loads were calculated based on the maximum modeled 4-day average concentration and the loads presented in the table are based on the middle range flow rate category. The percent reductions shown in the table represent the maximum required percent reductions based on model results and the middle flow rate category. Table 70 presents the same information for Revolon Slough.

Table 69. Comparison of Current Total Copper and Nickel Loads to Loading Capacity (Average Flow Category) in Calleguas at PCH During Dry Weather Critical Conditions.

Constituent	Target	Dissolved Capacity (lb/day)	Current Dissolved Load (lb/day)	Reduction (%)
Dissolved Copper	3.1 (no WER)	0.38	1.03	63%
	12.6 (WER)	1.56	1.03	0%
Dissolved Nickel	8.2	1.02	2.12	52%

Table 70. Comparison of Current Total Copper, Nickel and Selenium Loads to Loading Capacity (Average Flow Category) in Revolon at PCH During Dry Weather Critical Conditions.

Constituent	Target	Capacity (lb/d)	Current Load (lb/d)	Reduction (%)
Dissolved Copper	3.1 (no WER)	0.24	1.23	84%
	6.6 (WER)	0.43	1.23	65%
Dissolved Nickel	8.2	0.61	1.29	59%
Total Selenium	5	0.32	2.98	89%

Model results indicate that nickel and selenium do not exceed the wet weather allocations under any flow conditions. For copper, the model indicates that a 46% reduction is required in both Calleguas and Revolon to achieve the CTR targets. Because the wet weather loading capacity is variable, the 46% reduction will serve as a guideline for implementation activities.

9.6 Allocations - Copper, Nickel, and Selenium

Estimated background loading of copper, nickel, and selenium is presented below; followed by waste load allocations and load allocations for copper, nickel, and selenium.

Background Load - Copper, Nickel, and Selenium

Although “ambient sources” contribute to discharges from all land use types (including agricultural, urban, and open space runoff), only loads from undeveloped open space and natural groundwater seepage are generally unaffected by anthropogenic influences. Thus, calculation of the “background load” for the copper, nickel, and selenium TMDLs includes only open space discharges and natural groundwater seepage.

As explained in the source analysis sections, naturally occurring content in local soils is the primary ambient source contributing copper, nickel, and selenium to open space runoff and groundwater seepage. Atmospheric deposition also contributes to loading from open space. Naturally occurring groundwater with high selenium concentrations is likely the major source of selenium in the watershed.

In developing allocations, the HSPF model was used to estimate the background load by running the model with all discharges from agriculture, urban sources and POTWs turned off. It is assumed that background loads will not change significantly over time (except in the case of selenium where background reductions are necessary to achieve the targets). Thus, background loads are assigned an allocation equal to the current loading. In reality, some activities undertaken to reduce loadings for this TMDL and other CCW TMDLs will likely result in some reduction in this background load from open space and groundwater, so this is a conservative assumption for the purposes of developing allocations.

The background load is set equal to the median percentage of the current load for each flow category. The following table shows the estimated percentage of current loads for each flow category that are assigned for each constituent as background loads for this TMDL.

Table 71. Background Loads for Each Flow Category for Copper, Nickel, and Selenium.

	Constituent	Background Percentage	Background Load (lb/day)
Calleguas	Low Flow (Dry)		
	Copper	21%	0.15
	Nickel	52%	0.45
	Average Flow (Dry)		
	Copper	15%	0.08
	Nickel	49%	0.42
	Elevated Flow (Dry)		
	Copper	10%	0.13
	Nickel	32%	0.56
	Wet Flow		
	Copper	6%	Variable
	Nickel	17%	Variable
Revolon	Low Flow (Dry)		
	Selenium	94%	0.68
	Copper	16%	0.05
	Nickel	2%	0.01
	Average Flow (Dry)		
	Selenium	97%	2.43
	Copper	23%	0.12
	Nickel	3%	0.02
	Elevated Flow (Dry)		
	Selenium	96%	4.56
	Copper	10%	0.11
	Nickel	1%	0.02
	Wet Flow		
	Selenium	69%	Variable
	Copper	2.50%	Variable
	Nickel	1%	Variable

Table 72 and Table 73 present the current total copper, nickel and selenium loads <u>during dry weather conditions</u> for each discharger.

Table 72. Current Estimated Loads for Each Source in Calleguas (lb/day)

		Low Flow (Dry)		Average Flow (Dry)		Elevated Flow (Dry)	
	Source	Copper	Nickel	Copper	Nickel	Copper	Nickel
Calleguas	Hill Canyon WQCP[1]	0.83	0.57	--	--	--	--
	Camarillo WRP[1]	0.85	0.45	--	--	--	--
	Simi Valley WWTP[1]	1.38	0.79	--	--	--	--
	Agricultural Runoff	0.52	0.73	0.31	0.47	1.18	1.68
	Urban Runoff	0.31	0.18	0.30	0.22	0.69	0.76

[1] Current loads for the POTWs are based on the design flow and the 90th percentile concentration observed in the effluent discharge and apply to all flow conditions. Design flows for POTWs in the CCW are as follows: Hill Canyon 10.2 MGD (expanding to 14 MGD by approximately 2018), Camarillo 6.75 MGD, Moorpark 3 MGD, Simi Valley 12.5 MGD (expanding to 17.5 MGD by 2012), Camrosa 1.5 MGD.

Table 73. Current Estimated Loads for Each Source in Revolon (lb/day)

Low Flow (Dry)	Agriculture	Urban
Selenium	0.03	0.01
Copper	0.34	0.15
Nickel	0.64	0.08
Average Flow (Dry)		
Selenium	0.06	0.02
Copper	0.72	0.31
Nickel	1.14	0.11
Elevated Flow (Dry)		
Selenium	0.17	0.04
Copper	1.96	0.70
Nickel	2.62	0.19

Waste Load & Load Allocations - Copper, Nickel and Selenium

This section summarizes the allocations for POTWs, urban stormwater dischargers (MS4, Caltrans, general construction, general industrial, and the Navy), agriculture, and other NPDES dischargers.
Table 74 through Table 81 present dry and wet weather load allocations for the various discharges. The allocations include an explicit margin of safety of 15% for copper and nickel (as discussed in the MOS section). In addition interim limits are presented in Table 76 and Table 79 in order to allow time for dischargers to put in place implementation measures necessary to achieve final allocations. Daily and monthly dry weather interim allocations and daily wet weather interim allocations are included. The interim allocations are concentration-based allocations. The daily interim allocations are set equal to the 99th percentile of available discharge data for each source collected during dry weather for the dry allocations and collected during wet weather for the wet allocations. The monthly dry weather interim allocations are set equal to the 95th percentile of available discharge data for each source collected during dry weather. All available discharge data presented in the Source Analysis section were used to create a robust data set to calculate the interim limits. Interim limits are based on the available data and may be revised based on additional water quality data, if appropriate. The available discharge data used to calculate interim allocations for urban and agricultural dischargers was collected throughout Ventura County. Sufficient Calleguas Creek specific discharge data were not available for calculating interim limits.

The wet weather allocations presented in the table are developed based on the loading capacity equations presented in Table 67and Table 68. The allocations were developed by subtracting the background load from the loading capacity and multiplying the resulting equation by the percentage of the load attributable to the source and the margin of safety.

Allocations for selenium were only developed for Revolon Slough, where the listing exists. Although there are potentially other reaches of the watershed that exceed the water column criteria for selenium, the sources of selenium are almost exclusively related to background loading (primarily groundwater seepage). As shown in the allocations table, it is not possible to achieve the water column targets by solely controlling agriculture, urban runoff, or POTW discharges. Significant reductions in background loads are necessary to achieve the selenium targets. Therefore, allocations are included for the listed reach and an implementation strategy is included to address the background loadings of selenium throughout the watershed.

POTWs are assigned two different types of allocations. To achieve the loading capacity required to meet the saltwater criteria in the lower Calleguas Creek Reach 2 and Mugu Lagoon, POTWs are assigned daily loads based on the allocation process discussed above. In addition, POTWs are assigned concentration-based allocations equal to the freshwater dissolved CTR targets divided by the default CTR translator. The daily allocations are based on the acute target and the monthly allocations are based on the chronic target. Because POTWs are the largest source of flow during dry weather, the concentration-based allocations are assigned to ensure that the freshwater criteria are not exceeded in the upstream reaches. The concentration-based allocations are currently being met by all POTWs and do not have a direct relationship to the waste load allocations necessary to achieve the saltwater criteria loading capacity in Calleguas Creek Reach 2 and Mugu Lagoon. Percent reductions and implementation actions presented for POTWs are necessary to meet the waste load allocations for the saltwater criteria.

Table 74. Total Copper and Nickel Waste Load Allocations with CTR as Targets for POTWs

	Copper			Nickel		
	Final Daily Concentration Limit (ug/L)	Final Monthly Concentration Limit (ug/L)	Final Daily WLA (lb/day)	Final Daily Concentration Limit (ug/L)	Final Monthly Concentration Limit (ug/L)	Final Daily WLA (lb/day)
Hill Canyon WWTP	(2)	(2)	0.07	(2)	(2)	0.33
Simi Valley WQCP	29.8	29.3	(1)	958	168	(1)
Moorpark WWTP	29.8	29.3	(1)	958	168	(1)
Camarillo WRP	(2)	(2)	0.07	(2)	(2)	0.26
Camrosa WRP	26.3	25.9	(1)	856	149	(1)

1 The allocation analysis determined that load allocations are not required for Simi Valley, Moorpark, and Camrosa because they do not contribute loadings that cause exceedances of numeric targets. Monitoring will be conducted and the allocations reevaluated if targets are not met in Arroyo Simi/Las Posas or downstream reaches.

2 Concentration-based final limits may be included in permits, but were not calculated as part of the TMDL.

Table 75. Total Copper Waste Load Allocations with Copper WER as Target for POTWs [3]

	Copper		
	Final Daily Concentration Limit (ug/L)	Final Monthly Concentration Limit (ug/L)	Final Daily WLA (lb/day)
Hill Canyon WWTP[1]	(4)	(4)	1.63
Simi Valley WQCP	29.8	29.3	(2)
Moorpark WWTP	29.8	29.3	(2)
Camarillo WRP[1]	(4)	(4)	1.63
Camrosa WRP	26.3	25.9	(2)

1	The current loads do not exceed the TMDL when the copper WER is effective. The sum of all the loads cannot exceed the load shown.
2	The allocation analysis determined that load allocations are not required for Simi Valley, Moorpark, and Camrosa because they do not contribute loadings that cause exceedances of numeric targets. Monitoring will be conducted and the allocations reevaluated if targets are not met in Arroyo Simi/Las Posas or downstream reaches.
3	As explained in the numeric targets section, a copper WER has been developed in parallel with this TMDL and proposed to the LARWQCB for review. Final allocations will be set in accordance with the final WER which is adopted by LARWQCB
4	Concentration-based final limits may be included in permits, but were not calculated as part of the TMDL.

Table 76. Total Copper and Nickel Interim Waste Load Allocations for POTWs [1]

	Copper[2]		Nickel	
	Interim Daily WLA (ug/L)	Interim Monthly WLA (ug/L)	Interim Daily WLA (ug/L)	Interim Monthly WLA (ug/L)
Hill Canyon WWTP	20	16	8.3	6.4
Camarillo WRP	57	20	16	6.2

1	Should the copper WER become effective, interim limits for copper will no longer be effective and the final limits will become effective.
2	Should the copper WER become effective, interim limits for copper will no longer be effective and the final limits will become effective.

Table 77. Total Copper, Nickel and Selenium WLA and LAs with CTR as Targets for Urban & Agriculture (lb/day)

Flow	Calleguas and Conejo Creek			Revolon Slough		
Constituent	Agriculture	Urban	Background	Agriculture	Urban	Background
Low Flow (Dry)						
Selenium[4]	(2)	(2)	(2)	0.008	0.004	0.18
Copper	0.04	0.03	0.15	0.043	0.019	0.05
Nickel	0.42	0.10	0.45	0.39	0.050	0.01
Average Flow (Dry)						
Selenium[4]	(2)	(2)	(2)	0.007	0.003	0.31
Copper	0.04	0.04	0.08	0.070	0.030	0.12
Nickel	0.26	0.12	0.42	0.69	0.069	0.02
Elevated Flow (Dry)						
Selenium[4]	(2)	(2)	(2)	0.018	0.004	0.49
Copper	0.17	0.10	0.13	0.28	0.101	0.11
Nickel	0.97	0.44	0.56	1.60	0.116	0.02
Wet Weather Flows						
Selenium [1,4]	(2)	(2)	(2)	0.1*Q2+1.8*Q	0.027*Q2+0.47*Q	0.027*Q2+0.47*Q
Copper	0.00017*Q^2+0.0053*Q-0.034	0.00054*Q^2+0.0168*Q-0.106	0.0000537*Q^2+0.00321*Q	0.00123*Q^2+0.0034*Q	0.0002*Q^2+0.0005*Q	0.0000432*Q^2+0.000765*Q
Nickel[4]	0.014*Q^2+0.82*Q	0.014*Q2+0.82*Q	0.014*Q2+0.82*Q	0.027*Q^2+0.47*Q	0.027*Q2+0.47*Q	0.027*Q2+0.47*Q

1	Selenium allocations for Revolon Slough require major reductions to background loading. In order to achieve numeric target concentrations, an 80% or greater reduction in background loads is necessary (which may not be attainable). The allocations assume that all sources (including background) will be reduced by the same percentage.
2	Selenium allocations have not been developed for this reach as it is not on the 303(d) list. Implementation actions include consideration of watershed-wide selenium impacts.
3	Reductions in background loads are not included for these constituents and interim background load requirements are not necessary.
4	The current loads do not exceed the TMDL under wet weather conditions. The sum of all loadings cannot exceed the load shown.
Q	Daily storm volume

Table 78. Total Copper WLA and LAs with Copper WER as Target for Urban and Agriculture (lb/day) [2]

Flow	Calleguas and Conejo Creek		Revolon Slough		
Constituent	Agriculture	Urban	Agriculture	Urban	Background
Low Flow (Dry)	Final LA[1]	Final WLA[1]	Final LA	Final WLA	Final LA
Copper	1.63	1.63	0.12	0.054	0.05
Average Flow (Dry)					
Copper	1.82	1.82	0.23	0.099	0.12
Elevated Flow (Dry)					
Copper	3.02	3.02	0.67	0.243	0.11
Wet Weather Flows					
Copper	0.036*Q^2+0.22*Q	0.036*Q2+0.22*Q	0.0026*Q^2+0.0071*Q	0.00043*Q^2+0.0012*Q	0.000092*Q^2+0.0016*Q

1 The current loads do not exceed the TMDL when the copper WER is effective. The sum of all the loads cannot exceed the load shown.

2 As explained in the numeric targets section, a copper WER has been developed in parallel with this TMDL and proposed to the LARWQCB for review. Final allocations will be set in accordance with the final WER which is adopted by LARWQCB.

Q Daily storm volume

Table 79. Total Copper, Nickel, and Selenium Interim Waste Load and Load Allocations for Urban and Agriculture [1]

Constituent	Calleguas and Conejo Creek						Revolon Slough					
	Agriculture			Urban			Agriculture			Urban		
	Interim Dry Daily LA	Interim Dry Monthly LA	Interim Wet Daily LA	Interim Dry Daily WLA	Interim Dry Monthly WLA	Interim Wet Daily WLA	Interim Dry Daily LA	Interim Dry Monthly LA	Interim Wet Daily LA	Interim Dry Daily WLA	Interim Dry Monthly WLA	Interim Wet Daily WLA
Selenium [4]	(2)	(2)	(2)	(2)	(2)	(2)	6.7	6.0	(3)	14	13	(3)
Copper	24	19	1390	23	19	204	24	19	1390	23	19	204
Nickel	43	42	(3)	15	13	(3)	43	42	(3)	15	13	(3)

1 Interim allocations are applied in the receiving water at the compliance points.

2 Selenium allocations have not been developed for this reach as it is not on the 303(d) list. Implementation actions include consideration of watershed-wide selenium impacts.

3 The current loads do not exceed the TMDL under wet weather conditions. Interim limits are not required.

4 Compliance with interim limits for selenium will be evaluated in consideration of instream background load, when necessary data are available.

Note regarding interim limits for selenium: although interim limits are calculated using discharge data from agricultural and urban runoff sources, they are applied as instream concentrations. Even when ag/urban discharges are in compliance with interim limits, actual in-stream concentrations may exceed interim limits due to contributions from ambient sources. Thus, compliance with interim limits for selenium will be evaluated in consideration of instream background load, when necessary data are available.

Other NPDES dischargers are not considered significant sources of metals and selenium to the watershed and there is insufficient information to assign loads to these sources. Therefore, concentration-based allocations are assigned (Table 80). Dischargers will be allocated loads based on the reach to which they discharge. Allocations are set equal to the dissolved CTR target divided by the default CTR translator. The dry allocations are equal to the chronic targets and the wet allocations are set equal to the acute targets.

Table 80. Total Copper and Nickel Waste Load Allocations with CTR as Targets for Other NPDES Dischargers.

Reach	Copper		Nickel	
	Final Dry Daily WLA (ug/L)	Final Wet Daily WLA (ug/L)	Final Dry Daily WLA (ug/L)	Final Wet Daily WLA (ug/L)
1	3.7	5.8	8.2	74
2	3.7	5.8	8.2	74
3	27	27	149	859
4	3.7	5.8	8.2	74
5	3.7	5.8	8.2	74
6	31	31	169	960
7	31	31	169	960
8	31	31	169	960
9	29	43	160	1295
10	29	43	160	1295
11	29	43	160	1295
12	29	43	160	1295
13	29	43	160	1295

Table 81. Total Copper Waste Load Allocations with including Copper WER for Other NPDES Dischargers.

Reach	Copper	
	Final Dry WLA (ug/L)	Final Wet WLA (ug/L)
1	8.0	5.8
2	15.2	5.8
3	27	27
4	8.0	5.8
5	8.0	5.8
6	31	31
7	31	31
8	31	31
9	29	43
10	29	43
11	29	43
12	29	43
13	29	43

9.7 Impacts of Ambient Sources - Copper, Nickel, and Selenium

As discussed in the Source Analysis section, ambient sources (i.e., natural soil concentrations, natural groundwater seepage, and atmospheric deposition) contribute to the loading of copper, nickel, and selenium in the CCW. Some allocations for copper, nickel, and selenium may not be attainable without significant reductions in background loads and/or other ambient sources. Special studies included in the implementation plan will determine the potential for standards or regulatory actions such as natural background exclusion or site specific objectives to address any background loads which preclude achievement of numeric targets.

For the purpose of this TMDL, ‘ambient sources’ are defined as environmental sources of metals and selenium in the watershed, such as natural soil concentrations, atmospheric deposition, and natural groundwater seepage. The term ‘background load’ is used to describe the load of metals and selenium not affected by anthropogenic activities (i.e., discharges from undeveloped open space due to ambient sources, natural groundwater seepage). The component of agricultural and urban loading which results from ambient sources is not included in calculating the background load because human activities may affect the mobilization of naturally occurring constituents in these areas.

Copper and Nickel

As explained in the Source Assessment section, both anthropogenic and ambient sources are known to contribute loading of copper and nickel to receiving waters in the watershed. Several anthropogenic sources of copper have been identified which collectively are important relative to overall loading (e.g. pesticides, brake pads, architectural uses, copper pipes). Fewer anthropogenic sources of nickel are known to exist.

Although ambient sources contribute to the overall loading of copper, economic analysis presented in the implementation plan indicates allocations are likely achievable without major reductions in background loading. Nickel allocations are likely achievable in urban and agricultural areas during dry weather through the use of best management practices to reduce sediment discharges.

Selenium

Available data, source analysis (Section 6.7), and HSPF modeling indicate the majority of selenium loading to receiving waters in the CCW results from concentrations in local groundwater. Attainment of the CTR criteria for selenium will not be possible without major reductions in the background load. Consequently, the implementation plan will address the exceedances of selenium in all areas of the watershed, but allocations are designated only for the 303(d) listed reach (Revolon Slough). Special studies will be conducted to determine the potential for standards actions such as natural background exclusion or site specific objectives.

10 TMDL & ALLOCATIONS – MERCURY

Allocations for mercury are developed using a different approach from those for copper, nickel, and selenium because mercury in the water column is almost completely associated with particulate matter, while concerns about copper, nickel, and selenium are primarily associated with the dissolved portion in the water column. As explained in the Linkage Analysis section, the mercury TMDL is defined as an annual load of mercury in suspended sediment discharged from Revolon Slough and Calleguas Creek into Mugu Lagoon, in order to best address the potential for bioaccumulative impairments associated with mercury.

The following subsections are included in this Section 10:

10.1 Approach - Mercury TMDL & Allocations
10.2 Critical Conditions & Seasonal Variation
10.3 Current Loads and Loading Capacity
10.4 Allocations
10.5 Impacts of Loading from Ambient Sources

Calculation of the loading capacity (LC) is dependant on in-stream flows and as such is variable. However, by defining a critical condition, the LC can be calculated as the product of the in-stream flow rate at the defined critical condition, the TSS, the concentration of mercury on suspended sediment, the required percent reduction, and a margin of safety. Thus, the loading capacity is calculated according to the following equation:

$$\text{TMDL} = \text{LC} = Q * \text{TSS} * C_{\text{Sed}} * 1 - \text{PR} * \text{MOS} * f$$

Where:
LC = Loading Capacity (lbs/year)
Q = In-stream Flow at Critical Condition (cubic feet per second)
TSS = total suspended solids (mg/L)
C_{Sed} = current suspended sediment concentration (ug/Kg)
PR = percent reduction necessary for mercury suspended sediment loads (80%, or 0.8)
MOS = Margin of Safety
f = Conversion factor of 5.39E-06 [(pounds/year)/(mg/L * ug/Kg * cfs)]

The LC is allocated to a set of waste load allocations (WLAs) accounting for all identified point sources, a set of load allocations (LAs) accounting for all identified non-point sources, and a background load (BL) which accounts for ambient sources not related to human activities; as shown in the following equation:

$$\text{TMDL} = \text{LC} = \text{WLAs} + \text{LAs} + \text{BL}$$

Allocations to mercury sources are established to result in attainment of beneficial uses and water quality objectives. Mercury is on the 303(d) list for Mugu Lagoon and the current conditions analysis indicates that exceedances of the targets are currently occurring in Mugu Lagoon, Calleguas Creek and Revolon Slough. Allocations set for discharges from Revolon Slough and Calleguas Creek to Mugu Lagoon address all exceedances for mercury (since concentrations in the lagoon appear to be lower than concentrations discharged from Revolon and Calleguas).

10.1 Approach - Mercury TMDL & Allocations

The mercury TMDL is designated as a reduction in loading of mercury on suspended sediment, based upon percent reductions required to achieve numeric target concentrations for water and fish tissue. In order to translate required reductions in fish tissue and water column concentrations into suspended sediment mercury load reductions, it is assumed that a given percent reduction in water or fish tissue concentration results in a proportional percent reduction in suspended sediment mercury loads. The basis for this assumption is presented in the Linkage Analysis. The validity of this assumption will be evaluated by special studies included in the Implementation Plan and allocations adjusted if necessary to ensure compliance with numeric targets and achievement of beneficial uses.

The TMDL for mercury is developed according to the approach detailed below:

1. compare average mercury fish tissue concentrations in available data to numeric targets and calculate percent reduction required;
2. use HSPF model output to calculate percent reduction required for the annual maximum 30-day average mercury concentration in water to meet CTR, for each year of available data;
3. designate overall percent reduction representative of tissue concentrations and 30-day average water concentrations;
4. use HSPF model output to calculate current loads of mercury entering Mugu Lagoon on suspended sediment for each year of available data;
5. set allowable load equal to the current load * 1 - percent reduction (from step 3)
6. establish TMDL as allowable load of mercury on suspended sediment according to low, medium, and high annual flow scenarios.
7. allocate the allowable load to all sources based on proportional loading contributions.

Current and allowable loads are developed based on modeling of particulate-associated loading and the percent reduction required to meet numeric targets for water and fish tissue. Multiple allowable loads are defined according to low, medium, and high annual flow scenarios.

Alternatives Considered

Several alternative approaches were considered for developing the mercury TMDL and associated allocations, which are described briefly below.

Set TMDL and allocations as total mercury loads in water.

Deemed inappropriate because mercury in water is almost completely associated with particulate matter, and also because allocating loads in water is not practical for most sources in the watershed.

Include consideration of mercury loads in streambed sediment in addition to suspended sediment.

Reliable estimates of sediment transport in the CCW do not seem to exists, currently available estimates vary dramatically. Plus, the vast majority of sediment transport is captured in calculations of suspended sediment transport, and the high degree of interaction between suspended sediment and bottom sediment ensures comparable mercury concentrations exist.

10.2 Critical Conditions & Seasonal Variation - Mercury

The Clean Water Act stipulates a TMDL must appropriately consider and account for seasonal variations and critical conditions. Sediment concentrations generated by the Mugu Lagoon Metals and Selenium Model (MLMSLM) offer no indication that mercury contamination in the lagoon is consistently worse at any particular time of year. Since the potential effects of mercury are related to bioaccumulation in the food chain over long periods of time, any other short term variations in concentration which might occur are not likely to cause significant impacts upon beneficial uses. Therefore, concern about seasonal variability is not relevant for the CCW mercury TMDL. However, there is substantial variability in annual precipitation which directly affects the amount of sediment and water delivered into Mugu Lagoon across years. Given that allocations for this TMDL are expressed in terms of annual mercury loads in suspended sediment, the critical condition identified is total annual flow. The proposed load and waste load allocations represent long-term averages of annual loads based on varying annual precipitation and annual flow conditions. The implementation plan for mercury acknowledges and accommodates long-term inter-annual variability by evaluating whether sources are meeting allocations on a multi-year basis. Long-term averages help smooth out differences among high and low rainfall years.

10.3 Current Loads and Loading Capacity - Mercury

Since the mercury TMDL is designated according to a necessary percent reduction (PR), current loads are first developed then and categorized according to low, medium, and high annual flows. Figure 58 shows total annual loads of mercury in suspended sediment for each year from 1993-2003 (each year is calculated from October through September of the following year). The loads presented for Mugu Lagoon are based on concentrations in the lagoon itself, generated by the Mugu Lagoon Metals and Selenium Model (MLMSM); while the loads presented for Revolon Slough plus Calleguas Creek are based on concentrations discharged into Mugu Lagoon from the base of Revolon Slough and Calleguas Creek, generated by the HSPF model. Operation of each model is explained briefly in the Linkage Analysis section, and detailed in Appendix C, Appendix D, and Appendix E.

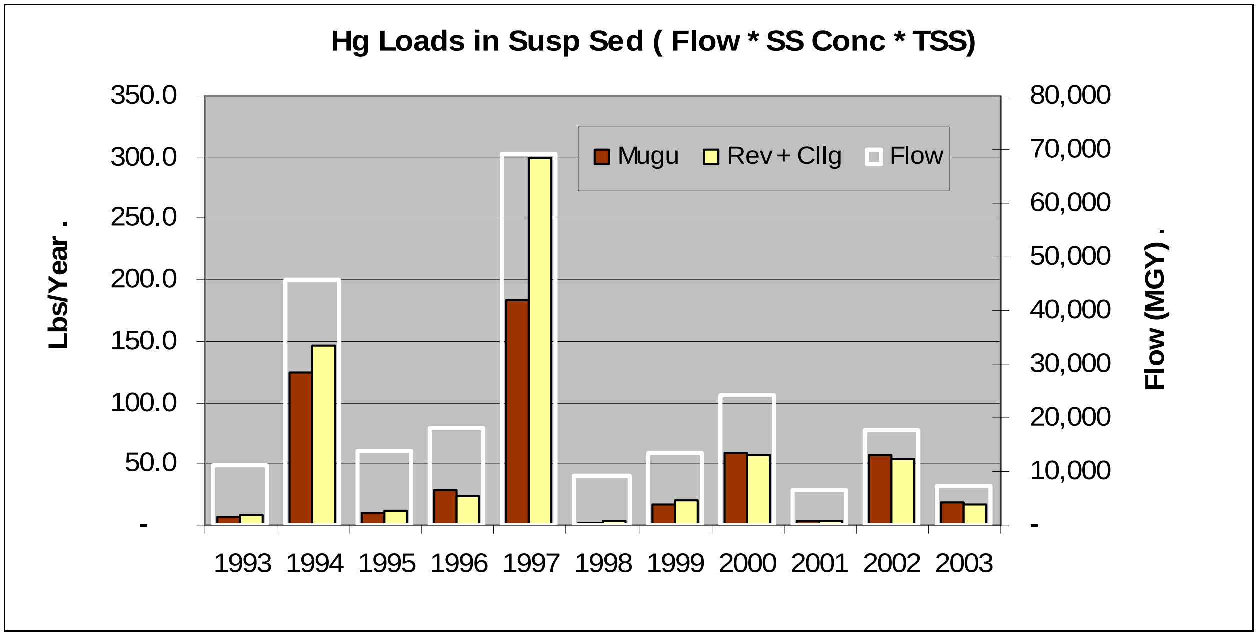


Figure 57. Annual loads of mercury in suspended sediment and associated annual flows in millions of gallons per year, for the years 1993 – 2003.

Figure 58 shows the same loadings shown above, sorted according to low, medium, and high annual flow categories. Low annual flow is defined as less than 15,000 million gallons per year (MGY), medium annual flow is defined as 15,000 – 25,000 MGY, and high flow defined as greater than 25,000 MGY.

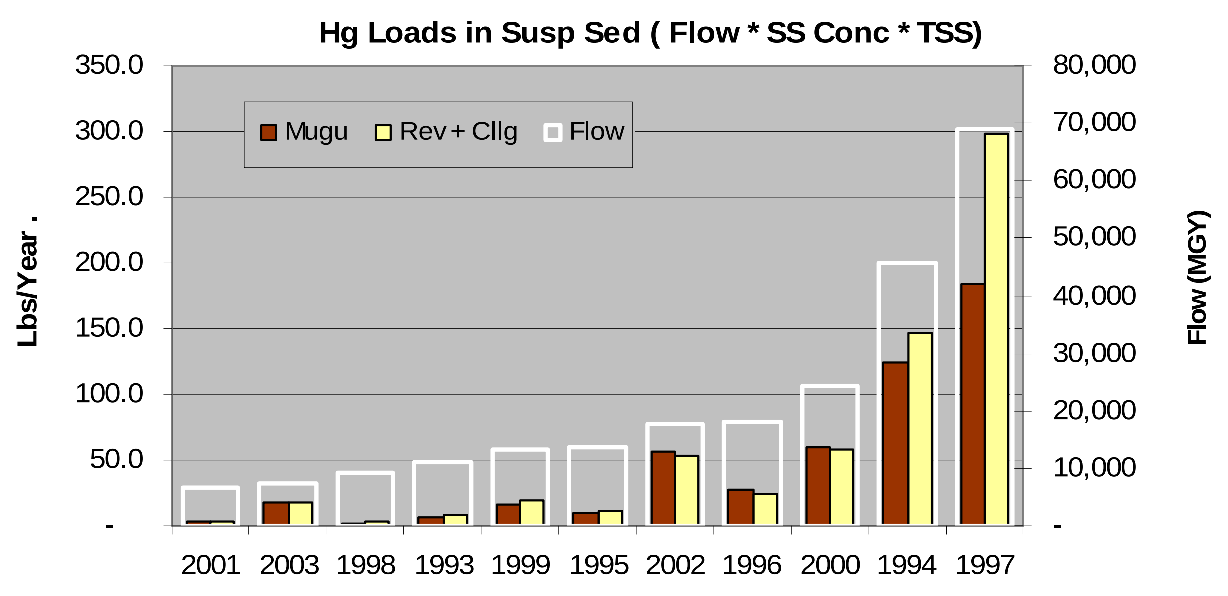


Figure 58. Total annual loads of mercury in suspended sediment (pounds per year), and associated annual flows in millions of gallons per year; sorted according to low, medium, and high annual flow years.

Loading capacity is calculated based on the 80% percent reduction necessary to achieve numeric target concentrations in the water column and fish tissue, as explained in the Linkage Analysis section. Loading capacities for mercury in suspended sediment for Revolon Slough and Calleguas Creek are presented below in Table 82, according to the annual flow categories described above. The loading capacity for each flow category is calculated as an 80% reduction from the average of all years occurring in each flow category.

Table 82. Current Loads and Loading Capacity for Mercury in Suspended Sediment for Mugu Lagoon, Revolon Slough, and Calleguas Creek; According to Annual Flow Category.

Waterbody / Reach	Flow Category [1]	Critical Condition Flow [2] (MGY)	Current Loading [3] (Lbs/Yr)	Loading Capacity [4] (Lbs/Yr)
Mugu Lagoon (sum of loads from Revolon and Calleguas)	Low	9,551	10.5	2.1
	Medium	17,863	44.8	9.0
	High	57,497	222.9	44.6
Revolon (at PCH)	Low	3,862	2.6	0.5
	Medium	6,669	13.6	2.7
	High	15,275	36.0	7.2
Calleguas (at PCH)	Low	5,687	7.9	1.6
	Medium	11,859	31.2	6.2
	High	38,489	186.9	37.4

[1] Flow categories, in millions of gallons per year (MGY): low (less than 15,000), medium (15,000 - 25,000), high (greater than 25,000).

[2] Mean annual flow for all years in each flow category, individual flows for Revolon and Calleguas not totaled here.

[3] Current mean annual load of mercury in suspended sediment for all years in each flow category.

[4] Average allowable annual load of mercury in suspended sediment for all years in each flow category, based on 80% reduction from current loads.

10.4 Allocations - Mercury

Allocations of mercury in suspended sediment to individual sources are assigned based on proportional loading contributions in water, for the following reasons: the load of total mercury in water is approximately equivalent to the suspended sediment load; and estimates of mercury concentrations on suspended sediment according to land use type are not available.

Background Load

As discussed in the Source Analysis section, the primary ambient sources of mercury are natural soil concentrations and atmospheric deposition. Although ambient sources of mercury are a component of the discharge from all land use types (including agricultural, urban, and open space runoff), only loads from undeveloped open space and natural groundwater seepage are unaffected by anthropogenic influences (because human activity on agricultural and urban lands can affect the mobilization of ambient mercury sources). Thus, calculation of the background load for the mercury TMDL includes only the contribution of mercury from open space ambient sources.

Loading of mercury from erosion and transport of natural soils [from all land use types] was estimated in the Source Analysis section to contribute about 54 pounds of mercury per year to receiving waters of the CCW (based on GIS analysis, using long term average annual precipitation and flow data). Estimates of the background load [from open space only] generated separately using the HSPF model are presented below in Table 83. Since about half of the CCW is open space, these two different methods yield comparable estimates of the background load during average/medium annual flow conditions (from text above, 54 * 0.5 = 27 lbs/yr; from the table below, 19.2 lbs/yr). The background loads shown in Table 83 represent about 40-50% of the total mercury loading to Mugu Lagoon, with Calleguas Creek contributing a greater share of the total than Revolon Slough.

Table 83. Background Load of Mercury for Each Flow Category, estimated by HSPF model.

Reach	Annual Flow	Current Loading [1] (Lbs/Yr)	Background Load (Lbs/Year)	Percent of Current Load
Mugu Lagoon (sum of loads from Revolon and Calleguas)	Low	10.5	4.7	45%
	Medium	44.8	19.2	43%
	High	222.9	99.7	45%
Revolon (at PCH)	Low	2.6	1.1	42%
	Medium	13.6	5.5	40%
	High	36.0	10.2	28%
Calleguas (at PCH)	Low	7.9	3.3	46%
	Medium	31.2	13.7	44%
	High	186.9	89.5	48%

1 See Table 82, above.

Waste Load and Load Allocations

The total allowable load for mercury is allocated to agricultural runoff, urban runoff, POTWs, and the background load. Allocations for agricultural and urban runoff are based on proportional contributions estimated by the HSPF model. POTW allocations are based on the design flow and 90th percentile concentration observed in effluent discharge, and apply to all flow conditions. Background load allocations are based on the HSPF estimates presented above.

Table 84 shows current average annual loads for each source in Calleguas Creek and Revolon Slough, according to annual flow category. Final and interim WLAs and LAs for mercury in suspended sediment are presented in Table 85, and the model output for individual years used to determine interim WLAs and LAs is presented in Table 86. Significant reductions in background loading, although likely impracticable, are necessary for achievement of WLAs and LAs. Thus, the percent reduction for mercury loads in the CCW (explained in the Linkage Analysis section) is applied to the background load as well as to agricultural and urban sources.

Table 84. Current Mercury Loads for Sources Discharging to Calleguas Creek and Revolon Slough (Lbs/Yr).

Reach	Source	Annual Flow Condition		
		Low	Medium	High
Calleguas Creek	Agricultural Runoff [2]	2.4	9.4	56.1
	Urban Runoff [2]	2.0	7.8	46.7
	Background (Open Space) [2]	3.3	13.7	89.5
	Hill Canyon WQCP[1]	0.26 - 2.76 lbs/year		
	Camarillo WRP[1]	0.18 - 0.36 lbs/year		
	Simi Valley WWTP[1]	0.37 - 2.16 lbs/year		
Revolon Slough	Agricultural Runoff [2]	0.8	4.1	10.8
	Urban Runoff [2]	0.7	3.4	9.0
	Background (Open Space) [2]	1.1	5.5	10.2
Total Loading to Mugu Lagoon [3]		10.3	43.9	222.3

1 Current loads for the POTWs are based on the design flow and the range of values from the median concentration to the 90th percentile concentration observed in the effluent discharge. Design flows for POTWs in the CCW are as follows: Hill Canyon 10.2 MGD (expanding to 14 MGD by approximately 2018), Camarillo 6.75 MGD, Moorpark 3 MGD, Simi Valley 12.5 MGD (expanding to 17.5 MGD by 2012), Camrosa 1.5 MGD.

2 Loads attributed to sources according to HSPF estimates.

3 Not including POTWs, since a range of loading values are presented above for POTWs; and because POTW loads are negligible under most circumstances.

Table 85. Final and Interim Annual WLAs and LAs for Mercury in Suspended Sediment (Lbs/Yr).

Reach	Source	Final WLAs and LAs, According to Annual Flow Categories			Interim WLAs and LAs, According to Annual Flow Categories		
		Low	Medium	High	Low	Medium	High
Calleguas Creek	Agricultural Runoff [2]	0.5	1.9	11.2	3.9	12.6	77.5
	Urban Runoff [2]	0.4	1.6	9.3	3.3	10.5	64.6
	Background (Open Space) [2]	0.7	2.7	17.9	5.5	17.6	108.4
	Hill Canyon WQCP[1]	0.022 lbs/month (0.26 lbs/year)			0.23 lbs/month (2.76 lbs/year)		
	Camarillo WRP[1]	0.015 lbs/month (0.18 lbs/year)			0.03 lbs/month (0.36 lbs/year)		
	Simi Valley WWTP[1, 3]	0.031 lbs/month (0.37 lbs/year)			0.18 lbs/month (2.16 lbs/year)		
Revolon Slough	Agricultural Runoff [2]	0.2	0.8	2.2	2.0	4.8	12.2
	Urban Runoff [2]	0.1	0.7	1.8	1.7	4.0	10.2
	Background (Open Space) [2]	0.2	1.1	2.0	2.9	6.7	17.1
Total Load Discharged to Mugu [4]		2.1	8.7	44.4	19.3	56.2	290.0

1 Waste load allocations for POTWs are based on the median monthly mercury effluent concentrations multiplied by the design flow, where the total load in water is assumed equal to the suspended sediment load. Interim allocations are based on the design flow and the 90th percentile concentration observed in the effluent discharge and apply to all flow conditions. Design flows for POTWs in the CCW are as follows: Hill Canyon 10.2 MGD (expanding to 14 MGD by approximately 2018), Camarillo 6.75 MGD, Moorpark 3 MGD, Simi Valley 12.5 MGD (expanding to 17.5 MGD by 2012), Camrosa 1.5 MGD.

2 Final allocations for all sources other than POTWs are set 80% reduction from HSPF load estimates. Interim load allocations are set equal to the highest annual load within each flow category, based on HSPF model output for the years 1993-2003.

3 Loads for the Simi Valley WWTP apply only during wet weather months (October-March). If

4 Not including POTWs, since a range of loading values are shown above; and because POTWs loads are negligible under most circumstances.

Table 86. Basis for Interim Limits, Highest Annual Mercury Load for Each Flow Category from HSPF model results.

Year	Crrnt Annl Ld, Susp.Sed. (lbs/yr)				Allwbl Annl Ld, Susp.Sed. (lbs/yr)				Flow
	Mugu	Rev, PCH	Cllg, PCH	Rev + Cllg	MuguSC	Rev	Cllg	Rev+Cllg	(MGY)
2001	2.6	0.5	3.5	3.9	0.5	0.1	0.7	0.8	6639
2003	18.2	3.8	13.1	17.0	3.7	0.8	2.7	3.5	7322
1998	1.7	0.4	3.4	3.8	0.3	0.1	0.7	0.8	9342
1993	6.4	1.9	6.0	7.9	1.3	0.4	1.2	1.6	11119
1999	16.7	6.8	12.7	19.5	3.4	1.4	2.6	4.0	13331
1995	9.7	2.2	8.7	11.0	2.0	0.5	1.8	2.2	13667
2002	56.4	15.9	37.3	53.2	11.6	3.3	7.7	10.9	17535
1996	28.2	9.4	14.4	23.9	5.8	1.9	3.0	4.9	18190
2000	59.3	15.4	42.0	57.4	12.2	3.2	8.6	11.8	24279
1994	123.8	31.2	115.6	146.8	25.4	6.4	23.7	30.1	45874
1997	183.7	40.8	258.2	299.1	37.7	8.4	53.0	61.3	69120

Other NPDES dischargers are not considered significant sources of mercury to the watershed and there is insufficient information to assign loads to these sources. Therefore, concentration-based allocations are assigned. Dischargers are allocated loads based on the CTR water column target for protection of human health from consumption of organisms (only).

Table 87. Total Mercury Waste Load Allocations with CTR as Targets for Other NPDES Dischargers in the CCW.

Reach	Mercury Final Daily WLA 30 day Avg (ug/L)
1	0.051
2	0.051
3	0.051
4	0.051
5	0.051
6	0.051
7	0.051
8	0.051
9	0.051
10	0.051
11	0.051
12	0.051
13	0.051

10.5 Impacts of Loading from Ambient Sources - Mercury

As discussed in the Source Analysis section, ambient sources (primarily natural soil concentrations and atmospheric deposition) represent the major contribution to loading of mercury in the CCW. Source and linkage analyses indicate mercury allocations, and thus targets, may not be attainable without reducing background loads and/or other ambient sources. Special studies included in the implementation plan will determine the potential for standards actions or other regulatory actions such as natural background exclusion or site specific objectives. Specifics relating to background loading of mercury follow:

- The background load associated with open space ambient sources represents about half of the total mercury loading in the CCW;
- Ambient sources are a component of urban and agricultural runoff (although human activity can affect the mobilization of mercury from those sources);
- Necessary reductions in the background load may not be attainable, and limiting ambient source contributions to urban and agricultural discharges may prove challenging and costly;
- An overall reduction in mercury loading of 80% which is predicted necessary for attainment of numeric target conditions cannot be accomplished by reducing anthropogenic sources alone.

Implementation measures put in place for other CCW TMDLs (OCs, Toxicity, and Siltation), in combination with implementation measures for this TMDL, will likely result in some reduction of background mercury loading. As implementation measures are put in place, compliance monitoring, special studies, and adaptive management will determine their overall effectiveness.

11 MARGIN OF SAFETY

A margin of safety for the TMDL is designed to address any uncertainties in the analysis that could result in targets not being achieved in the waterbodies. To identify whether an explicit margin of safety is necessary for each constituent, a summary of the significant uncertainties in the TMDL analysis was developed and compared to the conservative assumptions used to address the uncertainty in the analysis. A summary of the significant uncertainties in the TMDL analysis is included below. In cases where the impact that the assumptions made in the TMDL analysis is known, a discussion of that impact is also included. Then, the implicit margin of safety is discussed.

For both uncertainties and the implicit margin of safety, the first section discusses the uncertainties that are applicable to all of the constituents and then constituent specific uncertainties are discussed.

11.1 Uncertainties in the TMDL Analysis applicable to all Constituents

Flow categories were used to determine loads and there is uncertainty as to whether or not allocations based on those categories will result in achievement of targets in the stream. The assumptions used to develop those categories and allocations from those categories will likely be conservative in some situations and not conservative in other situations.

A model is used to develop the load allocations. A model is not a perfect reflection of environmental conditions and there are uncertainties associated with the quantification of current loads by the model and the determination of whether or not allocations will result in compliance with the targets based on the model results. The model results show that on average the model overpredicts receiving water concentrations and loads for all constituents except nickel. The following table shows a summary of the average difference between the model results and environmental data results. The table summarizes the overall difference and the wet and dry differences.

Table 88. Relative Percent Difference (RPD) between Model Results and Environmental Sampling Data

Constituent	Overall Average RPD	Wet RPD	Dry RPD
Total Copper	32.68	104.14	2.06
Dissolved Copper	31.49	31.88	31.30
Total Nickel	-2.03	61.12	-29.96
Dissolved Nickel	-26.98	-24.56	-28.29
Total Mercury	81.53	105.68	65.28
Total Selenium	24.01	98.60	-10.53

As shown in the table above, wet weather results tend to have a higher difference than dry weather results. In reviewing these results, it should be noted that limited environmental data were available for comparison to model results. Data for high flow conditions are especially limited, which may explain why the model seems to overpredict loading more during high flow conditions. The model predicts conditions during large storm events, but very few actual data representing the largest historical storm events are available for comparison. Thus, model predictions from the largest storm events are necessarily compared to actual data from the largest storm events.

Another uncertainty arises from the fact that HSPF model does not include Mugu Lagoon. A simplified bathtub model was developed for the Lagoon, but there is high uncertainties associated with that model. Finally, tidal influences are not considered in any of the models. Therefore, the loads for the TMDL are calculated based on the sum of the loads into the lagoon, rather than loads in the lagoon itself, to protect the lagoon. This likely results in lower allowable loads than would be required otherwise to protect the lagoon because dilution in the Lagoon is not considered and is therefore a conservative approach to addressing this uncertainty.

Finally, there is uncertainty as to the impacts of the loads on sediment toxicity in Mugu Lagoon.

11.2 Uncertainties in the TMDL Analysis Specific to Copper and Nickel

For copper and nickel, the major uncertainty is associated with the translation between dissolved allowable loads and total allocations. Conservative assumptions were made in the TMDL analysis that resulted in translators that are equivalent to or lower than the translators observed in the environmental data. The following table summarizes the comparison between the chosen translators and the translators calculated from available environmental data.

Table 89. Comparison of TMDL Translators to Environmental Sampling Data Translators

	Constituent	Critical Condition Translator	Maximum Translator From Environmental Data	Minimum Translator from Environmental Data	Median Translator from Environmental Data
Calleguas	Low Flow				
	Copper	0.83	N/A	N/A	N/A
	Nickel	0.8	N/A	N/A	N/A
	Average Flow				
	Copper	0.86	1	0.22	0.86
	Nickel	0.85	1	0.31	0.86
	Elevated Dry Flow				
	Copper	0.63	0.51		
	Nickel	0.7	0.57	0.57	0.57
	Wet Flow				
	Copper	0.08	0.13	0.02	0.03
	Nickel	0.14	0.01	0.22	0.07
Revolon	Low Flow				
	Copper	0.96	0.98	0.3	0.86
	Nickel	0.97	1	0.8	0.93
	Average Flow				
	Copper	0.85	1	0.15	0.58
	Nickel	0.87	N/A	N/A	N/A
	Elevated Dry Flow				
	Copper	0.57	0.5	0.35	0.43
	Nickel	0.63	0.42	0.42	0.42
	Wet Flow				
	Copper	0.2	0.97	0.03	0.12
	Nickel	0.24	1	0.03	0.19

As shown in the table, the chosen translators are greater than or equal to the median environmental data translators for each category. However, in some cases, the chosen translators are lower than the maximum environmental data translator for the category.

For copper and nickel, the uncertainties related to flow characterization and the translator represent the most significant uncertainties because they are used to calculate the allowable loads. Uncertainties related to the source loads impact how the allocations are divided between sources and how much reduction each source is required to implement. However, the sum of all the sources must still meet the allowable load to achieve the targets. Therefore, the uncertainties related to the calculation of the allowable load are more significant than other uncertainties for copper and nickel.

11.3 Uncertainties in the TMDL Analysis Specific to Mercury and Selenium

For both mercury and selenium, data are insufficient to fully assess whether or not the wildlife targets are being achieved. Therefore, there is some uncertainty as to whether or not the allocations will result in compliance with the wildlife targets.

In addition, the allocation process for mercury has a number of assumptions that result in uncertainties as follows:

- Assumption of that a given percent reduction in suspended sediment loads will result in an approximately equal percent reduction in water column and fish tissue mercury concentrations.
- The model is used to estimate current loads from which the percent reductions are taken to determine allowable loads. The model appears to overestimate loading much of the time.

11.4 Selection of Margin of Safety

To address uncertainty, a TMDL includes a margin of safety, which can be explicit, implicit, or both. An implicit and explicit margin of safety is included for the copper and nickel TMDLs and an implicit margin of safety is included for the selenium and mercury TMDL. Implicit MOS factors common to all constituents are summarized below and factors specific to each constituent and the final MOS for each constituent follow.

MOS Issues Common to All Constituents

- The TMDL includes multiple targets for each constituent to ensure protection from impairment for all possible beneficial uses; each target employs conservative assumptions; and the most protective target will ultimately drive compliance.
- A background load is assigned to the TMDL and assumed to remain constant throughout implementation of the TMDL. This results in higher required reductions for the other sources than would be required if lower background loads were assumed or the background loads decreased over time through implementation.
- Calculation of allocations is based on never exceeding numeric target concentrations rather than the once in three year exceedance allowed by the CTR criteria.
- Calculations of current loads and loading capacity for Mugu Lagoon are based on the combined discharges from Calleguas Creek and Revolon Slough, which overpredicts actual concentrations in the lagoon (since dilution provided by tidal flushing are not accounted for);

Copper-Specific MOS Issues

- The model tends to overestimate total loads of copper on average. This results in a higher current total load and the prediction of a higher percent reduction in the total load than would be required on average to achieve the allowable load.
- For copper, the chosen K_D approach is conservative under almost all conditions and is especially conservative during dry weather conditions. Therefore, out of the total amount of copper in the stream, the model predicts more of it is in dissolved form than demonstrated by the data. Therefore, the total allocations calculated using this K_D are smaller than would be anticipated by looking at the environmental data and are consequently conservative (see translator uncertainty discussion above).

Nickel-Specific MOS Issues

- For nickel, the chosen Kp approach is conservative under almost all conditions and is especially conservative during dry weather conditions. Therefore, out of the total amount of nickel in the stream, the model predicts more of it is in dissolved form than demonstrated by the data. Therefore, the total allocations calculated using this K_D are smaller than would be anticipated by looking at the environmental data and are consequently conservative (see translator uncertainty discussion above).

Selenium-Specific MOS Issues

- The model tends to overestimate total loads of selenium on average. This results in a higher current total load and the prediction of a higher percent reduction in the total load than would be required on average to achieve the allowable load.

Mercury-Specific MOS Issues

- Comparison of total mercury concentrations against methylmercury targets for tissue and bird eggs (in development of this TMDL and in general practice) provides an implicit MOS because not all of the mercury contained in fish tissue and bird eggs is actually methylmercury;
- Maximum 30-day average mercury water concentrations (used to develop required percent reductions) were based on the highest concentration out of five sites located in the lowest portion of the watershed (Mugu Lagoon, Revolon at PCH, Calleguas at PCH, Revolon at Wood Rd, and Calleguas at Potrero).

Rationale for 15% Explicit MOS for Copper and Nickel

Although there is a sizeable implicit margin of safety for copper and nickel, as discussed above, two uncertainties were evaluated in more depth and considered to be significant enough to warrant an explicit margin of safety for these constituents.

- The calculation of the allowable load is based on the median flow rate for each flow category.
- The translation between dissolved allowable loads and total allowable loads is calculated using the median translator for each flow category.

To examine these concerns together, the allowable loads calculated using the median flow rate and median translator were compared to the variable allowable load calculated using the model flow rate and model translator and compared to the allowable load generated using the environmental data flow and translator. The comparison showed that for the low flow and average flow category, the chosen approach was fairly conservative, but it was less conservative for the elevated flow category. A 15% margin of safety was determined to be sufficient to address the elevated flow category, but still account for the more conservative nature of the low and average flow category. This assessment was made by looking at the percentage of time that the flows were in the elevated flow category as compared to the other flow categories.

Rationale for Implicit MOS for Selenium and Mercury

The two major uncertainties described above for copper and nickel are not relevant for selenium or mercury. Thus, selenium and mercury share the implicit MOS factors common to all constituents evaluated in this TMDL and are not associated with the most significant uncertainties. Plus, the development of allocations for selenium and mercury incorporates other individual implicit MOS factors.

12 FUTURE GROWTH

Ventura County accounts for slightly more than 2% of the state's residents with a population of 753,197 (US Census Bureau, 2000). GIS analysis of the 2000 census data yields a population estimate of 334,000 for the CCW, which equals about 44% of the county population. According to the Southern California Association of Governments (SCAG), growth in Ventura County averaged about 51% per decade from 1900-2000; with growth exceeding 70% in the 1920s, 1950s, and 1960s (Figure 59).

YEAR	POPLN	INCREASE
1900	14,000	--
1910	18,000	28.6%
1920	29,000	61.1%
1930	55,000	89.7%
1940	70,000	27.3%
1950	115,000	64.3%
1960	199,000	73.0%
1970	376,000	88.9%
1980	529,000	40.7%
1990	669,000	26.5%
2000	753,000	12.6%

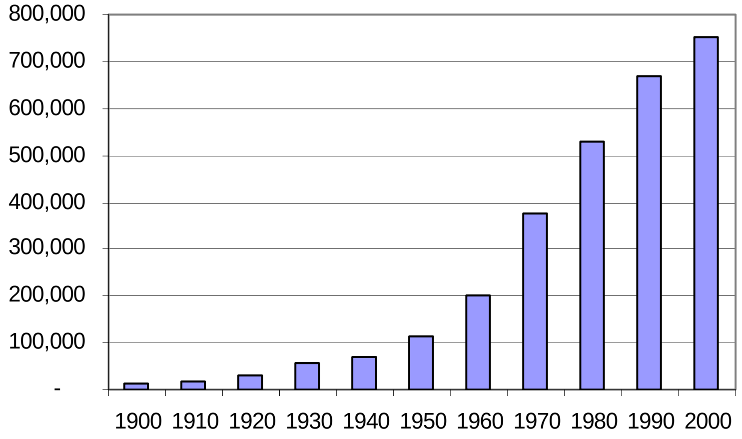


Figure 59. Population growth in Ventura County, 1900-2000 (SCAG, 2004).

Although Moorpark is expected to remain the smallest city based on population, it is also expected to have the highest growth rate from 2000-2020 (Table 90). Both Moorpark and Camarillo are predicted to experience greater than 30% growth in those years. Thousand Oaks is expected to have the lowest growth rate of the CCW cities during that same time period, and is likely to be surpassed by Simi Valley as the most populous city in the watershed by 2020 (SCAG, Minjares, 2004). In general, smaller cities in the watershed are likely to grow faster than larger cities.

Table 90. Growth Projections for CCW Cities and Region, 2000-2020 (SCAG, Minjares, 2004)

City / County / CCW	2000 Popln (July)[1]	2005 Popln (projected)	2010 Popln (projected)	2020 Popln (projected)	% Increase 2000-2010	% Increase 2000-2020
City of Moorpark	31,528	37,611	42,618	43,730	35%	39%
City of Camarillo	57,478	63,179	67,507	76,842	17%	34%
City of Simi Valley	112,190	125,456	131,198	140,902	17%	26%
City of Thousand Oaks	117,418	126,272	129,992	132,925	11%	13%
Ventura County	758,054	821,045	865,149	929,181	14%	23%
CCW[2]	336,121	364,051	383,607	411,999	14%	23%

1 Projected values for June 2000. Actual census values from April 2000 were slightly lower (VC population was 753,197).
2 Values in this row represent a rough estimate, calculated as 44% of the value for Ventura County (based upon the fact that current CCW population is approximately 44% of Ventura County total population).

12.1 Growth Management Efforts

Ventura County has been actively involved in growth management for several decades and continues to implement a range of growth management measures, such as: urban growth boundaries, ballot-initiative approved zoning, and encouragement of higher density and mixed-use development. The Save Open Space and Agricultural Resources initiative (SOAR) that was passed in 1998 is one such growth management policy. Ventura County's SOAR initiative aims to preserve farmland, open-space and rural areas by establishing a City Urban Restriction Boundary beyond which urban development is tightly controlled (Figure 60). County voter approval is required before any land located outside the City Urban Restriction Boundary can be developed for non-agricultural purposes.

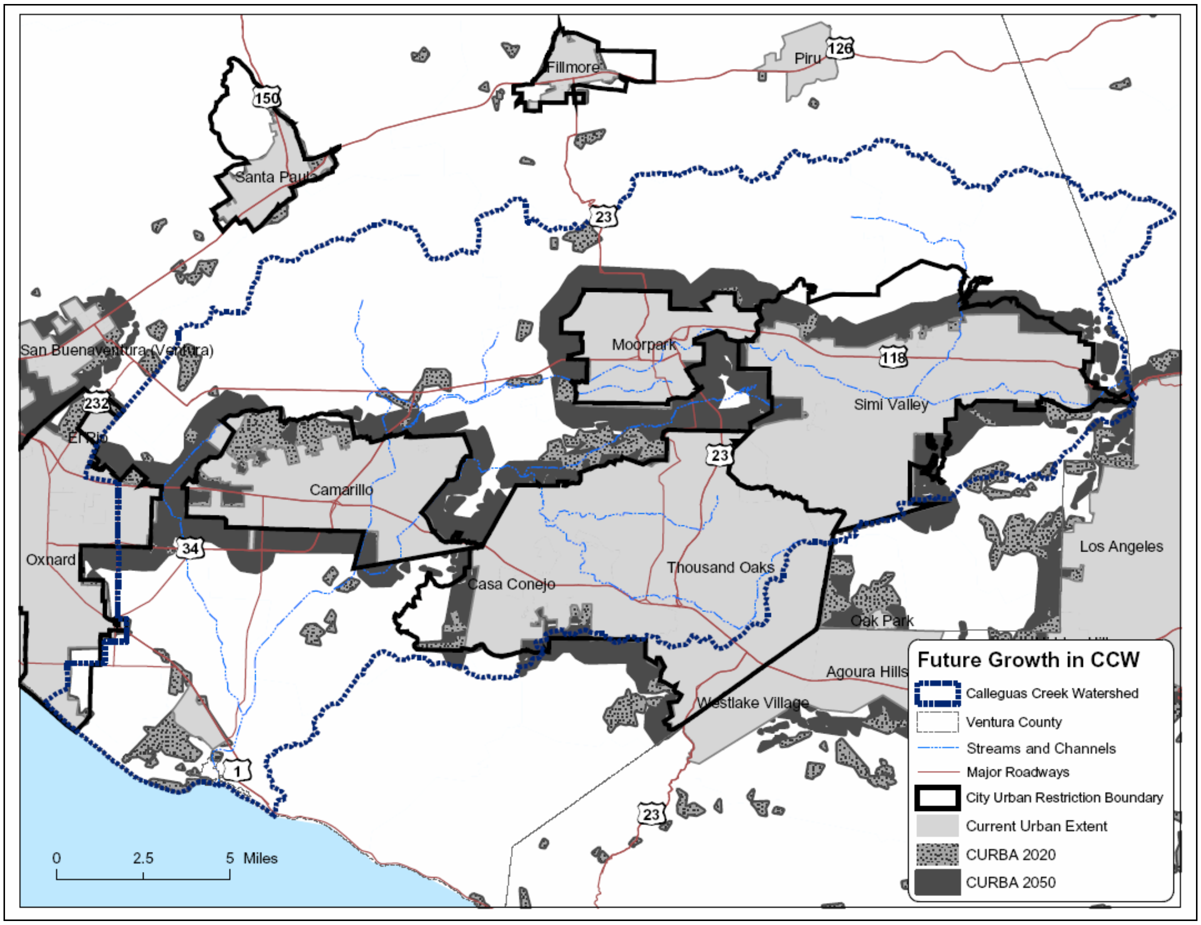


Figure 60. Urban growth in Ventura County (Ventura County CURB, California Urban and Biodiversity Analysis).

The results of California Urban and Biodiversity Analysis (CURBA) for lands within the CCW for the years 2020 and 2050 are also shown in Figure 60 (Landis et al, 1998). CURBA uses an urban growth model to predict future land-use scenarios, and a habitat loss and fragmentation analysis model to estimate the effects of various land use policies upon biodiversity (only results from the urban growth model are considered here). The urban growth model calculates future urbanization probabilities for all undeveloped sites in a given area, according to such factors as: proximity to highways, proximity to city boundaries, site slope, and site development constraints. The CURBA results shown here seem to have been heavily influenced by the “development constraints” variable, as evidenced by the fact that predicted growth is highly correlated with the City Urban Restriction Boundaries established by the SOAR initiative. Since SOAR is due to expire in 2020, it does not provide permanent protection for open space or farmland.

12.2 Effects of Growth on Metals and Selenium Loading

For mercury and nickel, future growth may initially increase loadings as construction activities expose bare soil and increase erosion related discharges to receiving waters. However, once development has been completed, the presence of impermeable land surface and landscaped areas may reduce the amount of natural soils that are eroded and carried to the stream. For copper, future growth could increase loadings from urban areas and POTWs due to increased traffic, architectural copper use and corrosion of copper pipes. Selenium loadings may increase if increased irrigation raises the groundwater table and increases high selenium groundwater seepage to the surface waters. However, if increased growth results in increased water demand and high selenium groundwater is pumped and treated to supply this demand, the selenium loadings could decrease.

To address possible increases in copper loadings due to future growth, the implementation plan includes monitoring that will evaluate trends in copper concentrations and trigger actions if copper concentrations exceed the targets.

13 IMPLEMENTATION PLAN

California Water Code section 13360 precludes the Regional Board from specifying the method of compliance with waste discharge requirements; however California Water Code section 13242 requires that the Basin Plan include an implementation plan to describe the nature of actions to be taken to achieve water quality objectives and a time schedule for action. This section describes the proposed implementation plan to meet numeric targets for copper, nickel, selenium, and mercury in the CCW.

As discussed in the source analysis and allocations section of this TMDL, ambient sources (natural soil concentrations, natural groundwater seepage, and atmospheric deposition) contribute to loading of metals and selenium in the CCW. Consequently, WLAs and LAs may not be attainable without reducing background loads and/or other ambient sources. Additionally, the TMDL is based on the assumption that the copper WER will be adopted prior to or concurrently with the TMDL. Should adoption and approval of the WER not proceed, additional implementation actions could be required. The implementation plan includes discussion of implementation actions to address these conditions. The implementation plan describes the following implementation processes.

For Copper and Nickel:

1. Implement and evaluate effectiveness of agricultural and urban best management practices (BMPs) and source control and/or effluent discharge removal for POTWs.
2. Conduct monitoring to evaluate compliance with targets during implementation and after implementation actions are in place.
3. If compliance with targets is not achieved after all feasible reductions in loadings from controllable sources have been implemented; natural background loadings of pollutants will be addressed through natural source exclusions, site-specific objectives, and/or use attainability analyses.
4. Reevaluate the WLAs and LAs, if necessary..

For Mercury and Selenium:

1. Conduct special studies to develop natural source exclusions for selenium and mercury. The studies could include site-specific objectives and/or use attainability analyses.
2. Implement agricultural and urban BMPs in conjunction with the implementation plans for all TMDLs in the CCW.
3. Evaluate effectiveness of controlling background loads of mercury through erosion control necessary for other CCW TMDLs and flood control. For selenium, identify areas of high groundwater concentrations that are discharging to the stream and prevent discharges to stream or treat discharges where possible.
4. Adjust targets to reflect natural sources exclusion and reevaluate the WLAs and LAs.
5. Conduct monitoring to determine compliance with adjusted targets.

The implementation plan also includes a schedule for conducting the activities listed above, a discussion of monitoring activities, and an economic analysis.

13.1 Waste Load Allocation Implementation - NPDES Permitted Dischargers

This section provides a discussion of the application of the final WLAs for permitted stormwater discharges, POTWs, and other NPDES dischargers and implementation actions that will be undertaken to achieve the allocations. Final WLAs will be included in NPDES permits in accordance with the compliance schedule provided in the Implementation Schedule section (Table 92), subject to the following condition:

> WLAs may be revised prior to the dates they are placed into permits and/or prior to the dates of final WLA achievement. Any revisions to these WLAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Plan Section.

Urban Stormwater Dischargers

A group concentration-based WLA has been developed for all permitted stormwater discharges, including municipal separate storm sewer systems (MS4s), Caltrans, general industrial and construction stormwater permits, and Naval Air Weapons Station Point Mugu. USEPA regulation allows allocations for NPDES-regulated stormwater discharges from multiple point sources to be expressed as a single categorical WLA when the data and information are insufficient to assign each source or outfall individual WLAs (40 CFR 130). The grouped allocation will apply to all NPDES-regulated municipal stormwater discharges in the CCW.

MS4 WLAs will be incorporated into the NPDES permit as receiving water limits measured in-stream at the base of Revolon Slough and Calleguas Creek and in Mugu Lagoon and will be achieved through the implementation of BMPs as outlined in this section. Compliance will be determined through the measurement of in-stream water quality at the base of Revolon Slough and Calleguas Creek and in Mugu Lagoon.

The control of the discharge of metal loads to the stream results from a reduction in the concentration on sediments and in water discharged to the stream and/or a reduction in the volume of sediment and flow that reaches the stream. Therefore, permitted stormwater dischargers can implement BMPs to reduce the concentration or implement BMPs that control sediment and water discharges to the stream. Since it is unlikely that the allocations can be achieved solely through reducing concentrations, BMPs to reduce urban runoff discharge to the stream will likely be necessary.

Activities to control sediment discharges are required by multiple TMDLs that have been adopted in the CCW over the past few years and a bacteria TMDL will be developed in the next few years. The implementation of this TMDL will be coordinated with activities and BMPs that are required under the nutrient, toxicity, organochlorine pesticide, siltation and to be developed bacteria TMDLs. As such, the implementation plan for this TMDL requires a source control study for each of the metals and selenium and the development and implementation of a management plan for permitted stormwater discharges that defines actions that will be taken to achieve the allocations in coordination with implementation actions for other TMDLs. Because loads can be achieved through the reduction of discharge as well as control of sources, the implementation actions for other TMDLs may result in large enough reductions in discharge that additional source control is not necessary. Therefore, overall coordination of implementation actions is important for these TMDLs.

To specifically address metals and selenium, a number of possible actions were identified and their effectiveness assessed. The following are some examples of actions that could be undertaken through the management plan:

- Evaluate existing street sweeping program for possible improvements to reduce discharges of metals and selenium.
- Establish ordinance prohibiting local use of architectural copper (e.g. roofing, gutters, flashing).
- Participate in national activities, such as the Brake Pad Partnership, to help reduce the content of copper in brake pads.
- Evaluate use of copper-containing pesticides in urban areas and implement actions to reduce pesticide use.
- Develop “Clean Business Program” to encourage commercial facilities to reduce sources of metals and selenium.
- Reduce municipal use of mercury-containing products.
- Develop and enforce water conservation ordinances to reduce discharges of water and sediment from urban areas.
- Investigate metals and selenium in groundwater discharges and if feasible develop treatment or alternative disposal for high concentration areas.

The actions listed above may be sufficient to address copper with the WER in place, but might not be sufficient if the WER is not adopted. Additional implementation actions to address mercury and selenium will be limited to reasonable source control activities conducted in conjunction with the implementation requirements for the other TMDLs (including toxicity, OCs, copper and nickel) until the natural sources exclusion special study has been completed. The results of the study may also result in the need to implement additional actions. The following are some examples of additional actions that could be necessary to achieve the allocations.

- Evaluate effectiveness of existing debris basins and detention basins and implement improvements to increase effectiveness.
- Construct BMPs to capture and infiltrate runoff from urban areas.

Ambient sources of selenium, mercury, nickel and copper (such as natural soil concentrations, groundwater seepage, and atmospheric deposition) contribute to the loadings from permitted stormwater dischargers. For selenium, mercury and potentially nickel, these ambient sources likely contribute a large proportion of the loads from these areas. Thus, the special study to evaluate natural background exclusions for these metals and selenium is included in the implementation plan.

In the Calleguas Creek sub-watershed, the POTW implementation plan includes the possibility of the removal of all effluent discharge from the creek system. If this plan is implemented, the POTW loads will be equal to zero and lower than their allocated loads. This could result in additional loading capacity in the stream that could be allocated to urban and/or agricultural sources.

Implementation of WLAs will be conducted over a sufficient period of time to allow for implementation of the BMPs, as well as coordination with special studies and implementation actions resulting from other TMDL Implementation Plans (Nutrient, OCs, Toxicity, Bacteria, Sediment, etc.). As compliance with the copper, nickel, selenium and mercury targets are determined in-stream, there is the potential for compliance with the targets to occur without attainment of WLAs. As such, WLAs may be revised prior to the final WLA achievement dates. Any revisions to these WLAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Plan sections of the Implementation Plan.

POTWs

WLAs established for the three major POTWs in this TMDL will be implemented through NPDES permit limits. The proposed permit limits will be applied as end-of-pipe concentration-based effluent limits for POTWs. Compliance will be determined through monitoring of final effluent discharge as defined in the NPDES permit.

To address salt loadings in the Calleguas Creek watershed, the Hill Canyon and Camarillo WRPs are working towards discontinuing the discharge of effluent to Conejo Creek by implementing reclamation activities and other measures. If this plan is implemented, POTW allocations for the watershed will be achieved by the removal of effluent discharges to the stream. The implementation plan includes sufficient time for this plan to be implemented. However, if this plan is altered, the POTWs will need to meet allocations through other methods, such as source control.

Examples of source control activities that could be implemented include the following:

- Control of copper pipe corrosion through design and maintenance of pipes, education of plumbers, designers, architects and facility managers.
- Implement additional industrial and commercial source control activities for metal finishers and platers, machine shops and metal fabricators, and vehicle repair facilities.
- Develop and implement a mercury control program for dentists.
- Develop and implement a mercury thermometer, thermostat, switches and gauges, and fluorescent lamp collection program in conjunction with the urban stormwater program implementation.
- Investigate use of copper, nickel, and mercury within the POTW and replace the use with alternative products where feasible.

Implementation of source control activities will begin according to the implementation schedule if progress towards the discontinuation of the discharge has not been made. Progress will be defined as completion of planning documents and the start of Phase I activities (see *Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed*. LWA, 2004).

If the copper WER proposed for this TMDL is not adopted and the POTWs do not discontinue discharging to the stream within the allowable time frame, effluent treatment may be required to achieve the allocations.

Other NPDES Dischargers

WLAs established for other NPDES permitted dischargers in this TMDL, including minor non-stormwater permittees (other than Camrosa WRP) and general non-stormwater permittees, will be implemented through NPDES permit limits. The proposed permit limits will be applied as end-of-pipe concentration-based effluent limits, and compliance determined through monitoring of final effluent discharge as defined in the NPDES permit.

Compliance schedules may be established in individual NPDES permits, allowing up to 5 years within a permit cycle to achieve compliance. Compliance schedules may not be established in general NPDES permits. A discharger that can not comply immediately with effluent limitations specified to implement waste load allocations will be required to apply for an individual permit in order to demonstrate the need for a compliance schedule.

If a permittee demonstrates that advanced treatment (necessitating long design and construction timeframes) will be required to meet final waste load allocations, the Regional Board will consider extending the implementation schedule to allow the POTW up to 10 years from the effective date of the TMDL to achieve compliance with the final WLAs.

13.2 Load Allocation Implementation - Agricultural Dischargers

Load allocations for metals and selenium will be implemented through Conditional Waiver of Discharges from Irrigated Lands (Conditional Waiver Program) adopted by the LARWQCB on November 3, 2005. Compliance with LAs will be measured in-stream at the base of Revolon Slough and Calleguas Creek and in Mugu Lagoon and will be achieved through the implementation of BMPs consistent with the Conditional Waiver Program.

For mercury and selenium, implementation actions will be limited to the activities required under the Conditional Waiver and other TMDLs until the natural exclusions study has been completed and additional actions are determined to be required to meet the revised allocations.

The Conditional Waiver Program requires the development of an agricultural water quality management plan (AWQMP) to address pollutants that are exceeding receiving water quality objectives as a result of agricultural discharges. Therefore, implementation of the load allocations will be through the development of an agricultural management plan for metals and selenium. As stated in the Conditional Waiver Program, the AWQMP should include the following elements:

- Source identification
- Implementation of BMPs
- Assessment of BMP effectiveness of BMPs
- Strategies to reduce discharges which are detrimental to water quality
- Monitoring strategies to assess the concentration and load of discharges
- Evaluation of compliance with objectives to determine if additional implementation actions are necessary
- Implementation of additional BMPs if determined to be necessary

Following are some examples of implementation actions that could be considered for inclusion in the AWQMP:

- Implement BMPs to reduce the discharge of copper containing pesticides to the stream.
- Investigate the feasibility of replacing copper containing pesticides with alternative methods, determine whether alternatives methods exist and the potential environmental impact of the alternatives. Additionally, the potential impact of reducing or eliminating copper pesticide use on organic farming and the economic impact on the lemon industry will be considered.

- Identify irrigation water containing high selenium concentrations and investigate the feasibility of providing an alternative water supply.
- Implement BMPs to reduce the discharge of sediment-associated nickel and mercury to the stream.

The BMPs utilized for compliance with the Conditional Waiver and other adopted TMDLs in the CCW are likely to reduce discharges of metals and selenium from agricultural fields. Therefore, the implementation plan for the load allocations will include the coordination of BMPs being implemented under other required programs to ensure discharges of metals and selenium are considered in the implementation. Additionally, agricultural dischargers will participate in educational seminars on the implementation of BMPs as required under the Conditional Waiver Program. After implementation of these actions, compliance with the allocations and TMDL will be evaluated and the allocations reconsidered if necessary based on the special studies and monitoring plan section of the implementation plan.

Studies are currently being conducted to assess the extent of BMP implementation and provide information on the effectiveness of BMPs for agriculture. This information will be integrated into the Agricultural Water Quality Management Plan that will guide the implementation of agricultural BMPs in the CCW. The Association of Water Agencies of Ventura County and the Ventura County Farm Bureau are actively working on outreach to local growers to educate them on the upcoming requirements of TMDLs and the Conditional Waiver Program.

An outstanding concern is the copper objectives and load allocations for Revolon Slough. The high TDS concentrations in the Slough result in the application of the more stringent saltwater CTR criteria to the entire length of the Slough. The saltwater criteria are designed to protect marine species that may or may not be present in the Slough. Additionally, when the site-specific objectives were developed for the watershed, Revolon Slough was not considered because it was not listed for copper. Subsequent monitoring has determined that the saltwater criteria for copper are exceeded in Revolon Slough.

Allocations designated for achievement of saltwater criteria in Revolon Slough, may require reductions in the use of copper-containing pesticides. However, replacing these pesticides may not be practical or feasible. Replacement pesticides may pose similar or greater toxicity risks to aquatic life. Copper alternatives for the major applications are not currently available, and any future availability will be determined by the Department of Pesticide Regulations. Registration of pesticides for new uses is a costly and time-consuming process that may not be practical. Finally, copper is registered for use in organic farming and the loss of copper as an organic alternative could have impacts on the viability of organic farming. To address this concern, the implementation of BMPs for copper will focus on controlling the mobilization and discharge of copper containing pesticides to receiving waters. Since BMPs have the potential to control discharges of other constituents of interest, such as nutrients, organophosphate pesticides and organochlorine pesticides, the implementation of BMPs required by this and other CCW TMDLs will be coordinated to achieve the maximum benefit for all constituents of concern.

A recommendation is included that a copper site-specific objective be developed for Revolon Slough. It is likely that a WER for copper exists in Revolon Slough and the development of an SSO could reduce the implementation actions that need to be taken to achieve the targets.

Ambient sources of selenium, mercury, nickel and copper (such as natural soil concentrations, groundwater seepage, and atmospheric deposition) also contribute to the loadings from permitted agricultural dischargers. For selenium, mercury and potentially nickel, these ambient sources likely contribute a large proportion of the loads from these areas. The implementation plan includes a special study to evaluate natural background exclusions for these metals and selenium. If the copper WER is not adopted and approved, additional implementation actions may be required to meet the allocations. However, additional actions will not be required until the TMDL has been reconsidered to account for the outstanding issues, especially in Revolon Slough.

In the Calleguas Creek sub-watershed, the POTW implementation plan includes the possibility of the removal of all effluent discharge from the creek system. If this plan is implemented, the POTW loads will be equal to zero and lower than their allocated loads. This could result in additional loading capacity in the stream that could be allocated to urban and/or agricultural sources.

Implementation of LAs will be conducted over a sufficient period of time to allow for implementation of the BMPs, as well as coordination with implementation actions resulting from other TMDL Implementation Plans (Nutrient, Historic Pesticides and PCBs, Metals, Bacteria, Sediment, etc.). As compliance with the copper, nickel, selenium and mercury targets are determined in-stream, there is the potential for compliance with the targets without attainment of LAs. As such, LAs may be revised prior to the final LA achievement dates. Any revisions to these LAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Plan sections of the Implementation Plan.

13.3 Special Studies

Several special studies are planned to improve understanding of key aspects related to achievement of WLAs and LAs for the Metals and Selenium TMDL.

Special Study #1 – Evaluation and Initiation of Natural Sources Exclusion

The TMDL has identified ambient sources as the primary cause of selenium and mercury loading in the watershed and as potentially significant sources of copper and nickel. The portion of all ambient sources associated with open space runoff and natural groundwater seepage is accounted for in this TMDL as ‘background load.’ This special study will evaluate whether or not background loads for each constituent qualify for a natural sources exclusion. Additionally, this study will consider whether or not any portion of the ambient source contribution for agricultural or urban runoff loads qualify for natural source exclusions and/or site specific objectives (since natural soil concentrations and atmospheric deposition are ambient sources which contribute to agricultural and urban runoff).

For selenium, available data from all sources except the Simi Valley POTW and groundwater dewatering wells are generally below the CTR criteria levels. Available mercury data from urban areas and POTWs are generally below the CTR criteria, and agricultural discharges above the CTR are likely due to mercury concentrations in natural soils plus atmospheric deposition. The presence of these natural sources makes achievement of selenium and mercury targets during all conditions unlikely. For copper, achievement of the WER based targets or the CTR (if the WER is not approved concurrently with the TMDL) in Revolon Slough may not be possible without reducing background loads.

This special study should follow a ‘reference system/anti-degradation approach’ and/or a ‘natural sources exclusion approach’ for any allocations included in this TMDL which are proven unattainable due to the magnitude of natural sources. The purpose of a ‘reference system/anti-degradation approach’ is to ensure water quality is at least as good as an appropriate reference site and no degradation of existing water quality occurs where existing water quality is better than that of a reference site. The intention of a 'natural sources exclusion approach' is to ensure that all anthropogenic sources of metals and selenium are controlled such that they do not cause exceedances of water quality objectives. These approaches are consistent with state and federal anti-degradation policies (State Board Resolution No. 68-16 and 40 C.F.R. 131.12).

Completion of site-specific objectives and/or a use attainability analysis may need be required to change the water quality objectives for these constituents, through either or both of the two approaches described above. This special study will be used to develop the necessary information to adjust the water quality objectives for selenium and mercury and possibly for copper and nickel if deemed necessary by the Executive Officer of the Regional Board or the stakeholders in the CCW.

Special Study #2 – Identification of Selenium Contaminated Groundwater Sources

The purpose of this special study will be to identify groundwater with high concentrations of selenium that is either being discharged directly to the stream or used as irrigation water. The investigation will focus on areas where the groundwater has a high probability of reaching the stream and identify practical actions to reduce the discharge of the groundwater to the stream. The analysis will include an assessment of the availability of alternative water supplies for irrigation water, the costs of the alternative water supplies and the costs of reducing groundwater discharges.

Special Study #3 – Investigation of Soil Concentrations and Identification of 'Hot Spots'

The purpose of this special study will be to identify terrestrial areas with high concentrations of metals and/or selenium, either due to anthropogenic sources or resulting from high natural concentrations in soils. Use of detailed soil maps for the watershed in combination with field survey and soil sampling may lead to identification of areas important for reducing overall loads to the stream. Identification of any areas with elevated soil concentrations of metals and/or selenium would create an opportunity for efficient and targeted implementation actions, such as remediation or erosion control.

Special Study #4 (Optional) - Determination of Water Effects Ratio for Copper in Revolon Slough

The purpose of this optional special study would be to calculate a WER for copper that is specific to Revolon Slough. As discussed above, a WER was not developed specifically for Revolon Slough because it was not listed for copper. Subsequent monitoring demonstrated that the saltwater copper CTR criterion was exceeded in the Slough. This study would parallel the developed WER for Mugu Lagoon and Calleguas Creek. This is an optional special study to be conducted if desired by the stakeholders.

Special Study #5 (Optional) - Conduct Site-Specific Objectives Studies for Mercury and Selenium

As discussed in earlier sections of this document, ambient sources of mercury and selenium likely preclude achievement of the CTR targets for the watershed. Consequently, Special Study #1 will evaluate whether or not a natural sources exclusion is appropriate for background loads or any portion of the ambient source contributions to non-background loads in the CCW. This special study will develop any site specific objectives (SSOs) deemed necessary in Special Study #1 to support development of a natural sources exclusion. SSOs might prove necessary to account for the background conditions and/or site-specific impacts of mercury and selenium (and possibly for copper and nickel) on wildlife and humans in the watershed.

This is an optional special study to be conducted if desired by the stakeholders or determined necessary for establishing a natural sources exclusion by the Executive Officer.

13.4 Determining Compliance with Targets, Allocations, and the TMDL

The ultimate goals of the TMDL are to protect aquatic and benthic life from toxicity due to metals and selenium, to protect wildlife from impacts due to mercury and selenium, and to protect human health from impacts due to mercury consumption. Consequently, compliance with this TMDL will be determined through water quality, fish tissue, bird egg, and sediment monitoring (with sediment toxicity testing of species sensitive to copper and nickel as explained below) and comparison with the selected numeric targets. If toxicity due to these metals and selenium is consistently not identified, and the allocations and/or targets have not been achieved, the TMDL may be reconsidered to adjust the allocations and targets. Likewise, if wildlife and human health assessments determine that impacts due to mercury and selenium are not occurring, but targets and/or allocations are not met, the TMDL may be reconsidered to adjust the allocations and/or targets.

Secondary targets for copper and nickel sediment concentrations in Mugu Lagoon are presented in this TMDL, as a trigger for initiating sediment toxicity testing for copper and/or nickel. These targets were developed as a compromise between the stakeholders and the Regional Board/EPA and are not intended as a basis for use in other cases. Additionally, exceedance of the sediment targets is not in and of itself evidence of sediment impairment due to copper and/or nickel. The sediment targets will not result in any allocations or implementation actions until sediment toxicity due to copper and/or nickel has been identified in the Lagoon. Sediment toxicity due to copper and/or nickel will need to be identified through spatially and temporally representative sampling. Multiple samples demonstrating toxicity due to copper and/or nickel, in accordance with the monitoring plan, will be required to trigger additional allocations and implementation actions.

13.5 Reconsideration of WLAs and LAs

A number of provisions in this TMDL could provide information that could result in revisions to the TMDL. Additionally, the development of sediment quality criteria and other water quality criteria revisions may require the reevaluation of this TMDL. For these reasons, the Implementation Plan includes this provision for reconsidering the TMDL to consider state and/or EPA developed sediment toxicity and chemistry criteria, revised water quality objectives/criteria, and the results of implementation studies, if appropriate.

13.6 Monitoring Plan

The Calleguas Creek Watershed TMDL Monitoring Plan (CCWTMP) is designed to monitor and evaluate implementation of this TMDL and refine the understanding of current metals and selenium loads. The information presented in this section is intended to be a brief overview of the goals of the CCWTMP. The CCWTMP is intended to parallel monitoring efforts of the CCW Nutrients TMDL, Toxicity TMDL, and Organochlorine Pesticides and PCBs TMDL; as well as the coordinated monitoring program which is currently being developed by CCW stakeholders to minimize duplicative sampling efforts between required monitoring programs in the watershed (e.g., NPDES, Conditional Waiver Program and TMDL monitoring). The goals of the CCWTMP include:

1. To determine compliance with copper, nickel, selenium and mercury numeric targets.
2. To determine compliance with waste load and load allocations for copper, nickel, selenium and mercury at receiving water sites and at POTW discharges.
3. To monitor the effect of implementation actions by urban, POTW, and agricultural dischargers on in-stream water quality.
4. To implement the CCWTMP in a manner consistent with other TMDL implementation plans and regulatory actions within the CCW.

Monitoring conducted through the Conditional Waiver Program may meet part of the needs of the CCWTMP. To the extent monitoring required by the Metals and Selenium TMDL Implementation Plan parallels monitoring required by the Conditional Waiver Program, it shall be coordinated with the Conditional Waiver Program monitoring conducted by individuals and groups subject to the terms and conditions of the waiver.

Compliance Monitoring

Monitoring will begin within one year of the effective date of the CCW Metals and Selenium TMDL. In-stream water column samples will be collected quarterly for analysis of water column toxicity, general water quality constituents (GWQC), and copper, nickel, mercury, selenium and zinc. In-stream water column samples will generally be collected at the base of Revolon Slough and Calleguas Creek and in Mugu Lagoon until numeric targets are consistently met at these points. Any necessary monitoring of flow-based factors (i.e., waste load and load allocations) will utilize the composite samplers and flow gauges located upstream of the tidal prism on Calleguas Creek at CSUCI and Revolon at Wood Road, in order to assure flow measurement are not affected by tidal influences.

Sediment samples will be collected semi-annually in Mugu Lagoon and analyzed for sediment toxicity resulting from copper, mercury, selenium and zinc. At such a time as numeric targets are consistently met at these points, an additional site or sites will be considered for monitoring to ensure numeric targets are met throughout the watershed.

Additional land use monitoring will be conducted concurrently at representative agricultural and urban runoff discharge sites as well as at POTWs in each of the subwatersheds and analyzed for GWQC and copper, nickel, mercury, selenium and zinc. The location of the land use stations will be determined before initiation of the CCWTMP. For metals and selenium, environmentally relevant detection limits will be used (i.e. detection limits lower than applicable target), if available at a commercial laboratory. All efforts will be made to include at least two wet weather-sampling events during the wet season (October through April) during a targeted storm event.

Assessment of compliance will be determined based on appropriate parameters for each constituent and the relevant numeric target(s). Thus, a single grab sample or 24 hour composite sample which exceeds a chronic (4-day average or 30-day average) criteria does not constitute an exceedance.

Table 91. Compliance Sampling Station Locations

Subwatershed	Station Id	Station Location	Sample Media		
			WATER	BIRD	FISH TISSUE[1]
Mugu Lagoon	01_11_Br	11th Street Bridge	Cu, Ni, Hg, Se. Zn	Hg, Se	Hg, Se [2]
Revolon Slough	04_Wood	Revolon Slough East Side Of Wood Road	Cu, Ni, Hg, Se. Zn		Hg, Se
Calleguas	03_Camar	Calleguas Creek At University Drive	Cu, Ni, Hg, Se. Zn		
	03D_CAMR	Camrosa Water Reclamation Plant	Cu, Ni, Hg, Se. Zn		
	9AD_CAMA	Camarillo Water Reclamation Plant	Cu, Ni, Hg, Se. Zn		
Conejo	10d_Hill	Hill Canyon Wastewater Treatment Plant	Cu, Ni, Hg, Se. Zn		

1 Attempts will be made to collect fish tissue samples in the same location as water samples. However, samples may be collected elsewhere if no fish are found at pre-established sample stations.
2 Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.

Reporting and Modification of Calleguas Creek Watershed TMDL Monitoring Program

A monitoring report will be prepared annually within six months after completion of the final event of the sampling year. An adaptive management approach to the CCWTMP will be adopted as it may be necessary to modify aspects of the CCWTMP. Results of sampling carried out through the CCWTMP and other programs within the CCW may be used to modify this plan, as appropriate. These modifications will be summarized in the annual report. Possible modifications could include, but are not limited to the, following:

- The inclusion of additional land use stations to accurately characterize loadings;
- The removal of land use stations if it is determined they are duplicative (*i.e.,* a land use site in one subwatershed accurately characterize the land use in other subwatersheds);
- The inclusion of additional in-stream sampling stations;
- The elimination of analysis for constituents no longer identified in land use and/or in-stream samples.

If a coordinated and comprehensive monitoring plan is developed and meets the goals of this monitoring plan that plan should be considered as a replacement for the CCWTMP.

13.7 Implementation Schedule

Interim allocations presented in TMDL & Allocations section and the implementation schedule will provide sufficient time to:

- Allow for the implementation of the Conditional Waiver Program by agricultural dischargers throughout the CCW;
- Allow for development of an Urban Water Quality Management Plan for metals and selenium;
- Determine the most appropriate BMPs, implement appropriate BMPs and monitor to evaluate effect on in-stream water quality;
- Evaluate and implement the removal of Hill Canyon, Camrosa and Camarillo Sanitary District effluent discharge;

- Conduct special studies to evaluate a natural sources exclusion;
- Allow for coordination of special studies and implementation actions resulting from other TMDL Implementation Plans;
- Allow for the completion of monitoring to verify the appropriateness of allocations; and,
- Implement adaptive management strategies to employ additional BMPs or revise existing BMPs to meet allocations, if necessary.

The implementation schedule is designed to parallel, where appropriate, the Nutrient TMDL, Toxicity, Siltation and Organochlorine Pesticides and PCBs TMDL Implementation Plans. Additional TMDL Implementation Plans may be developed before 2012, for Bacteria. The implementation schedule for this TMDL may be revised, if appropriate, when the Bacteria TMDL is completed.

Table 92 presents the overall implementation schedule for the Calleguas Creek Watershed Metals and Selenium TMDL. A concerted effort was made to incorporate ongoing efforts in the CCW with the overall implementation schedule. For instance, two studies assessing agricultural BMPs in Ventura County were initiated in the fall of 2003 and are expected to be completed in 2006. Additionally, the Organochlorine Pesticides and PCBs TMDL includes special studies that are relevant to the metals and selenium TMDL. These studies have been included in the implementation schedule because information from them will be used to inform decisions related to this TMDL. However, the inclusion of these studies is not intended to result in any additional study requirements to meet the requirements of this TMDL. Table 92 provides sufficient time to allow implementation measures to be put into place. In addition, time is allotted for the completion of special studies and the reevaluation of the TMDL, if necessary.

Table 92. Overall Implementation Schedule for Calleguas Creek Watershed Metals and Selenium TMDL

Item	Implementation Action [1]	Responsible Party[4]	Tentative Date
1	Effective date of interim Metals and Selenium TMDL waste load allocations (WLAs). [2]	POTWs, Permitted Stormwater Dischargers (PSD)	Effective date [2]
2	Effective date of interim Metals and Selenium TMDL load allocations (LAs). [2]	Agricultural Dischargers	Effective date [2]
3a	Submit Calleguas Creek Water Metals and Selenium Monitoring Program	POTWs, PSD, Agricultural Dischargers	Within 6 months of effective date
3b	Implement Calleguas Creek Watershed Metals & Selenium Monitoring Program.	POTWs, PSD, Agricultural Dischargers	Within 6 months of Executive Officer approval of monitoring program
4a	Conduct a source control study and develop and submit a Urban Water Quality Management Program for copper, nickel, mercury and selenium. The plan shall contain proposed mechanisms for demonstrating progress toward meeting load reductions and/or attaining TMDL targets.	MS4s	Within 2 years of effective date.
4b	Conduct a source control study and develop and submit a Urban Water Quality Management Program for copper, nickel, mercury and selenium. The plan shall contain proposed mechanisms for demonstrating progress toward meeting load reductions and/or attaining TMDL targets.	Caltrans	Within 2 years of effective date.
4c	Conduct a source control study and develop and submit a Urban Water Quality Management Program for copper, nickel, mercury and selenium. The plan shall contain proposed mechanisms for demonstrating progress toward meeting load reductions and/or attaining TMDL targets.	NAWS Point Mugu (US Navy)	Within 2 years of effective date.
5	Implement Urban Water Quality Management Program	Permitted Stormwater Dischargers	Within 1 year of approval of UWQMP by Executive Officer
6	Develop and submit an Agricultural Water Quality Management Program as described in the Conditional Waiver Program	Agricultural Dischargers	Within 2 years of effective date.
7	Implement Agricultural Water Quality Management Program	Agricultural Dischargers	Within 1 year of approval of AWQMP by Executive Officer
8	Seek delisting of zinc from the 303(d) list for Reach 1, Mugu Lagoon (available data suggest zinc is not causing impairment in the CCW, as explained in the Current Conditions section).	Interested Parties	During comment period for next 303(d) Listing cycle
9	Submit progress report on plan to remove effluent discharges from the Conejo and Calleguas reaches of the watershed	POTWs	Within 3 years of effective date
10	If progress report identifies that effluent discharge removal is not progressing, develop and implement source control activities for copper, nickel, mercury and selenium.	POTWs	Within 4 years of effective date
11	Re-evaluation of POTW Interim waste load allocations for copper, nickel, and mercury.	POTWs	Within 5 years of effective date of the amendment.
12a	Evaluate the results of the OCs TMDL, Special Study - “Calculation of sediment transport rates in the CCW” for applicability to the metals TMDL	Agricultural Dischargers, PSD	Within 6 months of completion of the study
12b	Include monitoring for Hg, Cu, Ni, and Se in the OCs TMDL Special Study - “Monitoring of sediment by source & land use type “	Agricultural Dischargers, PSD	Within 2 years of effective date
12c	Expand scope of the OCs TMDL, Special Study - “Examination of food webs and bioaccumulation in the CCW” to ensure protection of wildlife to include mercury.	Interested Parties	if necessary, prior to end of the implementation period
12d	Evaluate the results of the OCs TMDL, Special Study – “Effects of BMPs on Sediment and Siltation” to determine the importance of this issue relative to metals and selenium	Agricultural Dischargers, PSD	Within 6 months of completion of the study

13	Special Study #1 – Identification of Natural Sources Exclusion	Agricultural Dischargers, PSD	Within 4 years of effective date
14	Special Study #2 – Identification of Selenium Contaminated Groundwater Sources	POTWs, PSD, and Agricultural Dischargers	Within 2 years of effective date
15	Special Study #3 – Investigation of Metals 'Hot Spots' and Natural Soils	PSD and Agricultural Dischargers	Within 3 years of effective date
16	Special Study #4 (Optional) - Determination of WER and Associated SSO for Copper in Revolon Slough	PSD and Agricultural Dischargers	if necessary, prior to end of the implementation period
17	Special Study #5 (Optional) - Determination of Site-Specific Objective for Selenium	PSD and Agricultural Dischargers	if necessary, prior to end of the implementation period
18	Evaluate effectiveness of BMPs implemented under the AWQMP and UWQMP in controlling metals and selenium discharges	PSD and Agricultural Dischargers	6 years from effective date
19	Evaluate the results of implementation actions 12 and 13 and implement actions identified by the studies.	POTWs, PSD, and Agricultural Dischargers	Within 5 years of effective date
20	If needed, implement additional BMPs or revise existing BMPs to address any issues not covered by implementation efforts of related CCW TMDLs (Nutrients, Toxicity, OC Pesticides) and the Conditional Waiver Program	Agricultural Dischargers	7 years from effective date
21	Based on the results of items 1-20, Regional Board will consider reevaluation of the TMDLs and WLAs and LAs if necessary.	Regional Board	2 yrs from submittal of information necessary for reevaluation
22	Re-evaluation of Agricultural and Urban load and waste load allocations for copper, nickel, selenium and mercury based on the evaluation of BMP effectiveness and technical and economic feasibility. Develop milestones for reduction percentages.	Agricultural and Urban Dischargers	5, 10 and 15 years after effective date of the amendment.
23	Stakeholders and Regional Board staff will provide information items to the Regional Board, including: progress toward meeting TMDL load reductions, water quality data, and a summary of implementation activities completed to date	Regional Board	2 yrs from effective date, and every 2 years following
24	Achievement of Final WLAs and LAs for copper and nickel	Agricultural Dischargers, PSD	Within 15 years of effective date[3]
25	Achievement of Final WLAs and LAs for mercury and selenium	Agricultural Dischargers, PSD	Within 15 years of effective date[3]
26	Achievement of Final WLAs for copper, nickel, selenium and mercury	POTWs and Other NPDES Permittees	Within 10 years of effective date[3]

1 The Regional Board regulatory programs addressing all discharges in effect at the time this implementation task is due may contain requirements substantially similar to the requirements of these implementation tasks. If such requirements are in place in another regulatory program including other TMDLs, the Executive Officer may revise or eliminate this implementation task to coordinate this TMDL implementation plan with other regulatory programs.

2 Interim WLAs and Interim LAs become effective when the TMDL becomes effective. NPDES permits for POTWs will contain effluent limits based on the WLAs. NPDES permits for stormwater will contain in-stream limits based on the WLAs. LAs will be implemented using applicable regulatory mechanisms.

3 Date of achievement of WLAs and LAs based on the estimated timeframe for educational programs, special studies, implementation of appropriate BMPs and associated monitoring. The conditional ag waiver program will set timeframes for the BMP management plans.

4 Permitted stormwater dischargers include MS4s, Caltrans, the Naval Air Weapons Station at Point Mugu, and general industrial and construction permittees.

13.8 Adaptive Management

Implementation of the CCW Metals and Selenium TMDL will operate within an adaptive management framework where compliance monitoring, special studies, and stakeholder interaction guide the process as it develops through time. Compliance monitoring will generate information critical for measuring progress toward achievement of WLAs and LAs, and may suggest the need for revision of those allocations in some instances. Additionally, data from ongoing monitoring could reveal necessary adjustments to the implementation timeline and may serve to initiate reevaluation when appropriate. Special studies will increase understanding of specific conditions/processes in the watershed, allowing for more accurate prediction of results expected from various implementation efforts. Thus, adaptive management allows this TMDL to become an ongoing and dynamic process, rather than a static document.

Leadership of the adaptive management program will involve individuals from a range of groups. The LARWQCB will oversee compliance monitoring and any potential need for reevaluation of this TMDL. Various members or stakeholder groups may contribute time and expertise to special studies. The VCWPD has significant resources and personnel dedicated to improving the understanding of sediment transport in watersheds of the region, including the CCW. United Water is involved in a program to monitor effects upon water quality from various agricultural land uses, which will likely generate information beneficial for the efficacy of the Implementation Plan. Many stakeholders have been working together since 1996 toward the development of a Watershed Management Plan for Calleguas Creek. The purpose of the Watershed Management Plan is to develop a strategy to address a variety of needs in the watershed: flood control, erosion and sedimentation, water quality, water resources, and habitat. When developed, this plan will identify mechanisms for addressing the water quality issues within the watershed, including 303(d)-listed pollutants. As such, the plan will serve as the ultimate implementation plan for all of the TMDLs within the watershed.

13.9 Economic Analysis of Implementation

Water Code Section 13000 requires the State and Regional Boards to regulate so as to achieve the highest water quality that is reasonable, based on consideration of economics and other public interest factors. Water Code Section 13141 requires that prior to the implementation of any agricultural water quality control program; an estimate of the total cost of the program and identification of potential sources of financing shall be included in any applicable regional water quality control plan. An analysis of the impacts of implementing these TMDLs with respect to costs, benefits, and other public interests factors is presented below.

As discussed in the implementation plan, a number of different activities could be undertaken to achieve the TMDL allocations. Additionally, approval of a Copper WER would reduce the required reductions and the economic impact of the TMDL. To develop an economic analysis for this TMDL, cost and effectiveness information was gathered for the identified potential implementation actions. Using the cost and effectiveness information, the responsible parties can identify the most cost effective method of complying with the TMDL.

To estimate the effectiveness of BMPs in achieving the required reductions in loading corresponding to the allocations, an estimate of the required reductions in pounds per year were needed. For each constituent, there are a number of different flow categories and the possibility of allocations with and without a WER and/or SSO. To estimate the annual number of pounds to be reduced for copper, nickel and selenium, modeled flow results were used to estimate the percentage of the time that flows would fall into each of the dry weather flow categories . The annual reduction requirement is a weighted sum of the required reductions from each flow category based on the percentage of the time flows are expected to be in each category. Wet weather reductions are not required for nickel and selenium so the estimated pound per year reduction are reflective of the amount that needs to be reduced. For copper, additional reductions above the estimated pound per year reduction may be required to address wet weather. For mercury, the pound per year reduction for the highest flow category was used and represents the highest number of pounds per year that would need to be reduced.

Table 93 summarizes estimated cost and effectiveness information for the implementation actions discussed in the implementation plan. Table 94 summarizes the assumptions and references used for developing the cost and effectiveness estimates. For cost and effectiveness calculations, low and high estimates were developed based on the assumptions presented in Table 94. Annual costs were calculated by amortizing the capital costs over 20 years at an interest rate of 4% and adding estimated operations and maintenance costs. The cost information reflects the costs associated with implementing these actions in the absence of any other required programs. In reality, implementation of the actions will be coordinated with activities required under the Nutrient, Toxicity, and OC Pesticide TMDLs for the CCW and the Conditional Waiver. It is possible that the costs presented below are representative of the entire cost of implementing all of the TMDLs and the Conditional Waiver (except for monitoring and special studies). However, it might also be possible that the BMPs will need to be implemented in different areas depending on the sources of the pollutant and different BMPs will be required to address different pollutants. Therefore, the costs are presented here as separate costs for this TMDL, but these costs will likely overlap costs required by other regulatory programs.

Table 93. Estimated Cost and Effectiveness Information for Metals and Selenium Implementation Actions

Source	Possible Implementation Action	Estimated High Reduction (lbs/yr)				Estimated High Annual Cost	Estimated Low Reduction (lbs/yr)				Estimated Low Annual Cost
		Cu	Ni	Se	Hg		Cu	Ni	Se	Hg	
POTWs	Elimination of Discharge	613	373	-	0.44	$980,000					
	Total Possible Reductions and associated costs	613	373	-	0.44	$980,000					
	Total Reductions required to meet CTR allocations	*561*	*145*	-	*0.088*						
	Total Reductions required to meet WER and SSO allocations	*0*	*140*	-							
Urban	Develop Urban Water Quality Management Plan[1]	-	-	-	-	$500,000	-	-	-	-	$200,000
	Improve street sweeping program	47	6	-	-	$460,000	9	1	-	-	$0
	Establish ordinance prohibiting use of architectural copper	32	-	-	-	$400,000	12	-	-	-	$400,000
	Reduce content of copper in brake pads through participation in national activities[2]	47	-	-	-	$10,000	0	-	-	-	$10,000
	Implement outreach program to reduce copper pesticide use and collect mercury containing consumer products (municipal included)	5	-	-	8	$50,000	2	-	-	0.05	$50,000
	Implement program to reduce discharges of metals and selenium from commercial facilities	15	14	0.3	1.4	$200,000	3	3	0.1	0.3	$200,000
	Develop and enforce water conservation ordinances	21	12	0.66	1.8	$400,000	4	2	0.13	0.4	$400,000
	Construct BMPS to capture and infiltrate runoff	111	63	1.3	11.3	$36,000,000	32	18		7.5	$210,000
	Total Possible Reductions and associated costs	277	94	2	22	$38,020,000	62	24	0.2	8	$1,470,000
	Total Reductions required to meet CTR allocations	*186*	*51*	*6*	*37*		*186*	*51*	*6*	*37*	
	Total Reductions required to meet WER and SSO allocations	*71*	*35*				*71*	*35*			
Agriculture[3]	Develop Agricultural Water Quality Management Plan[1]					$700,000					
	Cover crops	149	223	5	21	$1,700,000	30	45	1	4	$290,000
	Mulch	149	223	5	21	$500,000	30	45	1	4	$41,000
	Irrigation controls	179	268	10	-	$1,000,000	20	30	1	-	$200,000
	Pesticide application management	149	-	-	-	$0	20	-	-	-	$0
	Drainage basins	278	292	-	26	$4,000,000	16	28	-	2	$400,000
	Filter strip	278	417	-	39	$2,000,000	20	30	-	10	$350,000
	Total Possible Reductions and associated costs	903	1007	20	68	$9,200,000	135	177	3	20	$1,281,000
	Total Reductions required to meet CTR allocations	*351*	*242*	*18*	*45*		*351*	*242*	*18*	*45*	
	Total Reductions required to meet WER and SSO allocations	*174*	*185*				*174*	*185*			

1. Development of management plans will be one time costs, not annual costs.
2. Implementation of load reductions from this strategy will be long term and assume the Brake Pad Partnership can achieve significant reductions in the copper content of brake pads. The actual reduction in copper content in brake pads is not within the control of any of the stakeholders in the watershed and may not be achievable.
3. Costs for agricultural BMPs do not include the costs of taking agricultural land out of production to install any of the structural BMPs.

The removal of POTW discharges from the stream is proceeding to comply with salts objectives in the CCW. For POTWs, removal of effluent discharges is considered the primary implementation action and the costs for the entire project are contained in the table. Therefore, POTWs are expected to meet allocations for all constituents at an annual cost of approximately $980,000. This annual cost also likely covers implementation costs for Hill Canyon WWTP and Camarillo WRP for the toxicity and OC Pesticide TMDLs. The total load removed from the stream by the two POTWs is greater than the required reduction from POTWs included in the TMDL. The reductions from this source may be sufficient to result in compliance with dry weather targets for copper and nickel and reduce the need for dry weather reductions of copper and nickel loads from urban and agricultural sources in the Conejo and Calleguas subwatersheds.

The estimated effectiveness of the implementation actions shown in Table 93 show that urban and agricultural allocations for copper and nickel could be achieved through a combination of non-structural and structural controls. The minimum costs associated with compliance would be approximately $1.5 million per year for urban dischargers and $1.2 million per year for agricultural dischargers. For mercury and selenium, the estimated effectiveness of the implementation actions shown in Table 93, combined with information in the source and linkage analysis section, indicate mercury and selenium allocations may not be attained with currently available BMPs and/or without reduction of background loads and/or other ambient sources. The high cost estimates presented in Table 93 result from attempting to treat all discharges from up to a 0.75 inch storm from urban and agricultural areas. The cost differences between urban and agricultural areas result from the costs for retrofitting urban areas as compared to installations in agricultural areas. However, the agricultural costs do not include the costs of taking agricultural land out of production which could raise the costs significantly. Special studies included in the implementation plan will determine the potential for standards actions or other regulatory actions such as natural background exclusion or site specific objectives to address this issue.

Implementation of the agricultural load allocations will primarily be achieved through the requirements of the Conditional Waiver Program and prior TMDLs. Several BMPs are being evaluated for cost and effectiveness through a PRISM grant in Ventura County. The BMPs listed in the table above are those BMPs being evaluated through the study that are likely to be implemented to meet the Conditional Waiver Program requirements. Additional costs that are specific to this TMDL include the possible costs of registering replacement pesticides for copper and the costs of alternative water supplies to replace high selenium irrigation water. The costs associated with these activities will be evaluated prior to the implementation of those activities as part of the assessment of the practicality of conducting these activities.

Table 94. Assumptions used to Develop Cost and Effectiveness Information

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
POTWs	Elimination of Discharge	Reductions based on the average annual loading from the POTWs generated by the model.		Costs include the entire lower watershed implementation program	Calleguas Creek Watershed IRWMP Prop 50 Grant Application
Urban	Develop Urban Water Quality Management Plan	No reductions from plan development			
Urban	Improve street sweeping program	For copper, low and high estimates based on removal of 0.005 - 0.026 lbs Cu/mile Assumes 13 times per year sweeping of all streets. For nickel, used min and max of SCVURPPP results for nickel street sweeping study. Assumes 15% of material removed would reach creek.	Santa Clara Valley Urban Runoff Pollution Prevention Program. Summary of Copermittee Street Sweeping Activities for FY2004-2005.	Assume purchase of one additional street sweeper for each Thousand Oaks, Camarillo and two sweepers for Caltrans at $200,000 each (4% over 10 years). Include annual cost of driver for 4 sweepers ($400,000). Does not include traffic control costs.	

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
Urban	Establish ordinance prohibiting use of architectural copper	Reduction is proportional to surface area of copper features: roofs = 1 g/m^2 material/year; gutters = 2 g/m^2 material/year; composite roof with copper biocide = 0.17 g/m^2 material/year. Assumes 20% of copper reaches creeks.	TDC Environmental. 2004. Copper Sources in Urban Runoff and Shoreline Activities. Prepared for the Clean Estuary Partnership.	Assume ordinance costs would be similar to water conservation ordinance costs of $200,000 per year for each Camarillo and Thousand Oaks.	Comments from Anita Kuhlman, City of Camarillo on cost of Camarillo's water conservation program.
Urban	Participate in national activities to reduce content of copper in brake pads	Copper release from brake pads = #-vehicles * %wear * Cu/vehicle. Estimates show 60% wear at time of replacement and an average of 0.139 lbs/vehicle. Estimate (based on San Francisco study) that 11.5% of the total population has a car less than 3 years old (29,094 vehicles). LOW = low end of estimated transport of deposited debris to waterways (15%) and reduction of 10% in copper brake pad content, HIGH = high end of estimated transport to waterways (24%) and reduction of 25% in copper brake pad content.	TDC Environmental. 2004. Copper Sources in Urban Runoff and Shoreline Activities. Prepared for the Clean Estuary Partnership.	Costs for travel and participation in two meetings per year.	

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
Urban	Implement outreach program to reduce copper pesticide use and collect mercury containing consumer products (municipal included)	Assumes copper pesticides and algaecides are 5% of Residential load to creek. Mercury reductions based on assumption that the discharge of mercury from thermometers is 2.3 ug/household/day and from other mercury-containing products is . This assumes 52% of houses have a mercury thermometer. Assumes 10% of mercury reaches creek from these sources. LOW Assume 1/10 the households would dispose of thermostats, switches, fluor. lamps per year. Assume voluntary turn in program effectiveness. HIGH: Assume 1/2 of the households would dispose of thermostats, switches, fluor. lamps per year. Assume stores recommend product replacement for effectiveness.	TDC Environmental. 2004. Copper Sources in Urban Runoff and Shoreline Activities. Prepared for the Clean Estuary Partnership.	Assumes outreach program would be integrated with outreach program for toxicity and OC pesticides TMDL. Costs for that program were estimated at $150,000 per year.	OC Pesticide and Toxicity TMDL
Urban	Implement program to reduce discharges of metals and selenium from commercial facilities	Used model output to determine amount of loading from commercial and industrial facilities. HIGH- 50% reduction in loads based on enforced, regulatory program and LOW-10% reduction in loads based on outreach and incentive programs, such as Clean Business programs.		Assumes that one additional staff person in each Camarillo and Thousand Oaks would be hired to handle the program at a cost of $100,000 per year for each city.	
Urban	Reduce discharge of sediment and water from redevelopment	No reductions assumed, but assumes that there will be no net increase in loads as a result of new development.		Additional costs are not included because this program assumes that the existing new development program will cover reductions from this source.	

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
Urban	Develop and enforce water conservation ordinances	LOW-Assumes a 2% reduction in loads and HIGH-Assumes a 10% reduction in loads from urban areas based on goals set by Camrosa Water District for water conservation through the salts plan.	Calleguas Creek Watershed IRWMP Prop 50 Grant Application	Assume Camarillo expands program to cover entire city and Thousand Oaks institutes program for entire city. Camarillo current program is $140,000 per year. Assume an additional $60,000 per year to cover entire city and increase enforcement and the same total amount for Thousand Oaks program.	Comments from Anita Kuhlman, City of Camarillo on cost of Camarillo's water conservation program.
Urban	Construct BMPS to capture and infiltrate runoff	Estimated removal effectiveness based on Caltrans BMP studies. LOW-Assumes a 30% removal and treatment of 50% of dry weather runoff. HIGH-Assumes a 70% removal and treatment of 75% of dry weather runoff.	BMP Retrofit Pilot Program (Caltrans, 2004)	Costs assumed retrofit installations of BMPs to capture between 20% and 40% of dry weather runoff and up to a 0.75 inch design storm. Low costs assume the cheapest BMPs that would potentially accomplish this and high costs assume more expensive BMPs. Cost information from Caltrans BMP study and were not adjusted based on relative land costs in Ventura County. Calculations based on 4% over 10 years for all BMPs.	BMP Retrofit Pilot Program (Caltrans, 2004)
Ag	Develop Agricultural Water Quality Management Plan			Assumes plan would be integrated with requirements under the Conditional Waiver, OC Pesticides and Toxicity TMDLs, and Nutrient TMDL. Costs are same as presented in Toxicity and OC Pesticide TMDL	OC Pesticide and Toxicity TMDL

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
Ag	Cover crops	Assumes effective at reducing 75% of dry weather discharges based on information from EPA on effectiveness. LOW-Assumes implementation on 10% of acreage. HIGH-Assumes implementation on 50% of acreage.	EPA Management Measures for Agricultural Sources http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html	Costs based on NRCS cost information updated from 1995 to 2000. Costs from report are assumed to be annual costs for cover crops. High costs assume 50% of acreage in Revolon and Conejo/Calleguas use cover crops and low costs assume 10%.	NRCS, 1995
Ag	Mulch	Assumes effective at reducing 75% of dry weather discharges based on information from EPA on effectiveness. LOW-Assumes implementation on 10% of acreage. HIGH-Assumes implementation on 50% of acreage.	EPA Management Measures for Agricultural Sources http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html	Costs based on NRCS cost information updated from 1995 to 2000. Costs from report are assumed to be annual costs for mulching. High costs assume 50% of acreage in Revolon and Conejo/Calleguas use mulch and low costs assume 10%.	NRCS, 1995
Ag	Irrigation controls	Assumes effective at reducing dry weather discharges based on information from EPA on effectiveness. LOW-Assumes implementation on 10% of acreage and 5% effectiveness. HIGH-Assumes implementation on 50% of acreage and 90% effectiveness.	EPA Management Measures for Agricultural Sources http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html	Costs based on NRCS cost information updated from 1995 to 2000. Costs presented are for irrigation management from report and do not assume installation of any additional equipment or irrigation systems. Costs assume 50% of acreage in Revolon and Conejo/Calleguas implement controls.	NRCS, 1995
Ag	Pesticide application management	Assumes that 50% of dry weather copper load from agriculture is due to pesticides. LOW-Assumes a 10% reduction in those loads. HIGH-Assumes a 75% reduction in those loads.		No additional costs are included for pesticide management. It is assumed that pesticide application management will involve improvements in applications and will potentially reduce costs.	

Source	Possible Implementation Action	Assumptions used to calculate Estimated Reductions	Effectiveness Calculation References	Assumptions Used to Calculate Estimated Costs	Cost Calculation References
Ag	Drainage basins	Assumes effective at reducing dry weather discharges based on information from EPA on effectiveness. LOW-Assumes implementation on 10% of acreage and 40% effectiveness. HIGH-Assumes implementation to treat all acreage directly discharging to stream and 70% effectiveness.	EPA Management Measures for Agricultural Sources http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html, BMP Retrofit Study (Caltrans, 2004)	Low costs assume 20 drainage basins collecting runoff from 20 acres each targeted in high concentration areas. High costs based on treating entire agricultural drainage area in Revolon and Calleguas/Conejo subwatersheds to attempt to address mercury loads. Costs based on NRCS cost information updated from 1995 to 2000. Cost assumes 4% over 20 years for basin and maintenance costs estimated from Caltrans BMP study.	BMP Retrofit Pilot Program (Caltrans, 2004)
Ag	Filter strip	Assumes effective at reducing dry weather discharges based on information from EPA on effectiveness. LOW-Assumes implementation on 10% of acreage and 50% effectiveness. HIGH-Assumes implementation to treat all acreage directly discharging to stream and 70% effectiveness.	EPA Management Measures for Agricultural Sources http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html, BMP Retrofit Study (Caltrans, 2004)	Costs based on NRCS cost information updated from 1995 to 2000. Cost assumes 4% over 20 years for capital costs and maintenance costs estimated from Caltrans BMP study. Assumes that creekside acreage in Revolon and Conejo/Calleguas flows through a filter strip or buffer zone of between 10-20 feet in width. Low costs and high costs are based on the range of costs presented in USDA, 1995 and assumption of 50% of creekside acreage is treated for low costs and 100% of creekside acreage is treated for high costs. Costs of taking the agricultural land out of production are not included in the estimates.	NRCS, 1995

The analysis shown above demonstrates that source control activities may be able to achieve the required reductions for copper during dry weather. Structural BMPs will likely be required to meet achieve the wet weather copper allocations and dry weather nickel allocations. The effectiveness information suggests that selenium and mercury allocations will likely not be met with available BMPs, even with complete capture and treatment of urban and agricultural runoff from storms up to 0.75 inches.

The implementation actions discussed in Table 93 could have environmental impacts that affect the ability to implement the actions. The potential impacts include traffic during structural BMP construction, diversions of natural drainage patterns, and freeway and highway maintenance activities that increase traffic, dust, noise, and increase safety concerns e.g. "enhanced sweeping". Additionally, potentially significant environmental impacts could occur if implementation actions alter the sediment transport characteristics of the watershed. The environmental impacts of sediment control BMPs will need be considered during implementation of sediment control BMPs. The environmental impacts from these activities will be mitigated to some degree by the adoption of the Copper WER, the nickel SSO and special studies to evaluate standards actions such as the natural sources exclusion and SSOs.

14 NICKEL SSO

As discussed in the Numeric Targets section, a water effects ratio (WER) for copper and a site-specific object (SSO) for nickel are being proposed as part of this TMDL. Because the copper WER and nickel SSO have not yet been adopted and approved for the watershed, this TMDL includes allowable loads and allocations with and without the copper WER and the nickel SSO. For copper, the allocations with a WER are presented earlier in Section 9 (TMDL & Allocations for Copper, Nickel, and Selenium), since the WER will likely be adopted at the same time as the Metals and Selenium TMDL. Allocations for nickel based on the nickel SSO are presented below, since adoption of the nickel SSO will not occur prior to finalization of the Metals and Selenium TMDL.

14.1 Nickel Recalculation

A site specific objective (SSO) for nickel in the CCW is proposed, based on a study by Watson, et al. (1996, 1999), which set out to update the national dataset and calculate a new Final Acute-to-Chronic Ratio (FACR) and a national and site-specific water quality criterion for nickel for the Lower South San Francisco Bay. The same information is applicable to Mugu Lagoon, as species used in the Watson, et al. study included resident and non-resident species sensitive to nickel. The goal of the recalculation was to develop additional acute and chronic data on the toxicity of nickel, using west coast marine organisms. Three species were used, from three different phyla. The three species generated Acute-to-Chronic Ratios (ACRs) within 10% (coefficient of variation) of one another. Even when adding in the previously tested saltwater species, the 4 species were within 10% of each other. The results can be used to calculate several different criterion, depending on whether or not saltwater and freshwater species are combined. However, the testing of more resident saltwater organisms from different families is necessary for calculation of an exclusively saltwater ACR. Using data from both saltwater and freshwater, as was done by Watson, et al., provides adequate information for the development of a chronic national criterion for nickel of 13.9 ug/L. Using saltwater species alone resulted in a national acute criterion of 72.8 ug/L. The Nickel Recalculation procedure has been implemented in NPDES permits in the San Francisco Bay area, such as Order No. R2-2003-0085 for the cities of San Jose and Santa Clara, where the nickel site-specific objectives are used in assessing reasonable potential and in the development of effluent limitations. Additionally, the Nickel Recalculation was implemented into the San Francisco Bay Region's Basin Plan by means of Resolution R2-2002-0061 “Amending the Water Quality Control Plan for the San Francisco Bay Region to Adopt Site-Specific Objectives for Copper and Nickel in the Lower South San Francisco Bay and an Implementation Plan.” Full details of the nickel SSO are available in Appendix B.

14.2 Loading Capacity for Nickel with SSO

Total recoverable allowable loads for nickel according to the SSO were defined for dry and wet weather, using the approach shown earlier in Figure 53. The resulting allocations are presented below in Table 96

Table 95. Dry Weather Dissolved and Total Recoverable Allowable Loads Including Nickel SSO

	Constituent	Dissolved Target (ug/L)	Critical Condition Flow	Critical Condition Dissolved Load	Critical Condition Translator	Critical Condition Total Load
Calleguas	Low Flow					
	Nickel	13.9	20.0	1.50	0.80	1.87
	Average Flow					
	Nickel	13.9	23.0	1.72	0.85	2.03
	Elevated Dry Flow					
	Nickel	13.9	28.0	2.10	0.70	3.01
Revolon	Low Flow					
	Nickel	13.9	7.0	0.52	0.97	0.54
	Average Flow					
	Nickel	13.9	12.0	0.90	0.87	1.04
	Elevated Dry Flow					
	Nickel	13.9	19.0	1.42	0.63	2.27

The wet weather loading capacity is calculated based on the flow rate during a storm. The following table summarizes the wet weather load duration curve equations.

Table 96. Wet Weather Critical Condition Dissolved and Total Recoverable Loads using Nickel SSO as Target

Allocation	Dissolved Acute Target (ug/L)	Critical Condition Wet Weather Total Load Duration Curve Equation (lb/day)
Calleguas	72.8	(72.8*Q)*(1+0.0027(6.4Q+197.5))*C
Revolon	72.8	(72.8*Q)*(1+0.0019(27.8+75.9))*C

Q Daily storm volume
C Conversion from ug/L multiplied by cfs to lb/day

14.3 Comparison of Current Loads and Loading Capacity for Nickel with SSO

Table 97 presents estimated current dry weather total copper, nickel and selenium loads; total loading capacity for Calleguas during the critical condition; and the percent reduction in current total dry weather loads necessary to meet the allowable load. The current loads were calculated based on the maximum modeled 4-day average concentration and the loads presented in the table are based on the middle range flow rate category. The percent reductions shown in the table represent the maximum required percent reductions based on model results. Table 98 presents the same information for Revolon Slough.

Table 97. Comparison of Current Total Nickel Loads to Stream Capacity (Mid Flow range) in Calleguas at PCH During Dry Weather Critical Conditions

Constituent	Target	Dissolved Capacity (lb/day)	Current Dissolved Load (lb/day)	Reduction (%)
Dissolved Nickel	13.9 (SSO)	2.03	2.12	19%

Table 98. Comparison of Current Total Nickel Loads to Stream Capacity (Mid Flow Range) in Revolon at PCH During Dry Weather Critical Conditions

Constituent	Target	Capacity (lb/d)	Current Load (lb/d)	Reduction (%)
Dissolved Nickel	13.9 (SSO)	0.90	1.29	31%

Source and linkage analyses indicate allocations, and thus targets, may not be attainable without reducing background loads and/or other ambient sources. Special studies included in the implementation plan will determine the potential for standards actions or other regulatory actions such as natural background exclusion or site specific objectives.

14.4 Allocations for Nickel (with SSO)

This section summarizes the nickel allocations for POTWs, urban stormwater dischargers (MS4, Caltrans, general construction, general industrial, and the Navy), agriculture, and other NPDES dischargers. Table 99 - Table 101 presents dry and wet weather load allocations for the various discharges. The allocations include an explicit margin of safety of 15% for nickel (as discussed in the MOS section). In addition to the final WLAs and LAs, the table also includes interim limits in order to allow time for dischargers to put in place implementation measures necessary to achieve final allocations. The interim allocations are set equal to the 99th percentile of the observed data for each source. All available discharge data presented in the Source Analysis section were used to create a robust data set to calculate the interim limits. Interim limits are based on the available data and may be revised based on additional water quality data, if appropriate.

Table 99. Total Nickel Waste Load Allocations with Nickel SSO as Target for POTWs in the CCW

	Nickel		
	Final Daily Concentration Limit (ug/L)	Final Monthly Concentration Limit (ug/L)	Final WLA (lb/day)
Hill Canyon WWTP	1295	160	0.36
Simi Valley WQCP	960	169	(2)
Moorpark WTP	(2)	(2)	(1)
Camarillo WRP	1295	160	0.28
Camrosa WRP	(2)	(2)	(1)

1 Discharges from Simi Valley do not reach lower Calleguas Creek and Mugu Lagoon during dry weather. Load allocations are not required for Simi Valley. Monitoring will be conducted and the allocations reevaluated if targets are not met in Arroyo Simi/Las Posas or downstream reaches.

2 Discharger does not contribute loading during dry weather. Allocations are not required.

Table 100. Total Nickel WLA and LAs with the Nickel SSO as Target for Urban and Agriculture in the CCW (lb/day)

	Calleguas and Conejo Creek			Revolon Slough		
	Agriculture	Urban	Background	Agriculture	Urban	Background
Low Flow						
Nickel	0.46	0.11	0.45	0.40	0.051	0.01
Average Flow						
Nickel	0.37	0.17	0.42	0.79	0.078	0.02
Elevated Dry Flow						
Nickel	1.01	0.46	0.56	1.79	0.129	0.02
Wet Weather Flows						
Nickel	$0.013*Q^2+0.8*Q$	0.013*Q2+0.8*Q	0.013*Q2+0.8*Q	0.026*Q2+0.46*Q	0.026*Q2+0.46*Q	0.026*Q2+0.46*Q

Q Daily storm volume

Table 101. Total Nickel Waste Load Allocations with SSOs as Targets for Other NPDES Dischargers in the CCW.

	Nickel	
Reach	Final Dry WLA (ug/L)	Final Wet WLA (ug/L)
1	13.9	72.8
2	13.9	72.8
3	149	856
4	13.9	72.8
5	13.9	72.8
6	(2)	958
7	(2)	958
8	(2)	958
9	160	1292
10	160	1292
11	160	1292
12	160	1292
13	160	1292

1 The current loads do not exceed the TMDL when the SSO is applied. The sum of all loadings cannot exceed the TMDL.

2 Discharges from these reaches do not reach lower Calleguas Creek and Mugu Lagoon during dry weather. Allocations are not required for these reaches.

15 REFERENCES

40 Code of Federal Regulations (40 CFR) Part 130 (TMDL Rule). 2000. United States Environmental Protection Agency (USEPA).

Abrol, S., Augustenborg, C., Madden, C., Suffet, M. 2003. Development of a TMDL for Organochlorine Pesticides for the Calleguas Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board. Contract No. 01-172-140-0. September 2003.

Abu-Saba, K. 2004. Conceptual Model and Impairment Assessment for Selenium in San Francisco Bay. Prepared for the Clean Estuary Partnership by Applied Marine Sciences, Inc.

Anderson, B.S. et al. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California, Environmental Monitoring and Assessment, 78: 131-151-2002.

Aqua Terra. 2005. Hydrologic Modeling of the Calleguas Creek Watershed with the U.S.EPA Hydrologic Simulation Program – FORTRAN (HSPF), Final Report, March 10, 2005.

Armstrong, Louis J. October 12, 1994. “Contribution of Heavy Metals to Storm Water from Automotive Disc Brake Pad Wear” Prepared for Santa Clara Valley Nonpoint Source Pollution Control Program. Prepared by Louis J. Armstrong, Woodward-Clyde Consultants

Bailey, F.C., W., K.A., S., O.R. and J., K.S. 1995. Effect of sulfate level on selenium uptake by ruppia maritima. Chemosphere, 30(3): 579-591.

Baines, S.B., S., F.N., A., D.M. and A., C.G. 2001. Uptake of dissolved organic selenides by marine phytoplankton. Limnology & Oceanography, 46(8): 1936-1944.

Bradford, G.R., A.C. Chang, A.L. Page, D. Bakhtar, J.A. Frampton, and H. Wright. 1996. Background Concentrations of Trace and Major Elements in California Soils. Kearney Foundation of Soil Science, Division of Agriculture and Natural Resources, University of California Special Report, U.C. Riverside and Cal/EPA DTSC.

Brasher, A.M. and Ogle, R.S. 1993. Comparative toxicity of selenite and selenate to the amphipod Hyalella azteca. Archives of Environmental Contamination & Toxicology, 30: 274-279.

Braune, B. et al., 1999. Spatial and Temporal Trends of Contaminants in Canadian Arctic Freshwater and Terrestrial Ecosystems: a Review. Science of the Total Environment, 230(1-3): 145-207.

Buchman. 1999. NOAA Screening Quick Reference Table, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pages.

Bullock Jr., O. R., W. G. Benjey and M. H. Keating (2000). "Modeling assessment of transport and deposition patterns of anthropogenic mercury air emissions in the United States and Canada." Science of the Total Environment 259(1-3): 145-157.

Caffrey, P. F. and J. M. Ondov (1998). "Determination of size-dependent deposition velocities with multiple intrinsic elemental tracers." Environmental Science and Technology 32: 1615-1622.

California Department of Water Resources (DWR). 2000. Land use survey GIS data. Website visited April 2004: http://www.landwateruse.water.ca.gov/basicdata/landuse/landusesurvey.cfm ..

California Resources Agency. 1997. CWIS Mugu Lagoon. California Environmental Resources Evaluation System (CERES). Website: http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html.

Clark Jr., D. R. (1987). "Selenium accumulation in mammals exposed to contaminated California irrigation drainwater." Science of the Total Environment 66: 147-168.

Cutter, G.A. 1989. The estuarine behavior of selenium in San Francisco Bay. Estuarine, Coastal and Shelf Science, 28(1): 13-34.

Delta Tributaries Mercury Council/Sacramento River Watershed Program (DTMC/SRWP). 2002. Strategic Plan for the Reduction of Mercury-Related Risk in the Sacramento River Watershed. Appendix 1. Mercury Conceptual Model Report: Mercury Quantities, Fate, Transport, and Uptake in the Sacramento River Watershed.

Donat et al. 1994. Speciation of dissolved copper and nickel in South San Francisco Bay: a multi-method approach. Analytica Chimica Acta., 284, 547-571.

Duke, L.D. 2001. Evaluating Critical Flow Conditions for Pollutants in an Effluent-Dominated, Storm-Peaking Western U.S. Stream. California Regional Water Quality Control Board, Los Angeles. Water Environment Federation Publication.

Engberg, Catherine. July 1995. “The Regulation and Manufacture of Brake Pads: The Feasibility of Reformulation to Reduce the Copper Load to the San Francisco Bay.” Prepared for the Palo Alto Regional Water Quality Control Plant.

EPA, U. S. (2000). EPA Office of Compliance Sector Notebook Project Profile of the Oil and Gas Extraction Industry. Compliance. EPA/310-R-99-006.

Fraser, R.H., P.K. Barten, and C.D. Tomlin. 1998. SEDMOD: A GIS-based method for estimating distributed sediment delivery ratios. In *GIS and Water Resources.* R. DeWall, ed. Ann Arbor Press.

Granade, Steve. 2003. Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil. Personal communication with C. Minton, August 4, 2003.

Griggs, Gregory. 2005. *Waste Runoff From Field Lab Probed*. Los Angeles Times (latiimes.com). December 7, 2005. Gregory W. Griggs, Times Staff Writer

Hansen, D.D.P.J.Z.A.T.N. 1998. Selenium removal by constructed wetlands - role of biological volatilization. Environmental Science & Technology, 32(5): 591-597.

Haygarth, P. M., D. Fowler, S. Sturup, B. M. Davison and K. C. Jones (1994). "Determination of gaseous and particulate selenium over a rural grassland in the U.K." Atmospheric Environment 28(22): 3655-3663.

Helsel D.R. and R.M. Hirsch. 1992. Statistical Methods in Water Resources, Elsevier Science B.V., Amsterdam.

Helsel, D.R. and T.A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data, Water Resource. Res. Vol. 24, No. 12, pp. 1997-2004.

Helsel, Dennis. 1990. Less than Obvious, Statistical Treatment of Data Below the Detection Limit. Environmental Science and Technology, Vol 24, No 12.

Hoff, R. M., W. M. J. Strachan, C. W. Sweet, C. H. Chan, M. Shackleton, T. F. Bidleman, K. A. Brice, D. A. Burniston, S. Cussion, D. F. Gatz, K. Harlin and W. H. Schroeder (1996). "Atmospheric deposition of toxic chemicals to the Great Lakes: A review of data through 1994." Atmospheric Environment 30: 3505-3527.

Hoffman, D. J., H. M. Ohlendorf and T. W. Aldrich (1988). "Selenium teratogenesis in natural populations of aquatic birds in Central California." Archives of Environmental Contamination and Toxicology 17: 519-525.

Hothem, R.L. and Powell, A.N. 2000. Contaminants in Eggs of Western Snowy Plovers and California Least Terns: Is There a Link to Population Decline? Bulletin of Environmental Contamination and Toxicology, Volume 65, Pages: 42 – 50.

Jones, D. R. (1990). "Batch leaching studies of rundle oil shale." Journal of Environmental Quality 19: 408-413.

Kimmer, W. 2003. Draft. Open Water Processes of the San Francisco Estuary. White Paper Prepared for the CALFED Ecosystem Restoration Program. May.

Landis, John D. PhD. 1998. Development and Pilot Application of the California Urban and Biodiversity Analysis Model. Forthcoming in Computers, Environment, and Urban Systems, http://gis.esri.com/library/userconf/proc98/PROCEED/TO600/PAP571/P571.htm.

Landis, M. S. and G. J. Keeler (2002). "Atmospheric mercury deposition to Lake Michigan during the Lake Michigan Mass Balance Study." Environmental Science and Technology 36(21): 4518-1524.

Larry Walker Associates (LWA). 1999. Calleguas Creek Characterization Study, Surface Water Element, 1998-1999.

Larry Walker Associates (LWA). 2004a. Calleguas Creek Watershed Database. Accessed December 2004.

Larry Walker Associates (LWA). 2004b. Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed. Submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.

Laurier, F. J. G., R. P. Mason, L. Whalin and S. Kato (2003). "Reactive gaseous mercury formation in the North Pacific Ocean's marine boundary layer: A potential role of halogen chemistry." Journal of Geophysical Research 108(D17): 4529-4540.

Lemly, A. D. (1997). "Environmental implications of excessive selenium: A review." Biomedical and Environmental Sciences 10: 415-435.

Lemly, A. D., S. E. Finger and M. D. Nelson (1993). "Sources and impacts of irrigation drainwater contaminants in arid wetlands." Environmental Toxicology and Chemistry 12: 2265-2279.

Lindberg, S. E. and W. J. Stratton (1998). "Atmospheric mercury speciation: Concentrations and behavior of reactive gaseous mercury in ambient air." Environmental Science and Technology 32: 49-57.

Long ER, Field LJ, MacDonald DD. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environ Toxicol Chem 17: 714-727.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2002. Draft Staff Report – 2002 Update: Clean Water Act Section 305(b) Report and Section 303(d) List of Impaired Waters – LA Region. January 29, 2002.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments; Calleguas Creek Listings.

Luoma, S.N. and Presser, T.S. 2000. Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension. USGS Open File Report 00-0146, United States Geological Survey, Menlo Park, CA.

Luoma, S.N. et al. 1992. Determination of selenium bioavailability to a benthic bivalve from particulate and solute pathways. Environmental Science & Technology, 26:485-491.

LWA, 2002. Mercury Source Control & Pollution Prevention Program Evaluation. Prepared for the Association of Metropolitan Sewerage Agencies. March. Page 2.

Maier, K.J., Ogle, R.S., Knight A. W. 1988. The Selenium Problem in Lentic Ecosystems. Lake and Reservoir Management, 4: 155-163.

Maier, K.J.K.A.W. 1993. Comparative acute toxicity and bioconcentration of selenium by the midge chironomus-decorus exposed to selenate, selenite, and seleno-dlmethionine. Archives of Environmental Contamination & Toxicology, 25(3): 365-370.

Mason, R. P., N. M. Lawson and G. R. Sheu (2001). "Mercury in the Atlantic Ocean: Factors controlling air-sea exchange of mercury and its distribution in the upper waters." Deep-Sea Research II 48: 2829-2853.

Mason, R. P., N. M. Lawson and K. A. Sullivan (1997). "The concentration, speciation and sources of mercury in Chesapeake Bay precipitation." Atmospheric Environment 31(21): 3541-3550.

McIntyre, Sam. 2004. Pesticide Advisor, Somis Ag Management Inc. sompacag@aol.com . Personal communication to Michael Casterline, May 2004.

Minjares, Javier. 2004. Southern California Association of Governments, Population Growth by City for SCAG Region for 2000-2030 (pre-website release of population projections), minjares@scag.ca.gov.

National Oceanic and Atmospheric Administration (NOAA). 1999. Sediment Quality Guidelines Developed for the National Status and Trends Program. Office of Response and Restoration, National Ocean Service. Updated 6/28/99.

Ogle, R.S., Maier, K.J., Kiffney, P., Williams, M.J., Brasher, A., Melton, L.A., Knight, A.W. 1988. Bioaccumulation of selenium in aquatic ecosystems. Lake and Reservoir Management, 1988(4): 165-173.

Ogle, R.S.K.A.W. 1996. Selenium bioaccumulation in aquatic ecosystems .1. effects of sulfate on the uptake and toxicity of selenate in daphnia magna. Archives of Environmental Contamination & Toxicology, 30(2): 274-279.

Ohlendorf, H. M., D. J. Hoffman, M. K. Saiki and T. W. Aldrich (1986). "Embryonic mortality and abnormalities of aquatic birds: Apparent impacts of selenium from irrigation drainwater." Science of the Total Environment 52: 49-63.

Ohlendorf, H.M. 2002. The birds of Kesterson Reservoir: a historical perspective. Aquatic Toxicology, 57(1-2): 1-10.

Oremland, R.S. 1994. Biogeochemical transformations of selenium in anoxic environments. In: W.T. Frankenberger, Benson, S. (Editor), Selenium in the Environment. Marcel Dekker, Inc., New York.

Ottlely, C. J. and R. M. Harrison (1993). "Atmospheric dry deposition flux of metallic species to the North Sea." Atmospheric Environment Part A- General Topics 27(5): 685-695.

Palo Alto Regional Water Quality Control Plant. November 2000. Architectural Uses of Copper, An Evaluation of Stormwater Pollution Loads and BMPs.

Paode, R. D., S. C. Sofuoglu, J. Sivadechathep, K. E. Noll, T. M. Holsen and G. J. Keeler (1998). "Dry deposition fluxes and mass size distributions of Pb, Cu and Zn measured in Southern Lake Michigan during AEOLOS." Environmental Science and Technology 32(11): 1629-1635.

Poissant, L., M. Pilote, X. Xu, H. Zhang and C. Beauvais (2004). "Atmospheric mercury speciation and deposition in the Bay St. Francois wetlands." Journal of Geophysical Research 109(D11301): 1-11.

Presser, T. S. (1994). "The Kesterson Effect." Environmental Management 18(3): 437-454.

Presser, T. S., M. A. Sylvester and W. H. Low (1994). "Bioaccumulation of selenium form natural geologic sources in western states and its potential consequences." Environmental Management 18(3): 423-436.

Regional Water Quality Control Board (RWQCB), San Francisco Bay Region. 2000. Watershed Management of Mercury in the San Francisco Bay Estuary: Total Maximum Daily Load Report to U.S. EPA.

Sabin, L. D., K. C. Schiff, J. L. Lim and K. D. Stolzenbach (2004). "Atmospheric Dry Deposition of Trace Metals in the Los Angeles Coastal Region." Annual Report: ftp://ftp.sccwrp.org/pub/download/PDFs/2003_04ANNUALREPORT/ar05-sabin_pg50-60.pdf.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). January 2004. PCBs in San Francisco Bay, Total Maximum Daily Load Report.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2004. Mercury in San Francisco Bay Total Maximum Daily Load (TMDL) Proposed Basin Plan Amendment and Staff Report. September 2, 2004.

Schlekat, C.E.L.B.G.L.S.N. 2002. Assimilation of selenium from phytoplankton by three benthic invertebrates: effect of phytoplankton species. Marine Ecology Progress Series, 237: 79-85.

Shendrikar, A. D. and G. B. Faudel (1978). "Distribution of trace metals during oil shale retorting." Environmental Science and Technology 12(332-334).

Shia, R. L., C. Seigneur, P. Pai, M. Ko and N. D. Sze (1999). "Global simulation of atmospheric mercury concentrations and deposition fluxes." Journal of Geophysical Research 104(23): 747-23,760.

Sinclair, Kirsten. 2005. Copper Released from Non-Brake Sources in the San Francisco Bay Area. Kirsten Sinclair Rosselot Process Profiles Calabasas, California. Prepared for the Brake Pad Partnership. June 2005.

Shumway, Robert; Azari, Rahman; Kayhanian, Masoud. 2002. Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits. Environmental Science and Technology, Vol 36.

Smith, Randy. 2004. Ventura County Mosquito Abatement and Vector Control, randy.smith@mail.co.ventura.ca.us. Personal communication to Michael Casterline, March 2004.

Southern California Association of Governments (SCAG). 2004. Urban land use GIS data. Website visited June 2004: http://rtmisweb.scag.ca.gov/data_gis/ .

State Water Resources Control Board (SWRCB). 1997. Proposed Decision Regarding Application 29408 and Wastewater Change Petition No. 6 of the City of Thousand Oaks and Availability of Unappropriated Water for Applications 29816, 29819, 29581, 29959, 300317, 30092, and 30194--Arroyo Conejo, Conejo Creek, and Calleguas Creek in Ventura County. Sacramento, California. August 1997.

State Water Resources Control Board (SWRCB). 2004c. Water Quality Control Policy For Developing California's Clean Water Act Section 303(D) List. September 30th, 2004

State Water Resources Control Board (SWRCB). 2004a. State Mussel Watch Program (SMWP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html .

State Water Resources Control Board (SWRCB). 2004b. Toxic Substances Monitoring Program (TSMP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html .

Sweet, C. W., A. Weiss and S. J. Vermette (1998). "Atmospheric deposition of trace metals at three sites near the Great Lakes." Water, Air and soil Pollution 103: 423-439.

TDC Environmental. 2004. Copper Sources in Urban Runoff and Shoreline Activities.

Tetra Tech. 1998. Phase I Remedial Investigation Technical Memorandum Volume I - Chapters 1-13, Draft Final. Department of the Navy, Naval Engineering Command, Engineering Field Activity West.

Tetra Tech. 2005. Draft Review of USFWS (2003) Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California. January 10, 2005.

Tetra Tech. 1999. Task 1. Conceptual Model Report for Copper and Nickel in Lower South San Francisco Bay. December.

Topping et al. 2001. Benthic Flux of Dissolved Nickel into the Water Column of South San Francisco Bay: USGS Open-File Report 01-89, 50 p. http://pubs.water.usgs.gov/ofr01089

United States Census Bureau (USCB). Website visited May 2004: http://www.census.gov/population/projections/state/stpjpop.txt .

United States Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon. USDA Report prepared by Water Resources Planning Staff.

United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Nickel. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Zinc. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1984. Ambient Water Quality Criteria for Copper. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1984. Ambient Water Quality Criteria for Mercury. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1987. Ambient Water Quality Criteria for Selenium. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1991. Guidance for Water Quality-based Decisions: the TMDL Process. Office of Water. Washington, D.C. EPA 440/4-91-001. April, 1991. http://www.epa.gov/OWOW/tmdl/decisions/ .

United States Environmental Protection Agency (US EPA). 1994. Interim Guidance on Determination and Use of Water Effect Ratios. Office of Water. Washington, D.C. EPA-823-B-94-001. February 1994.

United States Environmental Protection Agency (US EPA). 2000. 40 CFR Part 131: Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule

United States Environmental Protection Agency (US EPA). 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Office of Science & Technology/Office of Water. Washington, D.C. EPA-823-R-01-001.

United States Environmental Protection Agency (US EPA). 2002. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California. US Environmental Protection Agency, Region 9. Established June 14, 2002.

United States Environmental Protection Agency (US EPA). 2003. Ambient Water Quality Criteria for Copper. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 2004. Draft Aquatic Life Water Quality Criteria for Selenium - 2004. Office of Water. Washington, D.C. EPA-822-D-04-001.

United States Environmental Protection Agency (US EPA). 1986. Ambient Water Quality Criteria for Nickel. EPA-440/5-86-004. Office of Water. Washington, DC.

United States Environmental Protection Agency (USEPA). 1996. The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From A Dissolved Criterion. USEPA, Office of Water. EPA 823-B-96-007. June 1996.

United States Fish & Wildlife Service (USFWS). 2003. Evaluation of the Clean Water Act Section 304(a) Human Health Criterion for Methylmercury: Protectiveness for Threatened and Endangered Wildlife in California. October, 2003.

United States Geological Survey (USGS). 2004. Website visited May 2004: http://ca.water.usgs.gov/archive/reports/ofr96_629/geog.html#1.5 .

United States Navy. 2000. Unpublished data from Steve Granade, Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil .

United States Navy. 1998. *Naval Air Weapons Station Point Mugu, California - Phase I Remedial Investigation Technical Memorandum, Volume I - Chapters 1 - 13. Draft Final.* Department of the Navy, Naval Facilities Engineering Command Engineering Field Activity West. June 1998 (Revised June 1999).

United States Navy. 2005. *Ecological Risk Assessment Addendum for Installation Restoration Program Sites 5 and 11 Naval Air Station Point Mugu Naval Base Ventura County, California.* October 2005

Ventura County (website), May 2004, http://www.countyofventura.org/visitor/visitor.asp.

Watson et al. 1996. Recalculation of the National Marine Water Quality Criterion for Nickel and Development of a Site-Specific Criterion. City of San Jose ESD, San Jose, CA and Tetra Tech, Inc. Owings Mills, MD.

Watson et al. 1999. Nickel Acute-to-Chronic Ration Study. City of San Jose water Pollution Control Plant. Environmental Service Department.

Williams, M.J.O.R.S.K.A.W.B.R.G. 1994. Effects of sulfate on selenate uptake and toxicity in the green alga selenastrum capricornutum. Archives of Environmental Contamination & Toxicology, 27(4): 449-453.

Wisconsin Department of Natural Resources (Wisconsin DNR). 1997. Wisconsin Mercury Source Bood, A Guide to Help Your Community Identify & Reduce Releases of Elemental Mercury.

xx - Ohlendorf et al. 1986; Clark Jr. 1987; Hoffman et al. 1988; Lemly et al. 1993; Presser 1994; Presser et al. 1994; Lemly 1997

15.1 References for Economic Analysis

Woodward-Clyde. 1994. Report for City of San Jose "Comparison of Sweepers": http://www.worldsweeper.com/Environmental/SanJosePt1.html#Table

California Coastal Conservancy. 2001. Calleguas Creek Watershed Information: http://www.wrpinfo.scc.ca.gov/watersheds/briefs/calleguas/

TDC Environmental. 2004. Copper Sources in Urban Runoff and Shoreline Activities. Prepared for the Clean Estuary Partnership.

Larry Walker Associates (LWA). 2002. Mercury Source Control & Pollution Prevention Program Evaluation. Final Report. Prepared for the Association of Metropolitan Sewerage Agencies under grant from the U.S. Environmental Protection Agency.

Yellowpages.com. 2006. Search for "dentists" in Simi Valley, Thousand Oaks, Camarillo, and Moorpark

Southern California Association of Governments (SCAG). 2000. Census information. http://www.scag.ca.gov/census/index.htm

Santa Clara Valley Urban Runoff Pollution Prevention Program. 2005. Summary of Co-permittee Street Sweeping Activities for FY2004-2005.

National Sustainable Agriculture Information Service. 2004. Tree Fruits: Organic Production Overview. http://www.attra.org/attra-pub/fruitover.html

U.S. EPA. 2006. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. Chapter 2: Management Measures for Agricultural Sources. Table 2-17: Estimates of Potential Reductions in Field Losses of Pesticides for Corn Compared to a Conventionally and/or Traditionally Cropped Field.

15.2 Additional References from Response to Comments - Added on 2/17/06

Ankley, G.T., Mattson, V.R., Leonard, E.N., West, C.W. and Bennett, J.L., 1993. Predicting the Acute Toxicity of Copper in Fresh-Water Sediments - Evaluation of the Role of Acid-Volatile Sulfide. Environmental Toxicology and Chemistry, 12(2): 315-320.

Bedsworth, W.W. and Sedlak, D.L., 1999. Sources and Environmental Fate of Strongly Complexed Nickel in Estuarine Waters: The Role of Ethylenediaminetetraacetate. Environmental Science & Technology, 33(6): 926-931.

Benoit, J. M. , Mason, R. P. and Gilmour, C. C. , 1999a. Estimation of mercury-sulfide speciation in sediment pore waters using octanol-water partitioning and implications for availability to methylating bacteria. Environmental Toxicology and Chemistry, 18(10): 2138-2141.

Benoit, J.M., Gilmour, C.C., Mason, R.P. and Heyes, A., 1999b. Sulfide Controls on Mercury Speciation and Bioavailability to Methylating Bacteria in Sediment Pore Waters. Environmental Science & Technology, 33(6): 951-957.

Besser, J.M., Ingersoll, C.G. and Giesy, J.P., 1996. Effects of spatial and temporal variation of acid-volatile sulfide on the bioavailability of copper and zinc in freshwater sediments. Environmental Toxicology and Chemistry, 15(3): 286-293.

Buck, K.N. and Bruland, K.W., 2005. Copper speciation in San Francisco Bay: A novel approach using multiple analytical windows. Marine Chemistry, 96(1-2): 185-198.

Casas, A.M. and Crecelius, E.A., 1994. Relationship between Acid Volatile Sulfide and the Toxicity of Zinc, Lead and Copper in Marine-Sediments. Environmental Toxicology and Chemistry, 13(3): 529-536.

Ciffroy, P., Moulin, C. and Gailhard, J., 2000. A model simulating the transport of dissolved and particulate copper in the Seine river. Ecological Modelling, 127(2-3): 99-117.

City of Palo Alto Regional Water Quality Control Plant, 2003. Copper Action Plan Report, Palo Alto, CA. http://www.cityofpaloalto.org/public-works/documents/cb-CuReport03.pdf

Flegal, A.R., Smith, G.J., Gill, G.A., Sanudo-Wilhelmy, S. and Anderson, L.C.D., 1991. Dissolved trace element cycles in the San Francisco Bay estuary. Marine Chemistry, 36(1-4): 329-363.

Gallagher, D.L., Johnston, K.M. and Dietrich, A.M., 2001. Fate and transport of copper-based crop protectants in plasticulture runoff and the impact of sedimentation as a best management practice. Water Research, 35(12): 2984-2994.

Gee, A.K. and Bruland, K.W., 2002. Tracing Ni, Cu, and Zn kinetics and equilibrium partitioning between dissolved and particulate phases in South San Francisco Bay, California, using stable isotopes and high-resolution inductively coupled plasma mass spectrometry. Geochimica et Cosmochimica Acta, 66(17): 3063-3083.

Gilmour, C.C., Henry, E.A. and Mitchell, R., 1992. Sulfate stimulation of mercury methylation in freshwater sediments. Environmental Science & Technology, 26(11): 2281-2287.

Grovhoug, T., Lau, G. and Abu-Saba, K.E., 2003. Mercury Management by Bay Area Wastewater Treatment Plants, San Francisco Bay Clean Estuary Partnership, Oakland, CA.

http://www.cleanestuary.org/publications/files/Task4%2E05%2DDraftWastewaterImpl%2Epdf

Morel, F.M.M. and Hering, J.G., 1993. Principles and Applications of Aquatic Chemistry. Wiley, New York.

Murphy, E.A., 1993. Effectiveness of Flushing on Reducing Lead and Copper Levels in School Drinking Water. Environmental Health Perspectives, 101(3): 240-241.

Romkens, P., Hoenderboom, G. and Dolfing, J., 1999. Copper solution geochemistry in arable soils: Field observations and model application. Journal of Environmental Quality, 28(3): 776-783.

Sedlak, D.L., Phinney, J.T. and Bedsworth, W.W., 1997. Strongly complexed Cu and Ni in wastewater effluents and surface runoff. Environmental Science & Technology, 31(10): 3010-3016.

Weng, L.P., Fest, E., Fillius, J., Temminghoff, E.J.M. and Van Riemsdijk, W.H., 2002. Transport of humic and fulvic acids in relation to metal mobility in a copper-contaminated acid sandy soil. Environmental Science & Technology, 36(8): 1699-1704.

15.3 Primary References Cited from Secondary Sources

Ansede JH, Yoch DC (1997) Comparison of selenium and sulfur volatilization by dimethylsulfoniopropionate lyase (DMSP) in two marine bacteria and estuarine sediments. FEMS Microbiology Ecology 23:315-324.

Bailey FC, Knight AW, Ogle RS, Klaine SJ (1995) Effect of sulfate level on selenium uptake by Ruppia maritima. Chemosphere, 30(3): 579-591.

Baines SB, Fisher NS, Stewart R (2002) Assimilation and retention of selenium and other trace elements from crustacean food by juvenile striped bass (Morone saxatilis). Limnology Oceanography 47(3):646-655.

Baines SB, Fisher NS, Doblin MA, Cutter GA (2001) Uptake of dissolved organic selenides by marine phytoplankton. Limnology & Oceanography, 46(8): 1936-1944.

Benoit, J.M., C.C. Gilmour, R.P. Mason, and A. Heyes (1999). “Sulfide controls on mercury speciation and bioavailability to methylating bacteria in sediment pore water.” Environ. Sci. Technol., 33: 951- 957.

Bloom, N.B. (1992). “On the chemical form of mercury in the edible fish and marine invertebrate tissue.” J. Fish Aquatic Sci., 49: 1010-1017.

Boisson F, Gnassia-Barelli M, Romeo M (1995) Toxicity and accumulation of selenite and selenate in the unicellular marine alga Cricospaera elongata. Archives Environmental Contamination Toxicology 28:487-493.

Bottino NR, Banks C, Irgolic KJ, Micks P, Wheeler AE, Zingaro RA (1984) Seleniumcontaining amino acids and proteins in marine algae. Phytochemistry 23(111):2445-2452.

Brown CL, Luoma SN (1995) Use of the euryhaline bivalve Potamocorbula amurensis as a biosentinel species to assess trace metal contamination in San Francisco Bay. Marine Ecology Progress Series 124(1-3): 129-142.

Coyle JJ, Buckler DR, Ingersoll CG, Fairchild JF, May TW (1993) Effect of dietary selenium on the reproductive success of bluegills (Lepomis macrochirus). Environmental Toxicology and Chemistry 12:551-565.

Cutter GA, Bruland KW (1984) The marine biogeochemistry of selenium: a re-evaluation. Limnology Oceanography 29:1179-1192.

Cutter GA (1989) The estuarine behavior of selenium in San Francisco Bay. Estuarine, Coastal and Shelf Science, 28(1): 13-34.

Cutter GA, Bruland KW (1984) The marine biogeochemistry of selenium: a re-evaluation. Limnology Oceanography 29:1179-1192.

Cutter GA, Cutter LS (2004) Selenium biogeochemistry in the San Francisco Bay estuary: changes in water column behavior. Estuarine Coastal Shelf Science 61:463-476.

Doblin MA, Baines SB, Cutter LS, Cutter GA (2005) Selenium biogeochemistry in the San Francisco Bay estuary: Seston and phytoplankton. Manuscript in review, Estuarine, Coastal, and Shelf Science.

Foda A, Vandermeulen J, Wrench JJ (1983) Uptake and conversion of selenium by a marine bacterium. Canadian Journal Fisheries and Aquatic Sciences 40(supplement 2):215-220.

Fowler SW, Benayoun G (1976) Influence of environmental factors on selenium flux in two marine invertebrates. Marine Biology 37:59-68.

Gilmour, C.C. (1995). “Mercury methylation in freshwater.” In National Forum on Mercury, USEPA Office of Water. EPA 823-R-95-002.

Hansen D, Duda PJ, Zayed A, Terry N (1998) Selenium removal by constructed wetlands – role of biological volatilization. Environmental Science & Technology 32(5): 591-597.

Harrison PJ, Yu PW, Thompson PA, Price NM, Phillips DJ (1988) Survey of selenium requirements in marine phytoplankton. Marine Ecology Progress Series 47:89-96.

Heinz GH, Hoffman DJ, Gold LG (1989) Impaired reproduction of mallards fed an organic form of selenium. Journal of Wildlife Management 53(2):418-428.

Horowitz, A.J. (1995). The Use of Suspended Sediment and Associated Trace Elements in WaterQuality Studies. International Association of Hydrological Sciences, Special Publication 4, 58 pp. ISBN 0-947571-79-5.

Hu MH, Yang YP, Martin M, Yin , Harrison PJ (1997) Preferential uptake of Se(IV) over Se(VI) and the production of dissolved organic Se by marine phytoplankton. Marine Environmental Research 44:225-231.

Johnson TM, Bullen TD, Zawislanski PT (2000) Selenium stable isotope ratios as indicators of sources and cycling of selenium: results from the northern reach of San Francisco Bay. Environmental Science Technology 34:2075-2079.

Keating, M.H., K.R. Mahaffey, R. Schoeny, G.E. Rice, O.R. Bullock, R.B. Ambrose, J. Swartout, and J.W. Nichols (1997). “Mercury Study Report to Congress.” EPA-452/R-97-003, December, 1997.

Kim K, Kayes TB, Anundson CH (1992) Requirements for sulfur amino acids and utilization of d-methionine by rainbow trout (Oncorhynchus mykiss). Aquaculture 101:95-103.

Krabbenhoft, D.P., Wiener, J.G., Brumbaugh, W.G., Olson, M.L., DeWild, J.F. and Sabin, T.J., 1999. A National Pilot Study of Mercury Contamination of Aquatic Ecosystems Along Multiple Gradients United States Geological Survey, Madison, Wisconson.

Lasorsa, B., and S. Allen-Gil (1995). “The methylmercury to total mercury ratio in selected marine, freshwater, and terrestrial organisms.” Water, Air, and Soil Pollution, 80: 905-913.

Lindstrom K (1983) Selenium as a growth factor for planktonic algae in laboratory experiments and in some Swedish lakes. Hydrobiologia 101:35-48.

Luoma SN, Johns C, Fisher NS, Steinberg NA, Oremland RS, Reinfelder JR (1992) Determination of selenium bioavailability to a benthic bivalve from particulate and solute pathways. Environmental Science & Technology, 26: 485-491.

Luoma SN, Presser TS (2000) Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension. USGS Open File Report 00-0146, United States Geological Survey, Menlo Park, CA.

Maier KJ, Ogle RS, Knight AW (1988) The selenium problem in lentic ecosystems. Lake and Reservoir Management, 4: 155-163.

Maier KJ, Knight AW (1993) Comparative acute toxicity and bioconcentration of selenium by the midge Chironomus-decorus exposed to selenate, selenite, and seleno-dl-methionine.

Matilainen, T. Involvement of bacteria in methylmercury formation in anaerobic lake waters. Water Air and Soil Pollution 80(1-4), 757-764. 1995.

Mason, R.P., Reinfelder, J.R. and Morel, F.M.M., 1995. Bioaccumulation of mercury and methylmercury. Water Air and Soil Pollution, 80(1-4): 915-921.

Meseck SL (2002) Modeling the Biogeochemical Cycle of Selenium in the San Francisco Bay. Ph.D. Dissertation, Old Dominion University.

Ogle RS (1996) The bioaccumulation of selenium in aquatic ecosystems. Ph.D. Dissertation, University of California, Davis, CA.

Ogle, R.S., Maier, K.J., Kiffney, P., Williams, M.J., Brasher, A., Melton, L.A., Knight, A.W., 1988. Bioaccumulation of selenium in aquatic ecosystems. Lake and Reservoir Management, 1988(4): 165-173.

Ohlendorf, H.M., 2002. The birds of Kesterson Reservoir: a historical perspective. Aquatic Toxicology, 57(1-2): 1-10.

Oremland, R.S., 1994. Biogeochemical transformations of selenium in anoxic environments. In: W.T. Frankenberger, Benson, S. (Editor), Selenium in the Environment. Marcel Dekker, Inc., New York.

Purkerson DG, Doblin MA, Bollens SM, Luoma SN, Cutter GA (2003) Selenium in San Francisco Bay zooplankton: Potential effects of hydrodynamics and food web interactions. Estuaries 26(4A): 956-969.

Reinfelder JR, Fisher NS (1997) Assimilation efficiencies and turnover rates of trace elements in marine bivalves: a comparison of oysters, clams, and mussels. Marine Biology 129:443-452.

Reinfelder JR, Fisher NS, Luoma SN, Nichols JW, Wang WX (1998) Trace element trophic transfer in aquatic organisms: A critique of the kinetic model approach. Science of the Total Environment 219:117-135.

Rolfhus, K.R. and Fitzgerald, W.F., 1995 Feb. Linkages between atmospheric mercury deposition and the methylmercury content of marine fish. Water Air and Soil Pollution, 80(1-4): 291-297.

Robinson EH, Allen OW, Poe WE, Wilson RP (1978) Utilization of dietary sulfur compounds by fingerling channel catfish: l-methionine, d,l-methionine, methionine hydroxy analogue, taurine, and inorganic sulfate. Journal of Nutrition 108:1932--1936.

Rudd, J., M. Turner, A. Furutani, A. Swick, and B. Townsend 1983. “The English- Wabigoon River System: I. A Synthesis of Recent Research with a View towards Mercury Amelioration,” Canadian Journal of Fisheries and Aquatic Science, 40:2206-2217.

Stewart RS, Luoma SN, Schlekat CE, Doblin MA, Hieb KA (2004) Food web pathway determined how selenium affects aquatic ecosystems: A San Francisco Bay case study. Environmental Science Technology 38:4519-4526.

Vandermeulen H, Foda A (1988) Cycling of selenite and selenate in marine phytoplankton. Marine Biology 98:115-123.

Wang WX, Fisher NS, Luoma SN (1995) Assimilation of trace elements ingested by the mussel Mytilus edulis: effects of algal food abundance. Marine Ecology Progress Series 129:165-176.

Wang WX, Fisher NS, Luoma SN (1996) Kinetic determinations of trace element bioaccumulation in the mussel Mytilus edulis. Marine Ecology-Progress Series 140(1-3): 91-113.

Wang WX, Fisher NS, Luoma SN (1996) Kinetic determinations of trace element bioaccumulation in the mussel Mytilus edulis. Marine Ecology-Progress Series 140(1-3): 91-113.

Wang WX, Fisher NS (1998) Excretion of trace elements by marine copepods and their bioavailability to diatoms. Journal Marine Research 56:713-729.

Wang WX, Fisher NS, Luoma SN (1995) Assimilation of trace elements ingested by the mussel Mytilus edulis: effects of algal food abundance. Marine Ecology Progress Series 129:165- 176.

Wiener, J.G., D.P. Krabbenhoft, G.H. Heinz, and A.M. Scheuhammer (2002). “Ecotoxicology of Mercury”, Chapter 16 in D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. (editors), Handbook of Ecotoxicology, 2nd edition. CRC Press, Boca Raton, Florida.

Weiner, J.G., and D.J. Spry (1995). “Toxicological significance of mercury in freshwater fish.” In Interpreting Environmental Contaminant in Animal Tissue, (Heinz and Beyer, eds.). Lewis Publ., Boca Raton, FL.

Wheeler AE, Zingaro RA, Irgolic K (1982) The effect of selenate, selenite, and sulfate on the growth of six unicellular marine algae. Journal Experimental Marine Biology and Ecology 57:181-194.

Williams MJ, Ogle RS, Knight AW, Burau RG (1994) Effects of sulfate on selenate uptake and toxicity in the green alga Selenastrum capricornutum. Archives of Environmental Contamination & Toxicology, 27(4): 449-453.

Wrench JJ (1978) Selenium metabolism in the marine phytoplankters Tetraselmis tetrahele and Dunaliella minuta. Marine Biology 49:231-236.

Wrench JJ, Campbell NC (1981) Protein-bound selenium in some marine organisms. Chemosphere 10:1155-1161.

Wrench JJ, Measures CI (1982) Temporal variations in dissolved selenium in a coastal ecosystem. Nature 299:431-433.

Woock SE, Garrett WR, Partin WE, Bryson WT (1987) Decreased survival and teratogenisis during laboratory selenium exposures to bluegill, Lepomis macrochirus. Bulletin Environmental Contamination and Toxicology 39:998-1005.

Xu Y, Wang WX, Hsieh DPH (2001) Influences of metal concentration in phytoplankton and seawater on metal assimilation and elimination in marine copepods. Environmental Toxicology and Chemistry 20(5):1067-1077.

Zhang GH, Hu MH, Huang YP (1990) Se uptake and accumulation in marine phytoplankton and transfer of Se to thee clam Puditapes philippnarum. Marine Environmental Research 30:179-190.

Zillioux, E.J., Porcella, D.B. and Benoit, J.M., 1993 Dec. Mercury cycling and effects in freshwater wetland ecosystems. Environmental Toxicology and Chemistry, 12(12): 2245-2264.