Technical Report

MORAN LAKE WATER QUALITY STUDY
&
CONCEPTUAL RESTORATION PLAN






Prepared For:

Santa Cruz County Redevelopment Agency

701 Ocean Street, 5th Floor
Santa Cruz, CA 95060

Prepared By:

John Gilchrist & Associates
&
Fall Creek Engineering, Inc.

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1. EXECUTIVE SUMMARY & INTRODUCTION

1.1 EXECUTIVE SUMMARY

Moran Lake is a coastal lagoon located in the Live Oak Area of Santa Cruz County that seasonally connects to Monterey Bay. The Moran Lake watershed has been modified as a result of development and land use changes in the area. Increased impervious surfacing has decreased infiltration capacity and increased the volume of water entering Moran Lake and its principal tributary, Moran Creek. Roads, parking lots, commercial and residential land uses have contributed to impaired water quality within the watershed and in Moran Lake. Water and sediment sampling and testing conducted in this and previous studies have documented problems concerning water quality and low biologic productivity in Moran Lake. However, the Lake and its surrounding uplands also support two sensitive species, the tidewater goby and monarch butterfly. Presence of these species must be considered in any lake restoration planning. Vegetation in wetland and upland areas around the lagoon consist primarily of non-native trees, shrubs and herbaceous species. Blue gum eucalyptus is the dominant tree species, and is an important resource for the over-wintering monarch butterfly population. Wildlife surveyed during previous studies included relatively common shore birds, water birds and upland bird and mammal species. Numbers of water-associated wildlife species are lower than nearby lagoons such as Corcoran due to reduced aquatic productivity in Moran Lake.

Moran Lake, like other coastal lagoons, is a body of brackish or saline water impounded by a barrier beach, with a seasonal inlet/ outlet. The size and shape of the lagoon, inlet configuration, watershed drainage and other environmental factors influence the chemistry, water circulation and ecology of a lagoon under natural conditions. Moran lagoon has been altered by artificial fill, reducing its size from nine to five acres in the early 1960’s, and by constriction of the inlet with a culvert at East Cliff Drive. The 7-foot diameter culvert was replaced by a larger box culvert in 1981. Although culvert replacement increased water exchange, these changes have confined the lagoon to a relatively fixed configuration, with some limitation on ocean – lagoon water interchange. The box culvert may be slightly undersized to handle the full tidal prism and streamflows entering and exiting the lagoon. However, due to presence of a barrier beach and the current reduced lagoon configuration, replacing the culvert with a bridge or arch culvert may not produce significant changes to winter or summer lagoon conditions. In summer months hyperhaline conditions (high salinity), and algal blooms indicative of a eutrophic water body are prevalent in Moran Lake. During the 2004 study period, streamflow into the Lake was small compared to winter months. Lake bank erosion is a problem during higher winter runoff periods.

Because Moran Lake water quality concerns were the focus of this study, baseline water quality monitoring was undertaken at four locations between June and October 2003. In addition, lagoon sediments samples were collected and analyzed at several water sampling locations in November 2003. Fecal coliform contamination continues to be a problem in the lagoon with likely sources that include leaking sewers, domestic animals and wildlife. Nutrients, including total phosphorus, nitrate and ammonia were reasonably low during summer months, but were elevated after the "first flush" rainfall event in late October. Sources include urban pollutants such as waste products and fertilizers. Dissolved oxygen levels were low and then relatively high in morning and afternoon sampling which is typical of a eutrophic lake with urban pollutants and large algal blooms. Presence of high concentrations of sodium and chloride in late summer was expected due to hyperhaline conditions in the lake. The concentration of trace metals varied significantly both spatially and seasonally, with highest levels taken from the Moran Creek station and during the "first flush" rain event. Copper and zinc were present at potentially toxic levels. Sediment samples detected the presence of several polyaromatic hydrocarbons (PAHs), commonly known as oils and grease. Principal sources of PAHs are roads, parking lots and vehicle service areas. Several of the PAH compounds detected are carcinogenic and other compounds are potentially detrimental to aquatic life. Sediment testing for organochlorine pesticides and PCB's detected only the pesticide chlordane above threshold levels. This persistent pesticide may also adversely affect aquatic life. Water and sediment sampling yielded results that were generally similar to previous water quality testing for Moran Lake, but some contaminant levels were less than those found in other urban watersheds in the San Francisco Bay area.

Restoration opportunities exist in the Moran Lake watershed to improve water quality and habitat conditions in the lagoon. Many opportunities exist in the immediate vicinity of the lagoon, while other projects and actions can be taken in the upper watershed area. Restoration options include a broad spectrum of activities, including physical restoration projects, storm water management and treatment, recommendations for environmental education, site planning and design standards with the objective of reducing impervious cover in the watershed. Specific Moran Lagoon restoration options include modifying the lagoon inlet-outlet with a bridge or arched culvert to improve ocean-lagoon water exchange, although as noted, the presence of a barrier beach and the current reduced lagoon configuration may limit water quality improvement. The lagoon could also be dredged and expanded, artificially aerated, and/ or artificially breached, although there are constraints to each of these options. Upper watershed streamflow could be augmented with treated wastewater from a small treatment plant at Lode Street, however there are environmental and public perception issues associated with this alternative. There is an opportunity to create a 'treatment wetland' on public lands in the upper lagoon that could improve lagoon water quality and wildlife habitat. Other restoration options at Moran Lake include bank replacement and revegetation of the eroded east slope, removal of exotic plant species and revegetation with natives, and interpretative signing on park trails to inform the public about Moran Lake resources.

Restoration in the upper watershed can also improve Moran Lake water quality. Modification of the 38th Avenue Flood Detention Basin to accommodate a treatment wetland would reduce nutrients, bacteria and heavy metals contained in upper Moran Creek watershed urban runoff. The treatment wetland design would need to insure equivalent flood management currently provided by this facility. There are also opportunities to restore portions of Moran Creek to a functional riparian corridor. A restored flood terrace and native riparian vegetation can reduce upstream pollutant loadings. Storm water management and treatment practices are also available to reduce pollutants from the urban watershed. Source control and treatment best management practices (BMP) are discussed in Chapter 6 and Appendix A. These include innovative site design practices for new development, storm water treatment devices including drainage inlet filters, bioretention swales and constructed wetlands, and implementation of performance standards for storm water management. Finally, public awareness of maintaining good water quality in Moran Creek and Lake can be developed with informational brochures and volunteer watershed stewardship organizations. Prioritization and cost estimates for these restoration measures are set forth in Chapter 6 of this report.

1.2 INTRODUCTION

1.2.1. Background

Moran Lake, one of several coastal lagoons in unincorporated Live Oak, is located near East Cliff Drive in the Pleasure Point area. Previous studies and water quality monitoring have documented problems concerning water quality and low biologic productivity in the Moran Lake lagoon. These same studies have proposed drainage and water quality improvements in the lagoon and upper watershed.

Spoils from Yacht Harbor dredging were used to fill Moran Lake in the early 1960's reducing the size of the lagoon by over 3 acres. In 1981 a box culvert replaced a smaller culvert allowing increased tidal exchange and flushing of lagoon waters. At the same time, a paved parking lot and restrooms were constructed on part of the Harbor fill sediments and the Lake and adjacent uplands began to be managed by the Santa Cruz County Parks, Open Space and Cultural Services Department. Urbanization in the watershed upstream of the lagoon has increased significantly over the last 35 years, causing drainage and water quality problems for the upstream watercourse, Moran Creek, and for Moran Lake.

1.2.2. Public Concerns and Issues

Since 2001 a group of Live Oak neighbors expressed concerns regarding Moran Lake to Santa Cruz County Public Works, Planning and Redevelopment Departments, County Parks Commission and the Board of Supervisors. Specific concerns included the restriction of tidal flow caused by the box culvert, recent rip-rap installation at the culvert, decrease in lake water quality caused by impervious surfaces and polluted runoff from the watershed, and problems associated with lagoon fill from 1960's harbor dredging. The neighborhood group has asked the County to consider replacing the culvert with a bridge in order to restore tidal exchange and flushing of the lagoon. The group has also expressed concerns regarding expansion of the rip-rap at the outlet and continued deterioration of lagoon water quality from urban land uses in the watershed.

1.2.3. Scope of Project & Project Objectives

Previous studies that described Moran Lake as an impaired water body are over 25 years old. Because changes in the watershed and lagoon itself have occurred over the last 25 years, it is not clear whether water quality problems continue as previously observed in Moran Lake, and if so, the severity or magnitude of the problems.

To address these concerns and to update historical information, the Santa Cruz County Redevelopment Agency (RDA) agreed to undertake a baseline study to assess current conditions. The RDA retained John Gilchrist and Associates to conduct this baseline study. The objectives of the project are as follows:

- Obtain water quality data over a 5-6 month period that will provide information on current lagoon conditions
- Develop a better understanding of lagoon hydrology by reviewing watershed inflows, tidal exchange and lagoon configuration in order to assess potential for water quality improvement options and other lagoon/ watershed management opportunities.

- Review existing biologic information, including data on species of concern, to better understand the interactions between lagoon hydrology, water quality and biology, and recommend possible lagoon enhancement options.

- Provide recommendations on future focused studies or design work needed to implement restoration and enhancement options.

This report presents the results of the baseline study. The document is divided into the following technical sections:

Section 2 - Setting. This section provides an overview of the Moran Lake and watershed setting, including a description of the natural history (geology, hydrology, and biology), historic and present watershed boundaries, jurisdictional boundaries, and land use changes over several decades.

Section 3 - Lagoon and Watershed Hydrology. This section provides a detailed description of the historical and current drainage and morphology of the lagoon. It also provides a description of the hydrologic conditions in the upper watershed areas. Emphasis is placed on the effects that modifications to the lagoon and the watershed have had on the function and conditions of the lagoon and watershed hydrologic processes.

Section 4 – Water Quality. This section provides a review of historical and recent water quality studies of Moran Lake, and presents the results of water quality and sediment testing undertaken as part of this study.

Section 5 – **Restoration Options.** This section provides conceptual restoration opportunities in the Moran Lake watershed to improve water quality and habitat conditions in the lagoon. Restoration options presented include a broad spectrum of activities, including physical restoration projects, storm water management and treatment, recommendations for environmental education, and site planning and design standards to improve watershed conditions and reduce impervious cover.

Section 6 – Implementation. This chapter provides a general review of planning and implementation activities for each restoration option. Also included are cost estimates for the projects and a preliminary constraint analysis that reviews benefits and constraints for each project. Projects receive a preliminary ranking based on this constraint analysis.

Section 7 – Report References.

Appendix A – Stormwater Best Management Practices

2. SETTING

2.1 Regional Setting

Moran Lake is a coastal lagoon that seasonally connects to the Monterey Bay National Marine Sanctuary in the Pacific Ocean. Moran Lake is located in the Live Oak Area of Santa Cruz County, California, as shown in Figure 2.1. The lake and adjacent land comprise Moran Lake County Park and the Lode Street Sanitation facility, and are the property of the County of Santa Cruz. The 9.2-acre park is located north of East Cliff Drive between Twenty-Sixth and Thirtieth Avenues, south of Portola Drive. Park facilities include restrooms, picnic tables, trails, beach access, and vegetated open space.

The Lode Street facility includes a wastewater pump station, sanitation district offices and surrounding eucalyptus groves. A plan and memorandum of understanding is presently under preparation for management of the eucalyptus and open space lands, with County Parks, Open Space and Cultural Services Department assuming future jurisdiction over these areas together with their existing management of Moran Lake Park lands.

2.2 Natural History

2.2.1 Geology

Moran Lake watershed is located between the Pacific Ocean and the Santa Cruz Mountains. The steep valleys in the mountains transition to relatively flat marine terrace and sea cliffs with narrow beaches parallel to the Monterey Bay. Urban development in the area is generally located in the area between the mountains and the ocean.

Surficial deposits in the area around the lake are described as lowest emergent coastal terrace deposits, originating from the Pliocene Age. The Purisima Sandstone Formation, also of Pliocene Age, underlies the terrace deposits beneath Moran Lake and extends beneath the Monterey Bay.

Two fault systems, the San Andreas fault and the Zayante fault, trend northwest through the Santa Cruz Mountains. Recent significant seismic activity in the vicinity of Moran Lake was recorded in 1989 on the San Andreas Fault, measuring 7.1 on the Richter Scale.

A 1980 environmental study of Moran Lake reports on the soils in the vicinity of the Lake. The bottom one to two feet of sediments in the lagoon are composed of a fine black silty-clay material, enriched with organic matter, with about 20-30 percent beach sands (Stern et.al., 1980). The terrain around Moran Lake, dominated by landfill materials, is composed of a variety of materials from coarse to fine sand, clay, silt, and small pieces of crushed granite rock (Stern et.al., 1980). During this investigation asphalt and concrete debris was also observed around the edge of the lagoon.

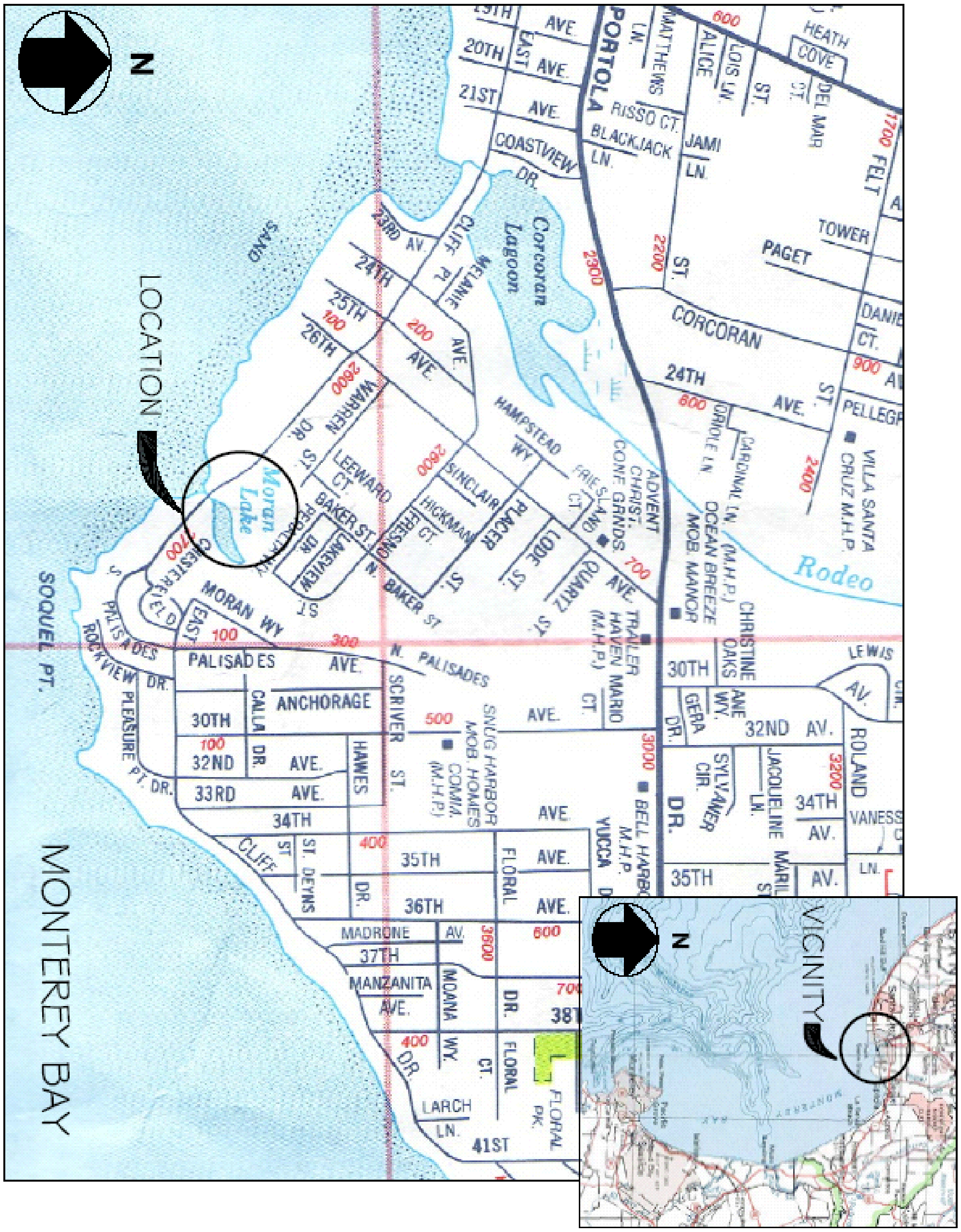

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FIGURE 2.1: VICINITY MAP OF MORAN LAKE SANTA CRUZ COUNTY

2.2.2 Hydrology

In the Moran Lake study area precipitation occurs almost entirely as rainfall. Precipitation rates on the coast range from 24 to 28 inches per year, with approximately 80 percent of the precipitation occurring between November and March (Hickey, 1968).

Groundwater in the vicinity of Moran Lake occurs within the sandstone beds of the Purisima Formation between the Zayante Fault and Monterey Bay. Drinking water is pumped from groundwater wells within the Live Oak area from the Purisima Formation. As freshwater is pumped from the Purisima Formation and if water levels are lowered, salt water can enter the freshwater aquifer (Hickey, 1968). Recent studies by the City of Santa Cruz Water Department indicate there is potential for salt water from coastal lagoons to enter groundwater.

The hydrologic response of surface waters in the Moran Lake watershed has been modified as a result of development and land use changes in the area. Increased impervious surfaces have decreased infiltration capacity and increased the volume of water entering Moran Lake, and its principal tributary Moran Creek. The decreased infiltration capacity has also increased the rate at which water moves through the watershed and enters these water bodies immediately after rainfall events. Impervious surfacing also decreases groundwater storage in the watershed, decreasing natural discharge to water bodies during dry months. Moran Creek and its smaller tributary channels have also been channelized, buried, or the riparian corridor reduced, causing impacts to the watershed hydrology.

2.2.3 Biology

Vegetation. Plant communities within the Moran Lake study area consist of annual grassland, disturbed ruderal, brackish wetland and open water. The upland areas of the lagoon have been colonized primarily by non-native plants, including some invasive species. (Species marked with an asterisk are non-native.) Dominant trees include blue gum eucalyptus* (*Eucalyptus globulus*), Monterey cypress* (*Cupressus macrocarpa*) and recent plantings of redwood (*Sequoia sempervirens*). Some black acacia* (*Acacia melanoxylon*) and arroyo willow (*Salix lasiolepis*) is also present in the upper park area near 30th Avenue. The majority of upland shrub and herbaceous species are also non-native. Dominant species include English ivy* (*Hedera helix*), Cape ivy* (*Senecio mikanioides*), French broom* (*Genista monspessulana*), wild radish* (*Raphanus sativus*), sea fig or ice plant* (*Carpobrotus edule, C. chilense*), wild mustard* (*Brassica nigra*), common plantain*(*Plantago major*), English plantain* (*Plantago lanceoloata*), poison oak (*Toxicodendron diversilobum*), mallow* (*Malvia parviflora*), nasturtium* (*Tropaeollum majus*), and curly dock* (*Rumex crispus*). Grass species are largely annual non-natives, including Italian ryegrass* (*Lolium multiflorum*), wild oat* (*Avena fatua*), barley* (*Hordeum leporinum*) and ripgut grass* (*Bromus diandrus*). A significant amount of invasive Himalayan blackberry* (*Rubus discolor*) is located along the upper streambanks near the Lode Street facility, and is preventing other riparian vegetation from becoming established.

Brackish wetland species are found on the lower lagoon slopes, in areas that are periodically inundated when Moran Lake is filled to capacity. Except for one plant, these species are native perennials adjusted to salt or brackish environments with differential tolerances for inundation. Pickleweed (*Salicornia subterminalis*) is found at the lowest zone, with alkali heath (*Frankenia grandifolia*), Jaumea (*Jaumea carnosa*), salt grass (*Distichlis spicata*) and fat hen (*Atriplex patula*) present at somewhat higher elevations, respectively. On the lower east lagoon bank, erosion has removed all wetland plants, while on the lower west side, the aforementioned non-native ice plant extends from the County Park parking lot to the lower Moran Lake shoreline, crowding out native upland and wetland species.

A somewhat disturbing trend is evident from a review of the 1980 Environmental Baseline Study (Stern et. al. 1980). The vegetation survey performed then identified some of the same non-natives found in 2004, but also included a significant number of native shrubs and herbaceous plants not in evidence today. Upland native shrubs identified in 1980 but not in 2004 include deerweed (*Lotus scoparius*), sky lupine (*Lupinus nanus*), bush lupine (*Lupinus arboreus*) and coyote brush (*Baccharis pilularis*). Herbaceous species included California poppy (*Eschscholzia californica*), coast hedge nettle (*Stachys chamissonis*), seaside dandelion (*Agoseris apargioides*) and loosestrife (*Lythrum hyssopifolia*). One native wetland species, *Carex obnupta* (slough sedge), was prevalent in 1980 but confined to one small area just south of the Lode Street facility in 2004. The brackish wetland species, *Scirpus americanus* (bulrush), was found in 12 locations on the lake edge in 1980 but was also absent in 2004. Conversely, the highly invasive non-natives, Himalayan blackberry, French broom, English ivy and Cape ivy were prevalent in 2004 but absent in 1980. Ice plant was found in several patches along the west lake shore in 1980, but did not cover extensive areas of the lagoon bank slope as it does today. Nearly all the dominant plant species in 2004 are non-native with a significant coverage of aggressive invasives.

Wildlife and Aquatic Invertebrates. Wildlife and in-lagoon benthic invertebrate surveys were not conducted as part of this study, although incidental observations of wildlife were made; however, wildlife and aquatic invertebrate populations are expected to be similar to those identified in 1980. Water birds associated with the lagoon include mallard ducks (*Ana platyrhynchos*), coots (*Fulica americana)*, western gulls (*Larus occidentalis*), sanderlings (*Crocethica alba*), western sandpiper (*Ereunetes mauri*), egret (*Cosmerodius albus*) and great blue heron (*Ardea herodias*). Compared with Corcoran Lagoon and other productive coastal lagoons, water bird usage at Moran Lake is comparatively light, with relatively low density and diversity of species. This is probably due to the small size of Moran Lake and the low productivity of small fish and aquatic invertebrates.

Mammal and bird species in upland areas include common species typical of the urban environment. Gray squirrel, opossum, western harvest mouse, gopher and skunk were observed or trapped during the 1980 survey. Avian species included robins, mourning doves, starlings, swallows, song sparrow, white-crowned sparrow, red-winged blackbird, Brewer's blackbird, Anna's hummingbird and scrub jay.

Examination of plankton samples taken in May 1980 yielded calamoid corepods, oligochaetes (annelid worms), Capitellid polychaetes (worms) and four species of phytoplankton. From benthos sampling in Moran Lake mud sediments performed at the same time, oligochaetes, juvenile sand crabs (*Emerita analoga*), copepods and polychaetes were detected. Generally, the low numbers and diversity of invertebrates found in Moran Lake indicates an aquatic ecosystem that has relatively low productivity and is unable to support large numbers of fish and aquatic birds. Sampling of Moran Lake phytoplankton in 2003 (Swanson Hydrology 2004) showed a vastly different species' composition when the lagoon was closed compared to results when it was open. This characteristic also indicates lack of a stable aquatic community that is probably due to extreme salinity variations under winter and summer conditions (see Water Quality section).

Special Status Species. Two special status species are known to occur at Moran Lake. The federal endangered tidewater goby (*Eucyclogobius newberryi*) has been observed in Moran Lake in the past (Smith 2002); however, the reconfiguration of the lagoon with harbor dredge spoils which removed backwater refuge areas, and annual runoff which empties the lagoon during winter months (see Figure 3.6) may have removed this species. Although no gobies, or other fish species were captured during Moran Lake seining in 1980, recolonization is possible from other nearby known localities such as Corcoran Lagoon and San Lorenzo River lagoon.

Tidewater goby is a small fish (~50mm) that inhabits low salinity coastal lagoons and lower reaches of coastal streams. Gobies have a short one to three year life cycle. Food sources include small crustaceans, aquatic insects, and mollusks including some benthos living in lagoon sediments. It requires backwater areas for long term survival, and threats to its existence include winter flooding, water diversions, water quality degradation from human, industrial and agricultural wastes and physical alterations to lagoons and marshes. The species has been extirpated from 56% of the localities it once occupied in southern, central and northern California.

The second species, monarch butterfly *(Danaus plexippus*) is a state species of special concern. The eucalyptus groves in Moran Lake County Park provide overwintering habitat for monarchs, and the Park is one of the larger and more important cluster sites in California. Destruction or alteration of overwintering sites is of concern for continued survival and conservation of the species. The eucalyptus grove surrounding the Lode Street facility has supported the largest cluster population of butterflies in the Park, although other Moran Lake eucalyptus groves support monarchs in early fall months ("autumnal sites"), or support butterflies as temporary refuge sites. Surrounding trees often function to provide a windbreak and create good microclimate conditions for butterfly roosts. Eucalyptus groves at Moran Lake Park have been adversely affected by resident tree-cutting or pruning, poor drainage and overcrowding. Increases in water and soil salinity is also a concern for future health of these trees. A Management Plan for

Monarch Butterfly Habitat at Moran Lake County Park (Janecki et.al. 2002) has been prepared which provides information on monarch life history and recommendations for enhancement of monarch wintering habitat. An effort has been made to make recommendations in this water quality plan consistent with that document.

2.3 Historic and Present Watershed Boundaries

The conversion of lands from open grasslands to urban, commercial, and residential developments has altered drainage patterns within the Moran Lake watershed. Stormwater management and construction projects in the 1980s diverted approximately 180 acres from the Moran Lake watershed to either the Rodeo Gulch drainage system to the west, or Soquel Creek to the east. Figure 2.2 shows the approximate predevelopment boundary of the Moran Lake watershed, extending north of Highway 1, and the approximate boundary of the current watershed.

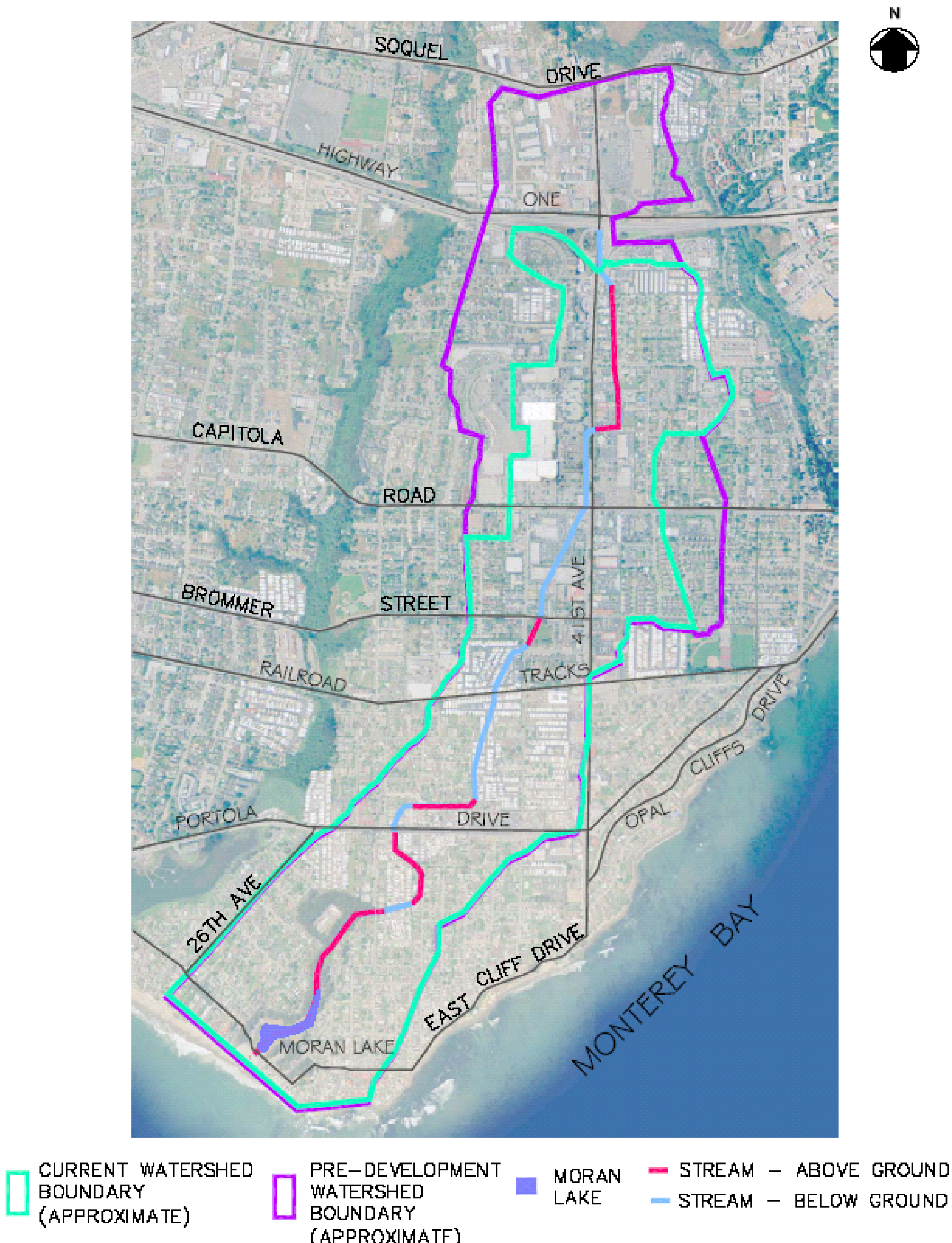
2.4 Jurisdictional Boundaries

The Moran Lake Watershed lies within the County of Santa Cruz and the City of Capitola limits. Moran Lake is within the County of Santa Cruz and the upper portions of the Moran Lake watershed, beginning east of 35th Avenue and north of Portola Drive, are within the City of Capitola boundaries. The majority of the land within the watershed is privately owned, and landowner(s) or owner agents are responsible for maintenance of these lands. Public agencies, in this case within the City of Capitola and the County of Santa Cruz, are responsible for maintaining lands with public easements, public right-of-ways, and/or public lands (including roads). Figure 2.3 shows the current watershed boundary in relation to the City of Capitola jurisdictional boundary.

2.5 Land Use

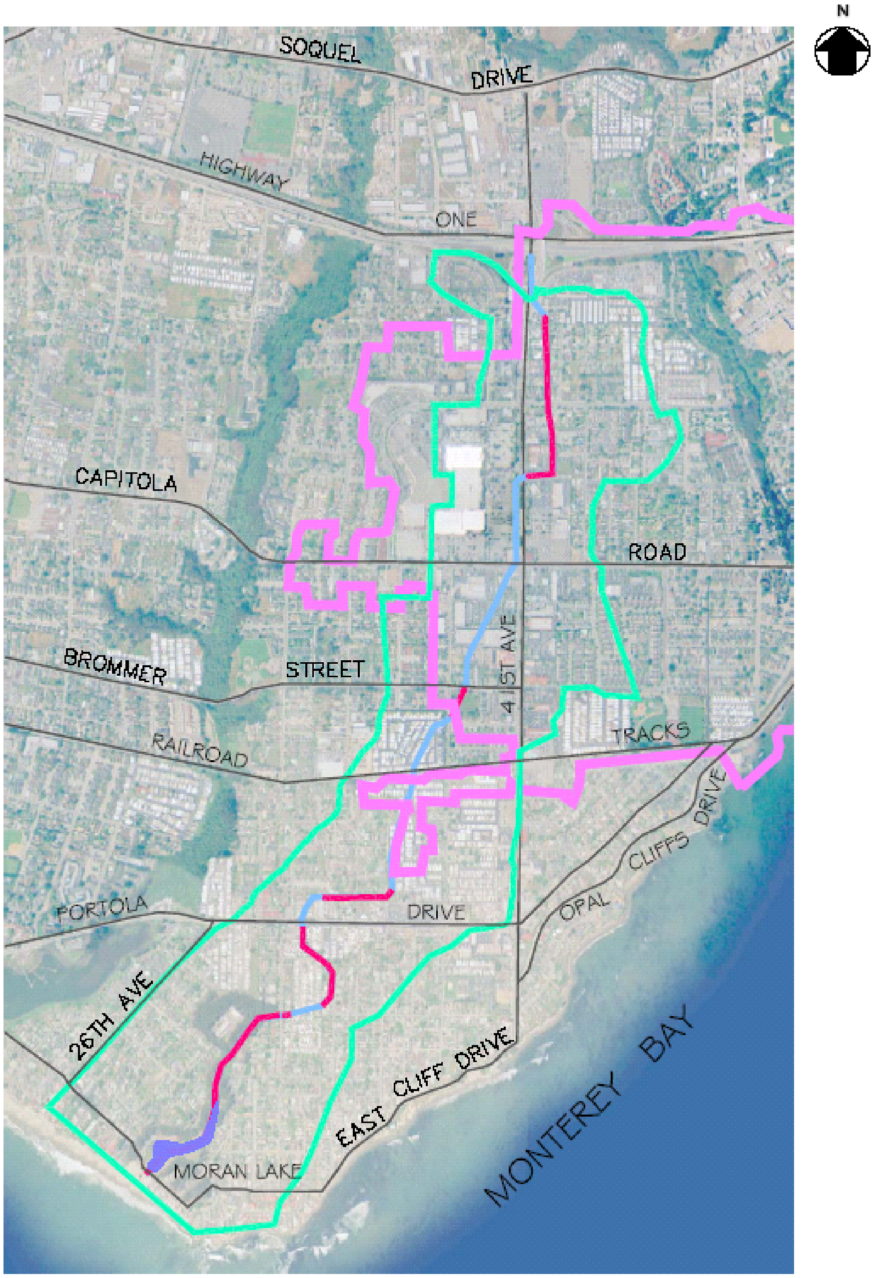
Land use activities in the Moran Lake watershed over the last century have evolved from primarily rural residential and agricultural to almost exclusively commercial, industrial, and urban residential land uses. As part of the land use changes impervious surface area has increased as urban hardscape has been introduced into the watershed to create roads, sidewalks, and parking lots. Aerial photographs taken of Moran Lake and the surrounding areas, beginning in 1931 depict these land use changes.

Figure 2.4 shows Moran Lake and the surrounding areas, including Corcoran Lagoon and Pleasure Point, in 1931. The area around the lake is mostly agricultural fields and rural residential developments. The existing eucalyptus trees have been planted adjacent to Moran Lake and at the current site of the Santa Cruz County Sanitation Lode Street Facility. The purpose of the eucalyptus plantings is unknown, and possible reasons include use for lumber, firewood, medicinal purposes, mosquito abatement, or as a wind break. The riparian corridor and channel of Moran Creek are visible in Figure 2.4 north of Moran Lake on the left side of the photograph.



SCALE: 1" = 1,500'

FIGURE 2.2: PRE AND POST DEVELOPMENT WATERSHED AREAS MORAN LAKE



CURRENT WATERSHED BOUNDARY (APPROXIMATE)

CITY OF CAPITOLA JURISDICTIONAL BOUNDARIES (APPROXIMATE)

MORAN LAKE

STREAM – ABOVE GROUND

STREAM – BELOW GROUND

SCALE: 1" = 1,500'

FIGURE 2.3: MORAN LAKE JURISDICTIONAL BOUNDARIES

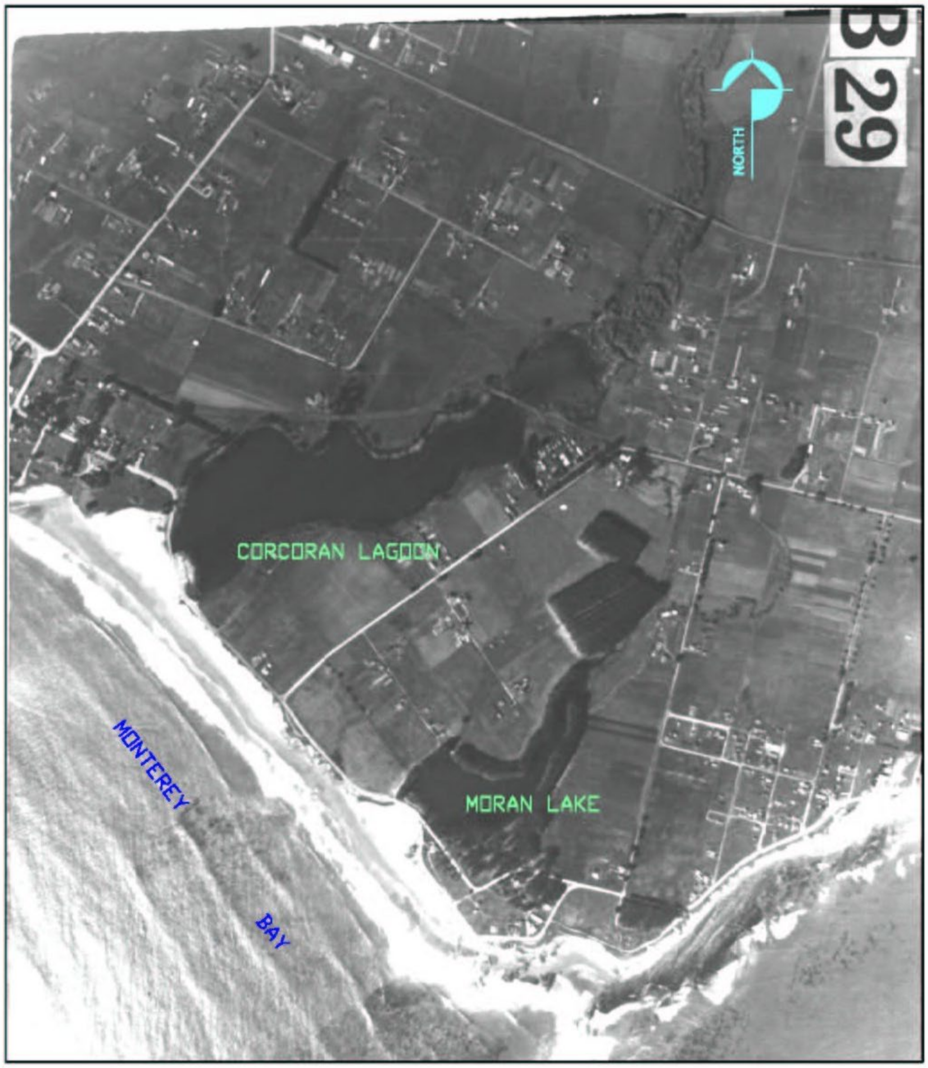


Figure 2.4. Aerial photo of Moran Lake taken April 1,1931

Figure 2.5. Aerial photo of Moran Lake taken August 25, 1953

Figure 2.5 is an aerial photograph taken in 1953 of Moran Lake and the surrounding area. Most of the agricultural lands adjacent to the lagoon have been converted to residential developments since 1931. The site of the current Lode Street Facility has been developed and the riparian corridor and channel of Moran Creek remain visible north of Moran Lake.

Figure 2.6. Aerial photo of Moran Lake taken March 26, 1986

Figure 2.6 shows Moran Lake and the surrounding areas in 1986. The open space and agricultural lands surrounding the lagoon have been almost exclusively converted to residential and urban land uses. The extent of the Moran Creek riparian corridor has diminished, and in some locations it has disappeared where the creek has been placed underground in culverts.

3. LAGOON AND WATERSHED HYDROLOGY

Moran lake is a coastal lagoon. In general terms a coastal lagoon is a body of brackish, marine or hypersaline water impounded by a sandy barrier and having an inlet connecting with the open ocean. Each coastal lagoon differs from all others. These differences fundamentally involve size, shape, tidal range, runoff of tributary streams, climate of the area, number and size of inlets and kind and amount of sediment available. Difference in water movement, chemistry, geology, and ecology result from these basic factors Phleger, 1981).

Using a physiographic classification of estuaries developed by Fairbridge (1980), Moran Lake is best described as a blind estuary with an ephemeral bar that develops in the dry season, creating an inland stagnate pool. Based upon a classification system developed by Kjerfve and Magill (1989), characterizing the type of channel connecting estuaries to the ocean, Moran Lake is a restricted lagoon connected to the ocean by an enclosing barrier. Barrier (bar) built estuaries, such as Moran Lake, occur where barriers enclose coastal embayments, forming extensive, shallow lagoons (Trenhaile, 1997).

Very small or "pocket" lagoons, such as Moran Lake, frequently occur at the seaward end of a stream, which has a small drainage basin and thus limited amount of runoff. Where the rainfall is seasonal, the inlet of such a lagoon is open during the rainy season and is closed by wave action and long-shore drift during the dry season. Under natural conditions these lagoons have significant water exchange with the open ocean by seepage through the porous sandy barrier (Phleger, 1981).

3.1 Historical Drainage and Morphology

Prior to development along the Santa Cruz County Coast, five coastal lagoons existed within the Live Oak area of Santa Cruz: from west to east, Wood's Lagoon, Schwan Lake, Bonita Lagoon, Corcoran Lagoon, and Moran Lake. All of these lagoons have been impacted by urbanization, and only Corcoran Lagoon is considered to be functioning in a relatively 'natural state'. In 1961 Wood's Lagoon was expanded and converted into the Santa Cruz Yacht Harbor, at which time dredge and fill materials from the project were placed in Moran Lake, dramatically altering the lagoon landscape. The following section describes the hydrologic processes occurring within Moran Lagoon, at the inlet and on the beach, prior to 1961 and then following the construction of the Yacht Harbor.

3.1.1 Lagoon Hydrology Prior to Yacht Harbor and Coastal Development

Beach Form and Shoaling. The beach at Moran Lake is one of many 'pocket beaches' along the Santa Cruz coastline. At low tides, prior to extensive development in the Live Oak Area, the development of the Yacht Harbor, and residential developments on East Cliff Drive, it was possible to walk from the Moran Lake beach to Lighthouse Point, on West Cliff Drive, approximately 4 miles north of Moran Lake. Based upon a review of historical aerial photos and observations of naturally functioning lagoon systems in relatively undisturbed drainage systems, the evolution and seasonal fluctuation of the Moran Lake beach in a natural setting can be hypothesized.

Beginning in late winter and early spring of each year, ocean waves would cause sands to shoal up on the beach forming an ephemeral bar blocking the entrance to the lagoon. The size and steepness of the sand berm would increase through the spring and summer until late fall or early winter when high tides and freshwater flows in the lagoon would breach the sand berm. A sinuous channel would form on a rather broad beach, snaking between the cliff boundaries on the east and west side of the beach. This channel would connect the lagoon to the sea until early spring when sands would again accumulate in the channel and the ephemeral bar would rebuild and block the lagoon entrance. Flushing of salt water into the lagoon would occur periodically throughout the year (but more often during winter-early spring), generally during high tides, or spring tides[1], when water would overtop the beach berm.

Inlet Morphology and Hydrodynamics. Prior to 1961, the inlet morphology, or channel geometry of Moran Lake was likely determined by frequency and volume of tidal events. These important tidal events are defined as the tidal prism; a volume of water in a tidal system contained between two defined tidal datums (low and high tides) (PWA, 1995). Similar to bankfull flows in river channels, the tidal prism in estuary and lagoon systems is influential in forming persistent channel characteristics in tidally influenced systems. The tidal prism or volume of water entering and leaving the natural inlet establishes the equilibrium cross sectional area, width, and depth of tidal channels and inlets. The size or cross-section of an inlet is a function of the amount of water, which flows through it due to tidal prisim and amount of streamflow.

The depth of the channel over the entrance bar, which is the shallowest part of the entrance area is a function of tidal range, amount of streamflow and the size and direction of approach of ocean waves which reach the shore. Waves are critical modifying factor in causing the entrance channel to shoal.

Inlets of small “pocket” lagoons tend to open by a process known as thixotropy. As the lagoon is filled with water, the sand of the barrier becomes saturated with water. If there is heavy surf, the pounding of the saturated sand on the barrier by waves causes sand to become fluid and flow seaward at the position of the previous inlet. Then water flow from the lagoon, where the water levels is higher than in the adjacent ocean, takes over and finishes the opening.

Detailed information about Moran Lake and the characteristics of the inlet and tidal prism prior to development in the lagoon is unknown. From aerial photographs of Moran Lake taken in 1931, it appears the channel inlet was approximately 45 feet wide. The inlet bed location was moveable and the depth would vary from year to year. The inlet channel would be scoured or deepened as result of several conditions, including high tidal storm surge or wave action, and/or high flood events. A review of tidal information for

[1] Spring tides occur when the moon, sun, and earth are in line, during the full moon or new moon cycle.

Monterey Bay in Santa Cruz, indicate that tides can vary from -1.98 feet to 6.55 feet relative to mean sea level (msl).

Lagoon Circulation. Prior to 1961 the lagoon surface area was approximately 9 acres and the principal mechanisms of mixing in the lagoon were wave action generated by tides or winds, and friction between the surface water body and the lagoon channel and bed material. As a result of these mechanisms, freshwater moves downward, mixing with saline water, and saline water moves up into the freshwater. The circulation of the lagoon would vary seasonally based upon freshwater inputs, tidal fluctuations, and the development of the ephemeral bar on the lagoon beach.

For a short period of time, usually in late October, early November after the beginning of winter storms and prior to the breach of the ephemeral bar, water in the lagoon was highly stratified. Low density freshwater from stormwater runoff formed a lens over the saltwater accumulated behind the sand berm during the summer months. During this period of time, wind processes likely provided the only mixing mechanism between the two layers.

In December and January, once the ephemeral bar breached and the lagoon received freshwater and tidal inputs, Moran Lake became somewhat less stratified, or partially mixed.

The lagoon became non-stratified or fully mixed when: (i) there was no or little flow from freshwater inputs causing the lagoon to become primarily filled with saline water, (ii) low tides coincided with large stream inputs causing high contributions from freshwater with little or no flow from the ocean, and (iii) prior to large freshwater inputs and breaching of the ephemeral bar, the lagoon probably experienced a prolonged period of stagnation becoming saline, or possibly hyperhaline.[2]

Many of these same processes continue today, albeit on a smaller lagoon.

Lagoon Opening and Closure. Lagoon opening and closure typically occurs on two different time scales. River flooding is the major natural determinant of inlet conditions on time scales longer than a few years. Over short time periods, ranging from a few months to several years, inlet status is primarily determined by the available tidal prism and littoral sand transport. Results of long-term studies of coastal lagoons in southern California show that natural inlets may remain open 34% of the time. The tendency to remain open is vastly smaller during years of dry weather (12%) versus times of above-average rainfall (66%) (Elwany, et. al., 1998).

Historically, the typical inlet opening and closing sequence at Moran Lake, prior to its modifications, began when a major river flood scoured the lagoon and inlet channels.

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[2] Hyperhaline refers to waters with a concentration of salt exceeding the ionic content of seawater with an ocean source.

During severe winter storms flood flows would have most likely scoured the main channel to an elevation well below the equilibrium depth that could be sustained by the maximum available tidal prism. Through the remainder of the year littoral-drift sand, washed into the inlet by tidal processes and wave surges, rapidly filled the entrance and exterior portions of the channel. Then by late fall the inlet would be filled with sand to near the equilibrium depth.

When there were periods of drought or extremely low flows the lagoon would remain closed. Exceptions would occur during unusually high tide events, when large waves temporarily overtop or breach the beach berm.

3.1.2 Watershed Hydrology and Drainage System

Prior to development in the Moran Lake watershed the hydrology and landscape were very different from what they are today. The Moran Lake watershed has a southern orientation, and prior to the installation of drainage infrastructure in the 1980s, which decreased the extent of the Moran Lake watershed by approximately 180 acres, it extended north of Highway 1 between the Rodeo Gulch and Soquel Creek watersheds. Prior to current development the watershed was likely well vegetated, with a high infiltration capacity. The channels were able to migrate and meander within the watershed. The watershed consisted of open grasslands and forested coastal terrace areas with ephemeral tributary streams entering Moran Creek, the principal tributary to Moran Lake.

3.2. Current Drainage and Morphology

Between 1961 and 1963, dredge material removed from Wood's Lagoon for the development of the Santa Cruz Yacht Harbor was deposited in Moran Lake, effectively reducing the surface water area of the lake from approximately nine acres to five acres. At this same time a 7-foot diameter culvert was installed at the lake outlet, approximately five feet above the mean high tide level, blocking the lagoon inlet and transforming the coastal lagoon into an inland lake. In 1981 the 7-foot diameter culvert was replaced with the existing box culvert beneath East Cliff Drive. The bottom (invert) of the box culvert was set at one foot below mean sea level.

Another significant change in the Moran Lake watershed was the transformation from open grassland and forested coastal terrace, to a rural farming community, and then into high density residential and commercial-industrial land uses. The result of these land use changes greatly increased the impervious surface area in the watershed, altering the hydrologic response, timing, volume, and quality of stormwater entering Moran Lake.

3.2.1 Lagoon Hydrology

Beach Form and Shoaling. The current beach form and shoaling processes function similar to historic processes. The Cabrillo College Geology and Oceanography Department has been monitoring the seasonal fluctuation of beach profiles along the

Santa Cruz County coastline, including the beach at Moran Lake for several years. Monitoring data provided by the Department (D. Schwartz, personal communication 2003) showing monthly beach profiles for the 2001 to 2002 season are presented in Figure 3.1. The zero elevation datum on the y-axis represents the elevation of East Cliff Drive, with distance from East Cliff Drive towards the ocean on the x-axis.

Figure 3.1 depicts how the sand on the beach fluctuates seasonally. Beginning in the late winter and early spring sand accumulates on the beach and forms an ephemeral bar across the Moran Lake inlet. The elevation and accumulation of sand on the beach continues through spring until late fall, with saltwater associated with high tides occasionally overtoping the ephemeral bar and entering Moran Lake. Based on discussions with Dave Schwartz, Oceanography Professor at Cabrillo College, in some years the elevation of sand on the beach exceeds the elevation of East Cliff Drive, with the amount and steepness of sand on the beach reaching its peak in the fall months. The graphical data also shows how the first large storm in the late fall or early winter, combined with large wave energy, erodes the ephemeral bar and opens Moran Lake to the ocean. Depending on storm and tide patterns, sand elevations fluctuate throughout the winter. During this time the lagoon bar remains open to the ocean, until early spring when the ephemeral bar closes.

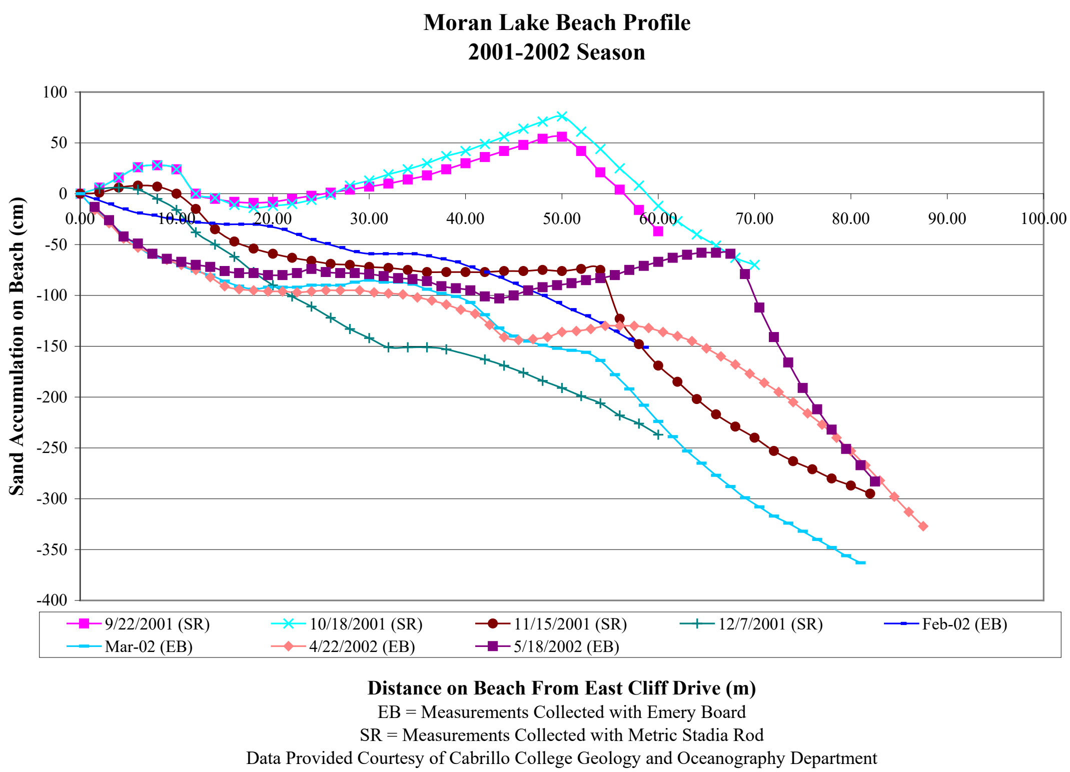

Figure 3.1. Moran Lake Beach Profile, 2001-2002 Season

While the connection remains open, storm surges and waves entering the lagoon carry sediment, primarily sands, that are deposited within the lagoon. At the time of this investigation, deposited material entering the lagoon formed shallow sand bars to the north of the box culvert, though it is anticipated the location and volume of these deposits varies seasonally and annually. The accretion of these sediments within the culvert and on the beach over numerous tidal cycles, eventually rebuilds the beach barrier blocking the connection between the lagoon and the ocean.

From aerial photographs it appears the width of Moran Lake Beach has diminished since the 1900s, possibly due to a combination of influences including the construction of the Harbor jetty and residential development adjacent to the beach.

When the Harbor jetty was built in 1961 it disrupted long shore sediment transport north and south of Wood's Lagoon. Sand accumulation on beaches north of the jetty increased while sand accumulation decreased on southern beaches, such as Moran Lake Beach. Recent changes in timing of harbor dredging and spoils deposition location south of the harbor may increase the amount of sand at Moran Lake Beach. However, more study is necessary to assess the relationship between the management of dredge material from the harbor and changes to the coastline south of the Harbor.

Residential developments and seacliff riprap placed to the north and south of Moran Lake Beach may also have limited sand production and accumulation. Though the Moran Lake Beach was historically small, these developments and the diminished beach size have restricted the development of the lagoon channel on the beach side of East Cliff Drive. Without these changes, a beach side lagoon similar to those existing at Corcoran or Schwan Lake would be expected at Moran Lake.

Lagoon Boundary and Tidal Inlet Structure. Development and infrastructure, such as the construction of East Cliff Drive has confined the lagoon to a relatively fixed configuration. The roadbed and adjoining upland areas are physical barriers to geomorphic changes in the shape and surface area of the lagoon.

The existing box culvert under East Cliff Drive seasonally connects Moran Lake with the Pacific Ocean. The box culvert is 71.6 feet long with 21-foot long wing walls extending into the lagoon. On the ocean side, the culvert extends 12 feet onto the beach and wing walls extend approximately 15 feet on either side of the culvert walls. The depth and width of the box culvert under East Cliff Drive is approximately 12 feet. The box culvert has a fixed bed at an approximate elevation of 1 foot below mean sea level. The box culvert is a grade control structure and limits the depth of the inlet channel to the invert elevation of the culvert.

Lagoon Morphology and Circulation. Water and salinity levels in Moran Lake vary seasonally based on a cycle of inlet blocking, tidal flushing, and freshwater inflow. Circulation and salt/freshwater mixing patterns depend upon seasonal fluctuations of the beach and tidal inlet, stream flow and climatic conditions. Over the course of this study, four mixing patterns were observed within the lagoon: highly stratified non-mixed, partially mixed, non-stratified freshwater, and non-stratified saltwater.

Highly Stratified Conditions. A highly stratified non-mixed regime was observed within Moran Lake during the first flush event of the season. At the time of the event on October 31, 2003, the ephemeral bar at the lagoon inlet had not been breached and limited interaction between the lagoon and ocean was possible. Rainfall-runoff entering the lagoon created a lens of freshwater above higher density saltwater that had accumulated during the summer months. The density difference between the fresh and saltwater and the lack of physical mixing by tides or winds prevented significant mixing between the two layers. Water quality measurements of salinity and conductivity, indicators of salt or freshwater content, clearly show the stratification of the salt and freshwater. Figure 3.2 shows the lagoon under highly stratified conditions with the transition between saltwater at the lagoon bottom and freshwater at the top. At the lagoon bottom from zero to six inches the water has a salinity of 29.6 parts per thousand (ppt) and a conductivity of 35.6 microSemens (mS). At the water surface the fresh stormwater has a salinity of 0.7 ppt and a conductivity of 0.96 mS.

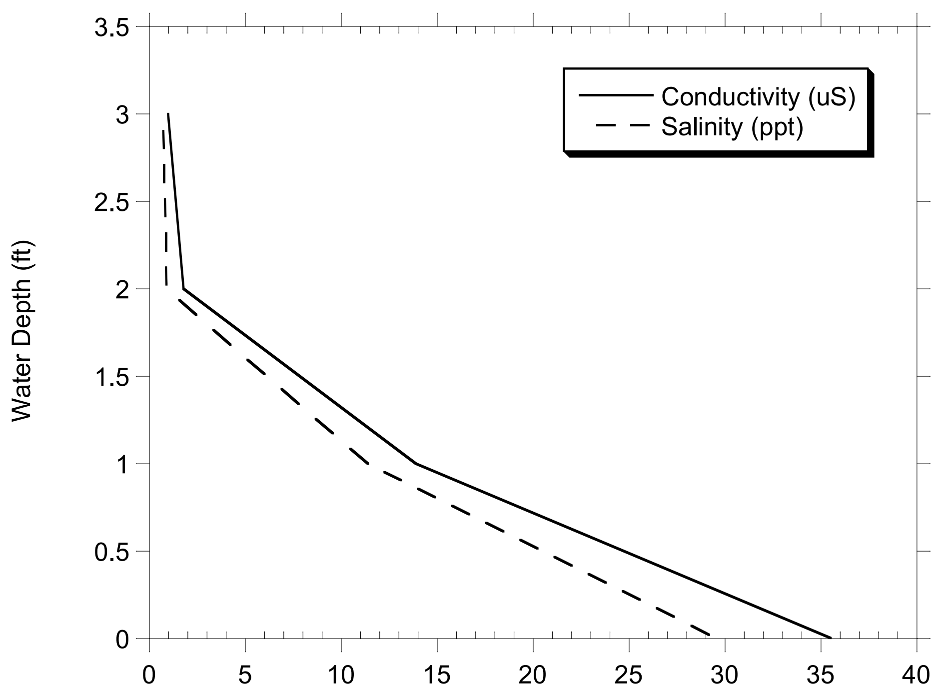

Figure 3.2. Summary of Conductivity and Salinity Measurements Collected During the First Flush Event on October 31, 2003 from Site 2

Partially Mixed Condition. A moderately stratified mixing regime was observed when the ephemeral bar breached, and the beach profile was not low enough to allow a continuous connection between the lagoon and ocean. Figures 3.3 and 3.4 show the lake and the channel on the beach when ocean and stormwater can enter the lagoon.

Figure 3.3. Moran Lake After Ephemeral Bar has Breached and Lagoon is Partially Mixed – ***November 12, 2003***

Figure 3.4. Moran Lake Beach After Ephemeral Bar has Breached and Lagoon is Partially Mixed – ***November 12, 2003***

Non-Stratified Freshwater Condition. The lagoon is non-stratified and primarily filled with freshwater when the sand bar elevation has dropped below the bottom or bed elevation (invert) of the box culvert. When the sand bar drops below the invert of the culvert stream flow does not backup and pond but flows through. In this condition the lagoon is functioning as a stream channel. When the water levels were low in the lagoon, it revealed fine-grained silt and clay sediments on the bottom of lagoon basin. Figures 3.5 and 3.6 shows Moran Lake and the channel on the beach during a low tide when the water in the lagoon is freshwater.

Figure 3.5. Lagoon Outflow Non-Stratified with Primarily Freshwater Flow – *February 2, 2004*

Figure 3.6. Moran Lake when the Lagoon is Non-Stratified with Primarily Freshwater Flow – *February 2, 2004*

Non-Stratified Saltwater Condition. The lagoon is non-stratified and primarily saltwater when the ephemeral bar reforms across the lagoon inlet and the stream flows are low occurring typically in later spring. The bar closure limits the interaction between the lagoon and the ocean. During this period, extensive algal blooms were observed on the surface of the lagoon, as shown in Figure 3.7. Figures 3.8 and 3.9 show Moran Lake when the ephemeral bar has formed across the inlet and sand has accumulated inside the box culvert.

Figure 3.7. Algal Blooms on the Surface of Moran Lake when the Lagoon is Non-Stratified with Little or No Flow from Freshwater or Tidal Inputs – ***October 28, 2003***

Figure 3.8. Moran Lake when the Lagoon is Non-Stratified with Little or No Flow from Freshwater or Tidal Inputs and the Lagoon is Primarily Filled with Saline Water– ***October 28, 2003***

Figure 3.9. Moran Lake Box Culvert Closed with Sand– ***October 28, 2003***

3.2.2 Watershed Modifications and Hydrology

Moran Creek and Drainage Modifications

The primary stream or drainage channel in the watershed is Moran Creek. Moran Creek is an intermittent stream, approximately 12,295 feet long, with an approximate slope of 0.6%. Approximately 6,395 feet of the channel is above ground, but is characterized by reduced riparian corridor width and discontinuous, mixed vegetation with a large non-native component. Approximately 5,900 lineal feet of channel has been collected below ground in culverts installed beneath roads and residential and commercial properties. Today most of the stream channel and riparian corridor has been encroached upon by urban development and the channel is confined to a very narrow channel. Only a few reaches of the stream remain in a relatively natural condition.

Figure 3.10. Moran Creek—Open Channel with Urban Encroachment

According to the County of Santa Cruz Storm Water Master Plan and Management Program, the Moran Lake watershed is approximately 546 acres in area (KVL, 1998). Urbanization in the watershed has included the installation of a complex drainage network that drains many of the developed lands to Moran Lake. With the shift from rural agricultural land use, runoff rates and volumes to the existing drainage systems have increased. To compensate for these changes the county and state have modified and reduced the drainage area of the watershed. With the construction of Highway One and development projects in the upper watershed areas, a substantial portion of the drainage area has been redirected to Rodeo Gulch and Soquel Creek.

Even with the reduction of the watershed drainage basin, continued urbanization has resulted in localized flooding in some portions of the watershed. To mitigate flood problems in the lower watershed, the County constructed the 38th Avenue Stormwater Detention Basin (Basin), as shown in Figure 3.11. The Basin is located on the southeast corner of the intersection of Brommer Street and 38th Avenue, and receives runoff from approximately 235 acres in the upper Moran Lake watershed. The Basin is designed to temporarily store runoff resulting from events that exceed the 150 cubic feet per second (cfs) capacity of the downstream culvert.

Figure 3.11. 38th Avenue Stormwater Basin

Based on discussions with local residents some reaches of the stream continue to experience localized flooding. These events are primarily attributed to older infrastructure projects, such as undersized culverts that have not been replaced to accommodate increased runoff rates. Ongoing development in the watershed continues to contribute to these problems.

Effects of Urbanization on Watershed Hydrology.

Land use within the Moran Lake watershed includes single family residences, shopping centers and commercial development, grassland, and mobile home parks. It is estimated that approximately 95% of the watershed has been urbanized with a substantial amount of impervious surface coverage. The increased impervious surface has dramatically altered the natural runoff patterns (hydrograph) and groundwater recharge in the watershed. Impervious surfaces, such as roads and parking lots, do not allow rainfall to infiltrate into soil, and shed it to drainage courses in a shorter period of time and at a higher volume than compared to a natural or landscaped area. As groundwater infiltration is reduced, flooding potential increases. Figure 3.12 shows changes that occur as a result of urbanization. As can be seen in the graphs the hydrograph for the urbanized area is much steeper and occurs over a shorter period of time indicating that the lag time between precipitation events and peak stream flows occurring in a stream has been shortened and the peak runoff flow and volume have increased.

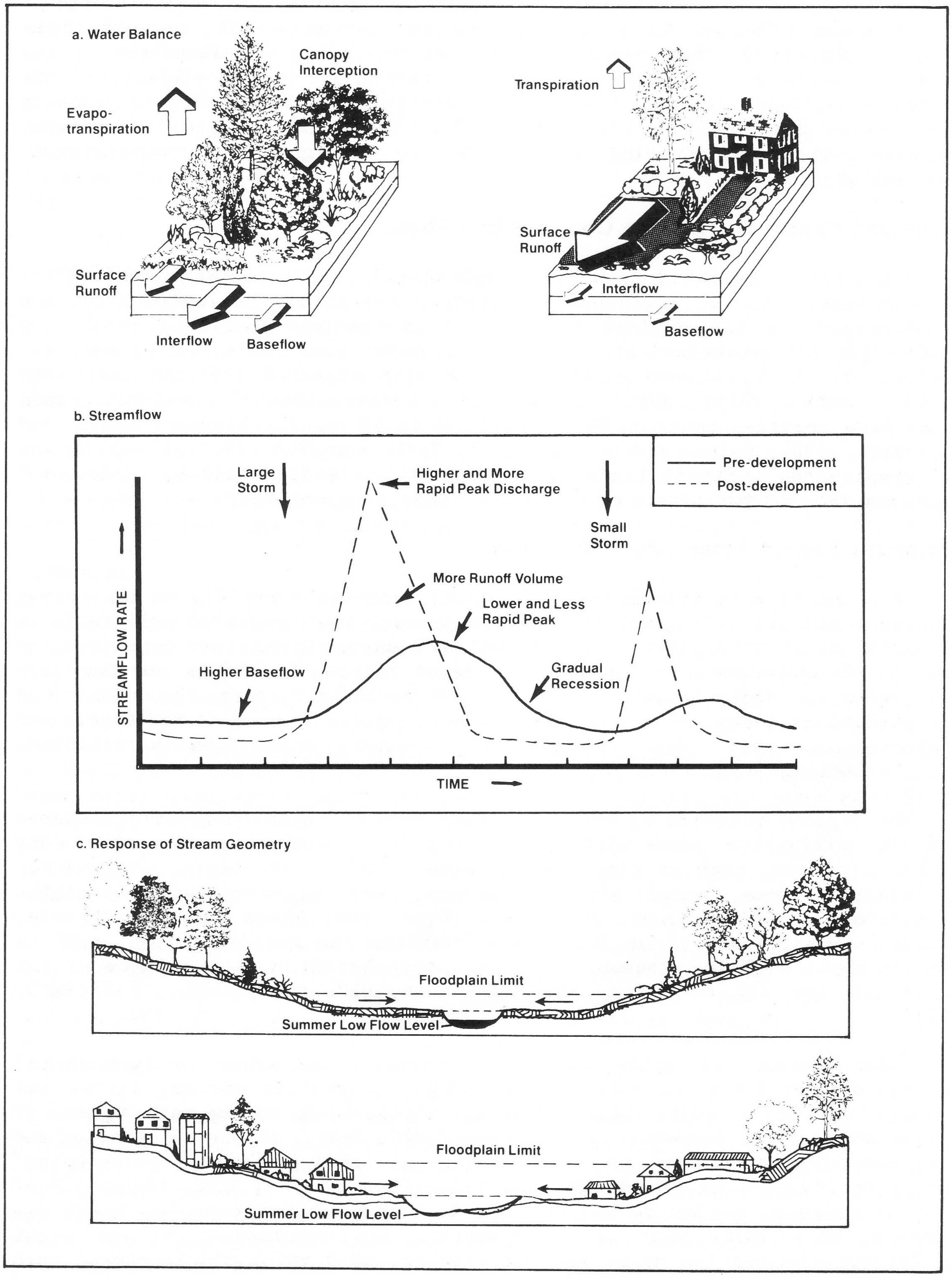

Figure 3.12. Typical Changes in Watershed Hydrology as a Result of Urbanization (Schueler, 1987)

Urban development reduces or eliminates natural rainfall storage within a watershed area. Natural storage areas include trees that intercept rainfall, depressions on the ground surface, and porous surface soils. When these areas are removed due to development activities, the rainfall storage capacity is reduced and rainfall is more quickly converted to runoff. Runoff rates are further accelerated when construction includes impervious surfaces such as rooftops, roads, parking lots, sidewalks, and driveways. Alterations to natural rainfall runoff patterns also change stream hydrology. Impacts to stream hydrology associated with urban streams, such as Moran Creek, can be summarized as follows:

Increased Flooding. The first change in stream hydrology in urban streams is an increased magnitude and frequency of severe floods. It has been estimated that peak discharges in urban watersheds increase two to five times from pre-development levels. The higher magnitude flows occur because natural storage and infiltration areas are reduced or eliminated, increasing the volume of water entering an urban stream channel. The frequency of severe flooding increases because flow magnitudes are higher in urban streams. For example, a flow that would be expected to occur once every two years in an undeveloped watershed can occur as often as three or four times a year in an urban stream.

Increased Bank Erosion and Sedimentation. The second change in stream hydrology is an increased frequency of erosive bankfull and sub-bankfull floods. A bankfull flow occurs once every 2 to 2.5 years and has the greatest influence on channel forming features, such as bank height and location and mid-channel bars. The frequency of a bankfull or sub-bank full flow increases in an urban watershed, causing high energy flows that disrupt the channel equilibrium, accelerating bank and channel erosion and sedimentation in the downstream stream and lagoon. Increased bank erosion can also result in costly damage and/or loss of private and public property and infrastructure. Figure 3.13 shows active bank erosion occurring in the upper stream reach of Moran Lake.

Figure 3.13. Channel Erosion in Upper Reach of Moran Lake

Groundwater Recharge. The third change in stream hydrology is reduced groundwater recharge. Surfaces such as sidewalks, roads, rooftops, and driveways cover areas that once would have absorbed or infiltrated rainfall. The decreased infiltration capacity in urban watersheds decreases the extent of groundwater recharge, and will therefore reduce stream baseflow during dry weather. It is likely that prior to urbanization in the watershed, stream flow in Moran Creek was higher throughout the year (except immediately following storm events).

Loss of Habitat. Urbanization and channelization has substantially reduced the extent of natural habitat along Moran Creek. The loss of natural habitat impacts wildlife and limits future restoration and recreational opportunities in the watershed.

Loss of Flood Plain. Development and covering of the creek has resulted in the loss of the natural floodplain of Moran Creek. In a natural setting a stream is bordered by a floodplain that is periodically inundated when stream flows overtop channel banks. Reducing the width of the stream and confining it to a narrow band prevents the stream from accessing the floodplain, increasing the frequency of flooding and forcing high energy flows to remain in a narrow channel that accelerates channel downcutting and bank erosion.

3.3 Summary and Conclusions

1. The size of the lagoon has been significantly reduced and confined to a small area as a result of dredge material disposal, development and infrastructure projects surrounding the lagoon. These modifications have restricted the natural geomorphic changes that would naturally occur in a coastal lagoon in response to episodic storm events, and have limited the expansion of the lagoon onto the beach west of East Cliff Drive.

2. Preliminary review and analyses indicate that the existing box culvert under East Cliff Drive may be slightly undersized to handle the full tidal prism entering and exiting the lagoon; however, beach profile monitoring at the mouth of the lagoon suggest that the box culvert is not a substantial barrier to flushing. Substituting a bridge or adding a new culvert may not produce significant changes to winter or summer lagoon conditions. This is due to the relatively small lagoon size, rapid formation of the sand bar, and altered runoff volumes from the watershed. Lowering the culvert depth to –2 to -3 feet below MSL may also allow greater water exchange, particularly at low tides, but could cause additional bank erosion and damage to public or private property. If either change is considered, possible effects of increased salinity on lagoon aquatic and upland wildlife habitats must also be reviewed. A more extensive hydraulic modeling study would be required to determine if replacing the culvert with a clear span bridge or arched culvert would substantially improve water circulation and water quality in the lagoon.

3. Urban land use within the Moran Lake watershed has altered the surface water hydrology of Moran Creek. The increased impervious surface has dramatically altered the natural runoff patterns (hydrograph) and groundwater infiltration in the watershed.

4. The change in stream hydrology has increased the frequency of erosive bankfull and sub-bankfull floods, and has accelerated bank and channel erosion and sedimentation in the stream and lagoon. These changes can result in costly damage and/or loss of private and public property and infrastructure.

5. Development in close proximity to the creek, and undergrounding the creek has resulted in the loss of the natural floodplain of Moran Creek. Reducing the width of the stream and confining it to a narrow band prevents the stream flow from accessing the floodplain, increasing the frequency of flooding and forcing high energy flows to remain in a narrow channel that also accelerates channel downcutting and bank erosion. Urbanization and channelization has also substantially reduced the extent of natural habitat along Moran Creek. The loss of natural habitat impacts wildlife and limits future restoration and recreational opportunities in the watershed.

6. In some reaches below the 38^{th} Avenue detention basin some existing culverts on Moran Creek are undersized resulting in localized flooding during peak storm events. More detailed hydraulic analyses would be required to assess the extent of flooding and to determine an appropriate solution to improve conditions along the stream.

4. WATER QUALITY

4.1. Overview

Eutrophic and hyperhaline conditions in Moran Lake have been well documented since the mid 1970's. Several factors are contributing to this, including poor circulation and flushing during the summer months and nutrient rich runoff entering the lagoon from urbanized lands.

Historical and recent testing continue to detect high concentrations of fecal coliform bacteria indicating the lagoon is receiving contaminated runoff from the surrounding urbanized areas. Although historic testing may have indicated sewage overflows from the treatment plant that once existed at Lode Street, it is likely that present coliform contamination comes from multiple sources, including domestic animals, leaking sewers, and wildlife (most notably water fowl) residing in the lagoon or riparian corridor.

A reduction in lagoon surface area and volume has diminished the ability of Moran Lake to dilute and assimilate contaminants.

Eutrophic or highly enriched watercourses, such as Moran Lake show highly varying levels of dissolved oxygen (DO). During early morning periods DO is suppressed with low concentrations, while in the late afternoon DO may be very high due to algae and other aquatic vegetation releasing oxygen into the water column. Urban pollution and storm water runoff act to decrease dissolved oxygen concentrations in lake water. Polluted runoff containing degradable organic matter introduced to a water body such as Moran Lake, exert an oxygen demand during the assimilation and decomposition of these waste products. This oxygen demand can deplete DO concentrations, creating unsuitable conditions for aquatic organisms.

General mineral analyses conducted in June, July and October 2004 clearly indicate that during the summer months the lagoon is filled primarily with salt water and the major ions in solution include chloride and sodium. During the first flush event, the water condition in the lagoon shifted rapidly to freshwater.

The concentration of trace metals varied significantly both spatially and seasonally. During the summer months the trace metals concentration was very low. However, the highest concentrations during this period were routinely detected in the samples collected from Moran Creek which receives dry weather runoff from urbanized areas. Dry weather runoff includes runoff from streets and driveways, construction- related washing activities, car washing, and over spray from landscape irrigation systems. A sample collected in late October during the first significant rainfall event ("first flush" event) contained significantly higher concentrations of these metals, which could adversely affect aquatic organisms. Comparing the test results to the different water quality criteria indicate that during the first flush event, the three metals tested were measured at concentrations that exceed several water quality criteria. The test results indicate that runoff from urbanized areas in the watershed discharge significant and potentially toxic levels of copper and zinc to Moran Lake.

Sediment samples detected the presence of several polyaromatic hydrocarbons (PAHs), commonly known as oils and grease. Principal sources of PAHsare roads, parking lots and vehicle service areas. Several of the PAH compounds detected are carcinogenic compounds and other compounds are potentially toxic to aquatic life. Comparing the PAH concentrations with different sediment quality benchmarks indicate that the phenanthrene, chrysene, benzo(a)anthracene and benzo(a)pyrene exceed criteria established by the British Columbia Ministry of Water, Land and Air Protection for protection of freshwater organisms. The total concentrations of PAHs is elevated, but are below the low and median effects levels established by the National Oceanic and Atmospheric Agency (NOAA). Based on the more conservative and contaminant specific criteria established by British Columbia, the levels of PAHs detected in the sediment may be impairing benthic and other aquatic life in the lagoon. Sediment test results detected total chlordane levels well above the probable and threshold effects levels established by several agencies. The results indicate that the residual and persistent chlordane levels in lagoon sediments may adversely affect aquatic life in the lagoon.

The following chapter provides a review of historical and recent water quality studies of Moran Lake, and the results of water quality and sediment testing undertaken as part of this study.

4.2. Review of Historical Water Quality Studies and Monitoring Activities

Staff Report on Moran Lake, 1976 (prepared by S. Singer and R. Aston)

Santa Cruz County Watershed Management staff conducted a water and sediment quality assessment of Moran Lake in 1976. The assessment provided a description of the watershed and the lagoon. The study also included a summary of summer field observations conducted on three separate occasions through the summer months. Two rounds of water quality and one round of sediment testing were performed as part of the study. Urban runoff loading calculations were also completed to estimate the amount of pollutants that could potentially enter the lagoon. The study concluded that there were two major water quality issues: (1) poor circulation and flushing during the summer months leading to euthrophic and hyperhaline conditions, and (2) urban development in the Moran Lake watershed that changed the amount, timing, and quality of surface runoff entering the lagoon. The report noted relatively high levels of nutrients, fecal coliform, oil and grease and heavy metals in the lagoon. Several alternative "corrective measures" are presented, including installing and maintaining a channel to "improve tidal flushing" and replacing the previous culvert with a bridge (The culvert was replaced with the present box culvert in 1981). The study also recommended ongoing summer maintenance to maintain the outlet channel open throughout the summer; installation of a tidal gate to prevent tidal flushing into the lagoon to maintain lower salinity levels in the lagoon; reshaping the lake by removing some of the fill material to try and improve mixing and flushing action; initiating public education efforts to reduce pollutant levels in runoff entering the lagoon; and finally, installing a treatment system for urban stormwater runoff.

Environmental Baseline Study for the Moran Lake Enhancement Plan, 1980 (prepared by G. Stern and P. Courter)

During the spring of 1980, the first phase of the Moran Lake Enhancement Plan was undertaken and summarized in this report. The study was sponsored by the California Coastal Conservancy, and was conducted to evaluate biological abundance and diversity in relation to sediment and water quality. Water quality testing was performed from November 1979 to February 1980 in several coastal lagoons, including Moran Lake, Corcoran and Schwan Lagoons. Water quality results showed an increase in nutrients attributed to storm water runoff in Moran Lake. The results of the study also indicated that the lake or lagoon had a "diminished capacity for handling nutrient loads". Fecal coliform levels in Moran Lake were higher than in neighboring Corcoran, which was attributed to the "restricted exchange between the lagoon and ocean". The high fecal coliform counts and nutrients were interpreted as signs of eutrophication. The results of the sediment sampling showed decreased levels of lead, chromium, and cadmium in Moran Lake as compared with the 1976 County study. A decrease in lead concentration was attributed to the use of unleaded gasoline, or removal of debris from the lake by community groups, which may have also removed other possible sources of metal contamination.

Santa Cruz County Environmental Health Monitoring Activities

The Santa Cruz County Environmental Health Agency has conducted periodic water quality testing at several locations in the Moran Lake watershed, including up and down stream of East Cliff Drive, at 30th Avenue, the 38th Avenue Stormwater Detention Basin, and at the intersection of 38th Avenue and Brommer Street. From 1976 through 1980 the County performed several tests at the 38th Avenue detention basin primarily for total suspended solids, turbidity and fecal coliform bacteria. The results routinely detected elevated levels of fecal coliform in Moran Creek. From 1979 through 1992 the County conducted field measures in the Lagoon for temperature, pH, conductivity and dissolved oxygen. During this period water samples were also collected from the lagoon and analyzed for general minerals, fecal coliform bacteria and trace metals. Field measurements and general mineral concentrations are very similar to results obtained during this study effort and indicate that the lagoon water quality is quite variable seasonally but relatively constant from year to year. Limited tests for metals detected elevated levels of chromium and lead in the early 1980's.

2003 Technical Summary: Comparative Lagoon Ecological Assessment Project (prepared by Swanson Hydrology and Geomorphology)

The Comparative Lagoon Ecological Assessment project is a phased 3-year project (2003-2006) funded by the California Coastal Conservancy and administered by the Santa Cruz County Resource Conservation District. A key goal of the study includes documenting the existing water quality, physical and ecological conditions of Santa Cruz County lagoons. In 2003, data collections efforts were undertaken to compare an array of physical, chemical and vegetation data from 11 lagoons on the Central Coast, including Moran Lake. The comparative information was used to generally assess the physical alterations and current land use pressures associated with the quality of each lagoon system, and evaluate the relative nutrient loading and summer function of each lagoon. The results indicated that Moran Lake had very high concentrations of phytoplankton when the lagoon was closed, with a low diversity of plankton consisting of 85% Pyrrhophytes, 13% Chrysophytes and 2% Cryptomonads. The predominant aquatic plant community is composed of submerged aquatic vegetation. A preliminary habitat conditions' ranking indicated that Moran is impaired as a result of reduction in surface area, reduction in summer inflows, urbanization in the watershed, substrate complexity, and excessive algae. Due to funding limitations, Moran Lake was not one of the five lagoons selected for further study under this project.

4.3. Water Quality Monitoring

Baseline water quality monitoring was undertaken as part of this study effort. Over a five-month period from June 2003 through October 2003, field measurements were taken at several locations in and upstream of the lagoon. In late October 2003 additional water samples were gathered after a significant rainfall event for general minerals, bacteria, nutrients, and trace metal concentrations. In November sediment samples were collected at several of the water sampling sites and analyzed by Toxscan and Soil Control Laboratories in Watsonville, California (both state certified laboratories). Water samples were analyzed by the Santa Cruz County Environmental Health Agency's Water Quality Laboratory for general minerals, bacteria, nutrients, and trace metal concentrations. Sediment samples were analyzed for trace metals, persistent pesticides, hydrocarbons and nutrients.

The objectives of the water quality monitoring included:

1. Establishing current baseline water quality conditions in the lagoon that can be compared to historical data and to other environmental criteria data to assess the general health of the lagoon;

2. To ascertain how and why water quality changes, both spatially and temporally in the lagoon; and

3. To guide future monitoring efforts.

The following sections provide a description of the program methods and a summary of the results and field observations.

4.3.1. Methodology

Monitoring and Sampling Locations. The consulting team in consultation with the Santa Cruz County Environmental Health Laboratory, selected four locations for regular water quality and sediment sampling. Three locations are within the lagoon and one is upstream of the lagoon in Moran Creek, as shown in Figure 4.1. The sampling locations are described as follows:

Site 1. Site 1 is located immediately upstream of the box culvert at the lagoon inlet.

Site 2. Site 2 is located ten feet from the west shore of the lagoon, approximately 420 feet north of the box culvert.

Site 3. Site 3 is located two feet from a storm drain outfall entering the lagoon from Lakeview Drive

Site 4. Site 4 is located on Moran Creek east of 30th Avenue, approximately three feet downstream of a culvert which is located between 30th and 34th Avenues, as shown in Figure 4.2.

Figure 4.2. Sampling Location #4, Moran Creek East of 30th Avenue

Water Quality Field and Laboratory Tests. Water quality measurements were taken in the field on ten separate events. On five occasions, water samples were also collected for analysis at the Santa Cruz County Environmental Health Lab. Field measurements were collected at one-foot increments throughout the depth of the water column at each

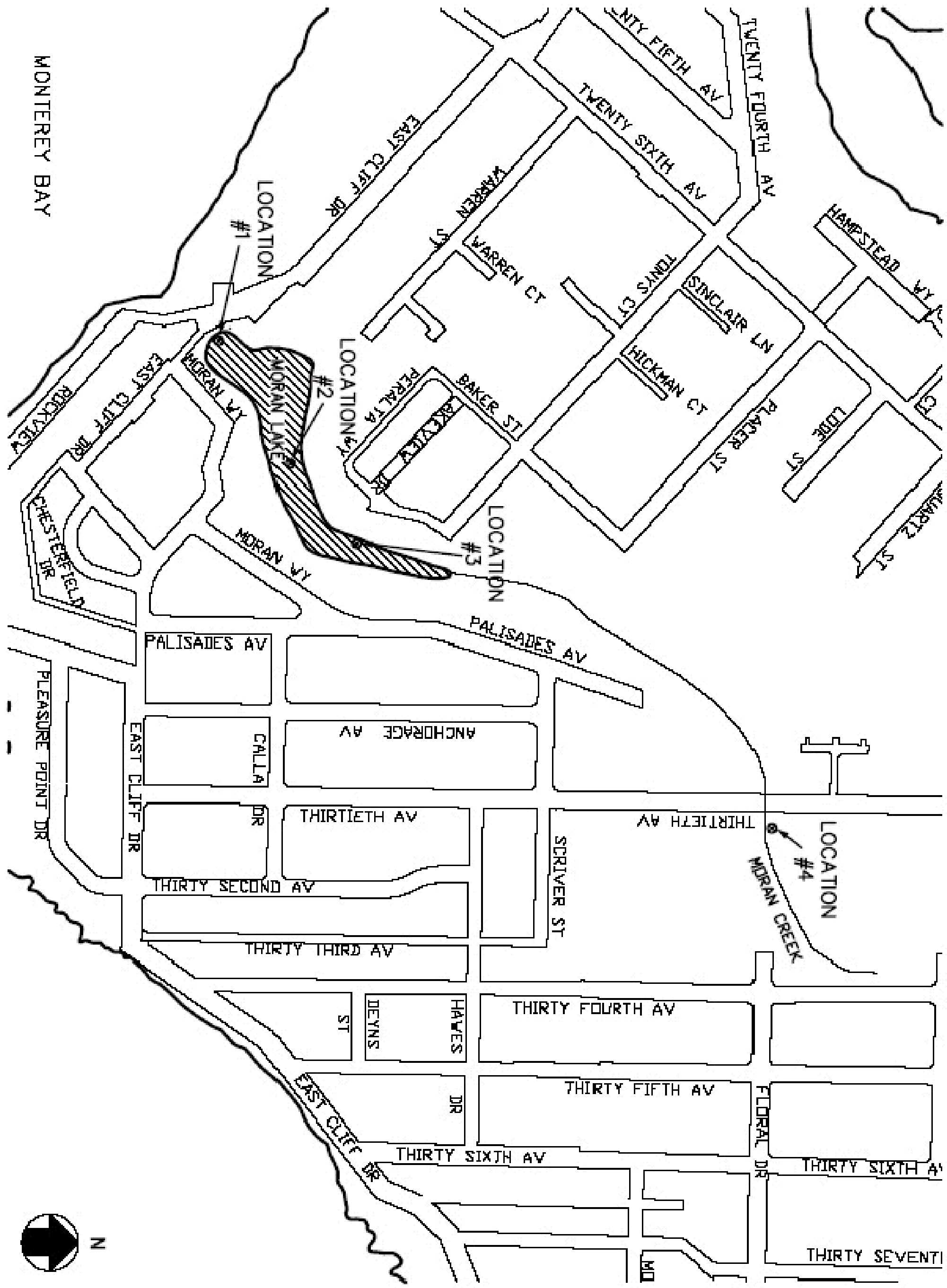

FIGURE 4.1: MORAN LAKE SAMPLING LOCATIONS

sampling location. Field measures were conducting using a multi-parameter meter and a portable turbidimeter for the following parameters:

- Water Temperature (ºC)
- Dissolved Oxygen
- pH
- Conductivity
- Salinity
- Turbidity (NTUs).

Five samples collected for laboratory analysis were analyzed for the following parameters:

Total and Fecal Coliform	Total Suspended Solids
Alkalinity	Chloride
Nitrate-Nitrogen	Ammonia-Nitrogen
Organic-Nitrogen	Total Phosphorus
Total Sulfate	Sodium
Potassium	Magnesium
Calcium	Lead
Copper	Zinc

Grab samples were collected from the lagoon. Careful attention was taken to insure that the samples were not contaminated during sampling process. Samples that contained preservative were filled to just below the bottle lip to ensure no preservative was washed out. Samples were stored on ice (4 ºC) during transportation to the laboratory.

On July 8, 2003, samples were collected in the morning and late afternoon to assess and measure diurnal variations in water quality, primarily fluctuations in dissolved oxygen. Water quality samples were also collected during the first flush event of the 2003-2004 water year, on October 31, 2003. The first flush event was defined as the first storm event of the season large enough to generate sheet flow across impervious surfaces in the watershed.

Sediment Quality Sampling. On November 25, 2003, sediment samples were collected at three locations within Moran Lake. Surface sediment samples were collected with bucket samplers at Sites 1, 2, and 3. At Sites 2 and 3, three soil samples were collected, at the right and left channel banks and one in the center of the channel. The three samples were composited prior to analysis. One additional sample was collected at Site 2 at a depth of six to eight inches below the surface. The samples were analyzed for the following parameters:

- Trace Metals
- Polynuclear Aromatic Hydrocarbons (PAHs)
- Organochlorine Pesticides
- Polychlorinated Biphenyls (PCBs)

- Nutrients (nitrogen and phosphorus species)
- General Minerals
- Iron and Manganese
- Oil and Grease
- pH and Conductivity

<u>4.3.2. Results and Field Observations</u>

This section provides a summary of the field and laboratory results. For the majority of parameters the results are presented graphically to illustrate the conditions measured either temporally (over time) or spatially (over the an area or depth in the lagoon). In some instances the results are compared to water quality standards or objectives that have been established to assess the potential impacts to water quality.

<u>pH</u>

Specifically, pH is a measure of the activity of hydrogen ions in water, and is defined as the logarithm of the reciprocal of the concentration of free hydrogen ions in a water sample. The pH scale ranges from 1 to 14, where neutral water will have a pH around 7 and a low pH water typically will have a pH of 4.5. The pH of natural waters is generally in the range of 6 and 9. However, in nutrient rich (or euthrophic) ponds or lakes, such as Moran Lake, pH can vary significantly throughout a day to due to photosynthesis and respiration. During the day aquatic vegetation, including algae and aquatic grasses uptake oxygen and release carbon dioxide, which reacts with hydrogen and results in an increase to pH, while during the evening and early morning aquatic plants respire and decompose consuming carbon dioxide and release hydrogen ions back into the water causing the pH to lower. This process is referred to as a diel fluctuation.

pH measurements were taken at the four sampling sites, at a depth of six inches below the water surface on nine events. The field measurements are presented in Table 4.1. pH values were generally within the range of natural waters, ranging from 6.6 to 9.3. The pH values varied spatially across the lagoon and temporally through the sampling period, as shown in Figure 4.3. In general the pH of the lagoon tended to increase as the lake became more eutrophic and saline. When the lagoon sand bar breached and the lagoon was primarily freshwater the pH dropped dramatically.

Table 4.1. pH Field Measurements

Date	Monitoring Location			
	Site 1	Site 2	Site 3	Site 4
06/05/03	6.0	6.0	6.1	5.2
06/26/03	7.3	7.3	7.2	8.0
07/08/03 (am)	7.7	7.3	6.9	7.7
07/08/03 (pm)	7.7	7.8	7.3	8.0
07/25/03	8.6	7.6	7.5	7.8
08/12/03	9.3	8.4	7.8	7.5
09/11/03	8.7	8.6	8.3	7.9
09/30/03	8.9	8.5	8.0	7.5
10/28/03	8.4	8.5	8.2	7.1
10/31/03	6.9	7.0	6.6	6.6

A daily fluctuation of pH was observed during a morning and afternoon sampling event on July 8, 2003.   Morning and afternoon pH measurements showed diurnal variations of pH, which is attributed to photosynthesis of algae in the lagoon.

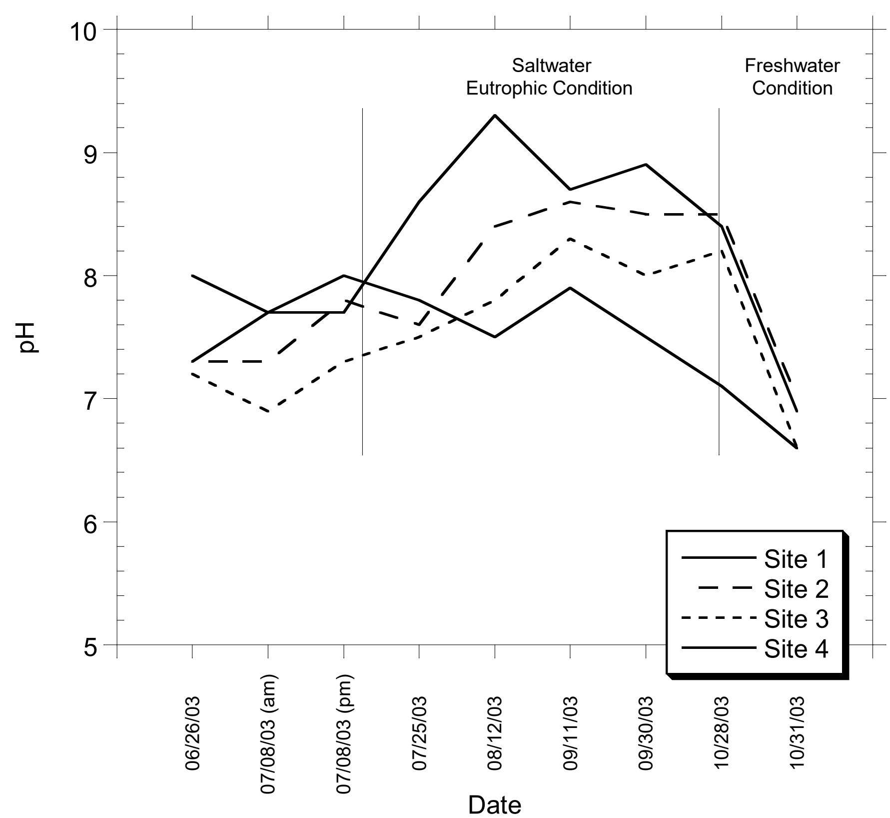

Figure 4.3. pH in Moran Lake (June 26, 2003 to October 31, 2003)

Dissolved Oxygen

Dissolved oxygen (DO) measures the concentration of molecular oxygen dissolved in water. Fish and other aquatic organisms assimilate dissolved oxygen in water through their gills and into their blood, and require a certain quantity of DO in water to survive. DO concentrations in water are dynamic depending on oxygen producing processes such as photosynthesis, and oxygen depleting processes such as respiration and decomposition. DO concentrations fluctuate daily, seasonally, with depth and at locations where physical factors increase water turbulence and water contact with atmospheric oxygen. Photosynthesis occurs near the water surface in the phototrophic zone where sunlight penetrates the water column. Decomposition occurs primarily on the lagoon bottom in the benthic zone where microorganisms decompose organic matter consuming oxygen. The concentration of DO in water is also temperature dependent. Colder water has the capacity to hold more DO than warmer water due to the density and pressure of the liquid.

Eutrophic or highly enriched watercourses, such as Moran Lake will show highly varying levels of DO. During early morning periods DO may be suppressed and very low concentrations, while in the late afternoon DO may be very high due to algae and other aquatic vegetation releasing DO into the water column. Urban pollution and storm water runoff often act to decrease dissolved oxygen concentrations in lake water. Polluted runoff containing degradable organic matter introduced to a water body such as Moran Lake, exert an oxygen demand during the assimilation and decomposition of these waste products. This oxygen demand can deplete DO concentrations, creating unsuitable conditions for aquatic organisms. In natural waters normal DO may fluctuate from 5 to 10 mg/L.

DO measurements were taken at each of the four sampling locations on ten separate events. Measurements were taken from the water surface to the lake bottom in one-foot increments. The DO data are presented in Table 4.2.

Each of the four sampling locations had unique patterns of DO fluctuation, likely related to their position within the lagoon. Figures 4.4.1 through 4.4.4 show the dissolved oxygen concentration measured at the surface and near the bottom of the lagoon at each monitoring site.

At Site 1 (Figure 4.4.1) the dissolved oxygen concentration was relatively constant throughout the water column, but varied significantly over time. During the early summer just prior to the lagoon closing the DO concentrations were relatively low, ranging between 4 to 6 mg/L. However, after the lagoon closed and became highly euthrophic daily DO concentrations increased significantly from mid july through September until the lagoon opened up again. DO concentrations were well above 10 mg/L in proximity to the culvert. DO concentrations were relatively constant at depth, which is attributed to the lagoon being well mixed due to wind action.

Table 4.2. Dissolved Oxygen Concentration (mg/L) Measurements

Date (Sample time)	Sample Location							
	Site 1		Site 2		Site 3		Site 4	
	Depth (ft)	DO (mg/L)	Depth (ft)	DO (mg/L)	Depth (ft)	DO (mg/L)	Depth (ft)	DO (mg/L)
06/05/03 (10:30)	0.0	5.73	0.0	6.08	0.0	4.32	0.0	8.38
	1.0	5.21	1.0	5.83	1.0	3.56		
	2.0	5.45	2.0	3.82	2.0	3.42		
	3.0	5.88	2.4	4.02	3.0	0.55		
	4.0	2.63			4.0	0.14		
06/26/03 (11:30)	0.0	4.95	0.0	6.33	0.0	4.86	0.0	11.40
	1.0	5.30	1.0	5.85	1.0	5.71		
	2.0	4.84	2.0	5.28	2.0	4.88		
	3.0	4.58	3.0	5.07	3.0	3.93		
	4.0	4.80						
07/08/03 (am) (08:30)	0.0	5.65	0.0	8.23	0.0	5.26	0.0	8.74
	1.0	5.44	1.0	6.40	1.0	4.32		
	2.0	4.34	2.0	5.49	2.0	0.17		
	3.0	4.04	2.5	4.02	2.5	0.06		
	3.5	4.20						
07/08/03 (pm) (16:30)	0.0	9.32	0.0	9.15	0.0	7.98	0.0	10.17
	1.0	8.94	1.0	9.39	1.0	7.99		
	2.0	8.56	2.0	8.71	2.0	7.09		
	3.0	8.99	2.5	8.33	2.5	0.27		
	3.5	8.22						
07/25/03 (11:30)	0.0	10.78	0.0	2.99	0.0	1.04	0.0	12.85
	1.0	9.83	1.0	3.27	1.0	0.83		
	2.0	11.90	2.0	6.65	2.0	1.20		
	3.0	12.12						
08/12/03 (9:30)	0.0	10.79	0.0	6.68	0.0	6.06	0.0	8.2
	1.0	10.3	1.0	6.08	1.0	0.81		
	2.0	10.29	2.0	6.07				
	2.5	10.0						
09/11/03 (3:30)	0.0	10.69	0.0	12.69	0.0	3.91	0.0	9.94
	1.0	9.8	1.0	13.38				
	2.0	10.15	1.9	15.06				
09/30/03 (9:30)	0.0	11.31	0.0	5.47	0.0	0.96	0.0	8.77
	1.0	11.7	1.0	1.50				
	2.0	11.94	1.5	0.35				
10/28/03 (11:30)	0.0	4.82	0.0	9.34	0.0	4.94	0.0	9.97
	1.0	3.2	1.0	4.64				
	2.0	5.43	1.5	1.28				
10/31/03 (6:45am)	0.0	10.74	0.0	11.27	0.0	16.65	0.0	11.28
	1.0	10.1	1.0	10.37	1.2	11.01		
	1.5	6.24	2.0	5.66				
			3.0	0.62				

At Site 2 the dissolved oxygen concentrations at the surface and near the lagoon bottom tended to vary seasonally. Eight of the ten sampling events showed a decrease in dissolved oxygen concentration with depth. During the summer months, when the lagoon was closed to tidal flushing and had limited freshwater flows the dissolved oxygen at the surface was typically higher at the surface than near the bottom. The stratification of DO with depth at this location is likely influenced by surface photosynthesis of algae and decomposition of organic material on the lagoon bottom. This condition was also observed at Site 3 where DO at the bottom of the lagoon was less than 1 mg/L on several occasions, as shown in Figure 4.4.3. Urban runoff likely contributes sediments, surfactants, oil and grease from adjacent urban areas, which can effect DO concentrations. During the first flush event in later October the DO concentration increased substantially at Site 2 and on the surface at Site 3, as a result of highly aerated runoff entering the lagoon.

Figure 4.4.4. shows the DO concentration measured in Moran Creek upstream of the lagoon. DO at Site 4 in Moran ranged from 8.2 to 12.85 mg/L. Shallow water depths prevented multiple depth sampling at this location. Compared to the other sampling locations the DO concentrations at Site 4 were generally higher. The observed DO concentrations were likely influenced by turbulent flow conditions in the stream immediately upstream of the monitoring point.

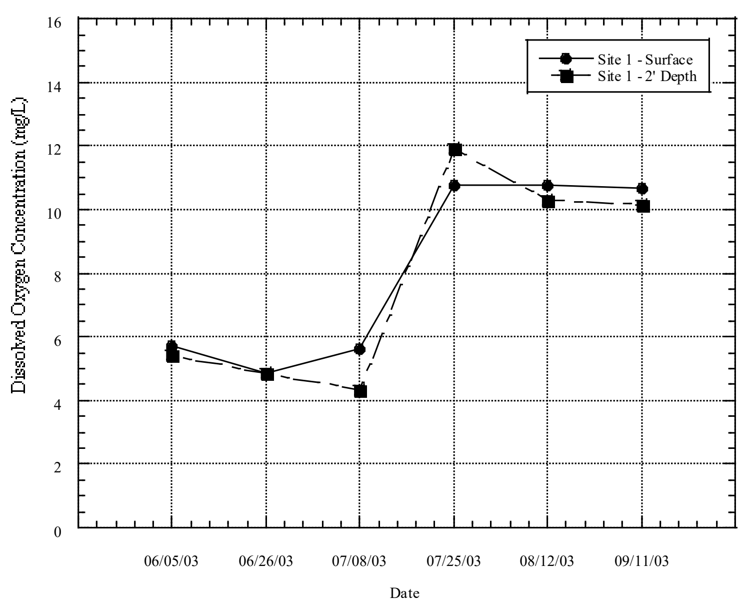

Figure 4.4.1. Dissolved Oxygen Concentrations at Lagoon Inlet (Site 1)

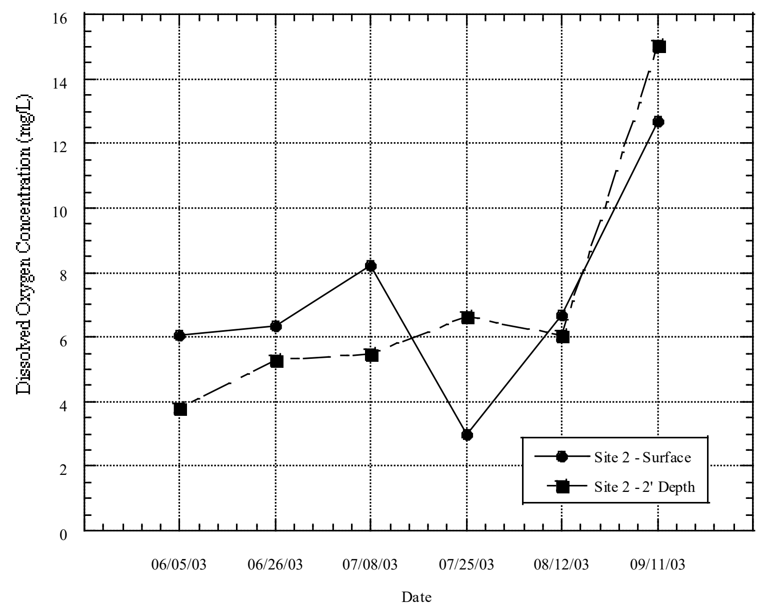

Figure 4.4.2. Dissolved Oxygen Concentrations at Site 2

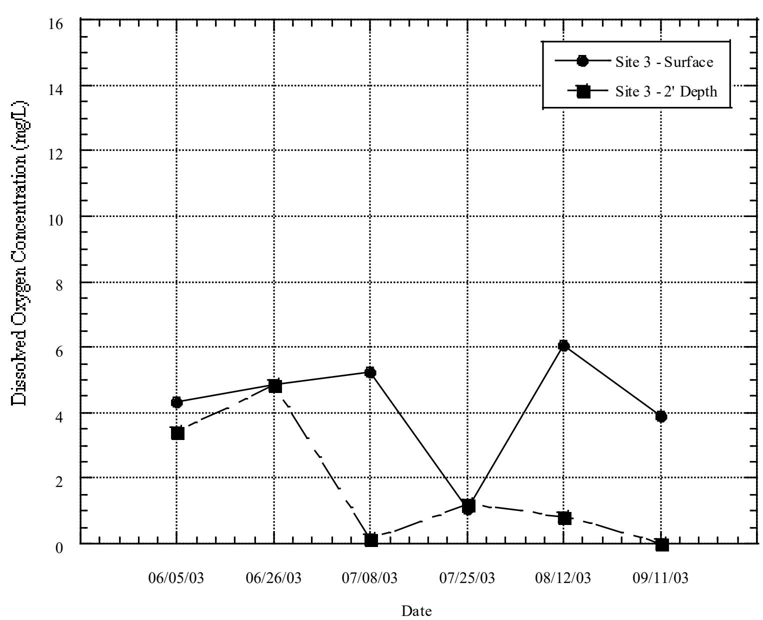

Figure 4.4.3. Dissolved Oxygen Concentration at Site 3

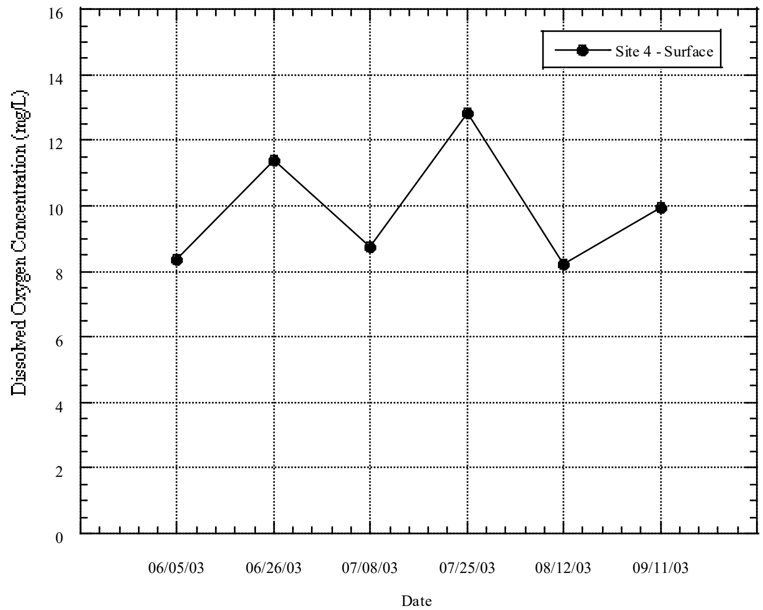

Figure 4.4.4. Dissolved Oxygen Concentration in Moran Creek

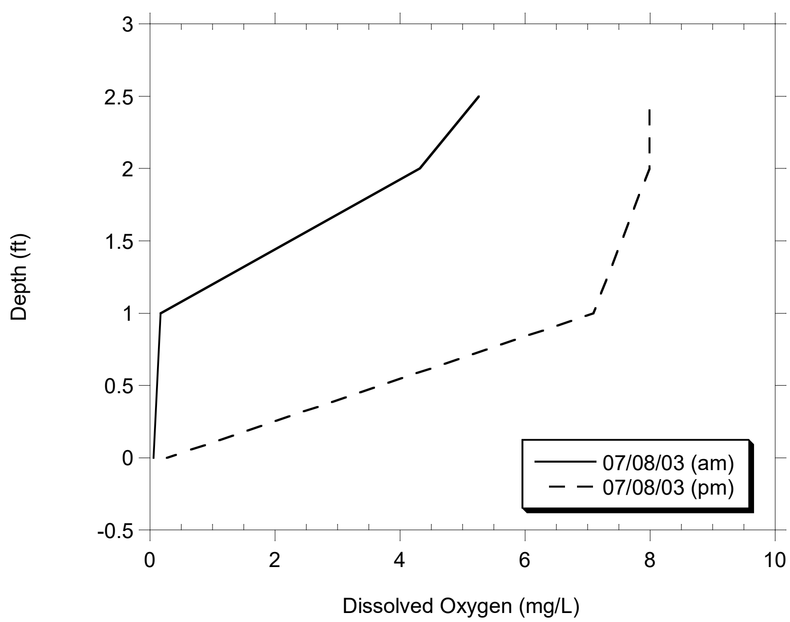

Figure 4.5. Morning and Afternoon Dissolved Oxygen Concentrations at Site 3

On July 8, 2003 DO measurements were conducted in the morning and afternoon at all four sampling locations. DO concentrations measured during the morning were less than recordings taken in the afternoon, as shown in Figure 4.5. The increase in DO during the daylight hours is a result of oxygen production by photosynthetic algae in the water column. Low or depressed DO concentrations results from the high DO demand exerted by the substantial algal blooms occurring in the lagoon, which is expected under highly euthrophic conditions that are present in the lagoon.

Temperature

At Moran Lake, temperature measurements were taken at each of the four sampling locations, from the water surface to the lake bottom in one-foot increments on ten separate monitoring events. As expected, water temperature generally increased from July to early September and began to decrease in late September and October (Table 4.3). Water temperature within the lagoon was generally higher (between five to ten degrees) in the lagoon than at Site 4 in Moran Creek, as shown in Figure 4.6. The increased temperature in the lagoon is likely the result of the high heat capacity of the lagoon resulting from the thick biomass in the water column, combined with shallow water depths. Figure 4.6 also shows a daily increase in water temperature, observed on July 8, 2003 during a morning and afternoon sampling event.

Table 4.3. Temperature Field Measurements (Degrees Centrigrade, ^oC)

Date (Sample time)	Sample Location							
	Site 1		Site 2		Site 3		Site 4	
	Depth (ft)	Temp (ºC)	Depth (ft)	Temp (ºC)	Depth (ft)	Temp (ºC)	Depth (ft)	Temp (ºC)
06/05/03	0.0	20.2	0.0	19.9	0.0	20.4	0.0	15.8
(10:30)	1.0	20.2	1.0	19.9	1.0	20.4		
	2.0	20.2	2.0	20.5	2.0	21.2		
	3.0	20.7	2.4	20.5	3.0	21.2		
	4.0	22.3			4.0	21.5		
06/26/03	0.0	23.7	0.0	24.6	0.0	25.7	0.0	18.0
(11:30)	1.0	23.2	1.0	24.6	1.0	24.5		
	2.0	22.7	2.0	24	2.0	24.2		
	3.0	22.5	3.0	23.7	3.0	23.2		
	4.0	22.4						
07/08/03 (am)	0.0	22.2	0.0	23.7	0.0	24.0	0.0	15.1
(08:30)	1.0	22.4	1.0	30.8	1.0	24.0		
	2.0	24.3	2.0	26	2.0	26.5		
	3.0	24.5	2.5	26	2.5	27.0		
	3.5	24.5						
07/08/03 (pm)	0.0	29.0	0.0	28.2	0.0	26.7	0.0	19.6
(16:30)	1.0	28.8	1.0	28.3	1.0	26.8		
	2.0	32.8	2.0	27.8	2.0	27.3		
	3.0	26.9	2.5	27.7	2.5	27.2		
	3.5	26.0						
07/25/03	0.0	22.6	0.0	22.4	0.0	23.7	0.0	17.5
(11:30)	1.0	22.3	1.0	22.3	1.0	23.5		
	2.0	22.1	2.0	22.3	2.0	22.8		
	3.0	22.1						
08/12/03	0.0	22.9	0.0	23.4	0.0	22.3	0.0	15.7
(9:30)	1.0	22.9	1.0	23.4	1.0	22.3		
	2.0	22.9	2.0	23.3				
	2.5	22.9						
09/11/03	0.0	23.5	0.0	27.8	0.0	26.7	0.0	19.8
(3:30)	1.0	23.1	1.0	26.1				
	2.0	22.4	1.9	23.7				
09/30/03	0.0	19.30	0.0	17.10	0.0	18.80	0.0	15.2
(9:30)	1.0	19.6	1.0	19.50				
	2.0	19.60	1.5	22.20				
10/28/03	0.0	18.80	0.0	22.20	0.0	21.80	0.0	15.7
(11:30)	1.0	17.0	1.0	18.10				
	2.0	18.10	1.5	17.30				
10/31/03	0.0	10.20	0.0	10.30	0.0	10.70	0.0	10.4
(6:45am)	1.0	10.4	1.0	10.40	1.2	10.40		
	1.5	11.10	2.0	11.50				
			3.0	12.5				

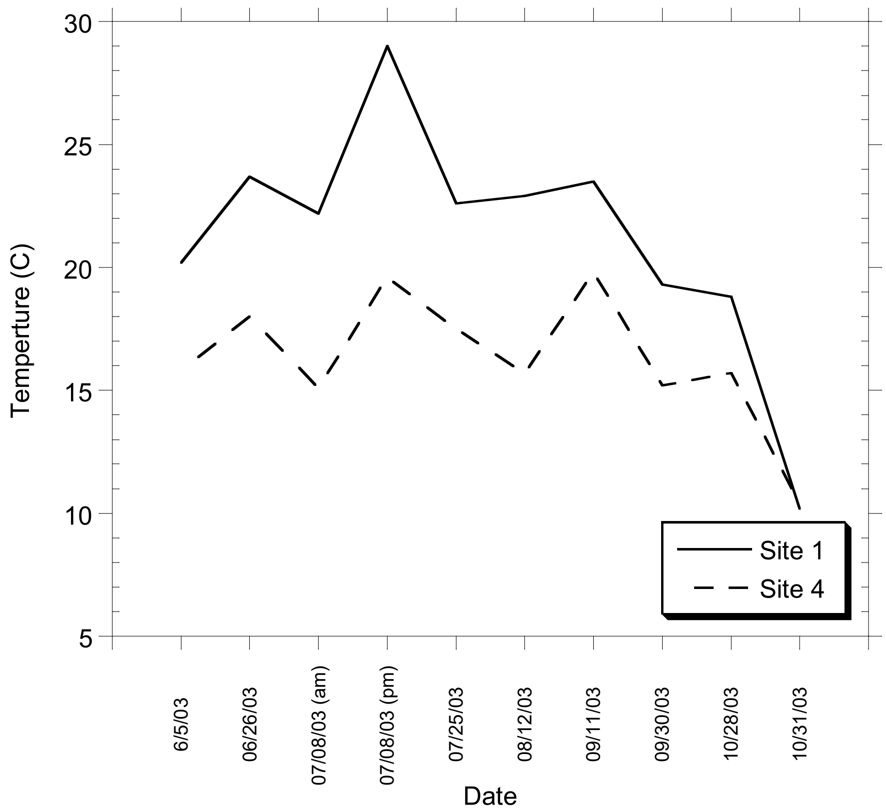

Figure 4.6. Water Temperature (Degrees ºC) Measured at Sites 1 and Site 4

Nutrients

Water samples were collected and analyzed by the Santa Cruz County Environmental Health Water Quality Laboratory for soluble nutrients including: organic-, ammonia- and nitrate-nitrogen, and total phosphorus.

Nitrogen and phosphorus at low levels are important nutrients in aquatic ecosystems. However, at elevated levels these constituents can result in excessive, invasive and some times noxious characteristics that lead to euthrophic and anoxic conditions in a lagoon system. Sources of nitrogen and phosphorus include storm water runoff, organic matter, lawn fertilizers, leaking sewer pipes and/or domestic animals. Natural nutrient sources include the decomposition of organic debris delivered to surface water bodies during storm events.

Over the course of the study, nutrients were measured on five separate monitoring events at each of the four sampling locations. The results are presented in Table 4.4.

Table 4.4. Nutrient (Nitrogen and Phosphorus) Measurements (in mg/L)

Sample Location	Date	Nitrate-N (mg/L)	Ammonia-N (mg/L)	Organic-N (mg/L)	Total Phosphorus (mg/L)
1	06/05/03	<0.01	0.54	5.44	<0.05
	07/08/03	<0.01	0.04	0.86	<0.05
	08/12/03	<0.01	0.09	1.6	<0.05
	10/28/03	<0.01	< 0.04	3.9	5
	10/31/03	1.7	0.72	8.8	0.9
2	06/05/03	<0.01	0.06	1.35	<0.05
	07/08/03	<0.01	0.05	0.85	<0.05
	08/12/03	<0.01	0.13	1.7	<0.05
	10/28/03	<0.01	< 0.04	3.7	<0.05
	10/31/03	1.5	0.74	6.4	0.7
3	06/05/03	<0.01	0.04	1.83	<0.05
	07/08/03	<0.01	0.07	0.83	<0.05
	08/12/03	<0.01	0.14	2	<0.05
	10/28/03	<0.01	0.07	4.2	<0.05
	10/31/03	1.2	0.44	5.2	0.5
4	06/05/03	1.10	0.07	0.82	<0.05
	07/08/03	0.50	< 0.04	0.68	<0.05
	08/12/03	0.26	0.11	1.3	<0.05
	10/28/03	0.09	0.06	0.8	0.09
	10/31/03	0.9	0.72	4.4	0.3

Nitrate-N (NO_3^-) concentrations at the four sampling locations ranged from less than the reporting limit, 0.01 mg/L, to 1.7 mg/L. Ammonia-N (NH_3) concentrations at the four sampling locations ranged from less than the reporting limit, 0.04 mg/L, to 0.74 mg/L. Organic-N concentrations at the four sampling locations ranged from 0.68 mg/L to 8.8 mg/L. Total phosphorus concentrations at the four sampling locations ranged from less than the reporting limit, 0.05 mg/L, to 0.9 mg/L.

The highest concentrations of total phosphorus, nitrate-N (NO_3^-), ammonia-N (NH_3), and organic-N were measured during the first flush sampling event on October 31, 2003. The concentrations are significantly higher than those measured on October 28, 2003, just three days before the first significant rainfall event of the season, as shown at Site 2 in Figure 4.7. The increased concentrations are likely a result of urban pollutants, such as waste products and lawn fertilizers, which were transported into the lagoon by storm water runoff.

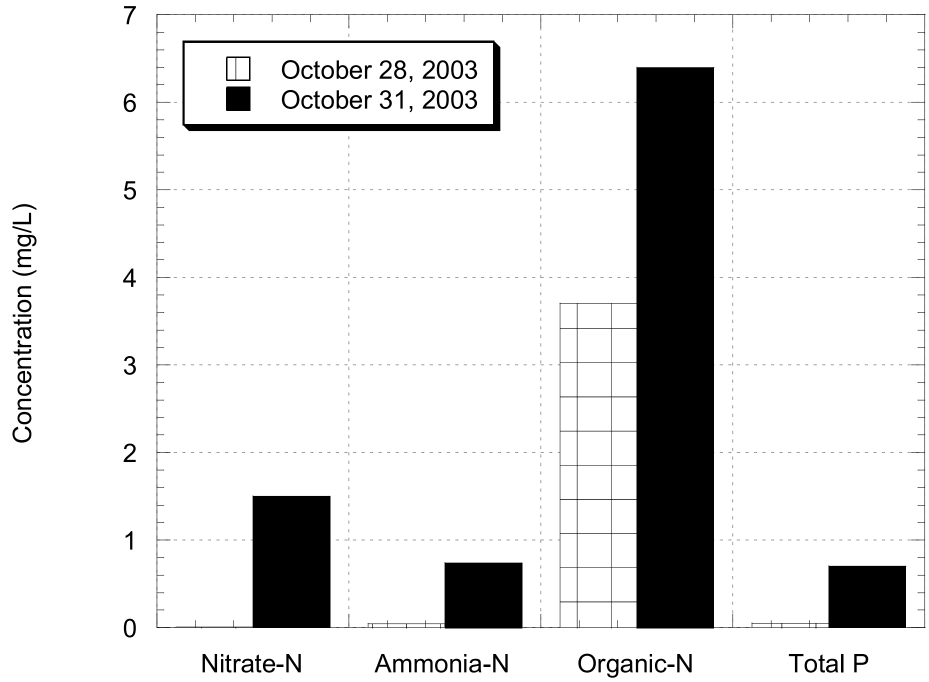

Figure 4.7. Nutrient Concentrations at Site 2 on October 28 and October 31, 2003

Total and Fecal Coliform Bacteria

Water samples were collected from each monitoring site and analyzed for total and fecal coliform bacteria. Total and fecal coliform bacteria are indicator organisms routinely used to test the quality of surface and drinking water sources. Testing for these organisms are relatively easy, inexpensive and provide a good indication of the level of pollution that may occur in a water body.

The total coliform bacteria group includes a large group of bacteria that can occur naturally in soils and water or in wastes from animals. Fecal coliform is a subgroup of bacteria that live in the intestines and waste material, or feces, excreted from warm-blooded animals. When fecal coliform bacteria are present in high numbers (greater than 200 colonies/100 milliliters of water sample) it means the water may contain fecal matter from a wide variety of animals including waterfowl, domestic and wild animals and humans, and may be unsafe for direct contact. Although coliform bacteria may not be pathogenic, the presence of these organisms may indicate the potential presence of other disease carrying organisms.

In an urban setting sources of fecal coliform are many, including storm runoff carrying waste from domestic and wild animals, decaying vegetation, organic sediment, leaking sanitary sewers, and water fowl that may reside in the stream or lagoon.

The Santa Cruz County Environmental Health Lab analyzed water samples for total and fecal coliform bacteria. Samples were taken at each of the four sampling locations and are reported in units of colony forming units per 100 milliliters of water sample (CFUs).

Total coliform counts ranged from 4 CFUs to 'too numerous to count', and fecal coliform counts ranged from less than 1 to 11,470 CFUs.

Table 4.5. Total and Fecal Coliform Measurements

	Membrane Filtration Tests (Colony Forming Units per 100 millimeters)							
	Site 1		Site 2		Site 3		Site 4	
Date	TC	FC	TC	FC	TC	FC	TC	FC
6/5/03	40	20	20	20	70	50	570	1350
7/8/03	16	<1	4	4	<1	<1	TNTC	56
8/12/03	12	4	4	16	16	880	240	5720
10/31/03	75,640	11,470	56,933	9,150	50,427	9,550	34,770	8,850
Water Quality Objectives								
Water Contact Recreation		200*		200*		200*		200*
Non-Water Contact Recreation		2000**		2000**		2000**		2000**

Notes:

TC- Total Coliform
FC - Fecal Coliform
TNTC - Too numerous to count

* - This is a benchmark objective only, the enforceable water quality objective is based on a minimum of not less than five samples for any 30-day period (ref. Water Quality Control Plan, CCRWQCB, 2001)
** - This is a benchmark objective only, the enforceable water quality objective is based on a minimum of not less than five samples for any 30-day period (ref. Water Quality Control Plan, CCRWQCB, 2001)

The highest total and fecal coliform counts were recorded during the first flush sampling event on October 31, 2003, and the highest values on that day were recorded at Site 1, as shown in Figure 4.8. Site 1 receives storm water runoff from Moran Creek as well as from a storm drain outlet under East Cliff Drive, which likely contributed to the increased fecal coliform counts at this location. The highest counts prior to October 31, 2003, sampling events, were recorded at Site 4 in Moran Creek, as shown in Figure 4.8 for samples collected on August 12, 2003.

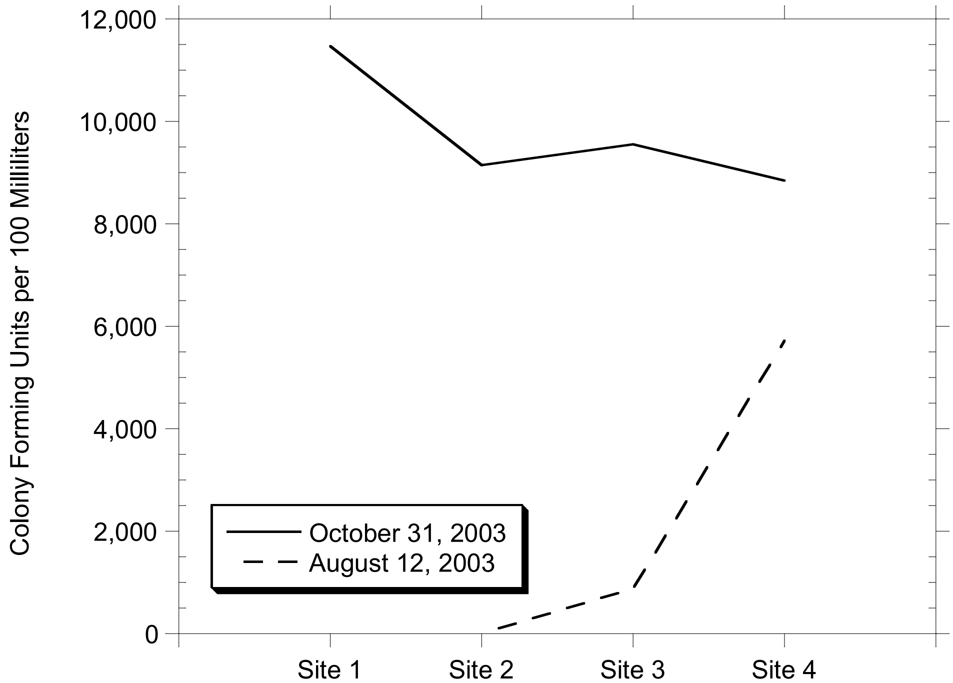

Figure 4.8. Results of Fecal Coliform Counts on August 12 and October 31, 2003

Total Suspended Solids and Turbidity

Total Suspended Solids

Water samples were also analyzed for total suspended solids (TSS), which is the concentration of solids suspended in water. These solids can be either mineral or organic (e.g. soil or algae) matter. A high concentration of TSS can adversely impact water quality by blocking light transmittance through water and adversely affecting photosynthesis and primary production in a lake, and can result in direct impacts to aquatic life by clogging or injury to fish gills and smothering benthic organisms on the lagoon bottom. Suspended solids can also transport attached pollutants, including metals and hydrocarbons in runoff, potentially increasing concentrations of these components within a water system.

TSS values can increase as a result of high-energy runoff that has eroded soil and transported soil and other debris into a water system. TSS also increases as a result of seasonal algae growth, which can be caused by warm temperatures or a release of nutrients from the decomposition of organic material.

The Santa Cruz County Environmental Health Lab analyzed three water samples collected at each sampling site for total suspended solids. Two samples were collected during the summer months when the lagoon was closed and a third sample was collected during the first flush event in late October. Turbidity results are presented in Table 4.6. The measured concentrations of total suspended solids ranged from 2.0 mg/L to 92.0 mg/L.

Table 4.6. Turbidity (in NTU) and Total Suspended Solids (in mg/L) Measurements

	Sample Location							
	Site 1		Site 2		Site 3		Site 4	
Date	Turbidity (NTU)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)
06/05/03	3.1	32.0	3.2	17.2	6.3	11.2	5.3	2.0
06/26/03	5.6	--	6.6	--	9.1	--	7.5	--
07/08/03 (am)	4.6	--	5.2	--	6.9	--	4.0	--
07/08/03 (pm)	4.9	16.8	5.2	24.8	7.3	19.2	4.8	2.4
07/25/03	0.2	--	3.4	--	7.2	--	0.3	--
08/12/03	0.79	--	2.8	--	8.28	--	1.42	--
09/11/03	1.46	--	5.8	--	8.40	--	1.93	--
09/30/03	0.84	--	5.1	--	4.45	--	1.33	--
10/28/03	2.06	--	14.3	--	12.19	--	14.60	--
10/31/03	43.10	84.4	35.3	59.3	35.50	67.7	25.50	92.0

Samples collected during the summer months, June and July, represent conditions during which the majority of TSS is algae floating in the water column. During this period the TSS concentrations ranged from approximately 5 mg/L to 35 mg/L. Samples collected in October during the first flush event had substantially higher TSS concentration ranging from 60 to 92 mg/L. The higher TSS concentrations are attributed to storm water runoff entering the lagoon from Moran Creek, local drainage and East Cliff Drive. Figure 4.9 shows the results of three representative sampling events collected from the four sampling sites within Moran Lake and analyzed for TSS.

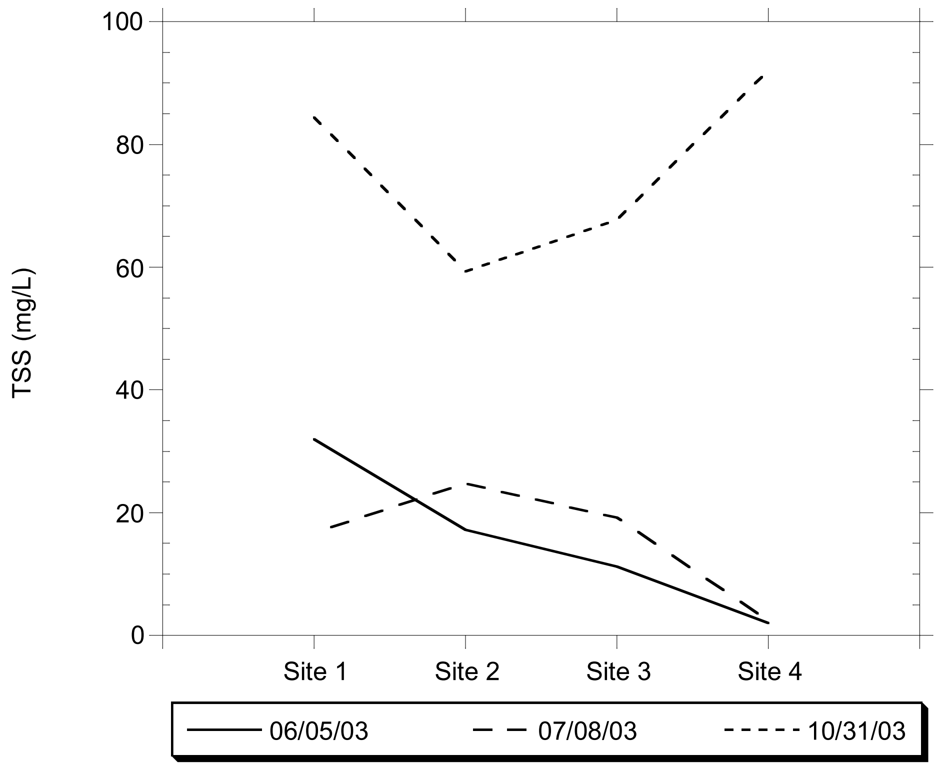

Figure 4.9. Total Suspended Solids Concentrations

<u>Turbidity</u>

Turbidity is an indirect measurement of suspended matter in water. The turbidity test measures the amount of light scattered through a sample of water. The presence of suspended matter or clay particles will tend to scatter focused light beam that is directed through a given thickness of water. A light sensor detects the amount of scatter and converts this intensity to a unit of transmittance, which is roughly approximated to the amount of suspended matter in the water. Generally, a high turbidity value indicates a high concentration of total suspended solids (however, in some instances there may be no direct correlation particularly if there is a high concentration of organic acids that may absorb the light in the water resulting in a low reading). Typically a high concentration of suspended solids increases the scatter of light and increases the turbidity value, and a low concentration of solids allows the light to pass through the water with little scatter.

At Moran Lake, turbidity measurements were taken from samples collected at each of the four sampling locations on ten sampling occasions. Turbidity was measured in the field and reported in Nephelometric Turbidity Units (NTU), and the results are presented in Table 4.6. The recorded turbidity measurements at the four sampling locations for the ten sampling events ranged from 0.2 to 43.1 NTU.

Turbidity measurements across the four sampling sites did not vary significantly, though overall Site 3 appeared to have higher readings than the other two locations. Site 3, in the upper lagoon, could have higher turbidity measurements due to the accumulation of organic debris at this location as well as the proximity to a storm drain outfall. The highest turbidity measurement at each sampling location was recorded during the first flush sampling event. The high readings occurred because of high energy storm water flows that introduced suspended sediments into the lagoon and also re-suspended sediment and organic debris from the lagoon bottom. Figure 4.10 shows the results of turbidity measurements collected from the four sampling locations on August 12, 2003, which depicts the increased readings at Site 3 during the summer months, and the increased turbidity measurements observed during the first flush on October 31, 2003.

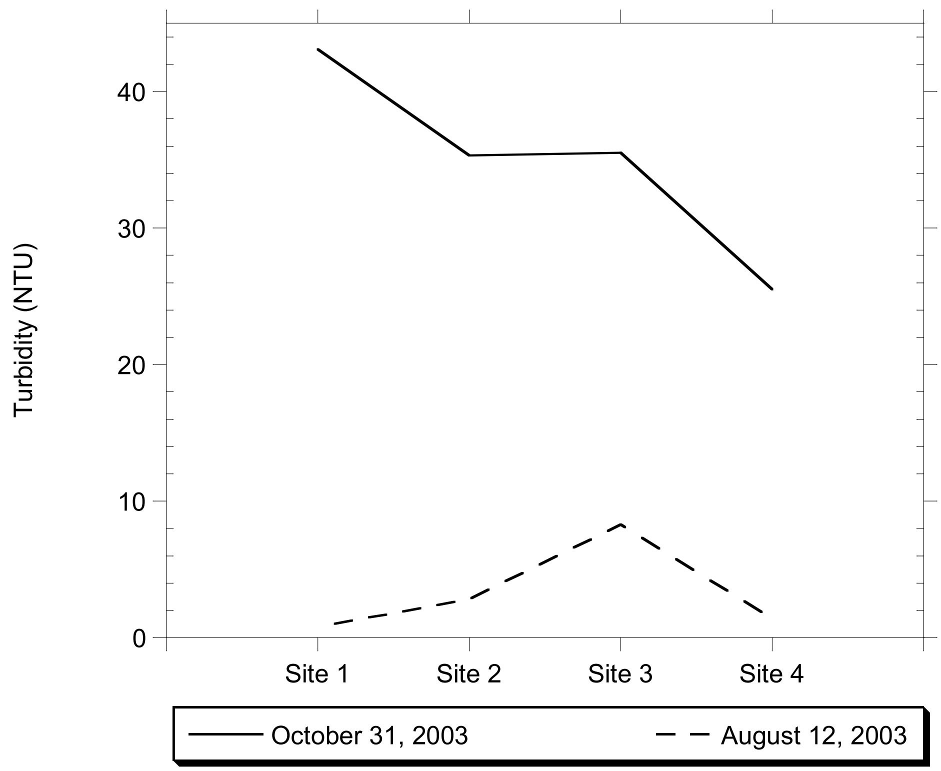

Figure 4.10. Turbidity Measurements taken on August 12th and October 31st 2003

Salinity and Conductivity

Salinity

Salinity measures the concentration of salt in water, and is generally reported in parts per thousand (ppt). Ocean water has a salinity of approximately 35 parts per thousand. Water with salinity levels in excess of ocean water is referred to as hyperhaline or hypersaline, depending upon if the salts are ocean or land derived.[1] Water with

[1] **Hyperhaline.** Term used to characterize waters with salinity greater than 40 ppt (parts per thousand) due to ocean-derived salts. **Hypersaline.** Term used to characterize waters with salinity greater than 40 ppt due to land-derived salts (Cowardin et al. 1979).

concentrations greater than ocean water is generally observed within enclosed water bodies where the effects of evaporation increase salt concentration as water evaporates and salts accumulate.

When salinity levels in Moran Lake exceed ocean water, the system can be characterized as hyperhaline as the salts in Moran Lake are ocean derived. Hyperhaline conditions in Moran Lake limit biological diversity and impact aquatic biota within the lagoon as salts accumulate and salinity levels increase above tolerable limits.

Salinity measurements were taken at each of the four sampling locations, from the water surface to the lake bottom in one-foot increments. Salinity measurements were taken on ten sampling events, as shown in Table 4.7. The recorded salinity measurements at the four sampling locations ranged from 0.3 to 36.5 parts per thousand (ppt).

Salinity in the lagoon increased from June to October, when the lagoon opening was closed and evaporation increased salt concentrations in the lagoon. The highest salinity measurements were recorded in August and September, and were in excess of 35 ppt, approaching hyperhaline conditions. Figure 4.11 shows increasing salinity measurements taken on the surface of the lagoon at Site 1. Salinity decreased rapidly during the first flush, when high freshwater flows entered the lagoon from Moran Creek. The decreased salinity on this date was recorded due to the freshwater lens formed on the surface of Moran Lake from Moran Creek and other surface water drainages adjacent to the lagoon that contribute storm water runoff.

Salinity measurements taken at the surface were generally less than measurements taken at depth within the lagoon. This phenomenon indicates that a warm wedge of saltier water forms in the deeper water in the lagoon. At the beginning of the sampling, in June, salinity measurements were generally uniform across the entire lagoon. Beginning in August and continuing into October, the salinity measurements generally decreased from the lagoon inlet towards the upper lagoon. All salinity measurements taken at Site 4 were less than or equal to 0.5 ppt, indicating the site was measuring freshwater flows from Moran Creek and is above any salinity influences from the lagoon. Figure 4.12 shows surface water salinity measurements collected during three sampling events within the lagoon at Sites 1, 2, and 3, showing the trend towards decreasing salinity in the upper lagoon during late summer.

Table 4.7. Salinity Field Measures (in parts per thousand, ppt)

Date (Sample time)	Sample Location							
	Site 1		Site 2		Site 3		Site 4	
	Depth (ft)	Salinity (ppt)	Depth (ft)	Salinity (ppt)	Depth (ft)	Salinity (ppt)	Depth (ft)	Salinity (ppt)
06/05/03 (10:30)	0.0	29.4	0.0	28.7	0.0	28.7	0.0	0.3
	1.0	29.4	1.0	28.8	1.0	28.7		
	2.0	29.3	2.0	29.1	2.0	29.2		
	3.0	29.4	2.4	29.1	3.0	29.4		
	4.0	30.7			4.0	29.8		
06/26/03 (11:30)	0.0	33.1	0.0	33.2	0.0	32.9	0.0	0.3
	1.0	33.1	1.0	33.1	1.0	33.2		
	2.0	33.1	2.0	33.3	2.0	33.3		
	3.0	33.1	3.0	33.2	3.0	33.0		
	4.0	33.1						
07/08/03 (am) (08:30)	0.0	30.9	0.0	30.5	0.0	30.4	0.0	0.5
	1.0	30.8	1.0	24.2	1.0	30.5		
	2.0	32.4	2.0	33.1	2.0	33.2		
	3.0	33.0	2.5	33.1	2.5	33.4		
	3.5	33.0						
07/08/03 (pm) (16:30)	0.0	32.6	0.0	31.0	0.0	31.0	0.0	0.4
	1.0	32.6	1.0	30.9	1.0	30.9		
	2.0	28.5	2.0	31.8	2.0	31.8		
	3.0	32.9	2.5	32.4	2.5	32.4		
	3.5	32.9						
07/25/03 (11:30)	0.0	34.4	0.0	34.1	0.0	33.3	0.0	0.3
	1.0	34.5	1.0	34.1	1.0	34.0		
	2.0	34.5	2.0	34.1	2.0	34.0		
	3.0	34.6						
08/12/03 (9:30)	0.0	36.0	0.0	35.4	0.0	34.8	0.0	0.4
	1.0	36.0	1.0	35.4	1.0	34.7		
	2.0	36.0	2.0	35.3				
	2.5	36.0						
09/11/03 (3:30)	0.0	36.3	0.0	36.0	0.0	34.3	0.0	0.4
	1.0	36.5	1.0	35.8				
	2.0	36.5	1.9	35.7				
09/30/03 (9:30)	0.0	35.8	0.0	30.0	0.0	27.1	0.0	0.4
	1.0	36.2	1.0	31.3				
	2.0	36.3	1.5	35.1				
10/28/03 (11:30)	0.0	31.9	0.0	31.6	0.0	31.0	0.0	0.3
	1.0	31.7	1.0	30.7				
	2.0	32.2	1.5	31.8				
10/31/03 (6:45am)	0.0	1.2	3.0	0.7	0.0	0.3	0.0	0.1
	1.0	1.4	2.0	0.9	1.2	0.3		
	1.5	10.4	1.0	11.4				
			0.0	29.6				

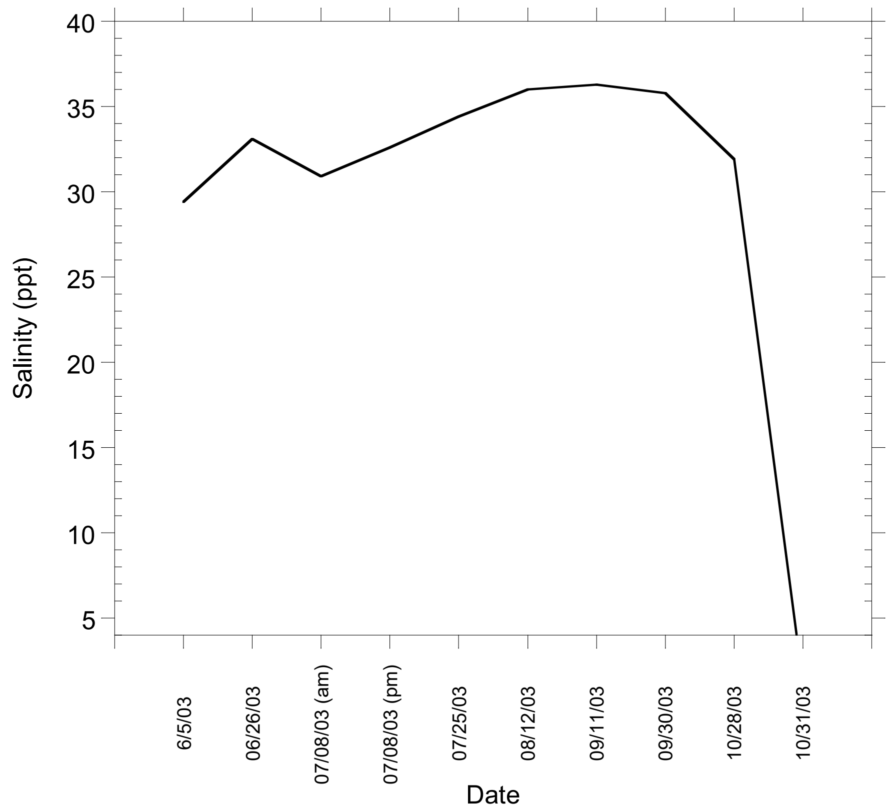

Figure 4.11. Salinity Measurements Collected at Site 1

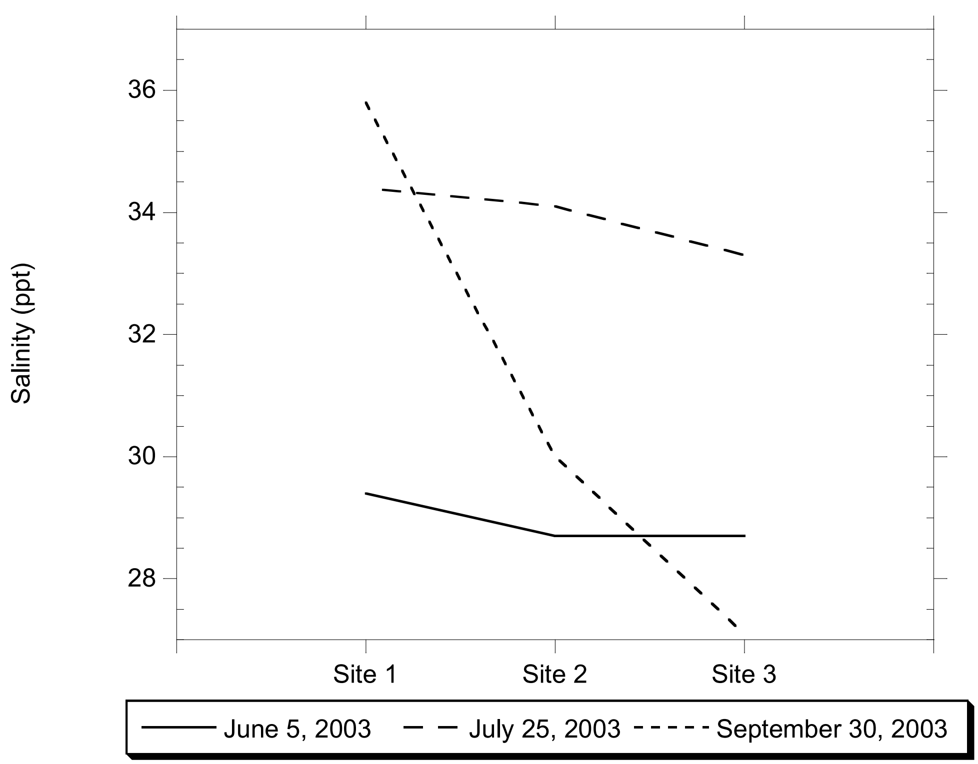

Figure 4.12. Salinity Measurements on June 5th, July 25th , September 30th , 2003

Electrical Conductivity

Electrical conductivity is the measure of a water samples ability to conduct an electrical current, and is reported in units of micromhos or microsiemens (□S). The electrical conductivity of water increases as the concentration of ions (charged particles) increases. For example pure water has a very low electrical conductivity, whereas ocean water with high sodium and chloride concentrations has a high electrical conductivity. The complexity of natural waters very rarely provides direct estimates of ion concentrations from electrical conductivity measurements.

At Moran Lake, electrical conductivity measurements were taken at each of the four sampling locations, from the water surface to the lagoon bottom in one-foot increments. The results are presented in Table 4.8. The recorded salinity measurements at the four sampling locations ranged from 0.105 to 53.5 □S.

The lowest electrical conductivity measurements were recorded at Site 4, in the freshwater of Moran Creek. The highest measurements were recorded during August and September at Site 1, where near-hyperhaline conditions were observed. Very little variation in electrical conductivity measurements between each of the three sampling locations within the lagoon was observed. Electrical conductivity measurements did generally increase with depth at each of the sampling locations within the lagoon, another indication of the warm lens of saltier water on the lagoon bottom. Figure 4.13 shows the transition of salinity and conductivity measurements with depth collected from Site 2 on October 31, 2003.

Table 4.8. Conductivity Field Measurements (in micron siemens, mS)

Date (Sample time)	Site 1 Depth (ft)	Site 1 Conductivity (mS)	Site 2 Depth (ft)	Site 2 Conductivity (mS)	Site 3 Depth (ft)	Site 3 Conductivity (mS)	Site 4 Depth (ft)	Site 4 Conductivity (mS)
06/05/03	0.0	41.2	0.0	40.2	0.0	40.4	0.0	0.468
(10:30)	1.0	41.1	1.0	40.2	1.0	40.5		
	2.0	41.0	2.0	41.1	2.0	41.8		
	3.0	41.3	2.4	41.0	3.0	42.0		
	4.0	47.4			4.0	42.8		
06/26/03	0.0	49.0	0.0	50.2	0.0	50.6	0.0	0.504
(11:30)	1.0	48.8	1.0	50.5	1.0	50.4		
	2.0	48.2	2.0	49.7	2.0	49.9		
	3.0	48.1	3.0	49.5	3.0	48.8		
	4.0	48.0						
07/08/03 (am)	0.0	44.8	0.0	45.8	0.0	45.9	0.0	0.555
(08:30)	1.0	44.9	1.0	46.7	1.0	46.1		
	2.0	48.1	2.0	51.6	2.0	52.3		
	3.0	49.8	2.5	51.6	2.5	53.0		
	3.5	49.9						
07/08/03 (pm)	0.0	49.9	0.0	51.2	0.0	48.9	0.0	0.637
(16:30)	1.0	53.5	1.0	51.2	1.0	49.1		
	2.0	53.4	2.0	52.6	2.0	51.0		
	3.0	52.1	2.5	53.0	2.5	51.7		
	3.5	51.3						
07/25/03	0.0	49.8	0.0	49.1	0.0	49.8	0.0	0.552
(11:30)	1.0	49.6	1.0	49.1	1.0	50.2		
	2.0	49.4	2.0	49.1	2.0	49.4		
	3.0	49.4						
08/12/03	0.0	52.1	0.0	51.9	0.0	49.9	0.0	0.598
(9:30)	1.0	52.3	1.0	51.8	1.0	49.9		
	2.0	52.3	2.0	51.8				
	2.5	52.2						
09/11/03	0.0	53.3	0.0	57.5	0.0	53.3	0.0	0.664
(3:30)	1.0	52.9	1.0	55.1				
	2.0	52.4	1.9	52.6				
09/30/03	0.0	48.0	0.0	39.4	0.0	36.5	0.0	0.614
(9:30)	1.0	48.9	1.0	40.2				
	2.0	49.1	1.5	50.3				
10/28/03	0.0	43.3	0.0	45.9	0.0	41.7	0.0	0.578
(11:30)	1.0	41.5	1.0	41.5				
	2.0	43.1	1.5	41.4				
10/31/03	0.0	1.6	0.0	0.960	0.0	0.434	1.8	0.105
(6:45am)	1.0	2.0	1.0	1.786	1.2	0.447		
	1.5	11.5	2.0	13.9				
			3.0	35.6				

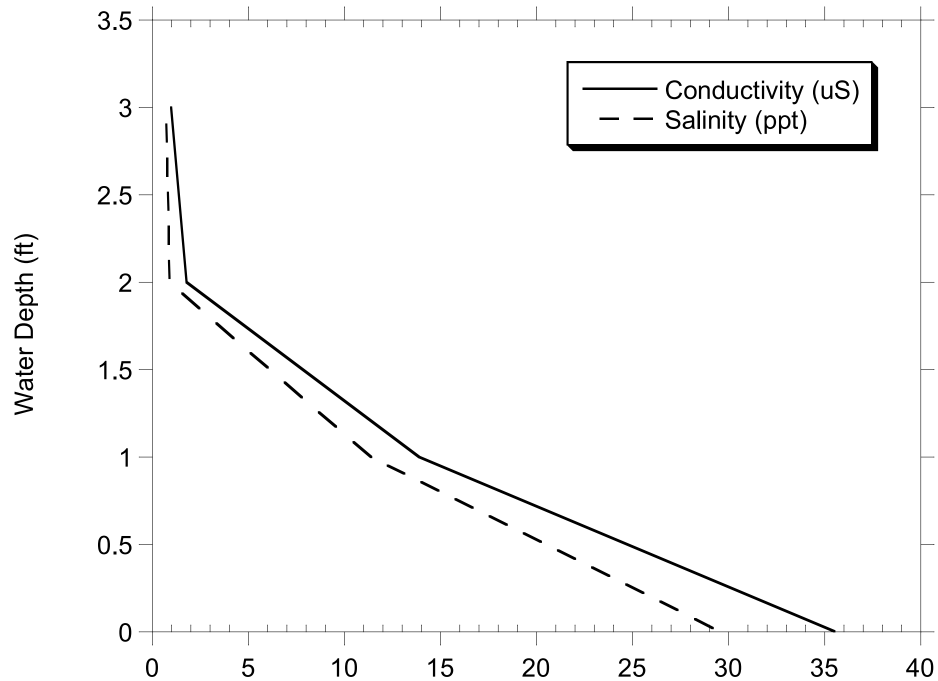

Figure 4.13. Salinity and Conductivity Measurements at Site 2 on October 31st 2003.

General Minerals

General mineral analyses were completed on four rounds of testing conducted in June, July and October, as shown in Table 4.9. The first three rounds of testing were completed when the lagoon was closed and the last sample was collected during the first flush event at the end of October 2003. The results clearly indicate that during the summer months the lagoon is filled primarily with salt water and the major ions in solution include chloride and sodium. During the first flush event that occurred on October 31, 2003, the water quality in the lagoon shifted significantly to represent freshwater conditions.

Table 4.9. General Mineral Analysis

Sample Location	Date	Chloride	Nitrate-N	Sulfate	Sodium	Potassium	Magnesium	Calcium	Bicarbonate
		(all in units mg/L)							
1	06/05/03	14991	<0.01	2118	8018	363	1065	357	114.4
	07/08/03	17118	<0.01	2320	9545	377	1123	399	124.2
	10/28/03	17475	<0.01	2319	9932	429	1308	839	248.5
	10/31/03	457	1.7	101	310	21	42	32	24.0
2	06/05/03	14968	<0.01	2097	8228	371	1051	349	117.4
	07/08/03	17251	<0.01	2317	9663	383	1193	410	126.3
	10/28/03	16702	<0.01	<0.05	2270	9664	409	1291	412.0
	10/31/03	331	1.5	61	187	15	25	22	19.3
3	06/05/03	12099	<0.01	1803	6483	293	915	303	121.4
	07/08/03	17448	<0.01	2313	9468	384	1188	410	128.0
	10/28/03	16524	<0.01	2230	9533	414	1258	426	249.3
	10/31/03	140	1.2	40	83	10	13	17	18.4
4	06/05/03	49	1.10	70	40	5	16	42	117.9
	07/08/03	61	0.50	110	45	7	20	65	125.9
	10/28/03	63.8	0.09	108	49.7	10.3	18.4	70.7	143.1
	10/31/03	17.1	0.9	16.4	11.2	5.8	3.6	12.1	18

Total Metal Concentrations

On three occasions during the study period water samples were collected and analyzed for lead, copper and zinc. The results are presented in Table 4.10. The concentration levels for trace metals were very low for all three metals tested for during June and July. The highest concentrations were routinely detected in the samples collected from Moran Creek, which receives dry weather runoff from urbanized areas. Dry weather runoff includes runoff resulting from street and driveway, and constructed related washing activities, residents washing cars, over spray from landscape irrigation systems. From these sources, dust laden with trace metals typically from tire wear and atmospheric deposition is washed into drainage ways, such as Moran Creek. The last sample was collected in late October during the first significant rainfall event (>0.5 inches of rain) or commonly referred to as the "first flush" event.

During the summer months the total metals concentrations was very low in the two rounds of testing conducted. The highest concentrations measured over the course of the study occurred in Moran Creek, which is attributed to urban runoff. Samples collected during the first flush event were also significantly higher than samples collected during the summer or dry period.

The test results have been compared to several water quality criteria to determine if the concentrations pose a threat to fresh and marine aquatic life. The State of California and the U.S. Environmental Protection Agency (EPA) have set different criteria for total metals concentrations, which are summarized below. In addition, the toxicity of copper, lead and zinc is also a function of the water hardness: in hard water the metal is less biologically available or toxic to aquatic life, and in softer water the metals may be more toxic at lower concentrations. Table 4.11 presents water quality criteria set forth in the *California Toxics Rule* (CTR), prepared by EPA. Different concentration values are a function of the water hardness calculated for the different water samples tested.

Table 4.10. Total Copper, Lead and Zinc Concentrations

(all in units ug/L)

Sample Location	Date	Copper μg/L	Lead μg/L	Zinc μg/L
1	06/05/03	1.3	<1	2.2
	07/08/03	2.6	<0.5	1.4
	10/31/03	34	6.9	400
2	06/05/03	1.2	<1	2
	07/08/03	0.8	<0.5	1.5
	10/31/03	27	4.5	350
3	06/05/03	1.5	1.3	1.2
	07/08/03	0.6	<0.5	1.6
	10/31/03	30	6.2	300
4	06/05/03	2.1	1.7	4
	07/08/03	4.5	0.6	4.7
	10/31/03	30	5.5	350

Table 4.11. California Toxics Rule (US EPA Water Quality Criteria) for the Protection of Freshwater and Saltwater Aquatic Life

		California Toxics Rule and USEPA Criteria for Fresh and Saltwater Aquatic life Protection					
		Copper Criteria		Lead Criteria		Zinc Criteria	
Date	**Total Hardness (in mg/L as $CaCO_3$)**	1-hr Average Total Recoverable (in ug/L)	4-day Average Total Recoverable (in ug/L)	1-hr Average Total Recoverable (in ug/L)	4-day Average Total Recoverable (in ug/L)	1-hr Average Total Recoverable (in ug/L)	4-day Average Total Recoverable (in ug/L)
Site 1							
06/05/03	>400						
07/08/03	>400	52	30	480	19	390	390
10/28/03	>400						
10/31/03	253	34	21	270	12.5	270	270
Site 2							
06/05/03	>400						
07/08/03	>400	52	30	480	19	390	390
10/28/03	>400						
10/31/03	158	22	14	150	5	175	175
Site 3							
06/05/03	>400						
07/08/03	>400	52	30	480	19	390	390
10/28/03	>400						
10/31/03	96	13	9	75	3	120	120
Site 4							
06/05/03	171	23	15	165	5	180	185
07/08/03	244	32	20	270	12	260	260
10/28/03	252	33	21	270	12.5	262	260
10/31/03	45	6.5	4.5	30	3	60	60

Table 4.12 presents water quality objectives established in the California Regional Water Quality Control Board's Water Quality Control Plan (Basin Plan) for the Central Coast

Region. The Basin Plan objectives include ambient water quality objectives to protect both fresh and marine life. The Basin Plan also encompasses water quality objectives established by the State's Ocean Plan.

Comparing the test results to the different criteria indicate that during the first flush event, all three metals were measured at concentrations that exceed several criteria. Total copper concentrations were measured in Moran Creek and at two locations in the lagoon at levels that exceeded both acute toxicity (1-hr average) and chronic toxicity (4-day average) criteria established by the CTR and Basin Plan objectives established to protect both fresh and saltwater aquatic life. Total lead concentrations were measured during this event at levels that exceeded the CTR chronic criteria. Total zinc concentrations measured during the first flush event exceeded both acute and chronic toxicity levels at all sample locations in the creek and lagoon. The test results indicate that runoff from urbanized areas in the watershed discharge significant and potentially toxic levels of copper and zinc to Moran Lagoon.

The total concentration of zinc is typically what has been found in runoff collected in other urban areas throughout the United States. Table 4.13 compares the total concentration of copper, lead and zinc to test results Copper concentrations were also comparable to average concentrations encountered in National Urban Runoff Pollution studies undertaken by the U.S. Environmental Protection Agency in the 1980's. Lead concentrations are substantially lower than what has been measured in other earlier studies in the Lagoon and nationwide, suggesting either the increased use of unleaded fuels has reduce the concentration of lead in runoff or runoff entering the creek and lagoon are substantially diluted. Based on the concentration of zinc and copper detected, the results suggest that runoff is not well diluted in the creek or lagoon and that the water in the lagoon is primarily urban runoff.

Table 4.12. Water Quality Objectives from the Central Coast Region Water Quality Control Plan

Metal	Unit	California Ocean Plan - Marine Aquatic life Protection		CCRWQCB Water Quality Control Plan - Water Quality Objectives		
					Water Quality Objectives to Protect Freshwater Life	
					Hard	Soft
		Instantaneous Maximum	Daily Maximum	Water Quality Objectives to Protect Marine Life	(>100 mg/L CaCO3)	(<100 mg/L CaCO3)
Copper	ug/L	30	12	10	30	10
Lead	ug/L	20	8	10	30	30
Zinc	ug/L	200	80	20	200	4

Table 4.13. Comparison of Moran Creek and Lagoon Water Quality to Urban Runoff Water Quality in Other Areas

Metal	Older Urban Area (Baltimore)[1]	National NURP Study Average[1]	Moran Lake - October 31, 2003			
			Site 1	Site 2	Site 3	Site 4
Zinc	397	176	400	350	300	350
Copper	105	47	34	27	30	30
lead	389	180	6.9	4.5	6.2	5.5

1. Source: Schueler, T.R., 1987, *Controlling Urban Runoff: A practical Manual for Planning and Designing Urban BMPs*

Sediment Quality

Four sediment samples were collected at three locations within Moran Lake on November 25, 2003, and analyzed for a combination of metals, polynuclear aromatic hydrocarbons, organochlorine pesticides, organophosphorus pesticides, polychlorinated biphenyls (PCBs), total ammonia as nitrogen, total sulfides, and oil and grease. Three samples were collected at the surface of the bottom of the lagoon and a fourth sample was collected approximately six (6) inches below the bottom of the lagoon bottom. The test results are summarized in Table 4.14.

General Parameters. All four samples were analyzed for total ammonia and sulfide. One sample was analyzed for oil and grease. The test results indicate that all four samples were in a reduced and anaerobic condition with high concentrations of total ammonia and sulfide. The results also indicate that the sample collected closest to the confluence of Moran Creek and the lagoon contained a relatively high concentration of oil and grease, which is attributed to the discharge of polluted urban runoff entering the lagoon.

Metals. All four sediment samples were analyzed for total concentration of chromium, copper, lead, mercury and zinc. The severity of contamination with heavy metals can be evaluated by comparisons to sediment quality benchmarks that indicate which concentrations are expected to pose a potential threat to the ecosystem. Table 4.14 shows the Moran Lake concentrations alongside several sediment quality benchmarks. The benchmarks are considered guidelines for evaluation of potential risk, rather than levels that require action. These benchmarks include the following:

- National Oceanic and Atmospheric Administration (NOAA) Effects Range low (ERL) and Effects Range Median (ERM). ERL: concentrations above which adverse biological effects may be expected 10% of the time. ERM: concentrations above which adverse biological effects may be expected 50% of the time.

- Ontario sediment quality guidelines (established by the Ontario Ministry of Environment and Energy) including lowest effect levels (LEL), levels that could affect the most sensitive 5% of the species, and severe effects levels (SEL) in which 95% of the species could be effected.

The concentration of the all metals tested in near surface sediments from Moran Lake are well below the reported Sediment Quality Benchmark values shown in Table 4.14. The data indicates that the metal concentrations in the surface sediments are at levels that are not potentially toxic to benthic organisms.

Table 4.15 compares the recent metals data with historical sediment data collected from Moran Lake in 1976 and 1980. Additional sediment data is also provided for comparison from the Crandall Creek Demonstration Urban Stormwater Treatment (DUST) Marsh in Alameda County and several San Francisco Bay Area streams, flood control channels, and natural wetlands. These data are also presented in Table 4.15. Comparing the 2003 sediment data to the earlier test results indicate that chromium concentrations appear to have increased, but the concentration is relatively low compared to other urbanized watersheds in the Bay Area. Lead concentrations measured in 2003 appear to be slightly lower than those measured in 1980, which was lower than concentrations measured in 1976. Mercury concentrations appear to have increased in 2003, as compared to results tested in 1976; however, the higher concentration may be attributed to better analytical methods and levels of detection. Metal concentrations detected in Moran Lake samples are relatively lower than sediment collected from other streams and wetlands in the San Francisco Bay.

Polycyclic Aromatic Hydrocarbons (PAHs). Two composite sediment samples were analyzed for polycyclic aromatic hydrocarbons (PAHs). The results of the test detected the presence of several PAHs, which are shown in Table 4.14. PAHs are formed during the burning of oil, gas, wood, and other organic substances. They are also present in coal tars, and petroleum products, such as creosote and asphalt. PAHs are ubiquitous environmental contaminants, and one particular PAH, benzo(a)pyrene, is considered an indicator of such contamination because it usually occurs in mixtures of PAHs (WWF, 1997). The likely sources of PAHs in the Moran Lake watershed are from roads, parking lots and vehicle service areas.

Many PAHs, such as benzo(a)anthracene, benzo(a)pyrene and chrysene, are carcinogenic, causing tumors in fish and other animals, and are acutely toxic to some organisms. Noncarcinogenic PAHs, such as fluoranthene, phenathrene, and pyene, are also toxic to some organisms (MacCoy and Black, 1998). Concern about PAHs initially focused on their ability to cause cancer, but more recently concern has turned to their interference with hormone systems and their potential effects on reproduction, as well as their ability to depress immune function (WWF, 1997). A particular concern is the effects of PAHs on egg production in fish, and their potential effects on the early life stages of many aquatic organisms that reside in the surface microlayer of the bottom of many wetlands and lagoons, where PAHs can become concentrated. .

Comparing the PAH concentrations with different sediment quality benchmarks indicate that the phenanthrene, chrysene, benzo(a)anthracene and benzo(a)pyrene exceed criteria established by the British Columbia Ministry of Water, Land and Air Protection for protection of freshwater organisms, as shown in Table 4.14. The total concentration of PAHs is elevated, but is below the low and median effects levels established by the National Oceanic and Atmospheric Agency (NOAA). Based on the more conservative and contaminant specific criteria established by British Columbia, the levels of PAHs detected in the sediment may cause impairment to benthic organisms in the lagoon.

Organochlorine Pesticides. Two sediment samples were tested for organochlorine (OC) pesticides. The test results detected chlordane. The presence of chlordane in Moran Lagoon sediments after being banned since 1980 appears to reflect either the slow movement of this persistent pesticide through groundwater to the lagoon, or the erosion of contaminated soils. Chlordane is still found in groundwater and storm water samples in most environments where it has been tested for, albeit at low levels (Scheuler, T.S and H. K, Holland, 2000). Chlordane was widely used as a residential fumigant in the 1960's and 1970s.

Most OC pesticides have been banned or restricted because of potential human and wildlife health effects, tendency to bioaccumulate, and ability to persist in the environment (Wong, Capel and Nowell, 2000). In general, OC pesticides have moderate to high chronic toxicity, and are associated with development and/or reproductive effects in animal studies. OC compounds are also very toxic to aquatic organisms.

The sediment test results detected total chlordane levels well above the probable and threshold effects levels established by several agencies, as shown in Table 4.14. The results indicate that the residual and persistent chlordane levels in lagoon sediments may impair aquatic life in the lagoon

PCBs, DDT derivatives, and other organic chemicals were not detected in the samples tested.

Table 4.14. Sediment Quality Test Results - November 25, 2003

Parameter	Unit	Sample Location 1	Sample Location 2 @ Surface	Sample Location 2 @ 6" Depth	Sample Location 3	Sediment Quality Benchmarks: NOAA ERL	NOAA ERM	OME LEL	OME SEL	FDEC TEL	FDEC PEL	CISQG ISQ	CISQG PEL	BCMWLA SC
General Parameters														
Ammonia	mg/kg	<10	52	20	41									
Sulfide	mg/kg	54	887	192	809									
Oil & Grease	mg/lg				2310									
Metals														
Chromium	mg/kg	18.2	13.9	13.8	11.7	81	370	26	110					
Copper	mg/kg	2.73	13.1	8.33	14.0	34	270	16	110					
Lead	mg/kg	1.89	20.6	14.5	20.3	46.7	218	31	250					
Zinc	mg/kg	14.2	95.7	66.6	102	120	270	120	820					
Mercury	mg/kg	<0.0200	0.0408	0.0552	0.0564	0.15	0.71	0.2	2.0					
Polycyclic Aromatic Hydrocarbons (PAHs)														
Phenanthrene	ug/kg		<100		**150**									40
Fluoranthene	ug/kg		190		440									2000
Pyrene	ug/kg		200		480									
Chrysene	ug/kg		150		**320**									200
Benzo(a)anthracene	ug/kg		<100		**230**									200
Benzo (b)fluoranthene	ug/kg		120		240									
Benzo (k)fluoranthene	ug/kg		<100		240									
Benzo(a)pyrene	ug/kg		**130**		**190**									60
Indeno (1,2,3-cd) pyrene	ug/kg		<100		230									
Benzo(g,h,I)perylene	ug/kg		150		250									
Total PAHs	ug/kg		940		2770	4000		4000						
Organochlorine Pesticides														
alpha-Chlordane	ug/kg		19		49									
gamma-Chlordane	ug/kg		15		39									
Total Chlordane	ug/kg		**34**		**88**	0.5	6			22.26	4.79	4.5	8.87	

Notes:

*Organophosphorus compounds and PCBs were not detected in samples.

NOAA Effects Range Low (ERL) and Effects Range Median. ERL - concentrations above which adverse biological effects may be expected 10% of the time. ERL - Concentrations above which adverse biological effects may be expected 50% of the time.

OME - Ontario Ministry of Environment and Energysediment quality guidelines, including lowest effects levels (LEL), levels that could affect the most sensitive 5% of the species, and severe effect levels (SEL) in which 95% of the species could be affected.

FDCE - Florida Department of Environmental Conservation, including: Threshold Effect Level (TEL), and Probable Effect Level (PEL)

CISQG - Canadian interim sediment quality guidelines (1998) for freshwater sediment, including: interim sediment-quality guideline (ISQC) and probable effect level (PEL).

BCMWLA - British Columbia Ministry of Water, Land and Air Protection Water Qualty Guidelines (Criteria) for sediment criteria for Polycyclic Aromatic Hydrocarbons (PAHs)

Table 4.15. Comparison of Moran Lake Sediment Quality to Other Areas

Metal	Moran Lake Sediment Testing Data (all reported in mg/kg): 11/26/03	02/05/1980[1]	08/76[2]	Regional Sediment Concentrations, mg/kg dry weight, Mean and (Range): Crandal Creek DUST Marsh System[3]	Alameda County[4]	USACOE Marsh Study[5]
Chromium	14.4 (13.9-18.2)	5.3	9.5	113 (58-140)	55 (29-104)	181 (110-224)
Copper	9.5 (2.7-14.0)	NA	NA	53 (12-410)	76 (13-1500)	63.8 (24.2-90.6)
Lead	14.3 (1.9-20.6)	22.84	50	72 (4-673)	113 (5.8-640)	35.4 (13.7-85.6)
Zinc	69.6 (14.2-102)	NA	NA	164 (50-769)	246 (49-2600)	143.3 (88.5-166.1)
Mercury	0.0508 (<0.0200-0.0564)	NA	0.007	0.25 (0.18-0.40)	0.23 (<0.03-0.98)	0.33 (0.059-0.515)

NA - Not Analyzed

References:

1. Stern, G. and P. Courter. 1980. *Report on Environmental Baseline Study for the Moran Lake Enhancement Plan, Santa Cruz, California*
2. Singer, S. and R. Aston. 1976. *A Staff Report on Moran Lake: Its Problems and Solutions* . County of Santa Cruz, California
3. Woodward-Clyde. 1998. *Demonstration Urban Stormwater Treatment (DUST) Marsh Long Term Evaluation.* Alameda Countywide Clean Water Program
4. Alemada County Clean Water program. 1998. Sediment sample results from 10 creeks and flood control channels
5. Lee, et al.. 1992. US Army Corps of Engineers, analysis of sediment data from natural wetlands in San Francisco Bay Area

4.4. Summary of Findings

1. Eutrophic and hyperhaline conditions in Moran Lake have been well documented since the mid 1970's. Several factors are contributing to this including poor circulation and flushing during the summer months and nutrient rich runoff entering the lagoon from urbanized lands.

2. Historical and recent testing continue to detect high concentrations of fecal coliform bacteria indicating the lagoon is receiving contaminated runoff from the surrounding urbanized areas. Although historic testing may have indicated sewage overflows from the treatment plant that once existed at Lode Street, it is likely that present coliform contamination comes from multiple sources, including domestic animals, leaking sewers, and wildlife (most notably water fowl) residing in the lagoon or riparian corridor.

3. A reduction in lagoon surface area and volume has diminished the ability of Moran Lake to dilute and treat contaminants.

4. In general the pH of the lagoon tended to increase as the lake became more eutrophic and saline. When the lagoon sand bar breached the pH dropped dramatically when the lagoon was primarily freshwater.

5. Eutrophic or highly enriched watercourses, such as Moran Lake show highly varying levels of dissolved oxygen (DO). During early morning periods DO is suppressed with low concentrations, while in the late afternoon DO may be very high due to algae and other aquatic vegetation releasing DO into the water column. Urban pollution and storm water runoff act to decrease dissolved oxygen concentrations in lake water. Polluted runoff containing degradable organic matter introduced to a water body such as Moran Lake, exert an oxygen demand during the assimilation and decomposition of these waste products. This oxygen demand can deplete DO concentrations, creating unsuitable conditions for aquatic organisms.

6. Water temperatures were relatively uniform throughout the lagoon and were generally higher (between five to ten degrees) than surface water entering the lagoon from Moran Creek. Due to the shallow conditions in the lagoon water temperatures did not vary significantly from the surface to the bottom of the lagoon, which would normally occur in a natural and unfilled coastal lagoon. The increased temperature results from the high heat capacity of the lagoon resulting from the thick biomass in the water column, combined with shallow water depths.

7. The highest concentrations of total phosphorus, nitrate-N (NO_3^-), ammonia-N (NH_3), and organic-N were measured during the first flush sampling event on October 31, 2003. These nutrient concentrations are significantly higher than those measured on other occasions. The increased concentrations are a result of urban pollutants, such as waste products and lawn fertilizers, which were transported into the lagoon by storm water runoff.

8. Total suspended solids measurements completed during the summer and early fall shows how the character of the lagoon water quality is distinct in these two periods. Samples collected during the summer months of June and July represent conditions during which the majority of TSS is algae floating in the water column. During this period the TSS concentrations ranged from approximately 5 mg/L to 35 mg/L. Samples collected in October during the first flush event had substantially higher TSS concentration ranging from 60 to 92 mg/L, which was composed primarily of fine inorganic suspended solids, which are attributed to storm water runoff entering the lagoon from Moran Creek and local Lake drainage sources.

9. Salinity in the lagoon increases from June to October, when the lagoon tidal inlet closes and evaporation increases salt concentrations. The highest salinity measurements were measured in August and September, and were in excess of 35 ppt, approaching hyperhaline conditions. Salinity levels in the lagoon decreased rapidly during the first flush, when high freshwater flows entered the lagoon from Moran Creek, further demonstrating that the volume and dilution capacity of the lagoon is very small relative to the watershed drainage area.

10. General mineral analyses conducted in June, July and October clearly indicate that during the summer months the lagoon is filled primarily with salt water and the major ions in solution include chloride and sodium. During the first flush event, the water quality in the lagoon shifted rapidly to represent freshwater conditions.

11. The concentration of trace metals varied significantly both spatially and seasonally. During the summer months the trace metals concentration was very low for all three metals tested (copper, lead and zinc) in the lagoon and Moran Creek. However, the highest concentrations during this period were routinely detected in the samples collected from Moran Creek which receives dry weather runoff from urbanized areas. Dry weather runoff includes runoff from streets and driveways, construction- related washing activities, car washing, and over spray from landscape irrigation systems. A sample collected in late October during the first significant rainfall event ("first flush" event) contained significantly higher concentrations of these metals, which could adversely affect aquatic organisms.

12. Comparing the test results to the different water quality criteria indicate that during the first flush event, all three metals were measured at concentrations that exceed several criteria. Total copper concentrations were measured in Moran Creek and at two locations in the lagoon at levels that exceeded both acute toxicity (1-hr average) and chronic toxicity (4-day average) criteria established by the California Toxic Rules (CTR) and Water Quality Control Plan for the Central Coast Region, established to protect both fresh and saltwater aquatic life. Total lead concentrations were measured during this event at levels that exceeded the CTR chronic criteria. Total zinc concentrations measured during the first flush event exceeded both acute and chronic toxicity levels at all sample locations in the creek and lagoon. The test results indicate that runoff from urbanized areas in the watershed discharge significant and potentially toxic levels of copper and zinc to Moran Lagoon.

13. The total concentration of zinc is typically what has been found in runoff collected other urban areas throughout the United States. Copper concentrations were also comparable to average concentrations encountered in National Urban Runoff Pollution studies undertaken by the U.S. Environmental protection Agency in the 1980's. Lead concentrations are substantially lower than what has been measured in other earlier studies in the Lagoon and nationwide, suggesting either the increased use of unleaded fuels has reduced the concentration of lead in runoff or runoff entering the creek and lagoon are substantially diluted. The concentration of zinc and copper suggests that runoff is not well diluted in the creek or lagoon and that the water in the lagoon is primarily urban runoff.

14. The concentration of the all metals tested in near surface sediments from Moran Lake are below reported Sediment Quality Benchmark values indicating that the metal concentrations in the surface sediments are at levels that are not potentially toxic to benthic organisms.

15. Comparing the 2003 sediment data to the earlier test results indicate that chromium concentrations appear to have increased, but the concentration is relatively low compared to other urbanized watersheds in the San Francisco Bay Area. Lead concentrations measured in 2003 appear to be slightly lower than those measured in 1980, which was lower than concentrations measured in 1976. Mercury concentrations appear to have increased in 2003, as compared to results tested in 1976; however, the higher concentration may be attributed to better analytical methods and levels of detection.

16. Metal concentrations detected in Moran Lake sediment samples are relatively lower than sediment collected from other streams and wetlands in the San Francisco Bay Area.

17. Sediment samples detected the presence of several PAHs. Principal source of PAHs is from roads, parking lots and vehicle service areas. Several of the PAH compounds detected are carcinogenic compounds and other compounds are potentially toxic to aquatic life. Comparing the PAH concentrations with different sediment quality benchmarks indicate that the phenanthrene, chrysene, benzo(a)anthracene and benzo(a)pyrene exceed criteria established by the British Columbia Ministry of Water, Land and Air Protection for protection of freshwater organisms. The total concentration of PAHs is elevated, but is below the low and median effects levels established by the National Oceanic and Atmospheric Agency (NOAA). Based on the more conservative and contaminant specific criteria established by British Columbia, the levels of PAHs detected in the sediment may be impairing benthic and other aquatic life in the lagoon.

18. Sediment test results detected total chlordane levels well above the probable and threshold effects levels established by several agencies. The results indicate that the residual and persistent chlordane levels in lagoon sediments may adversely affect aquatic life in the lagoon.

5. Restoration Options

Restoration opportunities exist in the Moran Lake watershed to improve water quality and habitat conditions in the lagoon. Many opportunities are present in the immediate vicinity of the lagoon, while other projects and actions can be taken in the upper watershed area.

Restoration options presented below include a broad spectrum of activities, including physical restoration projects, storm water management and treatment, recommendations for environmental education, site planning and design standards with the objective of reducing impervious cover in the watershed.

5.1. Lagoon Restoration and Education Opportunities

This section identifies restoration and environmental education projects that could be implemented in the immediate vicinity of the lagoon.

5.1.1 Improve Lagoon Water Circulation

Historical and ongoing water quality testing clearly indicates that lack of circulation and infrequent flushing of the lagoon with fresh and/or salt water is impairing water quality and aquatic life in the lagoon. As previously discussed many factors affect circulation, mixing and the occurrence of freshwater and tidal flushing in the lagoon. In review, these factors include the freshwater inflows, lagoon volume, frequency (how often) and duration (how long) the lagoon remains open or closed. Many of these factors are random or commonly referred to as stochastic variables that can vary both seasonally and annually depending on many conditions.

To improve circulation in the lagoon several different approaches could potentially be taken, such as, modifying the inlet to attempt to increase tidal and stream flushing, enlarging and deepening the lagoon to near its original size, actively managing the lagoon entrance (breaching the sand bar and removing sediments in culvert), installing an aeration system to increase biological decomposition of detritus and maintain higher levels of dissolved oxygen in the water column, and possibly augmenting stream flow with highly treated reclaimed wastewater. In all cases a more detailed technical and economic analysis would be required to assess the overall technical feasibility and benefit derived from the various alternatives. The following sections provide a brief summary of potential merits or constraints related to each alternative.

Modify Lagoon Inlet

As previously discussed a significant concern is that the lagoon inlet may limit the opening and closing of the inlet, and reduce circulation and tidal flushing of the lagoon resulting in degraded water quality and aquatic habitat conditions. The existing box culvert, an engineered structure, fixes the position, cross-sectional area, and depth or grade of the inlet channel. In a natural lagoon system the inlet is in a state of dynamic equilibrium, meaning that the inlet configuration (location, cross-sectional area and depth) responds primarily to seasonal variations in the water flow, water levels, littoral drift, and wave action. The culvert and roadbed have “stabilized” the lagoon inlet preventing the natural migration of the inlet channel in response to wave and storm events. Maintaining a stable inlet is also important to protect public infrastructure and private properties surrounding the lagoon from flooding.

Research efforts to understand and predict a “stable” or equilibrium flow area of a tidal inlet indicate that the cross-sectional area of an inlet is primarily a function of the tidal peak discharge, the mean tidal range in the sea, and the annual littoral drift. A review of beach profiling data indicates that the annual opening and closing of the lagoon may not be limited by the cross-sectional area of the inlet channel. However, if the opening were broader, it is likely that the lagoon may expand southerly beyond East Cliff Drive and onto the beach (as occurs at Corcoran Lagoon, see Figure 5.2). Similarly, if the opening of the lagoon was modified with a clear span bridge or arched bottomless culvert the lagoon would be able to equilibrate to a more “natural state”. How that would influence the frequency of opening and closing is difficult to predict without detailed hydrologic modeling. Historical studies of the San Dieguito Lagoon in Del Mar, California indicated that the opening and closing of the lagoon is principally a function of flood flows.

As previously described the lagoon inlet is a box culvert with a fixed bottom as shown in Figure 5.1. The culvert also fixes the depth of the lagoon inlet to -1 foot below mean sea level (msl). This elevation is most likely higher than would naturally occur if the inlet channel was not fixed or the bed of the channel was moveable. If the inlet channel were to be modified as a moveable bed, the depth of the inlet would change both seasonally and annually depending on storm flows and wave action affecting littoral drift and ephemeral bar formation. It is expected that the “equilibrium” elevation of the new channel would be deeper than the current elevation.

Figure 5.1. Moran Lake Outlet (September, 2002)

Figure 5.2. Corcoran Lagoon (September 2002)

The potential benefits of modifications to the lagoon inlet include increasing the frequency of lagoon flushing, increasing lagoon volume, and improving water quality within the lagoon.

Replacing the box culvert with an arched bottomless culvert or clear span bridge would not impede the lagoon inlet to a fixed depth, which may increase tidal flushing and the frequency of lagoon opening and closing. Figure 5.3 presents examples of a bottomless arched culvert used to restore stream and lagoon functions in sensitive habitat areas. However, limited beach profiling information collected during the period of study suggest that the inlet configuration at Moran Lake may function similar to an unimpaired lagoon system, with seasonal fluctuations of the ephemeral bar on the Moran Lake beach controlling the connection of the lagoon with the ocean.

Figure 5.3. Examples of Bottomless Arched Culvert Crossings

Replacing the box culvert with a new culvert or clear span bridge could modify the lagoon substantially. During wet years, flood flows could cause the lagoon inlet channel to scour and lower, and/or storm surges and wave action combined with high flows could result in more extensive bank erosion, as compared to what has been experienced in recent years. This change could result in further bank instability and erosion and possible damage to public and private properties. A change in the culvert size or invert elevation could also increase lagoon salinity affecting sensitive species such as tidewater goby and monarch butterfly. Further analysis would be required to more thoroughly assess the potential benefits and impacts associated with a modification of the existing culvert.

Enlarge and Deepen the Lagoon

Enlarging and deepening the lagoon to the original size and configuration is not considered feasible at this time due to the extent of surrounding development and existence of sensitive species' habitat. Reshaping and enlarging the lagoon would require dredging and be a major undertaking. The water quality benefits achieved are unknown at this time. Federal, state and local permits would be required, and proper disposal of potentially contaminated dredge spoils must also be considered.

Manage the Lagoon Entrance (Breach the Sand Bar)

A common practice previously implemented at several large lagoons in the Monterey Bay region, included the active breaching of sand bars. This practice was routinely conducted for flood control, primarily to protect private properties in close proximity to a lagoon from becoming inundated when the lagoon water levels rose in winter or late summer. However, in most instances this practice has been curtailed in response to sensitive species issues. Artifically removing sand from the culvert and excavating a drainage channel between the culvert and ocean is a related technique with similar consequences. Actively managing the sand bar would require a thorough, costly and possibly lengthy environmental review process to obtain and maintain permits to undertake the activities. Artificial breaching could lead to greater ocean- lagoon water exchange, however, the water quality benefit achieved by this action is unknown at this time.

Install an Aeration System

Similar to a wastewater treatment system, an aeration system could be installed in the lagoon to improve water quality. The aeration system would be designed to maintain high dissolved oxygen levels and improve mixing throughout the lagoon and water column. This management option may have some water quality and biologic benefits, but a more detailed water quality evaluation and design analysis would be required to determine the size and the capital, operation and maintenance costs of an aeration system for the lagoon.

Stream Flow Augmentation with Highly Treated Reclaimed Wastewater

Presently, freshwater flows to the lagoon are intermittent, with high flows during the winter months and very low or no flows during the summer. Stream flow augmentation using highly treated reclaimed wastewater, if it were to become available from the County Sanitation District, could be a method to maintain higher water quality in the lagoon. A small satellite wastewater treatment system could be constructed at the Lode Street facility (R. Lather, personal communication 2004). Introducing higher freshwater flows during the dry period would lower the salinity and increase the water level in the lagoon. However, at this time public sentiment may not support this project, and proceeding with this option would require a thorough, lengthy environmental, permitting, public review and education process.

5.1.2 Create Wetlands in Upper Lagoon

Historical fill practices have significantly impacted Moran Lake by diminishing over forty percent of the surface area of the lagoon. This has reduced the volume and depth of the lagoon, which has affected the lagoons ability to assimilate or dilute pollutants entering the lagoon during winter runoff events. Expanding the effective surface area of the lagoon would be beneficial. However, increasing the lagoon area is constrained by development, competing land uses and sensitive species protection (monarch butterfly habitat).

A potential opportunity to create an expanded wetland on public lands within the upper lagoon has been identified. Wetlands have been shown to be effective filters of urban stormwater pollutants, and could reduce the concentration of nutrients, solids, metals and other constituents entering Moran Lake. Figure 5.4 shows County owned land that may be suitable for development of a wetland.

Figure 5.4. Public Land in Upper Lagoon Identified for Possible Wetland

A wetland in the upper lagoon could potentially improve water quality and improve wildlife foraging and nesting habitat within the lagoon. Construction of a wetland would also develop more natural hydrologic conditions within the lagoon by restoring a wetland area where it likely existed historically. Figures 5.5 and 5.6 present a conceptual layout and cross section of how a wetland in the upper lagoon could be constructed. The wetland could incorporate walking trails for public access, as well as multiple pools with varying depths to maximize pollutant removal and habitat diversity.

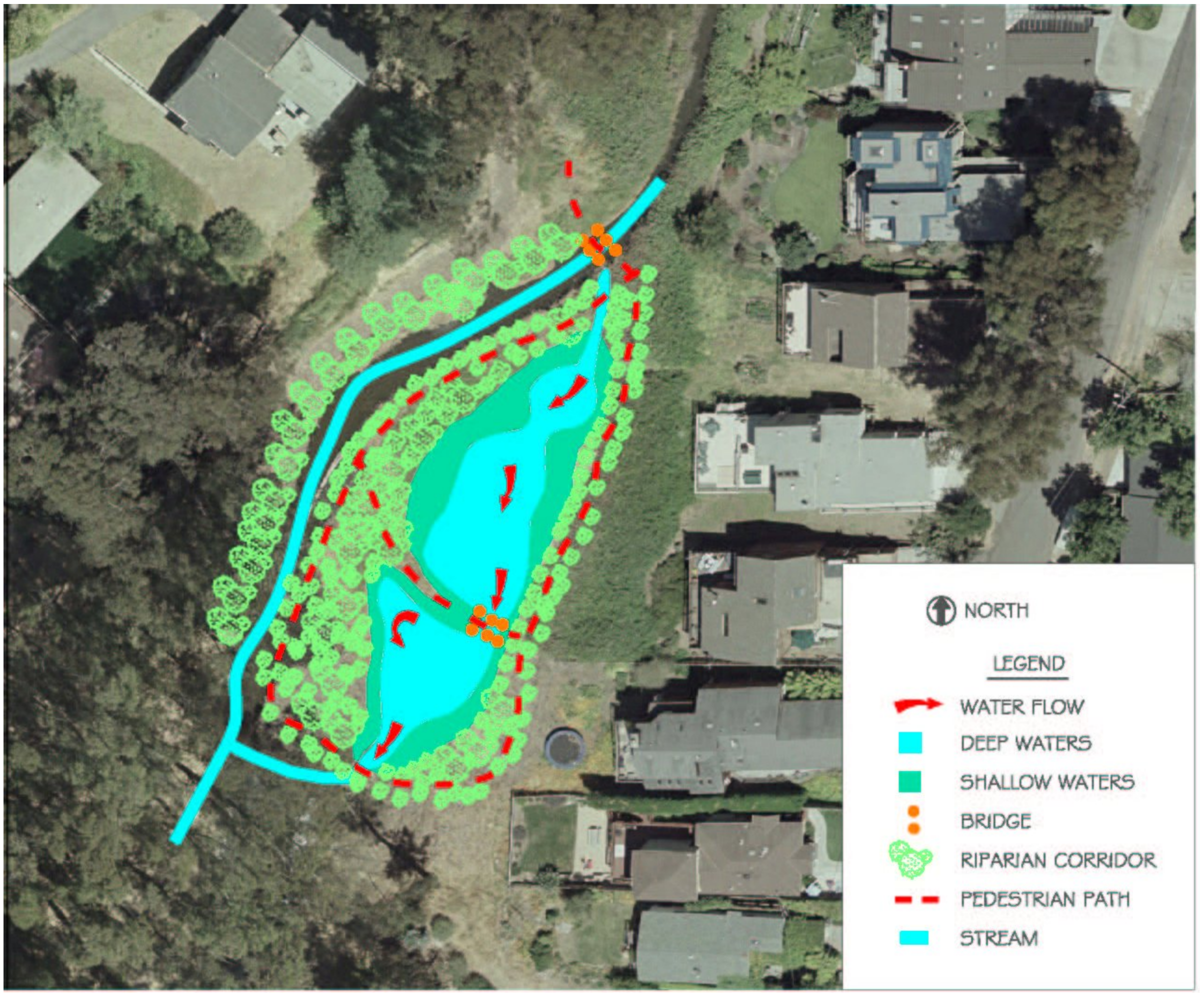

Figure 5.5. Conceptual Layout of Proposed Wetland in the Upper Lagoon Area of Moran Lake

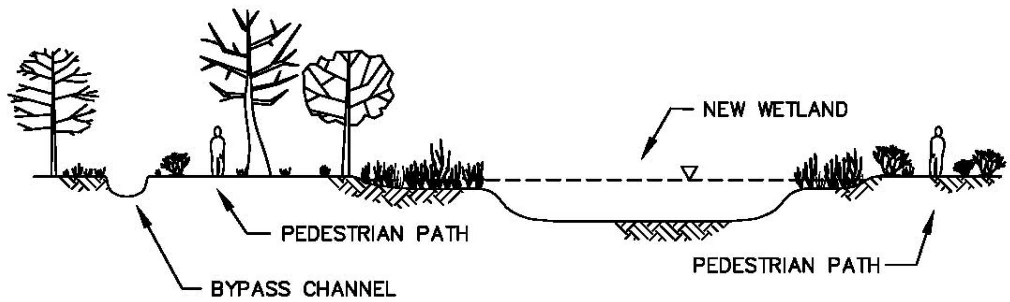

Figure 5.6. Cross-Section of Restored Wetland Area

The appropriate wetland depths, configuration, mix of wetland plant species, inlet and outlet structures need to be considered in final design of this facility. Future investigation into the creation of wetlands in the upper lagoon should consider the issue of mosquito abatement, particularly the public health issues associated with West Nile Virus, and the proper management of the wetland during high and low flow periods. This alternative would also require a significant environmental and public review process.

5.1.3 Reshape Bank Slopes and Restore Lagoon Fringe Wetlands

Due to urban development adjacent to the lake wetlands that once likely existed along the edges of Moran Lake have been destroyed. Concurrent with the removal or alteration of fringe wetlands, diminished vegetation and increased flows from a mostly impervious watershed have resulted in failing banks at some locations along the shore of the lagoon. The most notable failure has occurred on the lower east lagoon bankslope. Figure 5.7 shows the failing bank and its proximity to a frequently accessed bike trail. (A portion of the slope near the lagoon outlet has been reinforced with riprap.)

Figure 5.7. Eroding Bank on the Eastern Shore of Moran Lake (Photos taken on September 11, 2003 (lower) and February 2, 2004)

Undertaking a bank stabilization project is important to protect the bicycle path and to reduce further erosion. A bank stabilization project that employs a biotechnical solution, incorporating a combination of vegetation and structural elements, is desirable to restore the bank to a more natural configuration and to restore habitat value to the disturbed area.

A conceptual bank stabilization project is proposed utilizing a biotechnical approach to stabilize the bank to protect the bicycle path and improve wetland habitat along the fringe of the lagoon. The conceptual plan would regrade the existing steep bank to a 2.5:1 to 3:1 slope from the crown of the slope and incorporate a low terrace or bench at the toe that can be planted with native brackish wetland species. The upper bank could be planted with salt tolerant upland herb and shrub species with the upland flat planted with scattered trees, herbs, and grasses. This design would have the benefits of creating additional wildlife habitat while reducing or eliminating the current rate of bank erosion. In order to protect the bicycle path and adjacent upland, the restored bank may need to be rebuilt in a westerly direction recapturing the bank lost to erosion. Figure 5.8 is a cross section showing a conceptual design of the restored bank.

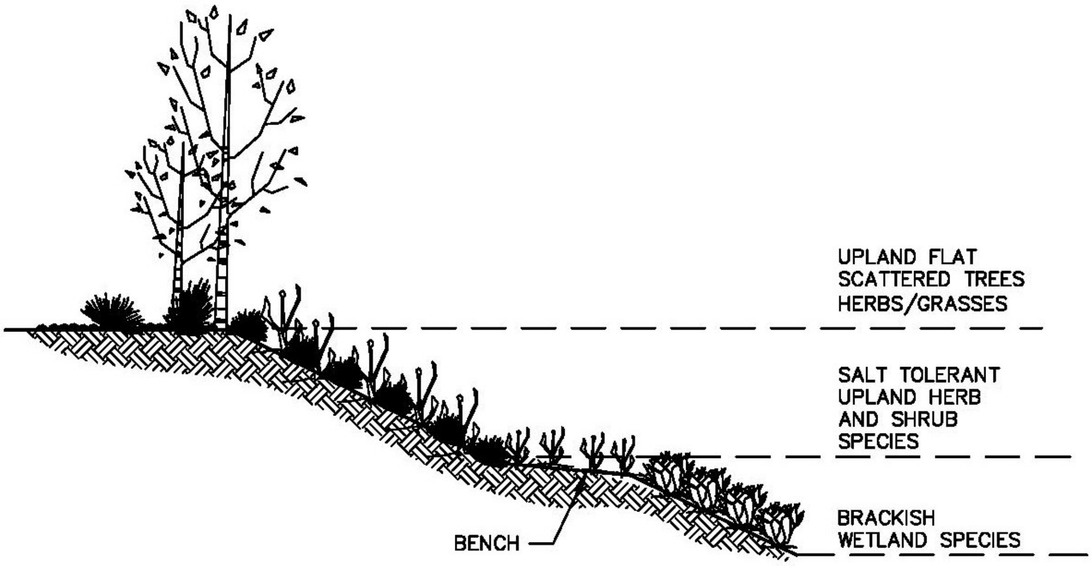

Figure 5.8. Cross-Section showing the Conceptual Layout of Restored Bank on Eastern Shore of Moran Lake

Further engineering analysis of this project may indicate the need to incorporate some additional structural protection (such as a crib type wall to reduce the slope of the bank) or hardscape (such as riprap at the toe of the bank to protect the toe of the bank from excessive scour) combined with the vegetative treatment.

5.1.4 Remove Non-Native Plants and Restore with Native Wetland and Upland Species

Many of the native plants that once lined the banks, shores and upland areas adjacent to Moran Lake have been removed, disturbed, or replaced with non-native species. The highly invasive exotics are of the most concern. To restore the lagoon and upland habitats to a more natural condition, removal of non-native plants and replacement with native wetland and upland species is recommended. Removal of non-native species along Moran Lake would eliminate aggressive species that can rapidly spread into adjacent natural areas. Complete elimination of the ice plant, French broom and Himalayan blackberry is recommended. Replacement with natives should follow a detailed revegetation plan that indicates species composition, planting guidelines, irrigation and other maintenance requirements, and a monitoring protocol. Figure 5.9 is one example of an area covered with iceplant (*Mesembryanthemum* spp.) which could be removed and revegetated with wetland and upland plants that would also provide slope protection. Exotics removal and revegetation should be handled in phases and coupled with erosion control to prevent slope destabilization during implementation. The hands on work of exotics removal and native plant installation would also provide an opportunity to involve volunteers from the Moran Lake community.

Figure 5.9. Possible Location for Revegetation with Native Plant Species (Area presently covered almost exclusively with non-native ice plant)

The eucalyptus groves within Moran Lake County Park provide critical Monarch butterfly habitat. Therefore elimination of eucalyptus (also somewhat invasive) is not recommended, but management of trees in these areas should follow guidelines contained in the Monarch Management Plan (Janecki et.al. 2002). English ivy and Cape ivy are highly invasive exotics that are growing beneath and up eucalyptus trees. As these species are one of few nectar sources for butterflies during fall and winter months, it is recommended they be retained and controlled only in high density butterfly areas. They should be selectively removed in other locations where they are spreading, and replaced with compatible native or non-invasive ornamental nectar plants.

5.1.5 Interpretive Trail and Signing

The existing trails within the Moran Lake County Park are well used and present an opportunity to develop an interpretive trail and signing. The unique lagoon ecosystem and monarch habitat provide educational themes for community members, visitors, and students. Possible signing themes include: lagoon wetland functions in maintaining/enhancing water quality; wildlife species information, including habitat and species' life cycles; monarch butterfly habitat, migration, winter roosting, and importance of specific microclimate conditions; and native plant species' identification and recognition. An example of the type of visual and factual information an interpretative sign could include is shown in Figure 5.10.

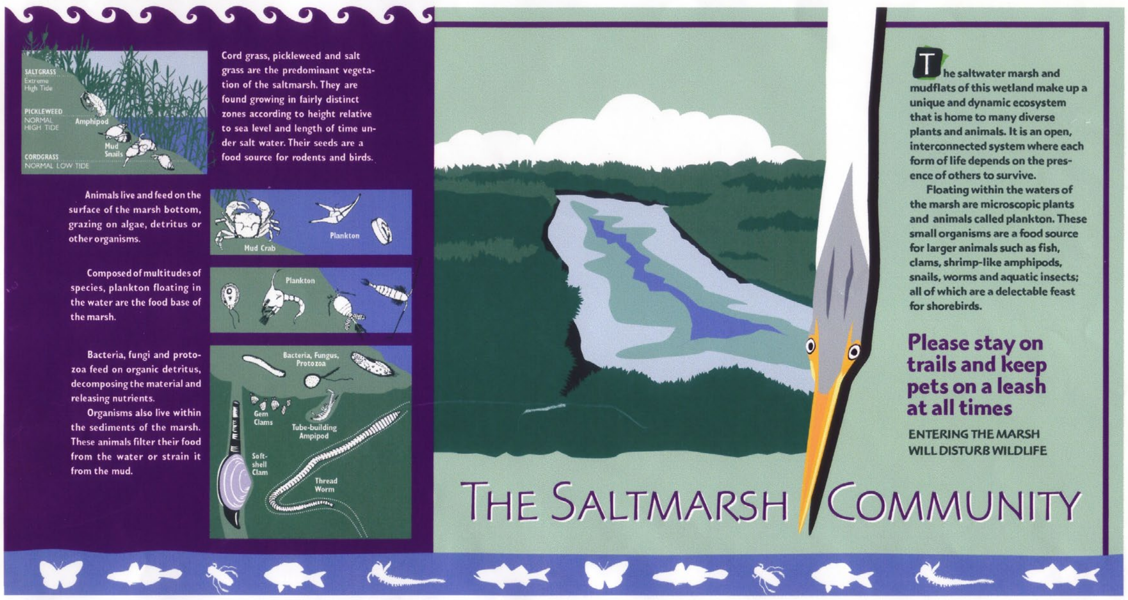

Figure 5.10. Example of Interpretive Sign (S. Erspalmer, Design Science, 2001)

The Monterey Bay Marine Sanctuary has recently placed a sign near the parking lot at Moran Lake County Park, and any future development of interpretive signs in the area should be consistent and compliment this existing sign. In developing the interpretive signs, careful consideration should also be given to protection against vandalism.

5.2. Watershed Restoration

This section presents a series of potential restoration opportunities that may be undertaken in the upper watershed of the lagoon. The primary goals of these projects are to establish better storm water treatment/ filtration systems, restore stream and riparian habitats, create better groundwater recharge, and reduce the need for costly flood control engineering measures.

5.2.1 Water Treatment Wetland at 38th Ave. Detention Basin

The existing storm water detention basin located at 38th could potentially be modified to function as a storm water treatment wetland during low flow events. The existing detention basin could be reconfigured to divert runoff through the wetland during low flow periods. During high flow events the wetland would be temporarily inundated, allowing it to capture nutrients, bacteria and heavy metals contained in urban runoff. The wetland could improve surface water quality entering the lower reaches of Moran Creek and ultimately the lagoon. The wetland could also be designed to provide wildlife habitat. A conceptual layout of how the 38th Avenue detention basin could be reconfigured to a low flow stormwater wetland is presented in Figure 5.11.

Figure 5.11. Conceptual Layout of 38th Avenue Detention Basin Modified to Include a Stormwater Wetland

Additional engineering and hydrologic analyses are required to develop a detailed conceptual and/or preliminary design of a stormwater wetland in the detention basin. It will be important that the new facility be able to provide an equivalent level of flood control currently provided by the detention basin. Further analysis will also be necessary to evaluate the actual water quality benefits to downstream watercourses provided by a modified basin.

5.2.2. Restore Moran Creek Riparian Corridor

Development in the Moran Lake watershed has significantly reduced the Moran Creek riparian corridor and floodplain. At many locations the Moran Creek channel has been placed in underground culverts. In other areas development has encroached into the riparian corridor eliminating the low flood terrace and riparian vegetation that plays an important role in natural stream function. It would benefit the overall condition of Moran Lake to restore the floodplain and riparian corridor to a more natural function to the extent practicable. Any opportunity to restore undeveloped or redeveloped lands to increase the stream corridor and daylight the stream would be a significant benefit to the watershed.

In areas where a narrow above-ground channel exists, widening of the stream corridor to provide for a functional riparian corridor buffer should be considered. High density development and urbanization severely limit restoration opportunities, and any possible stream restoration will be tied to new land use projects. Figure 5.12 presents a conceptual layout and cross section of an above-ground portion of Moran Creek that could be considered for restoration as land use in the area changes. The restoration concept plan suggestswidening and reshaping the stream channel to a more natural meandering flow path.

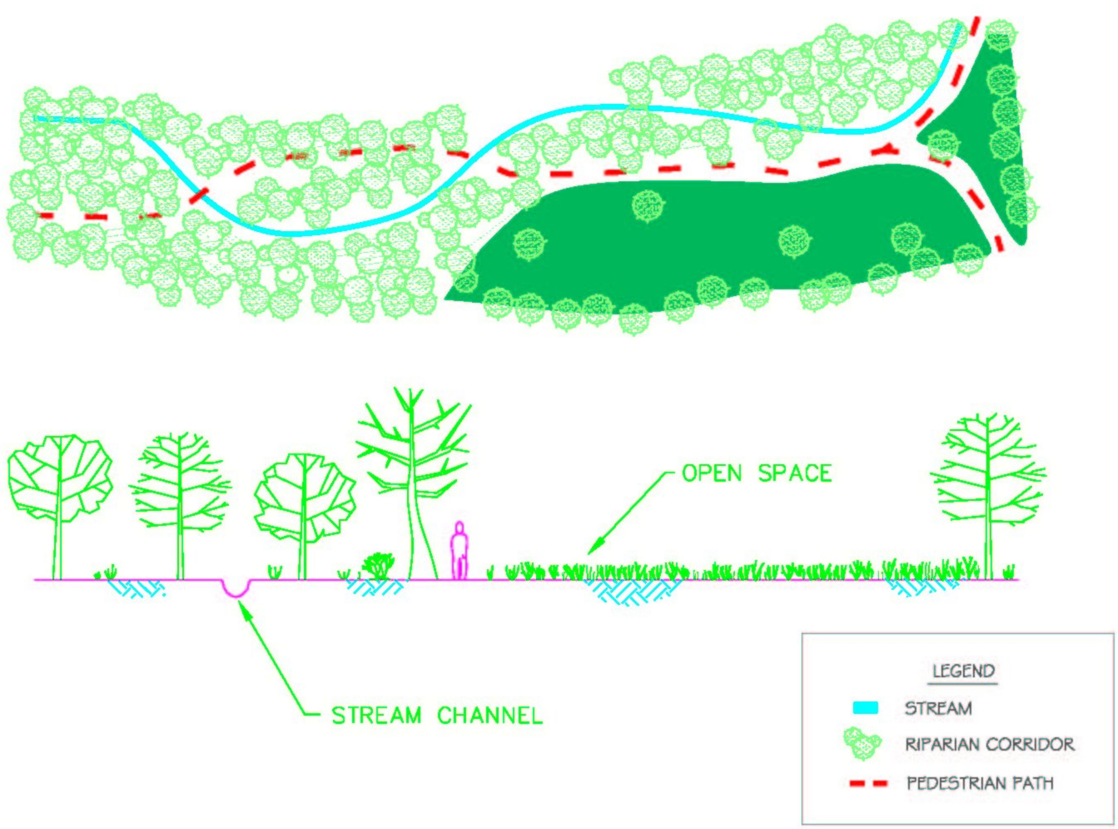

Figure 5.12. Conceptual Layout of Moran Creek Stream Restoration

5.3. Storm Water Management and Treatment

Adopting new storm water control measures are an important step towards reducing the amount of pollutants from urbanized areas in the watershed in order to protect the lagoon and Monterey Bay. Presently, a substantial number of source control and treatment best management practices (BMPs) are available to reduce pollutants (see Appendicies B&C). The following section presents a summary of the available BMPs that can meet a variety of treatment and site restoration goals. Several of the BMPs are landscaped-based techniques, such as bioretention and vegetated swales and constructed wetlands. These types of BMPs can achieve a high level of contaminant reduction, provide for ecologic restoration, and are considered integral to the restoration of water quality in the lagoon.

This section of the report provides a general overview of the type and use of BMPs. The information provided is not intended to be used for design purposes; several other technical resources area available for the site-specific design of BMPs. A list of technical resources is presented in Appendix C.

5.3.1. Innovative Site Design

Considering that many of the future projects in the urbanized areas will require substantial new site development, the opportunity exists to address storm water management at the onset of a project through the site planning and design process. Adopting innovative planning and design approaches that can minimize the volume, speed and quantity of pollutants released from the site will in turn reduce the size of structural BMPs required.

Several factors contribute to storm water degradation in a conventional development. Large paved roads and parking surfaces create and collect runoff. Building sites may be graded substantially, altering runoff patterns and removing natural vegetation that absorbs runoff. The curbs, gutters, and catch basins collect runoff and carry it rapidly, proving little opportunity for treatment or infiltration. Consequently large quantities of runoff may be carried to a conveyance storm water system, discharging sediments and other pollutants directly to the creek, lagoon and Monterey Bay.

Innovative approaches to site design can be incorporated into the planning and development process to reduce the volume and improve the quality of runoff leaving these sites. Innovative site design techniques employ a variety of methods to reduce total paved area, distribute and diffuse storm water, and conserve natural or landscaped areas. The approach seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase landscaped areas or natural areas set aside for conservation and recreation, and to use pervious areas for more effective storm water treatment. To meet these goals designers and planners must scrutinize every aspect of a site plan – its streets, sidewalks, driveways, and parking spaces, to determine if these elements can be incorporated. At the same time creative grading and drainage techniques should be employed to reduce the volume of storm water runoff and direct runoff to natural landscaped areas maximizing site infiltration and passive treatment of pollutants.

5.3.2. Storm Water Control and Treatment BMPs

A variety of storm water control and treatment BMPs can be selected for a site, including source control measures, and structural and non-structural treatment BMPs. Source control measures include a variety of hazardous materials management systems, such as enclosed fuel and hazardous material storage areas, secondary containment measures for fuel, waste oil and other hazardous wastes, street sweeping, and diversion of washwater and other process flows to the County's sanitary sewer system. Typical structural BMPs include various types of in-line filters and cyclonic separation technology. Non-structural BMPs typically include landscape based natural treatment systems, including bioretention areas, grass swales, constructed wetlands and other passive treatment systems. Appendix B includes an overview of storm water control practices, including source control measures, filtration control measures, and detention type storm water treatment systems.

5.3.3. Performance Standards for Storm Water Management

The greatest opportunity to protect water quality and reduce storm water runoff can occur during site planning and the design phase of any project. Therefore, adopting performance standards or criteria addressing site design standards is a critical element of any storm water management program. Early planning efforts afford the designer the opportunity to identify multi-site conjunctive uses including storm water control measures. Additionally, establishing performance standards for storm water best management practices clarifies the planning, selection and design of the specific BMPs appropriate for the site and related land use activities. New development opportunities in the Moran Lake watershed could provide the County and City of Capitola with an opportunity to adopt alternative site design standards that can reduce impervious surfaces and storm water runoff from these areas. Appendix C outlines typical site design performance standards and design standards for storm water management and treatment best management practices.

5.4. Public Education and Outreach

Development of public education and outreach projects within the Moran Lake watershed would ultimately benefit the lagoon by increasing awareness about lagoon functioning and proper watershed practices. Possible outreach could include informational brochures to community members, interpretive signs, and community activities focused on the stream or lagoon awareness, education and restoration. Simple brochures could be prepared addressing the importance of stream stewardship. For example, maintaining good water quality practices means not using the creek, drainage inlets or lagoon as an urban waste dump. The adverse effects of toxic chemicals on long-term habitat quality and public health should also be emphasized.

Possible community actions include formation of a watershed group through the California Coordinated Resource Management and Planning (CRMP) process, or developing a volunteer water quality monitoring effort through the Coastal Watershed Council (CWC). Outreach could also be accomplished through organization of community members to volunteer for stream cleanup and exotic plant species' removal. Public and educational workshops about Moran Lake would also help to strengthen a commitment from residents within the Moran Lake watershed to protect and restore the lagoon. Special attention should be given to upper watershed land uses especially commercial uses along 41st Avenue and Portola Drive, and the numerous mobile home parks within watershed.

6. IMPLEMENTATION

A series of restoration projects and programmatic activities have been presented in the previous section. In this section a general review of planning and implementation options is outlined for restoration, public education, and programmatic activities. Preliminary cost information is also presented for the projects. A preliminary constraint analysis that reviews the potential benefits and constraints associated with each project is also presented to rank and prioritize the projects.

6.1. Planning and Implementation

Several tasks are required to plan and implement the various restoration and programmatic activities outlined in this plan. In order to carry out many of the restoration projects, additional technical studies, engineering analysis and design, and environmental review and permitting will be required. Public resources of both staff time and funding would be required to implement several of the programmatic activities.

6.1.1. Funding

Because County funding sources are limited, other sources should be reviewed for partial or full funding of projects listed below. Current possibilities include the California Coastal Conservancy (grants and loans for coastal access and wetland enhancement), US Environmental Protection Agency and California State Water Resources Control Board (water quality grant funding) and the Monterey Bay National Marine Sanctuary.

6.1.2. Restoration Project Implementation

Planning and implementing a restoration project normally involves several phases of work, including:

1. Planning and technical analysis;
2. Environmental review and permitting;
3. Engineering and preparation of construction documents; and
4. Project implementation or construction.

Planning and Technical Analysis. At the initial phase of a project, additional data gathering, such as a topographic survey and completion of technical studies, including hydrologic, biotic and archaeological studies may be necessary to evaluate the feasibility and/or design and permit a project.

Environmental Review and Permitting. Once a project is considered feasible and supporting technical studies have been completed, the project will undergo an environmental review process to comply with the California Environmental Quality Act (CEQA). At this stage of project an environmental site assessment study may be conducted to determine the potential for adverse environmental effects that may require mitigation or alteration of the project design. Relevant CEQA documents would be prepared and subject to a public review process. Once the environmental review process is conducted, local, state and/or federal permits may need to be obtained in order to execute a project.

Preparation of Construction Documents. Once a project has been approved and permitted, construction documents are prepared. These documents typically include engineering design plans and specifications, an engineering cost estimate for the project, and construction bid and contract documents.

Project Implementation. Project implementation or construction typically involves pre-project, construction and post construction activities. Pre-project activities for many restoration projects occurring in stream and wetland settings can involve pre-project biotic monitoring, installing temporary dewatering or stream diversion systems, construction surveying and establishing a construction staging area. Once the pre-project activities are completed the project is constructed. After completion post-construction activities are commonly required to clean up the construction zones, and monitor and maintain the project, usually for a three to five year period.

Section 6.2 presents preliminary cost estimates to plan and construct seven proposed restoration and education projects identified in Section 5.

6.1.3. Public Education and Programmatic Activities

In Section 5 public education and programmatic activities have been identified. These include:

- Interpretative trail and signing around Moran Lake;
- Public education and outreach; and
- Storm water management activities.

Interpretative Trail and Signing. As previously discussed the existing trails within the Moran Lake County Park are well used and present an opportunity to develop an educational and interpretive signs. The unique lagoon ecosystem and monarch habitat provide educational themes for community members, visitors, and students. To develop and implement an interpretative trail and signing project the following activities are suggested:

1. Establish a voluntary oversight committee to raise funds and oversee the development and installation of interpretative displays;
2. Begin to acquire funds to plan, develop, and install interpretative displays;
3. Retain an individual or graphics design firm to prepare a plan for the interpretative trail and signing and to prepare the signs.
4. Install (or improve) trails and install signs.

Public Education and Outreach. Several public education and outreach activities have been mentioned in Section 5. In summary the main activities discussed include:

- Formation of a watershed group through the California Coordinated Resource Management and Planning (CRMP) process;
- Organized community activities and informational forums focused on the water quality issues, natural history, restoration of streams and coastal lagoons, and storm water management strategies;
- Storm water and water quality workshops for small commercial and industrial businesses in the Live Oak area;
- Preparation and distribution of informational brochures to community members; and
- Volunteer days for stream cleanup and exotic plant species' removal.

Through the watershed planning activities of the Santa Cruz County Resource Conservation District the community may be able to obtain technical assistance to start a watershed group. Once the watershed group is formed than the group might seek additional funds to hire a part-time coordinator to help organize watershed group activities, and to conduct fundraising activities for broader outreach efforts.

Storm Water Management Activities. Adopting new storm water control measures are an important step towards reducing the amount of pollutants from urbanized areas in the watershed to protect the lagoon and Monterey Bay. Various storm water management and treatment practices are available to reduce pollutants. In Section 5 three major areas of storm water management are outlined:

- Innovative site design;
- Use of storm water control and treatment best management practices (BMPs); and
- Establishing performance standards for site design and storm water control and treatment BMPs.

These activities would be implemented on a county-wide basis under the auspices of the County of Santa Cruz's Storm Water Management Program currently underway. The County Program should consider the recommendations contained in this plan as their activities relate to the Moran Lake watershed area. Additional implementation efforts beyond the County's program are not recommended at this time.

6.2. Project Cost Analysis

Preliminary costs have been prepared for several restoration and public education projects outlined in the plan. Eight separate projects were analyzed:

1. Replacing of the box culvert on East Cliff Drive with an arched and bottomless culvert;
2. Construction of a wetland in the upper arm of Moran Lake;
3. Reshaping and stabilizing the eroded bank on the east side of Moran Lake;

4. Removal of invasive and non-native plants and revegetation with native plantings;
5. Modifying the 38th Avenue Detention Basin to include a storm water wetland on the bottom of the existing basin;
6. Restoring portions of Moran Creek and riparian corridor;
7. Installing interpretative signs around the lagoon.

Costs for forming a watershed group, and conducting public education and outreach activities have not been included, although they are expected to be nominal.

6.2.1. Replacement of the East Cliff Drive Box Culvert with a Arched, Bottomless Culvert

Although limited benefits are expected to be achieved, an arched and bottomless culvert could replace the existing box culvert to restore the lagoon inlet to a more natural configuration. Using an arched culvert to provide a clear span across the lagoon inlet would be a least cost method, as compared to a clear span or trestle style bridge. Preliminary cost estimates for this project are presented in Table 6.1 below.

Table 6.1. Preliminary Cost Estimate for Arched Bottomless Culvert
For East Cliff Drive Crossing

Description	Total Cost
1. Planning and Technical Analysis	
1.1. Topograpic Survey & Mapping	15,000.00
1.2. Hydraulic Analysis	50,000.00
1.3. Preliminary Engineering Analysis and Design	30,000.00
1.4. Preliminary Engineering Costs Analysis	5,000.00
Sub-total	100,000.00
2. Environmental Review and Permitting	
2.1. Phase 1 & 11 Envionmental Site Assessment	10,000.00
2.2. CEQA Review	25,000.00
2.3. Permitting & Fees	20,000.00
Sub-total	55,000.00
3. Preparation of Construction Documents	
3.1. Engineering Design Plans and Specifications	50,000.00
3.2. Contract Documents	10,000.00
Sub-total	60,000.00
4. Project Implementation	
4.1. Site Work (Excavation/Grading, Drainage and Erosion Control)	75,000.00
4.2. Install abutments and wingwalls	100,000.00
4.3. Install arched culvert	250,000.00
4.4. Replace Utilities in Roadway	100,000.00
4.5. Finish Grading and Paving of Roadway	75,000.00
Sub-total	600,000.00
Total Project Sub-total	815,000.00
Contingency (15%)	122,250.00
Total Project Cost =	**$ 937,250.00**

6.2.2. Upper Lagoon Wetland

A wetland in the upper lagoon would improve lower lagoon water quality and create wildlife foraging and nesting habitat. Construction of a wetland would also restore more natural hydrologic conditions within the lagoon by recreating a wetland area where it probably existed historically. Table 6.2 presents a preliminary cost estimate to construct a wetland in the upper arm of the lagoon. The preliminary costs include trails and two small foot bridges to provide for recreational access around the wetland.

Table 6.2. Preliminary Cost Estimate for Wetland in Upper Lagoon

Description	Total Cost
1. Planning and Technical Analysis	
1.1. Topographic Survey	7,500.00
1.2. Hydrologic and Hydraulic Analysis	25,000.00
1.3. Preliminary Engineering Analysis and Design	10,000.00
1.4. Preliminary Engineering Costs Analysis	5,000.00
Sub-total	47,500.00
2. Environmental Review and Permitting	
2.1. Phase 1 & 11 Enviromental Site Assessment	15,000.00
2.2. CEQA Environmental Review	20,000.00
2.3. Permitting & Fees	15,000.00
Sub-total	50,000.00
3. Preparation of Construction Documents	
3.1. Engineering Design Plans and Specifications	30,000.00
3.2. Contract Documents	10,000.00
Sub-total	40,000.00
4. Project Implementation	
4.1. Site Work (Excavation/Grading)	250,000.00
4.2. Install Hydraulic Control Structures	100,000.00
4.3. Revegetation and Erosion Control	50,000.00
Sub-total	400,000.00
Total Project Sub-total	537,500.00
Contingency (15%)	80,625.00
Total Project Cost =	**618,125.00**

6.2.3. Reshape and Stabilize Lagoon Bank

Undertaking a bank stabilization project on the east side of the lagoon is important to protect the pedestrian/bicycle path and to reduce the likelihood of further erosion. A bank stabilization project that employs a biotechnical solution, incorporating a combination of vegetation and structural elements is desirable to restore the bank to a more natural configuration and to restore habitat value to the disturbed area. Access in this area is an important link to the surrounding neighborhood to the east. Table 6.3 presents a preliminary cost estimate for the project.

Table 6.3. Preliminary Cost Estimate for Bank Stabilization Project on east side of Lagoon

Description	Total Cost
1. Planning and Technical Analysis	
1.1. Topographic Survey	5,000.00
1.2. Preliminary Engineering Analysis and Design	10,000.00
1.3. Preliminary Engineering Costs Analysis	5,000.00
Sub-total	20,000.00
2. Environmental Review and Permitting	
2.1. Phase 1 & 11 Environmental Site Assessment	8,000.00
2.2. CEQA Environmental Review	20,000.00
2.3. Permitting & Fees	15,000.00
Sub-total	43,000.00
3. Preparation of Construction Documents	
3.1. Engineering Design Plans and Specifications	30,000.00
3.2. Contract Documents	10,000.00
Sub-total	40,000.00
4. Project Implementation	
4.1. Reshape Eroded Bank (~200 LF)	175,000.00
4.2. Revegetation and Erosion Control	50,000.00
Sub-total	225,000.00
Total Project Sub-total	328,000.00
Contingency (15%)	49,200.00
Total Project Cost =	**$ 377,200.00**

6.2.4. Modify 38th Avenue Detention Basin with a Low-Flow Wetland

The existing storm water detention basin located at 38th could be modified to function as a storm water treatment wetland during low flow events. The existing detention basin would need to be reconfigured to divert runoff through the wetland during low flow periods allowing it to capture nutrient, bacteria and heavy metals contained in urban runoff. During high flow events the wetland would be temporarily inundated, also providing some pollutant retention. The wetland could also be designed to provide some wildlife habitat value. Table 6.4 presents preliminary cost estimates to retrofit the detention basin.

Table 6.4. Preliminary Cost Estimate to Modify 38th Avenue Detention Basin with a Low-Flow Wetland

Description	Total Cost
1. Planning and Technical Analysis	
1.1. Topographic Survey	7,500.00
1.2. Preliminary Engineering Analysis and Design	30,000.00
1.3. Preliminary Engineering Costs Analysis	5,000.00
Sub-total	42,500.00
2. Environmental Review and Permitting	
2.1. Phase 1 & 11 Environmental Site Assessment	10,000.00
2.2. CEQA Environmental Review	15,000.00
2.3. Permitting & Fees	10,000.00
Sub-total	35,000.00
3. Preparation of Construction Documents	
3.1. Engineering Design Plans and Specifications	40,000.00
3.2. Contract Documents	5,000.00
Sub-total	45,000.00
4. Project Implementation	
4.1. Modify Flow Control Structures and Spillways	250,000.00
4.2. Reshape Pond and Soil Disposal	50,000.00
4.3. Revegetation and Erosion Control	50,000.00
Sub-total	350,000.00
Total Project Sub-total	472,500.00
Contingency (15%)	70,875.00
Total Project Cost =	**543,375.00**

6.2.5. Restore Moran Creek Corridor

Development in the Moran Lake watershed has significantly reduced the Moran Creek riparian corridor and floodplain. To enhance the condition of Moran Creek any opportunity to restore undeveloped or redeveloped lands to increase the stream corridor and daylight the stream would be a significant benefit to the watershed. In areas where a narrow above-ground channel exists, widening of the stream corridor to provide for a functional riparian corridor buffer should be considered. For planning purposes, preliminary cost estimates have been prepared to restore approximately 1,000 lineal feet of stream channel in the watershed. These costs, as presented in Table 6.5, do not include any property acquisition costs.

Table 6.5. Preliminary Cost Estimate for 1000 feet of Channel Restoration

Description	Total Cost
1. Planning and Technical Analysis	
1.1. Topographic Survey	10,000.00
1.2. Preliminary Engineering Analysis and Design	25,000.00
1.3. Preliminary Engineering Costs Analysis	5,000.00
Sub-total	40,000.00
2. Environmental Review and Permitting	
2.1. Phase 1 & 11 Environmental Site Assessment	20,000.00
2.2. Environmental Review	15,000.00
2.3. Permitting & Fees	10,000.00
Sub-total	45,000.00
3. Preparation of Construction Documents	
3.1. Engineering Design Plans and Specifications	40,000.00
3.2. Contract Documents	5,000.00
Sub-total	45,000.00
4. Project Implementation	
4.1. Restore 1,000 LF of Stream Channel	500,000.00
4.2. Revegetation and Erosion Control	100,000.00
Sub-total	600,000.00
Total Project Sub-total	730,000.00
Contingency (15%)	109,500.00
Total Project Cost =	839,500.00

6.2.6. Removal of Non-Native Invasive Plants and Revegetation with Natives

Table 6.6. Cost Estimate for Non-Native Plant Removal and Revegetation

Description		Total Cost
1. Planning and Technical Analysis		
1.1. Topographic Survey & Detailed Vegetation Mapping		4,000
1.2. Prepare Exotics Removal and Revegetation Plan		3,000
Sub-total		7,000
2. Project Implementation[1]		
2.1. Exotics removal[2]		15,000
2.2. Nursery Plant Propagation		30,000
2.3. Vegetation[2]		50,000
2.4. Maintenance and irrigation		10,000
Sub-total		105,000
Total Project Sub-total		112,000
Contingency (15%)		16,800
Total Project Cost =	**$**	**128,800**

1. Project phased over a 10 to 15 year period

2. Assumes volunteer labor force supervised by restoration specialist

6.2.7. Interpretative Signs

Table 6.7. Costs for Interpretative Signs and Trails

Description		Total Cost
1. Planning and Technical Analysis		
1.1. Prepare Trail and Interpretative Sign Plan		3,000
Sub-total		3,000
2. Project Implementation		
2.1. Prepare signs (three (3) signs)		8,000
2.2. Install (modify) trails and install signs		6,000
Sub-total		14,000
Total Project Sub-total		17,000
Contingency (15%)		2,550
Total Project Cost =	**$**	**19,550**

6.3. Constraint Analysis

A preliminary constraint analysis has been prepared to identify and rank potential benefits and constraints that would either be achieved or may impede the successful completion any of the projects. The results of the analysis are summarized in Table 6.8. Since the overall goal is to improve water quality and habitat conditions in Moran Lake, the potential benefits include basic water quality and habitat enhancement. Several potential constraints have been identified including:

1. Permit Complexity - The project could require numerous permits and a complex permit approval process

2. Technical Feasibility – Evaluates whether the project directly improves water quality or habitat conditions

3. Property Acquisition – The project may require purchasing private property or securing easements. Costs of this have not been considered

4. Environmental Remediation – The project may require environmental remediation of toxic materials, including environmental testing and remedial corrective action (eg. soil excavation and disposal)

5. Sensitive Species Mitigation - The project may have sensitive species present and would require mitigation of potential impacts or loss of habitat

6. Cost – Program costs are ranked based on cost estimates above

7. Maintenance and Monitoring – Project may require on-going maintenance or periodic monitoring to achieve stated goals

Table 6.8. Benefits and Constraints Analysis

Project	Benefits			Constraint							
	Water Quality Improvement	Habitat Enhancement	Public Awareness and Education	Permit Complexity	Technical Feasibility	Property Acquisition	Environmental Remediation	Sensitive Species Mitigation	Costs	Maintenance Requirements	Monitoring Requirements
A. East Cliff Drive Arched Culvert	7	3	0	4	7	6	7	4	4	6	5
B. Upper Lagoon Wetland	1	2	2	4	5	6	7	6	4	5	5
C. Reshape Bank and Erosion Control	3	1	3	4	6	6	6	6	5	5	5
D. Removal of Non-Native Plants	5	1	1	6	0	0	0	0	6	5	5
E. 38th Avenue Detention Basin	1	3	3	6	6	6	5	6	5	5	5
F. Restore Moran Creek	2	1	2	4	7	4	4	7	4	5	5
G. Interpretive Trail and Signing	3	0	1	0	0	0	0	0	6	6	0
H. Public Education and Outreach	2	2	1	0	0	0	0	0	6	0	0

0 Not Applicable
1 High Potential Success
2 Moderate Success
3 Low Potential Success
4 Significant Constraint
5 Moderate Constraint
6 Low Constraint
7 Unknown

To summarize: 1) The cost-efficient projects, d. non-native plant removal, g. trails/ signing and h. public education will have moderate to major benefits without significant constraints. 2) The moderate and higher cost projects—e. modification of 38th Avenue detention basin, c. erosion control on Moran Lake east bankslope, and b.the upper lagoon wetland also appear to have moderate to significant benefits without major constraints. The County should prioritize these projects and pursue funding from outside sources as needed. 3) Project f., restoration of selected reaches of Moran Creek above the lagoon could be very costly if land acquisition is necessary, but may be less expensive and provide water quality and habitat benefits if restoration occurred as part of the design for new development projects. Coordination with the Planning Department would be necessary to implement this recommendation. 4) Project a., replacement of the East Cliff box culvert with a bridge or arched culvert is also an expensive project that would require further hydrologic and environmental analyses to determine if benefits outweigh constraints.

7.0 References

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Appendix A

Overview of Stormwater Control Practices, Site Design, and Stormwater BMP Performance Standards

Appendix A – Overview of Stormwater Control Practices, Site Design and Stormwater BMP Performance Standards

A.1. Stormwater Control Practices

A.1.1. Source Control Measures

Source controls are management techniques that reduce the amount of pollutants and volumes of water entering the storm water drainage system. Reducing the volume of pollution entering the storm water system can often be the most effective and least expensive means of control. The following presents a brief description of the common source controls that are applicable to Moran Lake watershed.

Covering. Areas that are potential sources of chronic loading or acute releases of pollutants to the environment (such as fuel dispensing facilities, hazardous materials/waste storage areas, solid waste storage areas, and vehicle maintenance areas) should be covered with a permanent canopy, roof, or awning. Rainfall should not come in contact with materials and activities in these areas. Areas that are covered should be paved beneath the cover and hydraulically isolated through grading, berms, or drains to prevent uncontaminated storm water from running onto the area and carrying pollutants away. Drainage from the hydraulically isolated area is directed to an approved on-site industrial wastewater treatment facility, or other approved on-site temporary storage facility or containment device/structure.

Pavement. Areas used to store potentially reactive materials should be paved with Portland cement concrete and the pavement should be epoxy coated. Gasoline and other materials can react with asphalt pavement, causing the release of toxic oils from the pavement. If the area is already paved with asphalt, an asphalt sealant can be applied to the pavement surface.

Alternative Paving. There are two categories of alternative paving: porous pavement and concrete grid or modular paving. (This method of pavement is only applicable in areas where the sub-soils have adequate infiltration rates, which should be determined prior to final design.) Porous pavement is an open-graded aggregate laid on top of a permeable soil layer. Modular pavements are formed using concrete blocks with open spaces that are filled with sand and vegetation. Alternative paving is used to reduce the amount of impervious cover and to maximize infiltration of rainfall at a site. Alternative paving systems also provide passive treatment of storm water through adsorption and biodegradation of pollutants entering these systems. The use of alternative paving materials is appropriate in low-trafficked areas, such as employee parking lots and emergency access roads or driveways. Modular paving is generally more expensive than porous paving, however porous paving is subject to clogging.

Street Sweeping. Street sweepers remove debris and particulate from paved surfaces using rotating brushes, water jets, and/or vacuums. They are a good method of pollution reduction for urban areas that are hard to retrofit with physical structures or biological areas. Optimal frequencies of street sweeping are usually between weekly and monthly.

Revegetation. Revegetation is the conversion of paved areas to vegetated areas. This technique not only helps to reduce the volume of runoff from these areas, but runoff directed to these areas will infiltrate through the soil and passively reduce pollution levels. There are also secondary benefits associated with revegetation, such open space and soil stabilization.

<u>A.1.2. Filtration Control Measures</u>

Filtration controls are either structural or non-structural (landscape based) treatment systems that are normally installed or integrated as a part of a storm drain system. They usually take up less surface area than downstream controls and can be integrated into the site design as landscaped areas. Inline controls are often located underground.

Bioretention filter. Bioretention filters utilize landscaped areas to reduce pollutants in storm water runoff. In this system, the site is graded so that storm water runoff is directed over a curtain drain and buffer strip to a vegetated bioretention area. The bioretention area is composed of several layers including woody and herbaceous plants, mulch, soil, and a sand bed. As runoff percolates through the system, pollutants are transformed, sequestered, or filtered out by the plant and soil system. Bioretention areas are generally designed in a manner that allows water to pond on the surface for brief periods of time. Bioretention is typically used as a storm water management BMP in road medians and parking lot islands. An example of typical bioretention filter is presented in Figure A.1 actual dimensions of an installed bioretention filter will vary depending on actual site conditions and volume of runoff to be treated.

Typical maintenance for bioretention filters might include mowing grass and removing grass clippings, occasional removal of sediment especially at inlets, revegetation as necessary, and the removal of debris that has blown onto the filter.

Vegetated Channels. Vegetated channels refer to ditches, grass channels, vegetated dry and wet swales. These are vegetated channels with a slope that is similar to that of a standard storm drain, but is wider and shallower to minimize velocity and maximize infiltration and adsorption of pollutants. Often vegetated channels are used in road medians like bioretention filters, but unlike bioretention, they emphasize flow along the surface rather than infiltration and subsurface flow. An example of a dry swale is shown in Figure A.2. The actual dimensions of the swale, including depth, width and length will depend on site conditions, such a depth to shallow groundwater and volume of water conveyed in the swale system.

Sand filter. Sand filter units are located either in open units or in vaults. In a sand filter, storm water filters through a sand layer and into an underdrain. They are convenient for urban areas because they can be located underground. However, they can only treat a relatively small area and storm water must be pretreated to remove large solids. These systems have been shown effective at removing a range of pollutants, but they can require a high level of maintenance.

Filter traps. There are a variety of commercially available catch-basin type filter traps. These systems are typically designed with baffles and/or cartridge type filters that trap sediment, oil and grease. Many are designed to capture and treat the 'first flush' or rainfall events of one inch or less, and are designed to bypass peak storm events in excess of the one-inch event. These events are the most frequent events and often generate the highest pollution loads over the course of a rainy season. Routine cleaning, often after every storm, is critical to maintain the effectiveness of the traps. These units are designed to remove trash, sediment, oil and grease and some systems are designed specifically to remove hydrocarbons from storm water. Performance of these systems is highly variable and generally dependent on the design of the system and maintenance frequency. Filters are not worth using and should not be used unless they can be inspected and maintained on a very frequent basis.

Centrifugal Units. There are a variety of specially designed systems for storm water treatment that use vortex or adjustable weirs to route low flows to a water quality treatment unit to remove solids, oil and grease. Higher flows from more intense storms are restricted by low-flow orifices and directed over the adjustable weir, bypassing the water quality facility and preventing the resuspension of sediments. They can also be used in conjunction with other storm water treatment BMPs to provide higher levels of treatment. These systems are appropriate to pretreat runoff from areas with high concentration of solids and oil and grease, such as truck tire washing areas, processing plant yards and material storage areas. A conceptual drawing of this system is presented in Figure A.3.

Pre-Engineered Stormwater Treatment System. The Storm water Management's StormFilter™ is typical of a more advanced inline treatment system that is designed to remove solids, oil and grease and soluble metals. The StormFilter uses filter cartridges housed in concrete vaults creating a self-contained storm water filtering system that is inline with storm drains. The filter media traps particulate and adsorbs materials such as dissolved metals and hydrocarbons. A conceptual drawing of a typical StormFilter system is presented in Figure A.4.

Infiltration. Infiltration can be achieved using trenches and basins. They reduce pollution loading by infiltrating storm water into the ground. Media such as coarse gravel and sand are used to allow for rapid percolation into the soil. The life expectancy of infiltration system can be short if the permeable bed becomes clogged. Infiltration of polluted storm water into the underlying ground water can also be a concern.

A.1.3. Detention Type Stormwater Treatment Systems

Detention type storm water treatment systems are generally located at the outlet of the conveyance system just before storm water runoff enters receiving waters or exits a site. Detention type controls are typically larger then filtration systems because they usually handle a larger volume of water. They typically have higher construction costs than other types of treatments, but their cost per volume of water treated and pounds of pollution removed can be competitive or less than other treatment schemes.

Dry Ponds. Dry ponds are conventional extended ponds that are normally dry between storm events. They detain water over a course of days to allow particulates to settle out of the runoff. Pollutant removal efficiency is variable with dry ponds. Heavier pollutants that settle out of runoff can be partially removed; however, negligible removal of soluble pollutants is achieved.

Wet Ponds. Wet ponds have a permanent pool of water for treating incoming storm water runoff. Pollutants are removed via settling, plant uptake, and bacterial decomposition. The degree of pollutant removal is a function of the pool size in relationship to the drained area. Maintenance is often low and is partially a function of aesthetic value required.

Constructed Wetlands. Wetlands operate in a similar manner to ponds and can provide very effective storm water treatment. They are generally shallow, allowing vegetation to grow, but they are less tolerant to fluctuations in water depth. They provide more habitat value than ponds; however, they can require a lot of space. An example of a multiple pond storm water wetland is shown in Figure A.5.

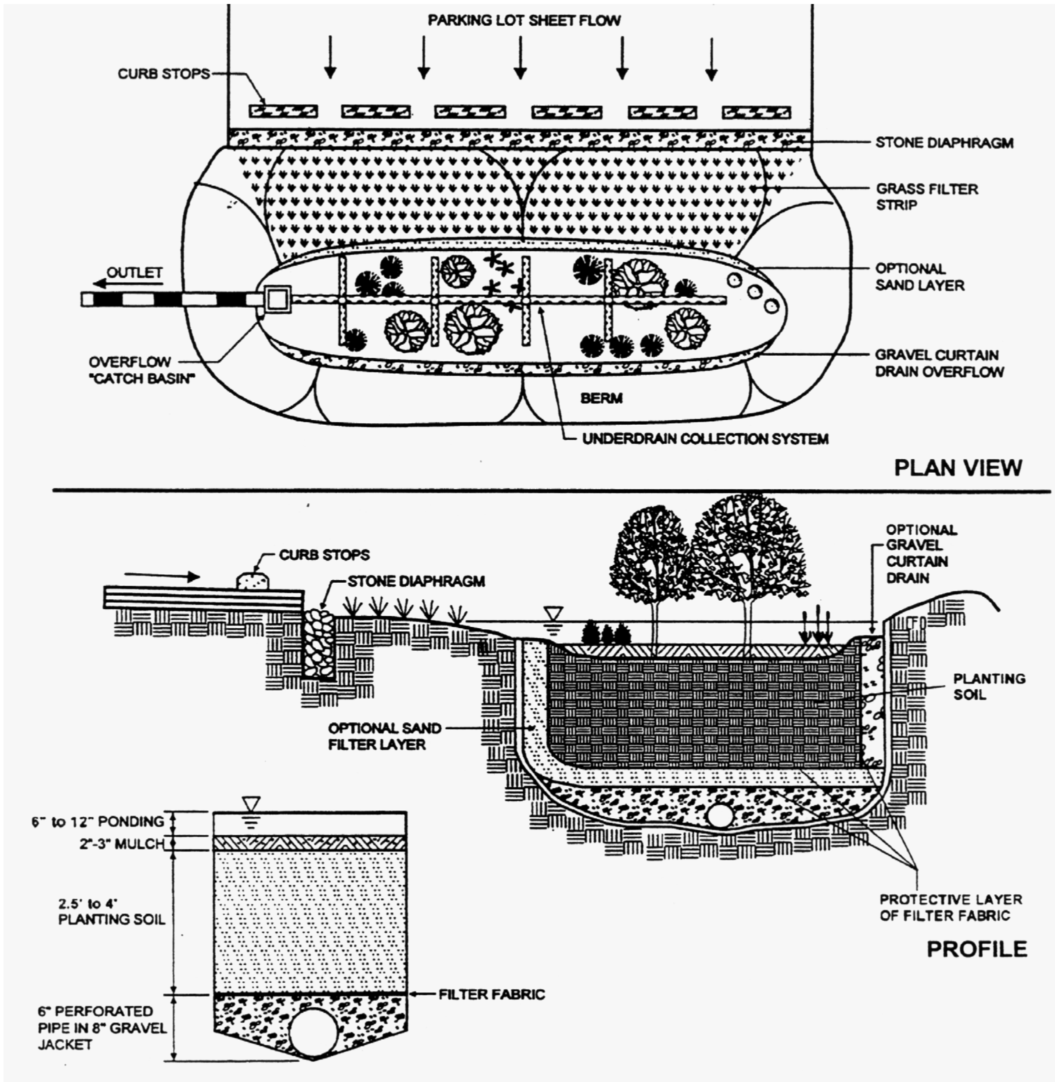

Figure A.1. Typical Bioretention Filter (MDE, 2000)

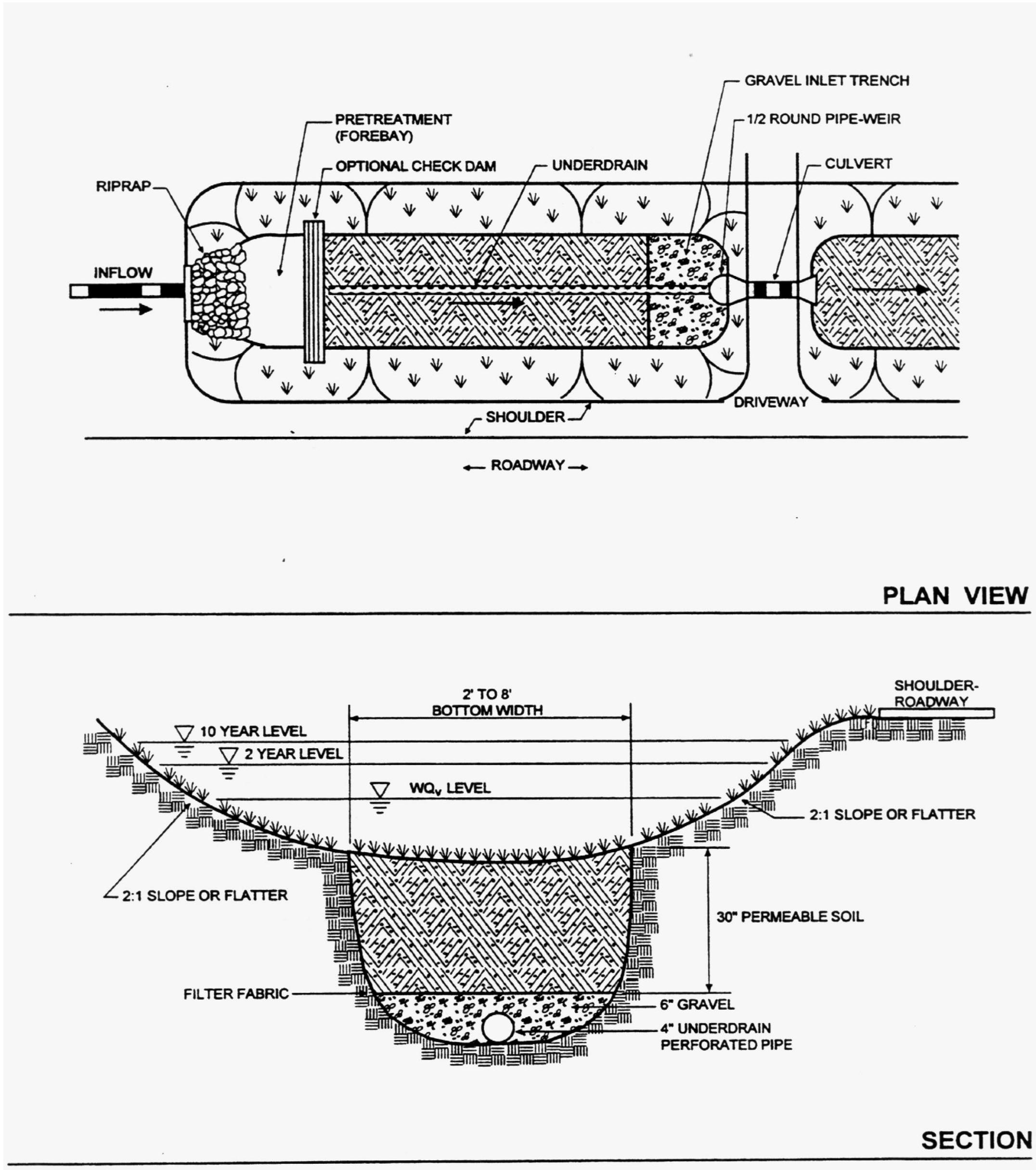

Figure A.2. Typical Dry Swale

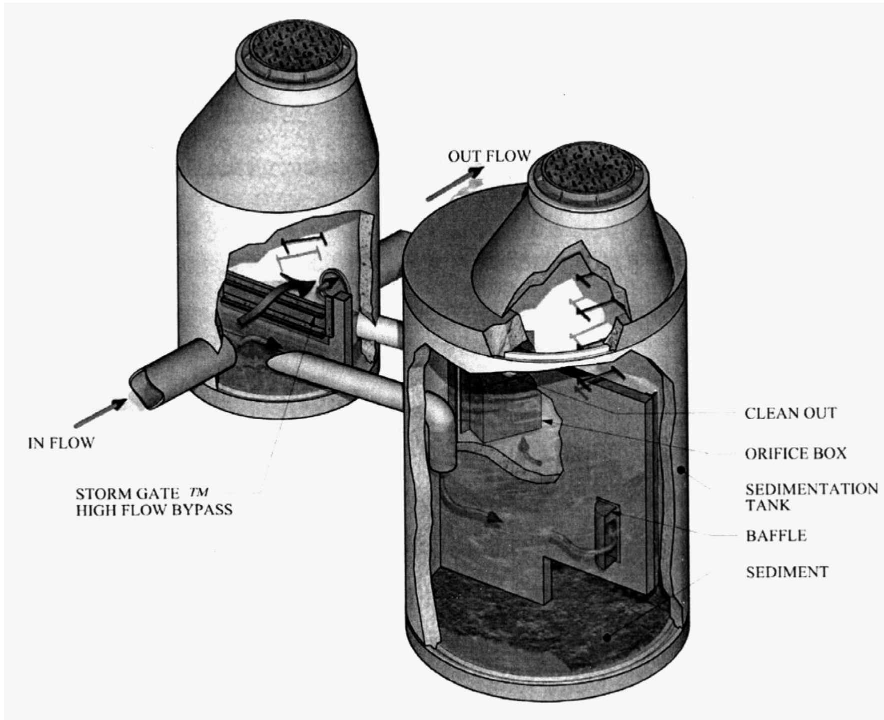

Figure A.3. Common Filter Trap Type System

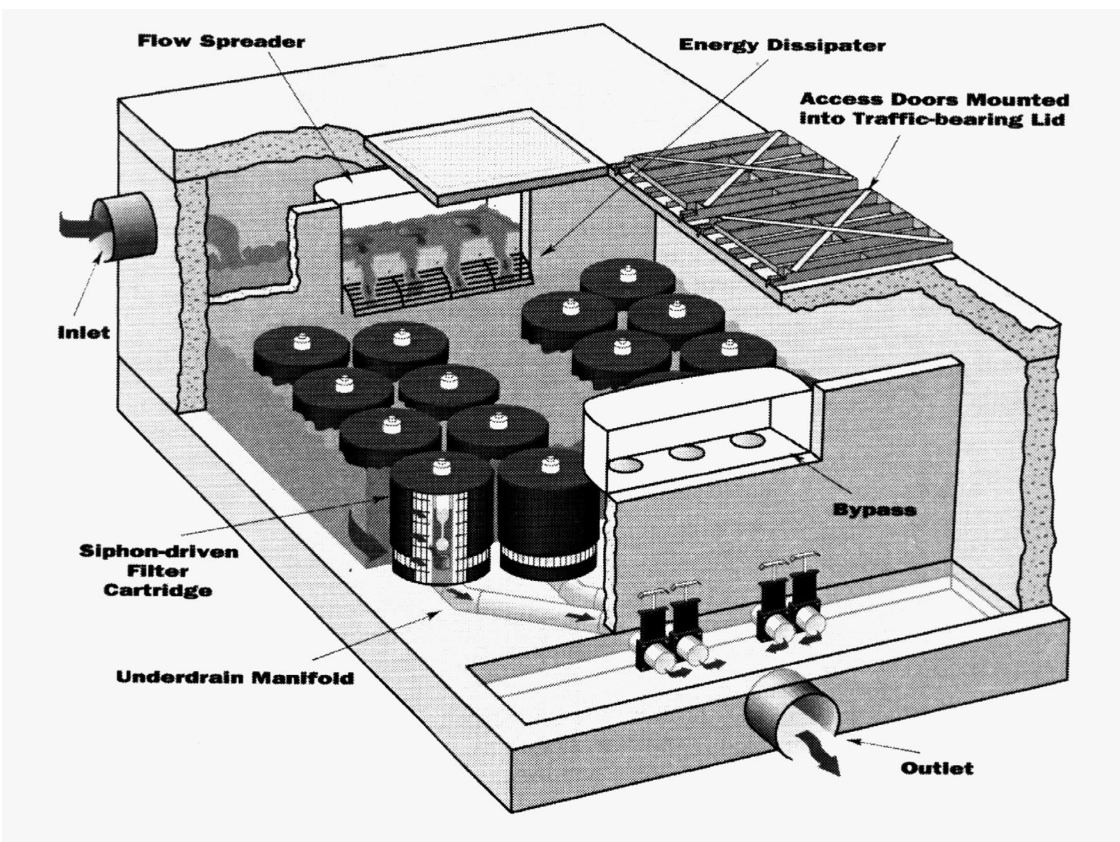

Figure A.4. Advance Storm Water Treatment System

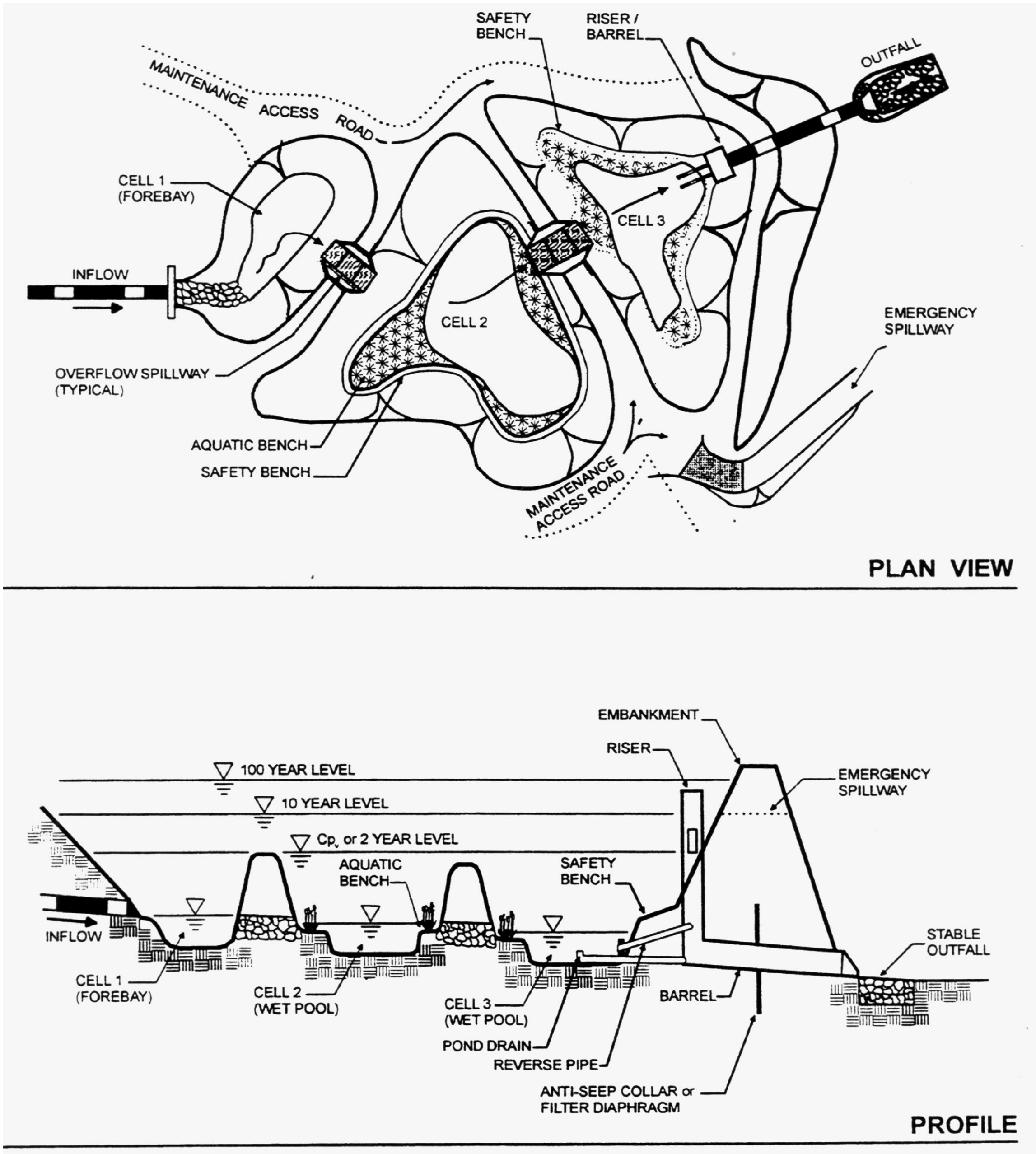

Figure A.5. Typical Multiple Pond Storm Water Wetland

Summary of Storm Water Treatment BMP Performance and Planning Information

Table A.1 presents a summary based on performance and planning information for the source control, filtration, and detention type treatment measures described in the previous sections.

Table A.1 Summary of Storm Water BMP Performance and Planning Information

	Runoff Reduction		Contaminant Reduction Capability						Comparative Cost		Maintenance & Longevity		Environmental/Community Benefits			
Management Practice	Peak Runoff	Volume Reduction	TSS	TPH	PAH	Metals	O&G	Nutrients	Capital Cost	O&M	Maintenance Requirements	Longevity (years)	Recreation	Natural/Open Space\	Bay Access	Environmental Education
Source Controls																
Covering	NA	NA	M	H	H	M	H	NA	L	L	L	20+	NA	NA	NA	NA
Drainage Controls	M	L	M	M	M	M	M	M	L	L	L	20+	NA	NA	NA	NA
Alternative Roofing	NA	NA	L	NA	NA	H	NA	NA	L	L	L	15+	NA	NA	NA	NA
Permeable Pavement	H	M	M	M	M	M	M	M	M	M	M	5+	NA	NA	NA	M
Street Sweeping	NA	NA	H	L	L	M	L	L	M	L	M	NA	NA	NA	NA	NA
Revegetation	H	M	H	H	H	H	H	M	L	L	M	10+	NA	NA	NA	NA
Inline Controls																
Bioretention	H	M	H	H	H	H	H	M	L	L	M	20+	L	M	L	M
Vegetative Channels	M	L	M	M	M	L	M	L	L	L	M	20+	M	M	M	M
Sand Filters	M	L	H	H	H	M	H	L	H	H	H	15+	L	L	L	L
Filter Traps	L	L	L-M	L-M	L-M	L	M	L	M	M	M-H	20+	L	L	L	L
Stormwater Filters	L	L	H	H	H	H	H	M	H	M	M	20+	L	L	L	L
Infiltration	H	H	H	H	H	H	H	M	H	H	H	5+	L	L	L	L
Downstream Controls																
Dry Ponds	H	H	H	H	H	M	H	M	M	M	M	20+	M	M	H	M
Wet ponds	H	H	H	H	H	M	H	M	M-H	M	M	20+	M	M	H	M
Constructed Wetlands	H	H	H	H	H	H	H	M	M-H	M	M	20+	H	H	H	H

Rating Criteria: L = Low; M = Moderate; H = High; NA = Not Applicable

A.2. Site Design Performance Standards

Adopting site design performance standards provides the opportunity for economically viable, yet environmentally sensitive development. In general, proper site design reduces the amount of impervious cover and reduces the amount of storm water runoff generated at a site. Therefore, reductions in impervious cover result in smaller required storage volumes and, consequently, lower BMP construction costs. Economic benefits can be derived directly by the developer from the reduced construction costs associated with narrower roads, smaller parking areas, use of landscaped based treatment BMPs, and other alternative development strategies designed to minimize impervious cover. In summary, the documented benefits of site design performance standards include (CWP, 1998):

- Minimize the generation of storm water runoff
- Reduced soil erosion during construction
- Reduced development construction costs
- More pedestrian friendly areas and more space for recreation
- Protection and enhancement of creek and lagoon habitat
- A more aesthetically pleasing and naturally attractive landscape
- More sensible locations for storm water facilities
- Easier compliance with stream and wetland and other resource protection regulations
- Neighborhood designs that provide a sense of community
- Urban wildlife habitat through natural area preservation

The County of Santa Cruz can seek opportunities for open space development that incorporate site design strategies to minimize total impervious cover, reduce the total construction costs, preserve and/or enhance natural areas, provide community open space, and promote watershed protection. These strategies are consistent with the County's long-term land use plans for the Live Oak area.

The following are examples of site design performance standards that can be applied to new development sites in the watershed to minimize the generation of storm water.

1. Site designs should minimize the generation of storm water and maximize pervious area for storm water treatment. Several municipal agencies have established impervious surface reduction rules for new and redevelopment projects. For example, the City of Santa Monica requires that any new or redevelopment project must reduce the amount of existing impervious cover by 20 percent. Similarly, in the City of Olympia, the reduction requirement for new and redevelopment projects are 15 percent.

2. Site designers can attempt to minimize the creation of impervious cover in new and redeveloped sites by:

    - Specifying narrow road sections

- Smaller turnarounds and cul-de-sac radii
- Permeable spill-over parking areas
- Smaller parking demand ratios
- Smaller parking stalls
- Angled one way parking
- Preservation or increased landscaped areas
- Shared parking and driveways
- Narrow sidewalks

3. New streets and driveways can be designed for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume and other issues as well.

4. Wherever possible, street right-of-away widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains can be located within the pavement section of the right-of-way, wherever feasible.

5. Where topography, soils, and slope permit, vegetated open channels can be used in the street right-of-way to convey and treat storm water runoff.

6. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.

7. Reducing overall lot imperviousness can be accomplished by using alternative driveway surfaces and shared driveways that connect two or more lots together.

8. Wherever possible, storm water treatment for parking lot runoff can be achieved using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaped areas and traffic islands.

9. Rooftop runoff can be rerouted to pervious areas such as landscaped areas and avoid routing rooftop runoff to the roadway and the storm water conveyance system.

10. Storm water discharges from land uses or activities with higher potential for pollutant loadings (fueling facility, etc.) may require the use of specific structural BMPs and pollution prevention practices. In addition, storm water from these areas should not be infiltrated without proper pretreatment.

A.3. Performance Standards for Storm Water Management and Treatment BMPs

Performance standards for storm water management and treatment BMPs have been recently established and adopted in different regions of the State for new and redevelopment projects. The overall goal of these standards is to reduce pollutant discharges and changes in runoff flows where they can cause damage to downstream water bodies to the maximum extent practicable. The standards are established to prevent exceedance of receiving water quality standards over the life of the project, through implementation of control measures. The following are example standards that reflect an approach to address provisions of the Phase II Municipal Storm Water Permit to be issued by the California Regional Water Quality Control Board in the near future.

1. All new or redeveloped projects, that create one acre (43,560 square feet) or more of impervious cover, including roof area, streets, parking, driveways, material storage areas and sidewalks, are required to install treatment Best Management Practices (BMPs). The treatment BMPs should be sized according to either a volume hydraulic design basis or a flow hydraulic design basis, as follows:

   a. Volume Hydraulic Design Basis

   Treatment BMPs whose primary mode of action depends on volume capacity, such as detention/retention units or infiltration structures, should be designed to treat storm water runoff equal to:

   - The maximized storm water quality capture volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in *Urban Runoff Quality Management*, *WEF Manual of Practice No. 23/ ASCE Manual of Practice No. 87,* (1998), pages 175-178 (e.g., 85 (%) percent of the average annual 24-hour rainfall event, equivalent to approximately 1 inch of precipitation (in the Live Oak area); or

   - The volume of annual runoff required to achieve 80 percent or more capture determined in accordance with the methodology set forth in Appendix D of the *California Stormwater Best Management Practices Handbook*, (2003), using local rainfall data.

   b. Flow Hydraulic Design Basis

   Treatment BMPs whose primary mode of action depends on flow capacity, such as swales, sand filters, or wetlands, should be sized to treat:

   - 10 (%) percent of the 50-year design flow rate, or

   - the flow of runoff produced by a rain event equal to at least two times the 85^{th} percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths; or
   - the flow of runoff resulting from a rain event equal to at least 0.2 inches per hour intensity.

2. To be considered an effective BMP for stand alone treatment of the water quality volume or flow conditions, a design should be capable of:

- Capturing and treating the required water quality volume or flow;
- Removing 80% of the TSS; and
- Having an acceptable longevity rate in the field (15 to 25 years).

3. A storm water management system should be designed to not adversely affect existing storm water conveyance capabilities. It is presumed that a system meets this criteria if one of the following are met:

    - The existing hydraulic conveyance is maintained; and
    - The applicant demonstrates that the storm water BMP will reduce the peak discharge to less than pre-project levels.

4. New or redeveloped projects should not discharge untreated storm water directly to a jurisdictional wetland or local water body without adequate treatment.

5. All storm water BMPs should be designed in a manner to minimize the need for maintenance, and reduce the chances of failure.

6. Storm water BMPs should be designed to accommodate maintenance equipment access and to facilitate regular operational maintenance (such as underdrain replacement, unclogging filters, sediment removal, mowing and vegetation control). Operational maintenance and operation easements shall be provided when necessary to facilitate equipment access.

7. In order to protect groundwater from pollutants that may be present in storm water runoff, the following conditions should be satisfied if infiltration treatment measures (such as infiltration trenches and infiltration basins) are considered as a treatment BMP:

    a. Pollution prevention and source control BMPs should be implemented at a level appropriate to protect groundwater quality at sites where infiltration devices are to be used.
    b. Use of infiltration devices should not cause or contribute to an exceedance of groundwater water quality objectives.
    c. The vertical distance from the base of any infiltration device to the seasonal high groundwater mark should be at least 10 feet.
    d. Unless storm water is first pretreated, infiltration devices are not be recommended for areas of industrial or light industrial activity; areas subject to high vehicular traffic; automotive repair shops; fleet storage areas (bus, truck, etc.); and other high threat to water quality land uses and activities.

A.4. Technical Resources

The following list provides information on readily available technical resources that can be consulted for the selection and design of source control, appropriate site design and treatment BMPs. The information provided pertains to technical literature and professional organizations, but does not include information for equipment manufacturers.

Site Planning and Design

1. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*. 1999. Bay Area Stormwater Management Agencies Association (BASMAA)
2. *Better Site Design: A Handbook for Changing Development Rules in Your Community*. 1998. Center for Watershed Protection (CWP)
3. *Site Planning for Urban Stream Protection*. 1995. CWP

Best Management Practice Performance

1. *Guide for Best Management Practice (BMP) Selection in Urban Developed Areas*. 2001. ASCE
2. *National Stormwater Best Management Practices (BMP) Database*. 1999. American Society of Civil Engineers (ASCE)
3. *National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition*. 2000. U.S. Environmental Protection Agency and CWP
4. *The Practice of Watershed Protection*: *Techniques for protection our nation's streams, lakes, rivers and estuaries*. 2000. CWP

Storm Water Treatment Design

1. *California Storm Water Best Management Practice Handbooks, Volumes 1 – 3, Municipal, Commercial/Industrial, and Construction BMP Handbooks*. 2003. Storm Water Quality Task Force
2. *Guidance Manual for On-Site Stormwater Quality Control Measures*. 2000. Sacramento Stormwater Management Program, City of Sacramento Department of Utilities, County of Sacramento Water Resources Division
3. *Design and Construction of Urban Stormwater Management Systems*. 1992. ASCE Manuals and Reports of Engineering Practice No. 77, Water Environment Federation (WEF) Manual of Practice FD-20
4. *Design of Stormwater Wetland Systems*: *Guidelines for Creative Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region*. 1992. Metropolitan Washington Council of Governments
5. *Stormwater Design Manual, Volumes I &II*. 2000. State of Maryland, Maryland Department of the Environment
6. *Surface Water Design Manual*. 1998. King County, Washington
7. *Urban Runoff Quality Management*. 1998. ASCE Manual and Report on Engineering Practice No. 87 and WEF Manual of Practice No. 23