California

Morro Bay Watershed
Section 319
National Monitoring Program Project

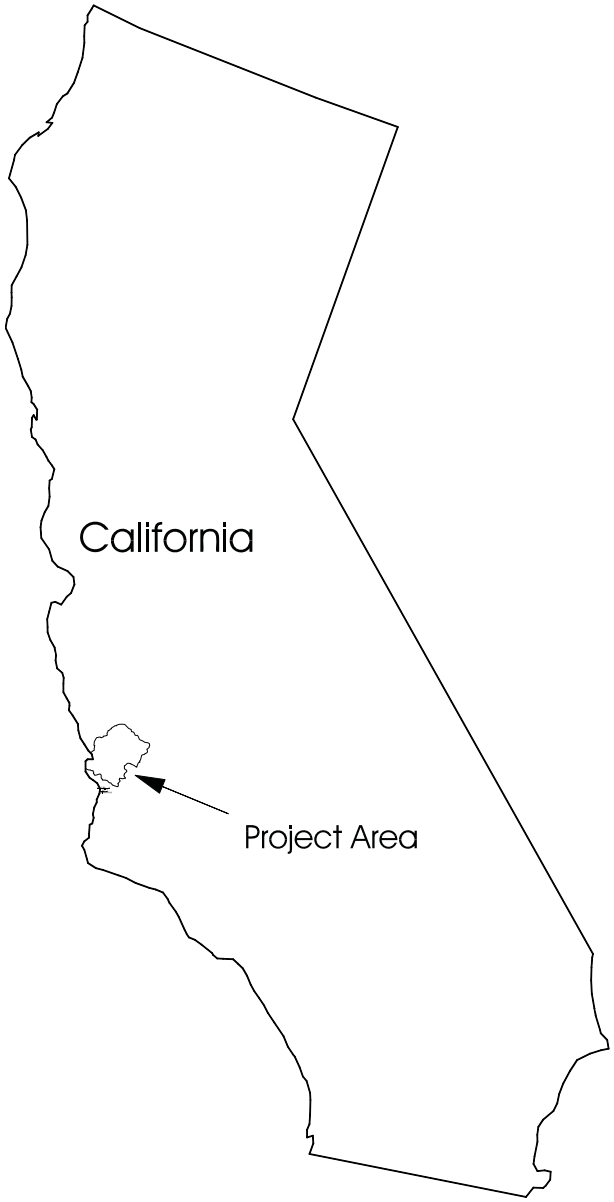

Figure 5: Morro Bay (California) Watershed Project Location

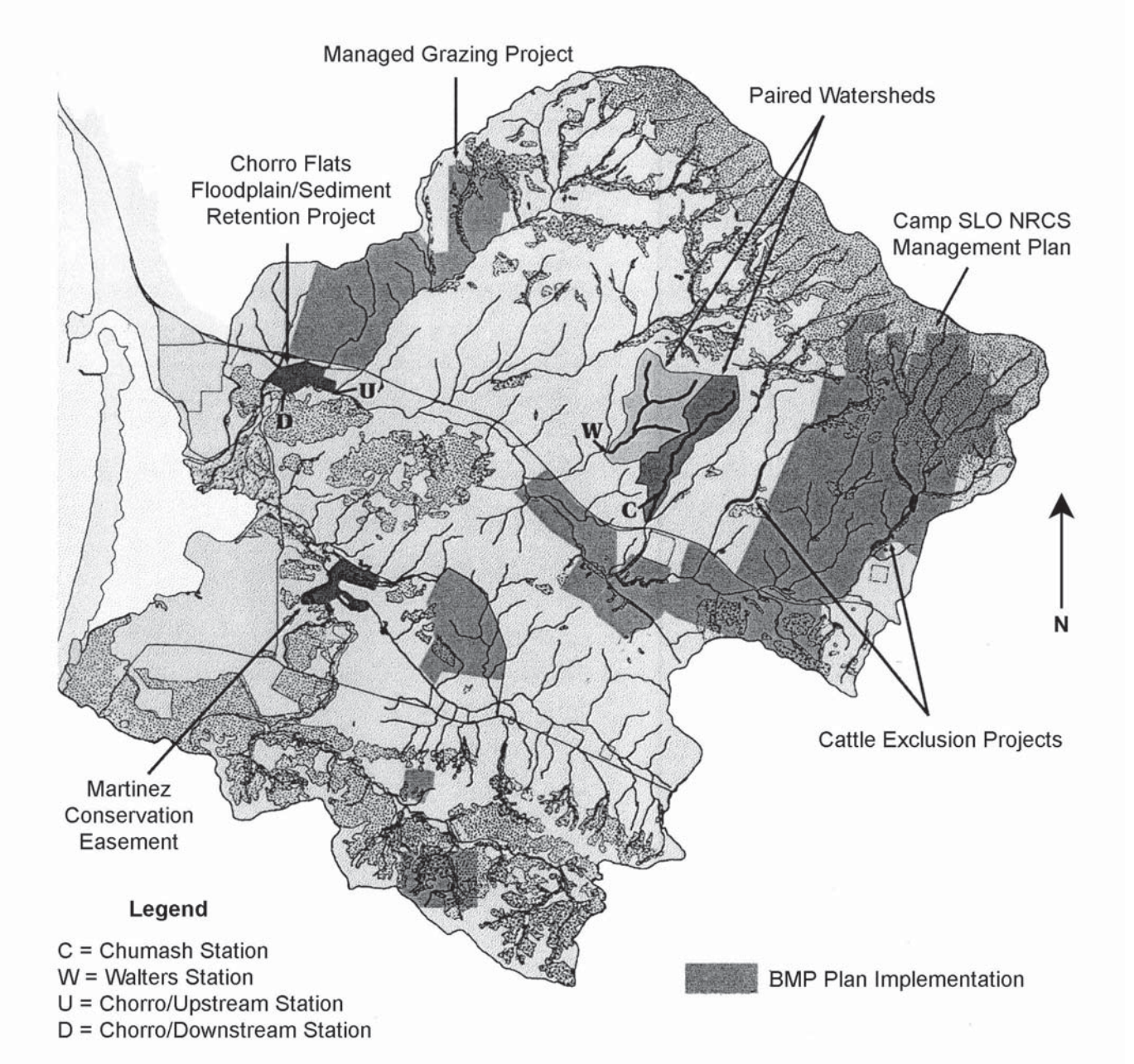

Figure 6: Paired Watersheds and other Projects in Morro Bay (California)

PROJECT OVERVIEW

The Morro Bay watershed is located on the central coast of California, 237 miles south of San Francisco in San Luis Obispo County (Figure 5). This 76-square mile watershed is an important biological and economic resource. Two creeks, Los Osos and Chorro, drain the watershed into the Bay. Included within the watershed boundaries are two urban areas, prime agricultural and grazing lands, and a wide variety of natural habitats that support a diversity of animal and plant species. Morro Bay estuary is considered to be one of the least altered estuaries on the California coast. Heavy development activities, caused by an expanding population in San Luis Obispo County, have placed increased pressures on water resources in the watershed.

Various nonpoint source pollutants, including sediment, bacteria, nutrients, and organic chemicals, are entering streams in the area and threatening beneficial uses of the streams and estuary. The primary pollutant of concern is sediment. According to recent studies, upland areas contribute the largest portion of sediment, and Chorro Creek contributes twice as much sediment to the Bay as does Los Osos Creek. At present rates of sedimentation, Morro Bay could be lost as an open water estuary within 300 years unless remedial action is undertaken. The main objective of the Morro Bay Nonpoint Source Pollution and Treatment Measure Evaluation Program, of which the Morro Bay Watershed Section 319 National Monitoring Program project was a subset, is to reduce the quantity of sediment entering Morro Bay.

The U.S. Environmental Protection Agency (USEPA) Section 319 National Monitoring Program project for the Morro Bay watershed was developed to characterize the sedimentation rate and other water quality conditions in a portion of Chorro Creek, to evaluate the effectiveness of several best management practice (BMP) systems in improving water quality and habitat quality, and to evaluate the overall water quality at select sites in the Morro Bay watershed.

The focus of the Morro Bay Watershed Section 319 National Monitoring Program project was a paired watershed study on two subwatersheds of Chorro Creek (Chumash and Walters Creeks). The purpose of the project was to evaluate the effectiveness of a BMP system in improving water quality (Figure 6). BMP system effectiveness was evaluated for sites outside the paired watershed. These projects included a managed grazing system on the Maino Ranch, two cattle exclusion projects (Dairy Creek and Chorro Creek), and a flood plain sediment retention project. In addition, water and habitat quality samples taken throughout the Morro Bay watershed have documented the changes in water quality during the life of the project.

The project was completed on Sept. 30, 2002. The Final Report, dated Aug. 31, 2003, is available through the Central Coast Regional Water Quality Central Board.

PROJECT BACKGROUND

Project Area

The Morro Bay watershed drains an area of 48,450 acres into the Morro Bay estuary on the central coast of California. The Bay is approximately 4 miles long and 1.75 miles wide at its maximum width. The project area was located in the northeast portion of the Morro Bay watershed.

Relevant Hydrologic, Geologic, and Meteorologic Factors

Morro Bay was formed during the last 10,000 to 15,000 years (NRCS, 1989a). A post-glacial rise in sea level of several hundred feet resulted in a submergence of the confluence of Chorro and Los Osos creeks (Haltiner, 1988). A series of creeks that originate in the steeper hillslopes to the east of the Bay

drain westward into Chorro and Los Osos creeks, which drain into the Bay. The 400-acre salt marsh has developed in the central portion of the Bay in the delta of the two creeks. A shallow ground water system is also present underneath the project area.

The geology of the watershed is highly varied, consisting of complex igneous, sedimentary, and metamorphic rock. Over fifty diverse soils, ranging from fine sands to heavy clays, have been mapped in the area. Soils in the upper watershed are predominantly coarse-textured, shallow, and weakly developed. Deeper medium- or fine-textured soils are typically found in valley bottoms or on gently rolling hills. Earthquake activity and intense rain events increase landslide potential and severity in sensitive areas.

The climate of the watershed is Mediterranean: cool, wet winters and warm, dry summers. The area receives about 95% of its 18-inch average annual precipitation between the months of November and April. The mean air temperature ranges from around 45 degrees F in January to 65 degrees F in July, with prevailing winds from the northwest averaging about 15 to 20 miles per hour.

Land Use

Approximately 60% of the land in the watershed is classified as rangeland. Typical rangeland operations consist of approximately 1,000 acres of highly productive grasslands supporting cow-calf enterprises. Brushlands make up another 19% of the watershed area. Agricultural crops (truck, field, and grain crops), woodlands, and urban areas encompass approximately equal amounts of the landscape in the watershed.

Land Use	Acres	%
Agricultural Crops	3,149	7
Woodland	3,093	7
Urban	3,389	8
Brushland	8,319	19
Rangeland	26,162	59
Total	44,112	100

Source: NRCS, 1989a Water Resource Type and Size

Water Resource Type and Size

The total drainage basin of the Morro Bay watershed is approximately 48,450 acres. The 319 project monitoring effort was focused on the Chorro Creek watershed. Chorro Creek and its tributaries originate along the southern flank of Cuesta Ridge, at elevations of approximately 2,700 feet. Currently three stream gauges are present in the Chorro Creek watershed: one each on the San Luisito, San Bernardo, and Chorro creeks. The San Bernardo gauge became inoperable in 1996; a new gauge has yet to be installed. Annual discharge is highly variable, ranging from approximately 2,000 to over 20,000 acre-feet, and averaging about 5,600 acre-feet. Flow in tributaries is intermittent in dry years and may disappear in all but the uppermost areas of the watershed.

Water Uses and Impairments

In spite of the intermittent nature of these creeks, both Chorro and Los Osos creeks are considered cold-water resources, supporting anadromous fisheries (steelhead trout).

Morro Bay is one of the few relatively intact natural estuaries on the Pacific Coast of North America. The beneficial uses of Morro Bay include recreation, industry, navigation, marine life habitat, shellfish harvesting, commercial and sport fishing, wildlife habitat, and rare and endangered species habitat.

A number of fish species (including anadromous fish, which use the Bay during a part of their life cycle) have been negatively affected by the increased amount of sediment in the streams and the Bay. Sedimentation in anadromous fish streams reduces the carrying capacity of the stream for steelhead and other fish species by reducing macroinvertebrate productivity, spawning habitat, and egg and larval survival rates, and increasing gill abrasion and stress on adult fish. Trout are still found in both streams, but ocean-run fish have been greatly reduced. However, several reports of sitings have occurred in the past years. The Tidewater Goby, a federally endangered brackish-water fish, was eliminated from the mouths of both Chorro and Los Osos creeks, most likely as a result of sedimentation of pool habitat in combination with excessive water diversion.

Accelerated sedimentation has also resulted in significant economic losses to the oyster industry in the Bay. Approximately 100 acres of oyster beds have been lost due to excessive sedimentation. Additionally, fecal coliform bacteria carried by streams to the Bay have had a negative impact on the shellfish industry, resulting in periodic closures of the area to shellfish harvesting (NRCS, 1992). Due to continually elevated levels of total and fecal coliform, the California Department of Health Services has reclassified the Bay from "conditional" to "restricted." Reclassification to "restricted" requires changes in harvesting practices, which have cost prohibitive for existing operations and have resulted in closure of a significant portion of the growing area. Elevated fecal coliform counts have been detected in water quality samples taken from several locations in the watershed and the Bay.

Pollutant Sources

It has been estimated that 50% or more of the sediment entering the Bay results from human activities. Sheet and rill erosion account for over 63% of the sediment reaching Morro Bay (NRCS, 1989b). An NRCS Erosion and Sediment Study identified sources of sediment to the Bay, which include activities on rangeland, cropland, and urban lands (NRCS, 1989b). The greatest contribution of sediment to the Bay originates from upland brushlands (37%) because of the land's steepness, parent material, lack of undercover, and wildfire potential. Rangelands are the second largest source of sediment entering into streams (12%). Cattle grazing has damaged riparian areas by removing vegetation and breaking down bank stability. The unvegetated streambanks, as well as overgrazed uplands, have resulted in accelerated erosion. Other watershed sources that contribute to sediment transport into Morro Bay include abandoned mines, poorly maintained roads, agricultural croplands, streambank erosion, and urban activities.

The Morro Bay watershed is listed as "impaired" by sediment, nutrients, organics, and bacteria. NMP data have been used to develop Total Maximum Daily Loads for Chorro Creek, Los Osos Creek, and the Morro Bay estuary. The Total Maximum Daily Loads (TMDLs) identify the sources, determine the loading capacity of the waterbodies, and reduce pollutant loading so that beneficial uses are protected. TMDLs for sediment and bacteria have recently been adopted, and efforts to develop TMDLs for nutrients and organics are currently underway.

The Morro Bay National Estuary Program conducted a Sediment Loading and Stream Flow Study to evaluate the sediment contributions from the creeks that feed the bay. The results of this study indicate that the majority of the sediments being transported to Morro Bay from Los Osos Creek and Chorro Creek are fines (silts and clays). The average annual loading is estimated at 70,000 tons per year. Los Osos creek is expected to contribute only 14% of the total average annual loading and 86% is from Chorro Creek (Tetra Tech, 1998). The event and even-interval data collected for the Morro Bay National Monitoring Program were used as the foundation for this study and numerical models.

Pre-Project Water Quality

Morro Bay and the two creeks that flow into the estuary (Chorro Creek and Los Osos Creek) are listed as "impaired waters" due to siltation, metals, organics, nutrients, and pathogens by the State of California (Central Coast Regional Water Quality Control Board, 1993). Studies conducted within the watershed have identified sedimentation as a serious threat in the watershed and estuary. Results of a U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Hydrologic

Unit Areas (HUA) project study show that the rate of sedimentation has increased tenfold during the last 100 years (NRCS, 1989b). Recent studies indicate that the estuary has lost 25% of its tidal volume in the last century as a result of accelerated sedimentation, and has filled in with an average of two feet of sediment since 1935 (Haltiner, 1988). NRCS estimated the current quantity of sediment delivered to Morro Bay to be 45,500 tons per year (NRCS, 1989b).

Water Quality Objectives

The overall goal of the Section 319 National Monitoring Program project was to evaluate improvements in water quality resulting from implementation of BMPs. The following objectives were identified for this project:

- Identify sources, types, and amounts of nonpoint source pollutants (see the list of parameters that will be monitored under Water Quality Monitoring), originating in paired watersheds in the Chorro Creek watershed (Chumash and Walters creeks).
- Determine stream flow/sediment load relationships in the paired watersheds.
- Evaluate the effectiveness of improving water quality in one of the paired subwatersheds (Chumash Creek) of a BMP system.
- Evaluate the effectiveness of several BMP systems in improving water or habitat quality at selected Morro Bay watershed locations, including a managed grazing project, cattle exclusion projects, and a flood plain sediment retention project.
- Monitor overall water quality in the Morro Bay watershed to identify problem areas for future work, detect improvements or changes, and contribute to the water quality database for watershed locations.
- Develop a geographic information system (GIS) database to be used for this project and in future water quality monitoring efforts.

The goals for these projects were to achieve:

- A 34% decrease in sediment yield from the sediment retention project
- A 66% reduction in sediment yield from the cattle exclusion project
- A 30% reduction in sediment as a result of the managed grazing project

Project Time Frame

The project began on September 1, 1992. Funding in the amount of $200,000 (from 91-92 and 92-93) was provided on September 1, 1992. Two years of pre-implementation data collection and equipment installation (93-94 and 94-95) were funded for the project. Sampling during 95-96 was ultimately also included in the pre-BMP period, because changes to the land resulting from BMP installation were minimal and water quality data showed little change from past years. The first and second year of post-implementation sampling was conducted during 96-97 and 97-98. Additional funding was obtained to extend the storm water monitoring at Chumash and Walters Creeks for an additional year. The project was completed on September 30, 2002. A Final Report is available through the Central Coast Regional Water Quality Control Board.

PROJECT DESIGN

Nonpoint Source Control Strategy

In the paired watershed, a BMP system was used to reduce nonpoint source pollutants. Cal Poly was responsible for implementing the BMP system on Chumash Creek, which is one of the streams in the

paired watershed, while Walters Creek serves as the control. The implemented BMPs include 1) fencing the riparian corridor, 2) creating smaller pastures for better management of cattle-grazing activities, 3) providing appropriate water distribution to each of these smaller pastures, 4) stabilizing and revegetating portions of the streambank, 5) installing water bars and culverts on farm roads where needed, and 6) removing and stabilizing a failed on-stream stock pond. The project team established a goal of a 50% reduction in sediment following BMP implementation.

The NRCS has designed several BMP systems in the Morro Bay watershed. Three of these systems were evaluated for their effect on water and habitat quality:

- A flood plain sediment retention project was developed at Chorro Flats to retain sediment (sediment retention project)
- A riparian area along Dairy Creek, a tributary of Chorro Creek, and a reach along Chorro Creek downstream of the Chorro Reservoir, was fenced and revegetated (cattle exclusion project)
- Fences and watering systems were installed to allow rotational grazing of pastures on the 1,400-acre Maino ranch (managed grazing project)

Project Schedule

Site	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Chumash/Walters Creek	1993-1996	1994-1997	1996-2001
Chorro Flats	1993-1995	1997	1998-2000
Upper Chorro Creek	1993-1995	1994	1995-2001
Dairy Creek	1993-1995	1994	1995-2001
Maino Ranch	1993	1994	1995-2000

Water Quality Monitoring

Two watersheds were selected for a paired watershed study. Chumash Creek (400 acres) and Walters Creek (480 acres) both drain into Chorro Creek. The watersheds of the two creeks have similar soils, vegetative cover, elevation, slope, and land use activities. The property surrounding the two creeks is under the management of Cal Poly. Because the rangeland treated is owned by Cal Poly, project personnel were able to ensure continuity and consistency of land management practices.

The paired watershed monitoring plan entailed three specific monitoring techniques: stream flow/climatic monitoring, water quality monitoring, and biological/habitat monitoring. The calibration period (the period during which the two watersheds were monitored to establish statistical relationships between them) was completed during the first two years of the project (1994/95 and 1995/96). Beginning in 1995/96, a BMP system of fences, watering troughs, and other improvements were installed in one of the watersheds (Chumash Creek). The other watershed, Walters Creek served as the control. 1996-2001 served as the post-BMP monitoring period.

Other systems of BMPs were established at different locations in the Morro Bay watershed. These projects include a managed grazing system on the Maino Ranch, cattle exclusion projects on Dairy Creek and Chorro Creek, and a flood plain sediment retention project on Chorro Creek. Water quality was monitored using upstream/downstream and single station designs to evaluate these systems. An upstream/downstream design was adopted to monitor the water quality effect of a flood plain sediment retention project and a cattle exclusion project. A single station design on a subdrainage was used to evaluate changes in water quality from implementation of a managed grazing program. Changes in channel profile rangeland composition and benthic invertebrate composition were also part of the monitoring design at these sites.

In addition to BMP effectiveness monitoring, ongoing water quality sampling was conducted at selected sites throughout the Morro Bay watershed to document long-term changes and to prioritize problem areas in need of further restoration efforts. The Morro Bay Volunteer Monitoring Program has taken over the watershed-wide monitoring now that the NMP project has come to an end.

Variables Measured

Biological

Total and fecal coliform (FC)
Riparian vegetation
Upland rangeland vegetation
In-stream benthic invertebrates

Chemical and other

Nitrate (NO_3)
Phosphate (PO_4^{3-})
Conductivity
pH
Dissolved oxygen (DO)

Physical

Temperature
Suspended solids (SS) (total filterable solids)
Turbidity
Cross-sectional stream profile/morphology

Covariates

Precipitation
Stream flow
Evaporation
Animal units

Sampling Scheme

In the paired watershed, SS samples were collected during storm events using automated sampling equipment set at even intervals (30-minute). The water collected from each individual sample were analyzed for SS, turbidity, and conductivity. Streamflow and climatic data were also collected for hydrologic response of watersheds. Flow is measured at 5-minute intervals during events. Weekly grab samples were taken for at least 20 weeks during the rainy season, starting on November 15 of each year or after the first runoff event.

The samples from the paired watershed stations were analyzed for SS, turbidity, NO_3, PO_4^{3-}, total and fecal coliform, and other physical parameters.

The Dairy Creek cattle exclusion reaches were analyzed for SS, turbidity, nutrients, total and fecal coliform, and other physical parameters.

Suspended sediment and turbidity were monitored at the Chorro Flats sediment retention area.

In addition, year-round samples for pH, DO, turbidity, temperature, and total and fecal coliform were conducted every two weeks at several additional sampling sites throughout the Morro Bay Watershed.

Monitoring Scheme for the Morro Bay Watershed Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency for WQ Sampling	Frequency for Vegetation Sampling	Duration
Paired	Chumash Creek[T] and Walters Creek [C]	Total & FC Riparian vegetation SS Turbidity NO_3^- PO_4^{3-} Conductivity pH DO	Precipitation Stream flow Evaporation Animal units	Start after first run-off and weekly grab samples thereafter for 20 weeks. Storm event based monitoring (every 30 minutes).	Vegetation transects twice per year. RBA once per year. Cross-sectional profiles once per year (cross-sections).	2 yrs pre-BMP 2 yrs BMP 4 yrs post-BMP
Upstream/ downstream	Chorro Flats Sediment Retention Project	SS Turbidity Sediment deposition	Precipitation Stream flow Evaporation Animal units	Storm event monitoring (hourly)	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	4 yrs pre-BMP 1 yr BMP 4 yrs post-BMP
Upstream/ downstream	Chorro Creek Cattle Exclusion Project	SS Turbidity FC NO_3^- PO_4^{3-} Physical parameters	Precipitation Stream flow Evaporation Animal units	Weekly during rainy season starting around Nov. 15.	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	2 yrs pre-BMP 1/2 yr BMP 6 yrs post-BMP
Upstream/ downstream	Dairy Creeks Cattle Exclusion Project	SS Turbidity FC NO_3^- PO_4^{3-} Physical parameters	Precipitation Stream flow Evaporation Animal units	Weekly during rainy season starting around Nov. 15.	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	2 yrs pre-BMP 1/2 yr BMP 6 yrs post-BMP
Single downstream	Maino Ranch Managed Grazing Project	SS Turbidity FC Riparian vegetation	Precipitation Stream flow Evaporation Animal units	Weekly during the rainy season.	March & Sept. aerial photography in 1st, 5th, & 10th year. Vegetation transects twice per year. RBA once per year. Cross-sections.	0-1 yr pre-BMP 8 yrs post-BMP

[T]Treatment watershed
[C]Control watershed

Land Treatment Monitoring

On both the paired watershed and the Maino property, four permanent vegetation transects were monitored two times each year to sample upland and riparian vegetation and document changes during the life of the project. Aerial photography was used to document large-scale vegetative trends.

Cross-sectioned stream channel profiles were conducted once each year to document stream channel shape, substrate particle size, and streambank vegetation. Rapid BioAssessment (RBA) was used as a tool to assess water and habitat quality of sites throughout the Chorro and Los Osos Watersheds. Samples were collected during April and May at a number of sites, including several upstream-downstream pairs. The Morro Bay Volunteer Monitoring Program has continued habitat monitoring at selected sites throughout the watershed.

Modifications Since Project Start

Modifications have been made to sediment analysis techniques at the paired watersheds and other locations since project inception. During the first year, evaporation was used to process suspended sediment samples; however, dissolved solids are high in this watershed and contribute significantly to the total weight of the samples. As a result, total filterable solids were determined for the majority of the project duration. A relationship between conductivity and dissolved solids was developed to convert past years' data to filterable solids. Conductivity was no longer measured for each suspended sediment sample during event monitoring as it was not proved to be of significant interest. Composite samples from event monitoring were no longer analyzed for total N, total P, or pH. Grab sampling continues unchanged for nitrate, phosphate, conductivity, turbidity, dissolved oxygen, and water temperature for the duration of the project.

Monitoring of Chorro Flats as part of the NMP project, included an upstream-downstream evaluation of water quality (suspended sediment and turbidity) including an even-interval and storm-event sampling regime, stream profiling, benthic macroinvertebrate analysis, and a qualitative evaluation of riparian and wetland re-establishment. The success of the event-based sampling was compromised by a lack of adequate flow data combined with sampling effectiveness in a high discharge stream, and the lack of a consistent relationship between the upstream and downstream stations. The RCD efforts partially funded by another Clean Water Act Section 319 (h) grant to monitor the effectiveness of the sediment floodplain proved to be more successful. These methods included the use of topographic surveys to record sediment deposition.

The winter rainy seasons varied dramatically during the project period. The winter of 1993-1994 was relatively dry, with only two runoff events. In contrast, the 1994-1995 rainy season was characterized by above average precipitation and periods of flooding. The 1995-96, 1996-97, 1998-99, and 1999-2000 winters were more representative of normal rainfall events and streamflow levels in the watershed, while the 1997-98 winter was a very heavy rainfall year as "El Nino" flow levels were evident throughout the watershed. Sediment, turbidity, and flow data from storm events were collected.

Even interval grab sampling was obtained, with sampling conducted once every two weeks. During the rainy season (20 weeks beginning after the first runoff event), grab samples were collected once per week. Although the study design requires even-interval sampling year round, this is not feasible in several locations (including the paired watersheds) because the flow becomes intermittent or ceases entirely during summer months.

In August, 1994, the "Highway 41 Fire" burned a significant portion (7,524 acres) of the upper Chorro Creek watershed and its tributaries. The paired watersheds, Chorro, Chumash, and Walters, were not burned. Above average precipitation and several periods of widespread flooding during the 1994-95 winter, following the wildfires, resulted in significant erosion and sediment loading throughout the watershed. Modifications occurred at Chorro Flats due to emergency post-fire concerns. An existing level breech was widened so that the flood plain could serve as a sediment deposition area.

Progress to Date

Public presentations about the Morro Bay 319 National Monitoring Program project were regularly made to groups such as Friends of the Estuary, Cal Poly State University (Cal Poly), Cuesta Community College, and the Morro Bay National Estuary Program (MBNEP). The data collected as part of the National Monitoring Program provided a foundation for the development and implementation of the MBNEP's Comprehensive Conservation and Management Plan.

Paired Watershed Study: Funding was acquired through CWA 319(h) for implementation of improvements on the paired watershed. A Technical Advisory Committee was formed and expanded its focus to include monitoring projects throughout the entire Morro Bay watershed. Implementation for land improvements on the Chumash Creek watershed included construction of riparian pastures, additional

upland pastures, installation of watering troughs, culvert improvements, and revegetation and stabilization of portions of the corridor. Removal and stabilization of an on-stream stock pond was completed in 1997.

Flood Plain Sediment Retention Project: The Chorro Flats project obtained funding ($960,000) for implementation of the Flood Plain Restoration Project. Construction of the project and revegetation was completed in 1997.

Cattle Exclusion Projects: Dairy Creek and Chorro Creek fencing for riparian exclusion was completed in the summer of 1995.

Managed Grazing Project: In 1994, the Maino Ranch completed installation of watering devices and fencing, and the land is being managed as planned in a timed grazing project.

The Morro Bay National Monitoring Program hosted the 7th Annual National Nonpoint Source Monitoring Workshop that took place September 12 -17, 1999. The purpose of this nationwide workshop was to bring together approximately 200 water quality specialists to share information on such topics as overall effectiveness of Best Management Practices (BMPs) on water quality, effective monitoring techniques, and statistical analysis of watershed data.

National Monitoring Program data was used to develop Total Maximum Daily Loads in the watershed. Water quality data collected at the paired watersheds were used to develop numerical models of sediment loading in the watershed. Additionally, nutrient data was used to identify concentrations in the various tributaries in the watershed and the percent reductions needed at these locations to achieve water quality targets.

Cal Poly has developed a website for the NMP project that features the BMP projects, photos, monitoring methods, and results. The Regional Board will be hosting the NMP website on their website in the future as well.

A brochure (fact sheet) was created as part of the NMP grant. The MBNEP has offered to print and mail the color brochure to interested agricultural entities locally and region-wide.

Additional efforts are also underway for continued BMP implementation. Cal Poly is seeking to implement BMPs on Walters Creek in order to duplicate the significant water quality improvements found at Chumash Creek. Funding has been acquired through the MBNEP to implement BMPs, funding is being sought to continue the monitoring on both. The new study will implement a more extensive set of BMPs that seek to answer the question of whether the maximum benefit to water quality has been achieved on Chumash Creek and also determine whether the water quality of Walters Creek can be improved beyond that of Chumash Creek.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

The program made significant progress in data storage, management, and analysis. Ten years of photographs and field data were archived at the Regional Board. Data management was coordinated with the Central Coast Ambient Monitoring Program. Much of the water quality data for the NMP was entered into STORET previously. The expanded dataset will be entered as soon as "version two" of the software becomes available. The data generated as part of the project will be made available along with the NMP Final Report. Data handling was greatly improved and streamlined, data storage was provided for on a web site, and data analysis detected changes resulting from BMPs.

A Quality Assurance Project Plan, for project water quality sampling and analysis, was developed by the Central Coast Regional Water Quality Control Board. The plan was used to assure the reliability and accuracy of sampling, data recording, and analytical measurements. It is available at the Central Coast Regional Water Quality Control Board.

GIS data layers that have been entered (using ARC/INFO) include sample site locations, streams, flood zones, ground water basins, geology, soils, vegetation, land use, and topography. Data analysis indicated that Chumash and Walters Creek were well paired and that sufficient baseline data were collected.

Statisticians were added to the team during the last year and have performed additional detailed analysis of the storm water data. Initial analysis of data focused on determining minimum-detectable change and comparing even interval data results to event data. The data was examined in a variety of ways, including simple creek-to-creek regressions, regressions of flow-weighted pollutant parameters, double mass curves, regressions of flux- and time-weighted averages of event data, multiple +/- tests, non-parametric ranking, time-series plots, and flow-averaging.

Additional funding was obtained in FY 2000-02 to conduct further statistical analyses using the even-interval water quality data. In order to better understand the temporal relationships between the paired watersheds and the effectiveness of the BMPs, two regression models were developed. These include a repeated measures linear regression model and a repeated measures binary logistic model.

Final Results

Data analysis for the Morro Bay NMP project focused on evaluating the effectiveness of the range-land BMPs. Results indicate that water quality sampling has been effective at detecting improvements at various locations where BMPs were implemented.

Paired Watershed Study

Two subwatersheds in the Chorro Creek watershed, both on Cal Poly cattle rangelands, were selected for monitoring over a ten-year period. Chumash Creek watershed (400 acres) and Walters Creek watershed (480 acres) are as similar as possible in size, geomorphology, geology, soils, climate, vegetative cover, and land use. They share a common divide, and are managed as cattle rangeland.

Cal Poly owns the land encompassed by Walters and Chumash watersheds. Chumash and Walters Creeks run through Cal Poly's Escuela Ranch, which is a cow-calf operation with approximately 150 cows grazing both creeks' watersheds, plus Pennington Creek watershed (not included in the paired watershed study). The BMPs fell within four categories of rangeland management practices: livestock fencing and water development, streambank stabilization, road improvement, and grazing management. Numerous findings were documented as a result of implementing BMPS at the paired watersheds. If implementing BMPs improved water quality on an already well-managed land, then it would help improve water quality on other, more traditional ranches. These are summarized below.

Storm-event Flow and Water Quality Findings

Examination of paired hydrographs from 1995 through 2001 revealed interesting trends. In the period of 1995 through 1998, the timing of peak flow in Walters and Chumash was approximately equal. Beginning early in 1999, peak flow of Chumash lagged behind that of Walters, by 30 minutes to 1 hour. This was most noticeable early in each post-BMP season. We hypothesize this was due to increased interception of water by plants, and increased infiltration in the Chumash watershed, as vegetation increased on streambanks and in the watershed.

As of the 2000-01 season, the complete data set contained 82 events that included paired data on turbidity, and 80 events that included paired data on sediment. Significant declines in turbidity and

sediment in Chumash Creek were found, as a result of implementing BMPs. Improvements have leveled off, or plateaued, beginning with the 1999-2000 sampling season. We hypothesize that the plateau occurred because fast-growing stream channel vegetation has reached its maximum protective affect, and slow-growing vegetation (such as sycamores and oaks) has not yet reached a stage of maturity where it is having a quantifiable affect on water quality.

Year-round Water Quality Findings

Results of even-interval water quality monitoring indicate that BMPs significantly lowered water temperature at Chumash Creek.

Fecal coliform bacteria did not improve at Chumash Creek post-BMP. The number of fecal coliform bacteria exceeding the threshold (200MPN) did not significantly change during the entire study period. This is possibly due to grazing practices in the upper Chumash watershed or an increase in birds and wildlife.

Nitrate exceeded the threshold value (0.300 mg/L) more often at Chumash Creek than at Walters Creek. The increase in nitrate-nitrogen at Chumash Creek was most notable in spring and summer and is thought to be indicative of early riparian succession.

Dissolved oxygen significantly decreased at Chumash Creek, but remained at a mean concentration of 8.15 PPM, and was less variable than in pre-BMP conditions. It should be noted that nitrate and dissolved oxygen values were still within the typical range of other creeks in the Morro Bay watershed.

Even-interval turbidity samples also exceeded a low threshold value (7 NTUs) more often at Chumash Creek than at Walters Creek post-BMP. This may be due to an increase in vegetation and algae at Chumash Creek year-round. Significant reductions in turbidity as a result of BMP implementation have been detected, however, in storm events data. It is expected that turbidity collected during storm events (rather than year-round) would be more likely to decrease as a result of BMPs, as most sediment is transported during storm events.

Rangeland Findings

Rangeland parameters in the paired watershed showed improvement, particularly bare ground and species diversity. Results were not statistically significant. The Cal Poly staff believes that if monitoring was to have been continued, or especially if pre-BMP monitoring had begun earlier, statistical verification of observations would have been achieved.

During the sixth year of monitoring, it was noted that the BMPs implemented in Chumash watershed seem to have resulted in an increase in residual vegetation that is harvested by cattle during the dry season. Supplemental feed costs have decreased, and we hypothesized that the grazing practices in Chumash watershed contributed to the increase in vegetation and decrease in supplemental feed costs.

Stream channel improvements were noted. These included proliferation of streambank and channel bottom herbaceous and woody vegetation, and healing of cattle trails and streambank erosion scars. The improvements were not systematically revealed by the Pfankuch monitoring method, but become strikingly apparent via photodocumentation, when pre-BMP photos are compared to post-BMP.

One of the most significant findings of a long-term study are the lesson's learned. As discussed, changes were detected due to BMP implementation at Chumash Creek, particularly significant reductions in sediment and turbidity during storm events and improvements in water temperature year-round. This is particularly meaningful because the Cal Poly ranches have been well-managed

and get more rest than a typical working ranch. If implementing BMPs improved water quality on an already well-managed land, then it would help improve water quality on other, more traditional ranches. And, there are additional benefits to the system (such as more docile cattle, and more time for observation of health of the cows and calves). A preferred experimental design would have maintained two separate watersheds, with each containing its own identical, randomly selected herd of cattle, but this was not a part of the initial study design. In this design, supplemental feed would be differentially determined between watersheds, and the water quality and rangeland results would be more easily transferable to other ranches. Additionally, body condition scores of the cows could be estimated throughout the year, and impact of BMP implementation on seasonal forage availability would be determined empirically. Another limitation is that the original design of the study did not plan for determination of the effects of BMP implementation on productivity of the rangeland as it relates to grazing animals. Therefore, effects of the BMPs on feed costs were dampened by the increased availability of feed in all three of the watersheds. As forage availability increased in the Chumash (treatment) watershed, the energy availability increased in the remaining two watersheds as the cattle acquired a greater level of nutrient intake in each. These considerations are included in the future plans for evaluating improvements on Walters Creek.

Dairy Creek

Dairy Creek, tributary to Chorro Creek, runs through El Chorro Regional Park, and is the site of a cattle exclusion project. NRCS partnered with San Luis Obispo County Parks Department fencing and revegetating the mile long riparian corridor through the park. Improvements to the lower mile of creek were completed during the summer of 1994, with the remaining upper half-mile of creek fenced during the summer of 1995.

BMPs did not significantly affect air temperature, fecal coliform bacteria, nitrates, ortho-phosphates, and turbidity (10 NTUs). BMPs significantly improved water temperature dissolved oxygen and total coliform. Fecal coliform bacteria improved in samples taken at the DAU site when compared to the samples taken at the DAM site, possibly due to the gaps in the cattle exclusion fencing to provide water access to cattle.

Chorro Creek

Cattle exclusion fencing was installed along the riparian corridor of upper Chorro Creek in 1994. Chorro Creek Dam and Chorro Valley Culvert are the upper and lower sampling stations of a cattle exclusion area on the Camp San Luis Military Reservation.

Fecal coliform has significantly decreased at the BMP treatment site CVC as a result of BMP implementation. Water temperature and dissolved oxygen have also significantly improved post-BMP implementation at CVC. The significant reduction in fecal coliform at this BMP evaluation project is most likely due to the fact that there is no cattle access to the creek via water gaps or riparian pasture.

Maino Ranch

The Maino Ranch is located at the intersection of Highway one and San Bernardo Creek Road in the Morro Bay watershed. The Maino Ranch is a privately owned, 1850 acre ranch located in the Morro Bay watershed within San Luis Obispo County California.

Trends in vegetative species and water quality were detected from rangeland monitoring, but these findings may be more associated with natural phenomena such as soil properties or rainfall. Changes following the implementation of BMPs were observed by the land owner, John Maino, including an increase in biodiversity and in perennial vegetation.

Chorro Flats

Chorro Flats, located near the mouth of Chorro Creek, is the site of a floodplain restoration and sediment retention project and was acquired by the Coastal San Luis Resources Conservation

District. The project was completed during the summer of 1997. Where the creek was channeled and levied, the project reestablished an active floodplain, riparian corridor, and overflow channels. The majority of the creek flow is now using the newly created main channel.

Monitoring of Chorro Flats as part of the NMP project, included an upstream-downstream evaluation of water quality (suspended sediment and turbidity) including an even-interval and storm-event sampling regime, stream profiling, benthic macroinvertebrate analysis, and a qualitative evaluation of riparian and wetland re-establishment. The success of the event-based sampling was compromised by a lack of adequate flow data combined with sampling effectiveness in a high discharge stream, and the lack of a consistent relationship between the upstream and downstream stations.

The RCD efforts partially funded by another Clean Water Act Section 319 (h) grant to monitor the effectiveness of the sediment floodplain proved to be more successful. Results from the Chorro Flats Enhancement Project Final Report prepared for the Regional Board indicate that approximately 23% of the total load, and 85% of the bed-load, from Chorro Creek between 1992 and 1998 was captured on Chorro Flats. The current estimate for sediment load from the watershed is more than twice the estimate used in 1993. Based on the annual sediment load, and the 23% trapping efficiency, it is expected that the Chorro Flats site will fill in 26 years.

Watershed-Wide Characterization

In addition to the water quality data collected at the BMP evaluation sites, data was also collected from several other locations throughout the Chorro Creek and Los Osos Creek watersheds during 1993-2001. These sampling stations were used to collect watershed-wide data for use in targeting and prioritizing areas for BMP implementation and to monitor various projects that are already occurring throughout the watershed.

Elevated percent saturation, exceeding values indicative of supersaturated conditions were found at numerous sites. Additionally, elevated nitrate (NO_3^--N) and phosphate (PO_4^--P) concentrations were found throughout the watershed. Elevated fecal coliform concentrations were also found. Elevated turbidity levels were found, particularly during the high winter flow periods following the Highway-41 Fire. Mean concentrations, however, were typically low throughout the watershed. Index of Biological Integrity scores were evaluated throughout the watershed, and the least disturbed sites received higher scores than the more impacted sites.

The Friends of the Estuary's Volunteer Monitoring Program is continuing much of the watershed-wide water and habitat quality assessment as part of another 319 (h) grant with the assistance of the Morro Bay National Estuary Program. Implementation efforts are underway by numerous organizations in the watershed. These actions are expected to improve water and habitat quality conditions throughout the Morro Bay watershed.

Overall MBNMP Conclusions

Results of statistical analyses indicate significant positive changes in water quality, including decreased suspended sediment, decreased turbidity, decreased water temperature, stabilized levels of dissolved oxygen, and decreases in fecal coliform as a result of the BMPs implemented at different project sites. Rangeland characteristics such as forage species composition and production improved and supplemental feed costs appear to have decreased following BMP implementation.

These data provided a basis for Total Maximum Daily Load (TMDL) development and self-determined nonpoint source implementation in the watershed. The project provided baseline values to establish the framework for a local Volunteer Monitoring Program and a regionally-scaled ambient monitoring program. The Morro Bay NMP is part of a continued effort to evaluate long-term effects of BMP implementation on California rangelands and water quality.

PROJECT BUDGET

This NMP project was conducted as a partnership between the Regional Water Quality Control Board (RWQCB) and Cal Poly State University. The RWQCB evaluated the effectiveness of BMPs, through the collection and analysis of even interval water quality sampling data, habitat evaluations, stream channel profiles, and rapid bioassessment. The RWQCB subcontracted to California Polytechnic State University (Cal Poly), to measure water quality and streamflow during storm events, to document quality assurance of recorded vs. observed data, to compare data from Chumash and Walters Creeks, to conduct habitat sampling, and to maintain sampling and recording equipment. The estimated budget for the Morro Bay Watershed Section 319 National Monitoring Program project for the two-year period of FY00-02 is $100,000, with 50% of the funding allocated to the Regional Water Quality Control Board (RWQCB) and 50% to Cal Poly State University. Project management includes contract management, personnel, data analysis, interpretation, and reporting. Matching funds have been made available in the past through the Coastal Conservancy. For the duration of the project, Cal Poly acquired $120,000 in Agricultural Resource Initiative grant funds to extend data collection and analysis to 2002. Matching funds have also been provided by the Total Maximum Daily Load Program, the Morro Bay National Estuary Program, the Central Coast Ambient Monitoring Program, and from the RWQCB general laboratory funds.

The ten-year project received a total of 1,000,000 from Section 319 (h) funds, with additional matching state monies. The last year of funding for the project was used over a two year period in order to write up the final results. The final two-year budget for the Morro Bay Section 319 National Monitoring Program project for the period of 00-02 was as follows:

	Funding Source ($)		
Project Element	**Federal**	**State**	**Sum**
Project Management	37,859	28,198	66,048
Information & Education	13,541	7,979	21,520
Land Treatment	0	0	0
WQ Monitoring	48,600	61,468	110,068
TOTAL	$100,000	$97,635	$197,635

Source: Katie McNeill (Personal Communication), 2001.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The California Assembly Bill 640 became law in January, 1995. The law establishes Morro Bay as the first "State Estuary," and mandates that a comprehensive management plan be developed for the bay and its watershed by locally involved agencies, organizations, and the general public.

On July 6, 1995, Morro Bay was accepted into the National Estuary Program (NEP). This "National Estuary" designation provides 1.3 million from USEPA dollars for planning over a three year period. Ongoing efforts have been made by the MBNEP to create the foundation for this "grass-roots" planning process. Stakeholders in the watershed have met continuously during the last several years to discuss pollution sources in the watershed and estuary and to explore management measures which could be implemented. A Comprehensive Conservation and Management Plan (CCMP) that identifies strategies for reducing pollutants such as sediment and bacteria was developed by MBNEP staff through input from numerous community and interested agencies in the watershed. A significant amount of funding ($4,000,000) was acquired for implementation of the CCMP. The Draft CCMP is currently undergoing public review and is expected to be revised and approved in early 2000. In addition to the USEPA 319 National Monitoring Program project being led by the California Central Coast Regional Water Quality Control Board, several other agencies are involved in various water quality activities in the watershed. The California Coastal Conservancy contracted with the Coastal San Luis Resource Conservation District in 1987 to inventory the sediment sources to the estuary, to

quantify the rates of sedimentation, and to develop a watershed enhancement plan to address these problems. The Coastal Conservancy then provided $400,000 for cost share for BMP implementation by landowners. USDA funding was obtained for technical assistance in the watershed ($140,000/year), Cooperative Extension adult and youth watershed education programs ($100,000/year), and cost share for farmers and ranchers ($100,000/year) for five years. An NRCS range conservationist was hired with 319(h) funds ($163,000) to manage the range and farm land improvement program. The Coastal San Luis Resource Conservation District has developed a program titled Project Clear Water to assist ranchers and farmers in implemented BMPs on their property. Cooperative Extension received a grant to conduct detailed monitoring on a rangeland management project in the watershed. The California National Guard, a major landowner in the watershed, contracted with the NRCS ($40,000) to develop a management plan for grazing and road management on the base. State funding from the Coastal Conservancy and the Department of Transportation was used to purchase a $1.45 million parcel of agricultural land on Chorro Creek, just upstream of the Morro Bay delta, which was restored as a functioning flood plain. Additional lands have recently been acquired through the Department of Fish and Game, the Trust for Public Land, and the MBNEP. Without the cooperation of many of these agencies and their financial resources, the Section 319 project would be unable to implement BMPs or educate landowners about nonpoint source pollution.

The Central Coast Regional Water Quality Board conducted a study of the abandoned mines in the watershed with USEPA 205(j) funds. The Board also obtained a USEPA Near Coastal Waters grant to develop a watershed work plan, incorporate new USEPA nonpoint source management measures into an overall basin plan, and develop guidance packages for the various agencies charged with responsibility for water quality in the watershed.

The Department of Fish and Game Wildlife Conservation Board provided funding ($48,000) for steelhead habitat enhancement on portions of Chorro Creek. The State Department of Parks and Recreation funded studies on exotic plant invasions in the delta as a result of sedimentation. The California Coastal Commission used Morro Bay as a model watershed in development of a pilot study for a nonpoint source management plan pursuant to Section 6217 of the Federal Coastal Zone Management Act Reauthorization Amendments of 1990.

The Friends of the Estuary at Morro Bay, working in conjunction with the Morro Bay National Estuary Program received a 319 (h) grant from the State Water Resources Control Board to continue the Volunteer Monitoring Program. The volunteer monitors have been collecting water quality and habitat data at established NMP sites since Fall, 2001.

Waterbodies within the Morro Bay watershed are listed as "impaired" by sediment, nutrients, organics, and bacteria. As such, Total Maximum Daily Loads (TMDLs) are required to identify the sources, determine the loading capacity of the waterbodies, and reduce pollutant loading so that beneficial uses are protected. NMP data have been used to develop Total Maximum Daily Loads for Chorro Creek, Los Osos Creek, and the Morro Bay estuary. TMDLs for sediment and bacteria have recently been adopted, and efforts to develop TMDLs for nutrients and organics are currently underway.

OTHER PERTINENT INFORMATION

In addition to state and federal support, the Morro Bay watershed receives tremendous support from local citizen groups. The Friends of the Estuary, a citizen advocacy group, is invaluable in its political support of Morro Bay. The Bay Foundation, a nonprofit group dedicated to Bay research, funded a $45,000 study on the freshwater influences on Morro Bay, developed a library collection on the Bay and watershed at the local community college, and is actively cooperating with the Morro Bay Section 319 National Monitoring Program project to develop a watershed GIS database. The Bay Foundation also recently purchased satellite photographs of the watershed, which will prove useful for long-term restoration efforts. The Bay Foundation co-wrote the nomination to the National Estuary Program along with the Regional Board. The National Estuary Program just completed four Technical Studies that heavily utilized data collected by the National Monitoring Program to develop several pollutant

loading and tidal circulation models. The National Estuary Program, Friends of the Estuary, and the Bay Foundation of Morro Bay are cooperating to implement a volunteer monitoring program for the Bay itself. Ongoing volunteer efforts that have been invaluable for the National Monitoring Program include water quality and habitat monitoring.

PROJECT CONTACTS

Morro Bay NMP project website: *http://www.swrcb.ca.gov/rwqcb3/WMI/MorroBay/*

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