Morro Bay Total Maximum Daily Load for Sediment (including Chorro Creek, Los Osos Creek and the Morro Bay Estuary)

State of California
Central Coast Regional Water Quality Control Board
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1. Introduction

A Total Maximum Daily Load is the greatest amount of a particular pollutant that a waterbody can receive without exceeding the water quality objectives established to protect the beneficial uses of that waterbody. The Federal Clean Water Act requires Total Maximum Daily Loads (TMDLs) for waters that exceed water quality standards or objectives. The TMDL, which can also be described as the loading capacity, is expressed by the following formula:

TMDL = ∑(Load from Point Sources)+∑(Load from Nonpoint Sources)+∑(Load from Background / Natural Sources)+(Margin of Safety)

Chorro Creek, Los Osos Creek, Morro Bay, and the Morro Bay Estuary[1] are listed as waters impaired by sedimentation/siltation, and are the subject of this TMDL. The loading capacity for all of the waterbodies is addressed in one TMDL, since the sources of sediment, nature of water quality impairments, sources of water quality data, pollutant-loading determinations, land uses, and water quality attainment strategies are very similar. Furthermore, the waterbodies are all part of the Morro Bay watershed and a watershed-wide approach was required to develop an understanding of sedimentation in the Estuary, and to address all controllable sources of sediment.

1.1 Documents Used

A large volume of information concerning Morro Bay's natural resources was considered in preparing this TMDL. Computer models constructed by Tetra Tech for the Morro Bay National Estuary Program provided the basis of sediment loads presented in the TMDL. Soil Conservation Service reports provided the basis for the 50 percent load reduction identified as necessary to protect beneficial uses. Among the numerous resources consulted, the following reports were particularly valuable and relied upon more than others:

- Sedimentation Processes in Morro Bay, California, Jeffrey Haltiner, 1988.
- Morro Bay Estuary Program Sediment Loading Study, Tetra Tech, Inc. 1998.
- Morro Bay National Estuary Program (MBNEP) Watershed Streamflow, Tetra Tech, Inc. 1998.
- Morro Bay National Estuary Program Habitat Characterization and Assessment Study, Tetra Tech, Inc. 1999.
- Erosion and Sediment Study Morro Bay Watershed, U.S. Dept of Agriculture, Soil Conservation Service, 1989.
- Morro Bay Watershed Enhancement Plan, U.S. Dept of Agriculture (USDA), Soil Conservation Service (SCS), 1989.

[1] In the Basin Plan, *Morro Bay* and the *Morro Bay Estuary* are identified as "ocean" and "inland surface waters," respectively, for the purpose of identifying the beneficial uses applied to these waters. The two names in fact refer to one waterbody, which is recognized to begin landward of the breakwater on the Pacific Ocean at Estero Bay.

2. Problem Statement

2.1 Overview/General Problem

Over time, all estuaries eventually fill with sediment due to the natural processes of erosion and sedimentation. However, the concern with Morro Bay is that these natural processes have been accelerated due to anthropogenic watershed disturbances. Studies conducted by various authors over the past 25 years have concluded that the rate of sedimentation to Morro Bay has rapidly increased. These studies have provided either estimates of sediment loadings to the Bay from the creeks emptying into the Bay, or estimates of sediment accumulations within the Bay.

2.2 Water Quality Standards

Water quality standards as set forth in the Central Coast Region's Water Quality Control Plan (Basin Plan) include the identified beneficial uses of a waterbody, the water quality objectives for those uses, and the antidegradation policy of the State Water Resources Control Board.

2.2.1 Beneficial Uses

The listed beneficial uses for the waterbodies in the Morro Bay watershed are shown in Table 1 and described below.

Table 1. Identified Uses of Inland Surface and Coastal Waters of the Morro Bay Watershed.

Waterbody Name	MAR	NAV	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRSH	COMM	AQUA	SHELL
Inland Surface Waters																				
Morro Bay Estuary					●		●	●	●	●		●	●	●	●	●		●	●	●
Chorro Creek			●	●		●	●	●	●	●	●	●	●	●	●		●	●		
Dairy Creek			●	●		●	●	●	●	●		●	●		●			●		
San Luisito Creek			●	●		●	●	●	●	●		●	●		●			●		
San Bernardo Creek			●	●		●	●	●	●	●		●	●		●			●		
Los Osos Creek			●	●		●	●	●	●	●	●	●	●		●		●	●		
Warden Lake Wetland				●		●	●	●	●		●		●		●			●		
Coastal Waters																				
Morro Bay	●	●			●		●	●	●						●			●		●

Source: Central Coast Regional Water Quality Control Board Basin Plan.

<u>Marine Habitat</u> (MAR): Uses of water that support marine ecosystems.

<u>Navigation</u> (NAV): Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

<u>Municipal and Domestic Supply</u> (MUN): Uses of water for community, military, or individual water supply systems including, but not limited to drinking water.

Agricultural Supply (AGR): Uses of water for farming, horticulture, or ranching.

Ground Water Recharge (GWR): Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Wildlife Habitat (WILD): Uses of water that support terrestrial ecosystems.

Migration of Aquatic Organisms (MIGR): Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms.

Preservation of Biological Habitats of Special Significance (BIOL): Uses of water that support designated areas of habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS).

Freshwater Replenishment (FRSH): Uses of water for natural or artificial maintenance of surface water quantity or quality which includes a water body that supplies water to a different type of water body.

Commercial and Sport Fishing (COMM): Uses of water for commercial or recreational collection of fish, shellfish, or other organisms.

Aquaculture (AQUA): Uses of water for aquaculture or mariculture operations.

Industrial (IND): Uses of water for industrial activities that do not depend primarily on water quality.

Water Contact Recreation (REC1): Uses of water for recreational activity involving body contact with water, where ingestion of water is reasonably possible.

Non-Contact Water Recreation (REC2): Uses of water for recreation activities involving proximity to water, but not normally involving bodily contact with water, where ingestion of water is reasonably possible.

Cold Fresh Water Habitat (COLD): Uses of water that support cold water ecosystems.

Warm Fresh Water Habitat (WARM): Uses of water that support warm water ecosystems.

Spawning, Reproduction, and/or Early Development (SPWN): Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Rare, Threatened, or Endangered Species (RARE): Uses of water that support habitat necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

Estuarine Habitat (EST): Uses of water that support estuarine ecosystems.

Shellfish Harvesting (SHELL): Uses of water that support habitats suitable for the collection of filter feeding shellfish for human consumption, commercial, or sport purposes.

2.2.2 Water Quality Objectives

The specific water quality objectives that apply wholly, or in part, to sediment are contained within the Central Coast Region's Water Quality Control Plan (1994, p. III-3) and are listed below:

Settleable solids: Waters shall not contain settleable material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses.

Sediment: The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Turbidity: Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.

Increase in turbidity attributable to controllable water quality factors shall not exceed the following limits:

1. Where natural turbidity is between 0 and 50 Jackson Turbidity Units (JTU), increases shall not exceed 20 percent.

2. Where natural turbidity is between 50 and 100 JTU, increases shall not exceed 10 JTU.

3. Where natural turbidity is greater than 100 JTU, increases shall not exceed 10 percent.

Allowable zones of dilution within which higher concentrations will be tolerated will be defined for each discharge in discharge permits.

2.3 Description of Morro Bay and the Morro Bay Watershed

Morro Bay is a natural embayment located on the central coast of California about 60 miles north of Point Conception and about 100 miles south of Monterey Bay (Figure 1). The Bay is situated approximately in the middle of Estero Bay in San Luis Obispo County (MBNEP, 2000. p. 2-1 draft). The Estuary is a shallow lagoon, approximately four miles long and 1.75 miles at its maximum width (Haltiner, 1988, p. 10). The water surface of the Bay is 523 acres at Mean Low Low Water (Tetra Tech, 1999b, p. B-14). It was formed in the last 10,000 to 15,000 years by the submergence of the river mouth at the confluence of Chorro and Los Osos Creeks, the two main drainages in the watershed. This submergence was a result of the post-glacial rise in sea level of several hundred feet. Littoral transport created the protective barrier beach (the sandspit) to the west. Under natural conditions, two narrow entrances to the Bay existed on either side of Morro Rock. The north entrance was artificially closed in the early 1900's, as discussed further under tidal circulation and sediment flushing.

The contributing watershed area for Morro Bay is estimated to be 48,450 acres (USDA, SCS, 1989a). Chorro Creek drains 65 percent of the watershed and Los Osos Creek drains the remaining 35 percent. The watershed's highest elevation is 2,763 feet above sea level and its farthest point from the Bay is approximately 10 miles. The primary land uses are agriculture, urban lands, and multi-use public lands (MBNEP, 2000, pp. 2-11 draft). The geology of the watershed is a mix of igneous, metamorphic and sedimentary rock less than 200 million years old. Debris landslides, soil creep, and large slumps occur within this terrain, usually triggered by intense rainstorms (USDA, SCS, 1989, p. 2).

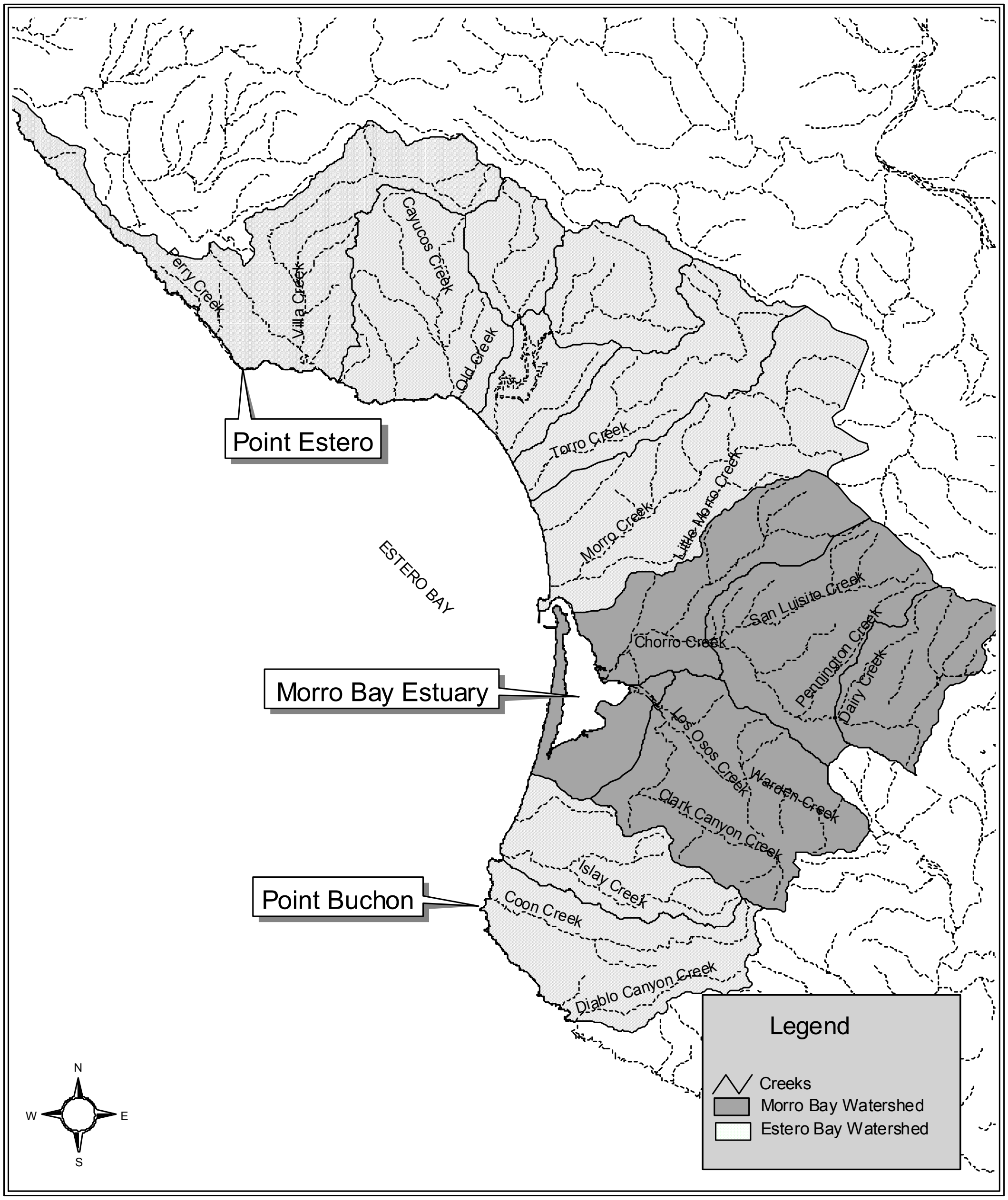

Figure 1: The Setting of Morro Bay
Source: MBNEP, 2000a. Figure 1.1, p.1-4

2.4 Stream Discharge into Morro Bay

Stream discharge into Morro Bay reflects the seasonal and annual variability in rainfall and runoff characteristic of the Central Coast Region. Based on limited stream gage data and rain gage data, discharge estimates were developed from a hydrologic model completed by Tetra Tech (Table 2). At the mouth of Chorro Creek, the larger contributor of flow to Morro Bay, average flows range from 1,476 cfs for a 2-year event to 35,390 cfs for a 100-year event. Farther upstream at Highway 1, peak discharges can be several orders of magnitude above the average for each event—an important factor in mobilizing and delivering sediment to Morro Bay. Similar relationships hold for Los Osos Creek.

Table 2. Estimated Discharge for Points along Chorro and Los Osos Creeks for Events of Different Magnitudes.

	2-year event Discharge, cfs		5-year event Discharge, cfs		10-year event Discharge, cfs		25-year event Discharge, cfs		50-year event Discharge, cfs		100-year event Discharge, cfs	
Basin	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
Chorro Ck												
At Highway 1	52	15	340	77	779	162	1,763	349	2,865	521	4,341	773
At Mouth (below Twin Bridge)		1,476		4,588		8,640		16,669		25,210		35,390
Los Osos Ck.												
At Upstream Gage	34	9	237	42	603	91	1,479	203	2,420	307	3,625	462
At Mouth (below Warden Ck.)		84		566		1,374		3,245		5,299		7,994

Source: Tetra Tech, 1998a, Table 4, p. 8, Table 8, p. 16, Table 11, p. 18.

2.5 Sedimentation in Morro Bay

2.5.1 Background Erosion

Background erosion is considered to be erosion that occurs in the absence of human influence on the ecosystem. Disturbance in the drainage area has been significant and the Soil Conservation Service conservatively estimates that half of the erosion in the watershed is accelerated erosion (USDA, SCS, 1989b. p. 31).

The first significant land use change that occurred in the watershed was the introduction of domestic grazing animals (USDA, SCS, 1989a, p. 8). During the 1800s, a drought and associated land use changes shaped the ownership patterns that still exist today. Dairies and crops were established along the valley floor, and creeks were rerouted to allow for roads, residences, and crop production.

The SCS indicates that agricultural practices and estimated soil erosion rates in the watershed are comparable to other areas in California. However, the relatively shallow initial conditions of Morro Bay and the fact that its configuration makes it an effective sediment trap indicates that an effective upstream sediment control program is required to prolong the life of the Bay (Haltiner, 1988, p. 9).

2.5.2 Estimates of Sediment Loading

The loss of Bay volume has been caused primarily by creek-born sediment transport (Haltiner, 1989, p. 6). Sedimentation at the harbor entrance is dominated by ocean transport, or longshore transport, whereas sedimentation in the southern and eastern Bay is dominated by fluvial or river transport. Wind is also a factor, as a good deal of sand is naturally deposited within the estuary as winds blow across the sandspit. From 1935 to 1987, the spit migrated 90 feet landward, translating into a 30-acre loss of Bay mudflats (Josselyn, 1989, p. 7).

Due to major changes in land use in the 1800's, the rate of sediment delivery to Morro Bay between 1890 and 1935 was estimated to have been as much as 57,033 tons per year. Between 1935 and 1986, the rate decreased to an estimated 46,894 tons per year, due to improved land use practices, agricultural methods, and the creek system regaining balance after changes in the watershed (USDA, SCS, 1989a, p. 9). In 1998, Tetra Tech estimated that the average annual sediment load to the Bay is 70,246 tons per year (1998a, p. 25). This estimate is one and a half times greater than that estimated by SCS in 1989, in part because the SCS study area excluded the headwaters of Chorro Creek and its tributaries. Ten percent of this total loading is sand and gravel, and 90 percent is fine material such as clay and silt particles (Ibid.). (See *Source Analysis* for more information on development of these estimates.)

2.5.3 Bathymetry and Sediment Flushing

The ultimate fate of sediment delivered to Morro Bay depends on the circulation and flushing that occur there. Sediment fate is influenced by two mechanisms, tides and freshwater inflows. The primary mechanism is tidal exchange with the Pacific Ocean through the open entrance to Morro Bay. The contours of the Bay bottom—its bathymetry—are an expression of these mechanisms' capacity to move sediment out of the Bay and into the Pacific Ocean. Measurements of bathymetry combined with total water area, permit calculations of total Bay volume at varying depths, and of tidal prism. These are discussed below to demonstrate the observed trend of increasing sedimentation in Morro Bay.

According to Haltiner, Morro Bay has lost 25 percent of its total volume in the last 100 years, with some areas showing greater decreases (1998, p. 6). Haltiner estimated that under "normal" circumstances, the Bay would naturally fill in with sediment in several thousand years but, if the present accelerated rates continue, open water areas would fill in within the next 300 years (Ibid., p. 45).

In 1998, Tetra Tech conducted a bathymetric survey and developed a Tidal Circulation model for the MBNEP. The general bathymetry of the Bay consists of extensive areas of mudflats with little variation in slope, and steep-sided channels +that cut through the mudflats (Figure 2). The depth and width of these channels show considerable variability. Tables 3 and 4 include historic acreage and volume at various depths in the Bay.

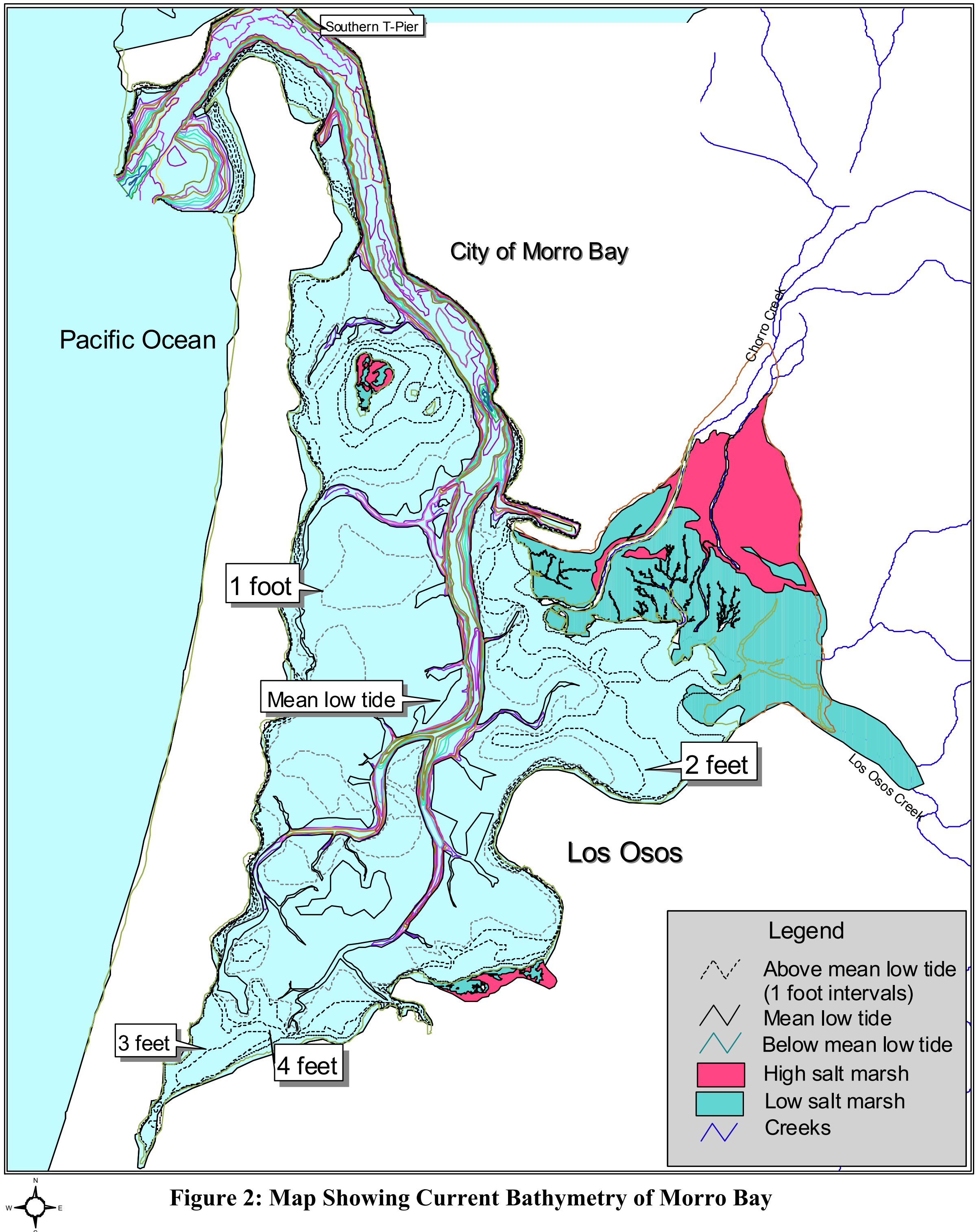

Figure 2: Map Showing Current Bathymetry of Morro Bay

Source: Tetra Tech Bathymetry Survey 1999 as presented in MBNEP, 2000.

Table 3. Hyposometric (Area vs. Depth) Data Summary for Morro Bay, 1884 to 1998.

Height above Mean Low Low Water (MLLW) (feet)		1998	1987	1935	1919	1884	Change in Area 1884-1998
		Cumulative Area (acres)					
5	High Tide (MHHW)	2,024					
4	Mean High Water (MHW)	1,897	1,891				
3		1,697	1,805	2,158	2,155	2,240	-15%
2		1,475	1,521	2,001	1,900	2,110	
1	Mean Low Tide (MLW)	1,147	1,155	1,733	1,743	1,985	-26%
0	Low Tide (MLLW)	523	629	1,423	1,455	1,697	-32%
-1	Extreme Low Tide	388	361	907	1,047	1,255	-58%
-2		358	315	673	780	955	-59%
-3		336	287	267	350	592	
-4		318		221	249	255	
-5		301					

Source: Adapted from: Table B-2, Tetra Tech, 1999b.

Table 4. Adjusted Volume-Depth Relationship for Morro Bay, 1884-1998.

Height above Mean Low Low Water (MLLW) (feet)		1998	1987	1935	1919	1884	Changes in Volume
		Cumulative Adjusted Volume (acre-feet)					
5	Mean High High Water (MHHW)	11,884					
4	Mean High Water (MHW)	9,923	9,316	10,516	11,216	12,216	-19%
3		8,126	7,616	8,516	9,316	10,216	-20%
2		6,540	6,116	6,716	7,416	8,116	-19%
1	Mean Low Tide (MLW)	5,229	5,016	5,416	5,916	6,416	-18%
0	Low Tide (MLLW)	4,394	4,316	4,516	4,816	5,116	-14%
-1	Extreme Low Tide	3,939	3,916	3,816	4,116	4,116	-4%
-2		3,566	3,566	3,416	3,666	3,516	1%

Adapted from Table B-4b, Tetra Tech, 1999b).

By comparing the 1998 bathymetry survey data with the historical estimate of 1884 water depths, Tetra Tech determined the following:

Area

- The entire area of Morro Bay at high tide has decreased by approximately 15 percent to about 2,024 acres.
- The area covered by water at low tide has decreased by 60 percent to 523 acres in 1998.

Volume

- The volume of water in Morro Bay at MHW has decreased by approximately 20 to 25 percent or 2,000 acre-feet.
- The decrease of volume of water in Morro Bay at MLW is approximately 18 to 22 percent or 1,200 acre-feet.

- Volume of water below –1 ft MLLW, which approximates the smallest volume of water remaining in the Bay during an extreme low tide, has remained relatively constant, decreasing by five percent, which is probably less than the accuracy of the assumptions and measurements used in the calculations (Tetra Tech, 1999b, p. B-15).

These results imply that encroachment from the margins and aggradation of the shallowest areas within the Bay are the processes causing the decrease in volume (Tetra Tech, 1999b. p. B-19).

Tidal Prism

The tidal prism is defined as the difference between the mean high water volume and the mean low water volume in an estuary. The volume of the tidal prism relative to the total volume of the Bay influences the flushing characteristics, tidal current speeds and the sediment transport and scouring characteristic of tidal currents. The decrease of tidal prism volume in Morro Bay between 1881 and 1998 is equivalent to a 20 percent to 30 percent reduction (Ibid.).

2.5.3.1 Flushing and Circulation

Tetra Tech developed a model to determine which areas of Morro Bay are susceptible to poor flushing under different flow conditions in Chorro and Los Osos Creeks (Tetra Tech, 1999b). The three stream flow rates included a low-flow condition typical of summer, a medium-flow rate of 64 cfs at Chorro Creeks and 3.3 cfs at Los Osos Creek, and an extreme high-flow rate of 1,146 cfs at Chorro Creek and 203 cfs at Los Osos Creek.

For the low- and medium-flow conditions, the model predicted that the least flushing occurs in the southwest portion of the Bay and inside the State Park Marina with flushing half-life times ranging from approximately 9 to 18 days. The high-flow simulation indicated extremely fast flushing throughout the Bay with a maximum half-life of seven days in the extreme southwest corner of the Bay. The Bay-wide average flushing half-life times for the low-flow, medium-flow, and high-flow conditions are 4.2 days, 3.2 days, and 1.1 days, respectively.

The simulations developed by Tetra Tech indicate that the freshwater flows from Chorro Creek and Los Osos Creek have a significant effect on flushing in Morro Bay. During the low-flow conditions that persist through summer, the Bay—in particular the southwest portion—is susceptible to a build up of pollutants, including sediment (Tetra Tech, 1999b, p. 5-2).

Tidal influence and effects from the Morro Bay Power Plant are localized to the mouth of the Bay. Sediment has been observed to collect in front of the Morro Bay Power Plant seawater intakes. Approximately 5,000 cubic yards of sediment is dredged from in front of the Morro Bay Power Plant intake every five to ten years (Jay, 2000, p. 4). The distinction between processes occurring in the interior and at the mouth of the Bay are reflected in the type of material accumulating, which—aside from aoelian input of sand—are primarily silts and clays of fluvial origin, as opposed to the sand dominated sediments found at the mouth of the Bay (Ibid.). Therefore, tidal transport of sediment, human alterations at the mouth of the Bay, and Morro Bay Power Plant intake influences are secondary relative to the load from the creeks.

It is likely that structural changes to the mouth of the estuary, in addition to the dynamics of outgoing tidal velocity and incoming sediment transport, have altered the dynamics of sand dominated transport at the mouth of the estuary. From 1941 to 1946 the Army Crops of Engineers dredged the Bay to create navigation channels and constructed breakwaters, a dike extending 1600 feet from Morro Rock to the main land, a stone groin and a revetment. It has not been quantified how these structural changes have specifically altered flushing dynamics in the estuary, but the rate of dredging has increased from an average of every five years between 1944-1975 to every two or three years currently (Noda and Jen, 1975).

2.5.4 Sedimentation in Chorro and Los Osos Creek Watersheds

Several factors have affected the channels of Chorro and Los Osos Creeks over the years, including accelerated erosion within the watershed from land uses, replacement of Twin Bridges, building of levees, and subsequent dredging. These alterations have affected not only the downstream portions of the creeks, but also reaches several miles above the mouth. Aggradation (an increase in sedimentation resulting in raised streambed elevations) in the lower reaches of Chorro and Los Osos creeks has reduced the capacity of these creeks to transport coarse sediments. Rather than only building outward into the Bay, the portion of the delta adjacent to Chorro Creek is now building upward. Major portions of the delta have been raised two to three feet as a result of channel overtopping and sediment deposition during major floods. However, with bayward expansion of the delta, Chorro and Los Osos Creek channels have become longer with a flatter slope, which in turn increases sedimentation in the channel because of decreased flow velocities. There is evidence of up to seven feet of channel aggradation in Chorro Creek, and similar amounts in Los Osos Creek (Josselyn, Los Huertos, 1991, pp.7, 9).

The changes due to increased sedimentation are most evident in the delta formed by Chorro and Los Osos Creeks and in the southern portion of the Bay in general. Accumulated sediment has caused the creek bottom at South Bay Boulevard to rise over 13 feet in the last 50 years (Haltiner, 1989). Increased deposition of coarse sediment in the vicinity of the crossing of South Bay Boulevard over Chorro Creek required the replacement of Twin Bridges—a multimillion-dollar undertaking.

As part of the National Monitoring Program, Regional Board staff and volunteers conducted quantitative analyses of streambed sediments in the two major streams and in several of their tributaries. While these data do not provide a baseline for comparing numeric targets for fish gravel, they do provide a description of surface particles in the creeks and point to significant differences in the sediment regimes of the subwatersheds.

Regional Board staff analyzed surface particle sizes in Chorro Creek and in Dairy Creek and Pennington Creek subwatersheds collected between 1993 and 1997. In Chorro Creek just downstream from the reservoir, the average dominant particle size found in five transects was 33.5 mm. Average surface particle sizes at Dairy Creek and Pennington Creek were 15.25 mm and 12.75 mm, respectively. Data collected during the 1994 sampling period were omitted from the analysis as they included values much lower than in other years, possibly an outcome of the Highway 41 Fire (CCRWQCB, 2002b).

Regional Board staff also performed a qualitative Habitat Assessment, which included an evaluation of bottom substrate and embeddedness using California Department of Fish and Games's Rapid Bioassessment protocols (1993, 1995, 1996). Results from 1993-1999 assessments show that average scores in the upper reaches of Chorro Creek, the Clark Canyon branch of Los Osos Creek, and Dairy Creek were similar (Ibid.). Bottom substrate scores were "sub-optimal" with scores between 10 and 20 percent fines. Embeddedness was "sub-optimal", with gravel, cobble and boulder particles between 25 and 50 percent surrounded by fine sediment (particles less than 6.35 mm).

Regional Board staff also found that Pennington Creek had the best scores, with "optimal" embeddedness of 0 to 25 percent. Average Pennington Creek bottom substrate scores were between 10 and 20 percent fines. Regional Board staff found that the Warden branch of Los Osos Creek and the lower reaches of Chorro Creek (near Chorro Flats) were "marginal", with average bottom substrate values between 20 and 50 percent fines and embeddedness between 50 and 75 percent surrounded by fine sediment (Ibid.).

2.5.5 Highway-41 Fire of 1994

The Highway 41 Fire began on August 14, 1994 and burned a total of 16,850 acres in the headwaters of all the major tributaries within the Chorro Creek watershed (USDA, Forest Service, 1994, P.1). According to the SCS (1989a), an even-aged plant community created an environment with a high fire potential in the northern brushland portions of the watershed. Table 5 shows total acres within each watershed and the area burned. Heavy rains followed the fire, producing flooding in the winter of 1994/95. Extremely high turbidity levels and suspended sediment concentrations resulted from erosion in the upper watershed (CCRWQCB, 1998, p. 30).

Table 5. Area Burned During Highway-41 Fire.

Watershed	Total Acres	Acres Burned	% Burned
San Bernardo Creek	5,424	3,920	72%
San Luisito Creek	5,400	2,166	40%
Pennington Creek	1,922	775	40%
Dairy Creek	1,804	627	35%
Upper Chorro Creek	2,300	36	2%
Total	**16,850**	**7,524**	**45%**

Source: USDA, Forest Service, 1994, p.1

2.6 Impacts to Beneficial Uses

Excessive sedimentation in Chorro Creek, Los Osos Creek, and the Morro Bay Estuary has impacted many of the beneficial uses of these waterbodies. The following describes the nature of the impairment to the extent it has been documented.

2.6.1 Fish and Wildlife (RARE, MIGR, SPWN, WILD)

Among the numerous species of fish and wildlife that occur in the Morro Bay Watershed, there are several endangered, threatened, or special status species (Table 6).

Table 6. Special Status Species Dependent on Morro Bay Estuary and Watershed

Species	State Status	Federal Status
Brown pelican	Endangered	Endangered
California black rail	Threatened	
California clapper rail	Endangered	Threatened
California red-legged frog		Threatened
California sea-blite		Endangered
Chorro Creek bog thistle	Endangered	Endangered
Cuesta Grade checkerbloom	Rare	
Indian Knob mountainbalm	Endangered	Endangered
Least Bell's vireo	Endangered	Endangered
Morro Bay kangaroo rat	Endangered	Endangered
Morro Manzanita		Threatened
Morro Bay shoulderband snail		Endangered
Salt marsh bird's beak	Endangered	Endangered
Southern sea otter		Threatened
Southern steelhead trout		Threatened
Southwestern Willow Flycatcher		Endangered
Swainson's Hawk	Threatened	
Tidewater goby		Endangered
Western snowy plover		Threatened

Source: MBNEP, 2000, pp. 3-25, 3-26, Table 3-4.

The effects of sedimentation on fish and wildlife typically derive from the alteration of their habitat (further discussion of habitat alterations follows this section). Indeed, the sedimentation-induced shift in estuarine habitat from subtidal to intertidal has most likely resulted in a change in the types of fish and wildlife found in Morro Bay (Josselyn, et al, 1989, p. 15). However, attempting to relate species population trends to sedimentation is difficult, since the lack of biological data on Morro Bay during the period of most rapid sedimentation makes historic comparisons impossible (Ibid., pp. 12, 21). Additionally, it is difficult to isolate the effects of sedimentation from other factors affecting species abundance and diversity, including the effects of urban development, invasive species, and, perhaps most importantly for aquatic species, freshwater diversion and pumping. Nevertheless, the susceptibility of some species to the deleterious effects of excessive sedimentation is known, and in certain cases actual effects have been observed in Morro Bay and its tributaries.

2.6.1.1 Fish

The Tidewater goby (*Eucyclogobius newberryi*) is a species of special concern in the State and a federally listed endangered species. Its presence in Los Osos and Chorro Creeks was recorded in 1970, 1976, 1981, and 1989. However, no tidewater gobies were collected during a 1998 survey (Ibid., 1989, p. 11; Tetra-Tech, 1999a, p. 4-17). These fish have a short life cycle (usually one year) and specialized habitat requirements. In Morro Bay their primary habitats are the creek mouths. However, siltation occurs at these locations and silt has filled in pools and greatly reduced aquatic habitat during low flow periods (Worcester, 1992, p. 8.1-5).

On August 18, 1997, the National Marine Fisheries Service published a final rule listing the Central California Coast and South/Central California Coast steelhead (*Oncorhynchus mykiss*) Evolutionary Significant Units (ESUs) as threatened species under the Endangered Species Act. While known to occur in Morro Bay, particularly in Chorro and Los Osos Creeks, steelhead were not collected in fish sampling conducted in 1999, as care was taken to avoid sampling in areas where this protected species was more likely to occur (e.g., shaded pools) (Tetra-Tech 1999a, p. 4-17).

The historical significance of the Morro Bay Watershed as a steelhead fishery is shown through the California Department of Fish and Game (DFG) habitat conditions survey on Chorro Creek in 1976. DFG found that between Canet Road and the Chorro Creek reservoir, the creek provided a significant percentage of the summer nursery habitat for steelhead and sustained about 60 percent of the juvenile steelhead populations (Chappell, 1976).

Morro Bay Estuary and Los Osos and Chorro Creeks' ability to support fish populations is determined by habitat availability and quality. Habitat availability is limited by streamflow, stream gradients, and physical barriers. Habitat quality is limited by channel bottom composition, pool structure, water temperature, pH, dissolved oxygen, food supply, and predation. However, this TMDL only addresses habitat quality impacts associated with excessive sedimentation. The key habitat problems in Morro Bay Estuary and Los Osos and Chorro Creeks associated with sedimentation appear to be pool quality, gravel quality (for spawning and food production), and changes in channel structure. The discussion of these specific impacts of sediment follows in section 6.6.2. Freshwater Habitat.

2.6.1.2 Reptiles and Amphibians

Reptiles and amphibians have been similarly affected by the sedimentation that has affected fish. Red-legged frogs (*Rana aurora draytoni*) are known from at least two locations on Chorro Creek and its tributaries. They are found on the lower portions of watersheds, where lower creek gradients produce slower, deeper flows. Quiet, moderately deep pools with dense, overhanging vegetation is their ideal habitat. Much of the lower watersheds of Los Osos and Chorro Creeks are impacted by siltation, reducing the available habitat for red-legged frogs (Worcester, 1992, p. 8.1-5).

The western pond turtle's (*Clemmys marmorata pallida*) aquatic habitat requirements are somewhat similar to that of the red-legged frog. Pond turtles are found in permanent pool areas of Chorro Creek with abundant underwater cover, including tangles of roots and submerged logs. They require standing or slow-moving water that forms pools about three feet deep and six feet in diameter with adequate bank cover. A reduction in surface water elevation resulting from a decreased flow rate will reduce the pools' suitability (Marshall, 1995, pp. 3, 6).

2.6.1.3 Birds

Coastal brackish marsh, a sensitive habitat present at the mouths of the creeks, is being rapidly lost due to sedimentation. This affects rare and/or endangered species such as salt marsh bird's peak, the California brackish water snail, and the California black rail (MBNEP, 2000, p. 5-4).

2.6.2 Freshwater Habitat (COLD, WARM)

Chorro and Los Osos Creeks serve an important role as warm and cold freshwater habitat for the spawning, reproduction, and early development of rare, threatened or endangered species of aquatic organisms. Aquatic vegetation, fish, and bottom dwelling organisms can be smothered by excessive sedimentation, both in the estuary and in adjacent tributaries. However quantitative data that document the level of impairment in Morro Bay are limited.

2.6.2.1 Riparian Habitat

Riparian habitat exists in corridors along creeks and includes tall overstory trees, shrubby vegetation, and understory grasses and forbs. These areas provide nesting, feeding and cover habitat for a number of birds, mammals, and other species, and serve as wildlife corridors for migratory animals (Ibid., p. 3-20). There are 147 acres of riparian habitat in the lower 1-mile reach of both Chorro and Los Osos Creeks (Tetra Tech, 1999a, p. 5-19).

2.6.2.2 Elevated Turbidity and Suspended Sediment

Elevated turbidity and suspended solids can result in decreased light penetration through the water column, impacting aquatic plants such as eelgrass and the organisms dependent on them. Potential effects on fish swimming directly in water in which solids are suspended, include: alarm reaction, increased morbidity (reduced resistance to disease, abrasion of gill tissue) and increased mortality. Turbidity can also affect the efficiency of methods for catching prey, reducing the catch per unit effort (Newcombe, 1997, p. 6). It is possible to relate severity of ill effect to concentration of suspended sediment and duration of exposure in: all life stages of salmonids, adult estuarine and freshwater nonsalmonids, freshwater invertebrates and freshwater flora (ibid. p. 8). However, data describing these effects specifically in Morro Bay and its tributaries are not available.

2.6.2.3 Fine Sediment in Spawning Gravels

As described above, sedimentation can affect the steelhead's freshwater habitat and interfere with the reproductive process when fine materials being deposited smother the gravel beds that are critical for spawning. Sediment can also fill the deep pools that smolts need to survive dry periods. Eroding gravel banks provide a source of spawning gravels for a stream, but erosion of fine-textured soils that contain clays, silts, and fine sands, can reduce habitat quality for fish.

Steelhead use the Chorro Creek drainage as adult spawning habitat and as nursery habitat for hatchlings and juveniles maturing toward their seaward migration. During winter and spring months when stream flows reach sufficient magnitude, steelhead migrate from Morro Bay into Chorro Creek and its tributaries. They require clean gravel substrate and clear swift-flowing waters for spawning. They also require deep pools for the young fish to feed and grow while protected from predators. Juveniles will remain in these nursery areas for one or two years (Marshall, 1995, exhibit 95-4, pp. 2, 3). Sedimentation within streams fills deep pools on which smolt depend during low flow periods (Josselyn, 1989, p. 11).

Regional Board staff found no spawning gravel surveys for Chorro and Los Osos Creeks. Nevertheless, the excessive sedimentation described by numerous authors suggests that many potential spawning areas are buried by fine sediment (Josselyn, et al., 1989, Marshall, 1995, Tetra-Tech, 1999a, Worcester, 1992). Fine sediment in spawning gravels has several effects on fish survival, including: 1) cementing them in place and reducing their viability as spawning substrate, 2) reducing the oxygen available to fish embryos, 3) reducing intragravel water velocities and the delivery of nutrients to and waste material from the interior of the redd (salmon nest), 4) and impairing the ability of young salmon to emerge as free-swimming fish (Kondolf, 2000. p. 265, 266). This statement relates to the SPAWN beneficial use and the potential for settleable material to affect spawning redds. Increased suspended sediment can also result in direct impacts to fish by clogging their gills (Reiser, Bjornn, 1979).

Visual observations on Chorro Creek indicate that the upper reaches are 0-25 percent embedded in fines, while smaller tributary streams are between 25-50 percent surrounded by fine particles. No data has been collected for Los Osos Creek.

2.6.2.4 Lack of Suitable Pools for Rearing Habitat

Pools in Chorro Creek potentially suitable as rearing habitat are impacted by fine and coarse sediment. Sedimentation in pools 1) reduces the volume of available rearing habitat by filling in pools and burying pool-forming structural elements such as large woody debris, 2) reduces pool depth and therefore the cool water refuge associated with temperature stratification, 3) reduces the availability of fish cover as a result of decreased depths and the burial of large woody debris and other structural elements, and 4) causes loss of surface flow as pools are filled in resulting in less available habitat and protection from predators. This statement relates to the SPAWN and COLD beneficial uses and the potential for sediment and settleable material to impact rearing habitat.

2.6.2.5 Channel Aggradation and Stream Channel Instability

In addition to these primary effects on steelhead and their habitat, several secondary effects on freshwater habitat for other species including western pond turtle, and red-legged frog have been observed in Chorro and Los Osos Creeks. For example, observed channel aggradation (Josselyn, et al., 1989, Worcester, 1992, Marshall, 1995) results in the burial of large woody debris and other structural elements, a loss of the stream's ability to effectively sort gravel, and a potential reduction in the dominant particle sizes. This statement relates to the COLD and EST beneficial uses and the potential for sediment to impact stream channel stability and habitat niches.

2.6.3 Estuarine and Marine Habitat (EST, MAR, BIOL)

The estuarine habitat of Morro Bay includes coastal wetlands such as salt and brackish tidal marshes, and intertidal flats, as well as deepwater channels, and coastal streams. This "estuarine system" can be defined as consisting of deepwater tidal habitat and adjacent tidal wetlands that are semi-enclosed by land but have access to the open ocean, and in which ocean water is diluted by freshwater runoff from the land (MBNEP, 2000. p. 3-1). Table 7 presents reported areal extent of the estuarine and riparian habitats of Morro Bay. In addition to these dominant wetland types, between 55 and 80 acres of brackish marsh and between 28 and 35 acres of freshwater marsh were identified in previous studies (Josselyn et al, 1989, p. 7, and MBNEP, 2000, p. 3-19).

Table 7. Areal Extent of Estuarine Habitat in Acres Reported by Various Investigators

	Haydock 1960	*Josselyn, et al 1989*	*Chesnut 1996*	*Chesnut 1999*	*Tetra Tech 1999*	*Chesnut 1999*	*Chesnut 2000*
Sampling Period	June-August	September	September	Spring, 1997	June, 1998	September, 1998	November, 1999
Eelgrass	335	723	458	50	81	120	400
Mudflat					1,319		
Salt Marsh		412 (Within State Park) 140 (Outside State Park)			436		

Source: Tetra-Tech 1999a, Table 6-1. p. 6-2; except: Chesnut 1999, and Chesnut, 2000, Josselyn, p.18.

The observed larger trend in Morro Bay is a sedimentation-induced shift in estuarine habitat from subtidal to intertidal, expressed as an increasing area of salt marsh, and decreasing deeper water areas supporting eelgrass (Josselyn, et al, 1989, p. 15). Additionally, riparian areas at the mouths of Chorro and Los Osos Creeks may be increasing (MBNEP, 2000, p. 5-3). At the same time, more localized alterations to habitat are evident as well. For example, the Chorro Creek delta salt marsh has experienced an invasion of brackish and freshwater exotic species along the Creek's natural levees.

Shoaling and net increases in sediment alter substrate elevations and water levels, which significantly affect the extent of any single wetland type. For example, as the potential growth area for eelgrass at or near Mean Low Low Water experiences increased shoaling, its potential habitat decreases (MBNEP, 2000, p. 3-14).

2.6.3.1 Loss of Eelgrass Habitat

Dense stands of eelgrass (*Zostera*) form meadow-like beds in the lower intertidal zone of the Morro Bay Estuary. Eelgrass is a perennial, submersed marine aquatic plant that usually grows from rhizomes, or root shoots. Eelgrass beds serve as spawning and nursery grounds for many species in the estuary and marine environment. The eelgrass beds in Morro Bay are known as the largest and least impacted of any in Central or Southern California (Chesnut 1999). They are the most significant of their kind available to wintering populations of the Black brant (*Branta bernicla nigricans*) in central and southern California. The density and diversity of benthic fauna are several times greater within the eelgrass beds than in other Morro Bay habitats (MBNEP, 2000. p. 3-7).

Estimates of eelgrass populations (or habitat range) in the Bay have fluctuated widely. Some fluctuations are due to natural variability, however, impacts to this habitat from sediment have also been evident. Prior to 1997, published estimates of eelgrass habitat ranged from 335 to 732 acres. Then, in the spring of 1997, eelgrass distribution was found to be as low as 50 acres (Chesnut, 1999, p. 1). This well documented decline coincides with the winter following the destructive Highway 41 fire in 1994, and the concurrent end of the 1990's drought cycle (Ibid.). Tetra Tech identified 81 acres of eelgrass in Morro Bay, but some "sparse" beds as defined by other researchers were not included in that analysis (Tetra Tech, 1999a, p. 6-2). In addition, the timing of the surveys (spring) was not optimal for the eelgrass resource. Chesnut mapped about 120 acres in September of 1998 (1999, p. 20). By November of 1999, the resource had recovered to its more typical acreage, as evidenced by sampling and maps prepared by Chesnut (Ibid.). About 400 acres of eelgrass were documented in that report.

In addition to the effects of shoaling and increased sedimentation on substrate depths, suspended and resuspended fine sediments and resultant reduced water clarity may also affect the distribution and extent of eelgrass beds in Morro Bay (Tetra Tech 1999a, p. 6-7). Increased turbidity from sediment loads combined with excess nitrogen and phosphorous may result in unbalanced algal growth that clouds the water.

2.6.4 Summary of Biological Beneficial Use Impacts

Sedimentation is not the only stressor affecting the biological integrity of Morro Bay. However, the effects of sedimentation are the subject of this TMDL and can be summarized as principally affecting habitat quantity and quality. Table 8 describes the impacts to habitat in qualitative terms.

Table 8. Summary of impacts to habitats associated with sedimentation in Morro Bay.

HABITAT	IMPACT
Saltmarsh	Expansion of salt marsh. Siltation in upper reaches.
Mudflat	Loss of mudflat due to salt marsh expansion. Increased mudflat area in south bay. Reduction in tidal prism.
Eelgrass	Siltation of eelgrass and reduction in potential area for colonization by eelgrass.
Subtidal Soft Bottom	Siltation of channels.
Riparian	Siltation within riparian habitat. Invasion of exotic and upland species. Reduction of flood plain. Loss of anadromous fish habitat.

Source: adapted from Josselyn, et al., 1989, Table 1.

Josselyn described the impacts to biological resources in Morro Bay as follows (1989, pp.30-31):

1. Degradation of stream bottom and brackish marsh habitat due to sedimentation from Chorro and Los Osos Creeks.
2. Invasion by undesirable exotics within the riparian zone due to an increase in elevation and frequency of disturbance.
3. Loss of steelhead and tidewater goby habitat within the upper tidal limits of Chorro Creek due to filling of deep-water pools by sediment. Decline in summer stream flows also contributes to habitat degradation for these species.
4. Historic loss of the potential area that could support eelgrass.
5. Decline in some species (i.e., Brant) dependent on eelgrass beds, though this conclusion is compounded by influences outside Morro Bay.
6. Greatest historic reduction of acreage is at elevations, which support mudflats and eelgrass beds near the MLLW datum. This is the area in which many of the Bay's fish and wildlife resources either forage or find suitable habitat.
7. Any declines in eelgrass beds in the future will likely lead to the decrease in fish and waterfowl utilization of Morro Bay especially in the case of catastrophic sedimentation events.

2.6.5 Water Contact and Non-Contact Recreation, Navigation (REC1, REC2, NAV)

The Bay is an important recreational area. Sedimentation has impacted recreational activities such as kayaking, boating, and wind surfing in that the area and volumes of water in the Bay available for these activities have decreased. Furthermore, the area of the mudflats exposed during periods of low tide has further limited navigation during lower tides.

2.6.6 Shellfish Harvesting, Aquaculture, and Commercial and Sport Fishing (SHELL, AQUA, COMM)

One local oyster grower reported $30,000 in lost revenue following the Highway 41 fire and winter storms (Williams Shellfish Farms, 1998). While the mechanism by which sedimentation can affect shellfish deleteriously is understood, beyond such reports, there has been no documentation of these effects in Morro Bay. Most commercial fishing in this area is conducted outside the Morro Bay Estuary and there has been no documentation of the affects of sedimentation in the Estuary on commercial fishing.

2.6.7 Industrial (IND)

The Morro Bay Power Plant is located on the north end of Morro Bay and is operated by Duke Energy of Charlotte, North Carolina. The power plant's interaction with the Estuary is primarily through its use of seawater. The plant's boilers use natural gas to create steam to drive turbines that in turn drive electrical generators. The plant pumps seawater (limited to 725 MGD) from its intake structure located near the northernmost end of Morro Bay. The seawater passes through the condensers and is discharged into Estero Bay via tunnels and a canal at the base of Morro Rock. The Regional Board through a National Pollution Discharge Elimination System (NPDES) permit (MBNEP, 2000, pp. 2-12, 2-13) governs the plant's discharge, and its use of seawater.

The plant has experienced direct impacts due to the high turbidity in the Bay primarily from sediment suspended during dredging operations. During periods of elevated turbidity, the intake water plugs the seawater/heat exchangers resulting in costly repairs and maintenance (Lott, 2000).

2.6.8 Municipal, Agricultural Supply, Freshwater Replenishment (MUN, AGR, FRESH)

These beneficial uses of the Morro Bay Estuary and Chorro and Los Osos Creeks are not currently affected by sedimentation.

3. Source Analysis

3.1 General Overview

The purpose of this source analysis is to characterize the types, magnitudes and locations of sources of sediment loading to Morro Bay and to Chorro and Los Osos Creeks. Sediment sources are discussed in terms of the quantities they generate, the types of erosion causing them, and the types of land use from which they derive. A discussion of the methods (*Section 3.2*) by which these loads were calculated precedes the presentation of quantities contributed by source (*Section 3.3*).

This source analysis only considers sediment delivered to listed waterbodies through fluvial transport from erosion sources. Other sources, including sand blown in from the barrier beach west of the Bay, and ocean sediments carried into the Bay by tidal currents, are not considered. Ocean sedimentation is not caused by anthropogenic activities that can be controlled by the TMDL's Implementation Plan. Barrier beach sands are deposited into Morro Bay through natural aeolian transport. While researchers believe this process is accelerated by anthropogenic disturbance of dune vegetation, the effects thus far appear to be minor in comparison with the natural process (Haltiner, 1988, p. 74). For this reason, the source analysis includes no estimates of the contribution of barrier beach sand to deposition in Morro Bay.

3.2 Methods

This discussion describes the methods used to calculate 1) quantities of sediment produced annually by the subwatersheds of Morro Bay, 2) quantities from certain types of erosion in the subwatersheds, and 3) quantities derived from sheet and rill erosion—the dominant erosion type—in different land uses. While intermediate calculations are presented in this section, the end results of these methods are discussed below in *Section C. Relative Contributions.*

3.2.1 Base Load Estimation Methods

This section describes the several steps required to calculate base loads. Tetra Tech delineated subwatersheds, generated flow statistics, and constructed a sediment yield model based on the Universal Soil Loss Equation.

Characteristics of the watershed important in sediment yield calculations include soil erodibility, the size and classification of material in the top layers of soil, the vegetative cover, land use practices, the slope and typical length of overland flow of rainfall runoff, and the local runoff. For the base load estimates developed by Tetra Tech for the Morro Bay Watershed, this information was obtained from available maps and from an available rainfall-runoff model. The information was combined with measured flow and sediment concentration data to calibrate a sediment yield model for two subwatersheds in the Chorro Creek Watershed. These two subwatersheds, Walters Creek and Chumash Creek, are gaged as part of an ongoing paired watershed study, being conducted by Cal Poly and the Regional Board. The results of the calibrated model were then extrapolated to remaining portions of the Chorro Creek and Los Osos Creek watersheds taking into account variations in local soils, topographic and hydrologic factors as well as sediment trapping characteristics of Chorro Reservoir. Tetra Tech then validated this procedure by comparing expected sediment concentrations with measured sediment concentrations at the mouth of Chorro Creek during the 1997 water year (1998a. p. 5).

The results of the model are expressed in tons of sediment per storm event, for storm events that could occur at frequencies of 2, 5, 10, 25, 50, and 100 years. Calculating a weighted average of these quantities allows the results to be expressed in tons/year—units that are the basis of total maximum annual loads. A more detailed description of the models follows.

3.2.1.1 Subwatershed Delineation

Load estimates were developed for subwatersheds within the Los Osos and Chorro Creek watersheds. These subwatersheds were identified using USGS quadrangle maps and represent areas of common characteristics (overland slope, drainage density). The entire Morro Bay Watershed was divided into 70 subbasins, including 54 in Chorro Creek and 16 in Los Osos Creek. These were then grouped into the major tributaries identified below (Table 9) (Tetra Tech, 1998b). Figure 3 illustrates the major subwatersheds of the Morro Bay Watershed.

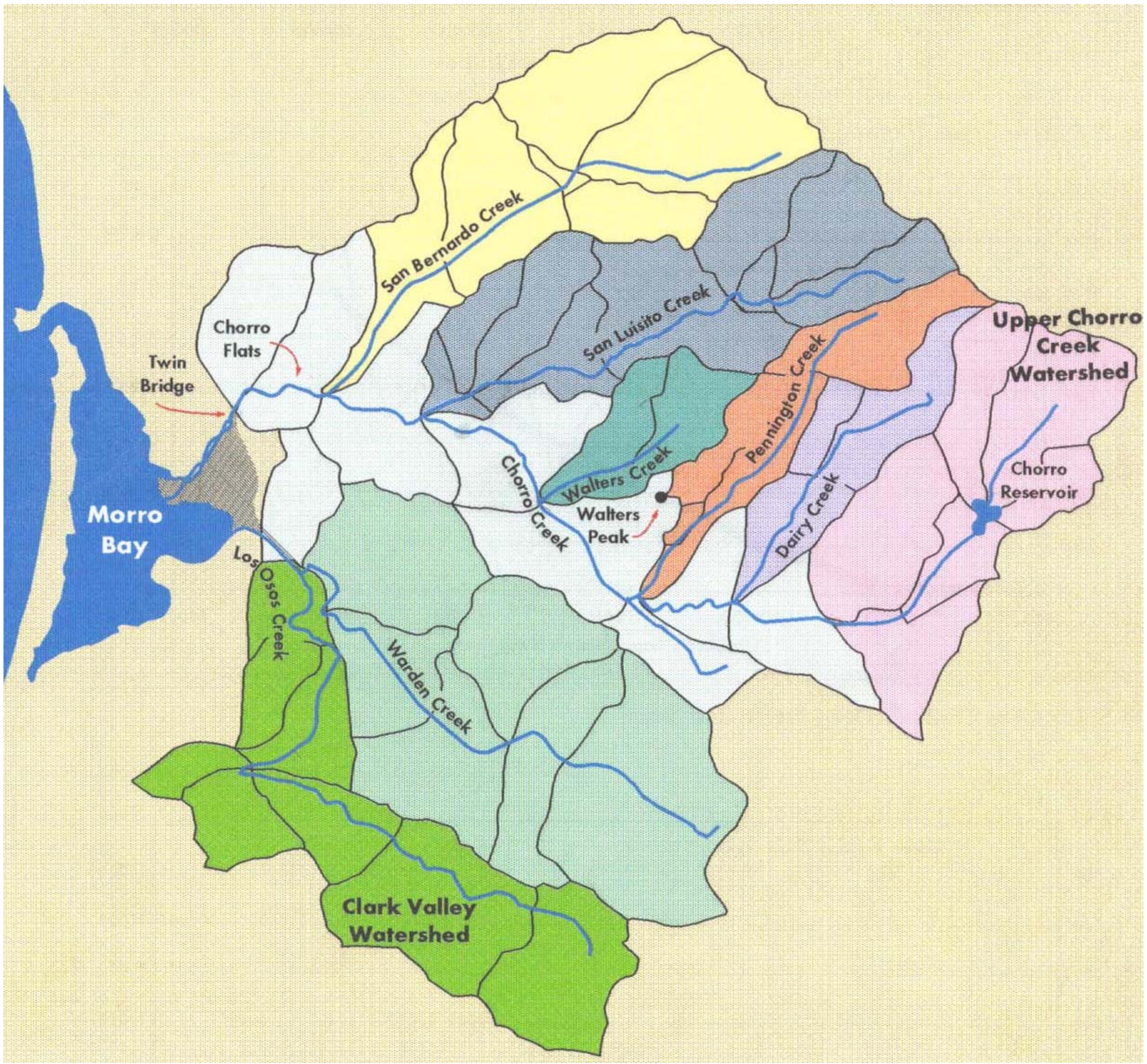

Figure 3: Subwatersheds of Morro Bay.
Source: TetraTech, 1998a, p. 3.

Table 9. Subwatersheds of Morro Bay Watershed.

Subwatershed	Area (square miles)
Chorro Ck. at Res.	3.67
Dairy Creek	2.52
Pennington Creek	3.09
San Luisito Creek	8.28
San Bernardo Creek	8.49
Minor tributaries[1]	11.42
Chorro Creek	**48.57**
Los Osos Creek	7.57
Warden Creek	12.93
Los Osos Creek	**7.57**
Morro Bay Watershed	**56.14**

Source: Based on Tetra Tech, 1998b, Table 1, p. 2.

[1] Includes Subwatersheds: Walters Creek, Chumash Creek and Chorro Creek at Highway 1.

3.2.1.2 Flow

Hydrologic factors required to develop event-based sediment yield estimates include the peak flow and total runoff volume associated with each flood event. These factors drive the sediment loading model. Because measured rainfall runoff data are available for only a limited number of events, locations, and timespans, these data were obtained from the hydrologic rainfall-runoff model completed in 1998 by Tetra Tech for the Morro Bay National Estuary Program (1998b, p. 7). That model used the U.S. Army corps of Engineers HEC-1 Flood Hydrograph Package. The model simulates the runoff response of Chorro and Los Osos Creek for recorded or hypothetical storm events occurring within the watershed. For a given storm event, the model allows peak discharges and/or hydrographs to be generated in 70 subbasins within the larger Morro Bay Watershed (Ibid.).

The data base used for development and calibration of the rainfall-runoff model, included: U.S. Geological Survey topographic maps, soils information from the Soil Survey for San Luis Obispo, historical peak discharge data available at several locations throughout the watershed and collected by San Luis Obispo County Engineering Department, and the 5-minute rainfall and streamflow records collected in 1995 and 1996 as part of the "paired watershed" study by Morro Bay National Monitoring Program (Ibid., 1998a).

3.2.1.3 Sediment Yield

3.2.1.3.1 Modified Universal Soil Loss Equation (MUSLE)

Sediment yield, or sediment yield refers to the rate at which sediment passes a particular point in the drainage system. It is usually expressed as volume or weight per unit of area per unit of time (Leopold and Dunne, 1978, p. 678). The Modified Universal Soil Loss Equation (MUSLE) was developed in 1975 to calculate sediment yield to a given point in a watershed for a given flood event. Tetra Tech based their estimates of sediment yield on a form of the equation adjusted for conditions in Chorro and Los Osos Creeks:

$$\mathbf{T = a\ K\ LS\ (Q_p V)^b}$$

T = sediment yield in tons for a flood event.
Q_p = the peak flow associated with the event.
V = the runoff volume associated with the event.
K = soil erodibility.
LS = watershed slope length.
a = the summation of several factors, including soils, basin topography and land use factors.
b = an exponent that varies with location.

This equation was calibrated using the data on flow and sediment concentrations available from the Walters Creek/Chumash Creek paired watershed study. The calibration resulted in values for "a" and "b." The equation was then applied to the gauged and ungauged portions of the watershed using known basin characteristics (area, erodibility (K), and watershed slope length (LS)) and hypothetical hydrologic data (Q and V) from the rainfall runoff model. Event total sediment yield tonnages were then calculated for each of the major drainages and the sum of other minor tributaries in the Chorro Creek and Los Osos Creek Watershed. In the case of Chorro Creek the yield estimates were adjusted for trapping of coarse sediment in Chorro Reservoir (Tetra Tech, 1998a. p. 10; Felhman, 2000).

3.2.1.3.2 Method for Calculating Average Annual Total Yields to Bay from Chorro and Los Osos Creeks

Events for which sediment yields were developed, included the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events. These event-based yields then became the basis for determining *average annual yield*. This required an assessment of the "average" hydrology of a typical year, including an estimate of the contribution from peak flood flows and low flows (Ibid., 1998a. p. 24). Regional Board staff applied the following formula to the event-based loads developed for each Subwatershed:

Average Annual Yield = (100-yr yield*0.02)+(50-yr yield*0.01)+(25-yr yield*0.04)+(10-yr yield*0.08)+(5-yr yield*0.2)+(2-yr yield*0.4)

Tetra Tech also developed independent estimates for total yield from Chorro and Los Osos Creeks based on: 18 years of average daily flow records at the Chorro Creek gage (at Canet Road), their rainfall-runoff model, and the results of sediment yield and transport calculations developed specifically for the Morro Bay Watershed (Ibid., p. 15 –22). This served two purposes: first, this method allowed them to partition the total load into its *suspended load* and *bed load* fractions, and second, it provided a check on the yields as calculated by the weighted average method applied to develop subwatershed loads. In developing these independent estimates, the following regression equations for sediment delivery (both total load and the bed load fractions) were developed for each creek:

Chorro Creek:
$$\text{Total Tons}_{\text{Chorro mouth}} = 0.005256 \times (\text{Avg Q}_{\text{Chorro mouth}})^{2.212}$$
$$\text{Bed Material Tons}_{\text{Chorro mouth}} = 0.0710 \times (\text{AvgQ}_{\text{Chorro mouth}})^{1.539}$$

Los Osos Creek:
$$\text{Total Tons}_{\text{Los Osos mouth}} = 0.032981 \times (\text{Avg Q}_{\text{Los Osos mouth}})^{2.118}$$
$$\text{Bed Material Tons}_{\text{Los Osos mouth}} = 0.002784 \times (\text{Avg Q}_{\text{Los Osos mouth}})^{1.901}$$

Where Total Tons represents the net total delivery to the Bay from the location indicated, and Bed Material Tons represents the bed material delivery to the Bay from the location indicated, for the given average daily flow value. These regression equations were applied to each day in the selected 18-year hydrologic record, and the summation of total tons delivered, divided by 18, provides an approximation of the average annual yield (Ibid., pp. 24, 25). The total loading calculated through this method was within one percent of the loading as calculated through the weighted average method.

3.2.2 Methods to Assign Loads to Erosion Types

3.2.2.1 Identify types, calculate rates, calculate percentages (SCS)

The Soil Conservation Service (SCS) identified principal land use and vegetation types in Morro Bay based on 1978 data from the Department of Water Resources Cropland Maps (USDA, SCS, 1989a. p 4). Rangeland, brushland, woodland, three types of croplands, and urban lands were the major land use categories identified. The land use patterns were then used to develop estimates of erosion by crop or land use.

Four source categories of erosion were identified by SCS: sheet and rill[2], streambanks, roads, and gullies[3]. The SCS used the Universal Soil Loss Equation (USLE) to estimate erosion from sheet and rill erosion—the dominant type of erosion. They used the Direct Volume Method to calculate erosion from streambanks, roads, and gullies. This method estimates the average annual thickness of bank or surface removed by erosion; then multiplies it by the area of bank or surface to give a volume estimate (USDA, SCS, 1989a. p. 16).

The sediment loads calculated by SCS from these methods allowed for a breakdown of erosion types expressed as a percentage of the total for Chorro and Los Osos Creeks (Table 10). Sheet and rill erosion is the dominant source, accounting for approximately 61-65 percent of total loading in the two tributaries. In Chorro Creek sheet and rill erosion contribute 38,945 tons/year and in Los Osos Creek 5,935 tons/year.

Table 10. Erosion Categories and Percent Contribution in Morro Bay Watershed.

	Sheet and Rill Percent of Total	**Streambanks** Percent of Total	**Roads** Percent of Total	**Gullies** Percent of Total	**Total Load Sheet and Rill Only (tons/yr)**
Chorro Creek	64.9%	20.3%	13.9%	1.0%	**19,200**
Los Osos Creek	61.0%	21.4%	16.4%	1.3%	**9,700**
Watershed Total	**63.5%**	**20.7%**	**14.7%**	**1.1%**	**28,900**

SCSyield%fromC&L(tt)

2 *Sheet Erosion*: when rainfall intensity exceeds infiltration capacity, the ground cannot absorb all the moisture, and water is ponded on the surface in small local depressions. These depressions eventually are overtopped, and water runs off the surface in thin laminar sheets. If the flow is sufficient to entrain soil particles, sheet erosion occurs.
Rill Erosion: Rills are small linear, rectangular channels that cut into a slope surface. They tend to be parallel, and they are most commonly observed on new road cuts (Chorley, et al, p. 264). With continued sheet flow, a point is reached where small rills appear, and flow becomes concentrated into larger rills, which eventually become gullies.

3 *Gully Erosion*: Gullies are "arbitrarily defined as recently extended drainage channels that transmit ephemeral flow, have steep sides, and a steeply sloping or vertical head scarp…" (Selby, 1982, p. 107). Because they are very rapidly developed erosional forms they are usually not regarded as features of normal erosion, but the result of changes in the environment, such as burning of vegetation, overgrazing, climatic change affecting vegetation, and extreme storms (ibid.).

Source: adapted from Table 3, USDA, SCS, 1989a. pp.16, 17.

3.2.3 Method to Assign Loads to Land Use Types

3.2.3.1 Determining Land Use on a Subwatershed Basis

Regional Board staff chose to perform subsequent analyses of sources based only on the sheet and rill component, since it is the dominant source throughout the watersheds. A Subwatershed basis for these sources was needed to provide a better understanding of sources. However, a subwatershed breakdown of landuses for the Morro Bay Watershed was not available from the SCS documents that identified the erosion types. Therefore, Regional Board staff used a Geographic Information System (GIS) to calculate landuses acreages within each subwatershed. Staff retained the five land use classes (Rangeland, Brushland, Woodland, Cropland, and Urban) identified by SCS. The GIS included layers from the UC Santa Barbara Geographic Approach to Planning[4] (GAP) to calculate subwatershed-based land uses areas (Table 11). This required an aggregation of vegetation and landuse types to conform to the SCS classification. Regional Board staff relied upon the USDA Forest Service Wildlife-Habitat Relationships (WHR) to aggregate the land uses for each of the subwatersheds (CDF, 1988).

[4] GAP data were obtained from the UCSB Gap Analysis FTP site at: ftp://lorax.geog.ucsb.edu/pub/data/gap_analysis/. (At time of this writing, the site has been replaced by http://www.biogeog.ucsb.edu/projects/gap/gap_home.html). The data files were downloaded for the Central Western Ecoregion on 6/12/97. The ARC/INFO Export files were imported into MIPS, converted from Albers to UTM projection and exported as Arc shapefiles. Accessory tables were transformed directly from ARC/INFO to .dbf format using ArcView's Export71 program. Key fields from these "lookup" tables (primary and secondary species, Holland communities, and Wildlife-Habitat Relationships (WHR) habitat types) were incorporated into the shapefile attribute table by joining the relevant lookup table to the attribute table and saving as a new shapefile. The GAP data shows vegetation as interpreted and classified from a 1990 Landsat satellite image. The best fields to use for viewing the polygons are "Holland1Name" or "WHRType1".

Table 11. Land Uses (acres) within Chorro and Los Osos Creek Watersheds.

	Land Uses						
Subwatersheds	**Rangeland**	**Brushland**	**Woodland**	**Cropland**	**Urban**	**Other**	**Total**
Chorro Creek at Res.	561	1,241	577				**2,379**
Dairy Creek	1,206	137	76				**1,419**
Pennington Creek	819	360	192				**1,371**
San Luisito Creek	3,831	1,497	62	108			**5,498**
San Bernardo Creek	3,295	1,043	434	659			**5,431**
Walters Creek	917						**917**
Chumash Creek	421						**421**
Chorro Creek below Reservoir	4,950	518	492	57	1,455		**7,472**
Chorro Creek at Twin Bridges	1,715		607	891	73		**3,286**
Chorro Creek	17,715	4,796	2,440	1,715	1,528		**28,193**
Chorro Creek %	**62.8%**	**17.0%**	**8.7%**	**6.1%**	**5.4%**		
Clark Canyon Tributary	1,159	272	3,164	180	77		**4,852**
Warden Creek at Turri	2,393			1,303			**3,696**
Warden Creek above Los Osos	2,867		161	1,608			**4,636**
Los Osos Creek (lower)	594	6		342	885		**1,827**
Other	*548*	*400*	*72*	*378*	*2,470*	*1,378*	**5,246**
Los Osos Creek	7,561	678	3,397	3,811	3,432	1,378	**20,257**
Los Osos Creek %	**37.3%**	**3.3%**	**16.8%**	**18.8%**	**16.9%**	**6.8%**	
Watershed Total	25,276	5,474	5,837	5,526	4,960	1,378	**48,450**

LandUsesGAP

Source: GIS Analysis performed by Regional Board staff based on UC Santa Barbara GAP (see preceding footnote) data and Wildlife Habitat Relationships (CDF, 1998).

3.2.3.2 Applying to Sheet and Rill

Regional Board staff based sediment load estimates from sheet and rill erosion in each land use type on Soil Conservation Service (SCS) estimates for Chorro and Los Osos Creeks, adjusted for more accurate total loads calculated in Tetra Tech's Sediment Loading Study, since the Tetra Tech study was more comprehensive and relied on additional data. SCS's estimates of sediment loads from sheet and rill erosion in each land use are shown in Table 12.

Table 12. SCS Estimates of Sheet and Rill Sediment Load for Land Uses in Morro Bay Watershed.

	Rangeland	Brushland	Woodland (tons/year)	Cropland	Urban	Total
Chorro Creek	5,200	9,400	900	2,800	900	**19,200**
Los Osos Creek	2,500	4,300	400	2,100	400	**9,700**
Watershed Total	**7,700**	**13,700**	**1,300**	**4,900**	**1,300**	**28,900**

S&RyieldfromC&LLU(SCS)
Source: USDA, SCS, 1989a, Table 4, p. 17.

While Tetra Tech's total loads were relied upon, Staff had confidence in SCS's estimates of percentages of sediment from sheet and rill from each land use and applied them to Tetra Tech's totals. To apply them proportionately, staff calculated a conversion factor for each creek:

Equation 1: Tetra Tech Load/SCS Load = Conversion Factor

Regional Board staff determined sheet and rill loads per land use using the conversion factors in Table 13. The sheet and rill loads per land use using SCS's percentages and Tetra Tech's estimates of sediment load are shown in Table14.

Table 13. Conversion Factors used to convert SCS's estimates to Tetra Tech's estimates.

	Loads (tons/yr)	Conversion factor
Chorro Creek	38,945/19,200	2.03
Los Osos Creek	5,935/9,700	0.61

Table 14. Adjusted Load from Sheet and Rill Erosion on Land Uses in Chorro and Los Osos Creek Watersheds.

	Rangeland	Brushland	Woodland	Cropland	Urban	Total
			tons/year			
Chorro Creek	10,548	19,067	1,826	5,679	1,826	**38,945**
Los Osos Creek	1,530	2,631	245	1,285	245	**5,935**
Watershed Total	**12,077**	**21,698**	**2,070**	**6,964**	**2,070**	**44,880**

S&RyieldformC&LLU(tt)

3.2.3.3 Assigning Sheet and Rill Load by Land Use in Subwatersheds

To apply these loads to each tributary (Subwatershed) within Chorro and Los Osos Creek Watersheds, Regional Board staff needed to determine a sediment yield from each land use type and then apply it to known acres of land use in each Subwatershed. Regional Board staff used the following two equations to do this.

Equation #2:

$$\text{Watershed Yield from Land Use “A” (tons/acre/year)} = \frac{\text{Watershed Sheet and Rill Load (tons/yr) from Land Use “A”}}{\text{Watershed Acres of Land Use “A”}}$$

For example, the following calculation determines sediment yield from rangeland within Chorro Creek Watershed: 10,548 tons per year/17,715 acres = 0.60 tons/acre/year. Table 15 shows the yield for each land use type for Chorro and Los Osos Creeks watersheds.

Table 15. Sediment Yield from Sheet and Rill Erosion by Land Use.

	Rangeland	Brushland	Woodland tons/acre/year	Cropland	Urban
Chorro Creek	0.60	3.98	0.75	3.31	1.19
Los Osos Creek	0.20	3.88	0.07	0.34	0.07
Watershed	0.48	3.96	0.35	1.26	0.42

S&RyieldperAC C&L LU(tt)

To determine the sediment load from sheet and rill erosion from each land use on a subwatershed basis, Regional Board staff multiplied the land use acres within each subwatershed (Table 11) by the sediment yield (Table 15). Equation 3 represents this calculation:

Equation #3:

Subwatershed Load from Land Use "A" (tons/yr) = Subwatershed Acres of Land Use "A" * Watershed Yield from Land Use "A" (tons/acre/year)

For example, the following calculation determines load from sheet and rill erosion on rangeland within the subwatershed of Chorro Creek at Reservoir: 334 tons/year = 561 acres * 0.60 tons/acre/year. The unadjusted sheet and rill load from each land use is shown in Table 16.

Table 16. Unadjusted Sediment Load (tons/year) from Sheet and Rill Erosion on Land Uses within Subwatersheds.

Subwatershed	Land Uses					
	Rangeland	Brushland	Woodland	Cropland	Urban	Total
Chorro Creek at Reservoir	334	4,933	432	-	-	5,699
Dairy Creek	718	545	57	-	-	1,319
Pennington Creek	488	1,431	144	-	-	2,062
San Luisito Creek	2,281	5,951	46	358	-	8,636
San Bernardo Creek	1,962	4,148	324	2,182	-	8,616
Minor Tributaries	4,765	2,059	822	3,140	1,826	12,612
Chorro Creek	10,548	19,067	1,826	5,679	1,826	38,945
Los Osos Creek	234	1,055	228	61	5	1,584
Warden Creek and Tributaries	1,295	1,575	17	1,224	239	4,351
Los Osos Creek	1,530	2,631	245	1,285	245	5,935
Morro Bay Watershed	12,077	21,698	2,070	6,964	2,070	44,315

S&Ryield tt

Regional Board staff had confidence in Tetra Tech's estimates of loads from each subwatershed. Therefore, staff applied a final adjustment based on Tetra Tech's subwatershed loads. The adjustment was made using equation 4:

Equation #4:

$$\text{Adjustment Factor} = \frac{\text{Total sheet and rill load from each tributary (Tetra Tech's estimates)}}{\text{Total sheet and rill load from each tributary (SCS's estimates)}}$$

For example, the following equation was used to get the adjustment factor for sheet and rill sediment load from rangeland within the subwatershed, Chorro Creek at Reservoir: 8,486 tons per year/5,699 tons per year = 1.49. The adjustment factors for each subwatershed are shown in Table 17.

Table 17. Adjustment factors for subwatershed loads from sheet and rill erosion.

Waterbody	**Tetra Tech's average annual yield totals** (tons/year)	**SCS's estimates of erosion from each land use type** (tons/year)	**Adjustment Factor**
Chorro Creek at Reservoir	8,486	5,699	1.49
Dairy Creek	571	1,319	0.43
Pennington Creek	1,253	2,062	0.61
San Luisito Creek	9,490	8,636	1.10
San Bernardo Creek	13,322	8,616	1.55
Minor Tributaries	5,824	12,612	0.46
Chorro Creek	38,945	38,945	1.00
Los Osos Creek	3,724	1,584	2.35
Warden Creek and Tributaries	2,211	4,351	0.51
Los Osos Creek	5,935	5,935	1.00
Morro Bay Watershed	44,315	44,315	1.00

Each subwatershed's adjustment factor was then multiplied by acres of each land use to determine the load from sheet and rill erosion from land uses within each subwatershed, according to equation 6 (results are discussed in the following section):

Equation # 6

Adjusted Load = (Sediment Load from Sheet and Rill Erosion from Subwatershed in Land Use "A") * (Adjustment Factor)

3.3 Relative Contributions

3.3.1 Total Loading from Subwatersheds

Tetra Tech estimated an average of about 70,000 tons per year of sediment is being delivered into the estuary from Chorro and Los Osos Creeks (Tetra Tech, 1988a, p.25). This value is much greater than the levels estimated by SCS in 1989, and Regional Board staff considers this value most accurate because it is based on more data and a more rigorous treatment of those data. According to Tetra Tech, ten percent of this total loading is sand and gravel, and 90 percent is fine material such as clay and silt particles. Wash load materials (fines) have a limited presence in Chorro and Los Osos creeks, indicating that the supply of fines available from the upper watershed is controlling the amount of these materials delivered to the Bay.

The Chorro Creek watershed is estimated to contribute 86 percent of the total sediment produced in the Morro Bay watershed according to Tetra Tech (Table 18). The watersheds of San Bernardo, San Luisito, and Chorro Creeks above Highway 1, and the Clark Valley segment of Los Osos Creek, contribute the greatest amounts of sediment to the Bay. Together, San Bernardo Creek, San Luisito Creek, and the reach of Chorro Creek upstream of Highway 1 are estimated to contribute about 68 percent of the total sediment load from the Chorro Creek watershed, although these three streams comprise only 58 percent of the total drainage area. These subwatersheds contain the vast majority of the upland areas of the Morro Bay watershed—areas of steepest slope and highest rainfall intensity. Consistent with the findings of both the SCS and TetraTech studies, these upland areas are considered to be the most significant source of sediment loading to Morro Bay (Ibid., pp.29, 30).

The yield per square mile in both Chorro and Los Osos Creek watersheds is similar. Los Osos Creek, which makes up about a third of the contributing drainage area, supplies only about 14 percent of the total average annual loading to the Bay and only about three percent of the coarse material. The Clark Valley is estimated to be the most significant source of sediment yield from within the Los Osos Creek watershed, despite its small size relative to Warden Creek. The Los Osos Creek Wetland Reserve has captured a large amount of sand-sized particles believed to be from stream bank erosion in the Clark Valley portion of Los Osos Creek.

Table 18: Event-based and Annual Average Loadings.

Watershed	**Events**						**Prob-wt.'d avg. event** (tons/year)	**Annual Average Loading** (tons/year)	**Annual Loading**
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**			
	(tons)								
Chorro Ck. at Res.	1,170	4,947	11,258	29,472	53,994	93,471	5,946	13,082	19%
Dairy Creek	17	157	551	2,135	4,631	9,303	400	880	1%
Pennington Creek	40	372	1,269	4,688	10,100	19,891	878	1,932	3%
San Luisito Creek	150	2,685	9,431	35,681	77,408	154,863	6,650	14,630	21%
San Bernardo Creek	263	3,940	13,463	50,244	107,498	214,041	9,336	20,539	29%
Minor tributaries	510	2,906	7,293	21,256	40,541	72,829	4,081	8,978	13%
Chorro Creek	**1,330**	**13,634**	**43,354**	**154,348**	**325,075**	**637,272**	**28,897**	**60,041**	**86%**
Los Osos Creek		551	2,838	14,509	34,624	75,554	2,775	6,105	9%
Warden Creek		413	1,870	8,559	20,040	43,616	1,647	3,624	5%
Los Osos Creek	**38**	**1,089**	**5,321**	**26,067**	**61,771**	**134,661**	**5,012**	**9,729**	**14%**
Morro Bay Watershed							**33,910**	**69,770**	100%

TetraTechTribSediment

Source: Tetra Tech, 1998a. Table 7.

3.3.2 Loading by Erosion Source Category

As shown in Table 19, sheet and rill erosion are the greatest sources of sediment. Chorro Creek contributes much more sediment than Los Osos Creek. Tetra Tech adjusted the values entering Chorro Creek to account for trapping of coarse material within the reservoir (Tetra Tech, 1998a, p. 10). The fines, expected to flow past the reservoir, were added to downstream points below the reservoir.

Table 19. Estimated Sediment Load (tons/year) by Erosion Category to Morro Bay.

Waterbody	Sheet and Rill	Streambanks	Roads	Gullies	Estimated Annual Average Loading
Percent Contribution					
	63.5%	*20.6%*	*14.7%*	*1.1%*	
Chorro Creek at Reservoir	8,486	2,652	1,812	133	13,082
Dairy Creek	571	178	122	9	880
Pennington Creek	1,253	392	268	20	1,932
San Luisito Creek	9,490	2,966	2,026	148	14,630
San Bernardo Creek	13,322	4,163	2,845	208	20,539
Minor Tributaries	5,824	1,820	1,244	91	8,978
Chorro Creek	38,945	12,170	8,316	609	60,041
Los Osos Creek	3,724	1,305	998	77	6,105
Warden Creek and Tributaries	2,211	775	593	46	3,624
Los Osos Creek	5,935	2,080	1,591	122	9,729
Morro Bay Watershed	44,315	**14,414**	**10,274**	**767**	**69,770**

TetraTechTribbasedonSCS%

Source: developed from USDA, SCS, 1989a and Tetra Tech, 1998a.

3.3.3 Loading from Sheet and Rill Erosion by Land Use

San Bernardo Creek watershed is the single largest contributor of sediment from sheet and rill erosion (Table 20). It is the largest subwatershed in Chorro Creek watershed at about 8.5 square miles. Here brushlands account for approximately twice as much sediment as either rangelands or croplands. The smallest load from this erosion type is from Dairy Creek (2.5 sq. miles) where rangelands contribute 311 tons/year to a total of 571 tons/year.

Table 20. Adjusted values for Sediment Load from Sheet and Rill Erosion on Land Uses in Morro Bay Watershed.

	LAND USES					Total
	Rangeland	Brushland	Woodland	Cropland	Urban	
	(tons/year)					
Chorro Creek at Reservoir	497	7,345	643	-	-	8,486
Dairy Creek	311	236	25	-	-	571
Pennington Creek	296	870	87	-	-	1,253
San Luisito Creek	2,507	6,539	51	393	-	9,490
San Bernardo Creek	3,034	6,414	502	3,373	-	13,322
Minor Tributaries	2,200	951	380	1,450	843	5,824
Chorro Creek	10,548	19,067	1,826	5,680	1,826	38,945
Los Osos Creek	551	2,482	536	143	13	3,724
Warden Creek and Tributaries	658	801	9	622	122	2,211
Los Osos Creek	1,530	2,631	245	1,285	245	5,935
Morro Bay Watershed	**11,925**	**21,425**	**2,044**	**6,877**	**2,044**	**44,315**

TTS&Radjust

3.3.4 Mines

Sedimentation from mines in the Chorro Creek watershed is included in the yields for brushland and woodland and accounts for approximately ten percent of the total sediment loading from this land type. Stabilization of tailings at the Primera mine site at Camp San Luis is underway and will be tracked in the Implementation Plan for this TMDL.

4. Numeric Targets

The Basin Plan contains no numeric objectives for sediment that apply to the Morro Bay Watershed. The turbidity objective in the Basin Plan, while numeric, is not applicable to this TMDL for two reasons: first, the objective is only appropriate in situations where there is an identifiable point source, which can be evaluated with discrete upstream and downstream monitoring; and second, the objective is expressed in the antiquated units for turbidity, Jackson Turbidity Units (JTUs), which have been replaced by Nephalometric Turbidity Units (NTUs) since development of the objective. (The Basin Plan is currently being updated to reflect the new units.)

Because the remaining sediment objectives in the Basin Plan are narrative, rather than numeric, this TMDL establishes numeric targets and parameters—indicators of water quality that are supportive of beneficial uses. The identified numeric targets serve to interpret the narrative water quality objectives and provide a measure to determine if the objectives and the TMDL are being met.

Numeric targets were selected for several parameters to represent attainment of water quality objectives for each of the listed waterbodies. The relationship of load reduction in tributaries to numeric targets is more direct for some parameters than others. For example, one target specifies the allowable decrease in tidal prism volume—a straightforward measure of volumetric increases in sedimentation in the Bay. An example of a less direct relationship to loading is that between the target for spawning gravel size and the load in Chorro Creek tributaries. No single parameter is expected to reflect accurately either reductions in sediment loading, or attainment of beneficial uses. Furthermore, because of the lack of historical data, there remains some uncertainty regarding the level of impairment to several of the beneficial uses in Morro Bay (fisheries habitat, recreation, shellfish harvesting). The approach of using multiple indicators is used here to account for this uncertainty and to address the complex in-stream and estuary sediment impacts and processes that drive sediment loading.

The combination of these parameters is considered an effective approach in lieu of directly measuring sediment loading to Morro Bay from Chorro and Los Osos Creeks. Furthermore, direct measurement of loads would not characterize the *effect* of those loads on beneficial uses. The selected parameters do characterize effect by targeting specific habitat requirements for aquatic organisms. The selection of these targets does not preclude efforts to directly measure loading, however the natural variability inherent in annual sediment loads in this region is large enough to preclude the collection of data from which clear trends could be identified in the near term.

Numeric targets are established for five parameters for Chorro Creek, Los Osos Creek and their tributaries, and for one parameter in the Morro Bay Estuary (Table 21). The four streambed parameters, and the one water column parameter selected for the creeks, include: pool volume, median gravel size diameter (D_{50}), percent fines in substrate, and turbidity. The parameter established for the Morro Bay Estuary is for tidal prism volume. Numeric Target compliance points, frequency of sampling, protocols and responsible party for each target are outlined in the Monitoring Plan.

Table 21. Numeric Targets

<table>
<tr><th>Parameter</th><th colspan="3">Numeric Target</th></tr>
<tr><td colspan="4">Chorro and Los Osos Creeks and Tributaries Streambed Sediment</td></tr>
<tr><td>Residual Pool Volume[5]</td><td colspan="3">V* =
Mean values ≤ 0.21
Max values ≤ 0.45</td></tr>
<tr><td>Median Diameter (D_{50}) of Sediment Particles in Spawning Gravels</td><td colspan="3">D_{50} =
Mean values ≥ 69 mm
Minimum values ≥ 37 mm</td></tr>
<tr><td>Percent of Fine Fines (< 0.85 mm) in Spawning Gravels</td><td colspan="3">Percent fine fines ≤ 21%</td></tr>
<tr><td>Percent of Coarse Fines (< 6.0 mm) in Spawning Gravels</td><td colspan="3">Percent coarse fines ≤ 30%</td></tr>
<tr><td colspan="4">Chorro and Los Osos Creek and Tributaries Water Column</td></tr>
<tr><td rowspan="4">Turbidity</td><td></td><td>% of Samples Below Target</td><td>Target (NTUs)</td></tr>
<tr><td rowspan="2">Wet Season</td><td>82%</td><td>≤ 5</td></tr>
<tr><td>93%</td><td>≤ 100</td></tr>
<tr><td>Dry Season</td><td>96%</td><td>≤ 5</td></tr>
<tr><td colspan="4">Morro Bay Estuary</td></tr>
<tr><td>Tidal Prism Volume</td><td colspan="3">4,200 acre-feet</td></tr>
</table>

4.1 Chorro Creek and Los Osos Creek Numeric Targets

4.1.1 Streambed Sediment Targets

Streambed sediment characteristics are the basis for numeric targets for Chorro Creek, Los Osos Creek, and their tributaries to ensure that sediment accumulation in pools, or fines around gravels do not degrade invertebrate, amphibian, and fish habitat. While there are several factors contributing to the decline in steelhead and other organisms' habitat, including low flows, competition with non-native species, and fish barriers, excessive sedimentation in these habitats is a significant factor. These numeric targets were developed with specific consideration for the steelhead. However, achieving these numeric targets is expected to support a broader spectrum of beneficial uses, including: COLD, MIGR, SPWN, BIOL, RARE, and WILD.

4.1.1.1 Pool Volume

Parameter: Residual Pool Volume (V*).

Numeric Target: ≤ 0.21 (mean) and ≤ 0.45 (max).

Discussion: V* gives a direct measurement of the impact of sediment on pool volume. It is the ratio of the pool volume filled in with fine, mobile sediment, to the total scour pool volume. Pool habitat in

[5] Residual Pool Volume refers to the portion of a pool in a stream that is available for fish to occupy. Pool habitat is the primary habitat for steelhead in summer. Overwintering habitat requirements include deeper pools, undercut banks, side channels, and especially large, unembedded rocks, which provide shelter for fish against the high flows of winter. V* gives a direct measurement of the impact of sediment on pool volume. It is the ratio of the amount of pool volume filled in with fine, mobile sediment, to total scour pool volume.

streams is the primary habitat for steelhead in summer. V* gives a direct measurement of the impact of sediment on pool volume. Staff selected this parameter because of its strong correlation with upslope disturbances (Knopp, 1993, p. 23). It is an unbiased measurement and its variance in a reach of stream has been shown to be low enough to provide precise estimates of mean values with a reasonable amount of effort (Lisle, 1993). Conclusive[6] data on V* are not available for the tributaries to Morro Bay, therefore numeric targets of 0.21 mean values and 0.45 maximum values are proposed based on V* data collected by Knopp (1993) in 60 streams on California's north coast. Knopp found that in reference streams (those having no human disturbance for the past 40 years or more) the V* mean measured 0.21 or less and the maximum measured 0.45 or less. These values represent the average of six separate pools. V* measurements exhibited a trend of increasing accumulations of fine sediments with increasing upslope disturbance, indicating that V* results were affected by upslope disturbance. Knopp found that V* results may take upwards of 40 years before mitigation of current disturbance is positively reflected (USEPA, 1998, p.20).

Regional Board Staff recognize the conditions in the north coast contrast sharply with those in the Central Coast and will modify these values as V* data for the Morro Bay Watershed become available. Modifications will be based on baseline data from Pennington Creek, a reference stream selected for the minimal amount of land use disturbance in its watershed, and the apparent low impact of those land uses on water quality. Pool conditions in Pennington Creek would be expected to protect beneficial uses, specifically the habitat of steelhead as described in the COLD beneficial use. Regional Board staff also assume that these targets will address the MIGR beneficial use. Since V* reflects sediment aggradation of pools, staff presume that as sediments are reduced in pools, other migration areas within the stream channel will improve.

Overwintering habitat requirements for salmonids include deeper pools, undercut banks, side channels, and especially large, unembedded rocks that provide shelter for fish against the high flows of winter. In some years, such as water years 1983, 1992, 1995, floods may make overwintering habitat the critical factor in steelhead production. In most years, however, if the pools have sufficient larger boulders or undercut banks to provide summer rearing habitat for yearling steelhead, then these elements are sufficient to protect them against winter flows.

Pool habitat is the primary habitat for steelhead in summer. The deeper the pool the more value it has. Fish biologists working in coastal streams in Santa Cruz County found that densities of yearling steelhead are usually regulated by water depth and the amount of escape cover that exists during low-flow periods of the year (July-October). In most small coastal streams, availability of this habitat provided by depth and cover appears to determine the number of smolts produced by the smaller streams (Alley, 1998, pp. 15, 16).

Compliance Point: Ten randomly selected pools adjacent to National Monitoring Program (NMP) sites (DAM, PEN, CHD) in the Chorro Creek Watershed. One or more reaches of Pennington Creek (PEN) will be selected as a reference condition. Additional sites in Chorro Creek (SLU, SBE) and Los Osos Creek Watersheds (LVR) will be used as accessible. Figure 4 shows NMP sampling points.

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6 Regional Board staff collected V* data on Pennington Creek in an effort to determine the applicability of the parameter and to refine the method for measuring it. Staff concluded that V* is appropriate, however the data from this reconnaissance effort were not sufficient to characterize the existing condition within Pennington Creek. Baseline data collection and subsequent monitoring of V* are proposed in the TMDL Monitoring Plan.

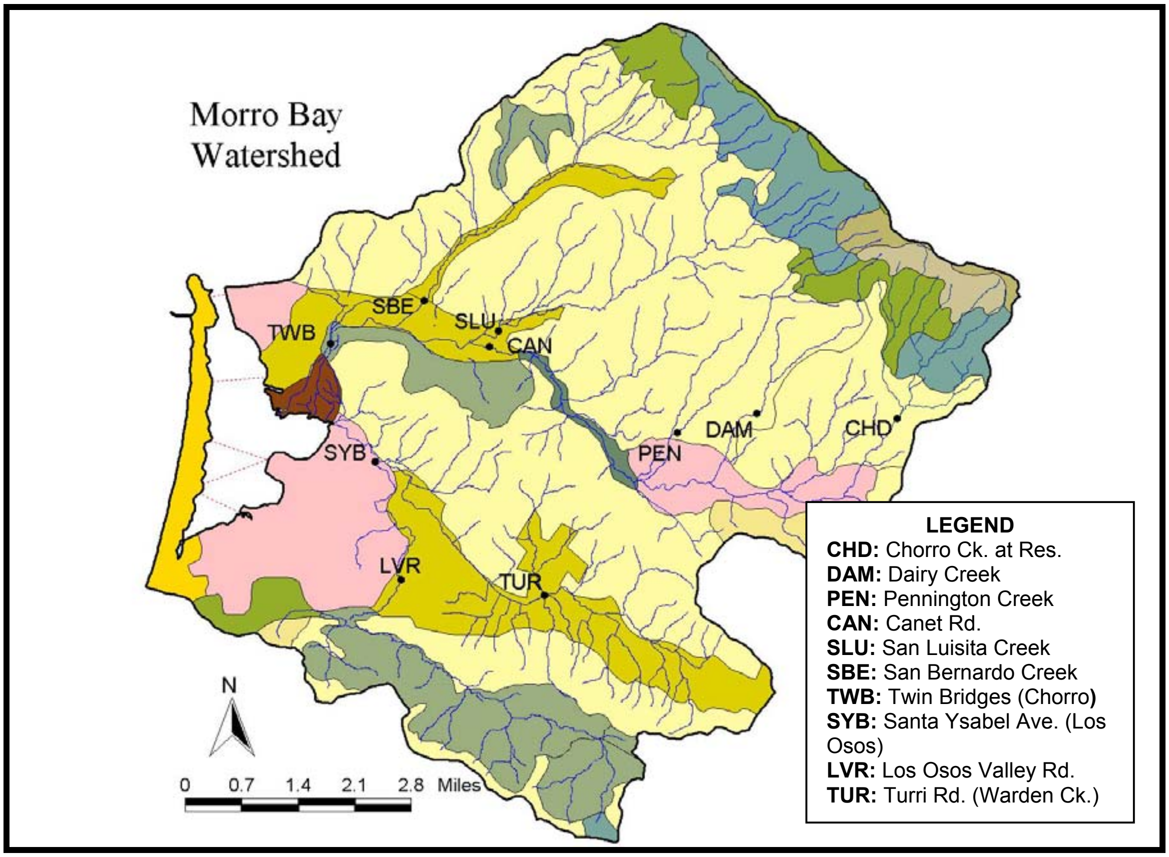

Figure 4. Established TMDL Monitoring Sites.

4.1.1.2 Median Diameter (D_{50}) of Sediment Particle in Spawning Grounds

Parameter: Median diameter (D_{50}) of sediment particle from riffle crest surfaces of spawnable gravels in major tributaries.

Numeric Target: ≥ 37 mm (minimum for a reach); ≥ 69 mm (mean for a reach); with an approximately normal distribution of grain size.

Discussion (adapted from Redwood Creek Sediment TMDL (USEPA, 1998)): The D_{50} is the median value of the size distribution in a sample of surface pebble counts. It is a measure of the central tendency of the whole sample, and thus is one of several indicators of how "fine" or "coarse" the sample is overall. As discussed below in the discussion for the percent fines targets, both amount and size of fine and coarse sediments can impact salmonid life stages. These targets are expected to ensure the protection of spawning habitat for species including steelhead.

The D_{50} indicator is selected for Chorro and Los Osos Creek and their tributaries because it is sensitive to sediment inputs, and it is relatively easy to obtain data from pebble counts. In a study that evaluated the relationship between hillslope disturbance and various instream indicators, Knopp (1993) found a clear trend of decreasing particle sizes in the riffles with increasing hillslope disturbance. Moreover, Knopp found a statistically significant difference in average and minimum D_{50} values when comparing reaches in undisturbed and less disturbed watersheds with reaches in moderately and highly disturbed watersheds.

The targets are based on Knopp's findings (1993) concerning D_{50} levels in north coast watersheds that were relatively undisturbed. The Regional Board Staff determined that because Knopp found the D_{50} to be a discriminating indicator (that is, an indicator capable of distinguishing between watersheds that are more or less disturbed as a result of prior management), this indicator and its associated targets identified in Knopp's study are appropriate.

These numeric targets will be evaluated as part of the TMDL Monitoring Plan to ensure the target's applicability to the Central Coast and to verify that the targets show attainment of the TMDL.

Compliance Point: In identifiable potential spawning areas of established NMP stream profile reaches at DAM, PEN, CHD, and Chorro Creek at Highway 1.

4.1.1.3 Percent of Fine Fines in Spawning Gravels

Parameter: Percent fines < 0.85 mm in spawning gravels.

Numeric Target: ≤ 21 percent using McNeil Bulk Sampler.

This value is derived from published, peer-reviewed literature (Kondolf, 2000) since no data currently exists for this parameter within the Morro Bay Watershed. Regional Board Staff determined this to be a legitimate numeric target for spawning areas in Los Osos and Chorro Creeks and their tributaries, since the impact to developing steelhead should be similar regardless of geographic location. The value of 21 percent was derived using research values for the base percentage of fines (14 percent) and multiplying it by a factor (1/0.67) to account for fine sediment removal that occurs when the redd (nesting gravels) is constructed. The value of 14 percent was used in the Garcia River Sediment TMDL (USEPA, 1998, p. 16) and is also referenced by Kondolf (2000, p. 271). Kondolf suggests that survival rates would be around 50 percent where fines less than approximately 1 mm make up 14 percent of the total redd gravel.

The factor used to account for the fines removal during redd construction was taken from Kondolf (2000, p. 268). It was derived using linear regression for data collected from eleven sites. Kondolf found that there was a linear relationship between the percent < 1 mm in the undisturbed gravel, and the percent < 1 mm (represented by "y") in the redd gravel. The following equation represents this relationship:

Equation A:

$$y = 0.67\,x$$

Where:
X = percent < 1 mm in the undisturbed gravel
Y = percent < 1 mm in the redd gravel

In order to go from a desired gravel condition to an initial gravel condition Equation A must be rearranged to:

Equation B:

$$x = y/0.67$$

The Numeric Target in potential spawning gravels then, is:

$$21\% = 14/0.67$$

Discussion: "Once the eggs are laid and fertilized, the spawners cover the redds with material from upstream, including clean gravels and cobbles. The interstitial spaces between the particles allow for water to flow into the interior cavity where dissolved oxygen, needed by the growing embryos, is replenished. Similarly, the interstitial spaces allow water to flow out of the interior cavity carrying away metabolic wastes. However, fine particles either delivered to the stream or mobilized by storm flow can get into those interstitial spaces, blocking the flow of oxygen into the redd, and the movement of metabolic wastes out of it. The reduced permeability into and out of the redd results in a reduction in the rate of embryo survival.

"Research on this subject has concluded that as the percentage of fines increases as a proportion of the total bulk core sample, the survival to emergence (i.e., out of the gravel) decreases. Fines that impact embryo development are generally defined as particles that pass through a 0.85 mm sieve" (Garcia River Sediment TMDL, USEPA, 1998, p. 16).

Monitoring of fine sediment for compliance with this target will be conducted using a McNeil bulk sampler applied directly to potential spawning substrates. The Monitoring Plan identifies sampling protocols. This numeric target will be evaluated as part of the TMDL Monitoring Plan to ensure the target's applicability to the Morro Bay Watershed and to verify that the targets show attainment of the TMDL. If after three years of monitoring, staff finds D_{50} values to be well correlated ($\geq r^2 = 0.70$) with percent fines in bedload, as collected in a McNeil bulk sampler, percent fines will be omitted as a numeric target.

Compliance Point: In identifiable potential spawning areas of established NMP stream profile reaches at DAM, PEN, CHD, and Chorro Creek at Highway 1.

4.1.1.4 Percent of Coarse Fines in Spawning Gravels

Parameter: Percent fine sediment particles < 6 mm in spawning gravels.

Numeric Target: $\leq$ 30 percent using a McNeil Sampler.

This value is taken from Kondolf (2000, p. 271). Regional Board Staff determined this is a legitimate numeric target for potential and existing spawning areas of the Morro Bay Watershed, since the impact to developing steelhead from fines should be similar for steelhead regardless of geographic location. The grain size of 6 mm was chosen because it falls between the values cited by Kondolf (3.35 mm and 6.35 mm) associated with the value of 30 percent used as the numeric target. No factor accounting for removal of coarser fines during redd construction was applied to this value, as was done for the percent fines less 0.85 mm, because the data is more variable, and therefore less dependable, than similar data for fines less than 0.85 mm.

Discussion: Sedimentation has been identified as one of the principal factors in determining the survival rate from deposition to hatching of eggs, and the survival rate from hatching to emergence from the gravel (Shapovalov and Taft, 1954, p. 155). The coarser fines, > 0.85 mm and < 6.5 mm, can impede emergence of fry from the redd thereby reducing survival rates for fry. Bjornn, et al (1977) have recommended using the percentage of fine sediment in selected riffle areas as an indicator of the "sediment health" of streams. Bjornn (1969) and McCuddin (1977) found that survival of steelhead embryos were reduced when fines (6.44 mm) made up 20-25 percent or more of the substrate.

Monitoring of fine sediment for compliance with this target will be conducted using a McNeil bulk sampler directly applied to potential spawning substrates. The Monitoring Plan identifies sampling protocols. This numeric target will be evaluated as part of the TMDL Monitoring Plan to ensure the target's applicability to the Morro Bay Watershed and to verify that the targets show attainment of the TMDL. If after three years of monitoring, staff finds D_{50} values to be well correlated ($\geq r^2=0.70$) with percent fines in bedload, as collected in a McNeil bulk sampler, percent fines will be omitted as a numeric target.

Compliance Point: In identifiable potential spawning areas of established NMP stream profile reaches at DAM, PEN, CHD, and Chorro Creek at Highway 1.

4.1.2 Creek Water Column Target

4.1.2.1 Turbidity

Numeric Target:

	Percent of Samples Below Target	Target (NTUs)
Wet Season	82%	≤ 5
	93%	≤ 100
Dry Season	96%	≤ 5

Discussion: Elevated turbidity and suspended solids can result in effects on fish swimming directly in water in which solids are suspended. Potential effects include: alarm reaction, increased morbidity and increased mortality. Turbidity can also affect the efficiency of methods for catching prey, reducing the catch per unit effort. It is possible to relate severity of ill effect to concentration of suspended sediment and duration of exposure in: all life stages of salmonids, adult estuarine and freshwater nonsalmonids, freshwater invertebrates and freshwater flora (ibid. Newcombe, 1997, p.8).

Regional Board Staff identified background turbidity in the Morro Bay Watershed as a basis for numeric targets for stream water column turbidity. A reference stream, Pennington Creek, was selected for the minimal amount of land use disturbance in its watershed, and the apparent low impact of those land uses on water quality. Conditions in Pennington Creek would be expected to protect beneficial uses from turbidity impacts described above. Turbidity values in Pennington Creek are therefore used as targets for other streams that are tributary to Los Osos and Chorro Creeks. Staff recognizes that turbidity and related sediment transport indices are sensitive to location and are subject to considerable natural variability within a drainage network. Thus, sampling locations are initially restricted to tributary streams only, and staff will evaluate monitoring data and site characteristics to determine whether these locations provide appropriate locations for compliance with the numeric target.

During the dry season (June-September), 96 percent of all turbidity samples collected monthly are to be five NTUs or less. During the winter season (October-May), 82 percent of turbidity samples are to be five NTUs or less, while 93 percent of samples are to be no greater than 100 NTUs.

Compliance Point: National Monitoring Program tributary sites: DAM, PEN, CHD, CAN, SLU, SBE, LVR, and TUR (See Figure 4).

4.2 Morro Bay and Estuary Target

4.2.1 Tidal Prism Volume

Numeric Target: 4,200 acre-feet

Discussion: The tidal prism is defined as the difference between the mean high water volume and the mean low water volume in an estuary. The decrease in tidal prism volume in Morro Bay between 1881 and 1998 was estimated to be 20 percent to 30 percent (Tetra Tech, 1999b, p. B-19). Regional Board staff developed the target for tidal prism volume based on this historical loss of volume and on the anticipated natural lifespan of the open water areas of the estuary of several thousand years (Haltiner, 1988).

Assuming a lifespan of 3,000 years for the estuary, staff calculated a natural rate of sedimentation using a historic volume of 6,800 acre-feet in 1884 (Tetra Tech, 1999b, p. B-21) and a volume of zero acre-feet for the year 5000 (approximately 3,000 years into the future). This overly simplistic approach assumes a linear change in tidal prism volumes over time and is presented graphically in figure 5 as the line labeled "assumed natural sedimentation rate."

Staff calculated an accelerated rate of sedimentation using data from 1884 and 1998 (ibid.). Again, assuming straight-line changes in volume over time, a line with a steep negative slope describes, approximately, the current rate of sedimentation. The extension of this line through time suggests that the open water areas of the estuary would be filled by year 2265. This figure generally agrees with Haltiner's estimation of approximately 300 years of remaining life for the estuary assuming current sedimentation rates (1988). This line is labeled "accelerated sedimentation rate" in figure 5.

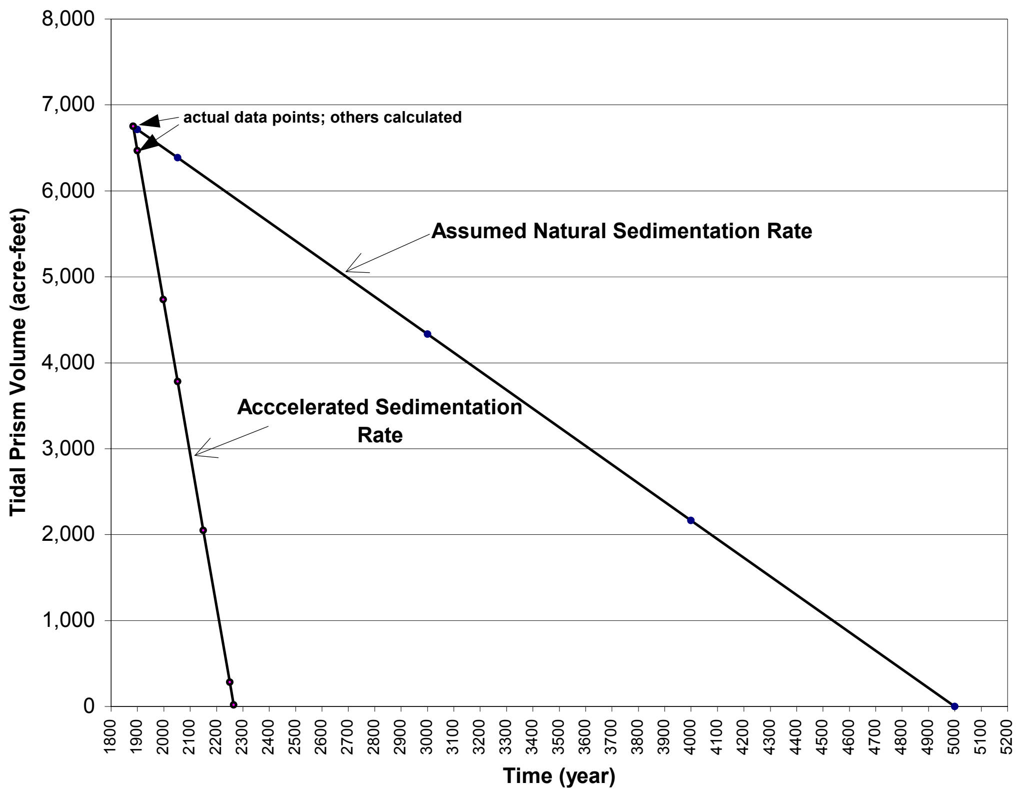

Figure 5: Projected Tidal Prism Volumes

The desired condition for the estuary, and one consistent with the goals of this TMDL, is to have sedimentation rates approximating those that would occur naturally, and for the estuary to approach its natural life expectancy of several thousand years. Thus, we would like to move from the more steeply sloped line to the less steeply sloped line in figure 5, and to arrive there within a reasonably reduced amount of time, e.g., 50 years, over which erosion control activities would be pursued and their effects realized.

Figure 6 displays the relevant time period for implementation of the TMDL (through the year 2052) and reveals how different the current tidal prism volume (approximately 4,700 acre-feet) is from where it would have been (approximately 6,500 acre-feet) had the last century not been marked by anthropogenically accelerated erosion. Figure 6 also shows three scenarios for arriving at the natural sedimentation rate by implementation year 50 (here represented as the year 2052):

- Point 1 assumes unrealistically that we could reduce sedimentation rates to their natural levels immediately and arrive at a volume of about 4,500 acre-feet in year 2052;
- Point 2 assumes no change in sedimentation is achieved and we arrive at year 2052 with only about 3,700 acre-feet remaining in the estuary's tidal prism. This outcome would be inconsistent with the goals of the TMDL.
- Point 3 is the midpoint between these two extreme cases. It represents a tidal prism volume of approximately 4,200 acre-feet in year 2052, and assumes successful sediment source reduction occurs throughout the implementation period. Staff selected this as the numeric target for tidal prism volume.

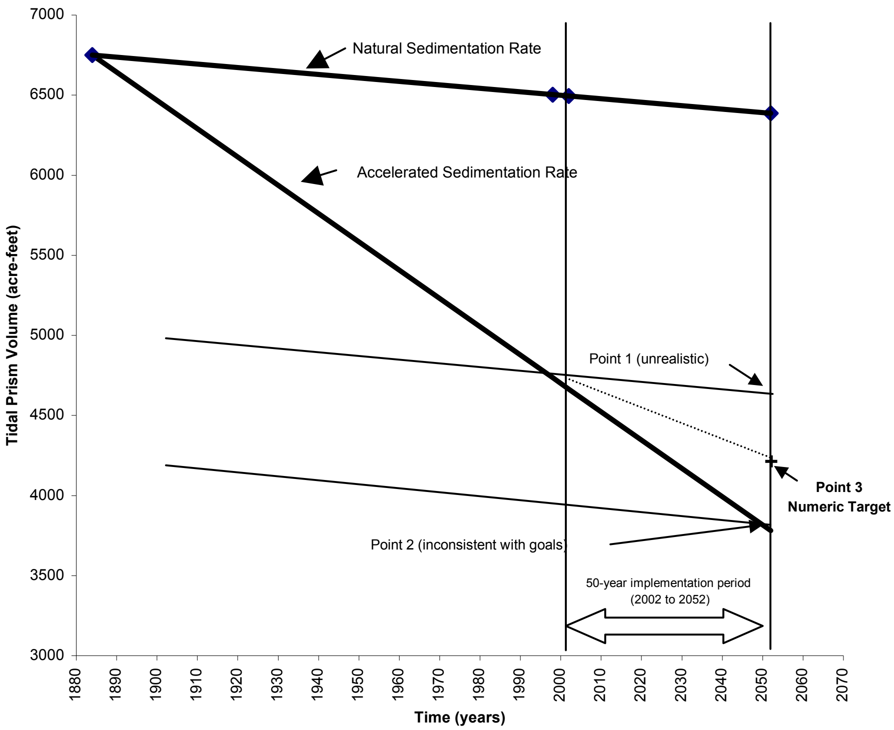

Figure 6: Tidal Prism Volume Target-Setting

As with other numeric targets for this TMDL, this target will be evaluated as more information comes available regarding both natural sedimentation rates and actual tidal prism volumes. Tidal prism volumes will be measured through bathymetric surveys every five years, pursuant to the monitoring plan for this TMDL. Natural sedimentation rates, and the estimate of life expectancy for the estuary, are likely to be adjusted by on-going research in this area.

5. Linkage Analysis

The linkage analysis shows how numeric targets and source analysis results relate to each other and how they combine to yield estimates of sediment assimilative capacity or needed sediment load reductions. This linkage makes it possible to determine the capacity of Morro Bay, Los Osos Creek and Chorro Creek to assimilate sediment loads while still supporting beneficial uses. In other words, the linkage analysis results in the load reductions needed to maintain water quality.

This linkage analysis examines the relationship between sediment loadings and numeric targets identified in the previous section. The linkages addressed are identified in the chart below. Improved linkage may be realized through evaluation of monitoring data collected to measure progress toward each target.

This TARGET	**is LINKED**	**to the LOADING to:**
Chorro and Los Osos Ck. Residual Pool Volume	←→	Chorro and Los Osos Creek from Major Chorro and Los Osos Creek Tributaries
Chorro and Los Osos Ck. Median Gravel Diameter		
Chorro and Los Osos Ck. Percent *Fine* fines		
Chorro and Los Osos Ck. Percent *Coarse* fines		
Chorro and Los Osos Ck. Turbidity		
This TARGET	**is LINKED**	**to the LOADING to:**
Morro Bay Tidal Prism Volume	←→	Morro Bay from Los Osos and Chorro Creeks.

Knopp's (1983) study of northern California coastal streams demonstrated that sediment generated from upslope disturbance had a measurable effect on the structure of the aquatic environment (p.40). He identified a statistical link between watershed disturbance and several in-stream sediment indicators, including residual pool volume (V*) and median gravel diameter (D_{50}). This linkage is the basis for selecting the four stream substrate targets on Los Osos and Chorro Creeks.

Calculating the actual loading that would produce the desired substrate conditions as expressed in the targets, would require data that are not currently available. These data would include accurate background sediment loads and baseline conditions of each parameter associated with those loads. In the absence of these data, Regional Board staff relied on USDA Soil Conservation Service estimates of accelerated erosion in the watershed to establish a load. The SCS estimated that half of the erosion in the watershed is accelerated or human-induced (1989b, p.31). Staff therefore assumed that a 50 percent reduction in sediment loading from each subwatershed would produce the target conditions, since the targets represent conditions expected to occur under natural sediment loading.

The goal of achieving a natural sediment loading in a watershed that has been significantly altered such as Morro Bay represents an aggressive strategy that compensates for the uncertainty inherent in the analysis conducted for this TMDL.

As the TMDL Monitoring Plan is implemented Regional Board Staff will collect data in relatively undisturbed reference streams (e.g., Pennington Creek), which are considered to approximate natural conditions. These data will be compared with data from compliance points and will provide staff with a part of the information upon which to make necessary modifications to the substrate targets.

The turbidity target is linked to sediment loads in tributaries to Chorro and Los Osos Creeks, since turbidity has been shown to increase with increased sediment loading in streams throughout the watershed. However, a quantitative link of load reductions to this target would require data that could become available in the future. In the absence of these data, staff assumes that a 50 percent reduction in loads will allow the target to be attained. Furthermore, turbidity data can assist staff in identifying chronic erosion sources in upslope terrains. Also, the persistence of turbidity events is a critical factor in the success of aquatic organisms' respiratory and feeding functions. Therefore turbidity data provides information about the actual *effects* of high sediment loading, rather than information about quantities of sediment.

Estuary tidal prism volume logically decreases as the estuary fills with sediment. Thus, a direct link exists between sediment loading to the estuary and the estuary's tidal prism volume. Regional Board Staff extended the assumption of 50 percent load reduction producing desired conditions for setting the numeric target for Estuary tidal prism. Staff assumed that a 50 percent reduction in sediment load would result in a sedimentation rate closer to the natural rate, hence reducing the rate of estuary infilling. Proposed monitoring of tidal prism volume will reveal whether these assumptions are realistic.

6. Total Maximum Load and Load Allocations

6.1 TMDL Calculation

The Total Maximum Loads for Chorro Creek, Los Osos Creek, and Morro Bay are the loads of sediment that these waterbodies can accept while supporting the identified beneficial uses. TMDL refers to these loads being expressed as a daily value. In this TMDL document, the maximum load is expressed as an annual load, not a daily load. For familiarity of terms, however, TMDL will be used. This is expressed by the following standard formula:

TMDL = ∑(Load from Point Sources)+∑(Load from Nonpoint Sources)+∑(Load from Background or Natural Sources)+(Margin of Safety)

This formula has been adjusted below to reflect the sediment loading analysis conducted for the Morro Bay Watershed. The first term drops out, since there are no point sources of sediment in the Morro Bay Watershed. Total nonpoint source loads were divided into the two major watersheds. Also, the Background or Natural Sources and Margin of Safety are implicitly incorporated into the equation through conservative estimates used throughout the TMDL. A more detailed description of the Margin of Safety can be found in the Margin of Safety section below. The adjusted formula is then:

$$\text{TMDL} = \sum(\text{Load from Nonpoint Sources})_{\text{Chorro Watershed}} + \sum(\text{Load from Nonpoint Sources})_{\text{Los Osos Watershed}} + \sum(\text{Load from Implicit Background or Natural Sources and Margin of Safety})$$

In Morro Bay, the TMDL is expressed as follows:

TMDL[7] $_{\text{Morro Bay}}$ = 34,885 tons/year = 30,020 tons/yr $_{\text{Chorro Watershed}}$ + 4,864 tons/yr $_{\text{Los Osos Watershed}}$

This TMDL represents a 50 percent reduction in the estimated current loading to the Bay and is based on the USDA, SCS estimate that current erosion rates are twice the natural rate. Table 23 shows TMDL allocations for the principal tributaries to Chorro and Los Osos Creek and to Morro Bay as assigned to the four erosion categories: sheet and rill, stream bank, roads, and gullies. These are the loads necessary to obtain compliance with the TMDL of 34,885 tons per year.

[7] The term TMDL, *Total Maximum DAILY Load* is used here for familiarity. The actual load is expressed as *Total Maximum ANNUAL Load*. The expression of sediment loading in *daily* increments is meaningless given the episodic nature of sediment transport. Rounding explains the discrepancy between summed and stated value.

Table 23. Load Allocations for Four Erosion Categories in Morro Bay Watershed

Watershed	EROSION CATEGORIES (tons/year)				Total
	Sheet and Rill	Streambanks	Roads	Gullies	
Chorro Creek at Reservoir	4,243	1,326	906	66	6,541
Dairy Creek	285	89	61	4	440
Pennington Creek	627	196	134	10	966
San Luisito Creek	4,745	1,483	1,013	74	7,315
San Bernardo Creek	6,661	2,082	1,422	104	10,269
Minor Tributaries	2,912	910	622	45	4,489
Chorro Creek	19,473	6,085	4,158	304	30,020
Los Osos Creek	1,862	653	499	38	3,052
Warden Creek and Tributaries	1,105	387	296	23	1,812
Los Osos Creek	2,968	1,040	795	61	4,864
Morro Bay Watershed	22,158	7,207	5,137	383	34,885

TetraTechTribbasedonSCS%

Table 24 further breaks down the sediment allocation for sheet and rill erosion to rangeland, brushland, woodland, cropland, and urban areas. These load allocations represent a 50 percent reduction in loading from the principal land uses of the Morro Bay Watershed.

Table 24. Load Allocations for Land Uses in Morro Bay Watershed (Sheet and Rill only)

Watershed	LAND USES (tons/year)					Total
	Rangeland	Brushland	Woodland	Cropland	Urban	
Chorro Creek at Reservoir	249	3,673	321			
Dairy Creek	155	118	12			
Pennington Creek	148	435	44			
San Luisito Creek	1,253	3,270	25	197		
San Bernardo Creek	1,517	3,207	251	1,687		
Minor Tributaries	1,100	475	190	725	421	
Chorro Creek	5,274	9,534	913	2,840	913	19,473
Los Osos Creek	276	1,241	268	71	6	
Warden Creek and Tributaries	329	400	4	311	61	
Los Osos Creek	765	1,316	122	642	122	2,968
Morro Bay Watershed	5,963	10,712	1,022	3,438	1,022	22,158

TTS&Radjust

The Morro Bay Enhancement Plan (USDA, SCS, 1989a.) estimated that implementing rural and urban land treatment measures alone could reduce 47 percent of the current average sediment loading. These measures in combination with others, including mine remediation, maintenance of sediment basins, and fire control above Chorro Reservoir, make the proposed 50 percent reduction of sediment load a feasible goal. This reduction would "help prolong the life of the estuary"(USDA, SCS, 1989a.). Continued monitoring and assessment will establish if this level is supporting beneficial uses in Chorro and Los Osos Creeks and Morro Bay.

6.2 Margin of Safety

The margin of safety is required because of uncertainty in several parts of the analysis conducted for this TMDL, including:

- estimates of total loading,
- estimates of erosion rates accelerated beyond background levels,
- the effectiveness of actions taken to reduce erosion or capture sediment,
- the effects of sediment on beneficial uses.

An implicit margin of safety has been incorporated into this TMDL through the use of conservative assumptions throughout the source analysis and characterization of beneficial use impacts. Conservative assumptions include the following: 1) use of Tetra Tech's 1998 values for the existing sediment load to the Bay, which include upper Chorro Creek and are one and a half times higher than SCS's estimates from 1989, 2) low range estimates of historical loss of Bay volume (tidal prism), therefore ensuring a smaller allowable loss for the future, and 3) sediment deposition values that do not account for the sediment that gets flushed out of the Bay.

The goal of reducing current sediment loading by 50 percent incorporates the margin of safety and represents an aggressive approach to sediment reduction. Monitoring and evaluation will be done to determine how well the loading capacity and the associated reductions proposed by the TMDL lead to attainment of water quality objectives.

6.3 Temporal Considerations

Seasonal and annual variations in sediment discharges and in flow rates occur in the Morro Bay watershed. The analysis indicates that a single 100-year streamflow event would contribute about 700,000 tons of sediment to the Bay—about 400 acre-feet of sediment (See Table 18). In contrast, a two-year event is expected to contribute about 1,300 tons of sediment to the Bay, or less than one acre-foot of sediment (Tetra Tech, 1998a). Most of the sediment is contributed to the Bay during storm events. In years with low rainfall totals or with smaller storms spaced evenly apart, only small amounts of sediment are delivered; in severe storm events, amounts much greater can be delivered. This variability is addressed in the TMDL by using probability-weighted averages for annual sediment yield developed by Tetra Tech modeling (Tetra Tech, 1998a).

Seasonality in streamflow also affects the rate at which water is flushed out of the Estuary. The flushing half-life of water out of the estuary to the ocean is reduced by lower stream flow rates. During low flow periods, flushing half-life is from two to three weeks, while during high flow periods, the maximum half-life is only one week. Creek flows and sediment discharges also affect tidal circulation and associated deposition in the estuary. Because of the efficiency with which the Estuary is known to trap sediment, and because of the poor understanding of the complex, dynamic process of sediment circulation within, and transport out of the Estuary, Regional Board staff did not subtract a component of flushed sediment when calculating total loading to the Estuary. This approach contributes to an implicit margin of safety, as discussed above.

7. Public Participation

The Regional Board Staff has conducted TMDL outreach by coordinating with forums and events of the MBNEP and Farm Bureau, as well as direct outreach to a MBNEP technical committee (Implementation Committee) and a steering committee of stakeholders for review and comment. In addition, a Board Hearing Process is scheduled for adoption of this TMDL as a Basin Plan Amendment.

8. Implementation Plan

8.1 Introduction

The overall intent of this Implementation Plan is to reduce sediment loading into the Morro Bay Estuary and its tributaries, Chorro and Los Osos Creeks. This Implementation Plan describes existing regulatory controls and cites relevant sections of the California Water Code (CWC) establishing the Regional Board's authority to enforce the provisions set forth in the Implementation Plan. The Plan also describes the way in which the Central Coast Regional Water Quality Control Board (Regional Board) will implement the TMDL in coordination with the Morro Bay National Estuary Program (MBNEP).

Because the sediment load of the Morro Bay Watershed derives principally from nonpoint sources (NPS), this Implementation Plan will emphasize the Three-Tier Framework for NPS pollution control (CWC §13369), and incorporate concepts set forth in the NPS Program Plan. However, the Plan provides for integration of the three-tier approach with continued implementation of regulatory controls on point sources, including storm water.

This Implementation Plan describes the Three-Tier Framework for nonpoint source (NPS) pollution control that will be used in determining when and what type of enforcement actions the Regional Board would use, should self-determined, voluntary actions (Tier 1) be ineffective or inadequate. The Plan identifies the specific actions that are expected to bring about the reductions in sedimentation specified in the TMDL. The Plan also builds on ongoing efforts of both the Regional Board and other Implementing Parties and stakeholders, and proposes new actions by these parties. The reader can go directly to Table 29 in the section entitled *Implementation Actions* to learn which of these actions are to be tracked by the Regional Board in its effort to ensure compliance with the TMDL.

Section 13242 of the CWC requires that a plan of implementation be incorporated into the Basin Plan when the Regional Board adopts TMDLs. The implementation plan must include: 1) a description of the nature of the actions necessary to achieve the water quality objectives, including recommendations for appropriate action by any entity, public or private; 2) a time schedule for the actions to be taken; and 3) a description of the monitoring and surveillance to be undertaken to determine compliance with the objectives. Pursuant to CWC §13141 this implementation plan identifies available means for complying with the TMDL; evaluates the economic impacts of implementation of the TMDL; and identifies potential sources of funding for implementation actions identified herein.

The Basin Plan amendment process has been certified by the Secretary for Resources as "functionally equivalent to," and therefore exempt from, the California Environmental Quality Act (CEQA) requirement for preparation of an environmental impact report or negative declaration and initial study (CCR Title 14, §15251(g)). However, a CEQA-required Environmental Checklist must be completed and is included in the Basin Plan Amendment package that will be considered for adoption by the Regional Board.

8.1.1 Watershed-Wide Implementation

The listing of Morro Bay and two principal tributaries prompted a watershed-scale analysis of sedimentation in this TMDL. Similarly, the Implementation Plan includes a broad selection of actions, which are to be implemented throughout the entire watershed. As the receiving water of all its tributaries, conditions in the Morro Bay Estuary are a reflection of conditions in all tributaries, not just the two listed tributaries, Chorro Creek and Los Osos Creek. Thus, load reductions are necessary in all major tributaries and from all sources (Table 23). The TMDL, as a Basin Plan amendment, requires implementation throughout and in any appropriate waterbody in the Morro Bay Watershed. Compliance with this amendment will be determined by monitoring representative locations in certain tributaries and the Bay (see monitoring plan) and by tracking all implementation actions taken.

8.2 Existing Sediment Control Programs

8.2.1 Morro Bay Comprehensive Conservation Management Program

In April 1994, through the efforts of the Friends of the Estuary, the Governor established Morro Bay as California's first State Estuary. This designation formally recognized the importance of "preserving and enhancing Morro Bay and its watershed as one of the state's rare natural treasures" and the special need for a multi-jurisdictional planning effort. The development of a comprehensive management plan by July 1997 was legislatively mandated. The Task Force convened an administrative committee, the Watershed Council, to oversee development of the plan. In 1998, the City of Morro Bay and the County of San Luis Obispo received the State Plan.

In October 1995, Morro Bay was accepted into the NEP primarily because of the long-term grass-root efforts, and because it was already a designated State Estuary. The Morro Bay National Estuary Program (MBNEP) is one of 28 national programs currently working to safeguard the health of some of the Nation's most important coastal areas.

The primary goal of the MBNEP is to develop and implement a Comprehensive Conservation and Management Plan (CCMP) that recommends priority corrective actions addressing point and nonpoint sources of pollution. These actions will restore and maintain the chemical, physical, and biological integrity of the estuary, including water quality, a balanced indigenous population of shellfish, fish, and wildlife, and recreational activities in the estuary, as well as assure that the designated uses of the estuary are protected. The Regional Board and the Bay Foundation, in conjunction with the USEPA Region IX, established a Management Conference to prepare the CCMP. Building on the efforts underway for more than two decades, the MBNEP has continued to work to further refine the problems, identify specific actions to address those problems, and define the necessary steps for implementing actions (MBNEP, 2000a, p.1-4).

The CCMP is recognized as the primary vehicle for implementation of BMPs that will reduce sedimentation in Morro Bay and its tributaries. The MBNEP takes the lead in implementation through coordinating the various parties that will perform on-the-ground projects and conduct educational programs to promote stewardship in the Watershed. The Regional Board considers these activities to be consistent with Tier One, (self-determined) of the State's Nonpoint Source, and proposes through this implementation plan to track their completion.

8.2.2 Morro Bay Watershed Enhancement Program

In 1987, the Coastal San Luis Resources Conservation District (CSLRCD) obtained funding through the California State Coastal Conservancy (SCC) to quantify the historical loss of open water in the bay, and to locate and quantify sediment sources to the bay in order to create a baseline for future reference. Utilizing the information gained from this research, the CSLRCD developed the Morro Bay Watershed Enhancement Plan (MBWEP). The U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (USEPA) have also contributed funding for the enhancement of the Morro Bay Watershed for education and technical assistance programs in the watershed region. To date, over 245 conservation practices have been installed in the watershed through technical and financial assistance provided through the MBWEP. The most significant single action included in the MBWEP is the Chorro Flats Enhancement Project (CFEP) constructed in 1997, which essentially reconnected Chorro Creek with its historical floodplain, thereby allowing sediment to be deposited there instead of in Morro Bay. These projects have resulted in the prevention of over 172,000 tons of soil erosion entering Morro Bay. Additionally, MBWEP projects have caught an estimated 300,000 cubic yards of sediment before it reached the bay (MBNEP, 2000a, p.1-4).

Resource Conservation District staff expect that in each year of implementation, the number and type of actions implemented would be similar to a typical year of the MBWEP. A typical year of the MBWEP resulted in the following actions:

Product/Practice	**Extent**
Ranch Conservation Plan	5 plans
Farm Conservation Plan	2 plans
Planned Grazing System	700 acres
Proper Grazing Use	700 acres
Deferred Grazing	450 acres
Grassed Waterway	1,500 feet
Critical Area Planting	4 acres
Lined waterway	150 feet
Filter Strip	1,500 feet
Vegetative Buffer Strip	1,200 feet
Stream Corridor Improvement	5,000 feet
Fish stream Improvement	500 feet
Livestock Exclusion	90 acres

8.2.3 Farm Bureau Watershed Program

Since 1996, the San Luis County Farm Bureau has been working to develop workable watershed programs. The general purpose of the program is to develop and implement voluntary, cost-effective, landowner/manager-directed programs for the identification and control of agricultural sources of pollution. A multi-county program is being developed to provide reasonable assurances that agricultural sources of pollution will satisfy load allocations.

Morro Bay is a priority watershed for the Farm Bureau (Fitzhugh, 2000) and efforts are under way to develop a local Agricultural Water Quality Program, which would include the development and presentation of "short courses" to the local agricultural community. The Farm Water Quality Planning short course is designed to provide training for growers in irrigated agriculture and rangeland management interested in implementing water quality protection practices. The short course is designed to teach basic concepts of watersheds, nonpoint source pollution (NPS), including erosion control, self-assessment techniques, and monitoring. Attendance at these short courses presented to date has been high among the ranchers and growers, and has included a strong cross section of landowners in both the Chorro and Los Osos Subwatersheds. This strong cross section interest will allow the Farm Bureau to concentrate initial efforts on projects in the areas with the highest erosion potential and concerns. The Farm Bureau will document implementation and success of BMPs through a coordinated effort for individual self-monitoring among the ranchers and growers.

Regional Board Staff have made presentations at the short courses to inform participants of the goals of the State's Nonpoint Source Plan and the Three-Tier Framework for its implementation. The TMDL development and implementation process is also described by Board Staff for participants.

8.3 Implementation Actions to Reduce Sediment

The Central Coast Regional Water Quality Control Board (Regional Board) will implement the TMDL in coordination with the Morro Bay National Estuary Program (MBNEP). The Conservation and Management Plan (CCMP) developed by a consortium of stakeholders, calls for the development and implementation of Total Maximum Daily Loads (TMDLs) in the Morro Bay watershed and identifies many water quality control and management actions to reduce sediment loads.

8.3.1 Sediment Reduction Activities

8.3.1.1 Rates of Sediment Reductions from BMPs

Numerous land treatment measures will be implemented to achieve the sediment TMDL for Los Osos Creek, Chorro Creek, and the Morro Bay Estuary. The SCS estimated that implementing rural and urban land treatment measures alone could reduce the average sediment loading to the estuary by nearly half. Reductions begin by implementing Best Management Practices (BMPs) in the watershed. Typical reduction rates are included in Table 25. Sediment capture projects include restoration of floodplains, wetlands, and other basins not in the stream channel. These could be secured through land acquisition, easements, and improvements in channel configurations that would function to reduce sediment loading to the bay. Sediment capture projects are considered off-site BMPs, since they collect sediment after it has been transported from its place of origin.

Table 25. Typical Sediment Reduction Rates from BMPs

Erosion Category		Land Area	BMPs	Sediment Reduction
Sheet and Rill	**On-Site Measures**	Rangeland	Fences, Seeding, Deferred Grazing	50%
		Brush/Woodland (includes mines)	Prescribed Burn, Regrading, Revegetation, Stabilization of Tailings	10%
		Cropland	Drip Irrigation, Cross-Slope Cultivation.	50%
		Urban Construction	Mulch, Sediment Fence, Sediment Basin	90%
Streambanks		Riparian Areas	Fences and Deferred Grazing or Clearing, Tree Planting	66%
Roads		Roads	Waterbars and Revegetation	40%
Gullies		Gullies	Shape, Seed, Fertilization, Mulch	60%
All Categories	**Off-Site Measures**	Sediment capture projects (changes in land use, stream meandering pattern alterations, flood area.)	Store Sediment	90%

Source: SCS, 1989a, Table 7, p. 29.

8.3.1.2 Expected Sediment Reductions from BMP Implementation

The extent of BMP implementation and its effectiveness in Chorro and Los Osos Creeks depends on each project site's erosion severity. The percent reduction of any BMP assumes even application and mean effectiveness rates on total acres. However, BMPs will actually be applied to prioritized areas to achieve the TMDL. Regional Board staff will coordinate with the MBNEP in prioritizing lands by relative sediment loads to each tributary as determined in this TMDL.

Regional Board staff applied on-site BMP reduction rates (Table 25) to erosion categories, and to land use categories for sheet and rill erosion. Table 26 shows current sediment yield, typical sediment reduction rates from BMPs, and the resulting load for erosion categories in Chorro and Los Osos Creeks. Table 27 further breaks down the sheet and rill component of erosion by land use category. As shown in Table 26, total sediment production would be reduced to 42,099 tons per year by implementing on-site BMPs. This is 7,214 tons per year more than that allowed by the 34,885 ton/year TMDL.

Table 26. Current Sediment Yield, Typical BMP Reduction Rates, and the Resulting Loading by Erosion Category in Chorro and Los Osos Creeks.

		EROSION CATEGORIES				
Subwatershed	**Existing annual average loading (tons/year) With out additional BMPs**	**Sheet and Rill (tons/year)**	**Streambanks (tons/year)**	**Roads (tons/year)**	**Gullies (tons/year)**	**Total Annual Average Loading with BMPs (tons/year)**
Typical BMP Sediment Reduction		**10%-90% (see Table 27)**	**66%**	**40%**	**60%**	
Chorro Creek at Reservoir (CHD)	**13,082**	7,438	902	1,087	53	**9,480**
Dairy Creek (DAM)	**880**	390	61	73	4	**527**
Pennington Creek (PEN)	**1,932**	1,009	133	161	8	**1,311**
San Luisito Creek (SLU)	**14,630**	7,381	1,008	1,216	59	**9,664**
San Bernardo Creek (SBE)	**20,539**	9,427	1,416	1,707	83	**12,633**
Minor Tributaries	**8,978**	3,107	619	746	36	**4,508**
Chorro Creek (TWB)	**60,041**	27,100	4,138	4,990	243	**36,471**
Los Osos Creek (LVR)	**6,105**	3,064	444	599	31	**4,138**
Warden Creek and Tributaries	**3,624**	1,380	263	356	18	**2,018**
Los Osos Creek (SYB)	**9,729**	4,020	707	955	49	**5,731**
Morro Bay Watershed	**69,770**	30,728	4,901	6,164	307	**42,099**

TTYIELDBMP%ALLocation

Table 27. Typical BMP Reduction Rates, and the Resulting Loading Rate from Sheet and Rill Erosion by Land Use Category in Chorro and Los Osos Creeks.

	LAND USES					
Subwatershed	**Rangeland**	**Brushland**	**Woodland**	**Cropland**	**Urban**	**Total**
	(tons/years)					
Typical BMP Sediment Reduction	**50%**	**10%**	**10%**	**50%**	**90%**	
Chorro Creek at Reservoir	249	6,611	579			**7,438**
Dairy Creek	155	212	22			**390**
Pennington Creek	148	783	79			**1,009**
San Luisito Creek	1,253	5,885	46	197		**7,381**
San Bernardo Creek	1,517	5,772	451	1,687		**9,427**
Minor Tributaries	1,100	856	342	725	84	**3,107**
Chorro Creek	5,274	17,160	1,643	2,840	183	**27,100**
Los Osos Creek	276	2,233	482	71	1	**3,064**
Warden Creek and Tributaries	329	721	8	311	12	**1,380**
Los Osos Creek	765	2,368	220	642	24	**4,020**
Morro Bay Watershed	5,963	19,282	1,840	3,438	204	**30,728**

TTS&RadjBMP%allocate

SCS indicated that by the installation of sediment capture projects, 90 percent of the sediment load could be reduced (Table 25). As an example of the effectiveness of sediment capture projects, the Coastal San Luis Resource Conservation District (CSLRCD) found that on Chorro Flats, a large scale floodplain restoration project, 23 percent of fine sediment, and 85 percent of bedload materials were collected during

El Niño years following the Highway 41 Fire (CSLRCD, 2000). The greatest load reductions would likely be achieved in sediment capture projects constructed primarily in the tributaries exhibiting: 1) a higher number of roads, and 2) land uses that result in less than 50 percent reduction by implementing other BMPs (brushland and woodland). As shown in Table 28, sediment capture projects would be most effective in the subwatersheds of San Luisito Creek, San Bernardo Creek, in the headwaters of Chorro Creek, and on Los Osos Creek. As a result of implementing on-site BMPs, along with sediment capture projects in the watershed, the final load will be below the load allocation, and thus, the TMDL will be achieved. The above subwatersheds are candidates only, since final selection of project locations will be subject to a variety of site-specific factors, including, topography, hydrology, access, and cost.

Table 28. Sediment Loads to be Collected by Sediment Capture Projects to Achieve the TMDL*.

Waterbody	Existing Loading	Sediment Load w/ BMP Implementation (w/o Sediment Capture Projects)	Load Allocation (TMDL)	Sediment Requiring Collection to meet Load Allocation (TMDL)
		A	B	C=A-B
	(tons/year)			
Chorro Creek at Reservoir	13,082	9,480	6,541	**2,939**
Dairy Creek	880	527	440	**87**
Pennington Creek	1,932	1,311	966	**345**
San Luisito Creek	14,630	9,664	7,315	**2,349**
San Bernardo Creek	20,539	12,633	10,269	**2,364**
Minor Tributaries	8,978	4,508	4,489	**19**
Chorro Creek	60,041	36,471	30,021	**6,450**
Los Osos Creek	6,105	4,138	3,052	**1,085**
Warden Creek and Trib.s	3,624	2,018	1,812	**206**
Los Osos Creek	9,729	5,731	4,864	**866**
Morro Bay Watershed	**69,770**	**42,099**	**34,885**	**7,214**

TTYieldBMP%Allocation

* Final selection of location for sediment capture projects will be determined by several site-specific factors including topography, hydrology, access, and funding.

8.3.2 Trackable Implementation Actions

Trackable Implementation Actions in this TMDL include both voluntary actions and those required under existing or anticipated regulatory requirements. Voluntary actions will be taken by a variety of implementing parties, while the required actions are to be taken by identified dischargers.

8.3.2.1 CCMP Projects

Under the auspices of the MBNEP, numerous actions that will reduce sediment loading were identified and prioritized by a consortium of stakeholders. These actions were included in the Comprehensive Conservation Management Plan (CCMP), and derive from the following objectives:

- Increase the use of management measures for road maintenance and construction activities to reduce damage to streams and the Morro Bay estuary.
- Install new and maintain existing sediment traps to reduce the delivery of sediment to Morro Bay.
- Develop and implement a watershed fire management plan to create and maintain an uneven age class of brush.

- Supply technical and financial assistance to landowners to implement BMPs on their land.
- Supply technical and financial assistance to landowners to implement creek restoration projects (including re-establishing floodplain and meander patterns) in Los Osos and Chorro Creeks.
- Provide incentives for landowners to encourage implementation of BMPs for erosion control and sediment retention.
- Acquire or otherwise protect lands that contain ecologically valuable habitat or habitats that provide beneficial functions to the estuary, in order to minimize nonpoint sources of pollution entering the estuary.

Currently planned projects to achieve these CCMP objectives range from land acquisitions to development of water quality short courses by the Farm Bureau. Each project includes a discrete action, identified benefits, a schedule, and a party responsible for its implementation. Table 29 includes the current and on-going projects as identified in the CCMP. Also, the projects are discussed in greater detail in Appendix A.

8.3.2.2 Actions Required of Existing Responsible Dischargers

In addition to the cooperative and voluntary implementation actions mentioned above (and described in detail in Appendix A), several implementation actions will be performed by responsible dischargers currently, or anticipated to be, under regulatory requirements. These include the California Army National Guard, responsible for Primera Mine remediation and erosion control, California Polytechnic University, currently under a WDR covering water quality management, and the County of San Luis Obispo and Caltrans, both subject to requirements of stormwater NPDES permits. Table 29 identifies the specific actions required of these responsible dischargers.

8.3.2.2.1 Remediation of the Primera Mine

This site consists of a five-acre mine pit and 15 acres of mine tailings that are located near Chorro Creek. Unstable mine tailings from this abandoned chromite mine are contributing large quantities of metal-rich sediment into Chorro Creek. To date, water quality analysis does not indicate the presence of metals in the water column of the creek. The existing 5-acre mine pit is internally draining and does not pose an erosion threat to the creek. The objectives of the project include regrading and stabilizing approximately 15 acres of mine tailings using bio-technical methods and revegetation with native species to provide long-term stability for the site. Any drainage generated at the site will be dispersed, infiltrated, or conveyed in a stabilized manner to a natural channel. The Camp San Luis California Army National Guard is still seeking sources to provide funding through their budget for this project.

Pursuant to Section 13304 of the California Water Code, Regional Board staff has entered into a cost-recovery agreement with the National Guard that covers investigation and remediation of known or suspected pollution source sites. This action by the Regional Board places mine site remediation activities into Tier Three of the Three-Tier Framework for NPS Pollution Prevention and progress toward implementing the necessary site improvements will be monitored through this TMDL’s Monitoring Plan.

8.3.2.2.2 Stormwater Management on County Roads and Caltrans Facilities

All roadwork activity implemented by the county is currently done so under a “common sense” approach, which includes sediment basins, the removal of dredged materials, cross culverts, routine maintenance, and any other work related to the design and construction of roads. Phase II municipal stormwater NPDES permit will identify the County as a discharger of stormwater and require the County to address erosion control on roads as part of the “pollution prevention good housekeeping” minimum requirement. The County is to have a Stormwater Management Plan in place by March 8, 2003 and show progress toward implementation in subsequent years, until year five when full implementation is required.

Through this Implementation Plan, the Regional Board will require the County to specifically identify road erosion control measures prior to their final submittal of the Stormwater Management Plan for enrollment in the General Municipal Stormwater NPDES. Additionally, the three-year review of progress toward implementation actions for this TMDL will include specific consideration of the County's progress toward implementing road erosion control measures in the Morro Bay Watershed.

Caltrans road maintenance activities in the Morro Bay Watershed are currently regulated under a General Stormwater Permit. Caltrans will also be subject to Phase II requirements and the Regional Board will track implementation in the same manner as described above for the County.

8.3.2.2.3 Cal Poly Waste Discharge Requirements

Three ranches owned and operated by California Polytechnic State University San Luis Obispo (Cal Poly) are located in the Chorro Creek Watershed. The ranches are managed for grazing and cultivated for dry-land crops. The ranches also have approximately 31 miles of unimproved roads and a variety of improvements, including: wells, residences, a maintenance shop, corrals, and barns (Cal Poly Facilities Planning Department, 2001, pp. 13, 14).

Ranch Water Quality Management Plans have been developed for these ranches and are now integrated into a Water Quality Management Plan for Cal Poly Land in San Luis Obispo Creek and Chorro Creek Watersheds (Ibid.). The plan identifies Best Management Plans for the ranches to prevent nonpoint source pollution. Waste discharge requirements identified from existing permits by the Regional Board are also incorporated into the Plan. Regional Board staff will review the existing Waste Discharge Requirements and incorporate elements of the Water Quality Management Plan pertaining to the Chorro Creek ranches into a new WDR.

Table 29. Trackable Implementation Actions

PROJECT NAME	ACTION	SCHEDULE	IMPLEMENTING PARTIES
Hollister Ranch Acquisition	Design and construct floodplain restoration project	January 2002-May 2005	CSLRCD and MBNEP
Los Osos Creek Wetland Restoration Project	Design and construct Los Osos Creek wetland restoration project	Fall 2000-Spring 2003	CSLRCD and MBNEP
Watershed Crew Curriculum	Develop a curriculum that will provide training for a year-round crew of CCCs	Winter 2001-Fall 2001	CCC
Catalogue of Erosion Control Projects	Develop a list of areas in need of erosion control projects	Spring 2001-Fall 2001; on-going	MBNEP
Project Clearwater	Provide technical assistance and cost sharing to install BMPs	2001-June 2004; on-going	CSLRCD
Agricultural Water Quality Program	Develop and implement a voluntary, cost-effective, and landowner/manager-directed program	2001-2002; on-going	Farm Bureau
Land Acquisitions and Conservation Easements	Acquire or otherwise protect lands in cooperation with willing land owners	2000-2010; on-going	MBNEP
Fire Management Plan	Develop and implement a Fire Management Plan	2001-2006; on-going	CDF
Maintenance of Sediment Basins Above Chorro Reservoir	Continue maintenance of the sediment basins above Chorro Reservoir	on-going	California Army National Guard
Road Maintenance	Increase the use of management measures for road maintenance and construction	2001-2006; on-going	County of San Luis Obispo, Public and Private Landowners; California Department of Transportation
Sediment Traps	Install sediment traps	2000-2007; on-going	CSLRCD; Natural Resource Conservation Service; DFG; Public and Private Land Owners
PROJECT NAME	**ACTION**	**SCHEDULE**	**RESPONSIBLE DISCHARGERS**
Primera Mine Rehabilitation and Erosion Control	Remediation of Primera Mine	2004	California Army National Guard
Stormwater Sediment Control on Roads	Include specific road sediment control measures in County stormwater management plan prior to enrollment in Stormwater Permit; track implementation of BMPs	Prior to March 2003; on-going	County of San Luis Obispo
	Track implementation of BMPs in Stormwater Permit	On-going	Caltrans
Water Quality Management Plans on Chorro Creek Ranches	Revise Waste Discharge Requirements to address Chorro Creek Ranches	Fall 2002-Fall 2003	California Polytechnic State University

8.4 Regulatory Mechanism by which TMDL Implementation is Assured

8.4.1 Regional Board Authority to Require Implementation

The Porter-Cologne Water Quality Control Act establishes the responsibilities and authorities of the Regional Water Quality Control Board, including authority and responsibility for regional water quality control and planning. The Regional Board establishes water quality objectives by amending its Water Quality Control Plan for the Central Coast Region (Basin Plan). To prevent water quality problems, the Regional Board enforces waste discharge restrictions. The waste discharge restrictions can be implemented through waste discharge prohibitions, Water Quality Certification (Clean Water Act §401), National Pollutant Discharge Elimination System (NPDES) permits, waste discharge requirements (WDRs), enforcement actions, and/or Best Management Practices (Basin Plan, p. IV-3.) These mechanisms facilitate monitoring and reporting, in addition to implementation of discharge controls and water quality protection actions.

The Basin plan specifies pollution controls from point sources by implementing a variety of full regulatory programs, including the NPDES Program, and the issuance of Waste Discharge Requirements. In the case of nonpoint sources, the Regional Board relies on the implementation of NPS controls, including Management Measures and associated Management Practices within the Three-Tier Framework for NPS pollution control (CWC §13369), and on the application of a wide range of State programs and enforcement authorities.

8.4.1.1 Three-Tier Framework for Nonpoint Source Pollution Control

The three-tier framework uses three different options of enforceable policies and mechanisms under the California Water Code to ensure implementation of the *"Plan for California's Nonpoint Source Pollution Control Program,"* (NPS Program Plan). The options, or *tiers,* are presented in order of increasing stringency:

Tier One: Self-Determined Implementation of Management Practices
Tier Two: Regulatory-Based Encouragement of Management Practices
Tier Three: Effluent Limitations and Enforcement.

Through the Three-Tier Framework, the Regional Board acknowledges that many NPS problems are best addressed through the self-determined cooperation of stakeholders in improving their management practices (Tier 1). However, persistent NPS water quality problems not effectively resolved through self-determined action will be addressed through applicable regulatory programs and authorities (Tier 2 and Tier 3). Sequential movement through the tiers is not required of the Regional Board. Depending on the severity of the NPS problem, the Regional Board may move directly to the enforcement actions specified in Tier 3. Also, the Regional Board can choose to implement a combination of water quality control mechanisms from each of the Tiers as well as additional remedies (e.g., enforcement orders) as provided under the CWC.

The listing of the Morro Bay Estuary and Chorro and Los Osos Creeks as impaired by sediment, is based on evidence of persistent nonpoint source water quality problems that are not responding adequately to self-determined actions in the watershed. In fact, no comprehensive program of self-determined actions has been implemented in the watershed. This implementation plan represents a programmatic response to these problems and will exercise all options available under the Three-Tier Framework.

8.4.2 Regulatory Control Measures to Reduce Sedimentation

Described below are existing regulatory pollution control measures used by the Regional Board that potentially affect sediment discharge in the Morro Bay Watershed. The manner in which these measures will be used to achieve the reductions in sediment loading is described in sections that follow.

8.4.2.1 401 Certification

This is a federal program that requires a permit for activities that may result in a discharge into a waterbody. The program requires project applicants to make a request for certification by the State to insure that the proposed activity will not violate any state or federal water quality standards. Most of the projects subject to water quality certification involve work in and around waterways.

In the Morro Bay Watershed, recent 401 projects have included: dredging within the harbor mouth, wharf piling replacements, and several culvert maintenance or replacement projects on streams within the watershed. However, a 401 certification with ramifications for sediment reduction activities is anticipated for the Sustainable Conservation program. That program is designed to streamline the permit process for conservation projects—many of which include Best Management Practices (BMPs) for erosion control. Under this program, permitting for these projects, when needed, will be covered under a set of watershed-wide permits that will be jointly held by the Natural Resources Conservation Service and the Coastal San Luis Resource Conservation District (CSLRCD). These permits are being developed with funding from an "Early Action" grant from the MBNEP and the Bay Foundation to "streamline" the regulatory process, including 401 Certification, and to remove a significant impediment to BMP implementation.

A total of sixteen conservation practices have been identified under this permit process to be implemented in the Morro Bay Watershed including critical area planting, filter strips, fish stream improvements, grassed waterways, streambank protection, and sediment capture projects. The Coastal San Luis Resource Conservation District has gone through the process of getting these 16 specific conservation practices approved by all the appropriate permitting agencies. Participants are covered under the watershed-wide permit for the implementation of BMPs on their land and would not be required to apply for any additional permits, unless they deviate from the original approved design criteria.

8.4.2.2 Stormwater National Pollutant Discharge Elimination System Permits

Phase I and Phase II federal storm water regulations require NPDES permits for construction activities, industrial activities, and for municipal separate storm sewer systems. Phase I of the USEPA Storm Water Program was promulgated in 1990 under the Federal Clean Water Act. Phase I relies on NPDES permit coverage to address storm water runoff from: (1) “medium” and “large” municipal separate storm sewer systems (MS4s) generally serving populations of 100,000 or greater, (2) construction activity disturbing five acres of land or greater, and (3) ten categories of industrial activity. Phase I municipal stormwater requirements do not apply to Morro Bay communities, since they fall below the population thresholds. However, Phase I construction and industrial requirements are currently in effect throughout the watershed. In the Morro Bay watershed, industrial facilities are not significant contributors of sediment through stormwater.

8.4.2.2.1 Municipal Stormwater General Permit

The Storm Water Phase II Final Rule is the next step in USEPA’s effort to preserve, protect, and improve waters polluted by storm water runoff. The Phase II program for municipal stormwater expands the Phase I program by requiring additional operators of MS4s in urbanized areas, through the use of NPDES permits, to implement programs and practices to control polluted storm water runoff. General Permits will cover these actions. General permit requirements include the submission of a Notice of Intent to comply with the permit and the submittal of Storm Water Management Plans.

A Storm Water General *Municipal* Permit covering all communities greater than 10,000 is scheduled for Regional Board adoption by December 8, 2002. Under the General Municipal Permit, the County of San Luis Obispo, and the communities of Los Osos, Baywood, Morro Bay will be required to develop and submit Stormwater Management Plans to the Regional Board by March 10, 2003. Upon submittal of the Storm Water Management Plan to the Regional Board, the entities will be covered under the General Permit.

The Phase II Final Rule will require San Luis Obispo County and the communities of Los Osos, Baywood, and Morro Bay to develop, implement, and enforce a program to reduce pollutants in storm water runoff to their storm sewer system. The entities have the option of working cooperatively to submit a region-wide program, but are nonetheless required to implement the following measures:

- Have an ordinance or other regulatory mechanism requiring the implementation of proper erosion and sediment controls, and controls for other wastes, on applicable construction sites;
- Have procedures for site plan review of construction plans that consider potential water quality impacts;
- Have procedures for site inspection and enforcement of control measures;
- Have sanctions to ensure compliance (established in the ordinance or other regulatory mechanism);
- Establish procedures for the receipt and consideration of information submitted by the public; and
- Determine the appropriate best management practices.

This TMDL estimates that sediment sources from roads are approximately 15 percent of the contribution to the Morro Bay watershed. Currently, there are no formal county guidelines, procedures, or ordnances that standardize practices in road maintenance or construction by San Luis Obispo County. All roadwork activity implemented by the county is done so under a “common sense” approach which includes sediment basins, the removal of dredged materials, cross culverts, routine maintenance, and any other work related to the design and construction of roads.

Through this Implementation Plan, the Regional Board will require the County to codify the implementation and enforcement of erosion control measures on County roads in the Morro Bay Watershed through its compliance with Phase II municipal stormwater regulations.

8.4.2.2.2 Construction Stormwater General Permit

Storm water runoff from construction sites often flows to storm sewers and is ultimately discharged into Morro Bay and its tributaries. Of the pollutants commonly discharged from construction sites, sediment is usually the main pollutant of concern. The Phase I NPDES Storm Water Program currently in effect requires operators of construction activities that disturb five or more acres to obtain a NPDES Construction Storm Water Permit. In San Luis Obispo County the Regional Board issues these permits. The Phase II Final Rule similarly regulates discharges from smaller construction sites disturbing equal to or greater than one acre and less than five acres.

The County has several programs and ordinances developed to control for erosion and sedimentation at the source. For instance, there is a specific ordinance that requires developers to draft a drainage and erosion control plan when new structures are constructed and subsequently maintained as a business or private residence in San Luis Obispo County. The requirement is triggered upon the submittal of an application for a building or grading permit for a project on a slope of greater than ten percent, on soils that are prone to poor drainage, and/or as needed at the discretion of county staff. Enforcement for the implementation of the drainage and erosion control plan relies upon infrequent surprise inspections by county staff, the Regional Boards enforcement of Stormwater Pollution Prevention Plans, and complaints from adjacent property owners.

A Storm Water General *Construction* Permit covering all small construction sites in communities of the Central Coast Region is scheduled for State Board adoption by December 8, 2002. Site owners/operators will be required to submit a Notice of Intent to be covered by this permit.

8.4.2.2.3 Caltrans Stormwater General Permit

The Caltrans statewide stormwater permit is scheduled for re-adoption at the time of the Phase II Municipal Permit adoption takes place in March 2003. The Caltrans permit covers all activities that take place in the right-of-way of Highway 1 as it passes through the Morro Bay Watershed. These activities include road re-surfacing, seismic retrofitting of bridges, culvert maintenance and installation, as well as guardrail and median maintenance. Regional Board staff will continue to perform inspections of Caltrans projects to ensure compliance with terms of the general permit.

8.4.2.3 Waste Discharge Requirements (WDRs)

The Regional Board, pursuant to CWC §13260, can stipulate requirements on any proposed or existing discharge of waste that threatens to cause or causes adverse effects to water quality, including nonpoint source discharges. Once issued, compliance and water quality protection are legal responsibilities of the WDR holder.

With rare exception, WDRs enforced in the Morro Bay Watershed address non-sediment related discharges—the majority being focused on domestic wastewater. However, WDRs can provide an appropriate context for requirements that reduce erosion and sedimentation. The WDR under which California State University, San Luis Obispo (CalPoly) manages campus facilities and ranch properties, including those in the Morro Bay Watershed, is an example of this. Implementation of CalPoly's Water Quality Management Plan will become a principal means of complying with the re-issuance of the WDR for these facilities.

8.5 Schedule of Compliance

Regional Board staff estimated an average reduction from on-site measures of 607 tons/year based on the annual pace of implementation anticipated by the Resource Conservation District (McEwen, 2000) and SCS's estimates of sediment reductions for each BMP (USDA, SCS, 1989a, p. 32). Assuming the measures were cumulative over time, within 50 years this would lead to a reduction of 30,350 tons/year (607 x 50), or, 4,545 tons/year less than required by the TMDL of 34,885 tons/year. With the additional direct measures of creating sediment capture areas and conducting prescribed burns in the watershed, staff estimates that a 50-year schedule for attaining the TMDL is feasible.

Because sediment loads are not to be directly measured over this 50-year period, the schedule of implementation for this TMDL tracks the completion of implementation milestones, and lays out a sequence of reviews and evaluations that form the basis of an adaptive management strategy (Table 30). This schedule includes an initial period to develop baseline information not currently available and to review that information to support or modify the selected numeric targets. The 50-year schedule also acknowledges that many implementation actions taken in the near term are expected to take years to produce a response as measured by Numeric Target monitoring.

Table 30. Implementation Compliance Schedule for Sediment TMDL for Morro Bay

At End of Implementation Year:	IMPLEMENTATION MILESTONE			MONITORING ACTIVITY			LOAD ALLOCATION[8] (tons/yr)		
	Chorro Creek	*Los Osos Creek*	*Morro Bay*	*Chorro Creek*	*Los Osos Creek*	*Morro Bay*	*Chorro Creek*	*Los Osos Creek*	*Morro Bay*
1	RB and MBNEP Staff meet to review progress. RB and County Staff meet to review inclusion of road erosion control measures in Stormwater Management Plan.			Baseline Streambed Parameters[9], Turbidity			60,041	9,729	69,700
2	*As above*								
3	RB and MBNEP Staff meet to review progress; RB requests implementation tracking report from Implementing Parties if not provided; RB staff consider modifications to Trackable Implementation Actions			Baseline Streambed Parameters, Turbidity					
4	RB and MBNEP Staff meet to review progress			Baseline Streambed Parameters, Turbidity					
5	RB and MBNEP Staff meet to review progress		RB Staff calculate: 5-year changes to Bay area and volume	Baseline Streambed Parameters, Turbidity		Bathymetry survey			
6	RB and MBNEP Staff meet to review progress; RB request implementation tracking report from Implementing Parties if not provided; RB staff consider modifications to Trackable Implementation Actions			Baseline Streambed Parameters, Turbidity					
7	RB and MBNEP Staff meet to review progress			Baseline Streambed Parameters, Turbidity					
8	*As above*								
9	RB and MBNEP Staff meet to review progress; RB request implementation tracking report from Implementing Parties if not provided; RB staff consider modifications to Trackable Implementation Actions			Baseline Streambed Parameters, Turbidity					
10	RB and MBNEP Staff meet to review progress; RB Staff calculate 10-year rolling average of Streambed Sediment data;		RB Staff calculate: 5-year changes to Bay area and volume	Baseline Streambed Parameters, Turbidity		Bathymetry survey			

[8] Direct measurement of sediment loading is not proposed for this TMDL. Parameters characterizing the effect of loading are to be measured instead and are identified as Numeric Targets. This 50-year schedule for achieving the TMDL acknowledges that implementation actions taken in the near term are expected to take years to produce a response as measured through Numeric Target monitoring.

[9] Streambed Parameters include: Residual Pool Volume; Median Diameter of Sediment Particles; Percent Fine Sediment; Percent Coarse Sediment. (See Table 21 and discussion of Numeric Targets).

At End of Implementation Year:	IMPLEMENTATION MILESTONE		MONITORING ACTIVITY		LOAD ALLOCATION[8] (tons/yr)		
11	RB and MBNEP Staff meet to review progress; RB Staff calculate 10-year rolling average of Streambed Sediment data;		Streambed Parameters, Turbidity				
12	RB and MBNEP Staff meet to review progress; RB Staff calculate 10-year rolling average of Streambed Sediment data; RB request implementation tracking report from Implementing Parties if not provided; RB staff consider modifications to Trackable Implementation Actions;		Streambed Parameters, Turbidity				
13	RB and MBNEP Staff meet to review progress; RB Staff calculates 10-year rolling average of Streambed Sediment data;		Streambed Parameters, Turbidity				
14	*As above*						
15	RB and MBNEP Staff meet to review progress; RB Staff calculate 10-year rolling average of Streambed Sediment data; RB request implementation tracking report from Implementing Parties if not provided; RB staff consider modifications to Trackable Implementation Actions;	RB Staff calculate: 5-year changes to Bay area and volume	Streambed Parameters Turbidity	Bathymetry survey			
16-49	*Repeat as above with 3-, 5- and 10-year milestones.*						
50	**Numeric targets achieved; load reduction achieved**				**30,020**	**4,864**	**34,885**

Because it will be several years before we are able to evaluate the effectiveness of the TMDL using water quality indicators, in the initial phase of implementation the emphasis will be on demonstrating compliance by tracking the completion of actions described in this Implementation Plan. Thus compliance is achieved initially by demonstrating through reporting requirements that implementation measures have been undertaken, and subsequently by showing that numeric targets are achieved through monitoring.

Regional Board and MBNEP staff will meet on an on-going basis at least annually to discuss progress. Every three years, Regional Board staff will consider modification of actions and reporting requirements. Modifications may include selection of additional BMPs, or substitution of Trackable Implementation Actions (Table 29) with in-lieu practices that achieve an equivalent or greater efficiency in controlling sediment.

8.6 Demonstrating Compliance

8.6.1 Measures of Success

The primary measure of success for implementation of this TMDL is attainment of the numeric targets (which represent or indicate the load allocations). However, recognizing the variability inherent in the factors affecting sediment loads within the Morro Bay Watershed, other measures of success, including attainment of trackable implementation actions (BMPs), will be considered in evaluating implementation of the TMDL. Therefore two measures of success are proposed: 1) water quality monitoring indicating numeric target attainment, and 2) evidence of implementation of BMPs.

Because it will be several years before we are able to evaluate the effectiveness of implementation using water quality indicators, in the initial phase of implementation the emphasis will be on demonstrating compliance by tracking the completion of actions described in this Implementation Plan. Thus compliance is achieved initially by demonstrating through reporting requirements that implementation measures have been undertaken, and subsequently by showing that numeric targets are achieved through monitoring. A complete description of compliance monitoring is presented in the next section, Monitoring Plan.

Regional Board and MBNEP staff and implementing parties will meet on an on-going basis at least annually to discuss progress in implementation. In assessing the status of compliance, Regional Board staff will consider the degree to which the implementing party has implemented, or is implementing, sediment control measures. Through these scheduled reviews, implementing parties will provide the necessary information upon which staff will make the determination of compliance. Every three years, staff will consider possible changes to the actions and reporting requirements. Modifications may include selection of additional BMPs, or substitution of BMPs identified in this TMDL as Trackable Implementation Actions (Table 29).

Should staff's third-year review indicate that activities were not completed, or that completed activities were ineffective, staff may identify responsible dischargers and move into Tier Two and Tier Three requirements. If a regulatory mechanism already exists for a responsible discharger (e.g., WDR, or a stormwater permit), then that mechanism will be used to insure that implementation moves forward. If no such regulatory mechanism is in place, then the Regional Board will identify responsible dischargers and request implementation-tracking reports pursuant to Section 13267 of the California Water Code. These reports would indicate the status of implementation actions or in-lieu practices that would effectively control sediment sources. Responsible dischargers would be those who fail to implement BMPs and who are responsible for discharges of sediment to waterbodies.

The Regional Board may request the first report(s) from existing responsible dischargers three years after TMDL adoption (implementation year 3). The Regional Board could request reports from the following responsible dischargers:

- County of San Luis Obispo (NPDES General Municipal Stormwater Permit)
- Caltrans (NPDES General Stormwater Permit)
- California Army National Guard (Cleanup and Abatement Order)
- California State Polytechnic University at San Luis Obispo (Waste Discharge Requirement)

If additional responsible dischargers are identified during triennial reviews, or at any time, the Regional Board may request implementation-tracking reports pursuant to Section 13267 of the California Water Code. Responsible dischargers may coordinate responses to the Board's request with implementing parties, depending on the actions they are implementing and the parties with whom they are cooperating to complete those actions.

8.6.2 Failure Scenarios

There are two "failure scenarios" in which implementation of the TMDL would be considered unsuccessful, and Regional Board action would be required. The first of these is a failure to achieve the numeric targets and corresponding load reductions while at the same time completing trackable implementation actions. Regional Board staff recognizes this outcome is a distinct possibility, based on past occurrences of uncontrollable natural disturbances, such as major floods and catastrophic wildland fires. Under this failure scenario, the Regional Board's action would be to re-evaluate the numeric targets and implementation actions and to adjust them as necessary. Staff will consider information provided by Implementing Parties, including effectiveness monitoring data and percent completion. This scenario would not prompt enforcement action by the Regional Board and would be consistent with Tier One, self-determined implementation of management practices.

The second failure scenario involves failure to meet numeric targets coupled with failure to achieve trackable implementation actions. Implementing Parties may implement in-lieu practices that are expected to be of equivalent or greater effectiveness in controlling erosion and/or trapping sediment. However, should the Implementing Parties fail to implement such in-lieu practices, or fail to achieve trackable implementation actions, the Regional Board could identify a responsible discharger and consider more stringent regulatory mechanisms, consistent with the Three-Tier Framework for NPS Control. (See *Compliance and Enforcement* below). Under Tier Two, regulatory-based encouragement of management practices, responsible dischargers would be required to report on progress taking these actions pursuant to Section 13267 of the California Water Code.

The parameters associated with numeric targets (e.g., residual pool volume, fine sediment percentages, etc.) are relatively insensitive to probable annual variations in the effects of sediment loading over time. Ideally, parameters would directly account for spatial and temporal variations in precipitation, runoff, and discharge, enabling analysts to distinguish changes in loading and its effects that result from land use practices, from changes attributable to differences in runoff intensity. Such indicators were not identified for this TMDL, therefore the numeric targets are expressed as ten-year rolling averages. Additional data, including effectiveness monitoring data and volunteer monitoring data will be collected in parallel with numeric targets data to better inform TMDL compliance evaluations and propose course corrections as necessary. This approach allows proceeding with BMP installation while additional monitoring data are collected to either strengthen the existing analysis or to provide a basis for reviewing and revising the TMDL. This "adaptive management" approach enables stakeholders to move forward with resource protection based on reasonably rigorous planning and assessment.

8.6.3 Compliance Assurance and Enforcement

As provided in the State Board's Water Quality Enforcement Policy, prompt, consistent, predictable, and fair enforcement are necessary to deter and correct violations of water quality standards, violations of the California Water Code, and to ensure that responsible dischargers carry out their responsibilities for meeting the TMDL allocations. This and progressive enforcement are particularly necessary to adequately deal with those responsible dischargers who fail to implement self-determined (Tier One) or regulatory-encouraged (Tier Two) sediment control measures. Thus, Tier Three of the State's NPS Framework for pollution prevention, relies on existing enforcement authority and mechanisms (effluent limitations and required actions), and is invoked when Tiers One and Two have failed to address a NPS pollution problem.

Among the enforcement actions available to the Regional Board are both informal and formal actions. An enforcement action is any action taken to address an incidence of actual or threatened noncompliance with existing regulations or provisions designed to protect water quality. To this end, the Regional Board may use, as the circumstances of the case may warrant, any combination of the following:

- Implementation and enforcement of Section 13267 of the California Water Code to ensure that all responsible dischargers submit, in a prompt and complete manner, documentation of effort to install BMPs.
- Consideration of adoption of waste discharge requirements, pursuant to Section 13263 of the California Water Code, as appropriate (i.e., for any responsible party who fails to implement voluntary or regulatory-encouraged sediment controls).
- Consideration of adoption of an enforcement order pursuant to Section 13304 of the California Water Code against any responsible party who violates Regional Board waste discharge requirements and/or fails to implement voluntary or regulatory-encouraged sediment control measures to prevent and mitigate sediment pollution or threatened pollution of surface waters.
- Consideration of adoption of enforcement orders pursuant to Section 13301 of the California Water Code against those who violate Regional Board waste discharge requirements and/or prohibitions.
- Consideration of Administrative Civil Liability Complaints, as provided for by the California Water Code, against any responsible party who fails to comply with Regional Board orders, prohibitions, and requests.
- Consideration of adoption of referrals of recalcitrant violators of Regional Board orders and prohibitions to the District Attorney or Attorney General for criminal or civil prosecution, respectively.

If the Regional Board were to find that significant discharges or threatened discharges of sediment occur despite the implementation of trackable implementation actions, it would consider the need to revise the actions and would consider the issuance of a Cleanup and Abatement Order (CAO), WDR, or Basin Plan Waste Discharge Prohibition to address the discharge. The Regional Board would not, in this case, impose administrative civil liabilities for violations of the existing waste discharge prohibitions. However if CAOs, WDRs, or prohibitions are established and discharges or threats continue to occur, Regional Board may take enforcement for failure to comply.

8.7 Cost

Porter-Cologne requires that the Regional Board take "economic considerations," into account when establishing water quality objectives. The Regional Board must analyze what methods are available to achieve compliance with the objective and the costs of those methods.

Regional Board staff identified a variety of costs associated with implementation of this TMDL, including: Trackable Implementation Actions (e.g., Los Osos Creek Wetland Restoration Project); BMPs for permanent to semi-permanent features (e.g., sediment capture projects), routine activities (e.g., road spoils removal); and operation and maintenance of semi-permanent BMPs.

A more complete estimate of costs would include consideration of the monetary benefits accrued by successful implementation of certain BMPs and implementation actions. Indeed, it is this benefit to cost ratio that will serve as an important motivation for various stakeholders to pursue implementation. As an example of the scale of these benefits, the USEPA reports on road repair costs for a 20-year period with and without BMPs, citing a benefit to cost ratio of 1.78 for road BMP installation versus a ratio of 1.0 for reconstruction and repair over the same period (1993, p. 3-56). The effect of such benefits would be to reduce the total costs of achieving the TMDL.

8.7.1 Cost of Trackable Implementation Actions

Anticipating the costs of Trackable Implementation Actions with any accuracy is challenging for several reasons. Many of the actions, such as the County specifying sediment control measures for roads, could incur only costs in the program budgets of those agencies. However, other actions, like maintenance of sediment basins above Chorro Reservoir, would incur discrete costs. Cost estimates are further complicated by the fact that some implementation actions are necessitated by other regulatory requirements (e.g., Phase II Stormwater) or are actions anticipated regardless of TMDL adoption (Fire Management Plan). Therefore assigning all of these costs to TMDL implementation would be inaccurate. For example, Phase II Stormwater program implementation costs could run as high as $51,000 for a community with a population of 65,000, based on preliminary estimates developed by Regional Board Staff. For smaller communities such as Los Osos, these costs would be lower, but still significant. These programs would include many components that address sediment management, such as: public education, a stormwater ordinance, and good housekeeping (erosion control, vegetation, storm drain maintenance, and agency staff training for municipal facilities).

The Morro Bay Comprehensive Conservation and Management Plan includes preliminary cost summaries for actions required to fully implement the plan. The Plan gives a preliminary five-year cost estimate of $13.5 million for the "sediment action category," and $20 million for "habitat acquisition" (MBNEP, 2000, Table 7.1, p. 7-10). The Plan emphasizes that these cost estimates are very preliminary and presented for broad comparison purposes only.

8.7.2 Cost of Erosion Control BMPs

While there is a range of discrete costs associated with on-the-ground BMP implementation, several factors influence the accuracy of the estimate of total costs. The most significant factor is the uncertainty surrounding the number of miles of road, acres of developed upland parcels, or floodplain areas to be treated. Additional assessment is required to identify where, when, and to what degree these areas would be best addressed with the techniques of erosion control. This uncertainty, contributes to the preliminary nature of the costs identified above. Example annual costs of BMPs reveal a range of options and expense (Table 31).

Table 31. Example Annual Costs for On-Site BMPs.

Practices	Actual Cost (Maximum)	Practices	Actual Cost (Maximum)
Access Road (repair)	$5/ft.	Range Seeding:	
Brush Mgt.	$10/ac.	Native species	$250/ac.
Channel Vegetation	$600/ac.	Introduced species	$100/ac.
Clearing and Snagging	$10/ft.	Riparian Buffer Strip	$600/ac.
Conservation Tillage	$20/ac.	Roads*	
Cover/Green Manure Crop:		Culverts and Water Bars	$150/mile
Native species	$250/ac.	Road Repairs	$1,500/mile
Introduced species	$100/ac.	Spring Development	$1000/ea.
Critical Area Planting	$1000/ac.	Streambank Protection:	
Fence (upland)	$2/ft.	mechanical	$100/ft.
Fence (riparian)	$2/ft.	vegetative	$12.50/ft.
Fence, Electric (upland)	$1.25/ft.	Tank	$2500 ea.
Fence, Electric (riparian)	$1.25/ft.	Tree Planting w/ irrig.	$600/ac.
Grade Stabilizer	$20,000 ea.	Tree Planting w/o irrig.	$300/ac.
Grassed Waterways	$20/ft.	Trough (w/ concrete pad)	$1000 ea.
Integrated Pest Mgt.	$20/ac.	Trough (w/o concrete pad)	$800/ea.
Irrigation Water Mgmt.:		Trough (small wildlife)	$500/ea.
Irrigation Pipeline	$5/ft.	Underground Outlet	$20,000 ea.
Land Leveling	$200/ac.	Upland Wildlife Habitat Mgt.	$400/ac.
Irrig. Water Mgmt..	$1000 ea.	Vegetative Buffer Strip:	
Tailwater Recovery Sys.	$5/ft.	Native Spp.	$200/ac.
Pipeline	$1.25/ft.	Introduced Spp.	$75/ac.
Pond (repair)	$10,000 ea.	Wildlife Watering Facility	$4000/ea.

Source: Templeton Service Center Enivornmental Qulaity Imporvement Program Practices Information.
*** Estimate provided by Cal Poly for Chumash Creek Watershed road improvements.**

Costs associated with BMP implementation, operation, and maintenance will be incurred by implementing parties. To the extent possible, these expenses will be offset with grants, loans, in-kind donations, and matching funds.

8.7.3 Total Estimate of Implementation Costs

The total preliminary cost for TMDL implementation in the first five years is estimated to be $23.5 million. This includes 50 percent of the habitat acquisition costs identified in the Comprehensive Conservation and Management Plan. Staff included this portion of the habitat acquisition costs since a substantial portion of these funds would likely be expended in acquiring land for sediment capture projects. These costs are preliminary estimates.

Sediment Reduction Actions:	$13,500,000
Habitat Acquisition	$10,000,000
TOTAL	**$23,500,000**

8.7.4 Cost of Monitoring

The cost to conduct monitoring for this TMDL will be incurred by the Regional Board and the Morro Bay National Estuary Program as funding and program resources are available. An accurate estimate of annual costs for monitoring will be made once final locations and access issues are resolved. However, an approximation of these costs is presented in Table 32. Other monitoring activities conducted by the County Farm Bureau, County of San Luis Obispo, and parties undertaking erosion control project implementation are not included in this cost estimate, since they are anticipated irrespective of TMDL adoption, and in many cases are integrated into effectiveness monitoring of BMPs. Watershed quality monitoring activities include the initial assessments necessary to make final selection of monitoring locations for streambed sediment parameters and turbidity, as well as subsequent data collection.

Table 32. Estimate of Annualized Cost to CCRWQCB for Monitoring TMDL Implementation

Monitoring Program Activity		**Person Years**	**Costs**
Water Quality Monitoring	Select final monitoring locations; Collect water quality data (Table 33)	0.08 PY	$8,000
Data Management	Create Monitoring Program database and make monitoring data accessible through CCAMP web site	0.01 PY	$1,000
Coordination with Other Monitoring Efforts	Coordinate nonpoint source-related and TMDL monitoring with Monitoring Program	0.02 PY	$2,000
	Finalize monitoring quality assurance guidance which includes recommended sampling, analytic protocols, and methods	0.01 PY	$1,000
	Compile data available from other monitoring programs for inclusion in the Monitoring Program database	0.01 PY	$1,000
	Aid local agencies and volunteer monitoring and watchdog; organizations disseminate data through websites	0.01 PY	$1,000
Monitoring Reports	Conduct detailed data analysis and write technical reports, summarizing monitoring data for use in TMDL compliance	0.06 PY	$6,000
	TOTAL	**0.20 PY**	**$ 20,000**

9. Monitoring Plan

9.1 Coordination

Water quality monitoring will be performed by Regional Board staff and by other parties identified in this Monitoring Plan, including the Friends of the Estuary Volunteer Monitors. This Monitoring Plan identifies the frequency, location, protocols and implementing party for each water quality parameter being evaluated.

This Monitoring Plan was developed in coordination with the planning and implementation efforts of the Morro Bay National Estuary Program (MBNEP) to develop a Comprehensive and Conservation Management Plan for Morro Bay (CCMP). A separate monitoring program was developed as part of the CCMP. A component of the MBNEP's monitoring program is the Friends of the Estuary Volunteer Monitoring Program. Current funding for the program extends to September 2003 and MBNEP intends to extend the program into the future. While the goal of the MBNEP's monitoring program is to evaluate the effectiveness of implemented actions in the CCMP, some of the data and analyses planned by the MBNEP will provide information for the TMDL. Likewise, the data collected for the TMDL will be useful for the MBNEP in evaluating trends towards meeting sediment reductions to the Morro Bay estuary.

The primary measures of success for implementation of this TMDL are attainment of the numeric targets, which represent or indicate corresponding load allocations. However, recognizing the variability inherent in the factors affecting sediment loads within the Watershed, other measures of success, including attainment of trackable implementation actions (BMPs), will be considered in evaluating implementation of the TMDL. Therefore two types of monitoring are proposed: 1) water quality monitoring indicating numeric target attainment, and 2) monitoring of implementation of BMPs.

9.2 Monitoring Numeric Targets

Numeric targets for several parameters were selected to represent attainment of the TMDL (Table 33). These parameters are indicators of the condition of several of the beneficial uses in the Watershed (cold water fisheries and estuarine habitat). Measured together they account for uncertainty in relying on any one parameter. The amount or degree by which the current sediment load in the watershed deviates from the TMDL, will be verified through monitoring of these parameters and comparing them to the numeric targets established for the parameter. Every three years Regional Board staff will evaluate how well the individual targets indicate water quality improvements. This evaluation will rely on a ten-year rolling average of monitoring results for each parameter at each site. Regional Board staff will calculate ten-year rolling averages for:

- Residual Pool Volume
- Median Diameter (D_{50}) of Sediment Particles in Spawning Gravels
- Percent of *Fine* Fines (< 0.85 mm) in Spawning Gravels
- Percent of *Course* Fines (< 6.0 mm) in Spawning Gravels
- Tidal Prism Volume

Table 33. Monitoring Plan

Parameter	Numeric Target			Responsible Party	Protocol
Chorro and Los Osos Creeks and Tributaries Streambed Sediment					
Residual Pool Volume	V* (a ratio) = Mean values ≤ 0.21 Max values ≤ 0.45			Regional Board staff or designee	RB's Protocols for Sediment Sampling
Median Diameter (D_{50}) of Sediment Particles in Spawning Gravels	D_{50} = Mean values ≥ 69 mm Minimum values ≥ 37 mm			Friends of the Estuary Volunteer Monitoring Program (VMP)	RB's Protocols for Sediment Sampling
Percent of *Fine* Fines (< 0.85 mm) in Spawning Gravels	Percent fine fines ≤ 21%			Regional Board staff or designee	RB's Protocols for Sediment Sampling
Percent of *Course* Fines (< 6.0 mm) in Spawning Gravels	Percent coarse fines ≤ 30%			Regional Board staff or designee	RB's Protocols for Sediment Sampling
Chorro and Los Osos Creek and Tributaries Water Column					
Turbidity		% of Samples Below Target	Target (NTUs)	VMP	National Monitoring Program QAPP (1996)
	Wet Season	82%	≤ 5		
		93%	≤ 100		
	Dry Season	96%	≤ 5		
Morro Bay Estuary					
Tidal Prism Volume	4,200 acre-feet			Regional Board staff or designee; MBNEP and VMP	Low-tide aerial photography, GPS and fathometer (depth meter)

Conditions in the Morro Bay Estuary and in Los Osos and Chorro Creeks are a reflection of conditions in tributaries flowing into these waterbodies. Therefore, assessment of compliance with targets is needed throughout the watershed. Representative locations established in certain tributaries by the National Monitoring Program will be used as TMDL target compliance monitoring sites. Figure 4 (see Section 4: Numeric Targets) indicates the TMDL target compliance locations for the creeks and the tributaries.

The Numeric Targets describe conditions believed to be representative of a system in dynamic equilibrium wherein sediment loading is half of what it is today. It is expected to take 50 years to reduce loading to this level, i.e., 50 years to achieve the TMDL. Therefore, the targets would not be achieved for 50 years. Between now and then, the Regional Board will look for improving trends in the ten-year rolling average of monitoring data for each parameter.

9.2.1 Streambed Sediment Target Monitoring

Since no baseline exists for the streambed sediment parameters, the initial three years of monitoring will establish a baseline for comparison to future years. Since the numeric targets are indicators of the load reductions desired, monitoring should reveal a trend toward target values such that they are achieved within 50 years. For example, during periodic review of data, a percent improvement over baseline for each ten-year period would demonstrate compliance with the TMDL.

9.2.2 Turbidity Target Monitoring

The National Monitoring Program established a reference condition for turbidity that was used as the basis for the water column numeric targets for both Creeks and the Bay. However, no baseline data are available to describe existing conditions at other target monitoring sites in the Watershed and a ten-year rolling average approach as described above will apply once these baselines are established in the first three years of monitoring.

9.2.3 Tidal Prism Volume Target Monitoring

A bathymetry survey will be conducted every five years until implementation year 15 in order to further establish the relationship between sediment loading and deposition, and then every ten years following, in order to also determine TMDL compliance. The survey will be conducted by flying the Bay at low tide or with the possible assistance of ground-based crews using a global positioning system and a fathometer (depth meter). The entire Bay will be surveyed, including the back bay, delta, and harbor areas. Regional Board staff, or a designee, and National Estuary Program staff will alternate responsibility for the surveys.

9.3 Monitoring Implementation Actions

The Regional Board will consider, in addition to water quality monitoring results, the degree to which the responsible party has implemented, or is implementing, sediment control measures equivalent or identical to those identified in Table 29. Through scheduled reporting, Implementing Parties will provide the necessary information upon which staff will make the determination of compliance.

The Regional Board will track implementation with the assistance of the MBNEP. Various entities, such as the County Farm Bureau and the CSLRCD, will assist by monitoring the number of BMPs implemented and by estimating the effectiveness of the BMPs. For example, the County Farm Bureau will be responsible for coordinating with local landowners in establishing a self-monitoring program throughout the watershed. The Farm Bureau will report monitoring results on a subwatershed basis to maintain confidentiality of landowners. This coordinated effort will provide protocols to the participants to keep monitoring consistent and provide accurate data that will allow for the evaluation of implementation projects. The CSLRCD will also monitor implementation projects and BMPs through site inspections and will submit findings in an annual report to the MBNEP to assist in tracking.

Regional Board and MBNEP staff will review progress of implementation activities annually and will assess compliance every three years. This will be done by reviewing the Volunteer Monitoring Program's annual reports, which include the data and results collected for the program, and by reviewing, the MBNEP's biennial review. The biennial review is a comprehensive report whose scope includes monitoring, implemented projects, and BMP effectiveness. The biennial review will also include, but is not limited to, actions in the CCMP and any other actions in the watershed that contribute to increased health of the estuary and water quality.

9.4 Data Management

Regional Board staff and the MBNEP (including VMP) will provide data in a format compatible with the Central Coast Ambient Monitoring Program (CCAMP). CCAMP includes data from projects within the Regional Board's jurisdiction (northern Ventura to southern San Mateo counties). The availability of this data provides opportunities for valuable data comparisons between the Morro Bay Watershed and other similar areas. This database and selected analytic tools will be available on the Internet as well as linked to the RWQCB website. Regional Board staff will evaluate data to determine when water quality is attained and sediment loading to the Bay is achieved.

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APPENDIX: Comprehensive Conservation Management Program Project Descriptions (Trackable Implementation Actions)

Hollister Ranch Acquisition.
The MBNEP and the Trust for Public Lands are working together to purchase the 580-acre Hollister Ranch on Chorro Creek. Located adjacent to Chorro Creek, this project has a larger floodplain area than Chorro Flats, and is expected to be an effective means of capturing sediment once levees are removed to restore the floodplain. Funding is currently being pursued through the Department of Transportation Environmental Restoration Grant (Transportation Enhancement Activities) and Proposition 13.

Action: Design and construct a floodplain restoration project
Benefits: sediment capture and habitat restoration
Timing: acquisition: January 2002; conceptual plans Nov 2003; construction May 2005
Responsible Party: CSLRCD and MBNEP

Los Osos Creek Wetland Restoration Project.
The CSLRCD is working with the MBNEP to restore a portion of Los Osos Creek to capture sediment from Los Osos Creek and to improve habitat. This project was identified as part of the Morro Bay Enhancement Plan (USDA, SCS, 1989a). The State Coastal Conservancy and the CSLRCD established the wetland reserve in 1996 with Coastal Conservancy funding support. Then in 1997, CSLRCD successfully implemented the Chorro Flats project on Chorro Creek. Together with the State Coastal Conservancy the MBNEP is providing funding and technical support for the design of the project. Numerous funding sources are being evaluated for construction.

Action: Design and construct the Los Osos Creek wetland restoration project
Benefits: sediment capture and habitat restoration
Timing: design: Fall 2000 to Summer 2001; construction: Spring 2002 to 2003
Responsible Party: CSLRCD and MBNEP

Watershed Crew Curriculum.
The California Conservation Corps (CCC) and the MBNEP are developing a Memorandum of Understanding (MOU) to develop a curriculum that will provide the appropriate training the CCC needs to continually install BMPs in the watershed. Through a mini-grant with the MBNEP, the CCC is proposing to develop training materials beginning in January 2001, in order to begin implementing additional BMPs in January 2002. The CCC Watershed Crew of 8-15 members will then be funded year-round to install BMPs.

Action: Develop a curriculum that will provide training for a year-round crew of CCCs
Benefits: Continually install BMPs in the watershed to reduce erosion and restore fisheries habitat
Timing: Winter 2001 to Fall 2001
Responsible Party: CCC

Catalogue of Erosion Control Projects.
The MBNEP is scoping a request for proposals to develop a list of areas in need of erosion control projects. Geographic identification of project areas in the Morro Bay watershed will be phased. Initially, the list of projects will be focused on public lands and on other private lands (i.e. the National Guard property on the headwaters of Chorro Creek and voluntary private landowners) in order to begin implementation in a timely manner. Project areas will be assessed beginning in April 2001 through December 2001. The projects will be prioritized according to erosion severity, effectiveness in protecting

beneficial uses, and accessibility. In addition, sediment load determinations developed, as part of the TMDL by the Regional Board will assist in identifying project areas. Projects will then begin to be implemented beginning in January 2002, and completed in two to five years, depending on the number of projects identified, and the size of each project and the severity of erosion at the site.

The CCC Watershed Crew of 8-15 members will be funded year-round through the Morro Bay Estuary Restoration Fund and other sources to install BMPs. Additional funding through projects such as Project Clearwater (see below) will be needed for technical assistance and materials. These projects will then serve to demonstrate further to other landowners and managers in the watershed the costs and effectiveness of BMPs. Prior to the completion of the first phase of priority projects identified, further project areas will be catalogued in order to continue implementation to achieve the TMDL. The MBNEP, or responsible party will estimate annual sediment reductions expected and achieved from the projects.

Action: Develop a list of areas in need of erosion control projects
Benefits: The projects will be prioritized according to erosion severity, effectiveness in protecting beneficial uses, and accessibility
Timing: Phase one: Spring 2001 to Fall 2001, and on going until TMDL is achieved
Responsible Party: MBNEP (through contract)

Project Clearwater
The Coastal San Luis Resource Conservation District (CSLRCD) has secured funding through the MBNEP and other sources, to continue the San Luis Obispo Watershed Enhancement Program through 2004. As part of this continuation a full-time watershed coordinator has been hired. The primary responsibilities of the coordinator include implementing conservation practices, providing outreach to stakeholders, and assisting watershed stewardship groups. Project Clearwater will provide technical assistance and cost sharing for landowners to install BMPs to reduce sediment to Morro Bay, and to protect and restore fisheries habitat. The catalogue of projects (described above) will aid in prioritizing areas for implementation. The Watershed Crew will assist the CSLRCD in installing the BMPs. The CSLRCD will supply technical assistance to landowners and will provide up to 90% of each BMPs installation cost. Landowners will supply at least 10% of each BMPs cost with cash, labor, or in-kind services such as use of earthmoving equipment.

Landowners will be recruited through existing networks within the watershed, including the Morro Bay National Estuary Program, the Farm Bureau, and contacts developed under the Morro Bay Watershed Enhancement Program. Two short-courses will be offered where landowners will learn conservation planning techniques, and will apply these techniques to their own land. Each landowner will finish the course by creating a conservation plan for his or her property. These conservation plans will provide the basis for implementing BMPs for soil, water, and habitat conservation. The CSLRCD will provide technical assistance to design and install these BMPs according to NRCS Manual of Practice standards and specifications. The CSLRCD will also assist in obtaining cost-sharing funds for each BMP.

Permitting for these projects, when needed, will be covered under a set of watershed-wide permits that will be jointly held by the Natural Resources Conservation Service and the CSLRCD. These permits are being obtained under an "Early Action" grant from the MBNEP and the Bay Foundation to "streamline" the regulatory process, and to remove a significant impediment to BMP implementation. Participants are covered under the watershed-wide permit for the implementation of BMPs on their land and would not be required to apply for any additional permits, unless they deviate from the original approved design criteria. The actual number of plans and BMPs will depend on landowner interest and the scale of individual projects.

Action: Provide technical assistance and cost sharing to install BMPs

Benefits: Reduction of sediment to Morro Bay and protection and restoration of fisheries habitat
Timing: 2001 through June 2004, ongoing as additional funding is obtained to reach TMDL
Responsible Party: CSLRCD

Agricultural Water Quality Program.
Since 1996, the San Luis County Farm Bureau has been working to develop workable watershed programs. Morro Bay is a priority watershed for the Farm Bureau (Fitzhugh, 2000) and efforts are under way to continue the presentation of "short courses" to the local agricultural community. The Farm Water Quality Planning short course is designed to provide training for growers in irrigated agriculture and rangeland management interested in implementing water quality protection practices. The short course is designed to teach basic concepts of watersheds, nonpoint source pollution (NPS), including erosion control, self-assessment techniques, and monitoring. The Farm Bureau will document implementation and success of BMPs through a coordinated effort for individual self-monitoring among the ranchers and growers.

Action: Develop and implement a voluntary, cost-effective, and landowner/manager-directed program.
Benefits: The identification and control of agricultural sources of pollution to achieve allocated loads
Timing: 2001-02, then on going as additional funding is obtained
Responsible Party: Farm Bureau

Land Acquisitions and Conservation Easements.
Much of the land in the Morro Bay Watershed is at risk from coastal development, or from land uses that damage natural habitat, and will require protection to minimize its contribution to sediment loading. Land prices are high, and therefore some prioritization of lands and species in need of protection must be made to optimize protection measures to be optimized. Land acquisition and preservation provide an avenue to control erosion and reduce the impact to the soil due to various land use practices. Land acquisitions and conservation easements provide the opportunity to implement restoration projects on all or part of a landscape. Restoring areas to their natural landscapes often function as water quality filters that capture and reuse sediment, as well as reduce the energy of surface water flows and increase groundwater recharge. In the example of the Chorro Flats Enhancement Project the result was a significant reduction of sediment into the estuary by diverting creek flow into an expanded flood plain.

Action: Acquire or otherwise protect lands in cooperation with willing landowners.
Benefits: Reduction of sediment problems through the setting aside of acquired floodplain areas and use of detention and retention solutions on low-lying lands. Protect ecologically valuable habitat and minimize nonpoint sources of pollution.
Timing: 2000-2007; Monitoring through 2010; then on going - some projects are currently being negotiated.
Responsible Party: Morro Bay National Estuary Program

Fire Management Plan.
The California Department of Forestry (CDF) and the U.S. Forest Service (USFS) are working with the MBNEP on a mechanism to develop a Fire Management Plan to reduce the frequency of catastrophic fires that increase sediment production and impact habitat values. The plan will identify and prioritize areas for prescribed burns in the Morro Bay watershed. The program will include land ownership, fuel types, erosion susceptibility, prescribed burn patterns, grazing and/or other fuel management techniques, as appropriate, for specific areas. It will specify management practices, a schedule for implementation, costs and funding, permission from landowners and managers, and monitoring techniques. Implementation will be phased as priority areas for prescribed burns are identified. Cooperating agencies include the San Luis County Air Pollution Control District and California State Parks. Costs associated with plan development

are $150,000, plus $20,000 for NEPA and CEQA review. Implementation ranges from $30,000 to $60,000 ($150/acre treated), with $5,000 for monitoring.

Action: Develop and implement a Fire Management Plan
Benefits: Prescribed burns in the Morro Bay watershed will reduce erosion from brush and woodlands
Timing: plan development 2001-02; implementation 2002 to 2006 and on going as determined in plan.
Responsible Party: CDF

Maintenance of Sediment Basins Above Chorro Reservoir.
The National Guard has maintained the sediment basins by periodic dredging, every 3 to 5 yeas. Also BMPs, such as prescribed burns (described above) implemented upstream of the basins will result in a 10% reduction of sediment loading, therefore, maintaining the basins will be required on a less frequent basis, every 10 to 20 years.

Action: Continue maintenance of the sediment basins above Chorro Reservoir
Benefits: Reduce amount of sediments downstream of Chorro Reservoir sediment basins.
Timing: on-going
Responsible Party: California Army National Guard

Road Maintenance.
The optimum time to address control of nonpoint source pollution from roads and highways is during the initial planning and design phase. New roads and highways should be located with consideration of natural drainage patterns and planned to avoid encroachment on surface waters and wet areas. Where this is not possible, appropriate controls should be used to minimize the impacts of runoff on surface waters.

Poorly designed or maintained roads on public and private lands can generate significant erosion that is deposited into surface waters. In areas where this is occurring, retrofit management projects or improved maintenance techniques can be implemented to reduce erosion and sedimentation to Morro Bay and its tributaries.

The community of Los Osos contains a number of dirt roads, the majority of which are not maintained by the San Luis Obispo County. The roads exist on rights-of-way dedicated to, but not accepted by, the County. Therefore, the ownership of these roads is split between the property owners on each side. While the primary management emphasis needs to be directed toward Los Osos roads, other watershed roads may also require maintenance. The county of San Luis Obispo and the city of Morro Bay will be required to incorporate management measures to prevent sedimentation from road construction or maintenance into storm water management plans being developed for NPDES Phase II Municipal Storm Water Regulations.

Action: Increase the use of management measures for road maintenance and construction.
Benefits: Reduced sedimentation to Morro Bay and its tributaries.
Timing: Monitoring and Planning 2001-2006; Implementation 2006 and then on going
Responsible Party: County of San Luis Obispo, City of Morro Bay, Public and Private Landowners; California Department of Transportation

Sediment Traps.
Sediment trapping upstream of the bay can take many forms. Every type of sediment trap has environmental and economic costs and benefits that need to be evaluated on a case-by-case basis to determine the correct project for the site. Examples of sediment traps include:

- Flood plain restoration
- Sediment ponds

- Stock water ponds
- Buffer and/or filter strips
- Natural lakes and wetlands
- Small ponds high in the watershed
- Small traps associated with the road network at culvert inlets and along roadside ditches

Within the road network there are opportunities to create small sediment traps. Inlets to culverts can be raised in order to create a sediment trap. Within a roadside ditch, small holes can be scooped out that will trap sediment. These types of projects require a commitment from the entity that maintains the roads to also maintain the traps.

Action: Install of sediment traps.
Benefits: Less sediment delivered to the bay.
Timing: plan development 2000-02; implementation 2002 to 2007; then on going.
Responsible Party: The Coastal San Luis Resource Conservation District, Natural Resource Conservation Service, DFG, and public and private landowners.

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