9. Conclusions

9.1 Major Findings Summary

9.1.1 Paired Watersheds

Finding #1
Collection of flow data was one of the most challenging tasks of the paired watersheds study, because of under designed flumes, occasional technological breakdowns, and operator errors in downloading data. And with gaps in flow data, reliable values of load were impossible to calculate. Still, with this, one of the most significant findings is that we have shown a linear modeling approach for evaluating differences in turbidity or suspended sediment collected from the paired watersheds have been successful in detecting change.

Finding #2
We have shown improvements in water quality, regardless of whether the response variable was turbidity or suspended sediment. This finding could significantly reduce costs if turbidity only was analyzed. Cal Poly personnel would still recommend that turbidity and suspended sediment concentration both be analyzed for this type of study, but with a reduced schedule (fewer samples) for sediment. This could be accomplished using a turbidity threshold approach. In other words, analyze each sample for turbidity, but analyze a smaller subset for sediment depending on turbidity levels.

Finding #3
An effective alternative for measuring suspended sediment concentration is method ASTM D 3977-97. This method essentially analyzes a complete water sample from a stream or other moving body of water by either of the following ways: sample evaporation, sample filtration, or wet-sieving and filtration. Which of these methods to use depends upon the characteristics of the suspended materials, mainly the amount of sands. Since the whole sample is analyzed, there is less error than trying to pipette particles out of a sample that is continually settling while the sample is being drawn. And, since the whole sample is used, multiplication of measuring errors is eliminated.

Finding #4
Following BMP implementation, peak stream flow of Chumash Creek has lagged behind that of Walters, by 30 minutes to 1 hour. This was most noticeable in the fall/early winter seasons. Cal Poly project staff hypothesize this is due to increased interception of water by plants, and increased infiltration in the Chumash watershed, as vegetation increased on streambanks and in the watershed. Later in the winter/spring, hydrographs of Chumash more closely match Walters, perhaps attributable to saturation of soils in the creek, and greater responsiveness of streamflow to rainfall.

Finding #5
One of the most key findings by Cal Poly is that turbidity and suspended sediment measured during storm events in Chumash Creek have shown a slight, but steady and significant improvement as a result of BMP implementation. The regression analyses on event-based sampling summarized above confirm that BMPs are reducing turbidity and suspended sediment in Chumash Creek. Each day following BMPs shows a slight reduction in turbidity and sediment. Results are statistically significant even though R^2 values are low. Chumash Creek has significantly lower event averages than Walters Creek.

Finding #6
Results of even-interval water quality monitoring indicate that BMPs significantly lowered water temperature at Chumash Creek.

Finding #7
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.

Findings #8 and #9
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 are still within the typical range of other creeks in the Morro Bay watershed.

Finding #10
Even-interval turbidity samples also exceeded threshold values (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. Also, the threshold value of 7 NTU is very low; the creek water appears clear at such a low NTU.

Finding #11
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.

Finding #12
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.

Finding #13
Based on the results of event-based water quality and rangeland and stream channel monitoring within the paired watershed study, Cal Poly staff believe that restricting cattle access to the creeks (not exclusion) was most effective in improving the condition of the watershed. Of course, this was achieved by a variety of BMPs: fencing the watershed into small pastures, water system development, and intensive rotational grazing alternating with rest periods. Dirt road improvements (recontouring and culverts) was probably also instrumental to improvements in water quality, by reducing runoff and sediment from the roads.

Streambank revegetation included trees, which were (and are) far from maturity at the end of the monitoring period and time of writing this report. The Cal Poly staff hypothesizes that as the trees reach maturity, further improvements in water quality will be noted.

Finding #14
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.

9.1.2 Dairy Creek
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.

9.1.3 Chorro Creek
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.

9.1.4 Maino Ranch

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 landowner, John Maino, including an increase in biodiversity and in perennial vegetation.

9.1.5 Chorro Flats

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. Performing pre- and post-project topographic surveys were preferred to detect BMP effectiveness for the Chorro Flats project, over event-based sampling using an upstream/downstream approach. 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.

9.1.6 Watershed-Wide Characterization

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. hese actions are expected to improve water and habitat quality conditions throughout the Morro Bay watershed.

9.2 Pertinence to Other State and Federal 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 met continuously to discuss pollution sources in the watershed and estuary and to identify action items which could be implemented. A

Comprehensive Conservation and Management Plan (CCMP) that includes action items for reducing pollutants such as sediment and bacteria has been developed by MBNEP staff through input from numerous community and interested agencies in the watershed. A significant amount of funding ($4,000,000) has been acquired for implementation of the CCMP. The CCMP has been approved and implementation of the action items are well underway.

In addition to the USEPA 319 (h) National Monitoring Program project being led by the Regional Board and Cal Poly, several other agencies are involved in various water quality activities in the watershed for over a decade. 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 has been 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. Cooperative Extension has also 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, has 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 has been used to purchase a $1.45 million parcel of agricultural land on Chorro Creek, just upstream of the Morro Bay delta, which has been restored as a functioning flood plain. These funds were used to match the 319 (h) grant. Without the cooperation of these agencies and their financial resources, the Section 319 NMP project would be unable to monitor the effectiveness of BMPs.

The Regional Board conducted a study of the abandoned mines in the watershed with USEPA 205(j) funds, and restoration of the mines has begun. The Board also completed 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.

An Agricultural Research Initiative grant ($50,000) was obtained by Cal Poly to provide matching funds for the “paired watershed” study. These funds allowed Cal Poly to

continue storm-event, range monitoring, and an analysis of rangeland quality for an additional year.

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 purchased satellite photographs of the watershed, which will prove useful for the monitoring program effort. The Bay Foundation co-wrote the nomination to the National Estuary Program along with the Regional Board. The Morro Bay National Estuary Program completed four Technical Studies that heavily utilized data collected by the National Monitoring Program to develop several pollutant loading and tidal circulation models.

The Friends of the Estuary at Morro Bay, working in conjunction with the Morro Bay National Estuary Program have received a 319 (h) grant from the State Water Resources Control Board to continue the Volunteer Monitoring Program. The volunteer monitors have assisted in collecting water quality and habitat data at the NMP sites throughout the project duration, and will continue monitoring NMP sites now that the NMP project has been completed.

The Central Coast Ambient Monitoring Program (CCAMP) managed by the CCWQCB has used the Morro Bay NMP data as a foundation for a long-term region-wide monitoring effort. Data collected as part of the NMP has been inputted in to the CCAMP database for quality assurance tracking, data management, and data analysis.

Total Maximum Daily Loads are being developed for siltation, pathogens, and nutrients in the watershed. Results from the National Monitoring Program and the NEP's Technical Studies have been used to determine allocations and loading capacity of the creeks that feed Morro Bay. The TMDLs are scheduled for Regional Board Adoption into the Water Quality Control Plan in 2002.

9.3 Lessons Learned

One of the most significant findings of any long-term, large scale project are the lessons that can be learned and transferred to future projects. The Regional Board and Cal Poly project staff, along with the TAC members have acknowledged areas of the study that could have been improved, and identified recommendations for future projects of this nature. These are discussed below.

Reduce the scope of the study

The scope of the original study design was perhaps too broad for the resources available. If a similar study were to begin, the Cal Poly staff would recommend putting more resources into a paired watershed type of design, increasing the pre-BMP monitoring period, and following the suggestions below if the objective of forage productivity and effects on cattle condition were to be included.

Maintain separate herds of cattle for each watershed

NMP project staff has detected changes 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. For example, even the control watershed (Walters) consisted of four pastures through which cattle were rotated. The proportion of rest days to grazing days was already much better than most grazing systems. In a traditional western cattle ranch, no crossfencing would be used, and the grazing system would be a complete open system. Cattle used in the project graze both the paired watersheds included in the study as well as an additional watershed (Pennington Creek) not part of the study. 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.

Design the flumes for peak flow and low flow

Parshall flumes were selected because they are designed to maintain high flow velocities and thus keep themselves free of sediment and debris, because they conform to the natural channel shape, and because they allow aquatic animals to pass freely upstream of the gauging stations. Parshall flumes are purchased ready made and inserted in the channel. They were designed to handle the maximum flow rate for a 10-year storm, but

also had to maintain flow at low-flow periods. The smallest flume that could handle the maximum flows without overflowing was desired. However, in January and March of 1995, unexpectedly intense storms occurred and the flumes overflowed. Flood damage was repaired in summer 1995. The flumes should have been designed for a larger return period. Low flows can be accommodated with a weir insert.

Collect flow data at all water quality sites

While flow was collected at many of the monitoring sites, flow was not collected at all of the even-interval water quality monitoring sites throughout the Morro Bay watershed. Having this information available would have allowed project staff to better characterize loads and evaluate percent reductions in pollutant loading.

Carry out a geometric, geomorphological, and geological/pedological study of the paired watersheds before monitoring begins

Holistic site characterization could focus on two major types of activities: field inventory and aerial photo interpretation. This would be beneficial to better understand how the two watersheds react differently due to natural differences, as well as management styles. It was also recommended that an evaluation of the soil profiles be conducted at the other BMP sites.

Have the statistical approach worked out before monitoring begins

Methods used to analyze data shape the methods of collecting data. Involving the statisticians earlier in the process would have provided the project with a stronger foundation in terms of collection methods, trend detection, and results synthesis.

Use ASTM method, instead

Cal Poly staff recommended using different procedure in the lab for measuring suspended sediment. This method (ASTM D 3977-97) essentially analyzes a complete water sample from a stream or other moving body of water by either of the following ways: sample evaporation, sample filtration, or wet-sieving and filtration. Which of these methods to use depends upon the characteristics of the suspended materials, mainly the amount of sands. Since the whole sample is analyzed, there is less error than trying to pipette particles out of a sample that is continually settling while the sample is being drawn. And, magnification of the error by multiplication is eliminated.

Hire a technical person to oversee the project for its duration

Budget for Project Management for the Contractor, and assign the duty to a specific person or hire someone specifically for this purpose. This is very important if students are used for labor in the lab and field. It would help continuity and training. Additionally, it would be helpful to hire clerical assistance for the duration of the project, and assign the duty to a specific person.

Ensure pre-BMP control is available

While the Maino Ranch project was not designed to be a "study" at the time that BMPs were implemented, in analyzing the data collected on the over the course of the study it would have been helpful to have a control for comparison. This was not set up to be a paired watershed study, thus there has been no basis of comparison of vegetative changes on the ranch. As a result, it was difficult to ascertain which trends are a result of the BMPs and which are results of weather, soils, or other natural causes. It was recommended by the land owner, John Maino, that monitoring of a project such as this occur every five years to evaluate long-term trends.

Consistency in field staff

One difficulty with this project was the high turnover rate of rangeland monitoring personnel. The high turnover and inconsistency of rangeland monitors was minimized to the extent possible, but in a long-range study at a university, turnover is inevitable due to graduation of students working on the project. In particular, species diversity was probably affected the most. One way to possibly mitigate for this problem during similar studies may be to establish a herbarium documenting the identification of species found during the study. During data collection, individual unknown species were identified using a variety of resources including a wide range of books and professors. Access to a site-specific resource such as a herbarium would have insured a greater degree of consistency among rangeland monitors. Likewise, inconsistent sampling times have been a hindrance to data analyses.

This project did have a good set of directions and instructions for conducting transect data collection; however interpretation of some parameters measured varied (especially on stream stability) due to a lack of hard and fast definitions and guidelines for interpretation. Similar long term studies done in the future could minimize the amount of experimental error by having a definitional database and procedural manual available for reference and required to be read as part of training for rangeland monitors and data analysis personnel. Cal Poly personnel would recommend such a monitoring and operations manual be developed for all aspects of a similar project, early in the project conception. This manual could (and should) be updated periodically or as needed, as methods become refined by use. A line item on the project budget should be provided for writing and updating.

Some obstacles to reproducible collection of field and laboratory data were encountered. This project was of long-term duration (10 years) and underwent two episodes of unavoidable personnel restructuring, as well as changes in software heavily involved in data collection. Undeniably, some field and laboratory procedures would have run more smoothly with more consistent training and a more explicit procedures manual. Overall, data collection became more successful in later years after restructuring that included a half-time field technician.

Some losses of streamflow data were software related. Cal Poly personnel would recommend including a means for backing up flow data using alternative methods for monitoring stage.

Consistency in sampling times

The results of spring vegetative sampling at the Maino Ranch seemed to be largely a function of sampling time. Percent cover of annual grasses increased when sampling occurred in June and July rather than May. The artifact of the varying sampling times made it difficult to tell if, overall, species diversity was increasing in response to BMPs. Monitoring was conducted when access to the private ranch was possible, however, as the sensitivity of cattle to unintentional disturbance was an important consideration in the land owner's successful management of the ranch.

Consistency in laboratories

NMP Project Staff recommend using laboratories that provide the lowest detection limits, depending on the objectives of the project. Ortho-phosphate was measured in Chumash and Walters Creek, however, much of the pre-BMP period data were not usable for analysis because the minimum detection limit (0.100 mg/L) was higher than the majority of the entire data set. In 1995, Regional Board contracted with a new laboratory, which used a lower detection limit (0.020 mg/L). Project Staff were able to evaluate data, using a data set from 1996-2001 to analyze trends, but the additional pre-BMP data would have been extremely useful in detecting changes.

Modify Stream Stability Evaluations

The use of the Pfankuch method was somewhat frustrating for monitors who felt it was too subjective, and many parts of the Pfankuch evaluation form are not applicable to xeric climate clay bottom streams predominant in the Morro Bay watershed. The method was designed for use in mountainous perennial streams. Due to the physiographic differences in our local streams in comparison with perennial cobbly streams, scores on Pfankuch Stream Stability varied inconsistently depending on interpretations of the monitor. As a result, subtle improvements were difficult to document.

Coordinate Monitoring with BMP Implementation

Unanticipated water quality results lead to the need to further understand grazing management on the project site. Communication between project staff that are managing the land and those that are evaluating water quality changes as a result of implementing BMPs is essential.

Additional Lesson's Learned can be found in Chapter 10, QAPP.

9.4 Future Directions

A paired watershed study has been proposed by Cal Poly staff for Walters Creek, incorporating many of the "Lessons Learned" from this paired watershed study. Separate cattle herds are proposed, in order to more effectively track effects of BMP on cattle and supplemental feed costs. Funding is currently (at the time of this writing) being sought. Monitoring of water quality in Chumash and Walters will continue, on a less intense basis, mainly by means of volunteer monitors, class projects and senior projects.

The Friends of the Estuary at Morro Bay, working in conjunction with the Morro Bay National Estuary Program have received a Clean Water Act Section 319 grant to continue monitoring through the Morro Bay Volunteer Monitoring Program. The volunteer monitors have assisted in collecting water quality and habitat data at the NMP sites throughout the project duration, and have continued monitoring the NMP sites now that the NMP project has been completed.