Waterway Management Plan

VOLUME I

San Luis Obispo Creek Watershed

City of San Luis Obispo
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1. INTRODUCTION

1.1 Background

San Luis Obispo Creek (SLO Creek) and its tributaries have significant problems that involve recurrent damaging floods and bank instability. These problems require active channel management. Some reaches of the creeks have areas with desirable riparian habitat, but they occur in discontinuous or fragmented segments, with long segments of degraded habitat. These areas provide opportunities for stream habitat enhancement and riparian restoration. Needed management actions for the waterways include channel sediment removal, vegetation control, stream restoration and enhancement, repair of existing failing bank protection structures, and construction of new bank protection and flood control channel modifications.

These management actions can impact wetlands within the stream zone, as well as surface water. Approval or permitting from the U.S. Army Corps of Engineers (ACOE), Central Coast Regional Water Quality Control Board (Regional Board), and California Department of Fish and Game (CDFG), collectively Regulatory Agencies will be required. Since there are endangered species present within SLO waterways, including California red-legged frog and southern steelhead, consultation with the U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS) will also be crucial for any project involving disturbance, modification or management of creekside water resources.

The City of San Luis Obispo last prepared a comprehensive Flood Management Plan in 1977, in response to the disastrous floods of 1969 and 1973 (Nolte, 1977). The plan was ambitious in scope and costs, but had some serious environmental impacts associated with proposed channel widening. As a result, only portions of the plan were implemented (such as replacement of undersized and old bridges). Since preparation of the 1977 plan, the City has experienced damaging floods on several other occasions: especially in 1995.

The 1995 flood caused widespread damage throughout the SLO watershed, including out-of-bank flooding and extensive bank erosion. In response to the damage, the City requested permits from the ACOE and other regulatory agencies to repair damage at the worst public areas. The City also decided to take a new look at flooding problems and to develop a new plan that would address the frequency and magnitude of flooding, in an environmentally sensitive and cost effective manner.

In response to the City's request for a series of ACOE Nationwide Permits for wetlands fill to construct bank repair projects at ten locations, and with concerns regarding potential cumulative impacts on creek resources, the Regulatory Agencies collectively requested preparation of a comprehensive, watershed-based management plan for SLO Creek. This Waterway Management Plan (WMP) was prepared in response to that request and will form the basis for future project planning, decision making and permitting.

The overall Waterway Management Plan (WMP) program is contained in a three volume set of reports (Volumes I through III). The WMP is Volume I and contains inventory information, a detailed hydrologic/hydraulic analysis of the watershed and its main tributaries, and an identification of the management problems and management needs of the waterways. Alternatives are reviewed for addressing flooding, bank instability, and habitat protection and enhancement, and a preferred project is presented.

Volume II presents a Stream Management and Maintenance Program (SMMP) for the waterways of the San Luis Obispo Creek Watershed. This document outlines the planning, design, and permitting approach the City and County will utilize for routine stream maintenance, such as vegetation management, bank repair, and sediment removal. Policies and Best Management Practices for these activities are also described. This document (Volume I) contains a brief summary of the SMMP document.

Volume III is a Drainage Design Manual (DDM), which contains revised policies for floodplain and stream corridor management and provides new design flows for stream channels within the City of San Luis Obispo. Procedures for hydrologic and hydraulic analysis, and guidelines and design criteria for the design of channel, storm drain systems, stormwater detention facilities, bank repair and stream restoration, and erosion control are presented in the DDM. Important policy revisions of the DDM are also summarized in this Volume (Waterway Management Plan).

Because of the large scope of the overall work program and the need to complete some management activities (principally bank stabilization) during the fall of 1998, prior to initiation of winter rains and high flows, the work program was divided into two phases, Phases I & II. Phase I was restricted in scope and geographic area, and addressed immediate management needs within a defined study area, generally the southern half of the City. Phase II would address overall stream corridor management throughout the SLO Creek watershed, including development of hydrologic and hydraulic models, flood management, sediment management and riparian restoration. In addition, Phase II would be based on comprehensive inventories and analysis, a Geographic Information System (GIS) to house the technical inventory and management data, and design criteria handbooks and maintenance manuals.

In April 1997, a Phase I report was prepared on behalf of the City and San Luis Obispo County Flood Control and Water Conservation District (Zone 9) that addressed problems of bank erosion at eight locations along several reaches of SLO Creek (Questa, 1997). These were areas damaged by the 1995 flooding, and most in need of management and bank repair. The Phase I report and the subsequent Design Concept Plan was submitted to the ACOE as part of the application for an Individual Section 404 Wetlands Fill Permit for these sites. The reports were also used as background information in submittals to the Regional Board for application for a Section 401 Water Quality Certification, Section 404 wetlands fill permit application and for the required CEQA/NEPA documentation. A separate Streambed Alteration Agreement was also obtained from the CDFG. Consultation and coordination with CDFG, USFWS and NMFS was required under Section 9 of the Endangered Species Act, because of the potential and likely presence of endangered species in the study area.

Following acceptance of the Phase I Report and the issuance of an Individual Permit by the ACOE and the CDFG, approximately 425 meters (1400 lineal feet) of bank repair (using biotechnical methods) was completed in the late summer and fall of 1999. Mitigation included creek enhancement and restoration (mainly between Prado Road and Los Osos Valley Road) in addition to on-site planting with native plants at the bank repair sites. Zone 9 funded the bank repairs, with some funds also received from the Federal Emergency Management Agency (FEMA). The City also committed to preparation of this Phase II Waterway Management Plan (WMP).

1.2 Project Location

The project area covers the entire San Luis Obispo Creek watershed. San Luis Obispo Creek originates in the foothills of the Santa Lucia Range near Cuesta Grade, flowing approximately 29 km (18 miles) to its discharge to the Pacific Ocean at San Luis Bay, near the community of Avila Beach. The creek closely follows State Highway 101 along most of its route. The SLO Creek watershed is centrally located in San Luis Obispo County between the Santa Lucia Mountains and coastal hills of central California (**Figure 1-1**). The City of San Luis Obispo covers an area of approximately 9.5 square miles near the center of the watershed, with the remaining watershed area (approximately 217 km^2 or 84 $mi^{2)}$ in County jurisdiction. The WMP focuses on the main stem of San Luis Obispo Creek but also incorporates the following major tributaries to San Luis Obispo Creek:

- East Fork of San Luis Obispo Creek
- Prefumo Creek
- Froom Creek
- Stenner Creek
- Brizziolari Creek (tributary to Stenner Creek)
- See Canyon Creek
- Old Garden Creek (tributary to Stenner Creek)
- Davenport Creek

1.3 Purpose and Objectives of the Waterway Management Plan

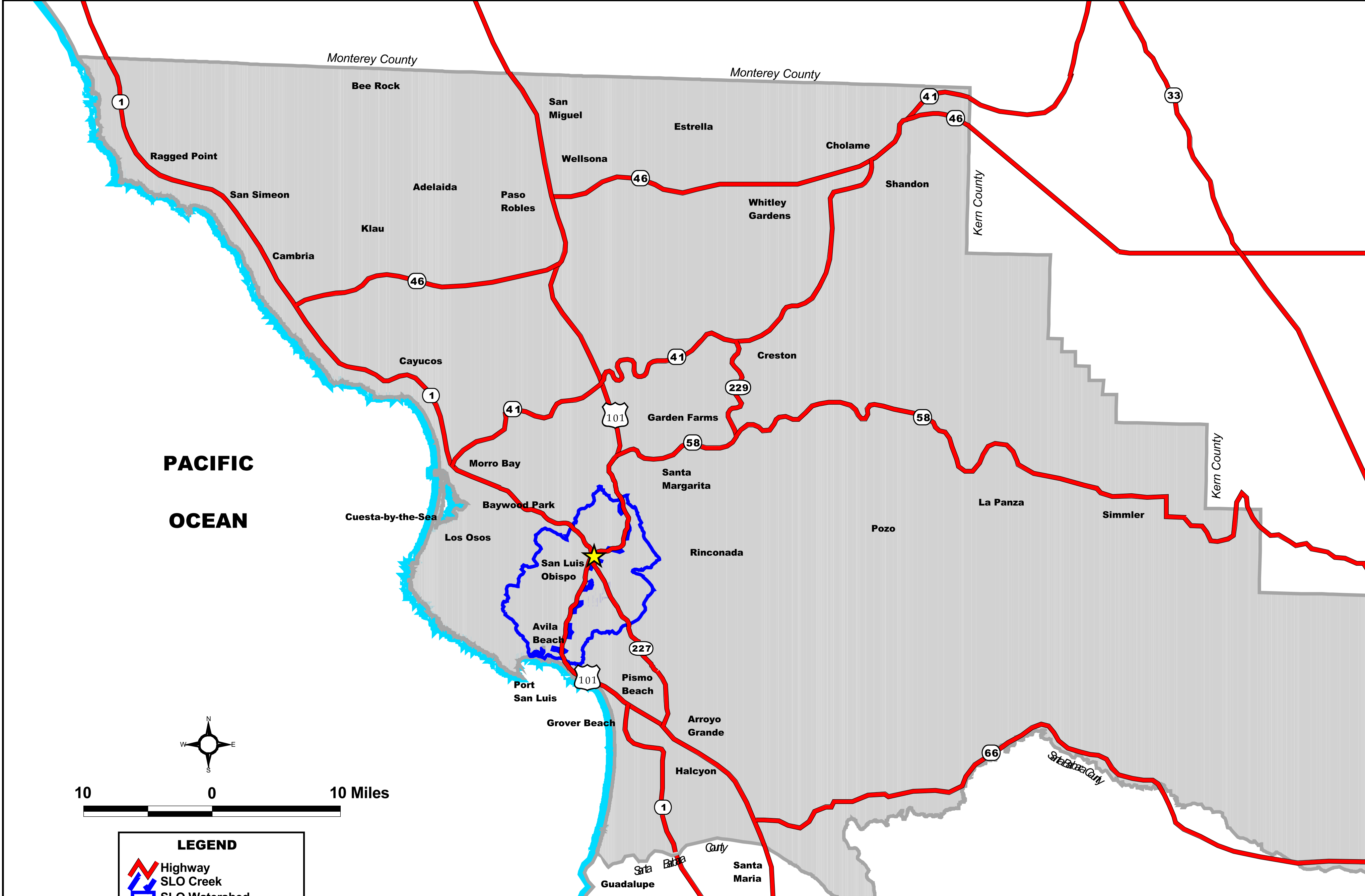
The purpose and objectives of the WMP, as developed by the Zone 9 Advisory Committee in consultation with the Regulatory Agencies are as follows:

Purpose

Develop an approach and schematic plans to address flooding, erosion, water quality, and ecological issues in the SLO Creek Watershed that can be implemented with approvals from various regulatory agencies.

Objectives

1. Identify and prioritize the amount and extent of flooding, erosion, water quality, and ecological issues in the SLO Watershed.



City of San Luis Obispo

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Watershed Location Map

SLO Creek Phase II
Waterway Management Program

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Figure

WMP 1-1

2. Identify and develop programs to address flooding, erosion, water quality, and ecological issues in the SLO Watershed.

3. Develop guidelines for design of future development or reconstructed developments in the SLO Watershed.

4. Develop a programmatic environmental and permitting review process for implementation of Objectives 2 and 3, as applicable.

5. Develop an Implementation Program.

1.4 Planning Process, Information Sources and Study Team

The Phase II planning process was initiated by the Zone 9 Advisory Committee and the City and County in January 2000. The approximately two and one half year planning process has involved the participation of City and County Engineering and Planning staff, landowners, regulatory agencies, and the general public, culminating in the development of this WMP and related documents. An informal Technical Advisory Committee (TAC) composed of representatives from the City, County, select resources and regulatory agencies, and other interested individuals and groups provided guidance in screening, selection and development of alternative waterway management approaches. Many members of the TAC also sit on the Zone 9 Advisory Committee (SLO Creek watershed). The study team presented information and alternatives at the monthly Zone 9 Advisory Committee meetings, which were open to the public.

Tasks included completion of detailed resource inventories, hydrologic and hydraulic modeling and analysis, problem identification, development and screening of alternatives to address the identified problems, and selecting a short list of alternatives for further environmental review and public hearings.

Advisory Committee members represented various interest groups, including City, County, Caltrans, Cal Poly, the Avila Beach area, and the agricultural community. In addition to guiding the scope of work and providing input and comments on each step of the process, the Advisory Committee members also insured that the developing plan was compatible with their interest groups' opinion and needs. For instance, a key issue of concern to the Avila Valley area is to make sure that any flood management projects proposed in the City of San Luis Obispo do not make flooding problems worse in their areas. A key concern of the agricultural community is to make sure that any new stream corridor and floodplain management regulations do not create new regulatory or permit procedures for routine agricultural practices, and that the Waterway Management Plan does not supersede the Goals, Policies, and Programs of the Agricultural and Open-Space elements of the San Luis Obispo County General Plan.

Members of the Zone 9 Advisory Committee and agency representatives include:

Agency	**Member**	**Alternate**
City of SLO-City Council	Jan Marx	Christine Mulholland
City of SLO-Staff	Jay Walter	Matt Horn
City of SLO-Public at-large	John French	*vacant*
Agricultural Liaison Advisory Board	David Pereira	Hunter Francis
Avila Valley Advisory Council	Carol Kiessig	*vacant*
Cal Poly State University	Brent Hallock	Brian Dietterick
Caltrans	Lance Gorman	*vacant*
Public at-large	Steve Gregory	Wayne Peterson

Questa Engineering Corporation of Point Richmond, California, provided technical engineering support. Morro Group, Inc., provided support for biology and the enhancement element recommendation. Marcelo Espiritu and Dale Norrington working under the supervision of Rollin Strohman, Ph.D., from the California Polytechnic State University at San Luis Obispo (CalPoly) assisted in the stream geomorphic field inventory, GIS development, and project web site development. Project documents can be found at www.slocity.org/natural resources/relatedlinks.asp or the CalPoly website.

A number of prior watershed, stream surveys and flood control studies were used in preparing this report, in addition to the field work and hydrologic and hydraulic analysis completed as part of the Phase II investigations. Previous investigations that were consulted included:

- *Floodplain Information San Luis Obispo Creek and Tributaries Vicinity of San Luis Obispo, San Luis Obispo County, California*, Nov. 1974 (Report prepared by U.S. Army, L.A. District. Provides information on flood history, flood damages, and extent of floodplain, but not a Flood Control Plan)

- *Flood Control and Drainage Master Plan for the San Luis Obispo Creek Watershed*, Aug. 1977 (First comprehensive Flood Control Plan for the City, prepared by George S. Nolte & Associates)

- *Flood Insurance Study, City of San Luis Obispo*, 1978 (Provides information on flooding and floodplains based on 1977 Nolte hydrologic and hydraulic analysis, issued by FEMA)

- *Flood Insurance Rate Maps for the City of San Luis Obispo*, 1981 (Floodplain Maps prepared by FEMA and used by the City for Floodplain Regulation)

- *San Luis Obispo Creek Restoration Plan*, 1988 (First watershed restoration plan for SLO Creek, prepared by Land Conservancy of San Luis Obispo County)

- *Nutrient Objectives and Best Management Practices for San Luis Obispo Creek,* May 1994. (A report focused on prepared for the Central Coast Regional Water Quality Control Board by the Coastal resources Institute of California Polytechnic Institute, SLO)

- *Final Plan for Restoration Actions within the San Luis Obispo Creek Watershed -Unocal Oil Spill, Avila Beach, CA 1992* (A report that summarizes and prioritizes restoration opportunities in the SLO Watershed, prepared for the Avila Beach Trustee Council by the Land Conservancy of San Luis Obispo County)

- *Biological Resource Assessment and Impact Analysis for the SLO Creek Water Reuse Project*, 1995 (Consultants report and EIR prepared for City of SLO by Fugro West, Inc.)

- *San Luis Obispo Creek Watershed Hydrologic Survey,* 1996 (Report prepared by the Land Conservancy of San Luis Obispo County for the Central Coast Regional Water Quality Control Board. Primarily addresses runoff hydrology and creek conditions, with focus on creek restoration and bank stabilization, not flood management)

- *San Luis Obispo Creek Trout Habitat Inventory & Investigation, 1995* (Report prepared for the Land Conservancy of San Luis Obispo County by P. Cleveland, fisheries biologist)

- *Phase I – San Luis Obispo Creek, 1997,* (Report prepared for the City and San Luis Obispo County Flood Control and Water Conservation District (Zone 9))

- *Storm Drain Master Plan for the Airport Area Specific Plan*, Jan. 1999 (Prepared for the City of SLO by Boyle Engineering Corporation)

- *San Luis Obispo Creek Watershed Enhancement Plan*, March 2002 (Report prepared by The Land Conservancy of San Luis Obispo County is an update of the 1988 report, further identifying problems and prioritized opportunities for restoration)

Other references used in preparation of this Plan are in **Section 9**.

1.5 WMP Components

There are five principal components of this Waterway Management Plan:

- A Stream Maintenance and Management Program (SMMP) covering routine stream maintenance practices and procedures and presenting proposed Best Management Practices as Volume II

- A new Drainage Design Manual (DDM) for storm water, flood control, and bank repair design as Volume III

- A Flood Management Plan that outlines the conceptual flood control alternatives that are proposed as the Preferred Project (Volume I)

- A Bank Stabilization Program that provides a management framework and conceptual plans for addressing current and future bank instability problem areas (Volume I), and

- A Habitat Enhancement and Restoration Program that provides a conceptual plan and framework for stream resource enhancement, restoration, and protection (Volume I).

1.6 Waterway Management Plan Organization

Volume I of the three-volume report is designed to be a "Concept Plan" for Waterway Management and a reference document for use in subsequent, detailed project planning, permitting, and CEQA/NEPA review. As such it will guide the development of future projects to construct flood management channels and storm drains, repair eroding banks, and manage the vegetation and other resources along the creeks of the watershed, and guide restoration and enhancement. The permit application and environmental documents will incorporate by reference sections of this WMP, DDM, and SMMP. The WMP includes supporting information contained in the appendices:

Section 1 describes the background and organization of the WMP, including project objectives and a summary of planning procedures.

Section 2 provides an overview of the resource inventory, including geomorphic and hydrologic conditions of the creek, existing hydraulic structures, erosion problem areas, and bank stabilization needs, as well as, existing biological conditions of the creek, including information on the plant communities, wildlife and fisheries, and rare and endangered species.

Section 3 describes the planning constraints, management needs, environmental sensitivities, and the opportunities for habitat restoration and enhancement.

Section 4 provides a watershed wide perspective to recognize and address the resource management problems of the watershed in an integrated and comprehensive fashion with eight goals and action items.

Section 5 presents four principal components of the Preferred Project. The preferred project for environmental review purposes was developed by the Zone 9 Advisory Committee and confirmed with some modifications by the San Luis Obispo City Council: Preferred project components include:

- A summary of Stream Maintenance and Management Procedures
- Design guidelines and requirements for storm drain facilities system design and channel modification projects

- A Bank Stabilization and Repair program
- A Habitat Enhancement and Protection Program

Section 6 contains an outline of the main components of the preferred project for flood management actions, including structural channel modifications and non-structural elements such as revised floodplain management regulations, possible purchases of flood-prone properties and flood proofing.

Section 7 evaluates project costs and expected project benefits.

Section 8 describes the Implementation and Financing Plan, including a discussion of the recommended prioritization of identified projects, implementation schedule, and funding sources.

Section 9 lists the references and literature cited.

Section 10 is a glossary of technical terms for use by the reader.

Appendix A of Volume I contains the creek geomorphic GIS Inventory data; **Appendix B** is the Biological Resources Inventory, **Appendix C** contains the Hydraulic and Hydrologic Report, and **Appendix D** discusses Project Alternatives.

2. RESOURCE INVENTORY

2.1 Introduction

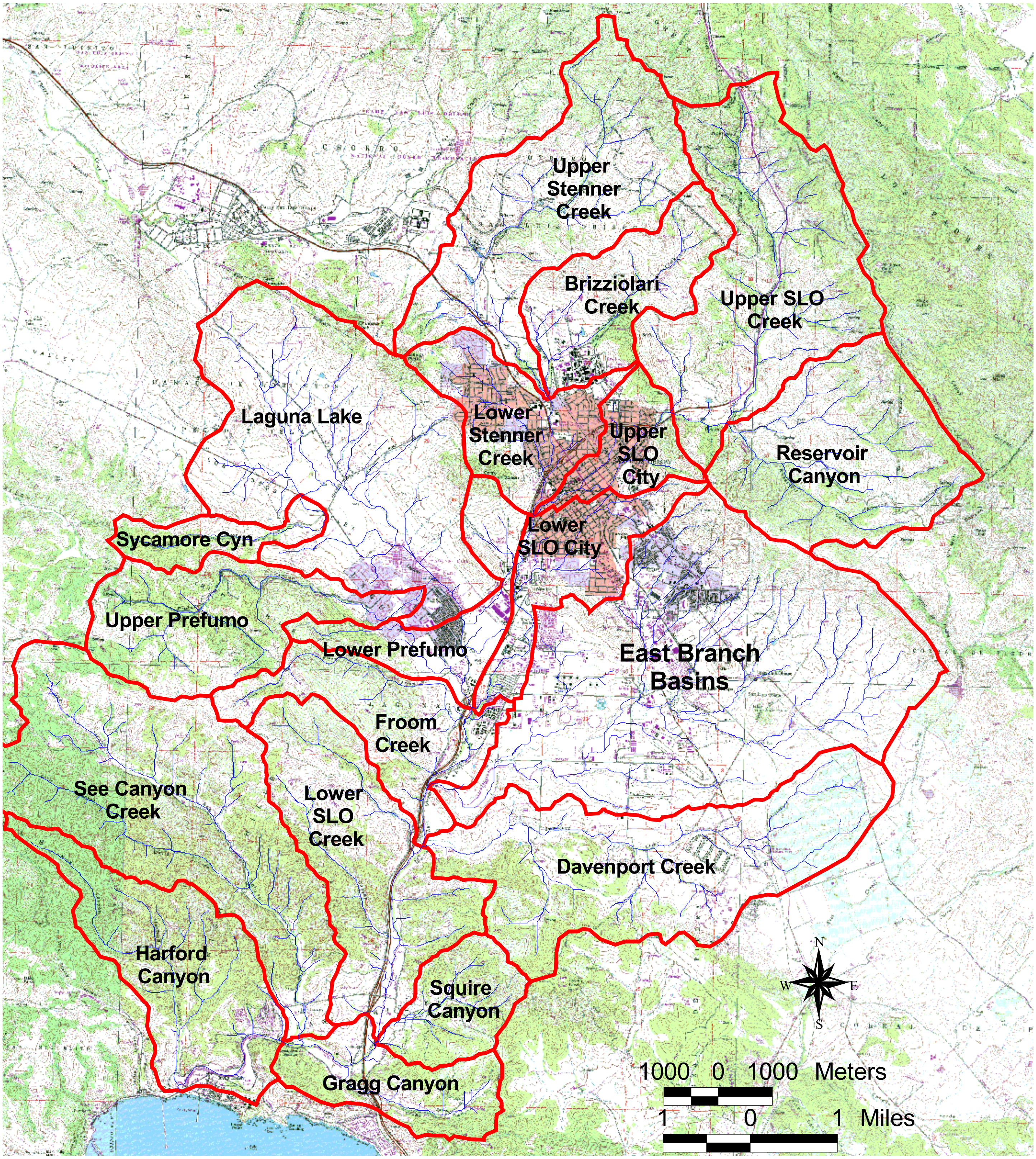
Management of a stream corridor requires an understanding and analysis of its watershed, including general watershed physical and biological characteristics, as well as the characteristics of the system of streams that drain it. The analysis and evaluation of watershed and waterway management problems and management needs requires the integration of basic information on the geology, geomorphology, hydrology and hydraulics, and biology of the system. Since a watershed and its streams respond to both natural and human influences, and the response manifests itself over long periods, the analysis should also include a review of the historical context of the changes that have occurred within the watershed and to its streams.

This section of the Waterway Management Plan describes the general geologic, hydrologic, and biologic characteristics of the SLO watershed, and summarizes the detailed resource inventory information that was collected as part of WMP preparation. It includes a description of the watershed, an overview of current and historical land uses and a generalized description of the existing geomorphic and bank and bed conditions of each reach.

Detailed inventory information of the creek channel geomorphic or stream physical conditions is presented in **Appendix A**, while **Appendix B** presents information on the biological resources that were inventoried. The inventory includes maps and data base information prepared in a GIS that is available on the City of San Luis Obispo's server (www.slocity.org/natural resources/relatedlinks.asp). **Appendix C** summarizes the results of the hydrologic and hydraulic analysis completed for the WMP.

2.2 Watershed Characteristics

SLO Creek is the major waterway that runs through the City of San Luis Obispo. The main stem of SLO Creek flows predominantly southwest, approximately 29 kilometers from its headwaters in the Santa Lucia Range to the Pacific Ocean at Avila Beach. The SLO Creek watershed extends from a high elevation of 750 meters above sea level near Cuesta Grade to sea level at Avila Beach. The City of San Luis Obispo is at an elevation of about 70 meters (downtown). The drainage area of the SLO Creek watershed at its mouth is approximately 218 km^2. The basin is a slightly elongated area about 21 km long and between 10 and 16 km wide, with a dendritic drainage pattern (**Figure 2-1**).



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Watershed and Major Sub-Basins

SLO Creek Phase II
Waterway Management Plan

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Figure

WMP 2-1

FILE REFERENCE: c:\arcview projects\98202 slo phase ii\98202hydrology.apr
LAYOUT: Figure 1 - Base Map B
DATE: Feb 4, 2002

The upper watershed is steep, and SLO Creek and its tributaries flow through narrow canyons with steep stream gradients in their headwaters areas. From its headwaters SLO Creek spills onto a small sparsely developed grassy plateau-like area below Cuesta Grade at Reservoir Canyon, before descending onto the gently to moderately sloping alluvial plain occupied by the City of San Luis Obispo. Within the City limits, the main stem joins Stenner Creek, which drains primarily agricultural and range land in the Santa Lucia Range, and at the lower end of the City by Prefumo Creek, which drains the Laguna Lake and above that, the steep chaparral and oak wooded lands of Prefumo Canyon. CalPoly is located at the northern end of the City, generally between Brizziolari and Stenner Creeks. Other major tributaries include:

- Brizziolari and Old Garden Creeks, both tributaries to Stenner Creek, within the northern part of the City
- East Fork (which drains an area of generally flat to rolling relief on the east side about 2 km below the confluence of Prefumo Creek and the City limits),
- Davenport Creek, (which drains a more rugged canyon area on the east side below East Fork), and
- See Canyon, a wooded canyon on the lower west side, above Avila Beach.

While SLO Creek is incised into an alluvial plain within the downtown and upper residential area of City of SLO, it crosses the broader upper Los Osos Valley and the lower Laguna Lake area before changing its character below Froom Creek and Los Osos Valley Road. The creek descends through a narrow alluvial valley bounded by the steep Irish Hills in this area. The narrowest part of this segment (only about 1 25 meters wide) begins near the confluence of Davenport Creek with SLO Creek, and is aptly called “The Narrows” by local residents. The SLO Valley downstream of the Narrows ranges from about 300 meters to 600 meters wide.

San Luis Obispo Creek turns abruptly westward from its southerly ascent through the City and lower valley area to enter a more narrow and steep-sided canyon before discharging into an estuary area at Avila Beach below the See Canyon confluence.

Only about 11% of the watershed is urbanized; principally the town of San Luis Obispo and the surrounding unincorporated area, and the small community of Avila Beach. However, the ubranzied area upstream of the lower urban reserve limits of the City (near Los Osos Valley Road) is about 15% of the watershed above this point. The urbanized area is predominantly suburban, with the exception of the central downtown area where building densities are higher with a larger percentage of impervious surfaces. Many watershed researchers believe streams begin to experience significant problems, including channel bed and bank erosion, when dense urbanization (or effective impermeable surface area) exceeds 10 -15% of the watershed (Booth and Reinelt, 1993, Schueler, 1994). Much of the upper and lower watershed is in open space, used as grazing land or range.

Upper watershed areas are not heavily wooded; oak forests occur predominantly only on north facing canyon slopes and canyon bottoms, with chaparral vegetation generally on steep south facing slopes and areas with shallow, rocky soils.

SLO Creek itself has a nearly continuous riparian corridor from its headwaters at Cuesta Grade to Avila Beach. However in many areas the corridor is narrow, has a sparse canopy cover, or is degraded with a significant mixture of non-native trees and shrubs. Although sheep and cattle grazing of hillside grassland areas may have been intensive in the historic past, that is not the case today. Cultivated agriculture is not extensive, mainly concentrated along the valley lands adjacent to SLO Creek between Los Osos Valley Road (LOVR) and San Luis Bay Drive.

2.3 Climate

The climate of the SLO Creek watershed varies significantly from the coast to the areas of the foothills and mountains of the Santa Lucia Range. Precipitation, in the form of rain, occurs primarily between November and March. It is least along the coast (averaging about 40 cm) but increases as the clouds move inland and rise over the mountains. The highest rainfall (averaging 76 cm) is normally recorded along the ridge tops northeast and southwest of the City of San Luis Obispo. Rainfall in the City averages approximately 54 cm. However, as a coastal watershed, it is subject to wide ranges in precipitation, from periods of drought, to unusually wet winters, and occasional short duration very high intensity storms, such as occurred in January and March 1995.

2.4 Biological Resources

Riparian vegetation is crucial to the maintenance and health of overall habitat quality. Well-developed, relatively undisturbed native riparian vegetation provides shelter and forage for a wide variety and abundance of wildlife. Riparian vegetation also provides stability for stream banks by reducing bank erosion, raindrop impact and erosion associated with overland flow. Additionally, riparian vegetation high in percent cover provides stream shading which, in turn effects water temperature, water quality and fisheries resources. The inverse is true for areas low in overall cover and diversity. These areas typically lack suitable habitat for native wildlife and fish, have increased erosion rate and bank failure and are lower in water quality. **Appendix B** contains a detailed *Biological Resources Inventory.*

Vegetation. Riparian plant community structure and composition vary according to environmental factors such as water regime, climate, disturbance frequency, substrate material, root-zone aeration, depth to ground water, width and depth of flood plain, aspect, slope, the presence and extent of exotic species, land use and water quality. A cross section of a typical stream corridor would reveal the extreme gradation that occurs in vegetative composition from hydric, aquatic bed and freshwater marsh to mesic, riparian forest and scrub, edaphic (conditions determined by soil characteristics). Coastal scrub and grasslands conditions persist where bedrock outcrops and shallow soils, or other soil conditions present limiting factors for plant growth. The structure of the riparian community occurring within the planning area consists of a mixture of native and exotic species, with few areas of undisturbed mature dense riparian canopy.

Wildlife. Riparian habitats provide significant features required by a wide range of wildlife. The variety of plant communities and species, cover values, and the presence of water create conditions which provide food, water, migration and dispersal corridors, and escape, nesting and thermal cover for a rich assemblage of species. Riparian habitat provides year round and seasonal habitat, migratory stopovers and breeding areas for mammals, amphibians, reptiles, birds, fish and invertebrates.

Birds. SLO Creek supports a tremendous variety of resident and migratory bird species. Within the riparian corridor are a multistoried canopy and a mosaic of vegetative communities that support a wide range of habitat requirements. Birds commonly found within the riparian corridor include; great blue heron (*Ardea herdonias*), belted kingfisher (*Ceryle alcyon*), mallard (*Anas platyrhynchos*), black phoebe (*Sayornis nigricans*), common bushtit (*Psaltriparus minmus*) and red-winged blackbird (*Agelaius phoeniceus*) (Fugro, 1995).

Fisheries. In general, pool habitat is the areas of calm water typically located along the margin of streams, which provide calm, cool surroundings for large and small fish. Riffle habitat is swiftly flowing stretches with exposed rocks that provide a niche for small fish, mix oxygen with water and produce an important food source of insects. Flatwater habitat is moderately flowing stretches with little or no flow obstructions that, if deep and swiftly flowing, can provide habitat to larger fish. A stream in good condition ideally has a mixture of pool, riffle, and flatwater habitat. Excesive erosion in a watershed can fill in pools and clog gravels in riffles with sediment.

Many of the persistent polls, which contain water year-round, are found in the middle and upper reaches of San Luis Obispo Creek and its major tributaries. The lower planning area reaches are dominated by flatwater habitat. The predominance of flatwater results in a shortage of riffle and pool habitat. The geomorphic processes, which create pools and riffles, are dependent upon one and other. That is, without pools, riffles will not form and without riffles, pools will not form. The lack of pool habitat and riffle habitat should recognize these constraints and should be aimed at achieving optimal habitat enhancement for endemic riparian vegetation, anadromous fish, amphibians and small mammals. Enhancement efforts include: (a) increase in the overall diversity, extent and continuity of riparian vegetation; (b) the control and/or removal of invasive exotic vegetation; and, (c) improvements to aquatic habitat by creating additional pool-riffle sequences and instream cover. Enhancement objectives such as these would result in an increase in overall ecological integrity in addition to improved aesthetic and recreational values.

2.5 Geology

The San Luis Obispo Creek watershed is located in a geologically complex area within the Coast Range geomorphic province of California. This area is characterized by the widespread occurrence of deformed and partially metamorphosed marine rocks of the

Franciscan Complex (Jurassic to Cretaceous age). The rocks are pervasively faulted and fractured, increasing their instability on steep mountain slopes. In places they are intruded by generally large serpentine rock masses that create unusual erosion and stability problems. The Franciscan Assemblage, a melange or mixture of various rock types, forms the foundation underlying the City of San Luis Obispo, the bulk of the Santa Lucia Hills, and the eastern flanks of the Edna Valley. (Hall, 1977, 1979, Chipping, 1987).

A blanket of Cenozoic marine and non-marine sedimentary rocks, including the Monterey and Pismo Formations, overlie the Franciscan rocks over large parts of the watershed, particularly in the central and southern parts, including the Irish Hills. These rocks can be more resistant to erosion than the fractured Franciscan rocks.

Several faults, including the active Los Osos fault along the northern flank of the Irish Hills and the Edna Fault Zone further south in the Edna Valley area, cross the watershed. These and other faults in this area run in a general northwest-southeast direction, roughly transverse to the general southwest flow of SLO Creek. These faults control the local geology and because of both geologic uplift and differential erosion of rocks of varying hardness, form several prominent ridge systems in the City, and the outline of the drainage sub-basins. Cerro San Luis Obispo (one of a series of ancient volcanic plugs beginning at Morro Rock in Morro Bay and extending just east of SLO) forms a broken ridgeline to the west with Terrace Hill to the east, near the center of town. Another fault occurs on an east-west trending ridge (Water Tank Hill) cut through by SLO Creek on the south side, near the Madonna Road off ramp of Highway 101. This ridge consists of predominantly serpentine rock.

Typically, Franciscan and related rocks yield shallow to moderately deep stony/clayey erosive soils, which occur on steep landscapes. Areas of serpentine rocks generally support a less dense grass and brush cover, because of their inherent infertility. Their consequent slow recovery upon disturbance makes them highly susceptible to erosion. Because of the steepness of the Franciscan landscape and the shallow stony soils, rainfall runoff rates are typically very high.

Franciscan rocks are exposed in the creek bed and creek bank throughout many parts of the upper watershed, including the northern third of the City of SLO. These often occur as bedrock exposures in the creek channel bed where the creek has cut down through the rocks and across the structural grain of the Franciscan terrain

Rainfall infiltrates and flows slowly through the Franciscan formation and travels along its many fractures. It is a good source of early summer base flow in the upper reaches, as well as several perennial springs in the upper tributaries. Groundwater discharge can occur when stream channels cut across these fractures.

Several large or massive landslides are slowly impinging on SLO Creek within the upper watershed area. Large landslide masses are also characteristic of the steep terrain underlain by Franciscan rocks. These areas can be prone to mud slides and debris flows in small colluvial-filled secondary drainages on steep slopes in the upper watershed, particularly following fire or disturbance.

As SLO Creek enters the northern limits of the City, it begins a descent through moderately sloping alluvial fans and then the alluvial valley fill sediments of SLO valley. The valleys through which SLO Creek and its tributaries flow are underlain by both younger and older alluvial deposits (Hall, 1977). Several older alluvial deposits and stream terraces occur well above the modern floodplain in the watershed, attesting to the various episodes of sea level rise and fall, uplift and consequent stream erosion as the creeks have adjusted to the changing base levels.

As viewed in stream cuts, the alluvial fan deposits forming the plain that underlies the City are generally only about three to five meters thick. Based on the degree of soil profile development reported in the *Soil Survey of the San Luis Obispo County, Coastal Part* (United States Department of Agriculture (USDA), 1984), and the fact that most of the plain is well above even the FEMA 500-year flood, these fan deposits should be considered older alluvium, but stratigraphically younger than the older alluvium and stream terraces of Hall (1977).

SLO Creek and its tributaries have incised into this older surface, however they have backfilled a narrow stream zone along the major creeks with younger alluvium, the boundaries of which are approximated by the 500-year FEMA flood limits.

The alluvial deposits are underlain by hard Franciscan rocks, which are exposed in the lower creek banks and creek bed in the northern part of the City, and by reddish brown siltstones, claystones, and conglomerate of the Paso Robes Formation (older Pleistocene) throughout much of the central and southern part of the City. This weakly to moderately consolidated rock is also exposed in the channel bottom and lower bank slopes along much of the middle reaches of SLO Creek, and along the southern side of Los Osos Valley. Locally it may form a subsurface barrier or retardance layer to water infiltration and groundwater recharge. In many areas, infiltrating water apparently moves along the contact between the Holocene sediments and the claystone, where it is intercepted in the creek channel. The claystone may also form a limit to stream downcutting in some sections, favoring or forcing lateral migration of creek channels.

The red-brown unit of the Paso Robles Formation is apparently replaced by a dark brown consolidated clay bed (older alluvium) beginning below Los Osos Valley Road. This unit is also more resistant to stream erosion than the modern stream alluvium that overlies it.

East Fork flows roughly westward, at the base of the serpentine ridge, following the general east-west trend set by the Edna Fault zone, located just to the south and within the lower Edna Valley. From the widespread distribution of the Pleistocene Paso Robles formation, a major drainage must have once occupied the ancient Edna Valley and surrounding area, flowing westward. The deposits have now been uplifted and tilted westward, and a series of consequent streams have cut through the structural and topographic grain of the east-west trending Edna Valley, flowing generally southward to the ocean at Pismo Beach. These include Corral Hollow and Arroyo Grande Creeks. San Luis Obispo Creek, on the other hand, turns abruptly westward from its predominantly southern alignment about 0.5

kilometers from the coast, where it has cut a winding valley through steep hills underlain by various Tertiary sedimentary formations, to emerge at the coast at Avila Beach.

The alluvial floodplain deposits in the lower SLO Creek area, below LOVR and in the Laguna Lake area show little or no indication of horizonation or soil profile development. They should be considered recent alluvium. The Soil Survey indicates that these soils have a gleyed horizon located at a depth of about three or four feet. The blue-gray or grayed color is indicative of poorly drained or anoxic conditions created by a permanent high ground water table during the period these soils developed. This apparently is a relict feature, as the high groundwater table is now only a seasonal occurrence, with the water table likely lowered several meters (three to four) by the historic incision of San Luis Obispo Creek in this area. This incision or downcutting of the channel bed has caused significant secondary channel degradation or stream headcutting of East Fork and Davenport Creek. The dark colors of the surface soils indicate high organic matter accumulation, such as occurs in a swampy flood plain or backwater environment of lower velocity flows, consistent with the flatter stream gradients in this and the Laguna Lake areas.

2.6 Streamflow

The steepness of the upper watershed, its shallow soils, chaparral vegetation and the typically short-duration, intense rainfall pattern result in stream hydrographs that is very flashy. This means that the flow of water moves quickly through the system yielding high peak flows that drop quickly back to winter base flow levels once intense rainfall ceases.

Many of the tributary streams in the watershed are predominantly seasonal, with significant flows occurring only during the winter and spring months. It is also common for some streams or portions of streams to not flow at all in drought years, and to maintain near perennial flow, especially in their lower reaches, during wet years. However, flow in the main stem of SLO creek can be complex, with areas of deep sands and gravels in the creek channel, where summer flow is lost, interrupted by creek bed exposures of hard rock, where creek flow can be forced back to the surface. In general, flow in San Luis Obispo Creek becomes consistently perennial below Prefumo Creek, due both to the interception of groundwater by the increasingly incised channel, and by the introduction of highly treated wastewater from the City's treatment plant discharge above this location. Some flow is maintained in pools in many upper creek tributary areas, fed by shallow surface flow and inter-gravel flow. These pools are critically important to fish, aquatic organisms, and wildlife.

The native fish and aquatic organisms of the SLO Creek watershed have adapted their life histories to meet the environmental challenges of dry summers and periodic draughts. Significant disturbances to the physical conditions and habitat can have profound adverse impacts on them. Because most of the streams in coastal California are impacted by urban uses, many of the native fish and aquatic organisms are considered sensitive, threatened, or endangered species by state and federal resource agencies.

Significant variations in rainfall can cause natural streams and disturbed watercourses to experience extensive, widespread channel erosion and sedimentation in wet years, recovering during dry years. Bank erosion at channel bends can migrate downstream over a period of years, with the gradual recovery of eroded upstream bends. Many of the most significant bank erosion problems occur at channel bends, or in areas of a former meander pattern that has been straightened. In addition to degrading aquatic habitat, erosion and sedimentation can reduce the flow capacity of creeks. Vegetative growth in the channel (from a channel conveyance perspective) occurs in moderate or drought years due to the lack of flushing flows. With the moderate climate of SLO County, vegetation can flourish throughout the year. In many cases the obstructive vegetation includes young shrubby willows, introduced exotic woody plants and ground cover.

The natural stream courses and adjusted floodplain in many areas originally had a higher conveyance capacity in their upper bank and over bank areas, because the natural climax vegetation along the stream corridors consisted of mature sycamores, cottonwoods and tree willows. These tall single-trunk species have lower flow retardance (Manning's N value) than the shrubby willows and exotics. Currently, nearly all of the streams in the watershed have significant conveyance limitations. Channel conveyance is commonly equivalent to less than 25-year flood flow capacity with several reaches in the 10- to15-year flow capacity range.

Fire in the watershed, such as the Highway 41 area in 1994, can also have a significant effect on erosion and sedimentation. The sediment load detracts from channel capacity and alters fluid dynamics. The effect can persist over many years as the sediment bed load slowly works its way through the fluvial system. Increased flood risks result from sedimentation and dense channel growth. With limited channel capacities, management of shrubby lower bank vegetation and sediment management are critical.

Some small headwater tributaries originate on upper alluvial fans, at the front of the foothills and mountain slopes that ring San Luis Obispo valley. These fans have formed though debris and massive sediment flow events, and their natural stream courses may not be stable. There are significant maintenance challenges where urban development has occurred on these upper fans. Without maintenance, (culvert and storm drain clearing before and during major storm events), these channels may clog and migrate from their present form and location. Fortunately, biological values tend to be low at these sites.

2.7 Historical Context Channel Changes

A summary of the more significant historical changes to the watershed and its creeks was prepared, based on a review and comparison of current and historic U.S. Geological Survey topographic maps and aerial photography on file at the University of California, Berkeley Map Library, and the Menlo Park Library of the U.S. Geological Survey. Among the historic USGS topographic maps reviewed were:

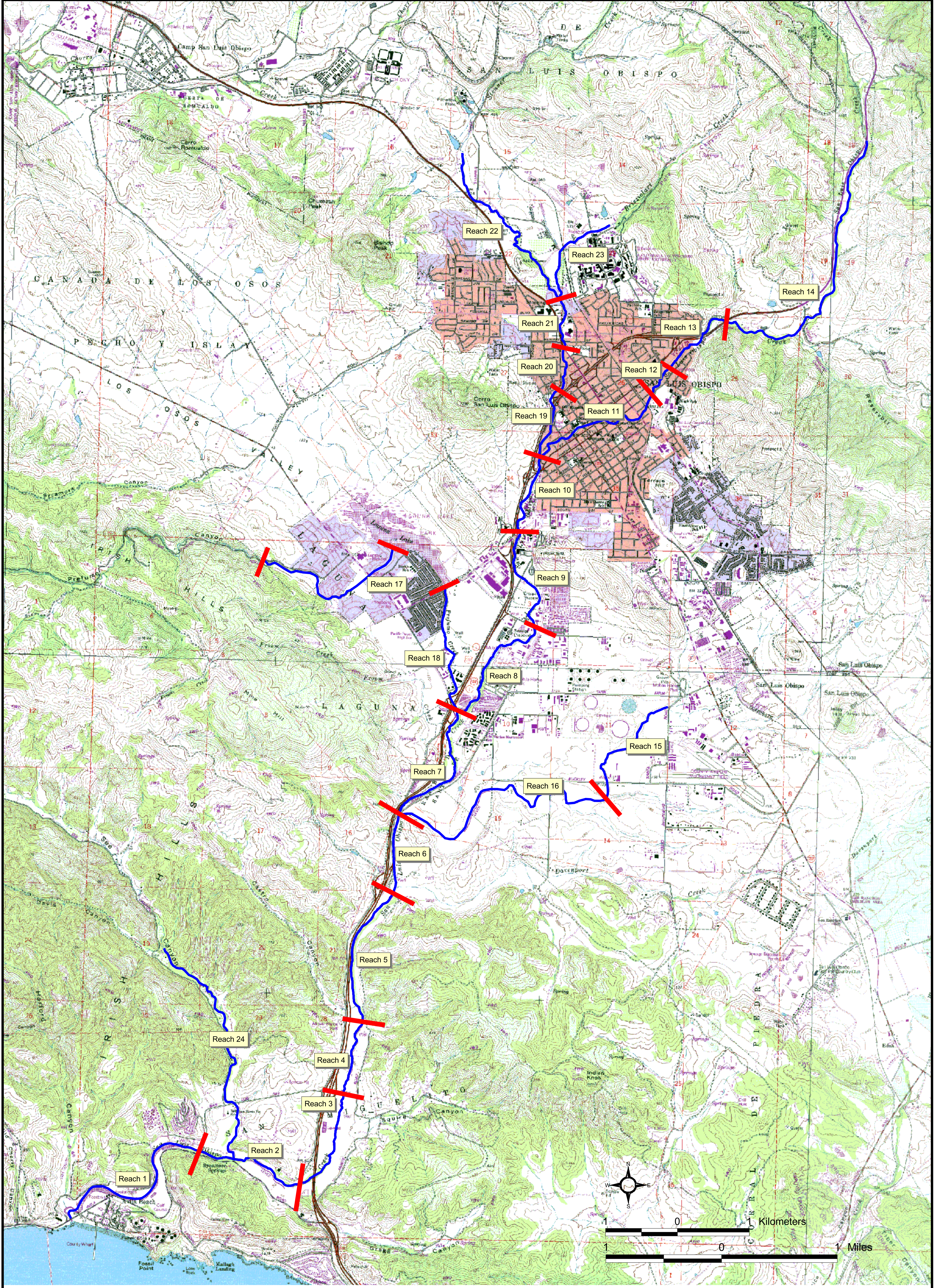
- San Luis Obispo and Arroyo Grande 15' sheets, 1897, 1916, 1952 editions

- San Luis Obispo, Pismo Beach, Arroyo Grande, and Lopez Mtn. 7.5' sheets, 1965, 1994 editions

Aerial photography reviewed included 1939 photos from the US Army Map Service, 1955 & 1977 USGS photography, and 1996 photography from Golden State Aerial Surveys of San Luis Obispo. A summary of historical newspaper articles dating back to the 1870's and interviews with long- time residents of the watershed, prepared by the Central Coast Salmon Enhancement was also helpful in outlining the major events that have occurred in this watershed (Cleveland, 1996). Historic changes to the streams and the current conditions of stream segments are described for various reaches. **Figure 2-2** identifies the numbered stream reaches as used in this WMP. The stream reach designations were established by the Land Conservancy of San Luis Obispo County (Conservancy) in their 1996 hydrologic analysis report of the watershed. The map numbers indicated on **Figure 2-3** coincide with the numbering on **Table 2-1** summarizing the historic channel changes.

Table 2-1
Historic Channel Changes

Map Reference	Description
Location 1: SLO Creek at Avila Beach river mouth	(1) 1897: Lagoon mouth substantially larger and wider. Current lagoon appears to be reduced by approximately 1/3 (now 2/3) historic size. Large tidal marsh present to the east of the lagoon, under present location of western Avila Beach. (2) 1939: 1952: Lagoon geometry quite similar and relatively unchanged. (3) 1977: Lagoon constrained by Avila Bay Drive, similar to present configuration as shown on 1995 USGS topographic map.
Location 2: SLO Creek at San Luis Bay Golf Course	(1) 1897: Lagoon meanders to the south beneath present location of Golf Course. (2) 1939: Lagoon geometry changes are minor. (3) 1952: Lagoon meander becomes straightened to the north, although not quite as far to the north as apparent on 1965 edition of USGS 7.5' Quad of Pismo Beach (or the present alignment). (4) 1994: Golf Course now displaces the historic meander loop and sand-bar. Several islands depicted in 1965 map have disappeared. It appears that the original migration of the bend to the north was natural, but golf course construction made significant alteration. (5) 1995: Some concrete segments of bend appear to have failed.



CITY OF SAN LUIS OBISPO

PUBLIC WORKS DEPARTMENT

LEGEND

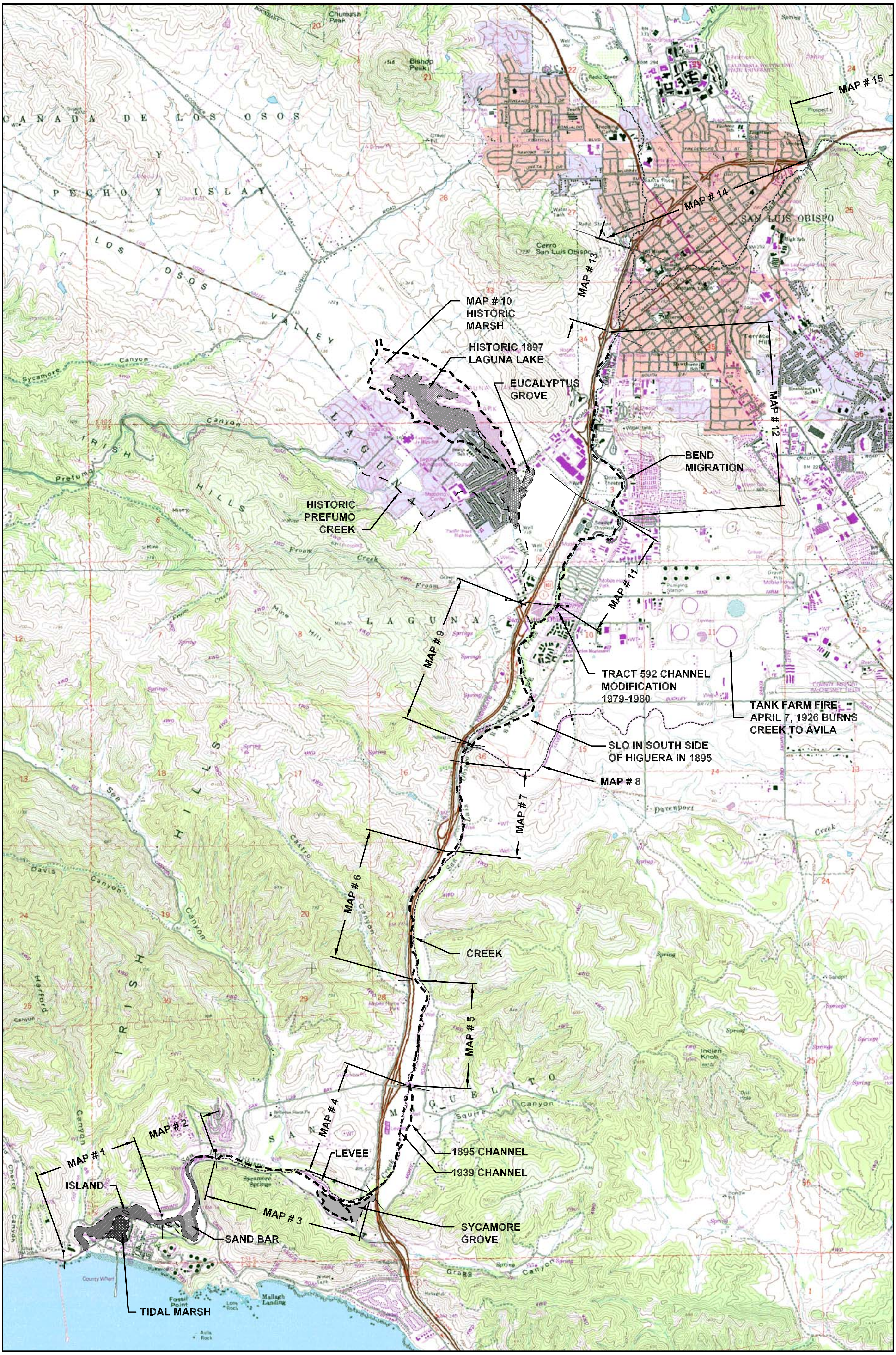
Prioritization Reach Boundaries
Stream Channel

Stream Reach Map

SLO Creek Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure WMP 2-2



	Waterway Management Plan **Historical Channel Changes**	Figure WMP 2-3
	QUESTA ENGINEERING CORPORATION	

Map Reference	Description
Location 3: SLO Creek below Sycamore Springs (between See Canyon and Gragg)	(1) 1939: Historic channel apparently 100-200 feet south of, but parallel to present channel; although scale and accuracy of original topo map makes this difficult to determine. Large Sycamore grove present. (2) 1952: Sycamore grove indicated as green shading. Similar shape as on photo. (3) 1977: Grove significantly reduced in size, remnant mainly along creek. Flood control levee constructed along channel in early 1970s, removing parts of the floodplain from connection with creek. Presently area now mostly in apple orchard, although some young Sycamores visible along channel.
Location 4: SLO Creek from Highway 101 Crossing to San Luis Bay Drive	(1) 1939: Historic channel 2-300 feet east of present channel. Historic channel shows fine meander pattern. Channel straightened and realigned to the west, largely devoid of vegetation in this reach. (2) 1965: Straightened alignment persisted and is apparent. (3) 1977: Some meanders become visible. Natural meander pattern re-exerting itself strongly within this straightened/aligned reach with significant natural willow re-colonization. (4) 1996: Apparent erosion of establishing channel bends observable. (5) 1995: Photo-revised location of SLO Creek in this reach shows re-establishment of same meander pattern as shown in original 19\895 survey. Floodplain appears active and frequently flooded in this area.
Location 5: SLO Creek from San Luis Bay Drive to Castro Canyon	(1) 1939: Channel apparently not significantly realigned in this reach. Natural channel meander pattern not apparent on photography and channel appears lines with willows. (2) 1950: Several of the channel bends straightened and line with broken concrete slabs associated with the widening of Highway 101.
Location 6: SLO Creek from Castro Canyon to near Davenport Creek	(1) 1950's: Several channel bends appear to have been straightened associated with Highway 101 construction. Channel and floodplain very active in this area, with several old channel meanders and traces of vegetated secondary channels apparent on photograph. This area appears to flood frequently. Several wet meadows apparent on floodplain to the east of the channel.
Location 7: SLO Creek from Davenport Creek to East Fork Creek.	(1) 1950's: Channel bends straightened and channel realigned associated with construction Highway 101.

Map Reference	Description
Location 8: Lower East Fork Creek	(1) 1895 (circa): Lower East Fork Creek apparently remained largely within its historic channel configuration, although no located 50 feet south. Earliest photographs show insignificant vegetation along channel. (Channel burned by explosion and fire at Tank Farm in April 1926. Burning oil fire reportedly carried along creek, destroying creek vegetation all the way to Avila). (2) 1970's: Upper section leveed and section near confluence with SLO Creek partially leveed in 1998. .
Location 9: SLO Creek from East Fork Creek to Prefumo Creek	(1) This section of SLO Creek changed significantly from historic (1897) conditions. SLO Creek on southeast side of South Higuera. Map indicates this section of the creek is intermittent, becoming perennial downstream of The Narrows, and upstream of Marsh Street. (2) 1939: Channel relocated to the north of Higuera; however the original trace of the channel still faintly visible. (Some problem with registration of the two maps here – so less certain). Channel well vegetated in this reach.
Location 10: Prefumo Creek and Laguna Lake area	(1) 1897: Laguna Lake historically smaller in size, with open water area terminating approximately 3000 feet northwest of Madona Road. Large wetland shown by symbols on map, surrounding Laguna. (2) 1952: Lake similar in size and shape. Laguna Lake deepened to present shape by mid-1960s. Apparently small area of wetland filled on southwest shore, but deepening predominantly within limit of what was historic marshland. (3) 1965: Lake extended further northwest, but this may be an artifact of the time of year and rainfall; as the shape of this shallow lake and wetland area can vary seasonally. This area may have been a major natural flood water detention area, as black marsh soils extend in a large area surround Laguna Lake. (4) Prefumo Creek originally shown as flowing through present day Shopping Center to join SLO Creek in large Eucalyptus grove below Laguna Lake outlet. Grove is present in 1939 photographs. (5) 1960's: Prefumo Creek re-routed through City Golf Course. Channel gradient too steep and area is experiencing bed incision and bank erosion. Several drop structures installed to arrest bed erosion; some are minor fish passage obstacles.
Location 11: SLO Creek from Prefumo Creek to Prado Bridge	(1) 1979-1980: This area significantly altered by major channel modification and flood control project (Tract 592). Channel significantly widened with a compound channel. Channel now experiencing erosion of some channel bends, and aggradations of in-channel willow covered terrace. Channel bends along portions of this reach protected with gabions, rip-rap, and other hard bank protection devices.

Map Reference	Description
Location 12: SLO Creek from Prado Bridge to Marsh Street Bridge	(1) This apparently is an unstable section of the creek, where the channel has been realigned associated with the historic construction of Highway 101. Elevated fill for Hwy 101 construction partially isolated historic floodplain on the west side of the creek. Several sharp channel bends were re-graded and the channel lined in some sections, particularly at Madonna Road associated with interchange construction in the 1960's. This is also a flood prone section of the creek.
Location 13: SLO Creek from Marsh Street Bridge to Santo Rosa Street Bridge	(1) 1916: Portions of this section of SLO Creek underground. Under-City culvert indicated. (2) Channel straightened and largely within present alignment, confined by bank protection devices at many channel bends.
Location 14: SLO Creek from Santa Rosa Street Bridge to Highway 101 at Cuest Park	(1) Channel remains largely within existing historic alignment from the 1890's. (2) 1939: Channel appears to be well vegetated with willows. (3) 1977: Streamside tree cover appears less dense, following reported period of channel clearing in response to floods of 1969 and 1973. Although not directly observable on aerial photographs, removal of tree cover and other flow obstructions are through to have contributed to rapid channel down cutting during the late 1970's through present, as stream flow velocities increased. This resulted in local bank failures, particularly at channel bends. Several historic channel retaining walls built in the 1950's and 60's have collapsed as their footings have been undermined by the incising channel.
Location 15: SLO Creek from Cuest Park to Cuest Grade (including Reservoir Canyon confluence)	(1) At map scale shown, channel alignment largely unchanged, few channel bends, except where canyon tributaries join main stem of creek. (2) 1897 USES Survey: Southern Pacific Railroad over Cuesta Grade indicated, along with water supply reservoir on Reservoir Canyon. Dirt access roads for railroad maintenance not shown.

Until the 1770s when the Spanish established the Mission of San Luis Obispo, the SLO Creek watershed was relatively undisturbed. Although the Chumash Indians inhabited the region for thousands of years prior to the Spanish settlement, their hunting, fishing and gathering lifestyle did little to alter the creeks. Under the Spanish, however, wheat farming and cattle and sheep ranching were intensive, and altered the region's hydrology, probably permanently.

By 1846, the government had secularized the mission's land, transferring it to private ownership and establishing more than 30 land grants, or ranchos, in San Luis Obispo County. Severe droughts in the late 1860s forced rancho owners to sell off portions of their lands. San Luis Obispo became a county of small farms and sheep and cattle ranchers. The population began to increase and the economic base began to change with the establishment of the railroad. The Southern Pacific Railroad completed its line from San Francisco to San Luis Obispo in 1884. Major hillside cuts were required in the Cuesta Grade area to accommodate the railroad tracks.

Much of the natural vegetation along SLO Creek was apparently removed by farming and grazing during this early period. In fact, many of the old photographs and artists sketches dating from the 1880s in the Historical Society Museum in the City show the stream bank tops as largely barren. Over the past century, urban development encroached upon the SLO Creek. This resulted in periodic exposure to flooding of structures located along creek banks, and increased flood damages. Damaging floods are reported to have occurred in 1861, 1862, 1884, 1897, 1911, 1948, 1952, 1962, 1973, and 1995. The 1861-62 floods were reported to have removed many of the mature sycamore trees (which may have been hundreds of years old) along large portions of the upper and middle reaches of the creek (Cleveland, 1996).

A lighting strike caused a fire in August 1926 at the Union Oil Tank Farm located in the present Airport Area of the East Branch of SLO Creek drainage. The strike ruptured a large tank and sent a stream of burning oil down East Branch to San Luis Obispo Creek. The burning oil reached Avila Beach. Nearly all of the mature woody vegetation was apparently destroyed from the creek between East Fork and Avila by this fire. A period of severe bank erosion apparently followed the fire and loss of protective vegetative cover.

Channelization, including straightening of creek meanders and realignment for farming and road and highway construction has also been common within the SLO Creek watershed. The lower estuary areas appear quite different on the 1877 topographic maps from those of the 1994 editions, with the extent of the estuary and marsh significantly smaller and several large gravel bars greatly diminished in size. The creek was apparently realigned in this area several times for road construction and for construction of a golf course in the 1970s.

In 1969, the Luigi Marre Land and Cattle Company constructed an approximately 1-meter high sheet-pile dam across the lower SLO Creek approximately 1.5-km above its mouth. (Morro Group, 2002). The reported purpose of the dam was to halt upstream saltwater intrusion into the underground aquifer of this area. This dam, constructed in the turn of a stream meander, also has significantly affected stream conditions in this area, including channel shape, pool formation below the dam, fine sedimentation upstream, and reduced salinity of the channel above the dam. (Upper Salinas River-Las Tablas Resource Conservation District, Dec. 2001) Although a fish ladder was constructed shortly after dam construction, the ladder has been ineffective, and the dam has changed the habitat conditions for the Tide Water Gobby, an endangered species that occurs in the lower estuary area.

The lower segment of SLO Creek in Reaches 4&5, (above Marre Dam) were apparently straightened for more efficient farming some time in the 1930's as the previous slight meander pattern of the channel in this segment was replaced by a straightened section, as shown on 1939 U.S. Army aerial photography and the 1952 U.S. Geological Survey topographic map of the quadrangle. Levees were also constructed along the creek in the lower part of this reach some time in the 1970s.

Major channel meander straightening and realignment took place along much of SLO Creek in the mid to late 1950's, associated with construction of Highway 101. The stream reach just upstream of the South Higuera off-ramp to Hi101, and the reach just below this, to the Narrows below Davenport Creek (Reaches 5, 6&7) were apparently realigned during this period, with portions of the west bank protected by riprap and concrete slabs. The realigned creek has a steeper gradient in this area than historically and has incised into the channel bed several meters.

Some channel realignment also took place between the Marsh Street Bridge and Madona Road (Reach 10) during this time period, associated with Highway 101 construction. The Highway was also elevated on fill in this section, more or less disconnecting the floodplain on the west side of Highway 101 from all but the most significant flooding. This fill likely exacerbated the already frequent flooding in the Mid-Higuera area. The floodplain had already been significantly encroached upon by fill placement and buildings on the east (South Higuera Street) side associated with more than 100-years of commercial use of this area. The channel modifications also apparently affected downstream channel segments, and portions of the channel were lined in the vicinity of the Caltrans yard and above the cemetery in the Elks Lane area (Reach 9).

The Laguna lake area appears somewhat similar when comparing the 1897 and 1994 editions of USGS topographic maps. The Lake itself is slightly larger, but the wetlands surrounding the lake are smaller, due to filling in the 1960's and 1970's for residential development. Prefumo Creeks was re-routed through Laguna Lake and an outlet control structure was installed.

SLO Creek and its tributaries, including Meadow Creek, Stenner Creek, and Old Garden Creek have undergone significant channel modifications by private property owners prior to the period of state highway construction, dating back to at least the 1920's. This included straightening associated with city block street layout, undergrounding of portions of Old Meadow Creek, and construction of a haphazard assortment of bank revetments and channel lining by private property owners along the creek.

The Under-City culvert, which passes SLO Creek flow through the downtown area between Chorro and Marsh Streets was apparently under-grounded sometime in the early 1900's, in part because of water quality and odor problems from the period when the creek was more or less used as part of the sewer system.

The early City also relied upon a series of dams and water diversions for its water supply. This included construction of the Stage Coach Dam on upper SLO Creek prior to the turn of the Century, and construction of Reservoir Canyon on the Reservoir Creek tributary circa 1911. These and other smaller, earlier dams constructed upstream of Stage Coach Dam virtually stopped the transport of all larger bed-load (gravels and cobbles) downstream. Such a disruption in sediment supply typically results in channel downcutting as the stream readjusts to a diminished sediment supply.

There is almost no evidence of the existence of the early small dams on upper SLO Creek. Stage Coach Dam, which is about 4 meters high, represents an almost insurmountable barrier to fish passage. (This dam is now completely filled in with large cobbles, and will be removed by the City under a grant from the California Department of Fish and Game in the fall of 2002, or summer of 2003).

The only major flood control project constructed within the watershed is located above the Los Osos Valley Road Bridge in Reach 8. In 1978, as part of the Tract 592 subdivision to the east of SLO Creek, a private developer channelized SLO creek to protect future development from the 100-year flood. The channelization consisted of excavating one of the channel banks (alternating east and west) to form an in-channel floodway terrace, leaving the existing channel bottom largely in its natural state, and revegetating the newly formed banks. The terrace is now densely vegetated with shrubby willows.

The most recent floods in 1995 followed an unusually a wet three-month period, January through March, which was reportedly the wettest period in 116 years of record. The stream banks remained saturated for months and were repeatedly attacked by moderate to high flows. The impacts of the 1995 flood were made more severe by the Highway 41 fire. A major portion of the Upper Stenner, Brizziolari and SLO Creeks west of Cuesta pass was burned in 1994. The denuded watershed responded to the 1995 storms with increased rates and volumes of runoff and significant movement of sediment into the lower channels. The 1995 storms were particularly devastating to channel conditions, because a series of storms swept through the area, resulting in prolonged high-flow, high velocity events, giving little time for the channel to recover and dry out between flood events. While the sediment input is returning to pre-fire conditions, the increased sediment discharge is anticipated to persist for many years. Creek flow may be re-mobilizing and re-working the sediments deposited earlier in the headwater channels, as well as along the bars throughout the main channel within the lower valley.

Many of the problems in the SLO watershed appear to have been caused by historic land uses, especially dirt access road for utility construction and maintenance, and railroad construction in upper watershed areas. The main impact of urbanization in this watershed appears to be its effect on increasing the 2-year or channel forming flow, and resultant channel instability concerns. The small dams in the upper watershed may also have had an effect on channel stability, by removing an important source of coarse sediment, thereby causing channel down-cutting and further bank instability

2.8 Existing Channel Conditions

The deeply incised character of SLO Creek today is evidence of the creek's response to the historical hydrologic changes noted above. Increased discharges from urban areas and grazing lands result in higher velocities that are capable of eroding the channel bed and banks. Erosion continues until the slope reduces to adjust to the changes in hydrology. In addition, dense creek-side vegetation, which had previously provided bank stability, was reduced in many areas during urbanization and encroaching agricultural uses, accelerating the erosional process. The channel response to the increased flows and sediment loads particularly following the 1994 fire and 1995 flood has been to widen its channel through bank erosion in flatter areas or areas underlain by harder claystone, and to incise, and scour in areas of steeper gradients or having softer bottoms. In reaches with meanders, the meanders typically are migrating (slowly) downstream, often impinging on the left bank, probably reflective of the tilt of the valley. As previously noted, stream realignment and straightening for agricultural purposes and for street and highway construction have also had a significant effect on the stability of the streams, as has the haphazard construction of bank lining and revetments which have moved problems cross-channel and downstream.

2.9 Channel Hydraulics and Stability Analysis

New computer models of the rainfall/runoff hydrology of the watershed (HEC-HMS model) and the channel hydraulics of the major streams and floodplains of the watershed (HEC-GEORAS model) were developed as part of the planning process (see **Appendix C**). These were used to help identify channel constrictions and flood prone areas, as well as areas where high channel velocities and shearing forces can attack unprotected and over-steepened channel banks. High and erosive stream velocities were found to occur in the upper watershed area of Reach 14, (in the Cuesta Grade area) as well as locally within reaches 9 and 10 (upstream of Prado Road to above Marsh Street). The highest shearing forces occur at the toe of the bank on the inside of channel beds. The computer models were also used to develop and test alternative methods to address the identified flooding problems.

The hydrologic/hydraulic analysis found that since development of the watershed the amount of flow in SLO Creek during the 100-year flood event has only increased a few percent (since the early 1960's), but the 2-year channel shaping flow has increased by as much as 10-12 % near the Mid-Higuera area. The hydrology and hydraulics models will also be useful for future site-specific planning in the watershed to insure that new development does not increase flooding and bank erosion problems, as well as to test the design of individual bank repair and flood management projects. Modeling methods and procedures are contained in the report entitled *Hydrology and Hydraulic of the SLO Watershed.*

2.10 Watershed Perspective on Channel Stability

Evaluations of channel bank erosion and other fluvial geomorphic processes included completing a detailed Global Positioning System (GPS) assisted field inventory of the main stem of SLO Creek and its tributaries, and studying historic maps and aerial photography.

San Luis Obispo Creek has undergone system-wide channel bed incision throughout much of its course, in places experiencing as much as 1.5 to 3 m (6 to 10 ft) of downcutting. The hydrologic analysis completed indicates that the incision is likely the result of increases in the volume of the two-year channel forming flow from urbanization of the watershed, combined with the extensive turn of the century livestock grazing that damaged watershed lands and has permanently increased runoff rates. Creek straightening and realignment associated with street and highway construction have also had significant effects on the stream system, by shortening and steepening reaches, increasing stream velocities. The haphazard placement of various bank protection structures has also created local instabilities. The hydrologic analysis showed relatively minor increases in the 50-year and 100-year recurrence interval flood flows (less than 2% increase).

2.11 Reach Descriptions (*refer to Figure 2-2*)

- **Reach 1** extends from the mouth of SLO Creek at Avila Beach to the San Luis Bay Drive Bridge, flowing past the San Luis Bay Drive Golf Course. Avila Drive is located on the south side in this reach. This reach is tidally influenced. The Marre Dam forms a barrier to tidal flow upstream, and blocks creek flow. Since it is an apparent obstacle to steelhead passage, (it includes an inefficient fish ladder) the Land Conservancy has a proposal to modify it. The channel banks are highly eroded along the golf course, and many areas failed during the flooding of 1995, including the loss of two pedestrian bridges.

- **Reach 2** extends from San Luis Bay Drive to the Ontario Street Bridge near Highway 101. This area has mature riparian vegetation, including large Sycamores and the banks are generally in good condition.

- **Reach 3** extends from the Ontario Road Bridge under the Highway 101 Bridge to the San Luis Bay Drive Bridge. This area is mostly agricultural, including an extensive apple orchard planted along both sides of the creek. Although the downstream end of this reach has mature riparian vegetation, most of the reach has dense young willow growth. Portions of this area was cleared and straightened in the late 1930's, and agricultural practices kept the channel banks mostly clear of willows until the last 10 to 15 years. The corridor is faily narrow and lacks diversity.

- **Reach 4** extends from the San Luis Bay Drive Bridge east of Highway 101 to a wooden agricultural access bridge crossing of the creek. The lower section is mostly young willow trees, while the upper section of the reach has a more structurally and species diverse assemblage of riparian plants. The riparian corridor is fairly narrow. Willows have become established on bars in the stream channel in this reach, forcing flow against the banks and causing extensive erosion. In part, this is a natural process as the stream regains its natural tendency to meander in a section that was lost when the channel was straightened in the late 1930's. Roads and structures are not threatened, and there are numerous pools with good cover. In places, concrete slabs have been placed haphazardly along the banks in an attempt to arrest erosion. These have been largely ineffective, and may be causing problems locally where flow is constricted.

- **Reach 5** is a reach between two private farm access bridges, to the Bunnell parcel on the south and the Maino parcel on the north. This reach has a generally good mix of riparian species of differing areas. However, the east bank top in one section is lined with Monterey Pines. Several of these have toppled into the creek in the past, and a number are undermined and in danger of toppling. This reach was also modified and realigned during the construction of Highway 101 in the 1950s. The channel is downcutting in this section, contributing to channel bank instability on the east bank. The west side was partially lined with broken concrete slabs, presumably when the highway was constructed, although many have been partially overgrown by willows. A small drop structure was apparently constructed in this reach at one time to arrest further channel bed incision. This structure is beginning to flank and is in danger of failing at some point in the future. Davenport Creek enters the channel in this reach from the east. Since the main channel has incised in this reach, channel headcutting is now working its way up Davenport Creek.

- **Reach 6** extends from the Maino parcel bridge to the bridge at the South Higuera Street on-ramp to Highway 101. This reach was also realigned during construction of Highway 101, and has a zone of almost continuous bank erosion on the west bank. East Fork enters the creek on the east side. The lower portion of East Fork was recently stabilized and enhanced in a cooperative project among the City, County, and Land Conservancy. Although some enhancement has been completed through this reach, there are opportunities for additional enhancement and stabilization where the creek parallels south Higuera.

- **Reach 7** extends between South Higuera Street and Los Osos Valley Road. It has a fairly continuous riparian cover. Bank erosion is occurring at channel bends, some of which have been stabilized recently by the Land Conservancy using biotechnical methods.

- **Reach 8** is a 2 km stretch between the Los Osos Valley Road Bridge (at the southwestern corner of the San Luis Obispo City limits) and the Prado Road Bridge. A large bend, with a steep near vertical bank, occurs just downstream of Prado Road. From the Los Osos Valley Road bridge to the City's wastewater plant (WWTP) the channel is a 40-meter wide floodplain that was constructed in the 1970s for flood control. San Luis Creek makes a sharp bend upstream of the Los Osos Valley Road Bridge. There is a wide low dense willow thicket floodplain on the east side where sediment is accumulating. The floodplain terrace is about three meters above the channel bed. On the west side, Prefumo Creek joins SLO Creek about 100 meters upstream of the Los Osos Valley Road Bridge. The City's WWTP discharge point is upstream of the confluence with Prefumo Creek. This area was enhanced in 1999 as mitigation for bank repair projects completed at that time.

- **Reach 9** is a 1.5-km. stretch between the Prado Road Bridge and the Madonna Road Bridge. In this area, SLO Creek makes a sharp bend. The outside of the bend is partially covered by broken concrete slab rubble. This rubble and small cement slabs downstream are being undermined at the toe, evidence that the river may be actively downcutting in this stretch. There is a 400-meter stretch downstream of the Elks Lane Bridge that is a straight, well-vegetated trapezoidal-like earthen channel. The banks in this stretch are significantly lower than other sections of the creek.. On the downstream side of the Elks Lane Bridge, the west bank steepens and is encroaching upon a small trailer park. Between the Elks Lane Bridge and the Madonna Road Bridge the creek meanders within a deeply incised channel, with bare vertical banks up to four meters high along the outside of the bend. On the inside of the bends are gravel bars with various degrees of willow colonization. The east bank of the remaining 200 meters of Reach 9 is actively eroding and threatening the Caltrans maintenance facility; although, some repair Caltrans completed work here in 1998. Directly downstream of the Madonna Road Bridge both banks are protected by a 30-meter long concrete slab. The east bank is partially protected for another 20 meters downstream by boulder rip-rap.

- **Reach 10** is a 1.2-km stretch extending from the Madonna Road Bridge upstream to the confluence with Stenner Creek. This reach was also surveyed in 1997 as part of the Phase I studies. For 125 meters upstream of the Madonna Road Bridge the steep west bank is being undercut at the toe, potentially threatening the Highway 101 roadway base fill. Moving upstream, the outside of the next meander bend is protected by a mixture of rip-rap, gabions and grouted rock. Upstream of this is a 100-meter stretch of relatively undisturbed channel before the creek bends back to the east. The outside of this bend, which is protected by sackrete, runs closely along side Highway 101. The west bank on the upstream edge of the sackrete is over-steepened and could result in gradual failure of the sackrete.

  The Hayward Lumber yard, which was repaired in 1999 as part of the Phase I program is 180 meters upstream of the sackrete wall. Approximately 50 meters upstream of the Hayward Lumber is the Bianchi Lane Bridge. On the west bank directly upstream of this bridge, there are a series of culverts that empty into the creek from the top of the bank. The flows from these culverts are creating gullies, which will continue to widen and may eventually jeopardize the bridge foundation. Between the Bianchi Bridge and the Marsh Street Bridge upstream, the channel is straight with steep moderately vegetated banks. Portions of the west bank in this 200-meter stretch show signs of incipient erosion. Between the Marsh Street Bridge and the confluence with Stenner Creek, SLO Creek passes under another small bridge and through a straight stretch of well-vegetated trapezoidal channel. Channel gradient steepens in this area.

- **Reach 11** extends from the confluence of Stenner Creek to the California Street Bridge at San Luis Bay drive. This is the Mission Plaza and downtown area. The under city culvert occurs in this reach, extending from just below Chorro Street to just below Marsh Street. The banks throughout this reach are mostly lined, including stacked concrete, gabions, and rock walls.

- **Reach 12** begins at the California Street Bridge and extends to the Andrews Street Bridge. This reach extends primarily through residential properties, many of which have built up to the top of the creek bank. Much of the banks in this section have been lined, some with vertical retaining walls. However, the creek channel is continuing to incise in this reach, potentially undermining some of the structures. In other areas, banks are largely barren and unprotected and subject to erosion.

- **Reach 13** extends from the Andrews Street Bridge to the Highway 101 culvert at Cuesta Park. This area is primarily residential, but with some commercial office buildings located along the creek banks. Several sections of this reach have been stabilized with gabion baskets and other "hard" bank protection structures.

- **Reach 14** extends 2.5 kilometers upstream from the Highway 101 culvert above Cuesta Park. Upstream of the Highway 101 culvert, the channel is relatively undisturbed with low, well-vegetated banks and frequent bedrock outcrops. The bed material is primarily cobbles with gravel and sand point bars. Moving upstream, the channel bends gradually to the north with a bare and vertical north bank. Inside of the bend, there is a wide cobble and sand bar, which rises gradually into a grass field. Many of the mature Sycamores in this reach are being undermined and are in danger of falling into the creek.

  Between Cuesta Park and the Reservoir Canyon Bridge, the channel is deeply incised with banks up to six meters high. SLO Creek is joined by Reservoir Canyon Creek from the south. The channel has steep banks, which are actively eroding at the toe, on the outside of the meander bends. The inside of the bends are cobble point bars below more stable partially vegetated banks. About 200 meters upstream of the City's Pistol Practice Range, the toe of a large landslide encroaches on the channel. This potential failure could contribute a great deal of sediment and large woody debris to the creek, which might cause log jams downstream and contribute to flooding problems.
  The Reservoir Canyon Bridge is located in the middle of a sharp bend in the creek. Bank protection measures undertaken at the bridge in 1998 include rock rip-rap and concrete. Approximately 100 meters upstream of the bridge the south lower bank is lined with concrete rubble below a large private home. Upstream of this home is a natural bedrock falls, which drops approximately one meter from a pure bedrock channel to a mixed bedrock and gravel channel downstream. The lower south bank is predominantly bedrock while the upper bank is gently sloping and moderately vegetated. On the north side are steep bedrock banks up to five-meters high. Upstream of the bedrock, the primary direction of flow of SLO Creek shifts from east-west to north-south.

  For the last 300 meters SLO Creek flows alongside Highway 101. There are several large culverts, which flow under the highway and drain into the creek. The final 200 meters is a straight narrow channel with one to three-meters high banks. The west bank along Highway 101 is lined with sackrete. The lower east bank is bare with many exposed roots, while the upper bank is well vegetated with large trees, including a mixtures of Eucalyptus and Sycamore. These are in danger of toppling into the creek with on going bank erosion.

- **Stenner Creek (Reach 19, 20, 21, 22).** The Stenner Creek reach begins at the confluence with the main stem of SLO Creek and extends 700 meters upstream to the Highway 101 Bridge. 100 meters upstream of the confluence, the west bank is claystone bedrock with a well-vegetated upper bank. Upstream east bank is a concrete floodwall, lined on the bottom with concrete rubble. The bank opposite the floodwall is well vegetated and gently sloping. Downstream of the concrete rubble is a scour hole exposing tree roots. Severe erosion is threatening a historic black adobe building.

  Near the Nipomo Street Bridge there are a variety of channel protection measures implemented by individual property owners. These include concrete and boulder rip-rap and cemented boulders, some of which show evidence of toe scour. There are large pieces of concrete debris, which indicate partial failure of the bank protection. Individual culverts drain into the creek with inadequate outfall protection.

  Between the Nipomo Street Bridge and Highway 101, the channel is straight and trapezoidal-like with moderately vegetated banks. The lower banks are covered primarily with grasses and willows, while the upper banks are covered with ivy and larger, mostly exotic trees. In this 300-meter stretch, there are patches of bank protection including concrete and boulder rip-rap. The bed material is gravel and cobbles with large chunks of concrete debris from failed bank stabilization efforts.

- **Prefumo Creek (Reach 17 –18).** The Prefumo Creek reach extends 950 meters upstream from the Los Osos Valley Road Bridge through the Laguna Lake Golf Course to the upstream edge of a trailer park. The channel in the lower half of this reach is primarily a grass trapezoidal channel. Between the Los Osos Valley Road Bridge and the first golf cart bridge, the trapezoidal channel has several small soil slips. Within this 240-meter stretch, there are three small concrete drop structures and one concrete ford before the creek drops under the Los Osos Valley Road Bridge.

  Upstream of the second bridge is a small grouted rock drop structure and gabion wall, with a north bank that is steep and poorly vegetated. At the upstream edge of the gabions, Prefumo Creek makes a sharp bend and a small tributary comes in from the south. For most of the final 320 meters of the reach, Prefumo Creek runs through a primarily undisturbed channel along the base of a steep hillside on the south and a trailer park on the north. The banks are moderately vegetated with a few short bank protection measures undertaken by individual property owners.

3. PROBLEM IDENTIFICATION AND WATERWAY MANAGEMENT NEEDS

3.1 Introduction

his section of the WMP discusses resource management problems, management needs, and restoration and enhancement opportunities that currently exist along SLO Creek and its principal tributaries. A separate part of this section discusses the flooding problems along SLO Creek and its main tributaries. Identification of resource problems and management needs is based on previous surveys completed as part of the SLO Creek Phase I report; planning studies completed by the Land Conservancy in 1996 (as part of a watershed hydrologic survey); this Phase II biologic and stream geomorphic inventory; detailed hydrologic and hydraulic modeling completed for the WMP, and a watershed reconnaissance.

3.2 Watershed Reconnaissance

A reconnaissance investigation of the watershed was completed to determine the principal management issues facing upland areas of the watershed. The reconnaissance was done after studying the previous *Land Conservancy Watershed Hydrologic Analysis* (1996) and reviewing a set of black and white stereo-paired aerial photography of the watershed, as well as select low altitude color photography of the watershed, focused on creek corridors.

The watershed reconnaissance and literature revealed:

- Turn-of-20th century and prior to that period intensive grazing (and in places overgrazing) led to changes in the rainfall-runoff dynamics of upland areas, including displacement of perennial grasses with annual grasses, soil compaction, and higher peak runoff rates. This has likely led to the stream incision or channel bed downcutting that is common throughout all of the creeks in the watershed.

- The effects of fire suppression in this watershed are not fully known, but the periodic large fires in the watershed (e.g.1994 Highway 41 fire) delivered high sediment loads, some of which are still working their way through the fluvial system. This may have contributed to the 1995 winter flooding, as runoff rates in fire areas are known to be higher, with much larger delivery of sediment to stream channels that reduce the flow carrying capacity of the streams.

- There are significant historic barren railroad grade cuts in the Cuesta Grade area. In some locations where the railroad or dirt access roads cross small tributaries, culverts have been installed which have unprotected having discharge points. These generate significant sediment loads to the upper creek system. Dirt utility access/maintenance roads also appear to be secondary contributors to upland erosion in some areas.

- Several historic water supply dams have been constructed in the upper watershed area, including a small dam near Stage Coach Road, and the larger Reservoir Canyon facility.

These structures trap bed load sediment (cobbles and large gravels) and remove a portion of the sediment load from the fluvial system. The loss of bed load can also result in stream incision as the channel responds to this loss by eroding stream bottom materials.

- Overall, the watershed appears to be in fair to good condition, compared to other coastal area watersheds in central California, because upland erosion, gullying and active landsliding areas are not extensive. The upper Prefumo Creek watershed and the Prefumo Canyon area is the sub-basin with the most significant upland erosion and stream-side landsliding and slope instability problems.

- Based on watershed reconnaissance and observations and the work completed by the Land Conservancy, it appears that most of the sediment yield entering SLO Creek is presently coming from erosion of secondary channels and the main SLO creek channel, not from watershed upland erosion.

- Based on the results of the hydrologic analysis completed for the Phase II studies, it appears that urban development since the 1960's have not had a significant effect on flooding. However, urban development has affected the 2-10 year channel-forming flows more than 25, 50 & 100- year flood flows. This may be important in a watershed where channel capacity is limited to the 20-25 year recurrence interval range. Increased flows at lower storm return intervals (e.g. increased 2-year channel forming flow) can cause channel incision and toe scour, which in turn can cause widespread bank failure.

3.3 Problem Identification

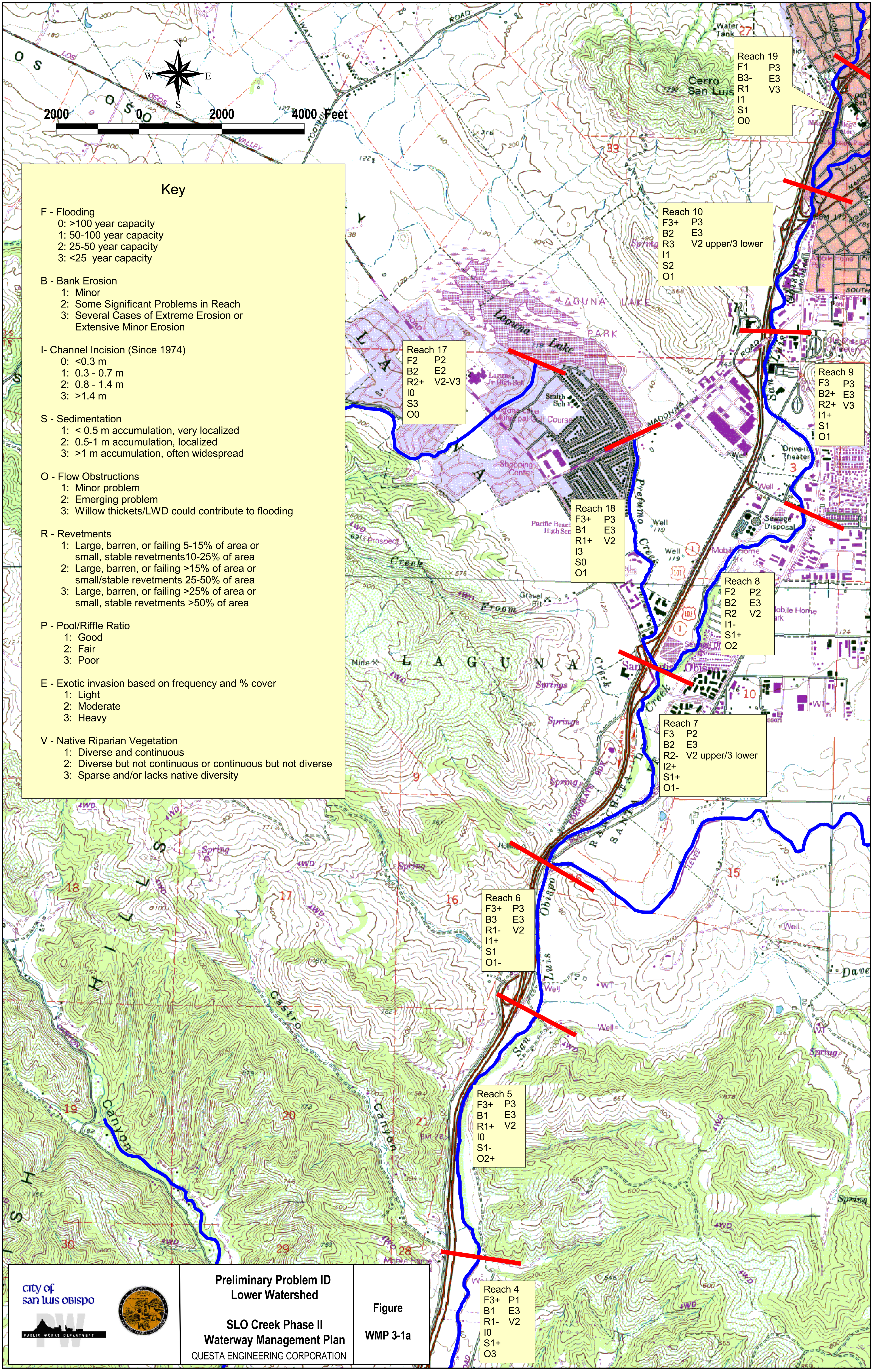
The main channel of SLO creek (and main tributaries) was divided into 14 reaches in the Conservancy study. Their reach numbering system was used for this WMP. East Fork SLO Creek was assigned Reach 15.

Figures 3-1A and 3-1B present Problem Identification maps. The maps identify and summarize the following problems and management needs:

- **Flooding**; whether flows are out of bank or not in the 10, 25, or 50 or 100-year-flood recurrence interval flow conditions.

- **Bank Erosion**, based on the field inventory.

- **Channel Bed Erosion**. This was determined by comparing the 1974 City surveyed cross-section geometry bed elevations used in previous FEMA hydraulic model with the LiDAR acquired channel topography. Adjustments were made for differing datums. Areas of active channel incision were also noted in the field based on exposure of culvert inverts and bridge abutments, and foundation lines of historic channel retaining walls and revetments. Creek bed incision can lead to undermining and collapse of retaining structures, and extensive bank erosion as new channel banks become over-steepened and too high for the natural soil foundation conditions to support.

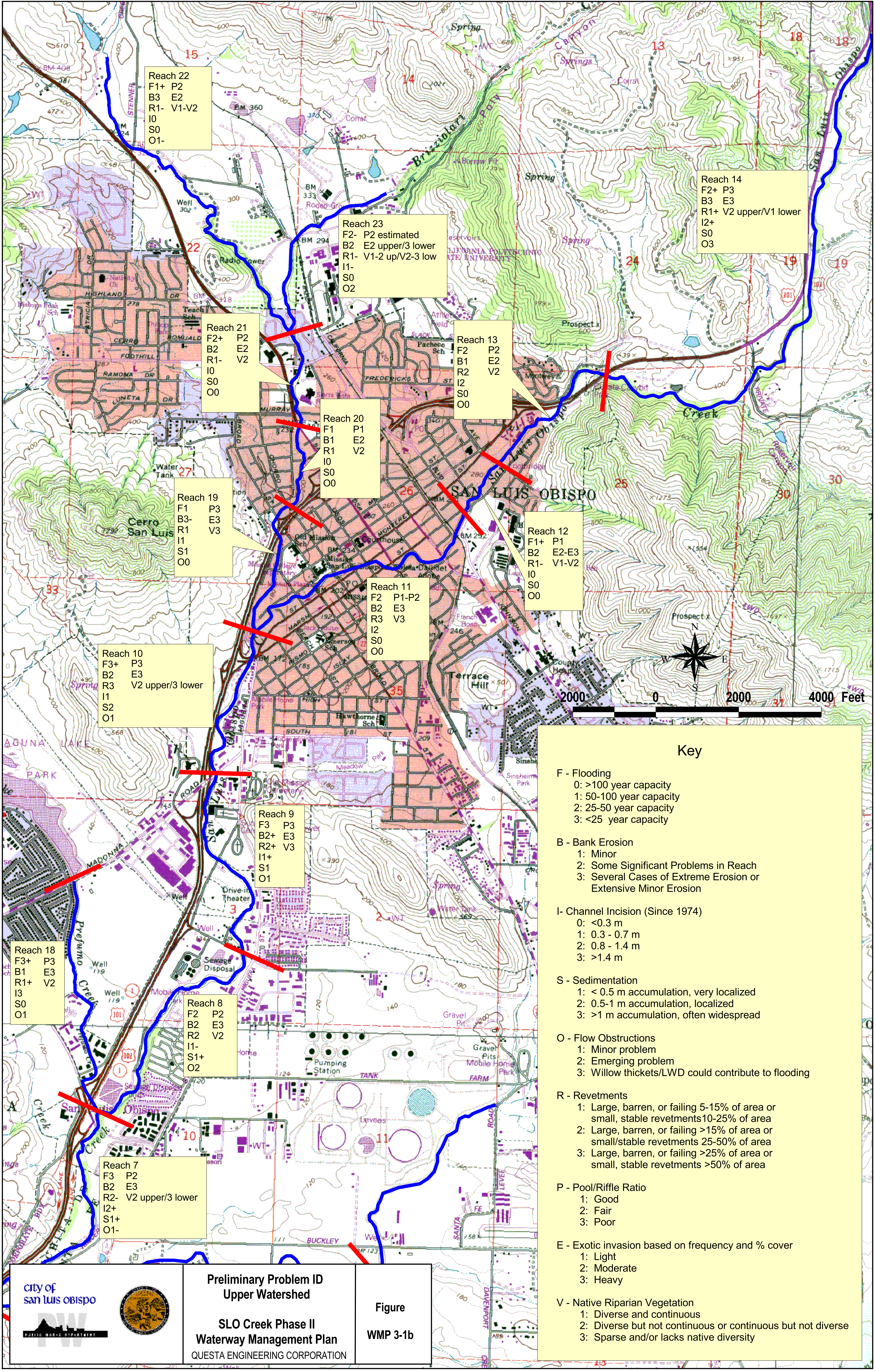


Preliminary Problem ID
Lower Watershed

SLO Creek Phase II
Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure
WMP 3-1a



Key

F - Flooding
- 0: >100 year capacity
- 1: 50-100 year capacity
- 2: 25-50 year capacity
- 3: <25 year capacity

B - Bank Erosion
- 1: Minor
- 2: Some Significant Problems in Reach
- 3: Several Cases of Extreme Erosion or Extensive Minor Erosion

I- Channel Incision (Since 1974)
- 0: <0.3 m
- 1: 0.3 - 0.7 m
- 2: 0.8 - 1.4 m
- 3: >1.4 m

S - Sedimentation
- 1: < 0.5 m accumulation, very localized
- 2: 0.5-1 m accumulation, localized
- 3: >1 m accumulation, often widespread

O - Flow Obstructions
- 1: Minor problem
- 2: Emerging problem
- 3: Willow thickets/LWD could contribute to flooding

R - Revetments
- 1: Large, barren, or failing 5-15% of area or small, stable revetments10-25% of area
- 2: Large, barren, or failing >15% of area or small/stable revetments 25-50% of area
- 3: Large, barren, or failing >25% of area or small, stable revetments >50% of area

P - Pool/Riffle Ratio
- 1: Good
- 2: Fair
- 3: Poor

E - Exotic invasion based on frequency and % cover
- 1: Light
- 2: Moderate
- 3: Heavy

V - Native Riparian Vegetation
- 1: Diverse and continuous
- 2: Diverse but not continuous or continuous but not diverse
- 3: Sparse and/or lacks native diversity

City of San Luis Obispo
Public Works Department

Preliminary Problem ID Upper Watershed

SLO Creek Phase II Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure WMP 3-1b

- **Sedimentation**, or the accumulation of sediment in the channel or under bridges. This also was based on field notes and comparisons of the FEMA profile with the LiDAR (airborne laser elevation survey) topographic data. Usually, but not always, sedimentation is observed as isolated sand and gravel bars, particularly at channel bends, or accumulations under and near bridges. Accumulation of sediment in a channel can reduce the flood flow carrying capacity of the channel or bridge section, and can clog or fill spawning gravels and shallow pools that form important aquatic habitat.

- **Flow Obstructions**. This was based on a review of the field inventory data and inspection of aerial photography. This is a more subjective determination, but has been assisted by hydraulic modeling to determine where debris jams and dense willow thickets can materially affect channel flood flow capacity.

- **Revetments**. This was also based on the field inventory of the distribution of rip-rap and retaining walls and other channel lining and armoring structures. The widespread distribution of revetments in a channel reach indicates historic and on-going instability problems. In addition, construction of revetments and hard channel lining can induce further downstream channel instability, as flows are deflected off of hard structures and problems are moved downstream.

- **Pool/Riffle Ratio**, as determined during the biological field inventories, using standard CDFG inventory procedures.

- **Exotic Vegetation**, or areas invaded by aggressive weedy non-native species.

- **Riparian Canopy**, including cover and species richness considerations.

A connotative letter was used on the summary maps to identify the nature of the major problem(s) in each reach (e.g. **B**=bank erosion, **F**=flooding, **S**=sedimentation, etc.). A number has also been assigned to each reach to reflect the severity of the problem, with **1**= minor problem, **2**= moderate problem, and **3**=major or significant problem. Criteria used to make the ratings are presented on the legend to the map. As an example, **B3** means that significant, widespread bank erosion problems occur within that reach. A summary of management problems by stream reach is provided in **Table 3-1.**

3.4 Waterway Problems and Needs

3.4.1 Flooding Problems

Background. There is a long history of flooding in the SLO Creek Watershed. Damaging floods have occurred in 1868-62, 1884, 1897, 1911, 1948, 1952, 1962, 1969, 1973, 1995, and 1998. Even so, relatively few structural flood control projects were implemented. The only major flood control project recently constructed within the San Luis Obispo watershed study area is located above the Los Osos Valley Road bridge, where in 1978, as part of the Tract 592 subdivision east of SLO Creek, a private developer channelized San Luis Obispo

Creek to protect future development from the 100-year flood (MDW Associates, 1982) and for the reference list from Phase I report. The channelization consisted of excavating one of the channel banks (alternating east and west) to form an in-channel floodway terrace, leaving the existing channel bottom in its natural state and planting the newly formed banks. The floodway terrace has not been managed since construction and has accumulated several feet of sediment. It is vegetated with dense, shrubby willows. This has reduced the channel conveyance capacity in this reach from the 100-year design to approximately 50-75 years.

The most recent damaging floods occurred during January and March 1995, with a lesser flooding problem in 1998. Within San Luis Obispo, flow overtopped streambanks near the intersection of Marsh and Higuera Streets and remained out of the channel for nearly three miles downstream, with damage estimated at nearly $2.3 million (ACOE, 2000). The City and Zone 9 also spent approximately $1 million to repair bank erosion caused during the winter of 1995. Damage occurred near the town of Avila during both the January and March 1995 events, where high flow and debris blockages caused extensive damage to several bridges across the creek.

Historically, the 1969 and 1973 events were more damaging than the 1995 floods, in present day dollars. According to ACOE estimates (in year 2000 dollars), the 1969 storm caused approximately $6.92 million damage within the SLO Creek watershed, and the 1973 storm caused $13.6 million (of which $899,000 occurred along Stenner Creek, $161,000 along Brizziolari Creek, $3.6 million along Prefumo Creek, and $241,000 along See Canyon Creek).

According to George S. Nolte and Associates 1977 *Flood Control and Drainage Master Plan for the San Luis Obispo Creek Watershed*, during the 1973 event, San Luis Obispo Creek spilled out of its banks downstream of Osos and Marsh Streets, flooding the downtown business district. Flood damage near the intersection of Marsh and Higuera Streets was extensive (as it was during the 1995 event). Floodwaters spilled across Highway 101 near the Madonna Inn, causing flooding four feet deep in places. Highway 101 overtopped near the confluence with Prefumo Creek, where flood depths as high as three feet were recorded. Along Stenner Creek, flow left the main channel above Foothill Boulevard and flowed overland through the area between Santa Rosa and Chorro Streets. Flooding in the Stenner Creek watershed was also caused by a constriction at the Highway 101 Bridge (which has since been replaced). The City has also replaced the Santa Rosa Street Bridge.

Table 3-1
Management Problems by Reach

Reach No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Reach Name	Avila Bay Rd- San Luis Bay Dr	San Luis Bay Dr – Ontario Rd	Ontario Road- San Luis Bay Dr	San Luis Bay Dr.- Farm Bridge	Farm Bridge- South Higuera on-ramp	S. Higuera onramp S. Higuera Bridge	South Higuera bridge LOVR	LOVR Prado Road	Prado Road – Madonna Road	Madonna Road – Marsh Street Bridge	Marsh Street bridge- California Street	California Street – Andrews Street	Cuesta park	Cuesta Grade	Upper E. Fork	Lower E. Fork	Upper Prefumo above Laguna Lake	Lower Prefumo below Laguna Lake	Lower Stenner below Chorro	Mid Stenner Chorro- Santa Rosa	Upper Stenner Santa	Stenner Cal Poly above Brrizziolari	Brizziolari Creek	See Cy n Creek
F - Flooding	F3	F3+	F3+	F3+	F3+	F3+	F3	F2	F3	F3+	F2	F1+	F2	F2+	F1	F2	F2	F3+	F1	F1	F2+	F1+	F2-	F2
B-Bank Erosion	B3-	B1	B2	B1	B1	B3	B2	B2	B2+	B2	B2	B2	B1	B3	B2	B3	B2	B1	B3-	B1	B2	B3	B2	B2
R - Revetment	R1-	R1-	R1-	R1-	R1+	R1-	R2-	R2	R2+	R3	R3	R1-	R2	R1+	R1	R1	R2+	R1+	R1	R1	R1-	R1-	R1-	R1
I-Channel Incision	I0	I0	I0	I0	I0	I1+	I2+	I1-	I1+	I1	I2	I0	I2	I2+	I2	I2	I0	I3	I1	I0	I0	I0	I1-	I2
S - Sedimentation	S0	S1-	S1+	S1+	S1-	S1	S1+	S1+	S1	S2	S0	S0	S0	S0	S0	S0	S3	S0	S1	S0	S0	S0	S0	SO
O-Flow Obstruction	O1	O3	O3	O3	O2+	O1-	O1-	O2	O1	O1	O0	O0	O0	O3	O1	O1	O0	O1	O0	O0	O0	O1-	O2	O1
P – Pool/Riffle Ratio	P3	P2U/3L	P2	P1	P3	P3	P2	P2	P3	P3	P1-P2	P1	P2	P3	-	-	P2	P3	P3	P1	P2	P2	P2 est	-
E-Exotic Vegetation	E2	E3	E2U/3L	E3	E3	E3	E3	E3	E3	E3	E3	E2-E3	E2	E3	E1	E1	E2	E3	E3	E2	E2	E2	E2U/2L	E1
V-Native Riparian Vegetation	V1U/3/L 8	V1 7	V2U/3L 8	V2 6	V2 8	V2 8	V2U/3L 7/8	V2 7	V3 9	V2U/3L 8/9	V3 7/8	V1-V2 4/6	V2 6	V2U/V1L 7/8	V3 4	V3 4	V2-V3 6/7	V2 8	V3 9	V2	V2	V1-V2	V1-2U/V2-3L	V1-V2

KEY: Flooding F3 = Flooding frequency < 25 years; F2 = 25-50 yrs; F1 = 50 + yrs.
Bank Erosion B3 = Several classes of extreme erosion, numerous critical sites, or very extensive minor to moderate erosion; B2 = some significant or critical problems in reach, B1 = minor, no critical sites
Revetments R3 = large, barren, or failing > 25% of area, or small, stable revetments > 50%/ R2 = large, unstable 0.15-25%, or small/stable 25-50%. R1 = large, barren, or failing 0.5 – 0.15%, or small/stable 10-25% of area.
Bed Incision I3 = Bed Incision > 1.4M; I2 = .8 – 1.4 M; I1 = 0.3 – 0.7M; I0 = < 0.3M (since 1974)
Sedimentation S3 = Sediment accumulation to 1.0M often widespread, S2 = 0.5 – 1.0 M, localized; S1 = < 0.5M thick, very localized,
Flow Obstruction O3 = willow thickets & LWD may be contributing to flooding/bank erosion, O2 = emerging problem; O1 = minor, but monitor problem development
Pool/Riffle Ratio P1 = Good; P2 = Fair; P3 = Poor
Exotic Vegetation Based on frequency and percent cover; E1 = Light; E2 = Moderate; E3 = Heavy.
Native Species Native Riparian Vegetation; V1 = Diverse and continuous; V2 = Diverse but not continuous or continuous but not diverse; V3 = Sparse, and/or lacks native diversity.

Note: U = Upper par of reach, L = lower part of reach – where indicated (i.e., V2U/2L).

The culverted section of SLO Creek beneath downtown San Luis Obispo, between Osos and Chorro Streets, was a particular problem during the 1973 storm. This structure, often termed the "under-city" culvert, has an estimated flow capacity according to (Nolte, 1977) of 127 cubic meters per second (4500 cfs), which is about a little more than a 15-year event according to the hydrologic analysis. This is less than the 25-year recurrence interval capacity reported by Nolte, based on ACOE studies. However, since flow during the 1995 storm, which was estimated to be between 140-150 cubic meters per second (4900-5300 cfs) through the under-city culvert, did not spill out of the channel at Osos Street, it appears that the under-city culvert may have additional capacity beyond what Nolte and Associates reported. According to the present hydrology numbers, the 1995 flood was approximately a 17-year event through Downtown, so it appears the channel has at least a 17-year capacity there. A detailed hydraulic study involving physical modeling would be necessary to improve the capacity estimate of the structure. In any case, structural improvements to the under-city culvert performed in 2000-2001 were not designed to improve the conveyance of the facility.

FEMA Floodplain Designation. The 1981 FEMA Flood Insurance Rate Map (FIRM) depicts a generally 300-400 meter (1000-1300 foot) band of flooding (100-year average recurrence interval) extending along SLO Creek, with narrower widths along Stenner and Prefumo Creeks. The extent of flood prone areas was verified by hydrologic/hydraulic studies completed as part of this WMP. However, the WMP Hydraulic/Hydrology studies (**Appendix C**) found the depth and frequency of flooding to be greater than in the FEMA studies. The 1995 flood caused significant damage to private property within the City and SLO Creek, especially the Mid-Higuera area, but provided some clearing and enlargement of the waterway. If this same flood occurred today, (2002) it would probably not produce the depth of flooding experienced in 1995. Conveyance capacity increased at many locations by down cutting and widening the channel through erosion and removal of flow inhibiting vegetation. However, in many areas the channel vegetation has recovered. At other locations the capacity has been reduced by sediment deposition (Marsh Street and Los Osos Valley Road Bridges), and at point bars on the inside of channel meanders. The most noticeable area of willow-hardened bars occurs in Reach 8 near and downstream of the City's Wastewater Treatment Plant below Prado Road.

Problem Identification. Flooding can occur (even during the 10 or 20-year recurrence internal flood flows) in some locations along SLO Creek, due to flow constrictions at bridges and other areas of limited channel conveyance. Denuded banks and erosion have added plant debris and sediment that re-deposited downstream. Undermined trees have toppled into the channel in some areas, or will, during the next large flood event. Vegetation can collect debris, reducing channel capacity and deflecting flows against banks. In many areas, the sediment bars that were deposited during the 1995 and 1998 high flows have now become overgrown with dense willow thickets, and have become more or less "hardened". These willow vegetated bars form significant channel obstructions, and can deflect flow against banks, causing bank erosion. Flood risk increases each year due to delayed channel management.

A set of rainfall-runoff and stream flow computer models that numerically describe the hydrologic and hydraulic performance of the watershed and stream system was developed as part of this WMP. The modeling results, along with existing reports of historic flood damage, provide a comprehensive picture of where flooding is likely to occur in the future. The hydrologic and hydraulic models provide information on flood channel conveyance capacity, flood reoccurrence intervals, and estimates on the extent of floodway. **Figure 3-2** summarizes the flooding problems that occur along SLO Creek and its principal tributaries.

Management Needs. The feasibility of providing 100- year flood protection for developed properties along all of the major streams in the watershed is limited by the large amounts of runoff generated during storms. The terrain and hydrology of the watershed are conducive to frequent and widespread flash flooding along the major streams. The hydrologic analysis revealed that urbanization of the watershed has had only minor effects on larger flooding events; severe flooding was common even under pre-development conditions. To a certain extent flooding is inevitable and the most cost effective/best strategy may to avoid building on flood prone areas in the lower watershed, selectively purchase buildings subject to recurrent flooding, and fix only the generally localized areas where flooding occurs to reduce the frequency and depth of flooding and flood damage. Flood proofing of buildings in flood prone areas can also be an important strategy.

Management of willows at hardened bars (and other areas with dense, in-channel vegetation) is a critical maintenance need and management problem. Informed management of the flood-modified channel and banks affords an opportunity to reduce the impact of future floods. Because of system wide channel capacity constraints, perennial vegetation in the active, most efficient part of the channel should be maintained at a low level. Willows should be discouraged from re-colonizing point bars for more than two or three consecutive years. If the growth persists, there will be increased flow friction losses and sediment deposition. This will increase the depth of flooding, or cause lateral erosion, particularly at channel bends. In contrast, performing selective vegetation removal and replanting with desirable species (replacing undesirable exotic vegetation, plugging gaps in canopy cover, or planting areas denuded by the 1995 flood) will help stabilize the bank, direct deposition into toe protecting berms, and reduce the sediment supply of future floods. Detailed procedures for vegetation management are included in the ***SLO Creek Watershed Stream Maintenance and Management Program*** document prepared as a separate work product of these Phase II studies.

Even with vegetation management, structural channel modifications will be needed to reduce flood risk in a number of areas of the City. Flooding problems along SLO Creek and proposed flood management solutions for specific areas are discussed in **Section 6.**

3.4.2 Bank Erosion

Background. Stream bank erosion is a natural process. Causes of erosion and bank failure include hydraulic forces as well as geotechnical instabilities, and local flow deflection, such as off of downed trees or adjacent "hard" bank repair structures. Natural processes can be

Flooding Problem Area Initial Identification
Upper Watershed

SLO Creek Phase II
Waterway Management Plan

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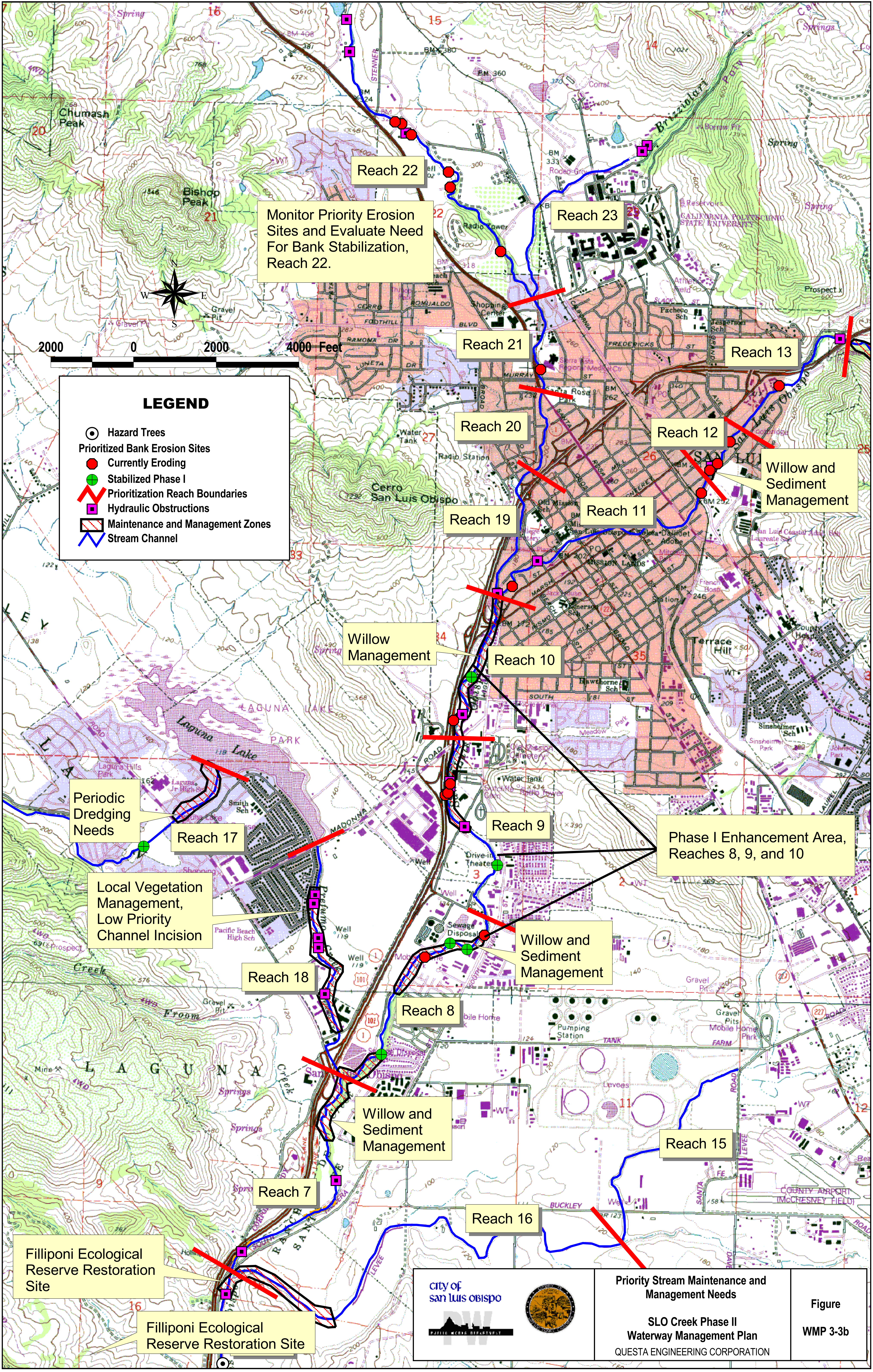
Figure WMP 3-2a



LEGEND
Hazard Trees
Prioritized Bank Erosion Sites
Currently Eroding
Stabilized Phase I
Prioritization Reach Boundaries
Hydraulic Obstructions
Maintenance and Management Zones
Stream Channel
2000 0 2000 4000 Feet
Reach 22
Monitor Priority Erosion Sites and Evaluate Need For Bank Stabilization, Reach 22.
Reach 23
Reach 21
Reach 13
Reach 20
Reach 12
Willow and Sediment Management
Reach 19
Reach 11
Willow Management
Reach 10
Periodic Dredging Needs
Reach 17
Reach 9
Phase I Enhancement Area, Reaches 8, 9, and 10
Local Vegetation Management, Low Priority Channel Incision
Willow and Sediment Management
Reach 18
Reach 8
Willow and Sediment Management
Reach 15
Reach 7
Reach 16
Filliponi Ecological Reserve Restoration Site
Filliponi Ecological Reserve Restoration Site
City of San Luis Obispo
Priority Stream Maintenance and Management Needs
SLO Creek Phase II Waterway Management Plan
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Figure
WMP 3-3b

accelerated by human intervention and land use changes, often at a watershed scale. SLO Creek bank conditions range from stable and well vegetated to near vertical eroding banks. All reaches of SLO Creek and its tributaries have some bank erosion problems, but widespread bank erosion is a significant problem upstream of Prado Road in Reach 8, and in the Cuesta grade area of Reach 14. Bank failure and significant bank erosion occurs throughout the study area. Bank protection has generally been the responsibility of the individual creekside landowner, except where channel modifications were implemented to protect public facilities.

Problem Identification. Accelerated bank erosion results from land uses that affect the stream corridor, including overgrazing, agriculture, roads and utility construction. The watershed reconnaissance completed as part of this WMP's geomorphic studies found that bank erosion is one of the biggest contributors to sediment load in the system, more than upland erosion. Bank protection is necessary when erosion:

- Causes or could cause significant damage to a property or adjacent property,
- Is a public safety concern,
- Negatively impacts recreational use,
- Negatively affects water quality, or
- Impacts riparian habitat.

Problem causes include toe erosion and bank undercutting; over-steepened vertical slopes too high for the natural soils to support do to channel bed incision, and natural downstream migration of meander bends. Many of the most significant failures occur due to slow bend migration. Bank protection has been used previously along SLO Creek to control erosion and provide bank stability, including rock rip-rap or gabion baskets. This can reduce creek shading and displace desirable riparian vegetation. Some previously installed revetments are now failing, with undermined foundations, due to channel incision. Banks are often high, ranging from three to seven meters.

Management Needs include repairing stream banks that are actively eroding and providing erosion protection at critical sites. Repairs may take several forms from installing hard structures (e.g., rock, concrete, sack concrete, gabions) to soft structures (e.g., erosion blankets, willow wattles, willow brush mattresses, log crib walls, pole plantings, etc.). Vegetative and biotechnical methods will be the preferred method of bank repair and protection, consistent with an engineering analysis of hydraulic, geotechnical and geomorphic constraints. Hard structural approaches will be used sparingly, and only at highly constrained sites.

Before new bank stabilization measures are applied to an eroding bank section, it is important to understand the cause of the problems, characteristics of the channel and bank, and the mechanisms of failure. Stabilization designs that are implemented without this analysis could transfer the problem to the other side of the channel, upstream or downstream, or result in failure and/or costly maintenance.

Since many areas of failing banks occur on private property along the creek banks, the bank erosion program is focused on providing design guidelines for use in developing acceptable repair plans, and an efficient regulatory permitting program. These are contained in the ***SLO Creek Watershed Drainage Design Manual***; a separate work product prepared as part of the Phase II studies.

3.4.3 Channel Bed Erosion

Background. Channel incision occurs in Reach 14, above Cuesta Park, along lower Prefumo Creek, and Reaches 5, 6, 7, 8, and 9 between Madonna and below South Higuera Road. Historically, channel incision has occurred upstream of these reaches, through much of the downtown area, but the rate of incision appears to have slowed in this area. The channel incision of SLO Creek in Reaches 5 and 6 have caused secondary erosion of creek tributary channels such as East Fork Creek and Davenport Creek, where headcuts are working their way upstream. These may require the installation of small grade control structures, or bank erosion of tributaries will worsen.

Problem Identification. Channel incision can pose significant hazards, particularly to rigid structures (retaining walls, bridges) when toe support is removed. Over-steepened, unprotected earthen banks affected by channel bed erosion can also fail. Channel incision de-waters stream side alluvial aquifers, affecting riparian communities and wetlands. In some areas summer base flows and channel hydraulic capacity may be increased as the channel cross-sectional area is enlarged through deepening.

Management Needs**.** One approach is to install series of small grade control structures, such as check dams, or boulder clusters, to slow velocities, flatten grades, and stabilize the bed. However, poorly designed structures trap sediment, deflect flows, and are potential barriers to fish passage. Therefore, use and placement of grade control structures must be well designed. Grade control structures consisting of boulder or rock weirs, extending no more than 0.3 meter (1 foot) above the channel invert, can stabilize the bed, allow fish passage, and introduce stream bottom diversity by providing pools and hiding habitat. Recommended grade control structures are in **Section 5.**

3.4.4 Vegetation And Woody Debris Management

Background. Dense vegetation can adversely affect the ability of the channel to contain the volume and velocity of floodwaters necessary to prevent flooding. Vegetation management may also be needed to meet local fire codes requiring the control of combustible weeds and grasses; to provide visual clearance for inspection of structures; and to provide maintenance road access. Vegetation management includes plant removal, thinning and limbing-up, pruning, weeding, and clearing. In the San Luis Obispo Creek Watershed, an important element of vegetation management is the control of aggressive weedy exotics, such as Giant Reed (Arundo donox). The City, Zone 9 and the Land Conservancy of San Luis Obispo have had an active Arundo donax eradication program for over 6 years.

A common but localized maintenance problem is woody debris caused by large trees falling into waterways. This includes large eucalyptus or cypress trees on slopes that have been undermined (by channel incision or toe erosion). Streamside landowners and maintenance staff have been concerned about the tendency of these large trees to divert flow against the bank, increasing the potential for erosion and bank failure. Fisheries biologists once considered log jams to be obstacles to fish passage, but recent research has shown that these are not normally barriers to movement.

Problem Identification. Vegetation management needs are widespread throughout SLO Creek. Some of the more critical areas include the channel section opposite the City's Wastewater Treatment Plant, upstream of the Prado Road Bridge, and throughout the Mid-Higuera area below the Marsh Street Bridge. Vegetation management is necessary to maximize capacity, and reduce the frequency of flooding from low recurrence interval storms. Dense shrubby streamside vegetation, often with lower terrestrial habitat value, is becoming rapidly reestablished. Vegetation management to selectively convert shrubby growth to a higher value, more hydraulically efficient mixed species riparian forest is a long-term management goal, although management must also recognize the need to retain important clusters of willows and other overhanging vegetation over important summer pools.

Downed trees are a part of the natural system. They provide structure, forming pools as well as providing habitat and cover to a number of aquatic organisms.

Management Needs. The **Stream Maintenance and Management Program** (SMMP) provides guidelines and techniques for how to manage woody vegetation along SLO Creek and its tributaries. Frequency of vegetation management varies from annually to 3-5 years. A gradual, phased approach may be used to convert shrubby willow vegetation, or areas of large Eucalyptus or other exotic trees, into a more hydraulically efficient stand of native sycamores, tree willows, oaks, or cottonwoods. This involves thinning and removing willow stands and exotics, pruning to thin and remove lower limbs of larger, more desirable forms of individual willows, and replanting with natives, such as sycamore, cottonwoods, and alders. This may take up to ten years to achieve, but habitat values would be improved, and maintenance costs reduced, as the larger trees eventually shade-out the understory. Native vegetation will also be planted as part of mitigation and habitat enhancement projects. Initially, it is important to control weeds and irrigate at revegetation sites to increase the survival and establishment of native species.

Vegetation management is also important to control invasive, non-native species. Exotics can spread into areas where they affect channel capacity and compete with native plant populations. In the SLO Creek watershed, this may include selective thinning and removal of Eucalyptus trees, as well as areas of dense castor bean, cape ivy and giant reed (*Arundo donax*). Timing of exotic removal must also consider nesting activities of raptors and other wildlife.

3.4.5 Sediment Management

Background. Sediment deposition is generally a natural process. It occurs where stream velocity slows and the channel gradient flattens out in the valley floor. This occurs at Marsh Street Bridge, near the City's Wastewater Treatment Plant (due to the previous downstream channel widening), upstream of the Los Osos Valley Road Bridge, and the arm of Prefumo Creek entering Laguna Lake below Los Osos Valley Road. In developed areas, sediment deposition affects flood control capacities, especially where modified channels were not designed to be self-maintaining.

Over time, development has encroached upon the flood plains. Most creeks that once flowed over a wider, meandering area that fluctuated in response to environmental conditions are now confined to narrow channels with homes and businesses built near the edge of the stream bank. Sediment is deposited as the stream attempts to recreate a meandering low flow within the modified and constrained channel. Sediment accumulation problems occur both locally and throughout a particular reach.

Problem Identification. Sediment accumulation reduces channel hydraulic capacity, which can lead to flood channel break-out points, backwater effects, or with point bars, can deflect flows against banks, causing erosion.

Management Needs**.** Mechanical removal of sediment deposited within a stream is needed to restore the flood capacity of existing streams, and to restore habitat values. Typically, sediment is removed when it 1) reduces capacity, 2) prevents structures such as outfalls, culverts and bridges from functioning as intended, 3) impedes fish passage and access to fish ladders, and 4) causes water quality problems.

In addition to sediment removal, source control through repair of eroding gullies will also be important to waterway management. This is addressed in Section 4.3, Watershed Management Frame Work.

3.4.6 Hydraulic Structures and Revetments

Background**.** Hydraulic structures consist of culverts, storm drain outfalls, weirs, dams, grade control structures, revetments and retaining walls (such as gabions and rock rip-rap or walls). These structures, including their size and condition were included in the Phase II inventory of existing creek conditions (**Appendix A**). In some reaches of upper SLO and Stenner Creek, there are extensive areas of hard structures.

Problem Identification. Many older structures were not well designed or constructed. Some structures have footings undermined by channel bed incision, or are in danger of toppling over, especially in Reaches 9 & 10 extending through the main part of the City. In other cases, the revetments encroach into the channel and act as flow obstructions, or deflect flow against unprotected banks. Many storm drain outfalls do not have energy dissipaters.

Management Needs. Some existing hydraulic structures can be replaced using designs that incorporate habitat elements, and reduce geomorphic impacts to the creek channel. However, many existing channel revetments were constructed privately to protect private property. City/Zone 9 can institute a program to inspect, repair and replace structures in failing condition and retrofit public hydraulic structures to include habitat elements. However, there is limited opportunity to retrofit private structures with more environmentally friendly designs. City/Zone 9 can require use of biotechnical designs when failing structures are replaced. Bank protection is not appropriate at all locations. Design guidelines for bank repair; including the use of biotechnical methods is included in the **Drainage Design Manual**, prepared as a Phase II work product.

3.4.7 Flood Channel Constrictions

Background. Channel constrictions are bottlenecks or channel segments that lack adequate cross-sectional area for flood conveyance. Channel constrictions can occur naturally, for instance, where bedrock exposure in the channel bank limits the width of a channel, from channel cross section conveyance restrictions, such as bridges, from natural occurrences, such as downed trees or shrubby channel growth, or from man-made obstructions, such as rip-rap or concrete-wall sections that encroach into the channel. Areas of channel constrictions due to dense willow growth occur in the Mid-Higuera area, from the Marsh Street Bridge to downstream of Madonna Road, (Reaches 9 & 10). Constrictions from built revetment obstructions in the channel occur in the downtown and Mission Plaza area, and upstream to the Santa Rosa Bridge, as well as lower Stenner Creek (Reaches 11 & 12).

Problem Identification. The most common form of channel constriction along SLO Creek is the haphazard placement of inappropriate channel protection structures (broken concrete, rock, etc.) on the channel banks and encroachment into the creek. In areas with flooding problems, these structures reduce the hydraulic capacity of the channel. Many of these private-party attempts at channel protection are old (prior to 1982) and are in danger of failing, especially in Reaches 9&10. The channel hydraulic analysis also indicated a number of bridges that present restrictions to flood flow during large events, including the Murray Street and Foothill Ave. Bridges.

Management Needs. Replacement of bridges that lack flood conveyance capacity should be considered a high priority. Bank protection structures that are hydraulically efficient, and do not cause water surface elevations to rise (due to channel constriction) can be designed and installed. A pro-active program to remove or retrofit obstructive revetments is also needed. Routine vegetation management in constricted sections is a critical management need. **Section 6** discusses structural measures to increase flood conveyance capacity by widening channel constrictions, along with the recommended program of bridge replacement.

3.5 Sensitivities, Constraints, and Opportunities

The resource inventory and hydrologic analysis provided the basis for exploring opportunities to achieve multiple benefits by managing resources in an integrated fashion. The analysis focused on opportunities for enhancing or restoring riparian and aquatic habitat, decreasing flooding problems, and stabilizing failing channel banks.

There is significantly less high quality riparian habitat along the major creeks and streams in the watershed than under pre-development conditions, and wildlife populations that depend on these habitats are declining. The corridor is narrow, invaded by aggressive exotics, and fragmented, and in many places there are not good connections with other important natural upland habitat areas.

Constraints to achieving habitat enhancement, flood hazard reduction, and bank stabilization have also been identified. Although opportunities for creating and enhancing habitat are abundant along the major creeks in the watershed, they require cooperation by interested landowners for successful project implementation. Most of the bank repair projects will be costly to implement. **Figure 3-3** summarizes the priority stream management and maintenance needs, including opportunities for stream restoration and enhancement.

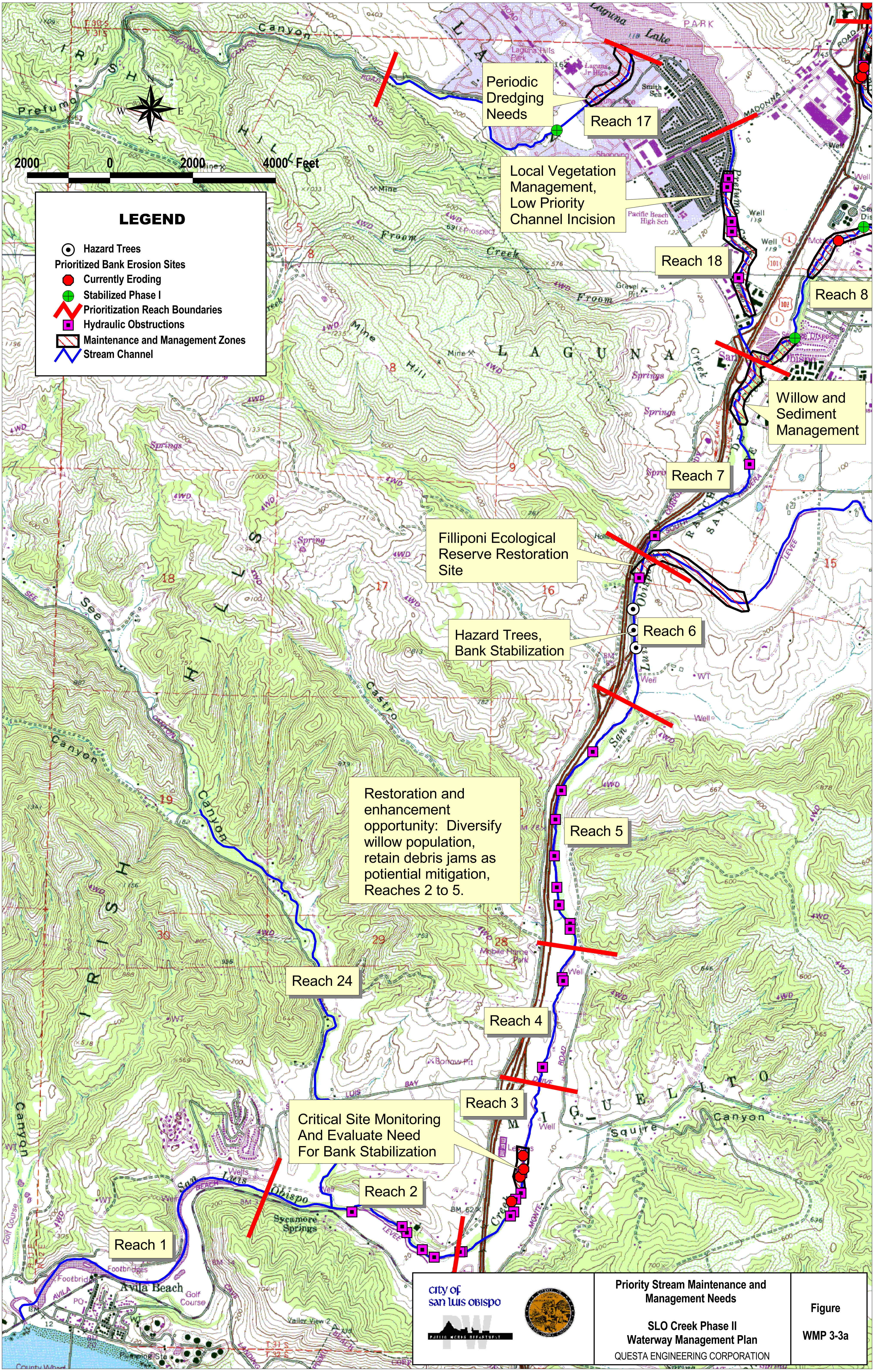
3.5.1 Sensitivities

Sensitive features that exist within the study area are the remnants of mature, mixed riparian forest, existing in small isolated to moderately sized patches, scattered throughout the study reaches and the few remaining pools and riffles. These areas represent a fraction of the natural landscape, but are still valuable even as fragmented habitat for many species of birds, small mammals and anadromous fish, including the Federally protected Red-legged frog and southern steelhead. The most significant stands of riparian forest exists within the lower portions of Reach 14, below the confluence of Reservoir Canyon Creek, along the east bank are those that include both mature coast live oak, California bay, sycamore, cottonwood, walnut and large willows. Scattered throughout the study reaches along creek banks and terraces exist smaller stands of endemic tree species or individuals of significance. Planning, design, and construction must be particularly sensitive to the local occurrence of these resources.

3.5.2 Constraints

Creek reaches within the study area have potential for restoration and enhancement, as well as significant constraints. The main constraints to any significant restoration or enhancement within the study area include: (1) the lack of undeveloped riverbank property along much of the study reach; and, (2) the need to acquire or use substantial private land to achieve a continuous riparian corridor. With the exception of Reach 14 and some sections of Reach 8 and Prefumo Creek reach, a significant portion of the stream banks and adjacent upland areas have been severely encroached upon by development and land use, resulting in a narrow riparian corridor within which the extent of natural vegetation has been severely reduced, limiting potential enhancement opportunities.

The majority of the study areas lack sufficient area to restore the riparian corridor to its original historic condition. Present and future land use, existing urban encroachment and disinterested property owners preclude the restoration of a sustainable natural riparian



City of San Luis Obispo

Priority Stream Maintenance and Management Needs

SLO Creek Phase II Waterway Management Plan

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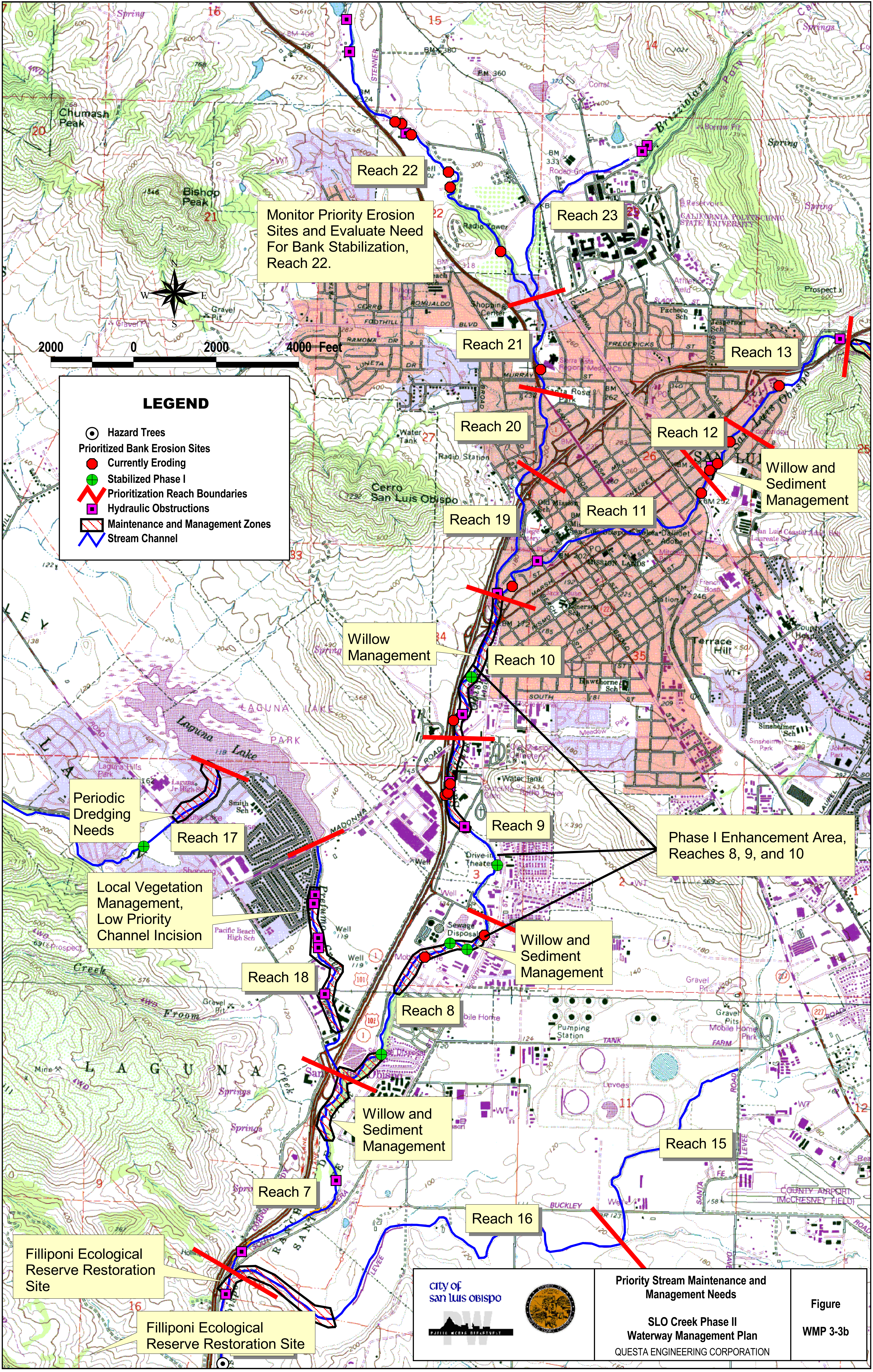
Figure WMP 3-3a



Reach 22
Monitor Priority Erosion Sites and Evaluate Need For Bank Stabilization, Reach 22.
Reach 23
Reach 21
Reach 13
Reach 20
Reach 12
Willow and Sediment Management
Reach 19
Reach 11
Willow Management
Reach 10
Periodic Dredging Needs
Reach 17
Reach 9
Phase I Enhancement Area, Reaches 8, 9, and 10
Local Vegetation Management, Low Priority Channel Incision
Willow and Sediment Management
Reach 18
Reach 8
Willow and Sediment Management
Reach 15
Reach 7
Reach 16
Filliponi Ecological Reserve Restoration Site
Filliponi Ecological Reserve Restoration Site
Chumash Peak
Bishop Peak
Cerro San Luis Obispo
Laguna Lake
California Polytechnic State University
2000 0 2000 4000 Feet
LEGEND
Hazard Trees
Prioritized Bank Erosion Sites
Currently Eroding
Stabilized Phase I
Prioritization Reach Boundaries
Hydraulic Obstructions
Maintenance and Management Zones
Stream Channel
City of San Luis Obispo
Priority Stream Maintenance and Management Needs
SLO Creek Phase II Waterway Management Plan
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Figure
WMP 3-3b

system with a diverse community of natural plants and animals. Restoration and enhancement should focus on the creation and maintenance of a system that supports and maintains native components of vegetation, wildlife and fisheries, provides for reduced erosion, flood risk, increased stream bank stability and is compatible with surrounding land use. Other constraints include: areas with active erosion, low cover values and low species diversity; exotic plant species; areas dominated by thickets of willows; areas dominated by exotic tree species; exotic understory areas; and areas low in cover values due to site disturbance.

3.5.3 Restoration and Enhancement Opportunities

Excellent opportunities exist to enhance, restore and preserve some of the remaining mixed riparian forest and scrub. These remnants of the natural landscape should be preserved whenever possible, and potentially provide the starting basis for a much more extensive riparian greenbelt or other stream-related easement. However, while it is important to preserve and maintain areas of existing quality habitat, numerous other opportunities exist for the restoration and enhancement of degraded habitat. Determination of these opportunities is a result of the inventory and examination of several features including actively eroding areas, low vegetation cover, presence and abundance of invasive exotic species and low native species diversity.

Preferably, to improve habitat value, exotic vegetation should be removed and replaced with native species. Replacement planting can be phased to allow continued shading. Priority should be given to enhancing habitat values in stream segments, which have some existing quality habitat in the vicinity or area of work, or in immediately adjoining reaches.

Continuity of quality habitat is important for aquatic life and most terrestrial species. Many species have a minimum habitat size or area requirement, require a diversity of plants for seasonally available food and cover, or require safe travel lanes or movement corridors between habitat patches and differing kinds of habitat, particularly watercourses. Protecting and enhancing existing valuable habitat or the fringe of such habitat generally has a better potential for success than enhancement of isolated pockets of habitat that result in a habitat fragmentation pattern.

Enlargement of an existing corridor of riparian vegetation is often a valuable habitat enhancement measure, along with inclusion of a buffer strip of limited permissible uses, separating urban uses from the corridor. In addition, habitat values are generally enhanced when channel beds and banks are earthen, rather than concrete or rip-rap. Where hydraulic conditions allow, an unarmored channel design should be given first priority.

Continuous, diverse riparian corridors are important for most species of mammals, reptiles, and amphibians. The lack of continuous or connected habitats is not as important for birds since they can fly to isolated patches of habitat. The existing fragmentation of numerous types of habitat prevents significant movement of species along this corridor. One goal of enhancement is to preserve and maintain areas that can provide this continuous corridor.

4. WATERSHED MANAGEMENT FRAMEWORK

A well-managed watershed is needed for a healthy stream ecosystem. The condition of the watershed directly affects a number of important stream functions, including summer low flow or base flow, peak flows and flood flows, channel bank stability and channel bed conditions, and water quality. Upland erosion of farmland and grazing land is a significant component of a watershed management plan, as is fire management and damage repair following wildfire in steep brushy and wooded watersheds, such as upper SLO Creek. In addition, watershed management and land use along the immediate stream corridor can also affect the streamside riparian zone that provides important shading and food resources to the creek system. Severe bank erosion can result in the loss of the riparian corridor.

Important upland habitat areas should be connected to the creek zones in some areas to allow movement of wildlife species between habitat types, and the creek riparian zones should not be fragmented, which prevents some species from moving safely under vegetative cover along the creek zone.

Although preparation of a detailed watershed management plan is not a part of the Phase II scope of work, some guidance and an overall framework is provided in this section, based on the results of the resource inventories and hydrologic studies.

A framework consisting of general management **Goals**, which respond to the identified management needs, problems and opportunities, as well as a list of recommended **Action Items** is provided. This framework can be used in future watershed planning efforts to focus on problem and priority areas, and to provide direction on important issues to resolve. A Watershed Enhancement Plan was recently prepared for the SLO creek watershed by the SLO Land Conservancy (2002), under a grant from the State Coastal Conservancy. Together these documents can direct future management efforts in this watershed.

The Zone 9 Advisory Committee developed eight Watershed Management Goals and recommended Action Items addressing the following issues:

1. Flooding
2. Erosion
3. Water Quality
4. Biological Resources
5. Land Use
6. Societal Values
7. Public Involvement & Education
8. Inter-agency Coordination

4.1 Flooding

Goal. Minimize and manage damages caused by recurrent flooding by utilizing both structural and non-structural flood management approaches in an integrated and cost effective manor, while also providing for the protection, restoration, and enhancement of the biological resources of the creek corridors.

Action Items

- Develop a comprehensive flood management plan that includes new floodplain management regulations and design standards, explores purchase of flood prone properties, and includes structural fixes to constricted channel sections that lack conveyance capacity.

- Develop an implementation plan, that includes a prioritization and implementation schedule, and identifies funding sources, including grant funding opportunities, existing government programs, and local revenues sources such formation of a drainage utility, imposition of drainage impact fees on new developments, and/or formation of a benefit assessment district covering flood prone properties.

Section 6 discusses these action items, included in the Phase II work program.

4.2 Erosion

Goal. Repair damages from upland watershed erosion and creek bank erosion at high priority locations; reduce the magnitude and severity of future erosion problems in the watershed.

Action Items

- Develop and implement a plan in coordination with watershed stakeholders to stabilize creek bank erosion in the priority locations identified in the resource inventory.

  Many of the bank erosion problems occur on private lands in the watershed, and/or on lands controlled by Caltrans under a Channel Change Easement (maintenance easement). Thus, it will be necessary to coordinate any design and construction work with Caltrans, a local non-profit, such as the Land Conservancy, or for farmlands, with the Coastal San Luis Resource Conservation District. This may be an expensive task, and will require grant funds and a long period to implement. The initial focus should be on the stabilizing high value habitat in the upper watershed in the Cuesta Pass area.

- Develop and implement a plan to stabilize the eroding railroad cuts in the upper SLO watershed, including repair of hanging and unprotected culverts.

- One of the most significant sediment sources in the SLO watershed emanates from historic railroad cuts and drainage crossings of the railroad, especially in the Cuesta

Pass. Since this historic construction activity predates most County ordinances regarding erosion and sedimentation, it will be necessary to work with the railroad authority in a cooperative fashion to plan and implement any remedial work. This activity can potentially be coordinated with the Regional Board's TMDL planning process.

- Develop and implement a plan to stabilize abandoned or seldom used dirt utility access roads and firebreak roads in upper Stenner and SLO Creek watersheds.

- Working with the Coastal San Luis Resource Conservation District and Cal Poly, and in cooperation with the Farm Bureau and other interest groups, develop and implement a program to address upland erosion on farm and ranch lands. The initial focus should be on the upper Prefumo Creek watershed.

  The watershed reconnaissance identified eroding dirt access roads to utility lines, and fire break roads as a potentially significant source of sediments in the upper Stenner and SLO Creek watersheds. Work could include installation of water bars and road drainage, reconstruction of culverted crossings, and removing old roads. The Mendocino County RCD has a useful publication on design and maintenance of dirt ranch roads that can be used for guidance.

- Integrate fire fuels management into the Watershed Management Plan. As evidenced by the Highway 41 fire that occurred in the upper Stenner Creek watershed in 1995, wildland brush fires can have devastating impacts on a watershed, increasing runoff , causing severe erosion and gullying of upland streams, and delivering large quantities of sediment to the creek system, causing bank erosion and other secondary problems. In the SLO watershed, the California Department of Forestry is responsible for fire management on private lands, while the US Forest Service, Los Padres National Forest is responsible for fire management on the public forest and range lands that occur in the Cuesta Pass area.

  Currently the fire management programs of the CDF and USFS are not integrated into other watershed management planning activities, and the importance and prioritization of fire management as an element of watershed management is not well understood or appreciated. Representatives from CDF and the USFS should be invited to attend the Zone 9 meetings, (and the CRMP, if established) to contribute their knowledge and expertise to this important aspect of watershed management.

4.3 Water Quality

<u>Goal.</u> Ensure that the waters of the SLO Creek watershed are of sufficient quality and quantity to sustain native riparian and aquatic habitat for both fish and wildlife populations, and human recreational activities.

Action Items

Many of the recommendations in this section are currently in place and being conducted by the City, County, SLO Land Conservancy, or Central Coast Salmon Enhancement.

- Continue to work with the Central Coast Regional Water Quality Control Board in NPDES Phase II Stormwater and TMDL planning and implementation efforts

- As part of Phase II NPDES and TMDL planning, educate watershed stakeholders and increase communication about pollution prevention by convening meetings among rural landowners, residential property owners and business operators to discuss methods and techniques for water quality management. Provide information on Best Management Practices at these meetings.

- Continue to support and coordinate volunteer stream monitoring programs in the watershed.

- Continue to support and coordinate creek awareness and creek cleanup days in the watershed.

- Coordinate with the Regional Water Quality Control Board to investigate and stabilize, as needed the abandoned mines, mine addits, and waste piles in the watershed.

  The significance of the abandoned mine addits on water quality is not fully known. This work can also be coordinated with the Regional Board's TMDL planning program.

4.4 Biological Resources

Goal. Protect, enhance, and restore the natural integrity of waterways of the SLO Creek watershed and their associated riparian and aquatic habitat.

Action Items

- Continue to provide support to ongoing programs for exotic species eradication and the restoration of riparian communities through creek planting and stream habitat enhancement programs.

- Support programs to identify barriers to fish passage and develop programs to remove or mitigate barriers.

- Cooperate with non-profit groups in programs to identify, acquire, enhance and restore sensitive and critical habitat areas along the creek corridor.

- The City and Zone 9 in cooperation with the Land Conservancy, Central Coast Salmon Enhancement, and California Conservation Corps currently have active programs in each of the above 3 areas, some of which are supported by funds from settlement of the Unocal Oil Spill, (Avila Beach, 1992).

- Work with the Coastal San Luis Resource Conservation District and/or Land Conservancy to develop and implement a stream fencing, buffer strip, and creek planting program where appropriate, in rural and agricultural areas of the watershed.

- Explore the feasibility of selectively acquiring existing Caltrans right-of-way and/or channel management responsibility within the SLO Creek Corridor for proactive management and enhancement.

  Caltrans maintains a sizeable maintenance easement (termed a Channel Change Easement) along portions of the creek corridor and tributary drainages of SLO Creek from approximately the South Higuera Bridge to the San Luis Bay Drive overcrossing of the Creek. Apparently much of the stream corridor right of way or easements were acquired in the late 1940's and early 1950's when the former State Highway Department constructed the current alignment of Highway 101. This necessitated straightening and moving sections of the creek along portions of the highway.

  The straightening and realignment destabilized the creek in some areas, and the channel has responded by deepening and in places meandering to regain its once flatter channel slope. Serious bank erosion and bed instability problems occur in some of these areas.

  The Channel Change Easement that exists over much of this reach entitles Caltrans to conduct management or maintenance within the creek for the benefit of the adjacent highway, but specifically does not obligate Caltrans to perform channel maintenance.

  The primary mission of Caltrans is the maintenance and construction of the state highway and road system, not stream management. The County should explore with Caltrans the possibility of acquiring selective portions of the Caltrans right of way along the creek corridor, or assuming authority for creek management within the Channel Change Easement, for better management and enhancement. The legal issues associated with such a transfer would need to be explored. Such an acquisition or transfer of channel management authority should not be taken lightly as the County would be accepting responsibility for any liability, as well as for the costs of design, construction, monitoring, and ongoing management and maintenance of these stream reaches. This section of the creek has serious management needs as well as significant restoration and enhancement opportunities.

4.5 Land Use

<u>Goals</u>. Ensure that the political jurisdictions of the San Luis Obispo watershed implement or update land use policies and ordinances which provide responsible stewardship of the watershed's natural resources, protect people and property from flood damage, reduce erosion and stabilize banks, and prevent pollution.

Action Item

- Provide technical consultation to the City Community Development Department and the County Planning Department on the review and update of policies and ordinances that provide for protection and restoration of creeks during the next General Plan updates, including policies dealing with creek setbacks, buffer zones, and floodplain regulations.

- Develop a Public Promotion and Public Awareness Program in coordination with the City and County Floodplain Manager official to make the public aware of the need to protect open space areas within floodplains because of the hydrologic function they serve in storing floodwaters and filtering pollutant materials in flood flows.

4.6 Societal Values

Goal. Facilitate creation of public policies, ordinances, and planning and administrative mechanisms to discourage inappropriate and illegal uses of the creek corridors of SLO Creek and its tributaries.

Action Items

- Support and work with law enforcement agents and property owners to disband illegal encampments along the creeks.

- Utilize public works staff and contract agencies such as the California Conservation Corps to remove debris from the creek corridor.

- Support and work with City, County, and private social services providers to improve resources and services for displaced and homeless individuals outside of creek corridors

4.7 Public Involvement and Education

Goals. Broaden the public (and especially) creek property owner awareness and appreciation for the values of the waterway system and those of a healthy, diverse watershed

Educate the public, (especially students and future stakeholders), business interests, and creek property owners about watershed stewardship methods to protect watershed and waterway values.

Facilitate communication and cooperation among various stakeholders concerning watershed issues.

Action Items

- Continue to promote community awareness and support of watershed management issues through newsletters, and riparian and agricultural outreach and educational workshops

- Provide resources and support for interested science teachers in the watershed

- Provide linkages and information to existing world wide web sites focused on SLO watershed issues

As with other action items, the City, County, and Conservancy have active programs for many of the above recommendations. Outreach meetings and dissemination of information on Best Management Practices are requirements of both the Phase II storm water and the TMDL program of the Regional Board.

4.8 Interagency Coordination

Goal. Facilitate on-going communication and coordination among local, state, and federal agencies, non-profit groups, and other watershed stakeholders responsible for management of the natural resources of the watershed

Action Items

- Consider formation of a Coordinated Resources Management Planning (CRMP) team as part of long-term watershed and waterway management efforts (see **Section 5.8**).

  CRMP members could include current Zone 9 Advisory Committee members, and other federal and State agencies currently not a formal part of the Zone 9 Advisory Committee. Zone 9 staff would serve as CRMP staff and provide technical and logistical support.

5. WATERWAY MANAGEMENT PLAN COMPONENTS

5.1 Introduction

This section of the WMP describes the comprehensive program proposed by City/Zone 9 to address the resource problem areas and management needs identified in **Section 3.** The five principal components of this WMP include:

- A **Stream Maintenance and Management Program** (SMMP) covering routine stream maintenance practices and procedures and presenting proposed Best Management Practices (Volume II)
- A new **Drainage Design Manual** (DDM) for stormwater, flood control, and bank repair design (Volume III)
- A **Bank Stabilization Program** (described in this section) that provides a management framework and conceptual plans for addressing current and future bank instability problem areas, and
- A **Habitat Enhancement and Restoration Program** (described in this section), the framework for cooperative stream corridor resource enhancement, restoration, and protection.
- A **Flood Management Plan**, which outlines the conceptual flood control alternatives that are proposed as the Preferred Project (this is described in **Section 6**),

These elements are integrated to meet the stated goals and objectives of the WMP. For instance, general policies for watershed management are included in **Section 4** (Watershed Management Framework) and policies specific to maintenance work in and near streams are contained in the SMMP component, while the Flood Management Plan includes both structural and non-structural elements as part of the proposed solution to address flooding. The designs for structural flood management projects (channel modifications) must utilize the concepts for natural channel design outlined in the DDM The Preferred Project contains both structural and non-structural approaches, including new floodplain management regulations, and the encouragement of flood proofing of existing structures. The SMMP relies on the design procedures for biotechnical bank stabilization outlined in the DDM (to minimize impacts), while mitigation is provided by coordinating enhancement of public and private lands as outlined in the Watershed Management Framework, (**Section 4**) and the Bank Stabilization and Habitat Enhancement elements of the WMP (**Section 5**).

This section reviews the ***Drainage Design Manual***, the ***Stream Maintenance and Management Program*** documents, and the conceptual physical projects and management approach proposed by the City/Zone 9 for flood management, bank stabilization, and habitat enhancement.

5.2 Drainage Design Manual (DDM)

This component of the WMP provides guidance for the planning and design of both public and private storm drain and waterway systems that will be used to convey storm water drainage and flood flows associated with new development and redevelopment projects. The guidelines are intended to ensure that storm drain and waterway systems are designed and managed to:

- Minimize environmental impacts to the creek corridor;
- Avoid or minimize the effects of new development on increased flooding and bank erosion;
- Reduce flood damage (where possible);
- Stabilize eroding banks; and,
- Enhance and restore riparian and aquatic habitat.

In addition to providing criteria for designing open channels and closed conduits (underground storm drains) the DDM also addresses procedures for bank stabilization and flood management facility design, including storm water detention basins, and provides guidelines for erosion control, and for revegetation, restoration, and enhancement of the streamside zone. Erosion control standards are also provided.

Parts of the DDM deal with routine engineering analysis and design of pipes, roadside ditches, drop inlets, and culverts, and represent only minor changes to the existing City and County Design Manuals. Even though they are included in the new DDM, they represent no significant changes to current design procedures.

The DDM replaces both the 1983 City "Flood Policies" book (Pink Book) and recommends revisions to current City and County engineering design standards, for those parts associated with channel, culvert, and storm drain system design, and bank stabilization in the SLO Creek watershed. A section on design of storm water detention facilities has also been included in the DDM. The City and County will need to amend some of their construction standards to be consistent with the DDM.

Current City creek dedication and creek setback policies have not changed. The County currently does not have a creek setback policy for development along creeks in the SLO watershed, and relies on staff recommendations during plan review, and on mitigation measures contained in specific projects and their CEQA documents and permit conditions. No new County creek setback policies are contained in the WMP. A section on Erosion Control and Stormwater Quality Management is included to address the requirements of the Regional Board's Phase II NPDES Stormwater Management Program.

Significant revisions to the current "Pink Book" flood policy and City and County ordinances are summarized in **Table 5-1.** They include:

- Special Floodplain Management Zones
- Managed Fill Policy
- No Adverse Impact Policy
- Channel Classification and Design Guidelines
- Bank Stabilization Guidelines
- Drainage Impact and Stream Zone Impact Fees, and Design Review Fees
- Revised Design Flows
- Erosion Control and Storm water Quality Management
- Revegetation Guidelines
- Channel Maintenance and Management

The following sections summarize the major points of the DDM. It should be noted that the DDM contains a section on "Core Requirements", which represent proposed City and County Policy on flood plain management, stormwater management, and channel design and protection for the SLO Creek watershed. Adoption of the core requirements will mean a higher level of engineering analysis and design, (including project design review) for new projects than is currently required, but a project size limitation has been included to determine when the analysis and design efforts are necessary.

Table 5-1
Creek Policy Revisions

Policy Revisions	Comments
1. Drainage Design Manual a) Create Special Floodplain Mgt. Zone for Mid-Higuera – regulate flow impeding structures	• May also require new City/County Ordinances • Policy included in Mid-Higuera Specific Plan
b) Create Special Floodplain Mgt Zone for Elks Lane area and undeveloped areas along lower SLO and Prefumo Creek with "Managed Fill Policy"	• May also require new City/County Ordinances • Puts burden of proof on developer • Toughens development standards for flooding issues along Elks Lane and southwest of Madonna Road-Hwy 101 • May reduce developable footprint of some sites
c) Adopt "No Adverse Impact" policy making developers demonstrate no hydrologic impacts via new Zone 9 hydrology models	• May also require new City/County Ordinances • Follows recommendations of Association of State Floodplain Managers • Would be one of the strongest floodplain regulations in California • Increases City/County staff review time • Increases design & development costs • Does not necessarily require stormwater detention, but provides design guidelines where used.

Policy Issues	Comments
d) New Creek Classification and Design Policy making it difficult to modify "Natural" creek areas	• Few "natural" areas in City, mostly below LOVR and tributaries
e) New policy of preference for biotechnical bank stabilization designs making use of hard bank structures difficult	• SF District Corps of Engineers Nationwide Permit conditions generally require use of biotechnical designs, although LA District (which SLO is in) currently does not. • Biotech used in Phase I FEMA projects
f) New "Drainage Impact Fee" for new development & "Stream Zone Impact Fee" for Regional mitigation	• May require new City & County Ordinances • Needs follow-up study to set formula for fee collection • About 85% City – "built-out" • Fees applicable only where mitigation not provided
g) New Erosion Control and Stormwater Management Regulations	• Includes provisions for adoption of standard erosion control and stormwater management for small parcel development. • Requires detailed Erosion Control Plans for large parcel development and in critical locations.
2. Stream Maintenance & Management Plan (SMMP) - Adoption of BMP Manual provides permit streamlining but places more responsibility on City & County	• SMMP required by agencies • Provides mechanism for regional mitigation and enhancement • Increase in Design Review Fee may be necessary
3. Design Flows	• Design Flows would guide both City/County sponsored projects and private projects
4. Non-Structural Flood Control (WMP) programs have increased emphasis: a) Wet and Dry flood-proofing b) Building elevation c) Building relocation d) Floodplain acquisition	• Would require additional staff to develop and implement non-structural programs • Would require additional staff to develop a lower CRS, but offsets Drainage Utility fees • Participation is voluntary in FEMA or DWR building elevation, relocation, or property purchase.
5. Bank Repair and Habitat Enhancement (WMP)- Provides mechanism designating recommended biotechnical bank stabilization for 48 mostly private bank failure sties. Private parties agree to design and become part of SMMP subject to Individual Corps permit.	• Bank Repair Program and Habitat Enhancement Element work together with SMMP and Drainage Design Manual in guiding design and mitigating cumulative impacts • No public funds used to construct private repair works, but staff time to coordinate

Throughout the DDM a size standard of 1.0 hectare (2.5 acres) has been used as the development threshold requiring more detailed analysis. This represents a typical 8-10 unit or larger residential subdivision, and many commercial development projects. The City Engineer or County Public Works Director can, however, require more detailed engineering analysis for any project considered to be located in a sensitive area, or if there are significant concerns about the environmental effects of a project, including effects on flooding and bank erosion, or wetlands and stream biology issues.

5.2.1 Special Floodplain Management Zones

Current City and County floodplain management policy allows the importation of fill onto the FEMA defined 100-year floodplain, consistent with FEMA minimum guidelines, up to a point where a maximum 1 foot rise in the 100-year flood water surface elevation occurs. This can occur because of the loss of floodplain storage and the reduction in channel and overbank flow conveyance.

The DDM establishes two new *Special Floodplain Management Zones*, one in the Mid-Higuera area, and one (generally) in the undeveloped lands downstream of Madonna Road and in the lower Prefumo Creek area, as shown in **Figure 5-1.** A *No Net Fill* provision would be applied in this area. Floodplain management policies in the remainder of the developed portions of the City are unchanged, except that a new *No Adverse Impact* policy is proposed watershed-wide.

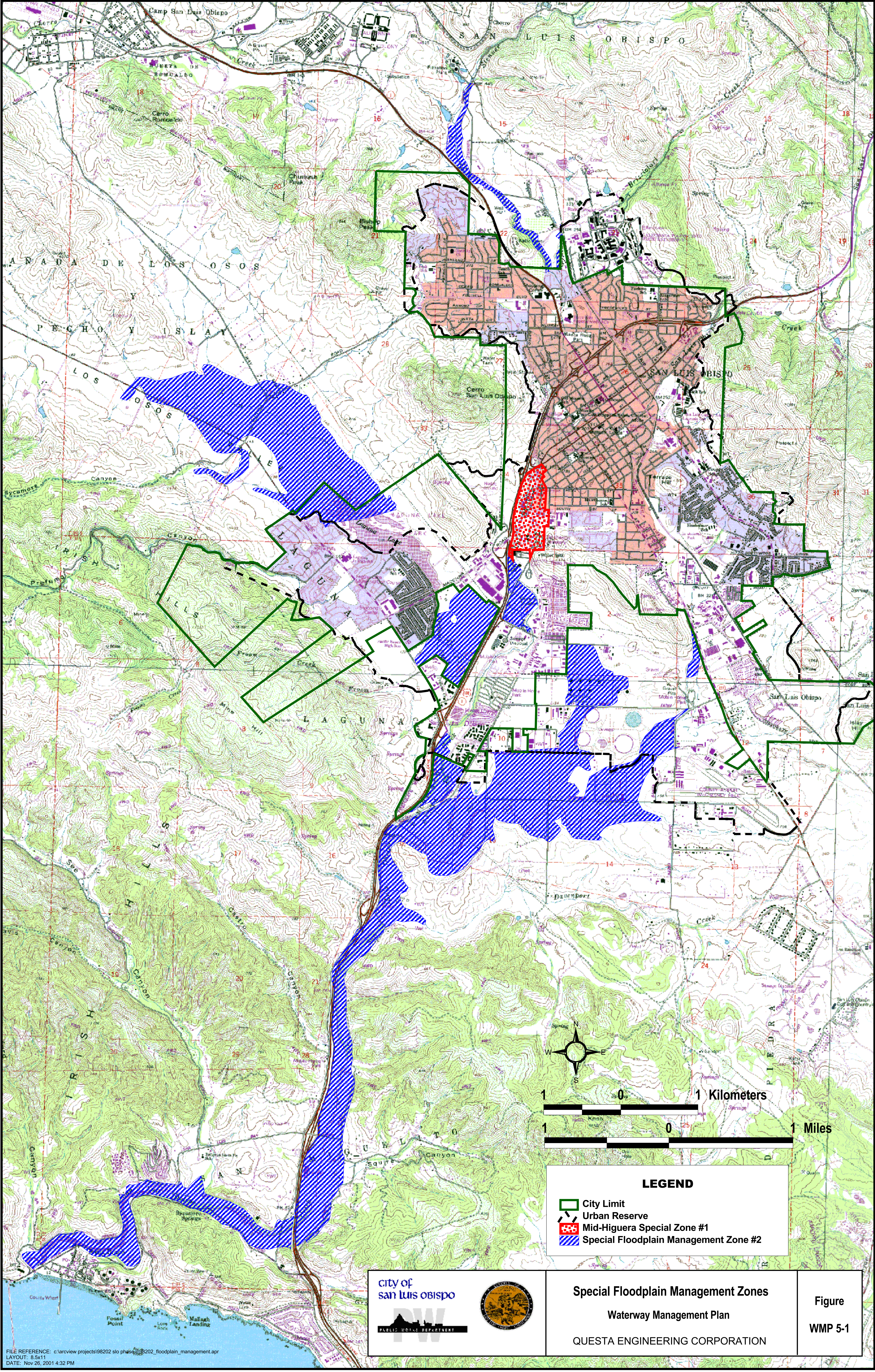
Revised floodplain management policies for the Mid-Higuera Special Zone are proposed to insure that new development and redevelopment does not block overland flood flow conveyance and return flow, such as limiting street medians and fencing and requiring "shadowing" of new buildings. (Note: This policy is already included in the *Mid-Higuera Specific Plan*).

5.2.2 Managed Fill Policy

A *Managed Fill* provision has been added to the City's Floodplain Management Policies for the undeveloped portions of the watershed's principal floodplains in the Madonna Road/lower Prefumo Special Zone. This zone extends downstream from Madonna Road along SLO Creek all the way to Avila Beach, as well as the undeveloped floodplain areas along Prefumo Creek and in the Laguna Lake area. This policy would minimize the impact of development on loss of floodplain storage and consequent higher flood flows by requiring that fill for elevating portions of a property above the 100 year flood come from excavation of other portions of the property within the floodplain, generally. This is shown diagrammatically in **Figure 5-2**. Implementation of this policy will require more creativity and careful design in floodplain areas to insure that projects do not create upstream or downstream flooding and bank erosion problems. It may affect the acreage of developable area on a given parcel. The policy will also necessitate more comprehensive design review by City and County staff.

5.2.3 No Adverse Impact Policy

A *No Adverse Impact* policy is proposed for the entire SLO Creek watershed to insure that future development and redevelopment does not cause additional flooding, bank erosion, or habitat destruction. The *No Adverse Impact* policy is modeled after the policy contained in the Association of State Flood Plain Managers (www.floods.org) position paper on this issue. The new Zone 9 computer hydrology and hydraulic models would be utilized by project applicants to demonstrate that a project design does not have an adverse impact. The models can predict changes in runoff, downstream water surface flood elevation, stream


Camp San Luis Obispo
SAN LUIS OBISPO
CAÑADA DE LOS OSOS
PECHO Y ISLAY
LOS OSOS
LAGUNA
IRISH HILLS
SAN LUIS OBISPO
County Wharf
Fossil Point
Mallagh Landing
N
W
E
S
1 0 1 Kilometers
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LEGEND
City Limit
Urban Reserve
Mid-Higuera Special Zone #1
Special Floodplain Management Zone #2
City of San Luis Obispo
PUBLIC WORKS DEPARTMENT
Special Floodplain Management Zones
Waterway Management Plan
QUESTA ENGINEERING CORPORATION
Figure
WMP 5-1
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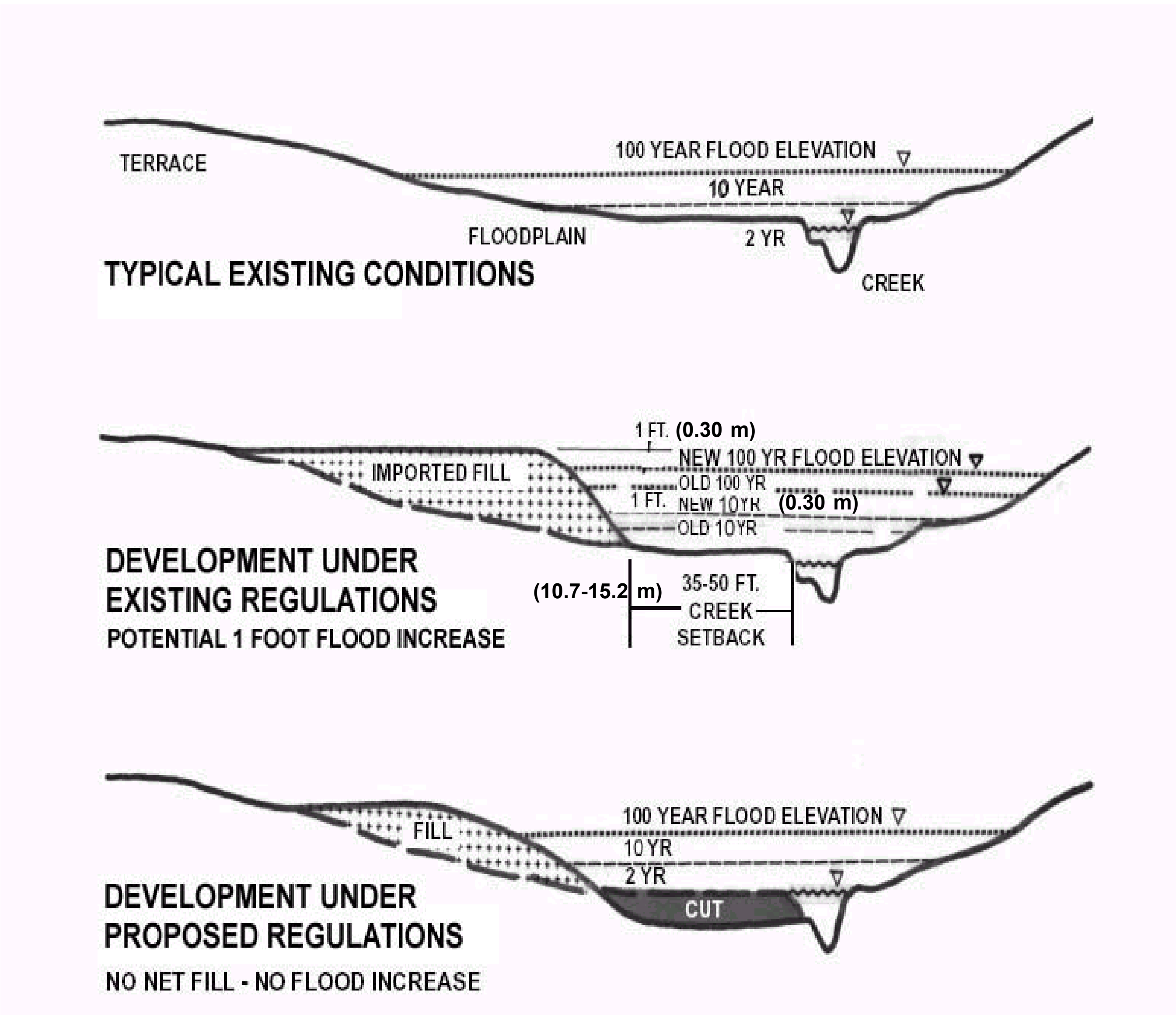


City of San Luis Obispo PW PUBLIC WORKS DEPARTMENT 955 MORRO ST. 93401-3218	**No Net Fill** **Waterway Management Plan** **City & County of San Luis Obispo** QUESTA ENGINEERING CORPORATION	Figure **5-2**

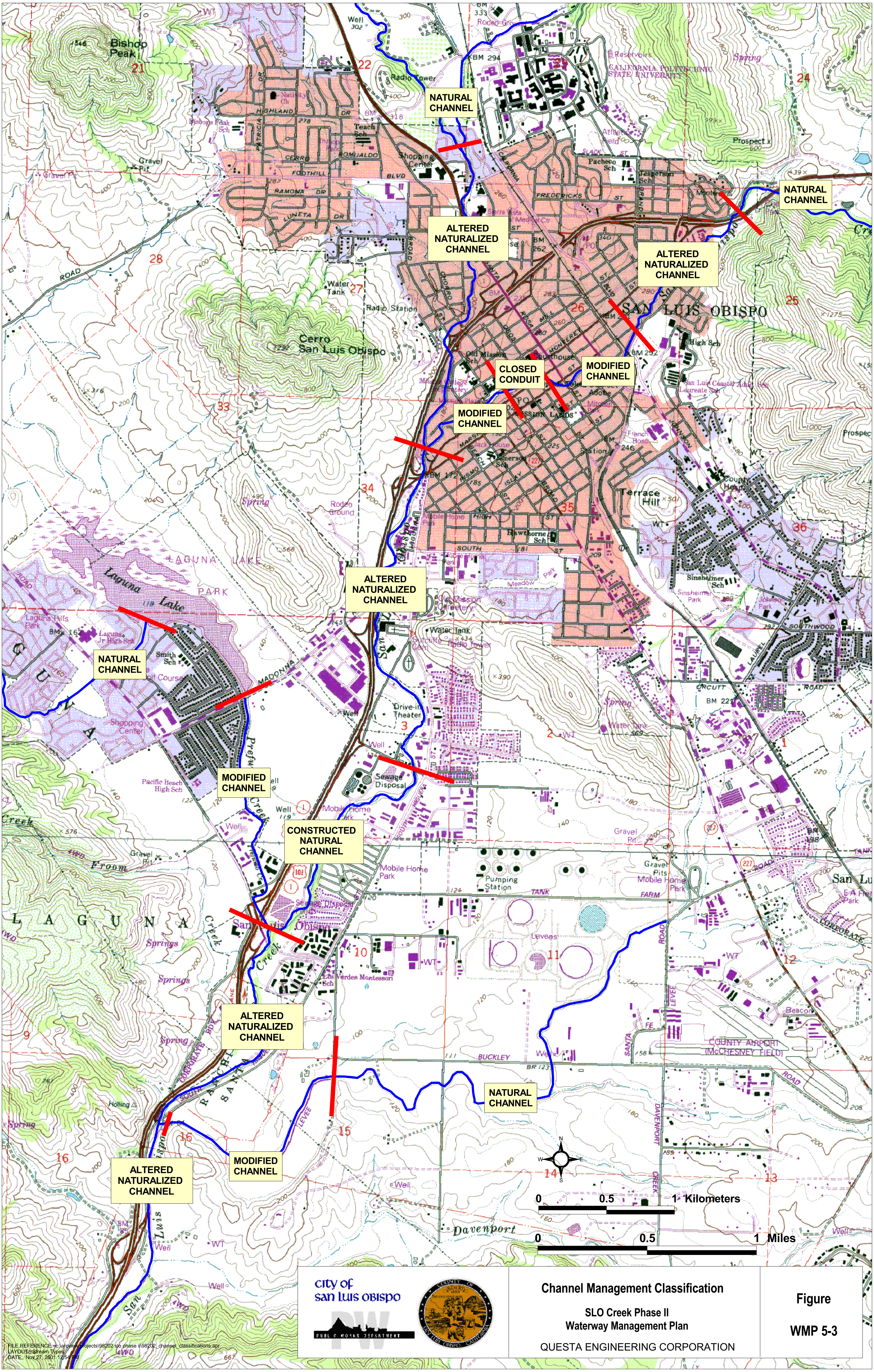
velocities and shearing forces (predictors of possible bank erosion) following development. These would be compared to the capacities and tolerances of existing channel conditions to determine potential impacts. It should be emphasized that the "No Adverse Impact" policy does not necessarily require an on-site stormwater detention basin to facilitate no net increase in runoff. The focus is on determining and mitigating impacts of increased runoff, recognizing that on-site stormwater detention may not be needed or even recommended in some lower portions of the watershed.

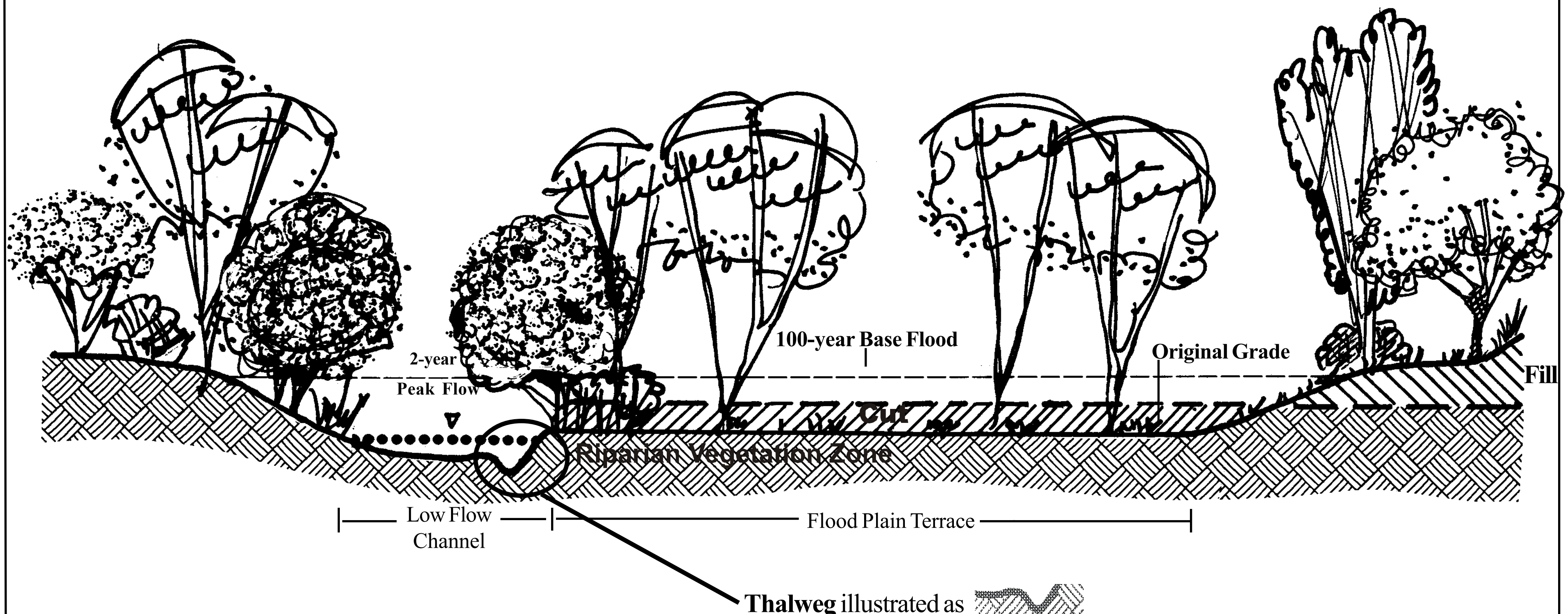
Project applicants would also complete a detailed review of project impacts on stream biology and geomorphology. The policy exempts very small residential and very small commercial development projects from this analysis. As with the *No Net Fill* provision, implementation of this policy will require a higher level of hydrologic design analysis by project applicants and a more comprehensive review by City and County engineering staff.

The applicant would be required to mitigate identified adverse impacts, such as downstream flooding and drainage, due to lack of conveyance capacity, or bank erosion and channel instability. This might mean that the project proponent must construct an on-site storm water detention facility (for flood management, not necessarily water quality management), improve drainage system conveyance, or stabilize and restore on-site or downstream channel segments. If it is not feasible or practical to mitigate impacts on-site or in the immediate project area, then the proposed policies call for the City and County to impose an *impact fee* to help fund regional mitigation projects, such as regional stormwater detention basins. All such projects would be subject to additional environmental review.

5.2.4 Channel Design and Bank Stabilization Guidelines

The DDM includes a channel management classification system, identifying creek reaches based on existing conditions and the degree of prior disturbance (**Figure 5-3**). The DDM makes it more difficult to propose work that will disturb or significantly modify creeks with good habitat conditions, and provides guidelines to restore and enhance disturbed creek areas associated with new development projects. All of the creek reaches that are considered in good condition are located in undeveloped areas. Specific geomorphically and biologically sound channel design guidelines are included where channel modification is required (and approved in subsequent environmental and permit review). The design guidelines provide criteria for creating a geomorphically stable and biologically diverse stream environment with a summer low flow channel, pools and riffles, natural meanders, vegetated in-channel benches and floodplain terraces. This approach is sometimes called "*Natural Channel Design*", and the resultant channel termed a *"Constructed Natural Channel".* An example of a constructed natural channel is provided in **Figure 5-4**. In some areas the use of flood *"Bypass Channels*" is recommended (**Figure 5-5**). A bypass channel retains the thread and integrity of the existing channel by constructing a secondary (generally parallel) channel with a vegetated berm or undisturbed strip separating the natural channel from the bypass channel. The secondary channel is constructed with the channel bottom elevation higher than the natural channel so that only flood flows over a certain discharge (e.g. greater than 2-year recurrence interval) move through the secondary channel. This preserves the critical summer low flow regime of the main channel and allows a certain


NATURAL CHANNEL
ALTERED NATURALIZED CHANNEL
NATURAL CHANNEL
ALTERED NATURALIZED CHANNEL
SAN LUIS OBISPO
CLOSED CONDUIT
MODIFIED CHANNEL
MODIFIED CHANNEL
ALTERED NATURALIZED CHANNEL
NATURAL CHANNEL
MODIFIED CHANNEL
CONSTRUCTED NATURAL CHANNEL
ALTERED NATURALIZED CHANNEL
NATURAL CHANNEL
MODIFIED CHANNEL
ALTERED NATURALIZED CHANNEL
Bishop Peak
Cerro San Luis Obispo
Laguna Lake
LAGUNA LAKE PARK
COUNTY AIRPORT (McCHESNEY FIELD)
0 0.5 1 Kilometers
0 0.5 1 Miles
City of San Luis Obispo
PW
PUBLIC WORKS DEPARTMENT
Channel Management Classification
SLO Creek Phase II
Waterway Management Plan
QUESTA ENGINEERING CORPORATION
Figure
WMP 5-3



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Constructed Natural Channel

Waterway Management Plan
City & County of San Luis Obispo

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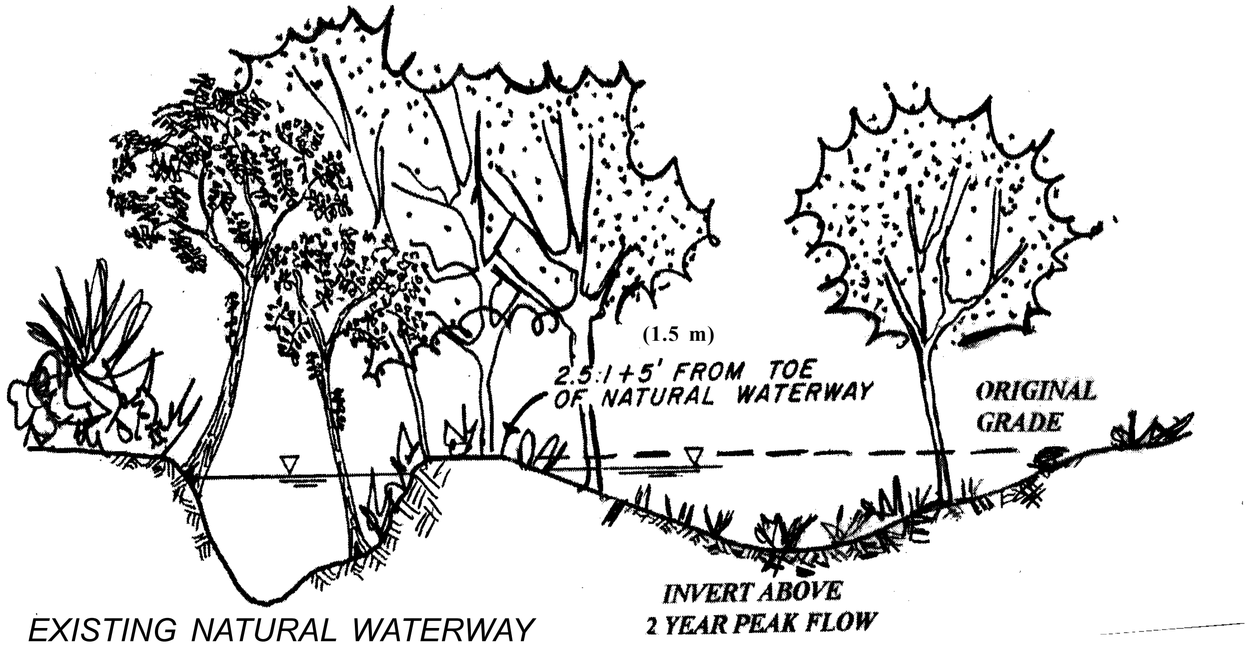
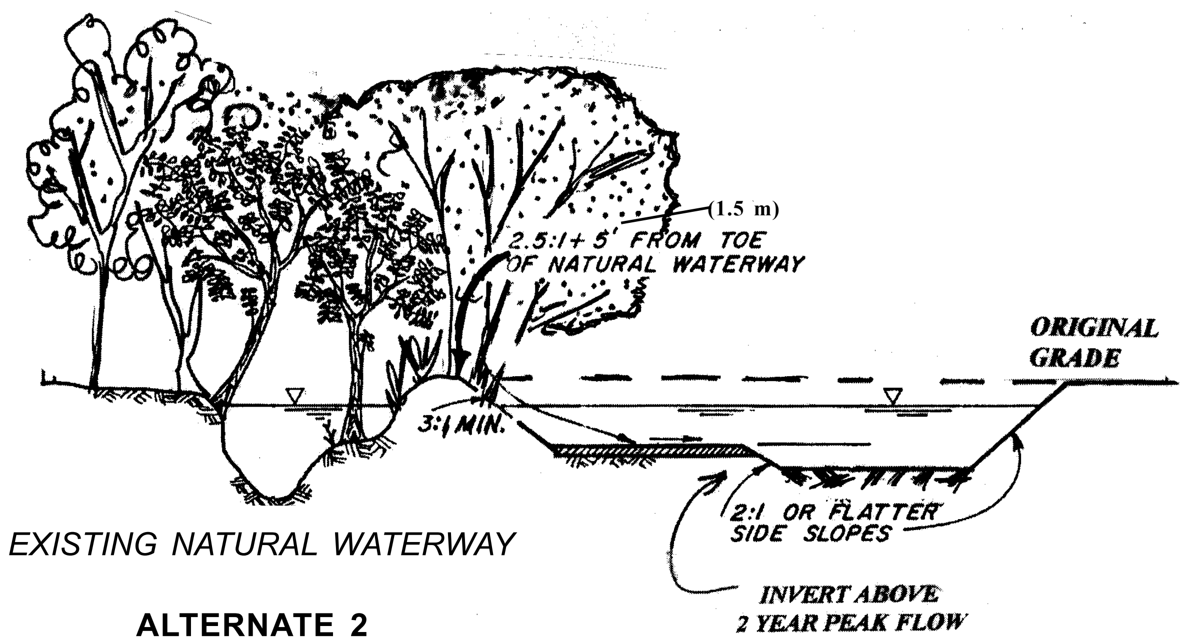
Figure
5-4

BYPASS SYSTEMS



ALTERNATE 1
CONSTRUCTED SECONDARY CHANNEL



ALTERNATE 2
RESTORED FLOODPLAIN

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Bypass Systems

Waterway Management Plan
City & County of San Luis Obispo

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Figure
5-5

amount of flooding to occur, which is important to maintain natural channel biologic and geomorphic functions.

5.2.5 Bank Stabilization and Revegetation

The DDM presents guidelines for bank stabilization and revegetation. For most projects the design approach requires hydraulic and geomorphic analysis of the bank failure site, to understand the cause of failure, and to determine channel velocities and shearing forces for selection of the most appropriate channel lining and protection material. The City/Zone 9 hydraulic model and the stream inventory data contain most of the information needed to complete the analysis. The objective of the analysis is to aid in the selection of the softest, most well vegetated approach to bank stabilization, consistent with sound engineering practice. In most cases biotechnical approaches to bank stabilization are emphasized along natural creek areas, with structural approaches generally limited to urban creek reaches where lack of room at top of bank and difficult geotechnical problems require use of harder materials.

5.2.6 Drainage Impact, Stream Zone Impact Fees, and Design Review Fees

The DDM recommends that the City and County consider the imposition of impact fees on some types of new development to fund City and County floodplain management programs. Impact fees would be collected for projects that do not adequately mitigate their impacts on-site. California law governs imposition of impact fees; fees must be tied directly to impact levels and the costs of administering the impact fee program. Impact fees can only be used to mitigate specific project impacts.

<u>Drainage Impact Fees</u> would be one-time charges assessed to compensate for impacts to the system of creeks and drainage structures that are otherwise not mitigated by an applicant. They would be tied to either a measure of impervious surface area, or increase in storm water runoff. The impact fee would likely require revisions to the City and County Codes.

The fees could be used to fund drainage improvements along waterways or the construction of regional stormwater detention/retention facilities.

<u>Stream Zone Impact Fees</u> would be tied to biological impacts to the wetlands and riparian areas along a creek. Impacts for fee assessment would be measured in lineal meters (or feet) along a stream. Stream Zone Impact Fees would assist the City and County in implementing Stream Habitat Enhancement projects as mitigation for the SMMP.

One advantage of such a program is that it enables a regional perspective in selecting and designing mitigation sites. This can result in the consolidation of numerous small, isolated or fragmented mitigation projects with limited and localized environmental values into larger, managed parcels with greater ecological benefit.

The DDM will require engineers and planners to perform a more detailed analysis (than currently required) along creeks and floodplains, and will require a greater amount of technical review by City and County staff. This will add staff time. The City will also need to periodically update and maintain the Zone 9 computer models. An increase in *Design Review Fees*, including use of cost recovery for projects located along creeks and flood prone areas, is anticipated.

5.2.7 Revised Creek Design Flows

A100-year flood protection designation is often used as a standard in flood design, yet this standard cannot be achieved in some communities. It may be infeasible because of costs or environmental impacts in many areas of the SLO watershed. Proposed *Design Flows* are contained in the DDM. They will be used for flood management planning. Designation of an alternative Design Flow (50 vs.100- year design flow in a stream reach) in the WMP will direct the selection of the structural flood control alternative needed to meet the design flow objective. In general, the higher the Design Flow, the greater will be the project size (channel modification or enlargement), with more environmental impacts. (Use of flood bypass channels does, however minimize impacts to the channel environment). Where channel modification is necessary and approved consistent with subsequent CEQA review, the channel should be enhanced and revegetated using native plant materials. Higher project costs will also be incurred in achieving them, although not necessarily in a direct relationship with project size.

Table 5-2 summarizes the proposed Creek *Design Flow* for the various reaches of streams within the SLO Creek watershed.

Table 5-2
Channel Design Flow Requirements[1]

Waterway	Design Flow
Major Waterways within the City of SLO	
SLO Creek above confluence with Stenner Creek	40 year[2]
SLO Creek below confluence with Stenner Creek to Madonna Road	20 year
SLO Creek from Madonna Road to Prado Road	50 year
SLO Creek from Prado Road to confluence with Prefumo Creek	100 year
SLO Creek from Prefumo Creek confluence to City Urban Reserve Line	100 year
SLO Creek below City Urban Reserve Line – maintain existing capacity	(aprx 10-year event for much of reach)
East Fork from SLO Creek to Broad Street3	varies- see footnote **3**
SLO Creek from Prefumo Creek confluence to Urban Reserve Line	100 year
Stenner Creek from SLO Creek to Chorro Street	50 year
Stenner Creek from Chorro Street to Urban Reserve Line	100 year
Prefumo Creek within Urban Reserve Line	100 year
Old Garden Creek within Urban Reserve Line	25 year
Other Major Waterways[4]	50 year
Secondary Waterways[5]	25 year
Minor Waterways[6]	10 year

Notes:

1. For purposes of designating Design Flows, the required design capacities and design requirements, the system of creeks and waterway in the SLO watershed is divided into major, secondary and minor waterways. All existing and proposed conveyance systems shall be analyzed and designed using the peak flows fro the hydrographs developed per the procedures described in Section 4 of the Drainage Design Manual to meet the design capacities.
2. 100-year protection can be provided with the Cuesta Park Detention Enhancement project.
3. East Fork of San Luis Obispo Creek is included in the Airport Area Specific Plan. Standards and plans for flood management are included in the plan and related environmental documents.
4 **Other Major Waterways** not named above and within the City Urban Reserve Line, or outside the City that have a drainage area of over 10 km^2 (4 square miles) shall be designed for an average recurrences interval of 25-years with 0.6-m (2-ft) of freeboard, and shall have sufficient capacity for a 50-year design discharge either by alternate surface routes (such as shallow street flow) or be contained within the channel without freeboard.
5. **Secondary Waterways** have a drainage area between 2.6 km^2 to 10km^2 (1 to 4 square miles) and shall be designated at a minimum storm recurrence interval of 10-years, with 0.3-m (1-ft) of freeboard.
6 **Minor Waterways** have a drainage area of less than 2.6 km^2 (1 square mile) and shall be designated at a minimum storm recurrence interval of 10-years, with 0.3-m (1-ft) of freeboard.

5.2.8 Erosion Control and Stormwater Quality Management.

This provision of the Core Requirements updates and strengthens current City and County Grading and Erosion Control ordinances, and includes erosion control as a part of the City and County Drainage Standards. As with most of the Core Requirements, a 1.0-hectare (2.5-acre) project size triggers the requirement for detailed erosion control planning and design analysis, and places greater restrictions on design and construction practices on parcels above that size. Steep slope areas (above 15% slope), and many sensitive areas along streams and near wetlands are included in this provision requiring detailed erosion control planning.

This Core Requirement outlines *Standard Erosion Control Measures* to be utilized to minimize or control soil erosion and sedimentation for smaller parcels (0.4-1.0-hectare, or 1.0-2.5-acres). Parcels smaller than 0.4 hectares (1.0-acre) are not covered by the specific requirement for erosion control planning, although the City, County, or Regional Board can still cite gross offenders under other local and state rules and regulations. This size standard will need to be lowered to 0.4-hectares (1.0-acre) when Phase II storm water regulations go into effect in the urban portions of the watershed in 2003 or 2004.

The Standard Erosion Control Measures may be implemented directly by the property owner or construction contractors without the need to prepare a detailed erosion control plan. In addition, this provision of the Core Requirements restricts the discharge or washing of common construction materials and by-products into the storm drain system, such as the clean up of paint brushes, painting equipment, and clean-up of concrete forms and poured concrete structures.

A detailed *Soil Erosion and Sediment Control Manual* has not been prepared as part of the development of the DDM. Instead, the DDM refers to the San Francisco Bay Association of Bay Area Governments (ABAG) *Manual of Standards for Erosion and Sediment Control Measures* (second edition, May 1995), and *Erosion and Sediment Control Field Manual,* available from the San Francisco Bay Regional Water Quality Control Board.

The Drainage Design Manual also provides Best Management Practices for construction related stormwater management, drawn from the CalTrans Best Management Practices Stormwater Manual. These measures will be required to be implemented for all projects in the SLO Creek Watershed that required a City or County issued building or grading permit.

5.2.9 Channel Maintenance and Management

This element of the Core Requirement means that project applicants must develop and implement plans to maintain, monitor, and manage all drainage facilities and hydraulic structures, and that such structures must be functioning correctly prior to their dedication to the City or County. Such structures include detention basins, channel modifications, and bank stabilization devices, as well as public storm drains. Where a regulatory agency has imposed mitigation requirements (such as bank top planting) in an area that will be dedicated to the City or County, the mitigation measure must be accepted as complete by all appropriate agencies before the City or County will consider acceptance of dedication. The maintenance and management plan must be consistent with the SMMP.

5.3 Stream Maintenance and Management Program (SMMP)

This WMP focuses on developing new and better methods for routine maintenance and management of the stream corridor. This includes:

- Management of aggressive exotic plant species,
- Selective management of native vegetation such as shrubby, dense willow growth that can interfere with flood flows in urban areas,
- Management of sediment accumulation and debris blockages, such as downed trees, and,
- Management of bank erosion problems, including repair of failing structures.

This component of the WMP is contained in a separate document entitled *SLO Creek Stream Management and Maintenance Program for the San Luis Obispo Creek Watershed* (SMMP). This document includes a specific set of watershed Best Management Practices for work in stream corridors, and incorporates by reference the *Channel Maintenance Best Management Practices Manual* developed in 2000 by the Bay Area Storm Water Management Association (BASMA). The important parts of the SMMP have been abstracted for inclusion here as part of the WMP report.

The SMMP is a “Policies and Procedures” document. It presents policies for management of creek resources, and contains Best Management Practices (BMPs) describing how the City and County will perform routine maintenance such as willow management and repair of bank failures. The SMMP will lead to a probable Memorandum of Understanding with the ACOE and other State and Federal Agencies, including the issuance of an Individual Permit for work within stream channels that are considered jurisdictional wetlands.

The intent of the SMMP is to increase efficiency in the permit review and approval process (and compliance with environmental regulations) by making the City and County responsible for the review and monitoring of routine maintenance projects, including follow-up assessment to ensure that the conditions of approval and mitigation requirements have been met.

The SMMP applies to public projects as well as projects proposed by private citizens, who elect to become a part of the Program. To take advantage of this Program, private property owners will be required to contribute to the preparation and submittal of an Annual Work Plan (AWP) by City/Zone 9, for certain kinds of projects. Routine projects that are currently considered CEQA/NEPA exempt and that do not currently require ACOE permits can proceed as before, and need not be included in the AWP. Large projects that require Individual ACOE permits will continue to require such permit review. The focus of the AWP will be on those projects that currently require a Nationwide permit from the ACOE, and consultation on Endangered Species issues with the U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). Those private parties who do not wish to be a part of the City and/or County Programs will need to go through a separate Individual permit process, along with permit applications to CDFG, and the Central Coast Regional Water Quality Control Board.

The Central Coast Regional Water Quality Control Board's Basin Plan (Section V.6.4) may also be applicable to construction practices and project designs, such as for bank repair. The Basin Plan will be incorporated into project design and design review of SMMP projects, as well as other development related construction projects along the creek, which will follow DDM design criteria. For instance, the Basin Plan states,

> *"a filter strip of appropriate width shall be maintained wherever possible between significant land disturbance activities and water courses…For construction activities, a minimum width of the strip shall be thirty feet, as measured to the highest anticipated water line…"*

Detailed vegetation and woody debris management, and stream bank repair policies and procedures are included in the SMMP. To determine vegetation management needs, stream reaches will be surveyed and trees marked for subsequent management (or protection) by a team consisting of a biologist and hydrologist. Creek activities will be completed by trained crews using an agency approved Maintenance Manual, which is provided as an Appendix to the SMMP. Management actions may include tree removal, thinning, and limbing to reduce the flow restrictive influence of the lower streamside trees. Tree removal, thinning and limbing to increase flood flow conveyance will focus on constricted areas and channel choke points within developed areas that experience recurrent damaging flooding, such as the Mid-Higuera area. Priority will be given to removal of non-native species and hazardous trees, or those that are undercut, diseased or dead and in danger of toppling into the creek. Where native hazard trees can be saved, provide snag habitat, or are undercut but provide valuable stream cover, alternative methods such as cabling and anchoring will be considered before removal.

In some areas, exotic trees such as Eucalyptus and Monterey Cypress line the bank top and shade out more desirable native understory plants. Tree removal may be phased in over a period of years, associated with replanting natives such as sycamores, oaks, and cottonwoods.

The goal of vegetation management is to create a closed tunnel-like canopy by encouraging larger, single trunk native trees to provide shade for stream temperature management and reduce growth of flow restrictive vegetation. Work may include selectively thinning dense willow growth on the lower banks, and limbing up selective trees, removing most limbs below 5-6 feet high. Trees growing over pools and mature native trees will be preserved. Some areas of dense willows, undercut trees, and snags will be retained for habitat value. Typical vegetation management techniques that will be used are shown in **Figure 5-6.**

In-stream habitat will be improved in areas where intensive vegetation management is completed to compensate for removal of shrubby streamside willows and mature exotic trees. Habitat improvement may include the installation of rock boulders to create new pools, artificial cover and habitat structures such as boulder clusters, (**Figure 5-7)**, root wads (**Figure 5-8**) or Lunker structures (**Figure 5-9**). Lunker structures consist of wood structures (similar in size and shape to a small to large coffee table) that are installed at the toe of creek near pools to provide fish shelter. They are usually cabled in place or anchored with rocks surround and over them, and planted. Gaps in the tree canopy and upper bank slopes will be inter-planted with native trees and shrubs as part of the stream management work.

Bank repair will focus on use of soil bioengineering techniques such willow wattles, planted geogrids, planted rock riprap, coir biologs and erosion blankets, and live crib walls. **Figures 5-10 through 5-14** provide examples of some of the kinds of biotechnical engineering designs for bank stabilization in the SLO Creek watershed.

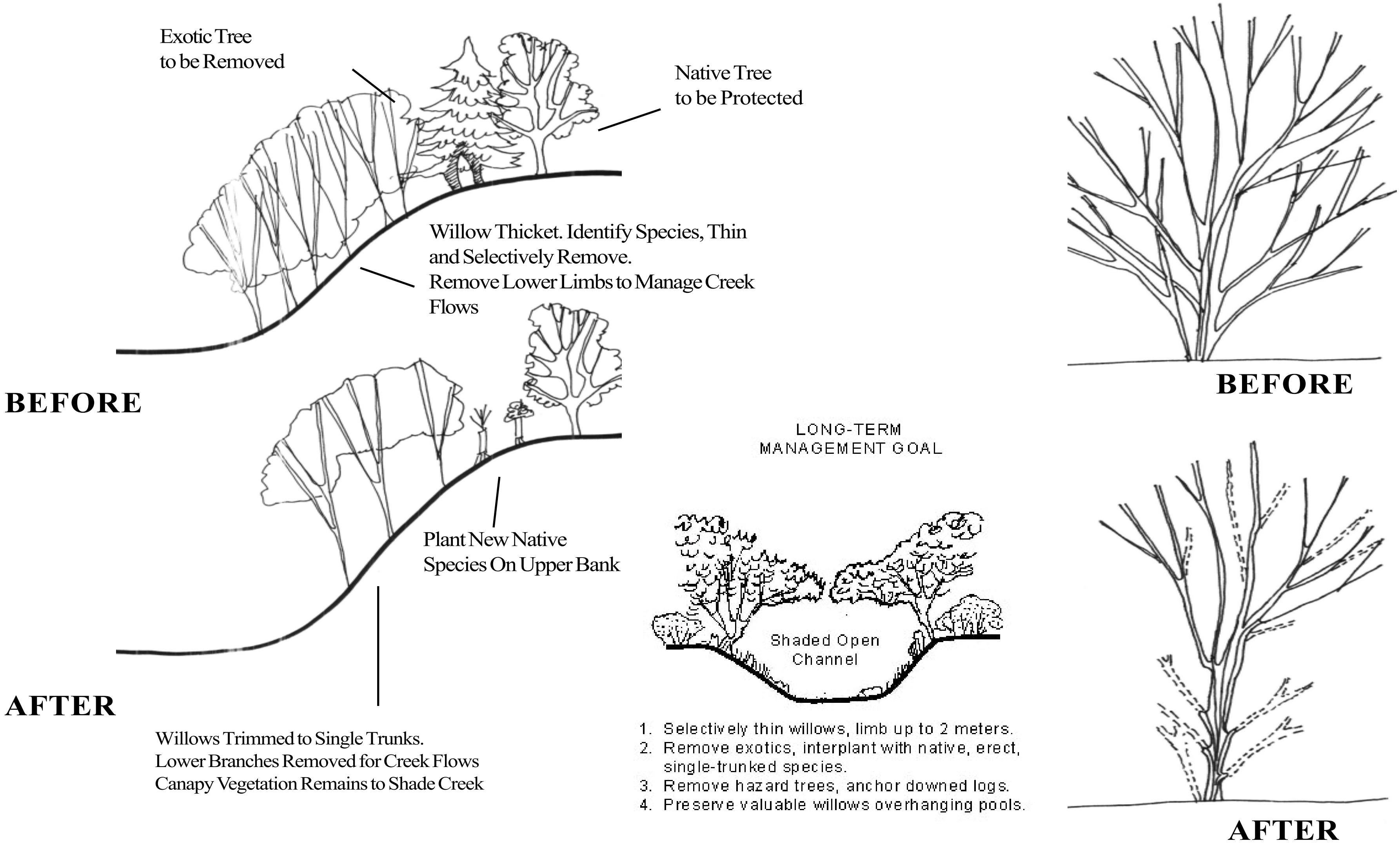
5.3.1 Environmental Issues addressed in SMMP

The SMMP provides procedures to avoid and minimize impacts to cultural, biological and other resources, including wetlands, riparian and aquatic habitat. Many streamside habitats support sensitive wildlife and aquatic species that have the potential to be affected by management and maintenance activities. Activities such as vegetation removal or earthwork may also affect the geomorphic (bank stability) and hydrologic (water movement and flooding) function of the creek system. The SMMP recommends a planning and design approach based on more complete hydrologic and geomorphic analysis than is currently being utilized for project planning and design, and use of Best Management Practices (BMPs) to minimize and mitigate environmental impacts.

5.3.2 SMMP Program Approach

The SMMP uses a tiered, or three (3) level or category approach to planning, project review, and implementation. A simple notification procedure will be used for most routine projects. Use of approved BMPs, self-monitoring by City and County Planning and Engineering staff and verification of work in “as-built” plans are also central to the program approach.

Category 1, *CEQA Exempt* and *Low Impact* Projects do not require a ACOE permit. This includes projects such as culvert cleaning, willow thinning, and maintaining or repairing existing bank protection structures using similar materials. California Department of Fish



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Vegetative Management

Waterway Management Plan
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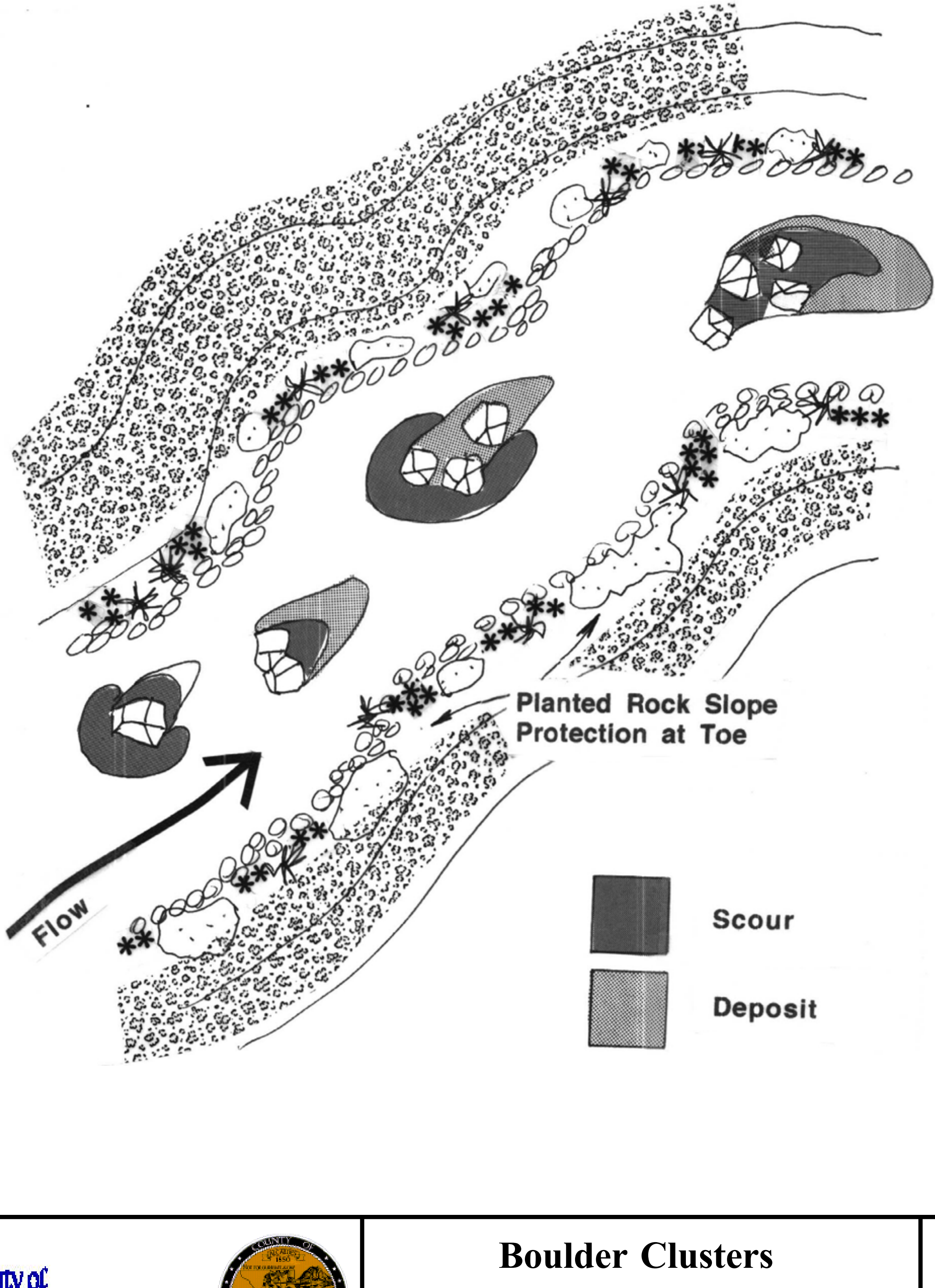
Figure
5-6



Boulder Clusters

Waterway Management Plan
City & County of San Luis Obispo

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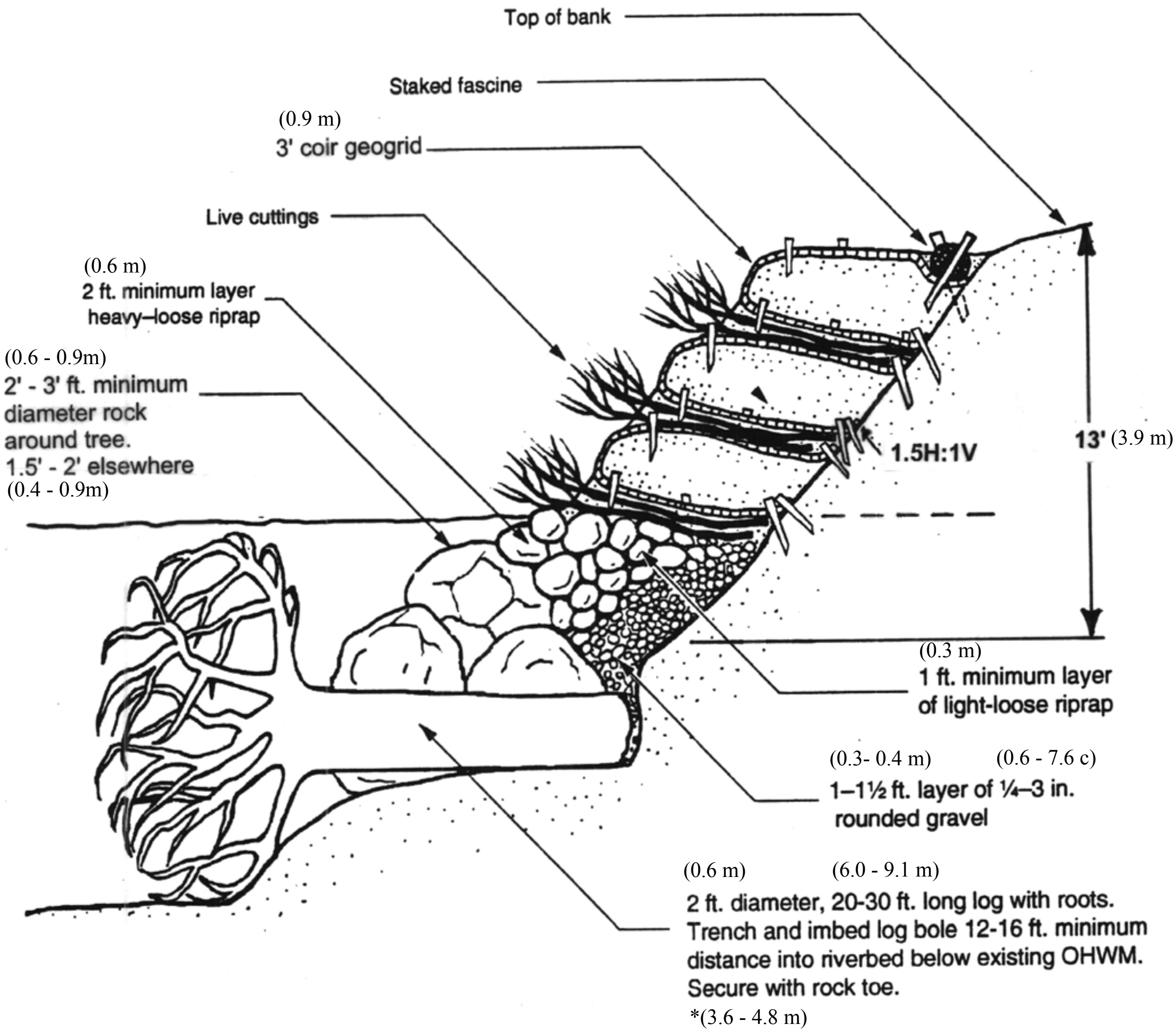
Figure 5-7



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Rootwad/Geogrid

Waterway Management Plan
City & County of San Luis Obispo

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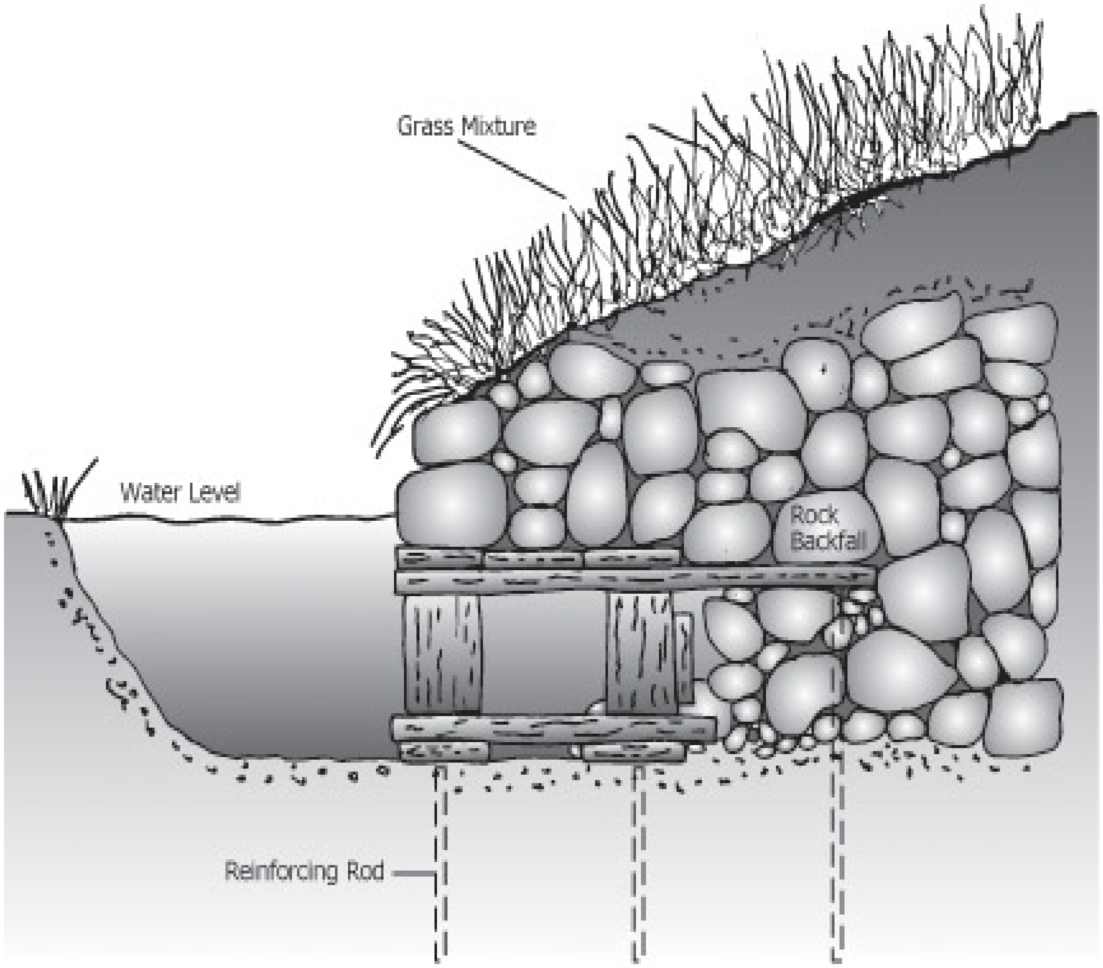
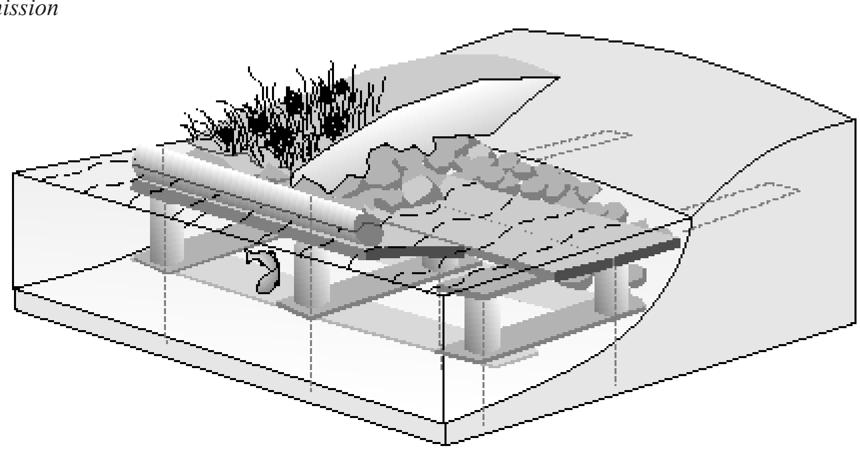
Figure

5-8



Based on illustration from Vetrano 1988. Used w/permission



"Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)."

City of San Luis Obispo

Lunker Structure

Waterway Management Plan
City & County of San Luis Obispo

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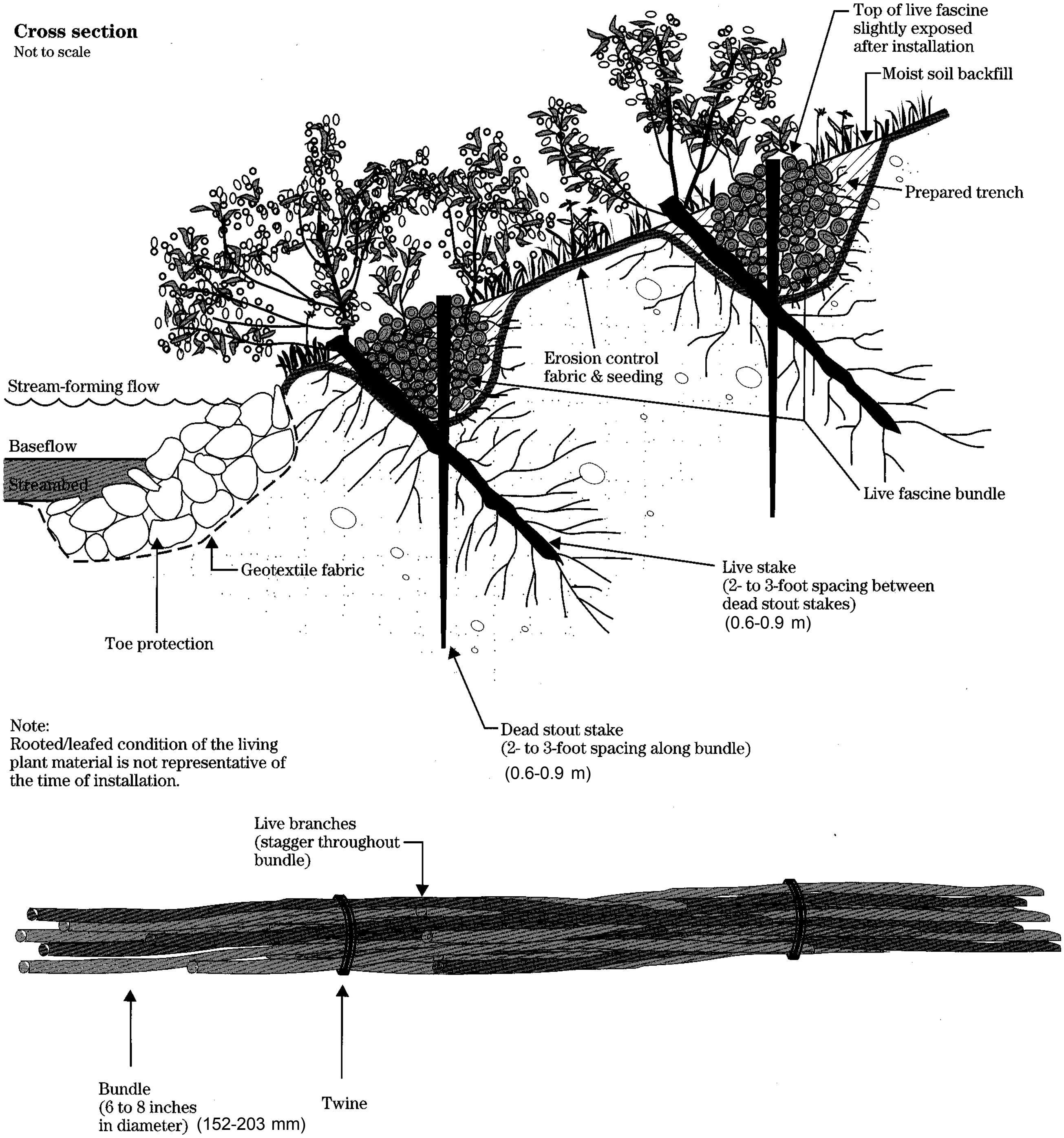
Figure
5-9



Live Stakes and Willow Wattles

Waterway Management Plan
City & County of San Luis Obispo

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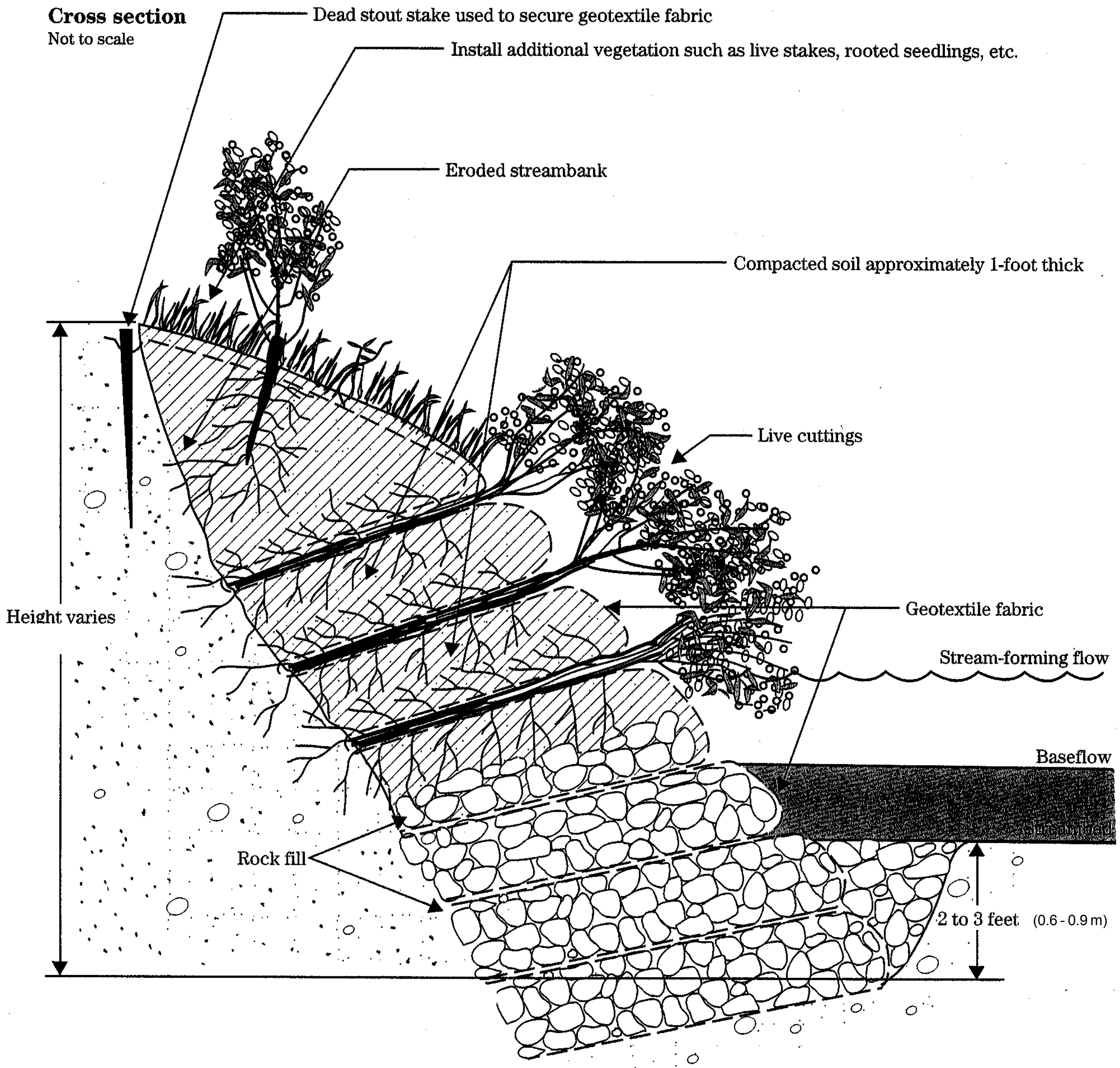
Figure

5-10



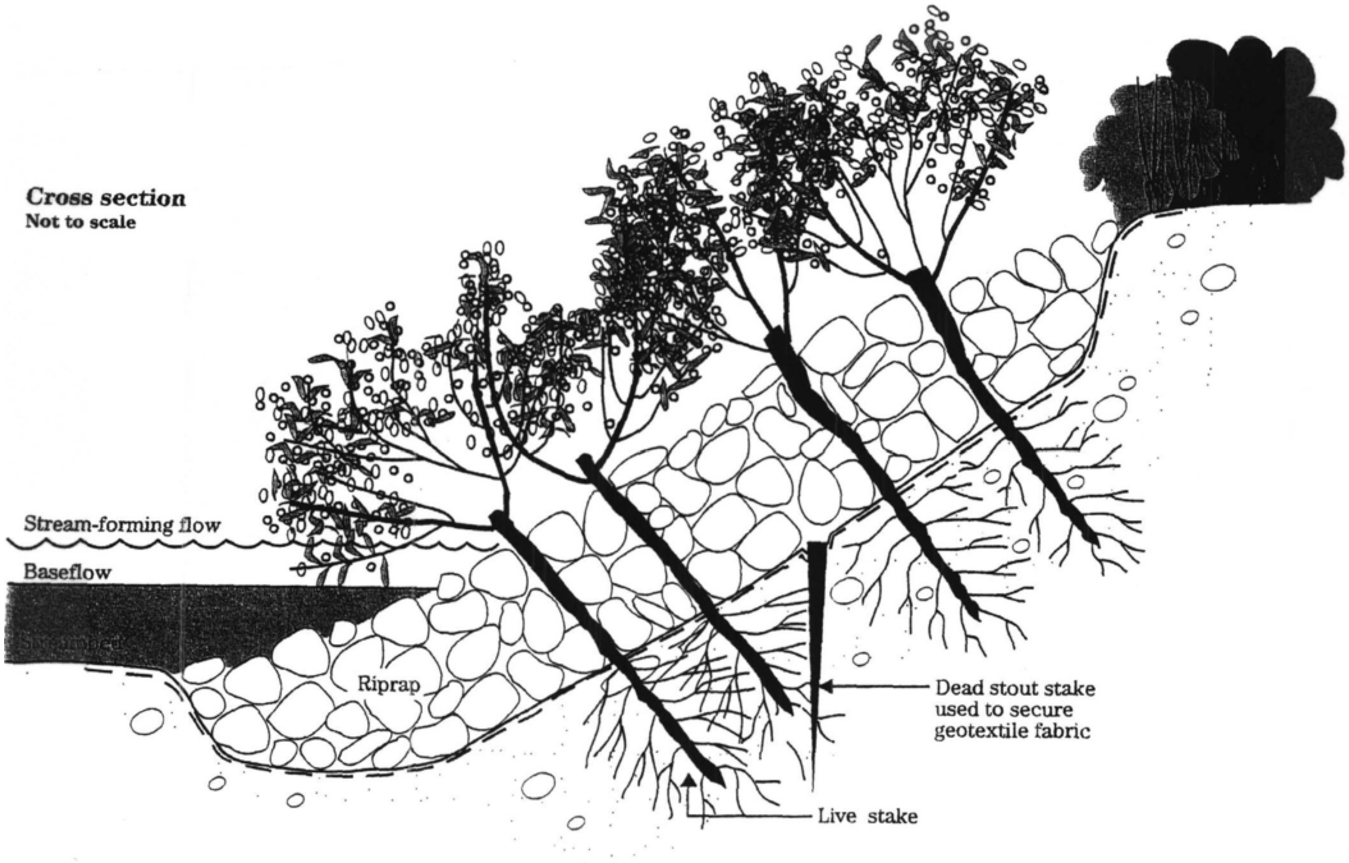
Note: Rooted/leafed condition of the living plant material is not representative of the time of installation.

Geogrid

Waterway Management Plan
City & County of San Luis Obispo

QUESTA ENGINEERING CORPORATION

Figure **5-11**



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Planted Rip Rap

Waterway Management Plan
City & County of San Luis Obispo

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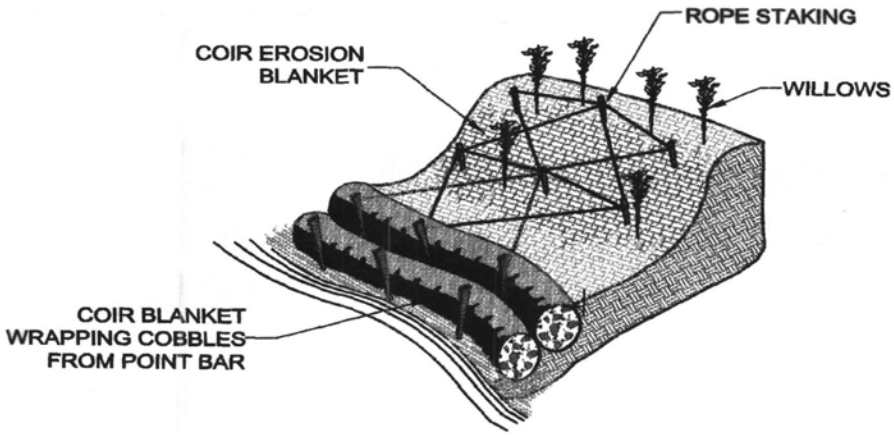
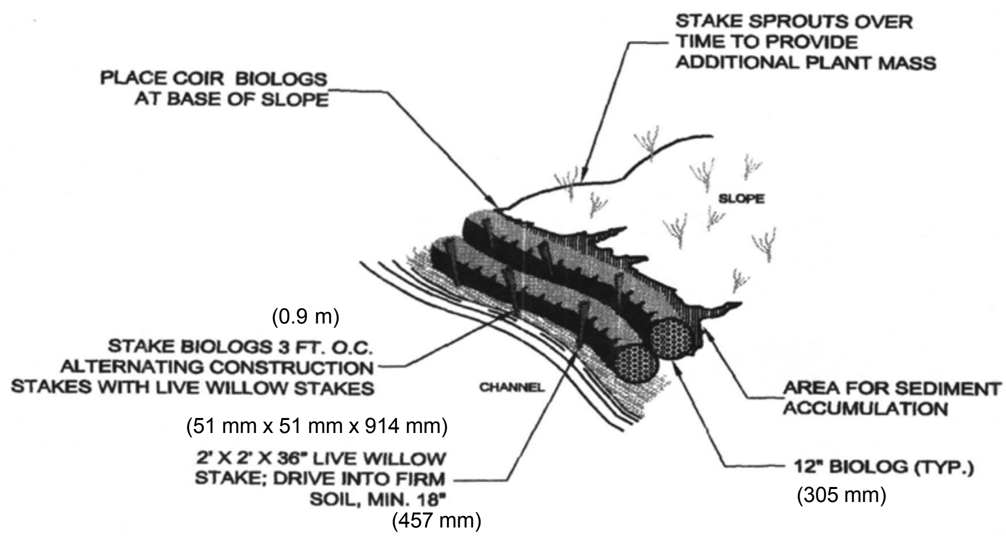
Figure

5-12

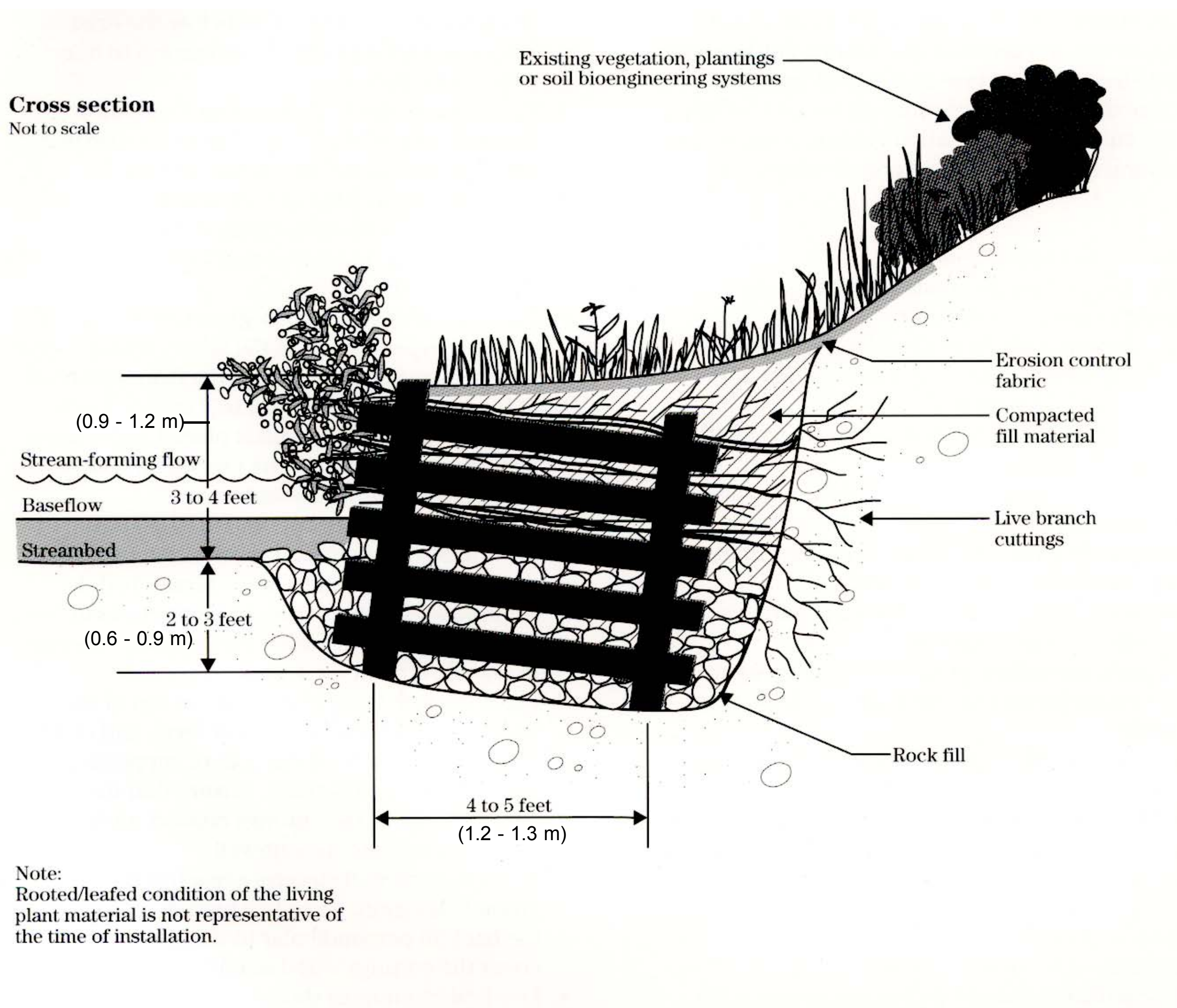


FIBER ROCK ROLL



BIOLOG TOE PROTECTION

City of San Luis Obispo PUBLIC WORKS DEPARTMENT 955 MORRO ST. 93401-3205	Coir Logs **Waterway Management Plan** **City & County of San Luis Obispo** QUESTA ENGINEERING CORPORATION	Figure **5-13**



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Live Crib Wall

Waterway Management Plan
City & County of San Luis Obispo

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Figure **5-14**

and Game biologists will be routinely consulted on projects that involve vegetation management and removal of large woody debris.

Category 2, *Minor Impact* Projects may require a ACOE Nationwide Section 404 permit. For these projects, an Annual Work Plan (AWP) will be prepared, based on an annual maintenance and management needs reconnaissance and assessment. The inventory data may be entered into a maintenance layer of the San Luis Obispo Phase II Project Geographic Information System as this system continues to be developed. The AWP will incorporate procedures, policies and BMPs outlined in this Program. The AWP will be reviewed by the City/County environmental officer for compliance agency permit conditions and with mitigation measures included in the Programmatic EIR/EIS. The compliance officer may recommend additional technical studies, environmental review, a change in practices, or additional mitigation. A public meeting will be held by Zone 9, and after approval at the local level, the AWP will be submitted to regulatory agencies for review. Additional requirements, including individual permit review and extra compensatory mitigation may be imposed by the regulatory agencies for those elements of the AWP judged to be outside of the approved Program.

Category 3 *Major Projects* include those with potentially significant impacts; such as bridge replacement and flood control channel modifications (requiring individual ACOE permits) are not included in this Program. These projects will still require a specific or Individual ACOE permit, and consultation with the US Fish and Wildlife Service and National Marine Fisheries Service on endangered species issues.

5.3.3 Mitigation for SMMP Activities

The SMMP provides an approach to vegetation management that involves the phased, gradual conversion of plant communities with exotic vegetation and shrubby willows (with high flow resistance), to a plant community composed of larger, single trunk native trees that shade the channel and have lower frictional resistance to flow. However, the Program also recognizes the special biological values of willow shrub communities, and requires that willow management for flood hazard reduction purposes be justified. Not all willow communities along the creeks will be managed for flood reduction, and Fish and Game biologists will be consulted on vegetation management projects. Normally, the need for extensive vegetation and sediment management will be dictated by hydraulic analysis of the stream conveyance system, with work prioritized in areas of most need (least flood flow capacity to achieve designated flood conveyance in urban flood prone areas). This may be difficult to achieve in many reaches.

Work would generally be completed in management units on alternating sides of the bank and be staged over a period of years to reduce short-term biological impacts. Restoration and biological enhancement of work areas should be included in each project element of the AWP. This includes riparian restoration and enhancement of aquatic habitat by creating new scour pools and hiding habitat, using structures such as rock boulder clusters, root wads, and Lunker structures. These structures will be designed in accordance with Programmatic permit conditions and adopted design guidelines. For bank repair and protection projects, the Program emphasizes that biotechnical approaches will be used where possible, based on completion of hydraulic, geotechnical, and geomorphic analysis.

Using the above approach, nearly all work will include components to mitigate project impacts on-site. For additional mitigation, City/Zone 9 proposes to work with local nonprofit environmental groups to identify additional restoration/mitigation opportunities. City/Zone 9 will budget money each year for watershed and stream restoration programs. The amount of money contributed annually will be based on the external off-site mitigation needs of the program. In addition SLO/Zone9 will cooperate with local groups to obtain grant funding for stream corridor restoration and enhancement.

Most of the public lands along SLO Creek will be restored or enhanced as part of ongoing City/Zone 9 and/or Land Conservancy programs. The mitigation program (for the SMMP and a part of the Flood Management Plan element) recommends that some areas of SLO Creek managed by Caltrans as part of a "Channel Change" easement be turned over to either the County or a non-profit watershed management entity such as the Land Conservancy, for enhancement and management. This includes a large area of creek corridor extending downstream from the South Higuera Bridge to San Luis Bay Drive. Legal issues regarding this transfer will need to be explored prior to implementation.

On private lands, partnership with the Conservancy or another not-for-profit entity provides the best opportunity to conduct enhancement/restoration activities. However, the City and County will retain the right to develop mitigation plans independently of non-profits, as part of City or County sponsored programs. It is envisioned that most of this enhancement work will focus selectively on private lands in Reaches 3 to 6, (the unincorporated portion below Los Osos Valley Road to See Canyon), and in Reach 14, (above Cuesta Park). The lower reaches have bank erosion problems associated with natural adjustment to historic straightening (associated with construction of Highway 101), and a predominance of low diversity shrubby willows. The upper reaches have bank erosion problems from channel incision that are undermining old stream-side stands of native sycamores that are toppling into the creek. Protection of valuable shaded pools associated with undercut banks is the key management issue that mitigation will focus on here.

5.4 Bank Stabilization Program

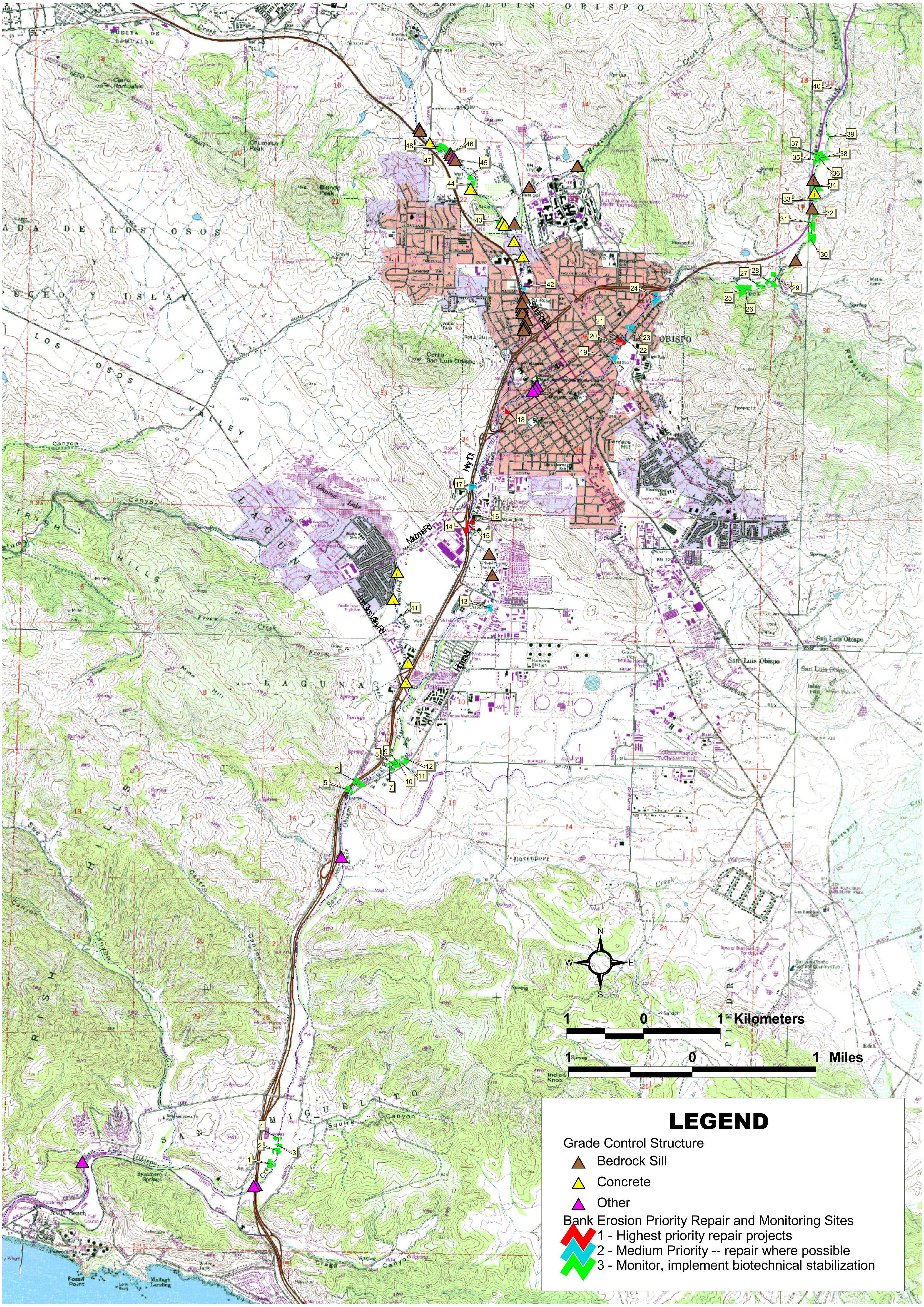
The WMP includes a bank stabilization, erosion protection, and bank repair program using integrated (combining hard structures and vegetation) and soil bioengineering (also called biotechnical) approaches to minimize impacts. An integrated approach is intended to minimize wetlands fill and stream impacts, remove ongoing sediment contribution to the stream system, and provide riparian and aquatic habitat enhancement. This section of the WMP describes the bank stabilization, erosion protection, and bank repair techniques that are considered appropriate for use within the SLO Creek watershed.

Bank stabilization techniques are outlined and presented at a conceptual level of detail**,** suitable for analysis in a general or Programmatic Environmental Impact analysis document, and as part of a Individual Section 404 Wetlands Fill Permit application to the ACOE and other regulatory agencies.

Figure 5-15 shows the principal creeks of the SLO watershed indicating the location of the major bank instability problems as they occurred during the 1999-2000 field geomorphic inventory. The map also shows priority bank repair sites as identified during the creek inventory and analysis. This recorded failure problems at that point in time; other bank failures may develop in future years, particularly following extreme winters. Many problems occur in creek bends, or in reaches that were straightened and realigned (such as road and highway construction). Bank stability problems will likely continue at these locations. In addition, historic stream incision threatens a number of revetments within the City of SLO. These will eventually need to be repaired or replaced by individual property owners.

Table 5-3 summarizes each site, web site photo link, site description, and recommended bank stabilization or repair approach. There are three (3) repair recommendations for each site, in decreasing order of preference. The recommendations consider physical and biological conditions, and adjacent land use. Other solutions may be feasible. **Figures 5-16 to 5-19** illustrate the repair concepts. These were adapted from the U.S.D.A's National Engineering Handbook 16, *Streambank and Shoreline Protection (USDA-NRCS, 1996).*

Property owners who elect to implement one of the recommended bank stabilization techniques will need to conduct a detailed and site specific study to verify the design recommendation, and adapt it to their specific site conditions. A team of professionals retained by the property owner, (e.g. civil engineer, hydrologist, geomorphologist, geotechnical engineer, landscape architect, revegetation specialist, etc.) should prepare the detailed design. Consultation with a fisheries biologist or aquatic biologist is also recommended for most sites.



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Bank Repair Program Sites

SLO Creek Phase II
Waterway Management Plan

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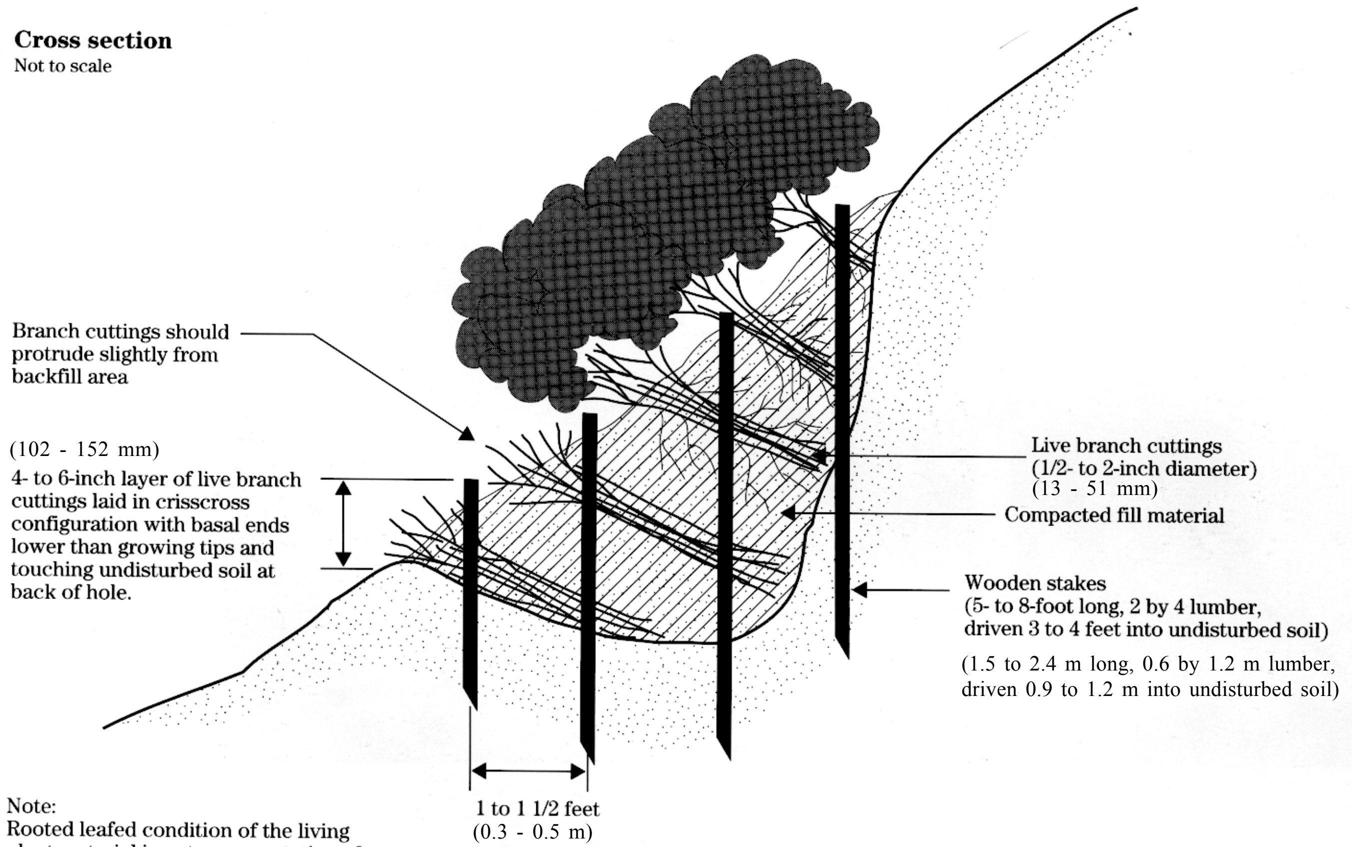
Figure
5-15



Note:
Rooted leafed condition of the living plant material is not representative of the time of installation.

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Brush Layering

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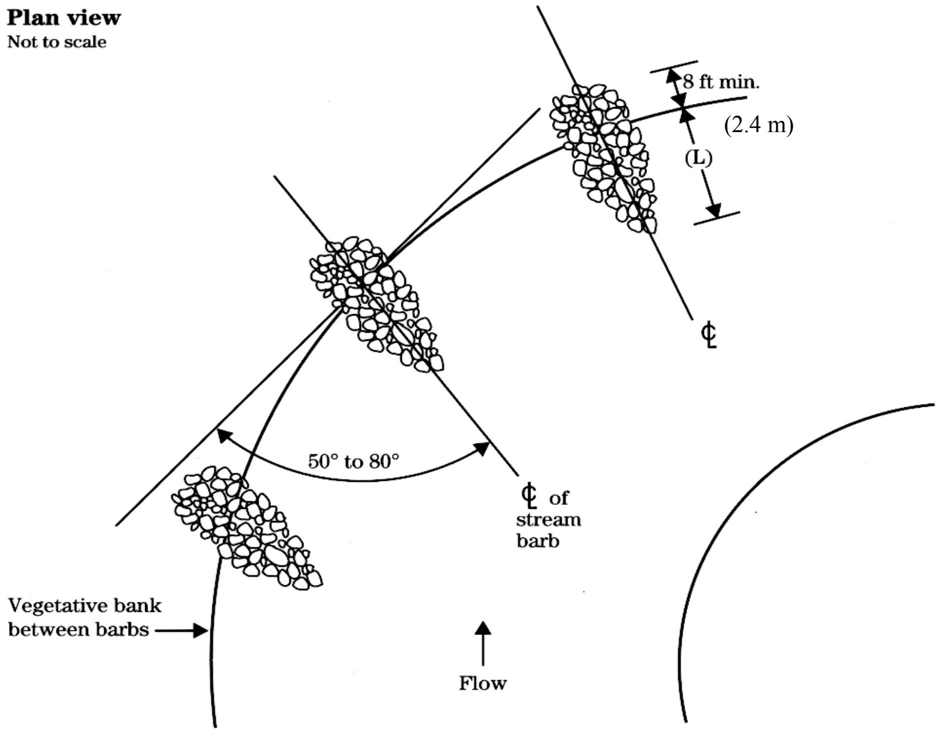
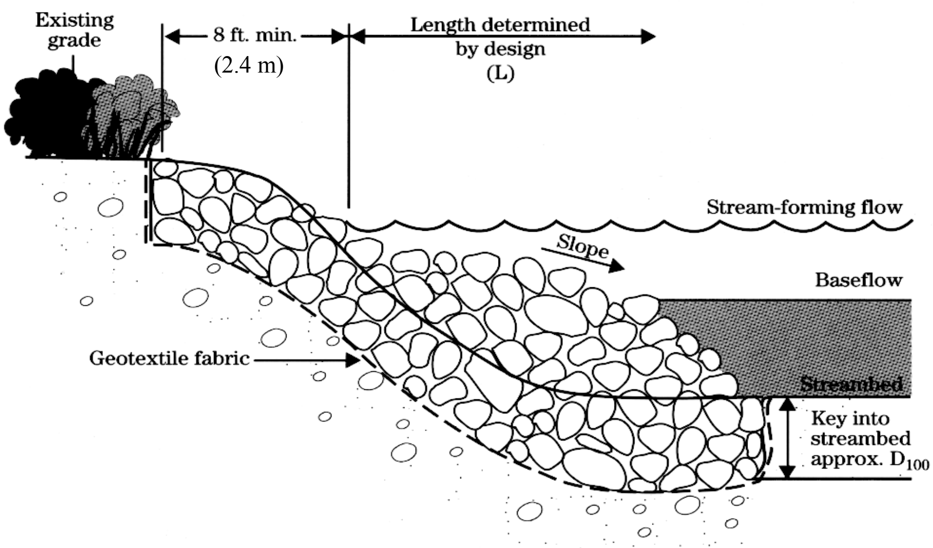
Figure **5-16**

Plan view
Not to scale



Cross section
Not to scale



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Flow Deflectors

Waterway Management Plan
City & County of San Luis Obispo

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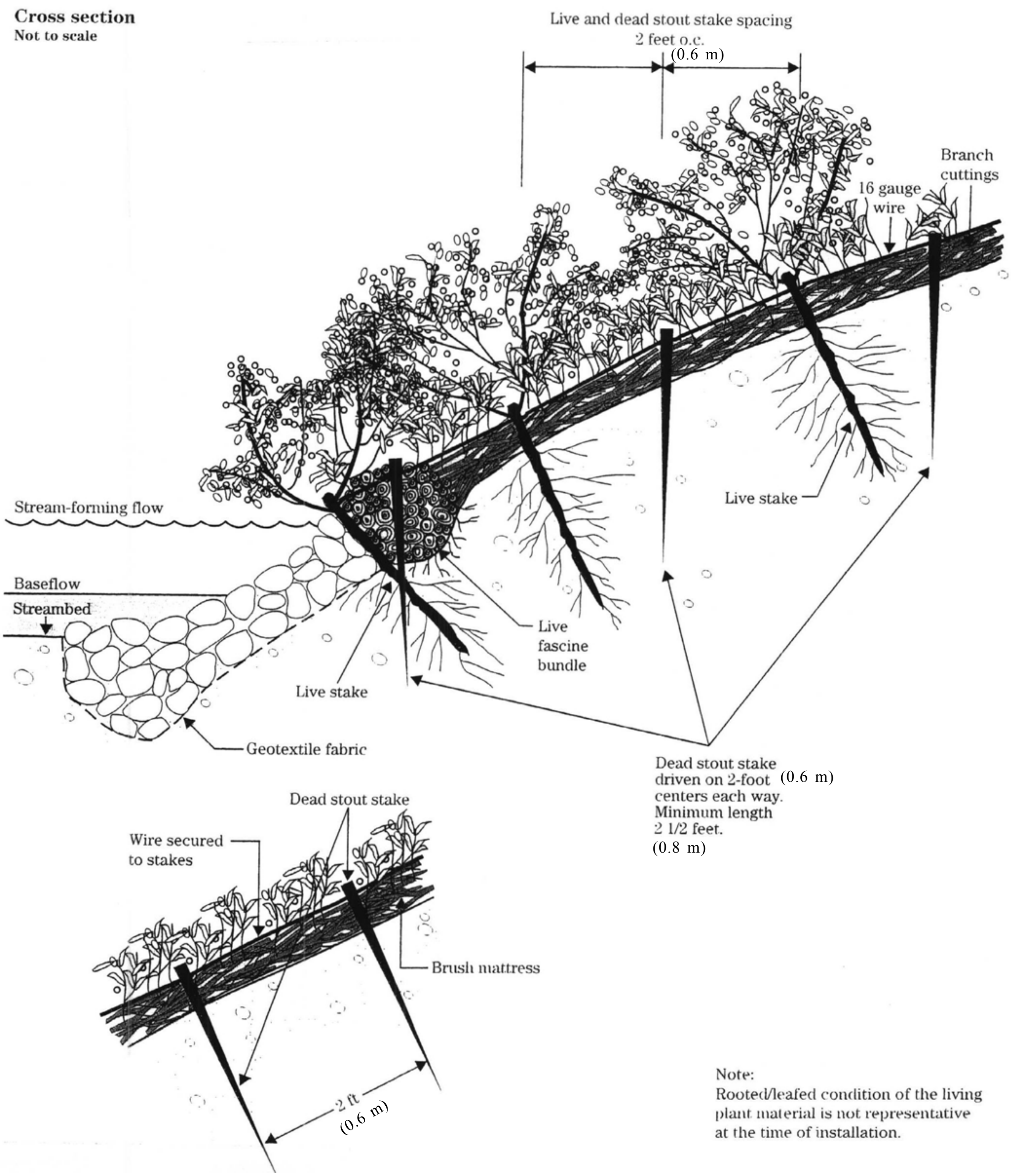
Figure

5-17



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Brush Mattress

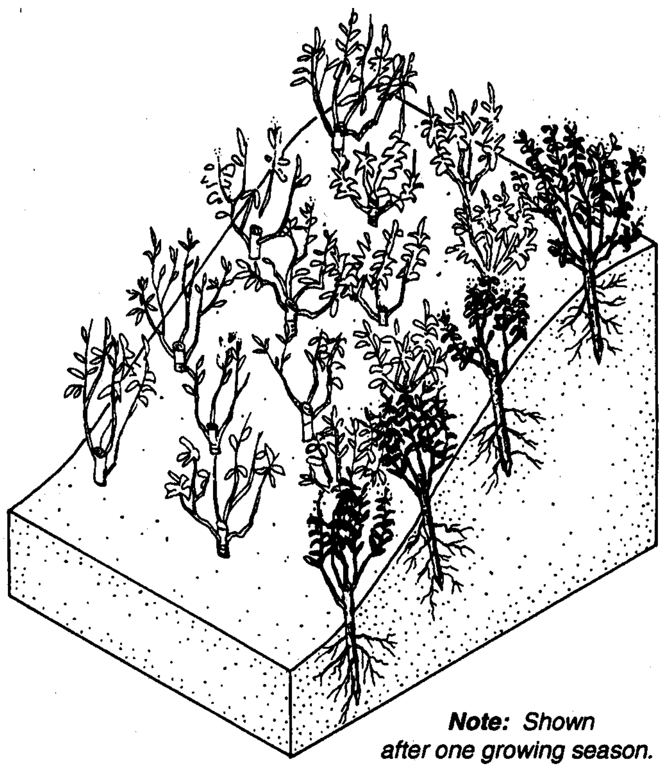
Waterway Management Plan
City & County of San Luis Obispo

QUESTA ENGINEERING CORPORATION

Figure

5-18

Live stake prior
to installation



Note: *Shown after one growing season.*

Live Willow Staking

Waterway Management Plan
City & County of San Luis Obispo

QUESTA ENGINEERING CORPORATION

Figure
5-19

city of san luis obispo
PUBLIC WORKS DEPARTMENT 955 MORRO ST. 93401-3218

Table 5-3
Bank Repair Program Project Sites

Map Number	Creek Reach	Photo_path	Length (ft)	Priority Category*	Shear (lb/ft2)	Recommended Approach Method 1	Recommended Approach Method 2	Recommended Approach Method 3
1	3	hotlinks/40374.gif	44.4	3	60	Brush Layering	Flow Deflectors	Loose rock with willow staking
2	3	hotlinks/40369.gif	52.1	3	60	Brush Layering	Loose rock with willow staking	Fiber Rolls
3	3	hotlinks/40367.gif	32.9	3	60	Brush Layering	Loose rock with willow staking	Fiber Rolls
4	3	hotlinks/40364.gif	25.4	3	60	Brush Layering	Loose rock with willow staking	Fiber Rolls
5	7	hotlinks/32330.gif	36.6	3	200	Brush Layering with Rock toe	Live Willow Staking	Fiber Rock Rolls
6	7	hotlinks/32325.gif	42.2	3	200	Brush Layering with Rock toe	Live Willow Staking	Fiber Rock Rolls
7	7	hotlinks/32315.gif	22	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
8	7	hotlinks/32313.gif	35.9	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
9	7	hotlinks/32311.gif	40.9	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
10	7	hotlinks/32310.gif	13	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
11	7	hotlinks/32309.gif	14.6	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
12	7	hotlinks/32308.gif	24.4	3	100	Brush Layering	Live Willow Staking	Fiber Rolls
14	9	hotlinks/40538.gif	23.1	1	250	Brush Layering	Planted Rock Rip-rap	Fiber Rock Rolls
15	9	hotlinks/40536.gif	31.7	1	250	Brush Layering with Rock Toe	Regrade Slope, Rock Toe, Erosion Fabric	Vegetated Geogrids
16	9	hotlinks/40533.gif	34	1	250	Brush Layering with Rock Toe	Regrade Slope, Rock Toe, Erosion Fabric	Vegetated Geogrids
17	10	hotlinks/40508.gif	64.5	2	100	Regrade Slope, Rock Toe, Erosion Fabric	Brush Layering	Vegetated Geogrids
18	11	hotlinks/30956.gif	26	1	275	Vegetated geogrids above Ajacks toe	Vegetated geogrids above rock toe	Fiber rock rolls
20	12	hotlinks/30763.gif	6	1	150	Vegetated Geogrids	Brush Layering with rock toe	
21	12	hotlinks/30761.gif	61.7	1	200	Loose rock with willow staking	Brush Layering with rock toe	Planted rock rip-rap
22	12	hotlinks/30760.gif	24.3	2	200	Flow Deflectors	Rock toe with willow staking	
24	13	hotlinks/30735.gif	36.2	2	220	Loose rock with willow staking	Rock toe, regrade bank	Planted Fiber Rolls
25	14	hotlinks/33131.gif	29.2	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
28	14	hotlinks/33120.gif	42.3	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
29	14	hotlinks/33115.gif	28.9	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
32	14	hotlinks/33191.gif	37	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
33	14	hotlinks/33184.gif	8.1	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking

Map Number	Creek Reach	Photo_path	Length (ft)	Priority Category*	Shear (lb/ft2)	Recommended Approach Method 1	Recommended Approach Method 2	Recommended Approach Method 3
35	14	hotlinks/30250.gif	39.7	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
36	14	hotlinks/30249.gif	29.9	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
37	14	hotlinks/30245.gif	59.6	3	0	Brush Layering	Planted Fiber Rolls	Loose rock with willow staking
40	14	hotlinks/30205.gif	3.7	2	0	Loose rock with willow staking	Ajacks	Fiber rock rolls
41	18	hotlinks/32226.gif	7.5	2	80	Drop Inlet w/ protected outfall	Planted Rock Rip-rap	Willow Wattling/Erosion Check
42	21	hotlinks/31668.gif	26	2	150	Loose Rock with Willow Staking	Fiber Rock Rolls	Ajacks
43	22	hotlinks/31625.gif	24.1	3	400	Loose rock with willow staking	Fiber rock rolls	Vegetated Geogrids
44	22	hotlinks/31601.gif	28.3	3	360	Brush Layering with rock toe	Flow Deflectors	Loose rock with willow staking
45	22	hotlinks/31576.gif	43.9	3	80	Brush Layering with rock toe	Loose rock with willow staking	Fiber rock rolls
46	22	hotlinks/31561.gif	49.2	3	280	Maintain existing willow stakes	Flow deflectors	Loose rock with willow staking
47	22	hotlinks/31555.gif	50.1	3	150	Planted rock rip-rap	Vegetated Geogrids	Loose rock with willow staking
48	22	hotlinks/31552.gif	67.3	3	150	Veg management (replace exotics w/ willows)	Fiber rolls/Erosion fabric	Loose rock with willow staking

* Priority Categories: 1) Highest Priority Repair Project 2) Medium Priority 3) Low Priority–monitoring recommended.

The design team must use the design approach and design procedures described in the companion document, *Drainage Design Manual for the City of San Luis Obispo*, *and portions of SLO County within the SLO Creek Watershed* (DDM). The DDM also outlines the required submittals and submittal format this document requires the design team:

1) To consider existing site geomorphic and hydraulic conditions in the design,
2) To consider potential downstream geomorphic consequences of the design,
3) To consider effects on flooding from stream encroachment or change in roughness values,
4) To select the softest approach to achieve a stable condition, and integrate native plantings into the design, to the maximum extent feasible.

Stabilization alternatives considered the physical conditions and biological constraints that occur within the stream reaches. The alternatives are at a conceptual level of detail, and the design will need to be adjusted to the actual horizontal and vertical dimensions of the bank failure problem. For some projects it may be necessary to mix and match elements of the alternatives presented (e.g. planted rock toe with coir erosion control blanket upper slope). It will also be important to transition the design upstream and downstream to stable sections of the creek, such as using planted rock, or sometimes with planted coir fiber rolls, or fiber rock rolls.

The proposed design will then be reviewed by the City or County, and if appropriate, and following revisions, included in the Annual Work Plan (AWP) submitted by the City or County to the ACOE as part of a Regional General Permit (RGP) agreement to be issued, associated with the SLO Creek Stream Maintenance and Management Program. The AWP would be submitted to regulatory agencies as part of a proposed Memorandum of Understanding (MOU).

All property owners will retain the right to submit their own proposed design and individual application to the regulatory agencies for separate consideration as an Individual permit, or for some small projects, a Nationwide Permit 13 (Bank Stabilization). However, the individual property owner will not be able to take advantage of the time and cost efficiencies, and permit streamlining created by the Programmatic CEQA document for the WMP, and any agency issued watershed-wide Individual Permit or MOU.

5.5 Habitat Restoration and Enhancement Program

5.5.1 Program Approach

Habitat enhancement opportunities and management needs were identified in **Section 3.** The WMP prioritizes sites that benefit from fisheries habitat enhancement and riparian restoration, such as removal of non-native plants, and native plant revegetation. Habitat Enhancement Projects would be completed as mitigation for impacts caused by structural flood control projects, bank repair and stream maintenance work, or as part of a strategy to better manage creek resources within the watershed.

For efficiency, and to make the best use of available funding, the Habitat Enhancement Program component will be integrated with work currently being completed by the City, County, Land Conservancy, and other agencies and nonprofit groups. For instance, the Enhancement Plan for the Filipponi property on lower East Fork of SLO Creek was a cooperative project recently implemented to resolve bank erosion, restore the historic riparian floodplain, and add pool forming structural stream habitat elements (root wads and boulders) to SLO Creek.

Portions of the ongoing enhancement work being completed by the Land Conversancy are being funded by the Unocal oil spill, Avila Beach, 1992 trust fund, with other sources of funding obtained from state and federal grants. Specific projects were identified in the *Final Plan for Restoration Actions within the San Luis Obispo Creek Watershed, Unocal Oil Spill, Avila Beach, 1992***,** prepared for the Avila Beach Trust Council by the Conservancy, and updated in 2002, as part of the *Land Conservancy Watershed Enhancement Plan.*

5.5.2 Fish Habitat Enhancement

Stream channels within the watershed are incised with many areas of steep eroding banks. The stream inventories completed as part of the Phase II studies and previous surveys completed by Cleveland (1996) noted a general lack of shaded pool habitat. Other deficiencies limiting steelhead populations include:

- Embedded spawning gravels
- Lack of canopy cover
- Elevated summer temperatures
- Deficiencies in the amount of in-stream structural elements providing cover, and
- Fish passage barriers

A program of adding in-stream structures in select channel reaches has been included as part of the WMP, based on the results of the creek inventories. The in-stream structures would consist of artificial cover structures such as lunkers, root wads, or rock weirs.

A rock vortex weir consists of boulders placed in a "V" pointing upstream, with gaps approximately the same size as the boulders, and with boulders in the center-the lowest in height. This boulder arrangement when designed, located, and placed sensitively, can create scour pools that remain viable during the summer, and can result in the deposition of gravels forming riffles at the pool tail. Other fish enhancement structures can consist of anchoring root wads onto the channel banks.

Barriers to fish migration were also mapped during the stream inventory work. One method to remove a barrier is to construct a boulder step-pool sequence. Step-pools consist of a series of boulder-formed pools across the width of the channel and downstream of the barrier that steps down in elevation in short drops. Typically the grade of the sequence of pools is 5-10% so some tall barriers may require a number of pools. The pools allow fish to rest and proceed in a series of jumps and movements. With this method, the barrier (often a dam) does not need to be removed completely and the channel grade upstream and downstream does not change. The pools can be integrated with bank repair and revegetation projects without needing maintenance or removal of debris.

The City and County propose to contribute technical expertise and financial aid to the watershed program of the Land Conservancy and other nonprofits as a component of the overall WMP. Specific restoration and enhancement programs will be coordinated through the Zone 9 Advisory Committee and appropriate funding and projects selected each year. The City and County will also actively participate with nonprofit partners to request grant funding from state and federal programs.

5.5.3 Riparian Habitat Enhancement

The enhancement and biological inventory work completed for the WMP (see **Appendix B** of Volume I) identified needed riparian restoration, as well as areas where the control of invasive non-native plant species should be undertaken. This built on earlier work completed by the Conservancy and reported in *San Luis Obispo Creek Watershed Hydrologic Survey* (1996), and the recent Land Conservancy's *SLO Creek Watershed Enhancement Plan* (2002). Riparian habitat enhancement projects include:

- Expansion of riparian corridor width
- Closing the canopy by inter-planting in canopy gaps
- Expanding canopy or overstory species diversity, especially in willow monoculture areas by planting native trees such as sycamore, black walnut, and cottonwoods
- Increasing understory species diversity by planting native shrubs and groundcovers to provide wildlife habitat, food and cover
- Removal of exotic invasive species such as giant reed, and phased removal of large and hazardous trees such as eucalyptus and Monterey Cypress
- Providing wildlife movement corridors connecting fragmented habitat areas along waterways and uplands
- Bank Stabilization to protect large sycamores that are in danger of being undermined and toppling into the creek.

5. 6 Project Mitigation Requirements

The Stream Restoration and Enhancement Program can serve as a framework for mitigation of impacts associated with the SMMP and Flood Management and Bank Stabilization projects. Impacts cannot be fully quantified at this time, as they depend on specific project design details, and for bank stabilization and flood control projects, the construction schedule. However, based on the present conceptual plans, the range of impacts and estimates of mitigation needs are as follows:

- If all bank repair projects were completed over next 20 years (Individual Permit timeline), the amount of mitigation required would be about 550 meters (1800 lineal feet) of stream restoration and enhancement. This assumes that part of mitigation is included and internally mitigated in project design.

- Mitigation requirements for the Preferred Project flood management element totals approximately 2100 meters (7000 lineal ft.) of creek bank. Assuming a 5 meter (16 ft) and a 2:1 mitigation ratio with ½ of the mitigation completed onsite, this represents 10,500 m^2 (2.7 acres) of mitigation.

- Mitigation requirements for the bank repair and flood management aspects of the project will likely exceed 2600 lineal meters and well over 7.5 hectares (3 acres) of restoration and enhancement work. This exceeds the amount of publically owned land along the main stem of San Luis Obiso Creek in need of restoration and enhancement.

- As previously indicated, the sites west in need of enhancement and restoration are located in Reach 14, above Cuesta Park, and Reaches 3 to 6, betwee4n San Luis Bay Drive and LOVR, and in upper Prefumo Creek. Other potential candidate sites include lower Davenport Creek and Castro Canyon in the Irish Hills natural area. Phase I enhancement focused on Reach 7 between Prado Road and LOVR.

Restoration and enhancement would be coordinated with ongoing projects by the Conservancy and other nonprofits. Mitigation for structural flood control projects will likely need to be funded and implemented by the City and County.

5.7 Mitigation Bank

A wetlands mitigation bank is a wetland area (or stream zone) that has been restored, created, enhanced, or (in exceptional circumstances) preserved, which is then set aside to compensate for future conversions of wetlands for development activities. A mitigation bank may be created when a government agency, a corporation, or a nonprofit organization undertakes such activities under a formal agreement with a regulatory agency. The value of a bank is determined by quantifying the wetland values restored or created in terms of "credits." Project proponents that need to "mitigate" or compensate for authorized impacts to wetlands associated with development activities may have the option of purchasing credits from an approved mitigation bank rather than restoring or creating wetlands on or near the development site. Advantages of the use of Mitgation Banks are as follows:

- Banking can provide more cost effective mitigation and reduce uncertainty and delays for qualified projects, especially when the project is associated with a comprehensive planning effort.
- Successful mitigation can be ensured since the wetlands can be functional in advance of project impacts.
- Banking eliminates the temporal losses of wetland values that typically occur when mitigation is initiated during or after the development impacts occur.
- Consolidation of numerous small, isolated or fragmented mitigation projects into a single large parcel may have greater ecological benefit.

A mitigation bank can bring scientific and planning expertise and financial resources together, thereby increasing the likelihood of success in a way not practical for individual mitigation efforts.

Although the concept of the formation of a formal Mitigation Bank (limited to flood control and bank stabilization projects) was discussed at a Zone 9 Advisory Committee meeting, such a Mitigation Program is currently not a part of the Preferred Project.

5.8 Coordinated Resource Management Plan (CRMP)

The WMP *Preferred Project* recommends the formation of a formal Coordinated Resource Management Plan (CRMP). A CRMP consists of a joint Memorandum of Understanding (MOU) among local, state and federal agencies to review resource management and permitting issues, and prioritize and recommend funding of enhancement and restoration projects. A CRMP is sometimes utilized for grant funding, resolving conflicts, and other issues, such as those related to Endangered Species management approaches, and may be useful if a mitigation bank is developed.

6. FLOOD MANAGEMENT PLAN PROJECTS

A primary purpose of the overall watershed planning efforts is to develop environmentally sensitive and cost effective solutions to the recurrent flooding problems along SLO Creek and its tributaries. This section of the WMP presents conceptual flood management alternatives that address flooding problems throughout the watershed. Two somewhat contrasting alternatives for flood management were developed for public review and environmental analysis, and two other alternatives were also studied:

- **Preferred Project -** the environmentally superior alternative
- **Alternative 1** - has similar flood management objectives but a differing design approach
- **Alternative 2** – is a low cost/low impact alternative, but does not achieve the same level of flood protection as the preferred project and the competing design alternative.
- **Alternative 3** - includes a series of separate projects that were investigated but found to be infeasible and unaffordable because of potential disruption to the community during construction, significant environmental impacts, and/or high property acquisition and construction costs. These were dropped from further consideration early in the planning process.

The Preferred Project is summarized briefly here and in Section 6.1. The other alternatives considered are also summarized here and presented in more detail in **Appendix D**.

Summary of Preferred Project The Preferred Project includes both structural and non-structural flood control elements. Proposed structural elements include:

- Construction of a flood bypass channel and culvert replacement along SLO Creek below Los Osos Valley Road, and vegetation management in lower Prefumo Creek;
- Bypass channel construction in the Elks Lane area, upstream of Prado Road;
- Bypass channel construction and construction on an in-channel floodway terrace between Marsh Street Bridge and Madonna Road; and
- Enhancement of the detention effect caused by the Highway 101 culvert upstream of Cuesta Park.

  Replacement of Stenner Creek bridges.

Non-structural flood control elements include:

- New floodplain management regulations;
- Greater emphasis on, and City and County Engineering Department assistance in floodproofing; and,

- Implementation of a primarily voluntary program of targeted floodprone property acquisition, dependent on state and federal funding.

Alternative 1- Design Modifications to the Preferred Project Alternative 1 represents structural projects that would provide a similar or higher level of flood protection, compared to the Preferred Project, but channel environmental disturbance would be higher. Construction costs would generally be lower, because less land would be purchased for channel widening than the Preferred Project. This alternative evolved from discussions and review of the Preferred Project by the Zone 9 Advisory Committee. It represents an alternative that could be constructed with less overall costs than the Preferred Project, but with higher environmental impacts.

All of the main elements of the Preferred Project would be included in Alternative 1 (Stenner Creek Bridge replacement, Cuesta Park Detention Enhancement, channel maintenance in Mid-Higuera); however, several of the components have modified designs that may differ in their environmental impacts and in costs of construction, as compared to the Preferred Project. Modified design components include:

- Widen SLO/Prefumo Creek Confluence near Los Osos Valley Road, just below the confluence of Prefumo and San Luis Obispo Creeks, to prevent flow from backing up onto highway 101 and into Prefumo Creek on the west side of the Highway. The widened channel project (an in-channel bench or floodplain terrace beginning at OHW) would be constructed instead of the bypass channel of the Preferred Project.
- Channel Widening Between Cemetery above Elks Lane and WTTP below Prado Road. This would include replacement of the Preferred Project bypass channel with a channel-widening project from above Elks Lane downstream to Prado Road. The widened channel would be designed to provide 50-year protection for the adjacent mainly undeveloped floodplain and would prevent flow from spilling across Highway 101 and flooding the historic floodplain on the west side of the highway at the 50-year event. This would also consist of an in-channel bench or terrace constructed above OHW or the approximate 2-year flow level. A 100-year flood protection plan could also be constructed, with little additional environmental impacts, but would necessitate bridge replacement.
- Floodplain Excavation in Mid-Higuera Area. This would include a floodplain bypass channel excavation within the Mid-Higuera Business District, similar to the Preferred Project. However, the initial channel excavation work just below the Marsh Street Bridge would occur on the east bank downstream to just below the Bianchi Lane Bridge, and not on the west side at the Madonna Company construction yard.

The Cuesta Park Detention Enhancement Project and Stenner Creek Bridge replacement projects would be constructed as in the Preferred project.

Alternative 2 – Low Cost/Low Impact Alternative This represents a lower cost and modest impacts but achieves significantly lower levels of flood protection than the Preferred Project and Alternative 1 (the Design Alternative). Several of the individual project elements of this alternative are similar to the smaller components of the Preferred Project; but the more extensive channel modifications and floodplain bypass channel excavation components have been eliminated. For the most part, the projects associated with Alternative 2 would be restricted to specific channel constrictions or breakout points along San Luis Obispo and Stenner Creeks. Alternative 2 includes the following:

- Minor channel excavation on the banks below the Marsh Street Bridge and a revised vegetation management program along the reach of San Luis Obispo Creek between Marsh Street and Madonna Road.
- Replacing three bridges on Stenner Creek, as in the Preferred Project.
- Improving flood detention storage on San Luis Obispo Creek above Cuesta Park, as in the Preferred Project.

Alternative 3 - Projects Not Considered Feasible and Not Evaluated Further In preparing the flood management section of the WMP, a large number of flood control concepts were initially evaluated as a "long-list" of possible flood management alternatives. A number of these were considered earlier in the 1977 Nolte studies, by the, or by Shaff and Wheeler in the late 1980's. Upon further analysis by the project study team, these were not considered feasible, either from a technical, cost, or environmental and permitting difficulty perspective. These conceptual projects were eliminated in developing the "short-list" of project alternatives and were recommended by the Zone 9 Advisory Committee to be placed in the category of "Not Considered Feasible, and Not Evaluated Further". They are described here to document for future reference purposes that these alternatives was considered in a preliminary fashion, and then discarded.

The projects, which were reviewed and determined to be infeasible, included:

- **Buried Bypass Culverts** - A buried bypass culvert around the downtown business district, running down Pacific Street or down Meadow Creek
- **Floodwalls** - Floodwalls along the east bank of San Luis Obispo Creek from Nipomo Street to Madonna Road.
- **Levees/floodwalls** along both creek banks above Prado Road combined with property acquisition of floodplain areas on the streamside of the floodwalls.
- **Small levees/berms** to prevent flow from spilling across Highway 101 between Madonna and Prado Roads.
- **Floodwall construction** near Andrews Street/San Luis Drive
- **Significant Channel Enlargement** between Marsh Street and Madonna Road to provide 50-year flood capacity
- **Flood Detention Basins** at Upper Stenner Creek and Upper SLO Creek above Reservoir Canyon Road.

6.1 Preferred Project Structural Flood Control

It is recognized at the outset that managing all of the flooding problems along SLO Creek to obtain a high level of flood protection, such as for a 100-year event, is not feasible for two reasons. First, environmental quality along most of the existing natural stream corridor would likely be adversely impacted by certain components of the project. Second, certain parts of these projects would be very costly, requiring right-of-way acquisition, extensive bridge, utility, and other infrastructure relocation, and complicated structural engineering. The structural solutions contained in the Preferred Project and the Viable Design Alternative do not provide 100 -year flood protection, but significantly reduce the frequency and depth of flooding and flood damage. Therefore a flood-proofing program for most reaches should be considered a complementary element. Flood control projects that are part of the Preferred Project are divided into structural solutions and non-structural solutions.

Table 6-1 summarizes the major project features of the City/Zone 9 Preferred Project. This important component of the WMP is based on:

1) Field inventory of creeks and GIS development
2) Hydrologic and hydraulic analysis
3) Problem Identification
4) Public Meetings (2) on inventory, problem identification and preliminary alternatives
5) Review and short-listing of “Long List” of alternatives by Zone 9 Advisory Committee
6) Engineering feasibility and benefit: cost analysis of “Short List” of alternatives
7) Designation of “Preferred Project” for CEQA/NEPA review purposes by SLO City Council
8) Development of “Other Alternatives Being Considered” for CEQA/NEPA review
9) Designation of non-feasible projects “Not Considered Further”

Table 6-1
Select Channel Modification Projects Land Requirements

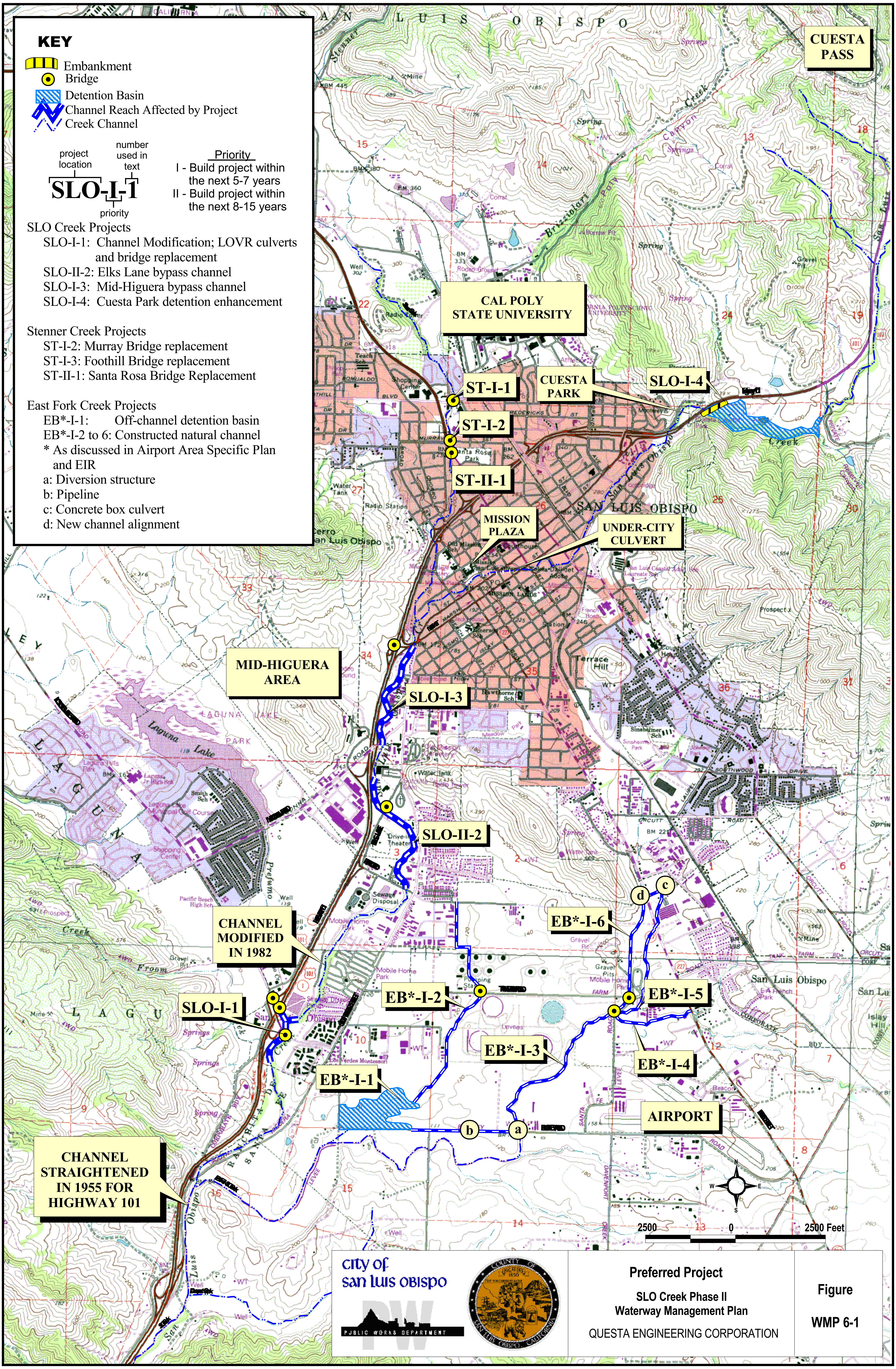
Project	Location	Design Flow	Major Project Features
SLO I-1	Channel Modification Below LOVR, LOVR Culvert and Bridge Replacement	100-year	• 400m (1300 ft) long by 45m (150 ft) wide bypass channel • Replacement of culverts where Prefumo Creek crosses Hwy 101 and the southbound off-ramp from Hwy 101 • Possible new bridge for bypass under LOVR
SLO II-2	Elks Lane Bypass Channel	50-year	• 1100m (3600 ft) long by 40m (130 ft) wide bypass channel • New bridge for bypass, adjacent to existing creek bridge on Elks Lane • 40m by 120 m-long terrace on west bank below Prado Road

Project	Location	Design Flow	Major Project Features
SLO II-3	Mid-Higuera Bypass Channel & Terrace	20-year	• 400m (1300 ft) long by 20 to 60m (65 to 200 ft) wide bypass channel
SLO I-4	Cuesta Park Detention Enhancement	Provides 100-year protection on SLO to Stenner Creek confluence	• Increases 100-year depth above culvert by about 3m (10 ft), and 10-year depth by about 2m (7 ft) • Increases drainage time for existing storage area from about 4 hours to approx. 8 hours at 100-year event • 5000-10,000m^2 embankment footprint
ST I-1 and ST I-2, ST II-3	Stenner Creek Bridge Replacements	100-year	• Replaces Foothill and Murray Street Bridges • Replaces Santa Rosa Street Bridge if further hydraulic studies indicate need.
EBI-1*	Buckley Road Detention Basin	Maintains current flow conditions on East Fork at SLO confluence	• 13.4 hectare (33 acre) detention basin
EBI-2 through 6*	East Fork Channel Modifications	100-year	• Constructed natural channel modifications along 8000m (25,000ft) of existing, mostly degraded channel.

* *For informational purposes only, project is part of Airport Area Specific Plan.*

The Zone 9 Advisory Committee, City, and County Engineering and Planning staff met monthly to review and provide input over an 18-month period. The structural elements of the Preferred Project are conceptual, and detailed environmental, engineering, cost estimating and financing studies must be completed before the concept plans proceed to final design, permit review, and construction. The Preferred Project provides a road map for how the SLO community intends to manage its flooding problems, and as such it can be used for forward planning and budgeting by the City and County. The Preferred Project is in draft form and changes to the concepts, including changed construction priorities, may occur as it proceeds through public review and agency comment.

Figure 6-1 references each of the Preferred Project flood management descriptions**,** with the map reference shown on the figure used in the text heading. The figure number also represents the proposed project prioritization. (Example, Project SLO I-1 is first project on SLO Creek, Priority 1). Individual projects are discussed below.


KEY
Embankment
Bridge
Detention Basin
Channel Reach Affected by Project
Creek Channel
project location
number used in text
SLO-I-1
priority
Priority
I - Build project within the next 5-7 years
II - Build project within the next 8-15 years
SLO Creek Projects
SLO-I-1: Channel Modification; LOVR culverts and bridge replacement
SLO-II-2: Elks Lane bypass channel
SLO-I-3: Mid-Higuera bypass channel
SLO-I-4: Cuesta Park detention enhancement
Stenner Creek Projects
ST-I-2: Murray Bridge replacement
ST-I-3: Foothill Bridge replacement
ST-II-1: Santa Rosa Bridge Replacement
East Fork Creek Projects
EB*-I-1: Off-channel detention basin
EB*-I-2 to 6: Constructed natural channel
* As discussed in Airport Area Specific Plan and EIR
a: Diversion structure
b: Pipeline
c: Concrete box culvert
d: New channel alignment
CUESTA PASS
CAL POLY STATE UNIVERSITY
CUESTA PARK
SLO-I-4
ST-I-1
ST-I-2
ST-II-1
MISSION PLAZA
UNDER-CITY CULVERT
SAN LUIS OBISPO
MID-HIGUERA AREA
SLO-I-3
SLO-II-2
LAGUNA LAKE
CHANNEL MODIFIED IN 1982
EB*-I-6
EB*-I-5
EB*-I-2
SLO-I-1
EB*-I-3
EB*-I-4
EB*-I-1
AIRPORT
CHANNEL STRAIGHTENED IN 1955 FOR HIGHWAY 101
2500 0 2500 Feet
City of San Luis Obispo
PUBLIC WORKS DEPARTMENT
Preferred Project
SLO Creek Phase II
Waterway Management Plan
QUESTA ENGINEERING CORPORATION
Figure
WMP 6-1

6.1.1 Channel and Bridge/Culvert Replacement Work at Los Osos Valley Road (LOVR) (Project SLO I-1)

High water in San Luis Obispo Creek during storms as small as the 10-year event currently causes flooding of Highway 101 near Los Osos Valley Road (LOVR). This flooding extends up Prefumo Creek to Calle Joaquin. This proposed project would install a bypass channel to San Luis Obispo Creek near (below) LOVR to increase local capacity and reduce backwater flooding on Prefumo Creek and Highway 101 (**Figure 6-2**). The channel would be located on the east bank, and would extend downstream about 400 meters (1300 feet).

Prefumo Creek crosses under Highway 101 and the onramp to Highway 101 through two separate concrete box culvert structures. Replacing these culverts will be necessary to provide 100-year capacity in this area.

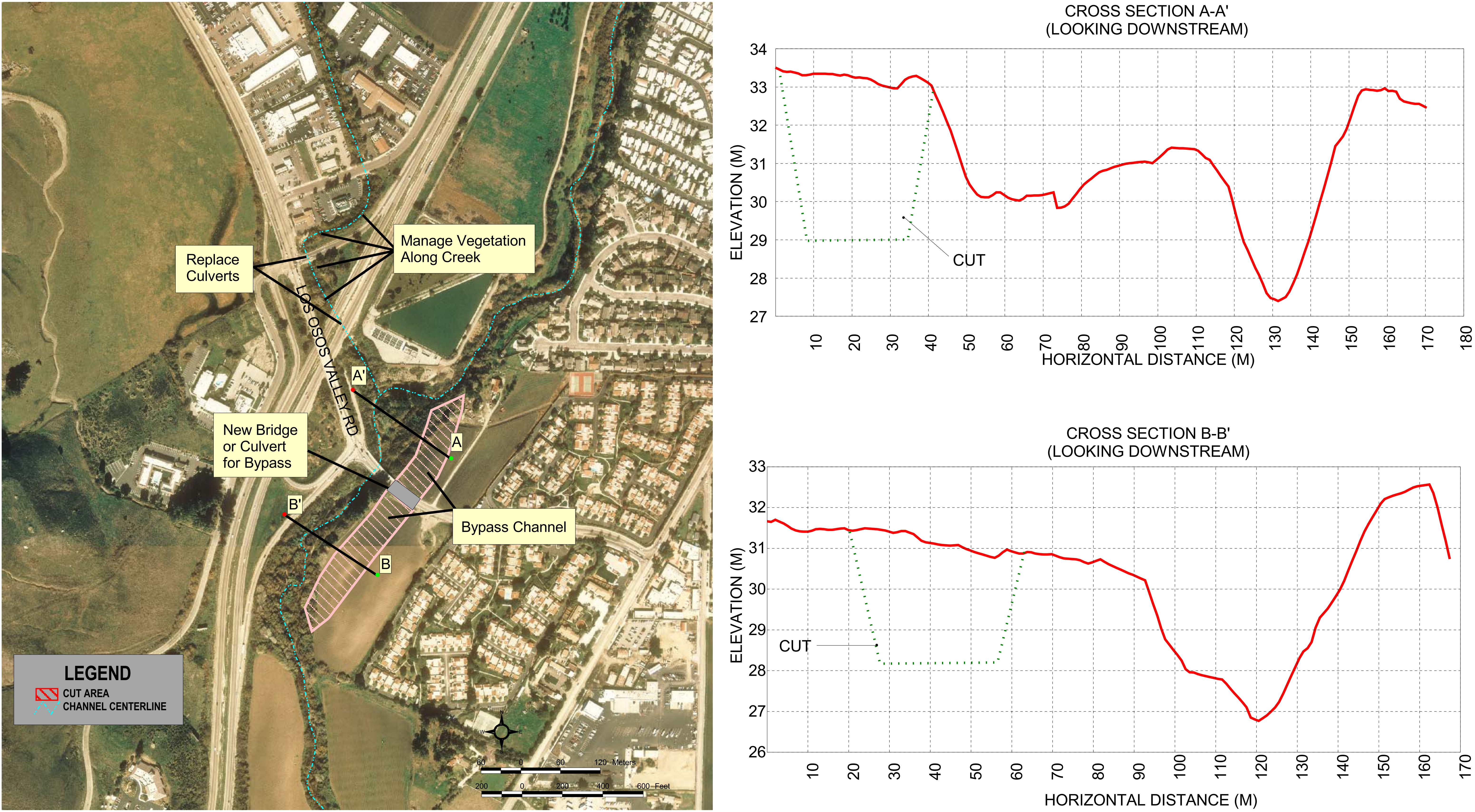
Currently, flow from San Luis Obispo Creek spills across Highway 101 during high flow events near Madonna and Prado Roads and eventually enters lower Prefumo Creek. The magnitude of the split flow is similar to the natural flow in Prefumo Creek. Installing culverts or a bridge with sufficient capacity to pass both the natural flow of Prefumo Creek and the added SLO Creek split flow would be difficult. This project assumes (for achieving 100-year protection) that the flow splits will be partially mitigated upstream by channel modifications or construction of a bypass channel parallel to SLO Creek in the Elks Lane area above Prado Road (see **SLO II 2**).

Additional lowering of the water surface elevations in lower Prefumo Creek would be achieved in this reach by managing the existing dense vegetation per the SMMP. This would involve selectively thinning and limbing up the willows, and inter-planting with single trunk species such as sycamores and cottonwoods. This work is also included as part of this project. Replacing the Prefumo Creek culverts under Highway 101 and the Highway 101 onramp are also included with this project, as is the construction of a bridge on Los Osos Valley Road across the proposed bypass channel (immediately east of the existing LOVR culverts crossing of SLO Creek).

6.1.2 Elks Lane Bypass Channel (Project SLO II 2)

Under existing conditions, at about the 20-year recurrence interval, flow spills out of the channel of San Luis Obispo Creek near Elks Lane (below the Lady Family Sutcliffe Cemetery) and flows overland across the floodplain, through the existing drive-in theater site, and eventually across Prado Road. The larger flood flows spill onto the City Corporation Yard and Waste Water Treatment Plant (WWTP) (Note: currently the sludge ponds and critical treatment facilities are not inundated by the 100-year flood). From there, larger flows spill across Highway 101 to enter lower Prefumo Creek while the rest returns to the main creek channel below the Wastewater Treatment Plant.

Flood protection to meet the proposed 50-year Design Flow for this area would be provided by creating a parallel bypass channel as shown in **Figure 6-3**. For most of its 1100-meter (3600 feet) length the 40-50 meter (130-165 feet) wide bypass channel would be separated



city of san luis obispo
PUBLIC WORKS DEPARTMENT

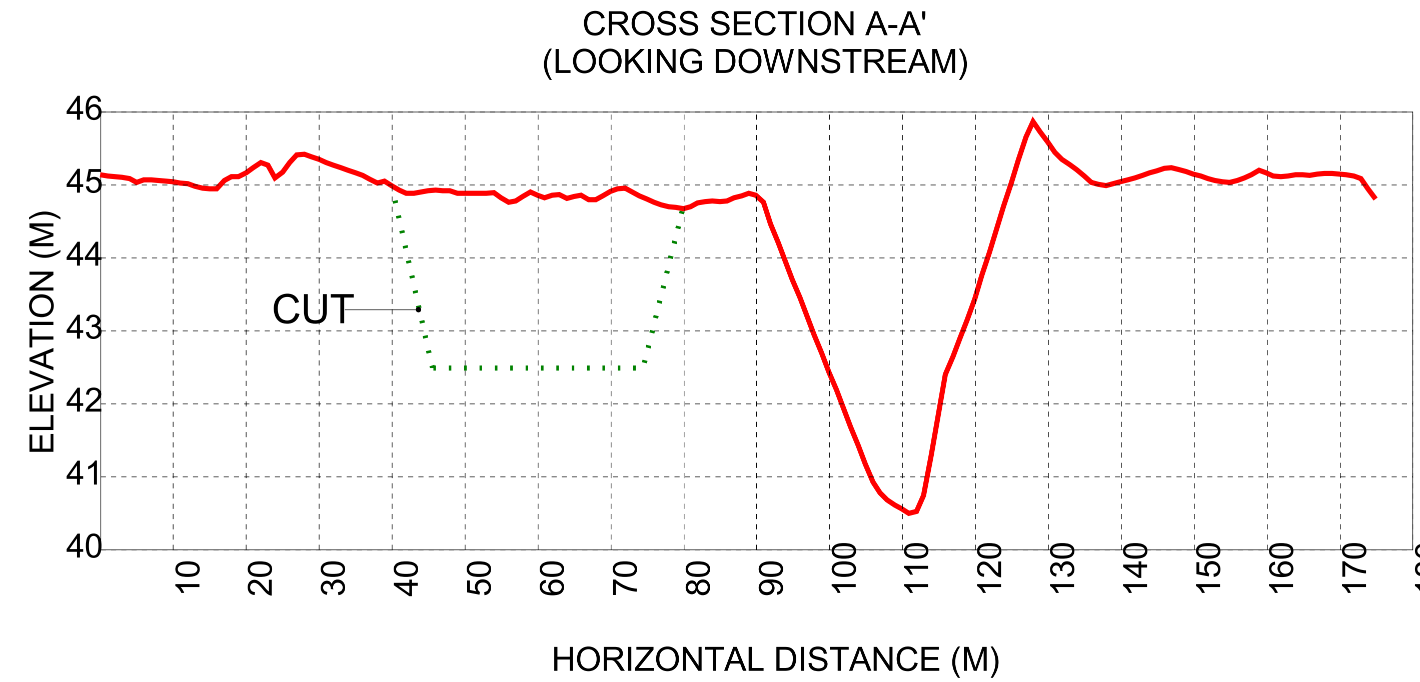
Channel / Bridge Replacement - LOVR

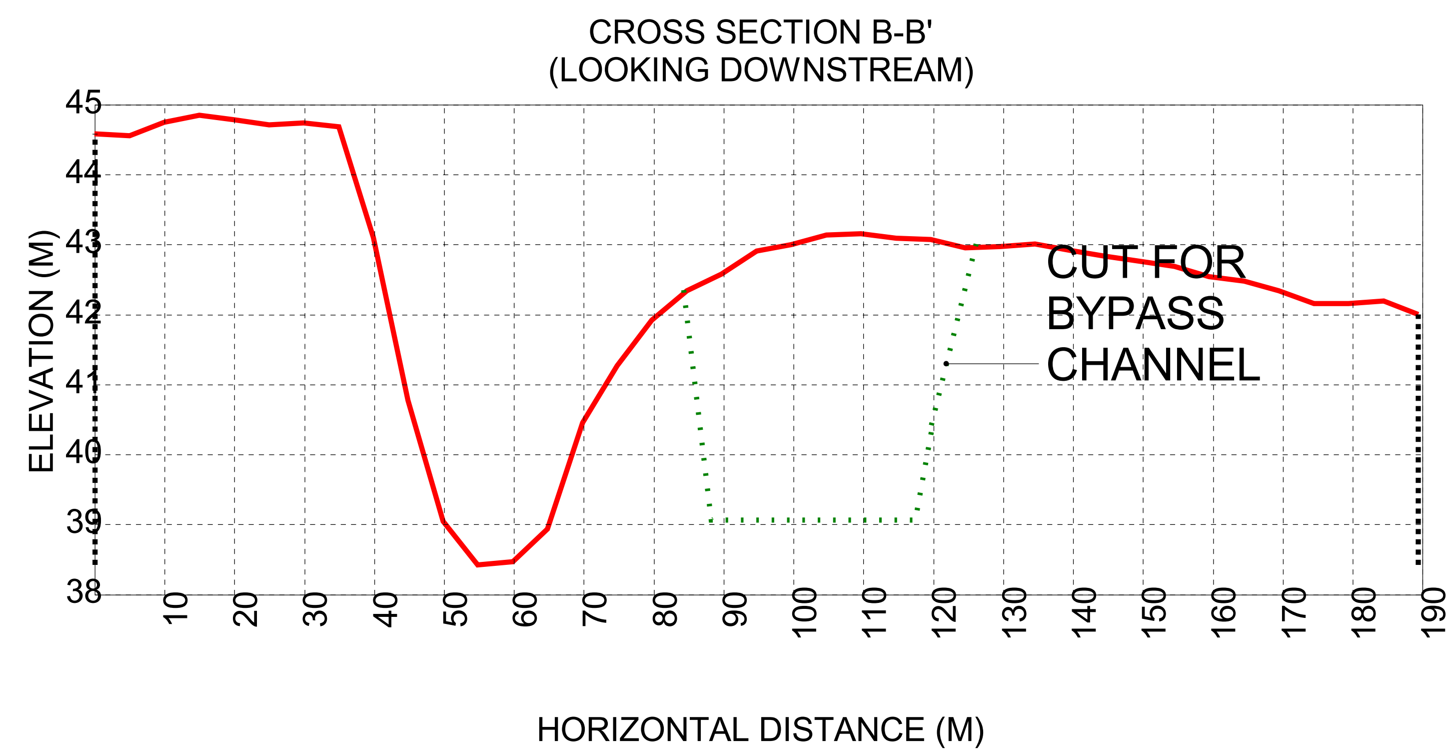
SLO Creek Phase II
Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure

WMP 6-2





city of san luis obispo
PUBLIC WORKS DEPARTMENT

Elks Lane By-Pass

SLO Creek Phase II Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure

WMP 6-3

from the existing channel by a variable width vegetated buffer at least 30 meters (100 feet) wide. Where the bypass crosses Elks Lane, a new bridge structure would be built.

Some channel modification work is also included with this project in the most constricted channel portion, adjacent to the Mausoleum below Madonna Road. There is not enough room here for a bypass channel or construction of an in-channel floodplain terrace, so a biotechnical retaining structure such as a live crib wall or vegetated geogrid is proposed for this approximately 70 meter (210 foot) section along the channel banks (west side). Even so, some continued flooding would occur in the cemetery area.

(Note: Further widening the bypass channel could contain the 100-year event flow with little additional impacts to SLO creek, but there may be little public benefit in this, considering the costs of the project. This widened bypass project, if constructed, may be the obligation of adjacent property owners and would be subject to additional environmental review, permitting and City Council approval. At another constricted location, just above Prado Road, it would also not be possible to provide 100-year protection without both widening the existing channel and replacing the existing bridge (assuming that portions of the WWTP cannot be relocated). The bridge currently passes the proposed 50-year Design Flow. The existing bridge at Elks lane would also require replacement for 100-year level of protection.)

At certain locations, it will be necessary to construct a levee or berm along low points on the west bank of the creek or bypass channel, especially near Elks Lane where the bypass will need to terminate and where flow currently leaves the stream channel. Any levees here would have minimal impact on upstream water surface elevations since the channel capacity would have been increased due to the channel modifications.

The downstream impacts of the project are more complicated, since flow that currently spreads out across the floodplain and spills across Highway 101 would be kept within the existing channel. It would be necessary to construct low levees or floodwalls on the east bank of the creek at certain locations near Prado Road, since the 100-year water surface elevation would be raised to near the top-of-bank at this location. Furthermore, the 100-year water surface elevation downstream of Prado Road could be elevated above the bank top at the existing mobile home park. This would be mitigated by constructing a low (1 meter or 3 foot) floodwall at this location.

By reducing the amount of floodplain available for storage, the hydraulic modeling shows that this project would result in less attenuation of the hydrograph (flood flow rate reduction) through the reach than currently occurs. The flood peak would travel through the reach more quickly than it currently does, reaching the confluence with the East Fork of SLO Creek about 10 minutes earlier than under existing conditions. Since under existing conditions, flow in the East Fork has already peaked by the time the flood wave on SLO Creek passes through, having the wave come through earlier could increase the total flow in the creek below Buckley Road. The increase in flow ranges from less than 1 percent above the confluence with the East Fork to between 2 and 3 percent below the confluence. There are no structures in this area that would be affected by the changed hydrograph and the effect is significantly dampened by the time peak flows reach the Avila Beach area.

Any flow that overtopped the stream banks in this reach would contribute directly to flooding of most of the "25-year protected" floodplain. The hydraulics of this flooding is very complicated and is impossible to analyze without knowledge of the way development would occur in the protected area. It is likely that the flooding would occur in different areas than currently experience flooding. Since this scenario could occur relatively frequently (4 times in 100 years, on average), providing 25-year protection for this reach is not recommended without strict land use controls that ensure floodplain development will not greatly reduce the existing conveyance provided by the floodplain. These are provided for in the DDM *No Adverse Impact* and *No Net Fill* policies.

Any development plan for areas protected by this project needs to consider the impacts to flood conveyance through the floodplain. The DDM would also require that a Drainage Master Plan be developed for the area that ensures no increase in flooding because of the channel modification project and adjacent floodplain development.

6.1.3 Mid-Higuera Bypass Channel, Terrace and Vegetation Management (Project SLO I-3)

Over the past 40 years, there have been six significant flooding events between Marsh Street and Madonna Road. The last major flood event occurred on March 10-11, 1995. Historically, this reach has had some of the most frequent and significant flooding problems in the community. There are several reasons for the recurrent flooding problems***:***

- The channel has a smaller cross-sectional area and lower flood conveyance capacity than the channel immediately upstream and downstream. In addition, the channel grade flattens below Marsh Street.
- The floodplain has been significantly encroached upon by buildings and floodplain fill on Higuera Street.
- The Marsh Street Bridge, located at the upper end of the reach, historically becomes partially blocked by sediment and debris during high creek flow events, causing flow to spill out of the channel just upstream of the bridge. Flows travel down Higuera Street through the business area.
- During very large storm events, flow in SLO Creek can exceed the capacity of the large buried culvert under Higuera Street between Osos and Chorro Streets, with overflow from the break-out point traveling down Higuera, Marsh, and Pacific Streets, flooding the businesses before re-entering the channel at various return-flow points within the Mid-Higuera business district.

Previous studies (Nolte, 1977) identified several flood mitigation alternatives that are not considered economically justifiable or permissible by environmental regulatory agencies. Consequently, a project was developed within relatively strict design constraints that the project could not significantly modify the stream channel bed or remove major areas of native riparian vegetation.

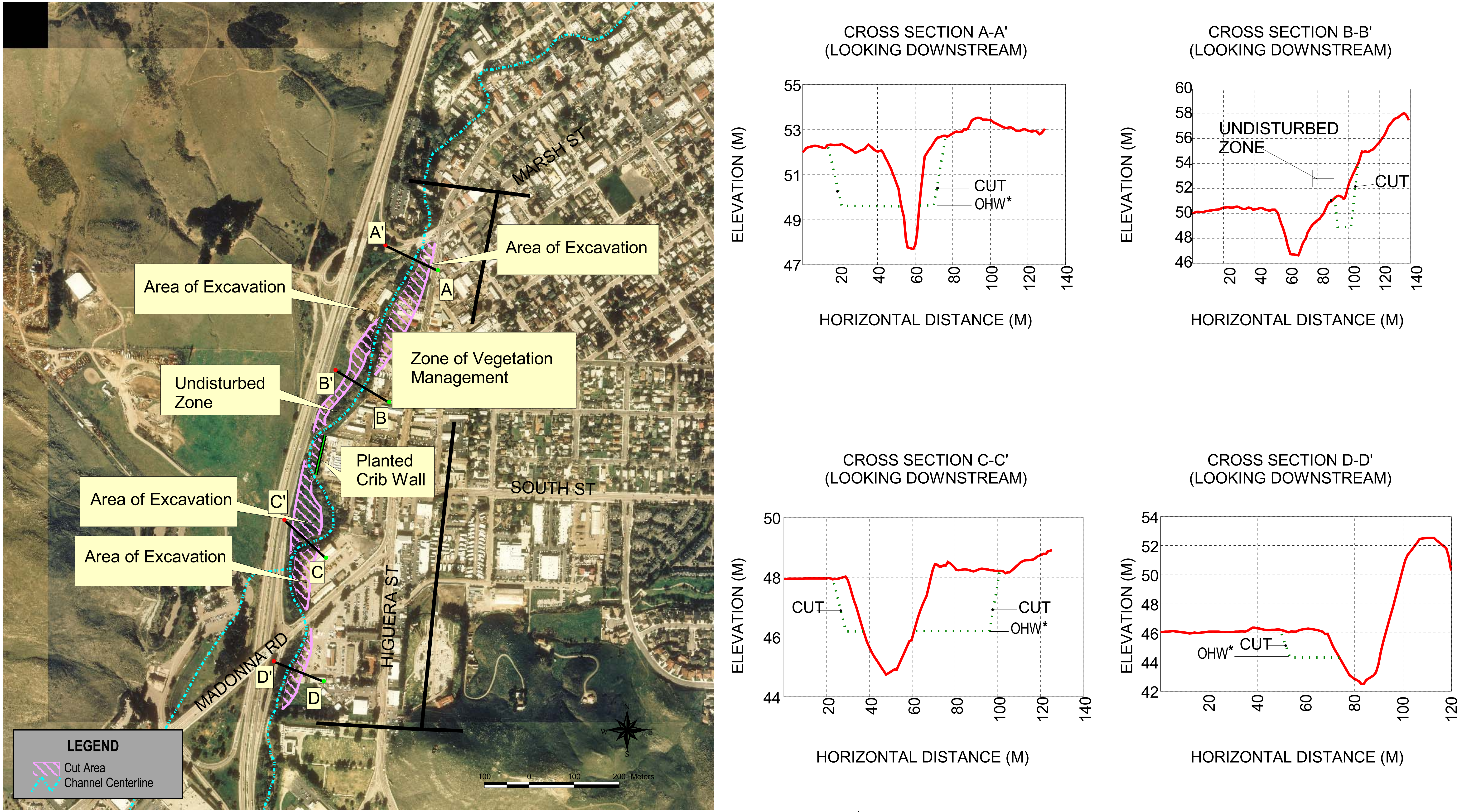
In the Mid-Higuera area the channel work would consist of construction of a terrace along the creek located above the 2-year flow-line, and a bypass system constructed parallel to but mostly away from the existing creek alignment. The channel would be designed to carry an approximately 20- year storm (**Figure 6-4**). The excavation of the secondary overflow flood pathway on the floodplain would be on the west side of the creek. Where possible (and in most areas), the excavation of the flood secondary pathway would be isolated from the active channel by an island of higher ground ("untouched area") adjacent to the channel that supports native trees and shrubs. However, in several locations, including on the east bank at the Caltrans Maintenance yard, and on the west bank through much of Madonna Construction Company's yard, floodplain excavation would be contiguous to the creek. Excavation would begin above the 2-year flow line (above ordinary high water or ACOE jurisdiction), about 2 m (6.6 ft) above the channel bed. The floodplain would be lowered by 1.8 to 2.4 m (6 to 8 ft). All material would be hauled off-site and out of the 100-year floodplain.

The reconfigured flood pathway would extend from the Marsh Street Bridge downstream to the Madonna Bridge, primarily on the west side of the channel. Approximately 400 meters (1300 feet) of creek length would be involved. The bypass channel would be built above the channel bottom of the existing channel, about 1/3 of the way up the bank, at the upstream and downstream transition points. These transitions would be protected with willow planted rock rip-rap.

Only floodwaters in excess of a 2-year storm would move through the bypass channel. This would maintain summer low flow and prevent sedimentation in the pools in this area. The natural channel would remain to maintain in-stream fisheries habitat. The bypass channel would be planted with a scattered to semi-dense stand of native, wood-plant species. Periodic maintenance would be needed to remove low branches and other hydraulic roughness elements. The Bianchi Lane Bridge would be replaced with a clear span, arched structure as part of this project, if the property on the west side of the creek is to have all weather access.

<u>Marsh Street Property Floodway Terrace.</u> This component of the Mid-Higuera project would entail excavation of a floodway terrace on the creek's east bank immediately downstream of Marsh Street Bridge (at the McNamara Real Estate property). In addition, minor improvements to the channel upstream of Marsh Street Bridge would be included to reduce the effects of sediment and debris blockage of the bridge barrels. Implementation of this element of the project would result in a predicted drop in water surface elevations of 0.28 m (0.9 ft) at the Marsh Street Bridge but has little direct impact elsewhere in the reach.

<u>Channel Vegetation Management Program.</u> An intensive, long term vegetation management program is included with the Mid-Higuera area project work. This constitutes measured, environmentally sensitive channel maintenance, reducing the channel roughness of the creek banks by carefully and selectively thinning and limbing up the willows, and inter-planting taller growing, single trunk native trees (Sycamores and cottonwood) on the upper creek banks. These would eventually shade out many shorter willows. In the short term, the lower branches on existing willows would be thinned during an annual maintenance visit, and any large gaps in the canopy would be inter-planted with tall, straight, tree forming species. Work would focus on willows along the lower channel banks, and phased replacement of



*Area below OHW to be protected and remain undisturbed.

city of san luis obispo PUBLIC WORKS DEPARTMENT	**Mid-Higuera Design Alternative** **SLO Phase II** **Waterway Management Plan** QUESTA ENGINEERING CORPORATION	**Figure** **6-4**

non-native trees, avoiding sensitive areas such as dense willow clusters adjacent to summer pools.

Each year the proposed channel maintenance work (City-wide) would be described in an Annual Work Plan (AWP) that will be provided to the ACOE and other regulatory agencies for review. A team consisting of a hydrologist and biologist would pre-mark in the field all sensitive areas, including trees to be preserved, hazard trees to be stabilized, trees to be thinned and limbed, and areas to be inter-planted with native trees and shrubs. A CDFG Biologist will be invited to review the proposed work, prior to implementation. The actual maintenance work will be supervised in the field by a qualified biologist.

The Mid-Higuera project would also include an intensive creek restoration effort involving both enhancement of channel conditions through the installation of in-stream structures (root wads, boulder clusters and lunkers as determined by a Fisheries Biologist), and revegetation of bank top areas.

Vegetation management would be completed in phases, and only become fully effective in 7-10 years or more. However, each year some important net reduction in channel flow resistance would be accomplished. Annual channel maintenance would be accomplished within the conditions of the overall SMMP.

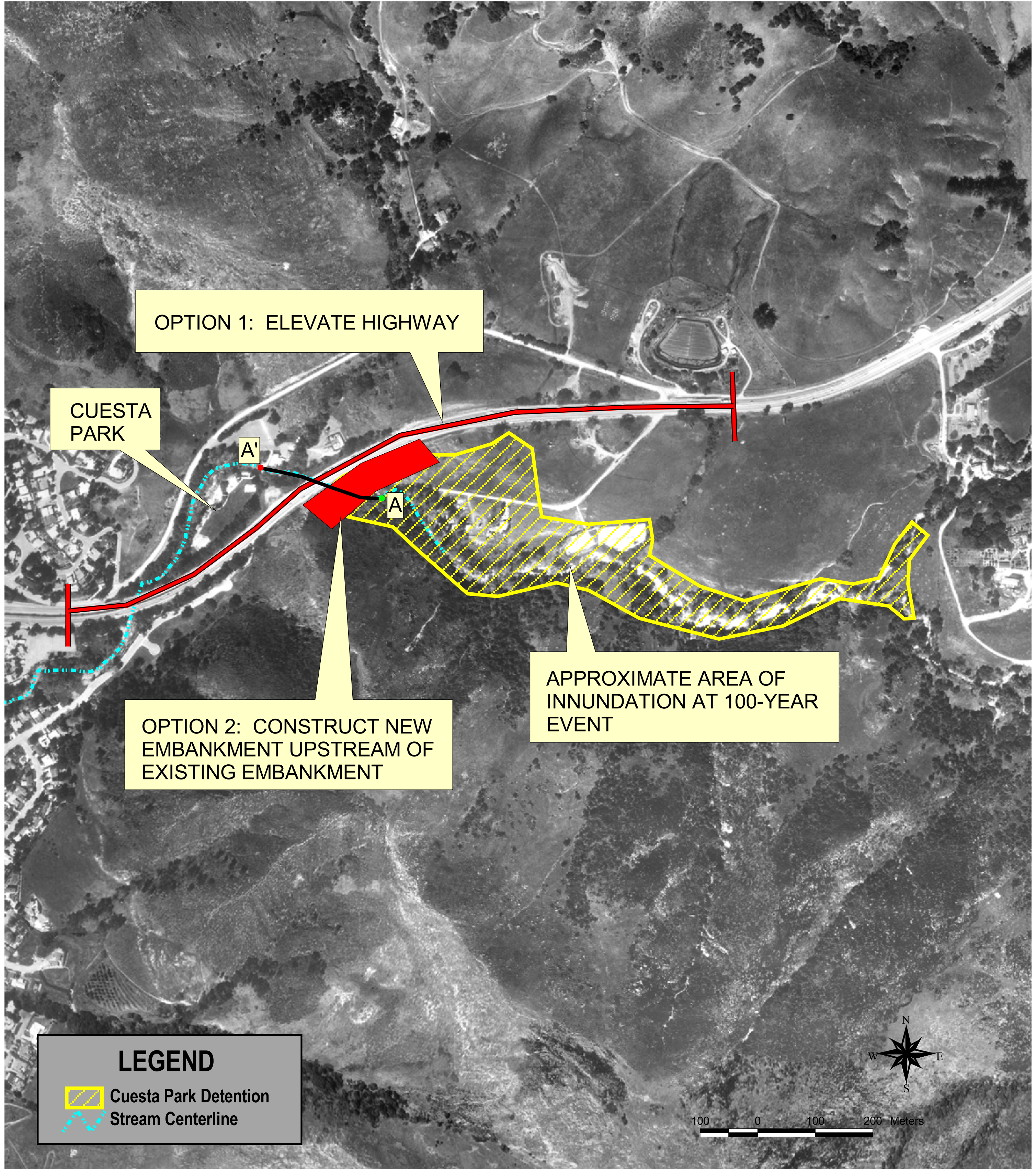
Vegetation management to achieve reductions in flood flow resistance must be completed carefully, balancing needed flood conveyance improvements with the risks of increased channel bed erosion from the resultant increases in channel velocity.

In some cases, channel bed and lower channel bank stabilization, (for instance using low 5 m or 18" rock channel grade stabilization structures, or planted rock rip rap) will be needed. The SMMP require that channel vegetation management field decisions be conducted by a team consisting of a hydrologist and biologist, and that the California Department of Fish & Game and National Marine Fisheries be invited to consult informally in the field on all such projects.

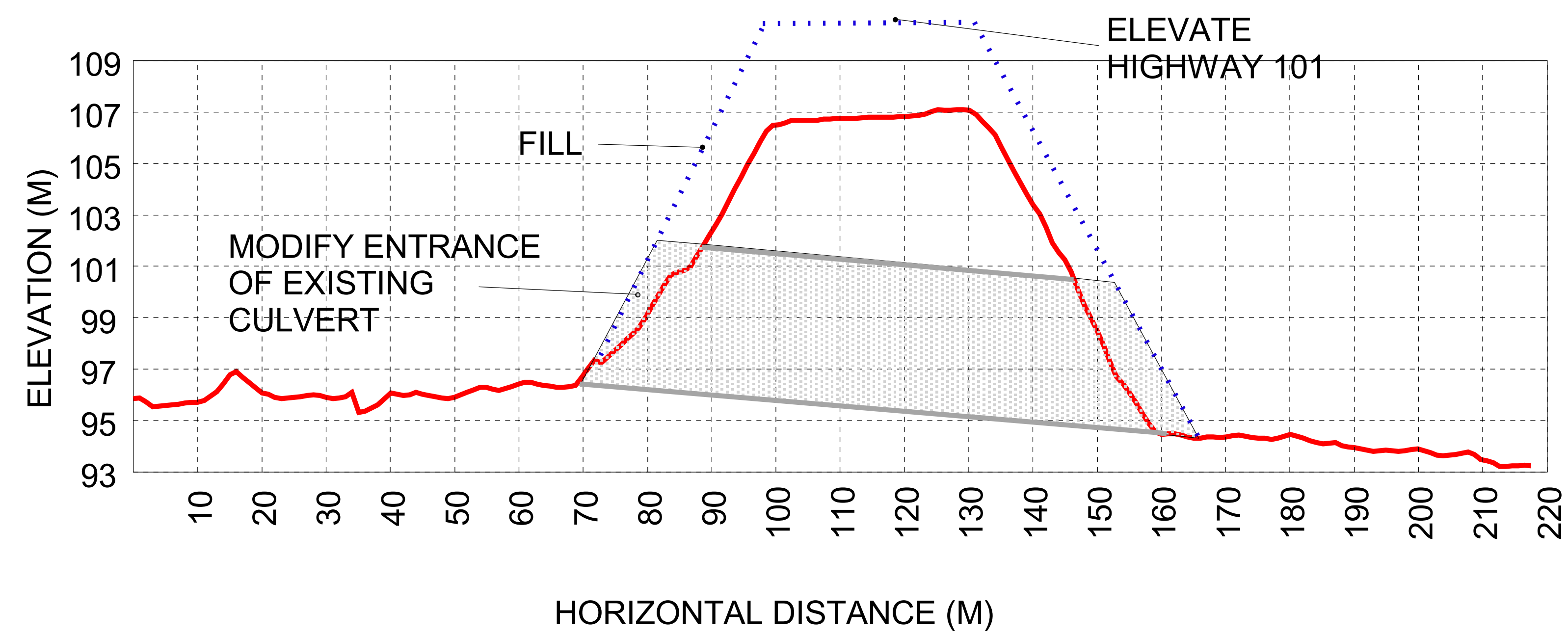
A program of active channel vegetation maintenance will have some benefit in this stream reach, reducing flood water surface elevations for the 10-year flood event by about 0.1 to 0.3 meters, (0.4 to 1.0 foot), depending on location within the reach.

6.1.4 Cuesta Park Detention Enhancement (Project SLO I-4)

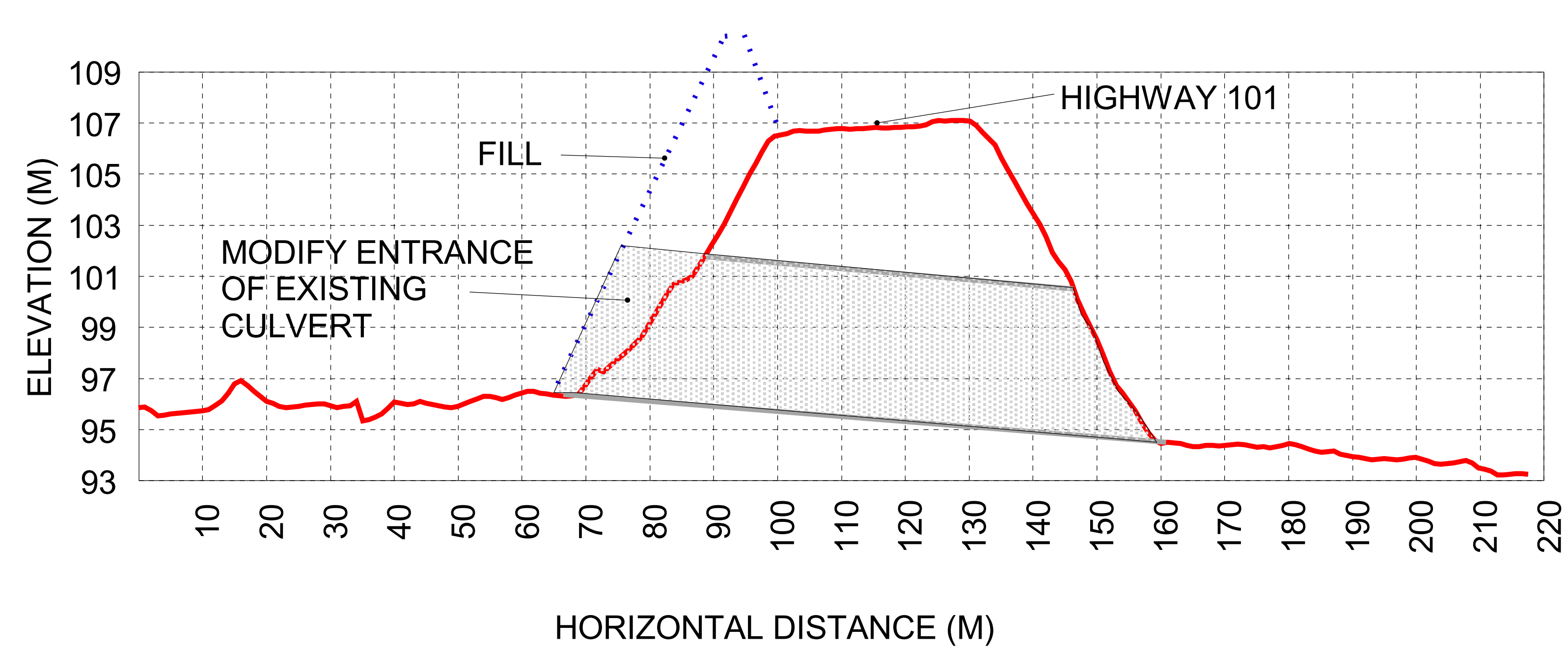
Currently, the Highway 101 culvert crossing of San Luis Obispo Creek above Cuesta Park acts as a dam during very large storms, providing an important measure of flood protection storage for the City. This function would be enhanced by elevating the highway shoulder by about 5 meters (16 feet) and modifying the existing culvert (choking down the culvert to reduce flow and increase detention storage-see **Figure 6-5**). The upstream storage area would only fill (greater than it currently does) during rare events, and the flow detention would be temporary, lasting only several hours to at most a day. During most storms and most years, the upstream channel system would be essentially unaffected by the project.



SECTION A-A'
OPTION 1: ELEVATE HIGHWAY 101



SECTION A-A'
OPTION 2: CONSTRUCT UPSTREAM EMBANKMENT



City of San Luis Obispo Public Works Department	**Cuesta Park Detention Storage** **SLO Creek Phase II** **Waterway Management Plan** QUESTA ENGINEERING CORPORATION	**Figure** **6-5**

The structures proposed would be sufficient to reduce the 100-year flow rate within San Luis Obispo Creek through downtown San Luis Obispo to about 127 cms (4500 cfs), which is the reported capacity of the under city culvert (Nolte 1977). A slightly smaller structure (approximately 1-m lower) would be sufficient to provide 50-year protection. Also, if the capacity of the under-city culvert is determined to be higher than the reported 127 cms (4500 cfs), the embankment structure's size may be reduced. While the benefits of the project would potentially be quite large on San Luis Obispo Creek above the Stenner Creek confluence, they are not as significant below the confluence, (i.e. Mid-Higuera area) where the other projects are still required to address existing flooding problems. Since the culvert is owned by the California Department of Transportation, and embankment modifications would be within the Caltrans right-of-way, their authorization and cooperation is essential. The size of the detention structure will mean that the California Division of Dam Safety will need to be involved with project design review and approval. An emergency spillway will almost certainly be needed (there is not one for the existing structure). The design of the emergency spillway structure will make the project challenging, with potentially significant construction impacts on Highway 101.

The Cuesta Park project is a high priority. It will be one of the most beneficial in terms of flood reduction benefits with few environmental impacts. The conceptual plan needs to be further coordinated with Caltrans and the State Division of Dam Safety to address institutional feasibility issues.

6.1.5 Stenner Creek Bridge(s) Replacement (Projects S I-1, S I-2, SI I-3)

The Foothill, Murray, and Santa Rosa Street Bridges across Stenner Creek do not have sufficient capacity to pass the proposed Design Flows. Starting at between a 10-year and 25-year event, flow spills out of the channel, across Santa Rosa Street and through a residential neighborhood toward Chorro Street and Old Garden Creek. Replacing the three bridges would prevent this from occurring, removing the threat of flooding to a significant number of residences.

The proposed replacement of the Foothill Bridge is currently in environmental review and preliminary design. Since the Foothill and Murray Street bridges each cause flow to be lost from Stenner Creek, the replacement bridges must be designed and staged so that the no-longer detained flows do not move downstream and cause worse flooding at a downstream bridge (either Murray or Santa Rosa Streets). Installing temporary channel constrictors, or temporarily blocking portions of the structures until the downstream bridges are replaced can accomplish this.

The channel below Santa Rosa Street has an estimated 100-year flood conveyance capacity, so replacing all three bridges concurrently will not create increased downstream flooding risk. The Santa Rosa Street Bridge on Stenner Creek has undergone several stages of construction, which has resulted in an irregular bridge opening, making modeling the hydraulics of the Santa Rosa Street area quite difficult. Before a final decision is made to replace that bridge, a more detailed bridge hydraulic study and/or observation of performance during high flow events are needed. However, it is unlikely that the Santa Rosa Street Bridge has 100-year capacity.

6.1.7 Detention Basin and Channel Work along East Fork - Airport Specific Plan (Projects EB I 1 to 6)

The WMP includes several drainage and flood control projects recommended in the Draft Airport Area Specific Plan, including a proposed regional storm water detention facility off Buckley Road, several bridge and culvert replacement projects, and modifications to the East Fork of SLO Creek and several of its tributaries. The Specific Plan-proposed East Fork modifications may not be entirely consistent with the DDM guidelines and the final design may have to be modified to reflect the DDM. A Constructed Natural Channel is required by the DDM. The drainage facilities shown in the Specific Plan have been included to provide the reader with a cumulative picture of the watershed-wide flood management facilities that may be built over the next ten years.

The recommended channel design would have a narrow in-channel vegetated terrace constructed at the 2-year flow line, with the upper banks sloped back 2.5:1 and revegetated with native trees and shrubs. A wide (100-foot minimum) buffer would be established along the bank tops on either side of the channel in most areas. The buffer area would be within the 100-year floodplain of the East Fork of SLO Creek and its tributaries. This corridor would also be planted with native trees and shrubs, although less densely than on the main branch of SLO Creek, reflective of the natural plant community throughout this area. A public access trail may be included within the buffer zone.

6.2 Preferred Project Non-Structural Flood Control

Non-structural measures in the Preferred Project include:

- Planning and Community Outreach
- Building Relocation/Demolition
- Flood Prone Property Land Acquisition

6.2.1 Planning and Community Outreach

There are three components to the proposed Planning and Community Outreach part of the Non-structural Flood Control Element: (1) Floodplain Management Policies; (2) Community Rating System, and (3) Flood proofing.

Floodplain Management Policies. The new and revised Policies contained in the DDM and discussed earlier are progressive and would comprise one of the strongest floodplain management programs in California. This is a major emphasis of the overall WMP flood management program.

Community Rating System. Educating residents that live in flood prone areas about the hazards of flooding and what they can do to be better prepared for the eventual flooding that will occur should be a major part of a flood management plan, and is a part of the WMP.

FEMA recognizes a number of community programs that involve educating residents in flood prone areas, a flood alert system, flood preparedness, as well as flood proofing in a program called "Community Rating System" or CRS. A community achieves points for each of several categories including those outlined above to get a total CRS score. Depending on the CRS score, the community falls into 1 of 10 categories, 1 being good, 10 poor. A low CRS score enables a reduction in federal Flood Insurance Program insurance premiums of up to 40%. Currently the City of SLO has a rating of 8, slightly below average for California cities, entitling City residents to a modest 5% insurance premium reduction. The WMP programs, including the planning and outreach efforts that went into the WMP will allow the City to improve its CRS rating by 1 or 3 points, and obtain an additional 5-15% reduction in premiums paid by private property owners. With annual premiums of about $250,000.00, this could save an aggregate $12,000-$30,000.00 to area residents annually living within the FEMA 100-year floodplain and participating in the federal Flood Insurance Program (FIP).

Flood Proofing. Flood proofing has several elements:

- Wet and dry flood proofing,
- Building elevation, and
- Purchase, relocation, and (occasionally) demolition of buildings in recurrent high hazard or high damage flood prone areas.

<u>Wet and Dry Flood Proofing.</u> Dry flood proofing involves protecting buildings with structures (such as concrete block walls) that completely prevents flood water entry, while wet flood proofing involves selection of flood resistant building materials, elevating utilities, and the use of other techniques to minimize damage to buildings and contents once flood waters enter. Flood proofing (wet and dry) has been used to some extent in SLO and is encouraged by the Community Development and Public Works Departments. The Land Conservancy had a voluntary flood-proofing program that provided matching funds in the early 1990's that had little participation.

City Building Regulations provide guidance on flood proofing based on FEMA standards. Flood proofing does not allow removal of property from the FEMA Flood Insurance Program (FIP). Although the WMP does not propose any major changes to current City flood proofing policies or programs, they really are the only element currently used by the City to minimize flooding. More emphasis will be placed on this area by providing additional technical assistance and advice to property owners. This will be achieved by planning and engineering staff comments and recommendations made on building renovation and remodeling applications submitted to the City or County for review and approval.

<u>Building Elevation.</u> Building elevation involves raising habitable portions of buildings above the 100-year flood level. Although this is not practical in many commercial areas that depend on walk-in business, it has applicability in some residential areas of the City. The Community Development and Public Works Departments currently considers Building Elevation as an important option to be considered on every property in a FEMA Flood

Zone “A” (100 – year floodplain) area. The City currently does not have a program to assist with building elevation but the City will explore a cost-sharing program to help qualified residents through grant programs afforded by FEMA and the California Department of Water Resources.

6.2.2 Building Relocation/Demolition

Building relocation is another common element of many non-structural flood control programs. Buildings in flood prone areas can be purchased and moved to areas outside the 100-year flood plain. A flood damaged home in the lower Stenner Creek area was purchased after the 1973 floods. This flood prone property is now the site of a community garden. In addition, as part of the building permit process for remodeling on a parcel within the FEMA 100-year floodplain, the City requires that they raise or flood proof, depending on the type of building.

Many residential buildings and mobile homes that are potential candidates for relocation represent affordable housing, a diminishing resource in the SLO community. Furthermore, there are not many sites available in the City for a large building relocation program.

Where it is not cost-effective to relocate the buildings, or where existing buildings create significant obstacles to implementation of the Flood Management Plan, the City may acquire the property and demolish the buildings. Although the City prefers a program of voluntary purchase at Fair Market Value, the City has authority if necessary to acquire the properties through condemnation proceedings, for the public good. Two properties with existing buildings will potentially need to be purchased and their buildings demolished to accomplish the objectives of the Mid-Higuera project (SLO-I-3), as currently designed. They are located immediately downstream of the Marsh Street Bridge on both banks, and currently occupied by McNamara Real Estate (eastside) and Madonna Construction (westside).

Building relocation is not practical for many of the commercial buildings in the Mid-Higuera area, given the general slab-on-grade method of construction of common commercial buildings in this area, and the high costs of moving. In addition, building relocation or demolition would need to extend all the way past Higuera Street, essentially destroying the Mid-Higuera commercial district. This is costly, and a drastic measure that would not be well accepted and was therefore not seriously considered. Nonetheless, some of the older housing including mobile homes in the Mid-Higuera area will be selectively targeted as part of a voluntary building relocation or demolition program, and several state and federal programs are available to help establish and cost share in such a program. The City will explore these. Overall, building relocation and demolition in areas of recurrent flooding is a minor but important part of the WMP.

Some houses on lower Stenner Creek could be targeted for voluntary moving, but considering the low recurrence interval of flooding in this area, (25-year return interval) and the generally low, nuisance type damages that occur from shallow flooding, a voluntary program may not attract many interested parties.

6.2.3 Flood Prone Property Land Acquisition

Floodplain acquisition (in this context) refers to the voluntary public purchase of undeveloped or vacant flood prone areas to prevent their development and further contribution to creek management problems. Usually some development potential and entitlement is implied that would cause increased flooding, loss of habitat, or bank instability. Alternatively, property purchase may make adjacent channel modification projects to achieve flood protection unnecessary, thereby avoiding creek impacts.

Several vacant parcels in the Elks Lane area are potential candidates for public purchase. Vacant parcels in the Mid-Higuera area may also qualify. This would be a very costly program. The purchases will only be made if the property owners agree and state or federal funding is obtained. The City is currently evaluating the need for property purchase (for building demolition and riparian restoration) on several parcels downstream of the Marsh Street Bridge in the Mid-Higuera area.

7. BENEFIT/COST ANALYSIS

7.1 Definition of Benefit/Cost Analysis

Benefit/cost analysis is a way of determining the relative worth of a capital improvement project for decision making as part of the public approval process. It attempts to quantify the economic costs of a project and compare them with the economic benefits likely to accrue to the community as a direct result of project construction. If benefits are greater than costs (i.e. the benefit/cost ratio is greater than one), the project is considered a net gain to the community and therefore worthwhile. If the costs of building the project exceed its likely economic benefits (i.e. the benefit/cost ratio is less than one), the community must decide whether the project has non-economically quantifiable benefits that justify its construction. If there are not over-arching non-economic benefits, a project with a negative Benefits relative to Costs probably is not worthwhile.

Although there is a lot of judgment that goes into any Benefit/Cost analysis, some worthwhile project benefits are intangible, and are difficult or nearly impossible to quantify accurately. The environmental benefits of stream habitat restoration and water quality improvements are examples. These were not factored into the Benefit/Cost Analysis, although the project designs have gone to great lengths to minimize impacts and the WMP includes programs for protecting and enhancing stream corridors. Benefit/costs analysis as completed by some Federal agencies have also been criticized because of the tendency to overstate commercial benefits, underestimate costs and not adequately address environmental benefits.

Nonetheless, there are several reasons to use benefit/cost analysis in evaluating the desirability of a set of flood management projects. First, it provides a way of determining whether a given project is worth doing from a purely economic standpoint. Second, Benefit/Cost analysis can help in prioritizing projects from a large list of possible alternatives, with the most beneficial probably worth doing first. Finally, a beneficial ratio is often a prerequisite for Federal funding for large capital improvement projects. For instance the ACOE uses a Benefit/Cost analysis procedure in decision making on all federally funded flood control and bank stabilization projects where they are involved.

7.2 Methodology

A Benefit/Cost Analysis requires the computation of two basic items: project costs and the economic benefits that the project is expected to provide. These two items must be comparable; in other words, if the project under consideration is likely to be built during the current year, but the benefits of the project are likely to be seen 25 or 50 years in the future, the economic value of the benefits must be discounted into present day dollars. For example, it would not be a good investment to spend $100,000 now to build a project that will result in a net benefit of $100,000 in 25 years. The money would be better utilized if put in a savings account to earn interest over that 25 years, and then withdrawn. This becomes even more complicated for a flood management project, since some small amount of the benefit might occur soon, say from preventing small nuisance floods every 5 to 10 years, while the more major benefits would likely occur later, for instance in preventing a very large and damaging flood many years in the future. It is generally simplest to compute either an annual amount of damage prevented by the project or the net present worth of prevented damage, and compare that to the equivalent annual cost or net present worth cost, respectively, of the project.

Determining costs is generally the simpler part of a benefit/cost analysis, although cost estimation can be challenging for projects designed at a conceptual level. A Unit Cost Summary for constructing and maintaining the projects under consideration in the WMP is in **Table 7-1.**

Computing the economic benefits of the proposed projects is somewhat more complicated than computing costs. The economic benefits that a flood management project will provide to a community are generally considered to be the amount of flood damage and lost economic activity that the given project is likely to prevent. Consequently, the accuracy of the analysis depends on accurately defining flood risk; both before and after a flood management project is in place. The determination of benefits thus involves defining flood hazard risk and then estimating the damages this risk is likely to cause, and then comparing this to the flood risk (and thus damage risk) likely after a given flood management project is built. Damage is assumed to be directly related to flooding depth.

The WMP has defined a set of watershed hydrology and hydraulic models that together predict floodwater depth throughout the SLO Creek and tributary floodplains. The models predict flooding depths for storms with a 10 percent (10-year), 4 percent (25-year), 2 percent (50-year), and 1 percent (100-year) chance, respectively, of occurring in any given year. To convert this flood risk to economic damage risk, flooding depth near the entrance to each building in the floodplain (as identified on the City's 2000 digital orthophotographs) was computed using a Geographic Information System. A curve developed by the Federal Emergency Management Agency (FEMA, 1995), as shown in **Table 7-2**, was used to determine the damage likely to be caused to each building for the computed depth of water, as a percentage of total building value. Building value was computed based on the appraised value of buildings according to tax records for commercial buildings and was assumed to be $241,523 per property for residential buildings, based on typical real estate transactions for residential buildings in the year 2000 (Carter, pers. comm, 2001).

Several types of damage that would probably be associated with a large flood were not specifically accounted for in the analysis. These include:

- Loss of income for businesses during storm cleanup,
- Damage to building contents,
- Costs associated with homeowners finding temporary housing,
- Increased maintenance costs for the city,
- Difficult to quantify costs such as decreased emergency access to certain parts of the city during and after the flood, and
- Lost development opportunity on floodplain lands that are not developable because of their flood risk (these lands of course provide benefits to adjacent and downstream floodplain land by providing some flood attenuation, and provide useful open space to the city).

With damage computed for each storm probability level, a damage probability distribution function was developed by multiplying the probability of damage by the damage computed for that probability level. The area under this curve represents the long-term equivalent annual flood damage. This procedure was repeated for each different flood management project, so that an equivalent annual damage could be computed for each project. The difference between the equivalent annual damage for existing conditions and the equivalent annual damage after the project represents the project's equivalent annual benefit. This was converted to a net present worth so that a benefit/cost ratio could be computed. Costs were computed in present worth rather than annual cost.

Table 7-1
Unit Cost Summary

Item	Unit Cost	Unit
Clear and Grub	$2.00 to 8.00	m^2
Bridge construction	$2000.00	m^2 bridge deck area
Pavement Repair	$35	m^2
Property Acquisition (undeveloped land within city limits)	$100,000	ac
Property Acquisition (developed land)	$300,000	ac
Import select backfill	10	m^3
Earthwork: Excavation/Hauling	12	m^3
Earthwork: Backfill/Compaction	3	m^3
Earthwork: Spoils Disposal	5	m^3
Revegetation	2.50	m^2
Bridge Demolition	$50,000	each
Building Demolition	$50,000	each
Building Relocation	$150,000	each
Floodwalls	project specific	
Concrete Channels and Culverts	project specific	
Relocate Utilities	project specific	
Bank Stabilization	$500	m
Miscellaneous Structures	project specific	

Table 7-2

Flood Insurance Administration (FIA) Depth-Building Damage Data

Flood Depth	Building Damage Percent by Building Type (based upon replacement value)					
	1 Story without Basement	2 Story without Basement	Split Level Without Basement	1 or 2 Story with Basement	Split Level With Basement	Mobile Home
-2	0	0	0	40	3	0
-1	0	0	0	8	5	0
0	9	5	3	11	6	8
2	22	13	13	20	16	63
3	27	18	25	23	22	73
4	26	20	27	28	27	78
5	30	22	28	33	32	80
6	40	24	33	38	35	81
7	43	26	34	44	36	82
8	44	26	41	49	44	82
9	45	33	43	51	48	82
10	46	38	45	53	50	82
11	47	38	46	55	52	82
12	48	38	46	55	52	82
13	49	38	47	59	56	82
14	50	38	47	60	58	82
15	50	38	47	60	58	82
16	50	38	47	60	58	82
17	50	38	47	60	58	82
18	50	38	47	60	58	82

*FIA: Depth-Damage Data Table-*Units in Feet of Flood Depth.*

Source: FEMA, 1995

Both costs and benefits are affected by the period of analysis and the interest rate assumed to apply over that period. Interest rates for this analysis were taken from the White House Office of Management and Budget (OMB). A high interest rate tends to make large capital improvement projects appear less beneficial than a low rate does, because at a high rate, the money invested in the project would return more if not spent than it would if the rate were low. Another way of looking at this is that a property owner at risk of flooding who wanted simply to provide self insurance against likely flood damage would have to put less money aside every month with a high interest rate, because the money saved would grow faster than at low rate. In other words, damages likely to occur in the future are less costly in terms of present dollars with a high interest rate than with a low one. The OMB interest rate used in this analysis is 3.2% (taken as of April, 2001, when the analysis was performed). This compares with a rate of 5.875% used by Nolte, 1977, and 7%, which was the OMB rate in 1994. The useful life of all projects for this analysis was assumed to be 100 years.

7.3 Results

With both costs and benefits computed, it is a simple matter to compute a benefit/cost ratio by dividing the net present worth of the benefits by the net present worth of the costs. Assuming each project will have a 100-year useful life, and assuming a discount (or interest) rate of 3.2%, as published by the Federal Government for capital improvement projects, the net present worth value for these projects is shown in **Table 7-3**.

The Mid-Higuera and Cuesta Park Detention projects are beneficial or nearly so. The 100-year flood control Bypass channel and culvert replacement projects at Los Osos Valley Road and the proposed channel modifications at Elks Lane (the 50-year Design Flow By-Pass Channel) are not. These latter projects primarily protect undeveloped floodplain land, which was assigned no significant value in the benefits portion of this analysis. When channel modifications are completed to a 100-year design level, these projects do provide additional benefits by preventing floodwater from spilling across Highway 101. However, these benefits are not great enough to result in a beneficial project because most of the land on the west side of Highway 101 that is protected is currently undeveloped and is not assigned a significant public value in this analysis. They do provide private benefits to adjacent properties. Both projects however, provide significant improvements to traffic flow and safety during flood emergencies in the City, as well as along Highway 101, by avoiding highway closure, and preventing potential isolation of the City's Emergency Management facilities at the Corporation Yard near the Sewage Treatment Plant. It should be noted that there was one death in 1995 at the LOVR off ramp as a direct result of flooding.

If one assumes that the flood prone properties that would be removed from the floodplain have increased commercial real estate value, then the projects would no doubt have favorable Benefit/Cost ratios. However, these benefits would not accrue to the public, indicating a large portion of the costs should be borne by the principal beneficiaries, the property owners adjacent to SLO Creek, or those that would benefit the most.

Tables 7-4 through **7-8** identify estimated individual project costs.

Table 7-3
Benefit/Cost Summary

Project	Location	Costs Considered in Analysis			Computed Benefits[1]		Benefits Divided by Costs
		Initial	Annual	Total Present Worth	Annual	Present Worth	
SLO-1	Channel Modification Below LOVR, LOVR Culvert And Bridge Replacement (100 yr.)	**5,025,700**[2]	**0**	**5,025,700**	**16,200**	**486,000**	**0.09**
SLO-2	Elks Lane Bypass Channel (50 year)	**9,455,300**	**0**	**9,455,300**	**41,800**	**1,250,000**	**0.13**
SLO-3	Mid-Higuera Bypass Channel (25 year)	**3,836,550**	**26,000**	**4,805,000**	**154,800**	**4,629,000**	**0.96**
SLO-4	Cuesta Park Detention	**7,967,750**	**0**	**7,967,750**	**390,300**	**11,675,000**	**1.46**
ST-1, 2, and 3	Stenner Creek Bridges Replacement[3]	**1,990,925**	**0**	**1,990,925**	**46,400**	**1,387,000**	**0.20**

1 Assumes a 100-year project life and a discount rate of 3 percent
2 Does not include costs for replacing culvert under Highway 101
3 Assumes Santa Rosa Street does not require replacement.

Table 7-4

SLO-1: Los Osos Valley Road
Prefumo/SLO Confluence Improvements (100-year level of protection)

Item No.	Description	Est. Qty.	Unit	Unit Price	Total
1	Property Acquisition (undeveloped land)	5	ac	100,000	500,000
2	Clear and Grub	20,000	m^2	2	40,000
3	Earthwork:: Excavation and Hauling	33,000	m^3	12	396,000
4	Earthwork:: Spoils Disposal	33,000	m^3	5	165,000
5	New Bridge across Bypass, Los Osos Valley Road	400	m^2	2,000	800,000
6	Replace Hwy 101 Culvert Xing of Prefumo Creek	600	m^2	2,000	1,200,000
7	Replace Hwy 101 Onramp Culvert Xing of Pref.	120	m^2	2,000	240,000
8	Bank Stabilization/Revegetation	250	m	500	125,000
				Subtotal	3,466,000
				Engineering and Administration 25%	866,500
				Contingency 20%	693,200
				Total	5,025,700

Table 7-5

SLO-2. Elks Lane Bypass Channel

Item No.	Description	Est. Qty.	Unit	Unit Price	Total
1	Earthwork (includes excavation and spoils disposal)	160,000	m^3	17	2,720,000
2	Clearing and Grubbing. Erosion control.	45,000	m^2	4	180,000
4	New Bypass Bridge at Elks Lane	250	m^2	2,000	500,000
5	Levees/Floodwalls below Prado Road	350	m	400	140,000
6	Temporary Traffic Control	1	job	50,000	50,000
7	0.15 m thick Concrete Channel Lining at Mausoleum (assume $400/m3 concrete)	5,000	m^2	60.00	300,000
8	Live Crib Wall at Mausoleum	120	m	1200.00	144,000
8	Revegetation & Restoration	45,000	m^2	4.00	580,000
9	Property Acquisition - (Developed Parcels)	3	ac	400,000	1,200,000
10	Property Acquisition - Undeveloped banktop land	7	ac	100,000	700,000
				Subtotal	6,514,000
	Engineering, Permitting, and Administration 25%				1,628,500
				Contingency 20%	1,302,800
				Total	9,445,300

Note: This assumes that property will be acquired essentially only along the project footprint. It does not assume that additional area will be acquired where the project makes an entire parcel unusable.

Table 7-6

SLO-3: Mid Higuera Bypass Channel

Item No.	Description	Est. Qty.	Unit	Unit Price	Total
1	Earthwork: Excavation and Hauling	42,500	m^3	12	510,000
2	Earthwork: Spoils Disposal	42,500	m^3	5	212,500
3	Property Acquisition (developed land)	3.5	ac	250,000	875,000
4	Clear and Grub	30,000	m^2	8	240,000
5	Channel, Bank Stabilization/Restoration	800	m	500	400,000
6	Replace Bianchi Lane Bridge	100	m^2	2,000.00	200,000
7	Revegetation/Vegetative Management	30,000	m^2	4.00	120,000
				Subtotal	2,557,750
	Engineering, Permitting, and Administration 25%				639,375
	Contingency 20%				639,425
				Total	3,836,550

Table 7-7

SLO-4. Cuesta Park Detention Enhancement

Item No.	Description	Est. Qty.	Unit	Unit Price	Total
1	Engineering Study of Geotechnical Stability & Embankment & Spillway Design	1	job	allow	400,000
2	Import Select Backfill	80,000	m^3	10	800,000
3	Earthwork (Hauling and compaction of berm)	80,000	m^3	15	1,200,000
4	Clearing and Grubbing	10,000	m^2	8	80,000
5	Pavement Demolition & Repave Highway	16,000	m^2	35	560,000
6	Repave Highway	16,000	m^3	40	640,000
7	Emergency Overflow Structure (3' thick gabions)	1	job	allow	300,000
8	Culvert Modification	1	job	allow	100,000
9	Temporary Traffic Control	1	job	allow	75,000
10	Developed Property Acquisition	1	parcel	700,000	700,000
11	Open Space Property Acquisition in Impoundment Footprint	32	ac	20,000	640,000
				Subtotal	5,495,000
				Engineering and Administration 25%	1,373,750
				Contingency 20%	1,099,000
				Total	7,967,750

Note: This assumes that property will be acquired anywhere along the area inundated at the 100-year event. It does not allow for any existing easement which might existing along the creek. In addition, it does not assume that additional area will be acquired where the project makes an entire parcel unuseable/unbuildable (which is not likely the case here anyway).

Table 7-8

Stenner-1, 2 and 3: Stenner Creek Bridge Improvements

Item No.	Description	Est. Qty.	Unit	Unit Price	Total
1	Demolition	2	Bridges	50,000	150,000
2	Replace Foothill Boulevard Culverts	1	job	750,000	750,000
3	Replace Murray Street Bridge	180	m^2	2,000	360,000
4	Pavement Repair	1,800	m	35	63,000
5	Relocate Utilities	1	job	50,000	50,000
				Subtotal	1,373,000
				Engineering and Administration 25%	343,325
				Contingency 20%	274,600
				Total	1,990,925

Note: Foothill Boulevard Culverts do not need to be replaced to provide 25-year protection. This would save approximately $375,000 from the total price reported in the above table. Structure is being replaced due to structural failure.

8. IMPLEMENTATION AND FINANCING

8.1 Project Schedule and Build-Out Assumptions

The WMP *Preferred Project* presents recommended flood control, bank stabilization, and habitat enhancement projects at a conceptual level. As such, the WMP is intended to be a road map for future City and County action with multi-year implementation. The first step will be project approval by the City, County, and various state and federal regulatory agencies. Implementation will occur over the next two to ten years (or more), depending on funding. The WMP sets priorities and identifies needed expenditures for future Capital Improvement Projects (CIP) such as bridge replacement and channel modification. It is expected that the majority of these CIP will be subject to additional CEQA/NEPA review, public hearings, and SLO County Board of Supervisors and City Council approval as the projects move forward in the design and budgeting process. Nearly all of these projects will also be subject to additional environmental review and permitting at the state and federal level as detailed plans are developed and construction is proposed.

The policies and procedures contained in the Drainage Design Manual and the Stream Maintenance and Management Program will become effective upon the adoption of this document and the associated EIR/EIS by the City Council and County Board of Supervisors. The SMMP must also be approved by the regulatory agencies including the ACOE, USFWS, NMFS, Regional Board, and the Calif. Dept. of Fish and Game before it can be fully implemented. It is anticipated these programs will be in effect for planning and project design beginning no later than January 2003.

8.2 Project Prioritization

The SLO watershed community, including the public and private stakeholders will need to spend over $28 million dollars over the next ten years to address the major water resources management problems identified in this WMP. Private bank stabilization and creek enhancement will add additional costs. Follow up planning, detailed design and cost estimating, and project permitting work tasks will need to be completed before construction can be initiated. Some of the problems, such as flooding through the Mid-Higuera area, have been occurring since the community was first settled in the early 1700's, and it is not realistic to think that these problems can be easily and readily solved in a short time frame. Because of the large number of individual projects that constitute the Preferred Project, it is helpful to prioritize the projects so that the follow up planning and engineering studies, and the arrangement and allocation of project funding can proceed in an orderly manner. The recommended Project Prioritization, as determined by the Zone 9 Advisory Committee, is shown in **Table 8-1**. The table also indicates the lead agency recommended to tackle the projects.

8.3 Funding Background

Potential sources of financing the programs in the WMP, including the SMMP, Bank Stabilization and Habitat Enhancement Programs, and the Flood Control Preferred Projects are reviewed in this section and Section 8.4.

Selection of the ultimate financing mechanism for each kind of project should be based on:

Table 8-1
Preferred Channel Improvement Priorities

Project	Location	Priority	Years to Complete	Lead Agency
San Luis Obispo Creek				
SLO-1	Channel Modification Below LOVR, LOVR Culvert And Bridge Replacement	I+	3-5	City
SLO-2	Elks Lane Bypass Channel	II	8-15	City/Private
SLO-3	Mid-Higuera Bypass Channel	I+	3-5	City
SLO-4	Cuesta Park Detention Enhancement	I	5-7	City
Stenner Creek				
ST-1	Santa Rosa St. Bridge Replacement	II	8-15	City
ST-2	Murray St. Bridge Replacement	I	5-7	City
ST-3	Foothill St. Bridge Replacement	I	In progress	City

- Who or what is causing the problem(s), and is therefore potentially responsible for helping to correct it;

- Who (and in which reach) would benefit the most (directly or indirectly) from implementation of the specific WMP project;

In addition to tangible benefits of protection from flood damage, improved water quality, enhanced property values, and reduced erosion, there are also intangible project benefits to the larger SLO community, such as improved traffic flow during storm events, public safety, and environmental restoration. These benefits are not included in the **Section 7** Cost/Benefit analysis, and costs associated with these benefits may be most appropriately paid by the greater watershed community.

It should be noted that the cause of the problem (especially historic flooding problems) and the entities that benefit from the restoration project are not always easy to determine. However, the following can be summarized, based on the results of the hydrologic and hydraulic modeling and field inventories:

- Flooding problems are historic and natural and not highly related to recent watershed development in most areas;

- Watershed development hasmost significantly impacted low-return period events, such as the 10-year flood, some reaches (mid-Higuera) have been affected more by overall watershed development than others although it should be noted that the mid Higuera area has always historically flooded;;

- Bank erosion, sedimentation, water quality problems, and habitat degradation are more directly linked to watershed-wide urban development than are flooding problems, and a funding program for these management needs should consider distributing costs more broadly among stakeholders;

- Problems are not solely related to urban development. Rural land uses, including roads and utilities (County and private) in the upper watershed, historic water supply reservoirs that have trapped sediment and changed stream dynamics, fire, and agricultural land uses have all impacted the creeks of the watershed.

- Stream realignment associated with highway construction (especially through mid-Higuera) in the 1950's is also a significant local contributor to flooding and bank erosion. Although the causes are a result of watershed-wide development, the Preferred Project channel modifications in this area will primarily benefit property owners in this specific reach.

- SLO channel widening at LOVR also benefits the area along Prefumo Creek and west of Highway 101, as would channel improvements in the Elks Lane area (if the flow split across Highway 101 is corrected). In this area, it is difficult to determine who benefits and how much. A benefit assessment engineer's report would be needed to allocate benefits and apportion costs.

8.4 Potential Local Financing and Funding Sources

The WMP contains a diversity of projects, and multiple sources of funding are likely, depending on the nature of the project element. Some project elements may be funded by more than one program or source, with the City or Zone 9 assembling local sources of revenue together with assistance, grants and/or loans from State or Federal agencies. **Table 8-2** summarizes possible sources of funds that should be considered as Preferred Projects move forward in the planning and design stage, as approved by the Zone 9 Advisory Committee. Funding sources include:

8.4.1 Zone 9 Funds

The San Luis Obispo County Flood Control and Water Conservation District was established in 1945 by an act of the State Legislature. Zone 9, which comprises the SLO watershed, was formed as a separate management zone within the overall District in 1973. The Zone in concert with the District can assume responsibility for powers of assessment and bonding for financing for facilities construction based on a vote of affected property owners. This includes an annual *ad valorem* assessment on all property in the district (zone) to pay administrative costs and to carry out drainage improvement projects, including flood control and bank repair. Zone 9 also has the legislative authority to establish Benefit Assessment Districts. Zone 9 can act as the responsible local authority for projects constructed jointly with the State and Federal government.

Table 8-2: Funding Matrix

Project	Description	Zone 9	CIP	Benefit Assessment District	Mello-Roos District	Landscape/Lighting District	Drainage Utility	Development Impact	Land Development Fee	Subdivision Drainage Fee	Transit Occupancy Tax	Private Development Funded	FEMA	Flood Mitigation Assist	Community Assistance	Corps Flood Control	Corps Section 205	CA Riverine	CA Urban Streams	Other Grants
SLO-1	LOVR Culvert/Bridge Replacement	X	X																	X
SLO-2	Elks Lane Bypass Channel			X				X	X	X		X				X	X	X	X	X
SLO-3	Mid-Higuera Bypass Channel	X	X	X				X				X								
SLO-4	Cuesta Park Detention Enhancement	X	X					X		X			X	X	X		X			X
ST-1	Santa Rosa St. Bridge Replacement		X																	X
ST-2	Murray St. Bridge Replacement		X																	X
ST-3	Foothill St. Bridge Replacement		X																	X
	Airport Area Channel Modifications			X	X			X	X	X										
	Channel Management-Airport Area			X		X					X	X								
	Habitat Restoration and Enhancement	X	X				X	X	X	X	X	X					X	X	X	X
	Wet and Dry Floodproofing											X	X	X	X					X
	Floodprone Properties Land Acquisition	X	X	X				X	X	X	X	X	X	X	X		X		X	X
	Building Elevation and Relocation	X	X	X				X				X		X	X				X	X
	SMMP Bank Repair Program-Public Lands	X	X					X		X									X	X
	SMMP Bank Repair Program-Private Lands											X							X	
	SMMP Veg. Management- Public Lands	X						X		X							X		X	X
	SMMP Veg. Management- Private Lands		X									X								
	NPDES Phase II Stormwater Quality Program	X					X				X	X								

In addition:

- The current annual assessment is $.08 per $100.00 of assessed property value. This raises about $250,000.00 annually, an amount insufficient to pay for a major drainage improvement or large bank repair projects.

- Since the Zone includes both City and County unincorporated areas, revenues for maintenance projects are currently split 80% City and 20% County, based on revenue source.

- The City has typically been responsible for stream maintenance and bank repair on public lands within city boundaries, and Zone 9 for unincorporated areas.

- Major City or County projects (such as bridge replacement or flood control) are not funded by the annual *ad valorem* assessment. Funding could come from the City or County General Fund, from the sale of Bonds or other mechanisms.

8.4.2 Capital Improvement Program (CIP)

The City and County use their Capital Improvement Program as a way of planning, prioritizing and financing long-term major expenditures for infrastructure needs, such as parking structures, streets and interchange improvements, park and recreation facilities, and administrative facilities. Planning for major capital improvements is a formal process where the City or County identify long-term needs and expenditures, and establish them in a CIP account. Previous major CIP recommended expenditures for flood control were listed in the City's 1983 Flood Policies or "Pink Book", which this WMP replaces.

Financing for capital improvements can come from the sale of special municipal bonds, with revenue for major projects often assembled from a variety of General Fund sources, including sales and property taxes, use fees, grants and loans from the state and federal government, and redevelopment agency sources.

This funding method is best suited for projects with citywide benefits, such as bridges, or there is a general obligation to repair community-based problems.

8.4.3 Benefit Assessment District

A Benefit Assessment District is a common method to fund projects where the construction of improvements needs to be completed over a large, contiguous area or areas, instead of an individual parcel, but generally not over an entire City. Under this funding mechanism, the City or County builds the project on behalf of property owners, and then the property owners or businesses are assessed levies proportional to the benefits that they receive from the construction of direct and measurable benefit to the area.

Formation of a Benefit Assessment District usually requires the City or County to prepare an Engineering Report that defines project needs, construction details, and costs. The boundaries of the proposed District include only the properties that receive a benefit, and a formula is derived to determine how benefits and levies are to be assessed. An assessment is then completed to determine the benefits to each parcel, with the corresponding assessment or levy based on proportionate benefits and costs.

The City or County proposing formation of the Benefit Assessment District must provide a written notice to all property owners in the proposed District of the intention to form a District. At least one public hearing is held to consider formation of the District, and property owners who oppose District formation are required to notify (in writing) the City or County with their objections. District formation requires a simple majority of property owners, and an election is held if it appears that there is opposition to the project or formation of the Benefit Assessment District.

Benefit Assessment District formation should be considered to pay for a portion of flood control improvements in the Mid-Higuera area, combined with other citywide generated funds. This is because the improvements are needed to offset the effects of Citywide or watershed wide development, and benefits, (for instance traffic flow along South Higuera Street) accrue to a larger area.

8.4.4 Mello-Roos District

A Mello-Roos Community Facilities District is a financing tool to levy special taxes for designated community improvements, such as freeway interchanges, library service, or recreation programs. They can also be used to construct basic storm drain infrastructure. To levy a Mello-Roos tax, the area's voters must consent to being taxed. A two-thirds approval vote is required, since Mello-Roos is a special tax. This makes Mello-Roos formation difficult.

Most Mello-Roos Districts are established prior to development and used to finance basic infrastructure. Drainage improvements in the Airport area, including modifications to the East Fork of SLO Creek, construction of regional detention facilities, and other non-drainage infrastructure could be considered for funding with a Mello-Roos District.

8.4.5 Landscape and Lighting District

A Landscape and Lighting District (LLD) is similar to a Benefit Assessment District, in that it applies to a specifically defined area that receives an annual service, such as landscape maintenance of common areas. The LLD is a Special District created by the City or County, which assesses an annual fee for service related to long-term maintenance (where maintenance needs and costs vary over time). Formation of the LLD requires two-thirds approval vote by the property owners. For the WMP, a LLD is:

- Appropriate for long-term intensive vegetation management in common areas;

- Work could be contracted out annually and tied to the Annual Work Plan of the SMMP;
- Zone 9 Advisory Committee recommended the LLD funding concept be considered only for long-term maintenance of stream restoration work in the Airport area.

8.4.6 Stormwater or Drainage Utility Fees

A City-wide Stormwater or Drainage Utility Fee is currently being formulated by the City for implementation of its impending Phase II NPDES Storm Water Quality Program. Fees paid into the Drainage Utility are not considered a tax, but a use fee for users of the public storm drainage system. The fee will likely be collected as part of the city's utility bill on a monthly (or periodic) basis with the fee based on a formula determined by land use, parcel size, and square footage of impervious surface area.

The fee is being established specifically for water quality improvements, so any use of funds from this source must be related to water quality issues. Other communities (City of Santa Rosa and Santa Clara County) have considered creek restoration work to benefit water quality by providing shading and biofiltering along top of bank buffer strips.

A comparable Drainage Utility Fee could also be developed within the County area, and the County is beginning to investigate their Phase II NPDES storm water management needs. The Zone 9 Advisory Committee recommended that use of Drainage Utility fees be considered for creek restoration related water quality improvements, but not for flood management or bank repair.

8.4.7 Development Impact Fees and Biological Impact Fees

A Development Impact Fee is a one-time charge associated with the impacts of a development project, as determined in a project CEQA document. Impact fees are commonly assessed to provide for schools, parks, open space, and traffic issues, but are less commonly applied to drainage impacts (although some cities apply such fees). Drainage impact fees are typically based on square footage of new impervious surface area, a calculated net increase in runoff measured in acre-feet per year, or possibly a calculated increase in creek flow. Such fees can be used to build regional detention facilities or make improvements to undersized storm water drainage systems. However, since the City is about 85% built out, the collection of impact fees will be limited in the future, and would best be used to pay for improvements that can be directly linked to a proposed project. Other considerations include:

- Fees may be as high as $30,000.00 per acre foot of increased runoff (City of Petaluma);
- *Biological Impact Fees* are less common; often used for wetlands, stream zones and endangered species habitat;

- Fees are typically based on acreage impacted, but can be based on lineal feet of stream impacted (e.g. for a bank repair project)
- Stream zone impact fees may range from $10,000-40,000/impacted acre, or $50- $200.00/l.f. of stream, based on probable restoration costs;
- Fees can be used to support regional habitat enhancement projects. The concept is similar to a Mitigation Bank, but not necessarily with a formal bank established.

8.4.8 Land Development Fees

A Land Development fee is another option available to cities and counties to fund drainage and flood control improvement projects, especially where the benefits are spread out over a wide area of new development. Such fees were authorized by the State of California Flood Control Act of 1970, and are used in Ventura County. Currently there is a maximum fee that can be levied: $2,400/acre, or $600/single family dwelling. These fees may be insufficient to pay for required drainage improvements.

Like the Drainage Impact Fee, and since the City is about 85% built out, this option is appropriate only for large new residential and commercial developments where needed drainage improvements are very modest.

8.4.9 Subdivision Drainage Fees

The Subdivision Map Act of the State of California authorizes cities and counties to adopt an Ordinance requiring the payment of one-time fees as a condition of approval of a subdivision map (for a new development). A drainage fee Ordinance, (and the subsequent collection of subdivision drainage fees) based on this Act must:

- Refer to a Drainage Master Plan adopted for a particular drainage area which contains an estimate of the total costs of construction of the needed drainage improvements and facilities required by the plan, and a map of such areas showing the drainage area boundaries and the location of improvements and facilities;

- State that the drainage plan conforms by resolution to a City or County approved Drainage Master Plan for the area;

- Be based upon a legislative determination of costs that are fairly apportioned and based on the need for such improvements and facilities as created by development of properties in the fee collection area, and;

- Set fees that reflect a pro-rata share of drainage facility costs, (i.e. the gross facility costs for each zone divided by the total gross acres in each zone).

One difference between these fees and others is that the project must involve a subdivision of land in order to collect these fees. Some large-scale commercial developments do not necessarily involve the subdivision of land.

8.4.10 Sales Tax and Transient Occupancy Tax

Some communities impose a local Sales Tax or a Transient Occupancy Tax (hotel bed tax) to pay for specific programs, such as street improvements. The City of Santa Barbara uses a Transient Occupancy Tax to fund water quality and creek restoration efforts. Although these revenue sources can raise substantial sums of money annually, a local sales tax requires authorization by the state legislature and both sales and bed taxes require a two-thirds approval by voters in the affected area. In addition, sales taxes are considered a regressive tax, as they disproportionately affect some income groups, are not readily associated with problem causes and beneficiaries, and may make local businesses less competitive with other nearby businesses that do not impose such taxes.

8.4.11 Private Development Funding

It is common for developments adjacent to privately owned stream channels (with flooding or bank instability problems) to have the needed channel improvements completed by the developer. The channel is later offered for dedication to the City or County, following a period of developer-funded maintenance and monitoring. The Drainage Design Manual outlines the design requirements and procedures for privately funded and constructed channel modifications.

- Private development projects and any proposed channel modifications would require separate CEQA review, approval, and agency permitting.

- This method of funding is most appropriate for land development projects where flooding affects vacant private land, and where there is little direct public benefit from the channel modifications that would be constructed privately, other than as project impact mitigation.

- Private funding would not work where a nearby channel with flooding problems is not under the control of the developer, or where development may have off-site drainage impacts.

- Private funding of approved channel modifications in the Elks Lane area is a possibility, although the situation is complicated by multiple property owners and wider public benefit of flood control in this area, especially control of flood overflow of Highway 101.

8.5 State and Federal Funding Programs

A variety of State and Federal programs are potentially available to the City and Zone 9 for flood control, bank stabilization, and stream restoration purposes. Many of these programs are moving away from funding hard structural flood control projects in favor of projects that emphasize non-structural programs such as building elevation, building relocation, and acquisition of flood prone areas. The most successful projects in terms of achieving grant funding have significant stream restoration and enhancement components, emphasize biotechnical bank stabilization, and have strong local stakeholder support and involvement. Most programs also preclude eminent domain condemnations for property acquisition, which makes grant funding of portions of the Mid-Higuera project problematic. However, communities that have developed comprehensive watershed-based projects (such as this WMP) usually rank higher in the increasingly competitive grant funding process.

8.5.1 FEMA Programs

406 Flood Hazard Mitigation Program

- Requires declaration of a Federal Disaster Area
- Application required within 60 days of declaration (concept plans must be ready)
- Many kinds of projects funded, including design, bank repair, vegetation management, channel modifications, and detention basins
- Typical split is 75% Federal; 25 % state or local funding
- Flood Hazard Mitigation Grants will be harder to obtain in the future

Flood Mitigation Assistance (FMA)

- Federal program available through Department of Water Resources Floodplain Management Office
- Competitive program for mitigation; state selects recommended participants-communities

Community Assistance Program (CAP)

- Product-oriented assistance to Community for floodplain management
- Could potentially be used to help with National Flood Insurance Program (NFIP) and Community Rating System (CRS)
- SLO currently has a rating of 8 (lower is better) entitling a 10% reduction in flood insurance premiums (total is about $200,00/yr)
- An aggressive NFIP-CSR could lower the rating, some of the work in this WMP, comprehensive plan, community meetings, education and outreach, flood proofing, could lower CSR

- DWR and ACOE Section 206 Floodplain management programs may also help with CSR

8.5.2 ACOE Flood Control Programs

<u>Individually Authorized - Large Flood Control Projects</u>

- Typically requires a ACOE feasibility study, but can be completed by a City or County
- Requires direct Congressional authorization and funding
- Often takes 7-10 years or more from study initiation until completion
- Subject to substantial schedule delays and cost over-runs
- Designs sometimes neither innovative nor environmentally friendly
- Large backlog of individually authorized projects means this program is in doubt, especially for new structural flood control projects

8.5.3 Section 205 Program-Small Flood Control Projects

- Requires feasibility study and favorable cost/benefit ratio
- Cost share is 50% feasibility, 35 % local for construction, $7,000,000 Federal funding cap
- Local partner is responsible for lands, easements, rights-of-way, relocations, and spoil disposal
- Competitive and time consuming process
- Reform pressure to tighten up cost/benefit analysis, consider environmental impacts more fully, adopt mitigation standards applied to private projects, and reduce benefits to private undeveloped properties

8.5.4 Section 212 -Flood Mitigation and Riverine Restoration Program

- Program emphasizes non-structural approaches to preventing or reducing flood damage, such as floodplain purchase and building relocation
- Riparian restoration also an important program element
- Cost share is 50% feasibility, 35 % local for construction, $30,000,000 Federal cap

8.5.5 State Grants

Proposition 12 (Parks Bond), Proposition13 (Water Bond) were passed by State voters in 2000, and Proposition 40 (2001) include elements for flood control and habitat enhancement and restoration.

These are very competitive grants, but awards can range from $100,000.00 to $1,000,000.00.

<u>Riparian and Riverine Habitat Grant Program</u>

- Competitive program for public education, awareness, recreational access, and enjoyment
- Administered by Calif. Dept. of Parks and Recreation, $10,000,000 total funding
- Covers acquisition, development, improvement, and restoration of open space areas along rivers and streams
- Competitive, grants from $20,000-$400,000, Feb. 1 application
- Other California Department of Parks and Recreation Department programs annually funded include Land and Water Conservation Fund, and Habitat Conservation Fund, as the State contributor to these competitive Federally funded programs.

<u>Urban Streams Restoration Program</u>

- Competitive program for creek and floodplain management
- Administered by California Department of Water Resources
- Requires a local non-profit partner or watershed group
- Comprehensive, watershed based approach, and involvement of multiple agencies in multi-objective planning is important
- Focus on non-structural projects, such as land acquisition and habitat enhancement
- Emphasis is on implementation, not studies; projects must have CEQA approval
- Cuesta Park Project, coupled with habitat enhancement in Reach 14 is strongest candidate for Grants - possibly Mid-Higuera vegetation management and habitat enhancement

- Grant cycle twice a year, fall and spring, several hundred thousand dollars available

Other Grants

- Caltrans funds potentially available to help mitigate impacts of previous highway projects

- Many other grant programs available from Coastal Conservancy, US Fish and Wildlife Service, Dept. of Fish and Game, etc. -best accomplished in association with non-profit partner.

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10. GLOSSARY OF TECHNICAL TERMS

Aggradation. The geologic process by which streambeds and floodplains are raised in elevation by the deposition of material.
Alluvial. Deposited by running water.
Anadramous. Fish that leave freshwater and migrate to the ocean to grow, and return to freshwater to spawn.
Armoring. (a) The natural process of forming an erosion resistant layer of relatively large particles on the surface of the streambed. (b) The artificial application of various materials to strengthen streambanks against erosion.
Axil. The angle between the upper side of a leaf and its supporting branch or stem.
Bankfull Discharge. The discharge corresponding to the stage at which the natural channel is full. This flow has a recurrence interval of 1.5 to 4 years depending on the channel gradient and bank materials.
Bar. (a) Accumulation of alluvial material along the banks, midstream, or at the mouth of a stream or in the wakes of objects where a decrease in velocity induces deposition. (b) An alluvial deposit composed of sand, gravel, and other material that obstructs flow and induces deposition or transport.
Base flow. Can be defined as the volume of flow in a stream channel that is not derived from surface run-off. Base flow is characterized by low-flow regime (frequency, magnitude, and duration daily, seasonally, and yearly), by minimum low-flow events and in context of the size and complexity of the stream and its channel.
Bed load. Sediment moving along or near the streambed and frequently in contact with it.
Bed slope. The inclination of the channel bottom.
Bend. A change in the direction of a stream channel.
Benthic. Of or pertaining to animals and plants living on or within the substrate of a water body.
Berm. A levee, shelf, ledge or bench along a streambank that may extend laterally in the channel to partially obstruct flow, or parallel to the flow to contain the flow within its streambank. May be natural or constructed.
Best Management Practice. A practice used to reduce impacts from a particular land use.
Biotechnical approach. An applied science that combines structural, biological and ecological concepts to construct living structures for erosion, sediment and flood control.
Blanket. Material placed on a streambank to cover eroding soil.
Boulder. Sediment particle having a diameter greater than 256 mm (10 inches).
Brush layer. Live branch cuttings crisscrossed on trenches between successive benches of soil.
Brush mattress. A mattress-like covering that is placed on top of the soil. The covering material is living wood plant cuttings that are capable of rooting.
Buffer. A vegetated area of grass, shrubs or trees designed to capture and filter runoff from surrounding land uses.
Canopy. The overhead branches and leaves of riparian vegetation.
Canopy cover. Vegetation projecting over a stream, including crown cover (generally more than 3 feet above the water surface) and overhand (less than 3 feet above the water surface).
Channel. A natural or man-made waterway that continuously or periodically passes water.
Channel roughness. The irregularity of streambed materials sizes and channel form in plan and cross-section that causes resistance to flow.
Channel scour and fill. Erosion and sedimentation that occurs during relatively short periods of time; *degradation* and *aggradation* apply to similar processes that occur over a longer period of time.
Channel stability. A relative measure of the resistance of a stream or river to erosion. Stable reaches do not change markedly in appearance from year to year.
Check dam. A structure placed bank to bank downstream from a headcut.
Clay. Cohesive soil whose individual particles are not visible to the unaided human eye. Soil can be molded into a ball that will not crumble.
Cobble. Sediment particles larger than pebbles and smaller than boulders. Usually 64 - 256 mm (3 to 8 inches) in diameter.
Coir. A woven mat consisting of coconut fibers. Generally used for various soil erosion control practices such as surface slope protection and the construction of geogrids.
Cover. Anything that provides protection for fish and/or wildlife from predators or ameliorates adverse conditions of stream flow and/or seasonal changes in metabolic costs. May be instream structures such as rocks or logs, turbulence, and/or overhead vegetation. Anything that provides areas for escape, feeding, hiding, or resting.

Cribwall. A hollow structural wall used for bank and slope stabilization formed by mutually perpendicular and interlocking members (usually timber) into which live cuttings are inserted along with soil to stabilize roots.
CRLF. Calfornia Red legged frog.
Cross section. A vertical section of a stream channel or structure that provides a side view of the structure; a transect taken at right angles to flow direction.
Culvert. A sewer or drain crossing under a road or embankment.
Current. The flow of water through a stream channel.
Cutbank. The outside bank of a bend, often eroding and across the stream from a point bar.
D_{30}, D_{50}, D_{100}. The particle size for which 30, 50, and 100 percent of the sample is finer.
Debris. Any material, organic or inorganic, floating or submerged, moved by a flowing stream.
Deflectors. Structures used to deflect stream flow to a different location, usually away from an eroding bank.
Degradation. The long-term hydraulic process by which stream and river beds lower in elevation. It is the opposite of aggradation.
Deposition. The settlement of material out of the water column and onto the streambed or floodplain. Occurs when the flowing water is unable to transport the sediment load.
Development. A man-made change to improved or unimproved real estate. This includes, (not limited to) buildings and other structures, mining, dredging, filling, grading, paving, excavation, and drilling operations.
Dike (groin, spur, jetty, deflector). A structure designed (1) to reduce the water velocity as streamflow passes through so that sediment deposition occurs instead of erosion (permeable dike) or (2) to deflect erosive currents away from the streambank (impermeable dike).
Discharge. The volume of water passing through a channel during a given time, usually measured in cubic feet per second.
Dredge material. Soil excavated from a stream channel.
Encroachment. Any fill, structure, building, use, accessory use, or development in the floodplain or watercourse.
Energy dissipation. The loss of kinetic energy of moving water due to internal turbulence, boundary friction, change in flow direction, contraction or expansion.
Enhancement. Improvements to the existing conditions of the aquatic, terrestrial, and recreational resources.
Erosion. In the general sense, the wearing away of the land by wind and water. As used in this pamphlet, the removal of soil particles from a bank slope primarily due to water action.
ESA. Endangered Species Act
Failure. Collapse or slippage of a large mass of bank material into a stream.
Fascines. Sausage-like bundles of plant cuttings used to stabilize streambanks and other slopes (see *wattles)*
FEMA. Federal Emergency Management Agency. The agency which administers the NFIP at the federal level.
Fill material. Soil that is placed at a specified location. to bring the ground surface up to a desired elevation.
Filter. Layer of fabric, sand, gravel, or graded rock placed between the bank revetment or channel lining and soil for one or more of three purposes: to prevent the soil from moving through the revetment; to prevent the revetment from sinking into the soil; and to permit natural seepage from the streambank, thus preventing buildup of excessive groundwater pressure. If a filter is used by a landowner or local government, technical assistance should be obtained to properly match the filter with the soil.
Fine particles (or Fines). Silt and clay particles.
Fish habitat. The aquatic environment and the immediately surrounding terrestrial environment that meet the necessary biological and physical requirements of fish species during various life stages.
Flood. A general and temporary condition of partial or complete inundation of normally dry land areas.
Flood insurance rate map (FIRM). The official Flood Insurance Administration map which shows special hazard zones and risk areas of a community. This map is used for insurance rating purposes.
Floodplain. An area of land that would be covered with water during a flood. In connection with the Flood Insurance Program, the term usually refers to the 100-year floodplain. The term is identical to "flood hazard area".

Floodway. The river channel and overbank areas of riverine floodplains through which the base flood is discharged. This portion of the floodplain is where the highest flood velocities and greatest flood depths usually occur. Floodways are shown on the Flood Boundary and Floodway Maps (FBFM) prepared by FEMA for regular program communities. Upon the adoption of these maps by a community, the floodway(s) shown become "regulatory floodways" within which encroachment or obstructions must be prohibited
Fluvial. Produced by moving water.
Fluvial geomorphology. The study of surface forms produced by the action of flowing water.
Freeboard. The vertical distance between the design water surface elevation and the elevation of the bank, levee or revetment that contains the water.
Gabion. A galvanized wire basket with a hinged top, intended to be filled with stones and used to stabilize banks or channel beds, to control erosion, and to prevent bed material from shifting. Generally not recommended for placement in gravel bed streams.
Geomorphology. The geologic study of the evolution and configuration of land forms.
Gradient. Slope calculated as the amount of vertical rise over horizontal run
Gravel. Soil particles ranging from 1/5 inch to 3 inches in diameter.
Groundwater table. The depth below the surface where the soil is saturated; that is the open spaces between the individual soil particles are filled with water. Above the groundwater table and below the ground surface the soil either has no water between particles or is partially saturated.
Habitat. The area or environment in which an organism lives.
Headcutting. The action of an upstream moving waterfall or locally steep channel bottom with rapidly flowing water through an otherwise placid stream. These conditions often indicate that a readjustment of a stream's discharge and sediment load characteristics is taking place.
Headwater. The uppermost reaches of a stream or river.
Hydrology. The study of the properties, distribution and effects of water on the Earth's surface, soil, and atmosphere.
Hydraulics. Water or other liquids in motion & actions.
Hydric soils. Soils found in saturated, anaerobic environments usually characterized by a gray or mottled appearance, often found in wetlands.
Impermeable material. A soil that has properties which prevent movement of water through the material.
Incised channel. A stream that has cut its channel into the bed of the valley.
Infiltration. The portion of rainfall that moves downward into the subsurface rock and soil.
Instream. The instream channel includes the channel bottom up to 10 feet minimum above the Ordinary High Water (OHW) mark, or the 2-year peak flow line.
Instream cover. (a) Areas of shelter in a stream channel that provide aquatic organisms protection from predators or competitors. (b) A place in which to rest and conserve energy due to a localized reduction in the force of the current.
Intermittent stream. A stream that has interrupted flow or does not flow continuously.
Joint planting. The process of placing live woody plant cuttings in the spaces between pieces of rock rip-rap. When placed properly, the cuttings are capable of rooting and growing.
Large woody debris. Any large piece of woody material that intrudes or is embedded in the stream channel. Also called large organic debris.
Live Stakes. Cuttings from living branches that are inserted into the soil to stabilize slopes and streambanks when the cuttings root and grow.
Maintenance. The ***repair, care and upkeep*** of a channel at a pre-existing or approved design condition, within a designated flow conveyance capacity.
Management. Modification, alteration and change, where necessary, of physical and biological site conditions in response to evolving goals, objectives and changing environmental conditions.
Manning's "n". The resistance coefficient in the Manning formula used in calculating water velocity and stream discharge. It is a proportionality coefficient that varies inversely as a function of flow.
Meander. A circuitous winding or bend in the river.
Mean sea level (MSL). The average height of the sea at all stages of the tide. Mean Sea Level is also referred to as "National Geodetic Vertical Datum" (NGVD).
Obstruction. Any structure or assembly of materials including fill above or below the surface of land or water, and any activity that might impede, retard or change flood flows.
OHW. Ordinary high water mark. See below.
One-hundred year flood. Another name for the base flood, the flood having a one-percent of occurring in any single year.

Ordinary high water mark. The mark along a streambank where the waters are common and usual. This mark is generally recognized by the difference in the character of the vegetation above and below the mark or the absence of vegetation below the mark.
Overbank flow. Water flowing over the top of bank.
Perennial stream. A stream that flow continually.
Point bar. A gravel or sand deposit on the inside of a river bend; an actively mobile river feature.
Pool. Deeper areas of a stream with slow-moving water, often used by larger fish for cover.
Pool-riffle ratio. The ratio of pool and riffle areas, or pool and riffle length in a given stream reach.
Program. San Luis Obispo Creek Stream Management and Maintenance Program***Reach***. A relatively homogeneous length of stream having a similar sequence of characteristics.
Riffle. A shallow section in a stream where water is breaking over rocks or other partially submerged organic debris and producing surface agitation.
Riparian area. The area between a body of water and adjacent upland areas that is identified by distinctive soil and vegetative characteristics.
Riparian buffer. Trees and shrubs growing parallel to a stream that reduce the intrusion into the top bank area by humans, animals, and machinery. This vegetation also retards surface runoff down the bank slope and provides a root system which binds soil particles together.
Riparian vegetation. Vegetation growing along the banks
of streams and rivers or other bodies of water tolerant to or more dependent on water than plants further upslope.
Riparian zone. The vegetated zone adjacent to a stream or any other water body (from the Latin work ripa, pertaining to the bank of a river, pond or lake).
Rip-rap. A layer, facing, or protective mound of stones placed to prevent erosion, scour, or sloughing of a structure or embankment. Also refers to the stone used.
Roughness element. Any obstacles in a channel that deflect flow and change its velocity.
Run. The straight fast-moving section of a stream between riffles.
Salmonids. Fish of the family Salmonidae, including salmon, trout, char, whitefish, ciscoe, and grayling.
Sand. Mineral particles ranging from 0.0625 to 2 mm (0.0025 to 0.08 inch) diameter; 0.03 inch is the normal lower limit at which the unaided human eye can distinguish an individual particle.
Scour. Concentrated erosive action of flowing water in streams that removes material from the beds and banks.
Sediment discharge. Mass of sediment passing a stream cross-section at a defined unit of time.
Sediment load. The sediment transported through a channel by streamflow.
Sediment. Soil particles that have been transported and/or deposited by wind or water action.
Shear strength. The internal resistance of a body to shear stress. Typically includes frictional and cohesive components. Expresses the ability of soil to resist sliding.
Shear stress. The force per unit area tending to deform a material in the direction of flow.
Sheet erosion. The removal by surface runoff of a fairly uniform layer of soil from a bank slope.
Silt. Slightly cohesive to noncohesive soil composed of particles that are finer than sand but coarser than clay, commonly in the range of 0.004 to 0.0625 mm. Silt will crumble when rolled into a ball.
Sinuosity. A measure of the amount of a river's meandering; the ration of the river length to the valley length. A straight channel has a sinuosity of 1.0; a fully meandering river has a sinuosity of 2.0 or greater.
Slope. Vertical rise divided by horizontal run.
Sloughing (or sloughing off). Movement of a mass of soil down a bank into the channel (also called slumping). Sloughing is similar to a landslide.
Slumping. The collapse of slopes by undercutting.
Specifications. A detailed description of particulars, such as size of stone, quantity and quality of materials, contractor performance, terms, quality control, and equipment.
Stream. A body of running water moving over the Earth's surface in a channel or bed (also river).
Streambank. The portion of the channel cross section that restricts lateral movement of water at normal water levels
Streambank erosion. Removal of soil particles from a bank slope primarily due to water action. Climatic conditions, debris, chemical reactions, and changes in land and stream use may also lead to bank erosion.
Streambank failure. Collapse or slippage of a large mass of bank material into the channel.
Streambed. The substrate plane bounded by the stream banks over which water moves. Also called stream bottom. It is the area kept mostly or completely bare of vegetation by the wash of waters in the stream.
Streamflow. The movement of water through a stream channel.

Structural. Reducing flood hazards through physical means, such as dams, dikes, levees, or channelization of rivers or streams.
Structure. (a) Any object in the channel that affects water and sediment movement. (b) The diversity of physical habitat within a channel.
Substrate. The mineral or organic material that forms the bed of the stream.
Surface runoff. That portion of precipitation that moves over the ground toward a lower elevation and does not infiltrate the soil.
Thalweg. A line following the deepest part of the bed or channel of a stream.
Toe. The break in slope at the foot of a bank where the bank meets the bed.
Top of bank. The break in slope between the streambank and the surrounding upland terrain.
Transect. (a) A predetermined line along which vegetation occurrence or other characteristics such as canopy density are counted for monitoring purposes. (b) A channel cross-section.
Turbidity. Relative water quality conditions; measure of light passing through water affected by suspended material.
Upper bank. That portion of the streambank above the elevation of the average water level of the stream.

Vegetated geogrid. Soil wrapped with a geotextile fabric and with live woody plant cuttings placed in between each soil/geotextile wrap.
Velocity (of water in a stream). The distance that water can travel in a given direction during an interval of time.
Waters of the United States. Includes all dry land and water-covered areas below the ordinary high water marks on navigable and non-navigable streams.
Watershed. An area of land that drains into a particular river or body of water. Usually divided by topography.
Wattling. See fascines.
*Wetlands.*terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands have one or more of the following three attributes: (a) At least periodically, the land supports predominantly hydrophytes; (b) The substrate is predominantly undrained hydric soil; and, (c) the substrate is nonsoils and is saturated with water or covered by shallow water at some time during the growing season of each year.
Woody debris. Coarse wood material such as twigs, branches, logs, trees, and roots that fall into streams.

APPENDIX A

GIS Inventory Data

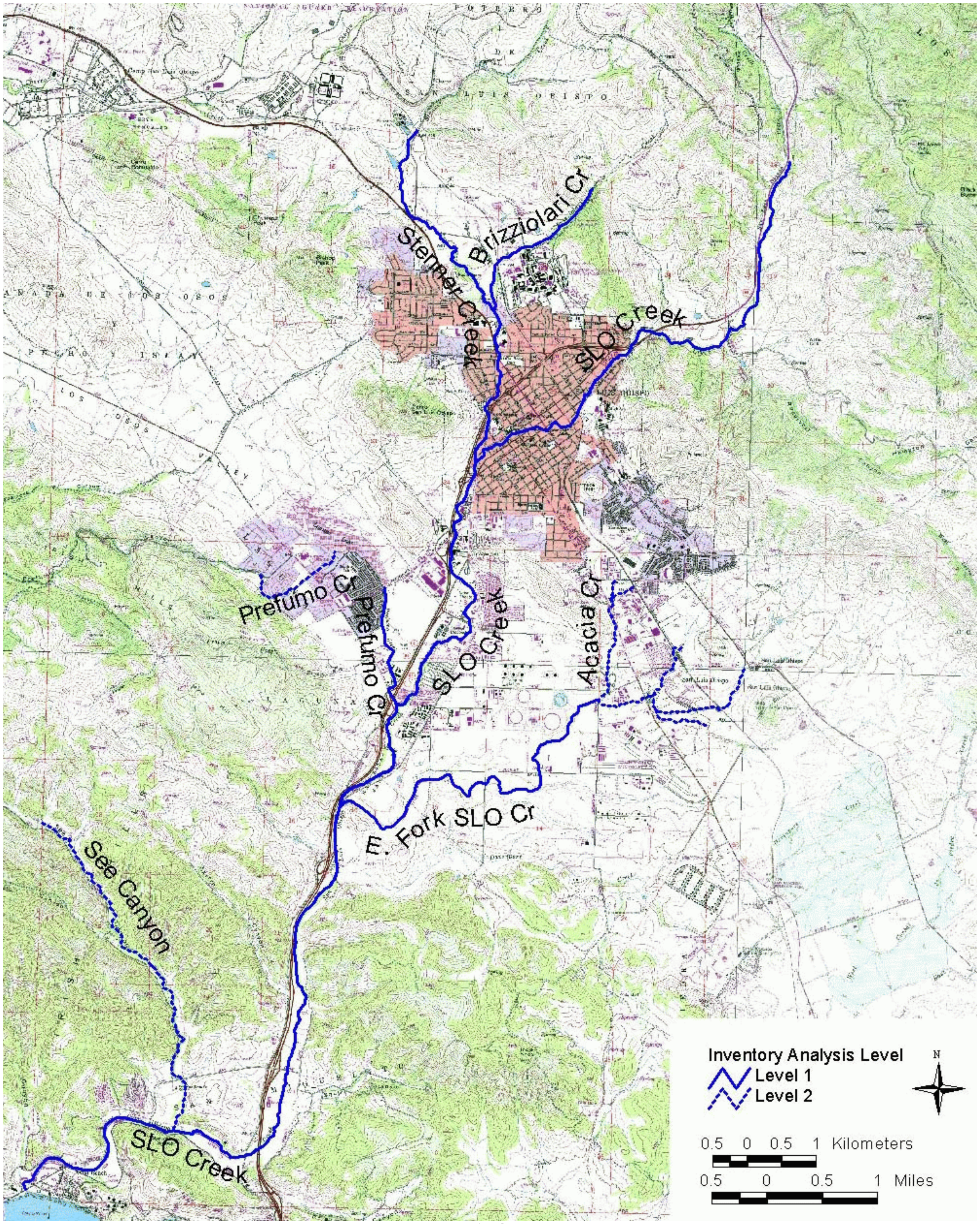
Hydraulic and Geomorphologic Field Inventory

The purposes of the hydraulic and geomorologic inventory performed as part of the San Luis Obispo Waterways Management Plan (WMP) are three-fold. First, the inventory is meant to identify banks and hydraulic structures that are at risk of failing in the foreseeable future, to quantify that risk, and to help identify whether projects at these sites could potentially increase the risk of failure on nearby banks. Second, the inventory classify's the stream system into a set of reaches containing similar geomorphic properties. Finally, the inventory will provide an existing baseline condition for the stream channel system.

The watershed inventory was performed during the spring, summer, and fall of 2000. Collected data included both hydraulic and geomorphic features such as eroding stream banks, existing structures, and grade breaks. A separate inventory of biological features (i.e. the type and quality of available habitat, the presence of endangered or exotic species, etc.) was performed concurrently by the Morro Group and is described in **Appendix B**.

The inventory was intended to cover the majority of the major perennial flow channels within the San Luis Obispo Creek Watershed. Each channel within the watershed was divided into one of three types. This classification is shown in **Figure A-1**. *Type 1* channels received the most detailed inventory, involving a team of technicians walking the entire channel and recording features in the field. The same types of data were recorded for *Type 2* channels, but since portions of these channels were either relatively inaccessible or ran through private property, or since a quick look at the channel was often sufficient to characterize the problems there, they were not walked in their entirety by the technical team. Instead, as many features as possible for these reaches were identified from accessible points at the top of bank or from bridges. *Type 3* channels were typically found high in the watershed (and are not specifically identified in **Figure 1**). Spot visits to these channels were performed as part of the survey, but the primary work here involved interpretation of orthophotographs and other existing maps.

Figure A-1
Field Inventory Methods - (Level 1 and 2 Channels)



The features included in the inventory were bank erosion sites, stream channel reaches, hydraulic structures, hydraulic obstructions, grade breaks in the channel profile, culvert outfalls, bedrock occurrence, and bridges. A detailed description of these features and their attributes is included at the end of this Appendix. Because of the geographical nature of the collected data, the results of the inventory are stored using a Geographic Information System (GIS). Data is available from the City of San Luis Obispo Geodata Services Department, at 955 Morro Street, San Luis Obispo, CA 93401. Most of the data is available online at http://suntzu.larc.calpoly.edu/slo_creek/.

For Type 1 channels (the majority of the survey), data was collected by physically walking the entire length of the stream system. When a feature requiring inventory was encountered, its position was recorded using a Global Positioning System (GPS) receiver worn by the data technician. Attributes about the feature were recorded at that point, directly in the field. For example, if a culvert outfall had been encountered, its type, size, and condition would have been recorded.

In many cases, often because of nearly vertical banks and dense vegetation, it was not possible to record the precise location of a feature while in the field. In these cases, the final position entered in the GIS data base was determined by the data collection technician back in the office using a scanned, geographically referenced aerial photograph (digital orthophotograph).

Some of the most important data collected during the inventory process were individual photographs for each significant feature. Since it was difficult to show some of the larger features in a single photograph, the photos were taken of what was considered a representative part of the feature. The photographs are accessible through the GIS database.

Detailed Descriptions of Hydraulic/Geomorphic Field Inventory Data Files

Eroding Streambanks (Erosion.shp)

Eroding streambanks are steep, sparsely vegetated sections of stream bank that in the opinion of the field technicians could experience substantial erosion during a high flow event. The goal in field data collection was to record easily measured attributes about the individual features such as feature height, type of bank and bed material, the amount of vegetation on the bank, etc.

A bank erodibility index was developed based loosely on a method described in Rosgen, 1996. This method ranked each of the raw data attributes on a scale of one to ten, with ten being the most likely to result in future bank erosion. The classification method is described in **Table A-1**. The sum of each index value resulted in a total bank erodibility index that theoretically varies from 0 to 100. (In fact, no erosion sites received an erodibility risk rating less than 31or greater than 84.) An index of 50 or greater denotes a fairly substantial erosion risk. However, even sites with index values less than 50 could become worse after future flow events and should be carefully monitored.

(Note: for most existing structures, it would be difficult to develop a system of recording raw data about the structure and then using that to develop a risk-of-failure index. It was much simpler for existing revetments and for culvert outfalls to record the technicians' opinion of risk made in the field. Photographs of these structures can be used to confirm the technicians' opinions.)

Table A-1. Bank Erosion Data Dictionary and Erosion Risk Rating Method

Attribute	**Possible Values**	**Description**	**Erosion Risk Index Value**
Mechanism	Toe Scour	Entrainment of toe material into flow leads to sloughing	n/a
	Geotechnical	Characterized by rotational slumping	n/a
	Shear (deflection)	Entrainment of material all along bank by deflected flow	n/a
	Complex	Combinations of all other factors	n/a
	Vegetation factors	Willows on central bar deflected flow into bank	n/a
	Rill/gully, bank top	Caused by local tributary flow, not by flow in main channel	n/a
	Other		n/a
Location	Left Bank	Failure located on left bank (looking downstream)	n/a
	Right Bank	Failure located on right bank (looking downstream)	n/a
Toe Material	Cohesive	Material appears to have significant clay/cohesive fraction	3
	Non-Cohesive	Very little clay - material crumbles in hand	6
	Stratified	A layer of non-cohesive material surrounded by cohesive	10
	Claystone	Very dense clay-like material	0
	Bedrock	Rock outcrops visible along majority of bank toe	0
Upper Bank Material	Cohesive	Material appears to have significant clay/cohesive fraction	3
	Non-Cohesive	Very little clay - material crumbles in hand	6
	Stratified	A layer of non-cohesive material surrounded by cohesive	10
	Claystone	Very dense clay-like material	0
	Bedrock	Rock outcrops visible along majority of upper bank	0
Root Density	80-100%	Root density describes a field estimate of the surface area	3
	55-79%	of bank that is potentially bound together by roots from	6
	30-54%	vegetation present on the bank. This differs from percent	10
	15-29%	surface cover in that it is intended to characterize the	13
	5-14%	below-ground strengthening characteristics of the bankside	17
	<5%	vegetation.	20
Percent Surface Cover	80-100%	Percent surface cover represents the bank soil area directly	3
	55-79%	shielded from impinging flow by any vegetation. Here, the	6
	30-54%	vegetation is directly visible. No estimates of below-ground	10
	15-29%	root coverage need to be made, as for the Root Density	13
	5-14%	attribute.	17
	<5%		0
Riparian Habitat	Pools	Stream becomes significantly deeper and/or slower	n/a
	Instream cover	Debris/undercut bank/vegetation present below flow line	n/a
	Canopy	Stream shaded by veg that could be removed if site stabilized	n/a
(represents the type of features that could	Pools & Instream Cover	see above	n/a
potentially be changed	Pools & Canopy	see above	n/a
by a bank stabilization project at the site)	Instream Cover & Canopy	see above	n/a
	Pools & Cover & Canopy	see above	n/a
Threatened Structures	None	No structure visible from stream channel	n/a
	Main Structure	Potentially inhabitable structure	n/a

	Outbuilding	Garages/sheds etc.	n/a
	Deck or Fence	self explanatory	n/a
	Other	self explanatory, usually highway, other infrastructure	n/a
Distance to structure		estimated distance from top-of-bank	n/a
Downstream Transition	low future instability	No visible reason to expect banks would begin eroding in future, even if site stabilized with hard structure	n/a
	possible instability this bank	Changing bank structure appears to have potential to destabilize same bank just downstream	n/a
	possible instability opp bank	Changing bank structure appears to have potential to destabilize opposite bank just downstream	n/a
	possible instability both bank	Changing bank structure appears to have potential to destabilize both banks just downstream	n/a
Bank Angle	0-20	Represents angle of representative portion of bank scarp.	3
	21-60	Measured by laying surveying rod on steepest continuous	7
	61-80	part of bank and measuring angle with inclinometer.	10
	81-90		13
	90-119		17
	>120		20
Approximate length		Estimated length of failure. Used only for QC purposes.	n/a
Photo time		Time feature was recorded. Used to match with photo.	n/a
Height (m)	0-1	Height from toe to top of bank. Measured using surveying	3
	1-2	rod. Where upper bank is not level, represents distance	7
	2-3	from toe to top of scarp.	10
	3-5		13
	5-7		17
	>7		20

Revetments (revetmnt.shp)

Revetments are constructed features such as rock rip-rap or concrete walls that are intended to stabilize eroding stream and river banks.

Table A-2. Revetments Data Dictionary

Attribute	Possible Values	Description
Type	Rock Rip-Rap	Broken rock placed as continuous layer on slope
	Broken Concrete	Broken concrete either stacked or placed randomly
	Masonry/Concrete	Any stacked, mortared masonry structure or monolithic concrete structure
	Gabion	Rock-filled wire basket
	Sacrete	Concrete sacks placed along bank, cured in place
	Grouted Rock	Similar to rock rip-rap but sprayed with concrete grout
	Cribwall	Earth retaining structure formed of members running parallel to stream anchored into bank with other perpendicular members
	Wood Retaining Wall	Any wood structure that retains soil
	Biotechnical	Any revetment specifically incorporating vegetation for strength in the design
	Automobiles/waste	Old cars, tires, etc.
	Other	Self explanatory
Location	Left Bank	Revetment located on left bank (looking downstream)
	Right Bank	Revetment located on right bank (looking downstream)
Condition	1) Like New	Configuration likely similar to newly constructed condition
	2) Damaged, works	Parts of structure moved or damage by flow, but structure still protects bank
	3) Failing	Structure no longer provides significant protection from erosion
Riparian Habitat	Pools	Stream becomes significantly deeper and/or slower
	Instream cover	Debris/undercut bank/vegetation present below flow line
	Canopy	Stream shaded by veg that could be removed if site stabilized
(represents the type of features that could	Pools & Instream Cover	see above
potentially be changed	Pools & Canopy	see above
by a bank stabilization project at the site)	Instream Cover & Canopy	see above
Length (m)		Estimated length of failure. Used only for QC purposes.
Height (m)		Height of structure, estimated using surveying rod.
Upstream Condition	Stable, no threat	No visible reason to expect banks would begin eroding in future
	Eroding, threat	Upstream bank is beginning to cut around structure, potentially destabilizing it

Downstream Transition	Stable	No visible reason to expect banks would begin eroding in future
	Unstable this bank	Bank is currently eroding, cutting in around structure and/or work on structure could destabilize same bank just downstream
	Unstable opposite bank	Work on structure appears to have potential to destabilize opposite bank just downstream
	Unstable both banks	Work on structure appears to have potential to destabilize both banks just downstream
Photo Time		Time feature was recorded. Used to match with photo.

Significant Changes in Channel Grade (grade.shp)

Significant changes in channel grade are points in the stream bed, either natural or constructed, where the channel steepens significantly. In many cases, these were located where bedrock crosses the stream bed. In these cases, the feature was copied into the bedrock database, but the original feature was retained in the Significant Changes in Channel Grade database.

Table A-3. Change in Channel Grade Data Dictionary

Attribute	Possible Values	Description
Type	Bedrock Sill	Bedrock extends entirely across channel, preventing upstream bed degradation
	Concrete	Concrete extends entirely across channel, preventing upstream bed degradation
	Other	Other type of structure that permanently prevents degradation
Photo Time		Time feature was recorded. Used to match with photo.

Hydraulic Obstructions (Hyd_obst.shp)

Hydraulic obstructions are features that could potentially block part of the flow in the stream channel during a large storm. They were three types: woody debris, willow thickets, or other (usually gravel bars). A rough estimate as to the amount of banktop to banktop flow capacity they could reduce was made in the field by the data technicians. However, these estimates are intended only to help determine the relative importance of the features and should not be considered a definitive hydraulic conclusion.

Table A-4. Hydraulic Obstructions Data Dictionary

Attribute	Possible Values	Description
Type	Willows	Willows colonizing gravel bar reducing stream capacity
	Downed wood	Large woody debris directly reducing capacity or anchoring large gravel bar that reduces capacity
	Other	Any other feature that locally reduces flow capacity
% Capacity Obstructed		Visual estimate of cross sectional area below banktop obstructed by feature
Riparian Habitat	Pools	Stream becomes significantly deeper and/or slower
	Instream cover	Debris/undercut bank/vegetation present below flow line
	Canopy	Stream shaded by veg that could be removed if obstruction removed
(represents the type of features that could	Pools & Instream Cover	see above

potentially be changed	Pools & Canopy	see above
by removing the obstruction)	Instream Cover & Canopy	see above
Photo Time		Time feature was recorded. Used to match with photo.

Reach Characterization Site (strse.shp)

Reach characterization sites were locations in the stream system where the channel characteristics changed as one walked from upstream to downstream. The characteristics of the reach immediately upstream from the sampling point were recorded at the reach characterization sites. Perhaps the most useful piece of data recorded at reach characterization sites were the photographs taken at each location.

Table A-5. Reach Characterization Site Data Dictionary

Attribute	Possible Values	Description
Depositional Features	none	No evidence of long-term deposition in reach
	point bars	Reach characterized by active point bars on inside of meander bends
	mid-channel bars	Reach characterized by several mid-channel bars
	side bars	Reach characterized by bars next to bank but not necessarily on inside of meanders
	delta bars	Reach characterized by bars adjacent to tributaries
	multiple bar types	Combination of above
Main Channel "n"		Field estimate of mannings roughness of low flow channel (note: dropped from hydraulic analysis)
Overbank "n"		Field estimate of mannings roughness for area above low flow channel (note: dropped from hydraulic analysis)
Bar Vegetation	not applicable	No significant bars present in reach
	0-25%	Percentage estimate represents proportion of bars that are stabilized against
	25-50%	further mobilization by bar-top vegetation..
	50-75%	
	75-100%	
Bed Scour Evidence	None	A reach-wide estimate of the magnitude of incision that could has occurred historically
	<1 foot	since the first structures were constructed in the stream channel. Evidence includes
	1-3 feet	undercut revetments, walls, bridge abutments, pipes, etc.
	>3 feet	
Bed Composition	clay	Cohesive consolidated bed. Material can usually support human weight.
	silt	Fine unconsolidated material, often organic. Material often can not support h human wt
	sand	Median particle diameter <0.062 mm (below surface armor layer).
	gravel	Median particle diameter between 2 and 64 mm (below surface armor layer).
	cobbles	Median particle diameter between 64 and 256 mm (below surface armor layer).
	boulders	Median particle diameter above 256 mm..
	bedrock	Bedrock comprises more than 50% of bed.
	concrete	Concrete lining across entire channel.
	other	Any other bed material.

Photo time		Time feature was recorded. Used to match with photo.

Channel Classification (rosgen channel classification.shp)

Data collected for Reach Characterization Sites, discussed above, was used to classify channel reaches using the geomorphic stream classification system developed by Dave Rosgen (1996). The purpose of the classification is to identify stream segments that have similar geomorphic characteristics and consequently are likely to have similar response to future flood events.

Data in the channel classification database is based on the reach characterization site database, strse.shp. The only addition to this database was the actual stream classification according to the Rosgen system.

Channel centerlines developed for the database taken from the WMP HEC-RAS computer model, which developed them based on a LiDAR aerial survey. Where inventory data was collected outside the boundary of the HEC-RAS models (primarily on SLO creek upstream of Cuesta Park and in See Canyon), the stream centerline was digitized from on a scanned USGS quadrangle map.

The Rosgen system relies upon channel cross-sectional geometry, slope, planform, and substrate to classify a given stream reach. The WMP HEC-RAS hydraulic model was used for defining bankfull flow elevation and cross-sectional geometry, channel slope, and planform. Substate material was observed in the field (as part of data collection for strse.shp).

Table A-6. Reach Classification Data Dictionary

Attribute	Possible Values	Description
Rosgen_class	See (Rosgen, 1996)	Geomorphic classification of each channel reach based on channel geometry, slope, substrate, and planform. Geometry data was obtained from WMP HEC-RAS model. Substrate was observed in the field.
Depositional Features	Same as for strse.shp	See description for strse.shp.
Bar Vegetation	Same as for strse.shp	See description for strse.shp. significant bars present in reach
Bed Scour Evidence	Same as for strse.shp	See description for strse.shp.
Bed Composition	Same as for strse.shp	See description for strse.shp.
Photo time	Same as for strse.shp	See description for strse.shp.

Bridges (Bridges.shp)

Bridges were recorded where the channel passed under a roadway, whether through a true bridge or through a culvert. The only information recorded about bridges during the field inventory was a photograph.

Culvert Outfalls (stormdr.shp)

Culvert outfalls were recorded where ever they were visible from the stream. The type, size, and condition were recorded. Small pipes under six inches in diameter and underdrains were not inventoried due to time constraints. Also, since it is possible that certain culvert outfalls were not visible from the stream channel, the database provided here is likely incomplete.

Table A-7. Culvert Outfall Data Dictionary

Attribute	Possible Values	Description
Type	CMP	Corrugated Metal Pipe
	RCP	Reinforced Concrete Pipe
	Plastic	Any form of synthetic pipe material
	Box	Concrete Box Culvert
	Other	Other
Diameter (inches)		
Width (in, for box)		for box culverts
Height (in, for box)		for box culverts
Pipe Condition	Good	Pipe is likely to remain functional for the foreseeable future

	Average	Pipe is functional but has evidence of corrosion
	Poor	Pipe is corroded, possibly structurally unsound
Outfall Condition	No Erosion	Outfall uneroded
	Eroding	Outfall eroding, often with gully present
Photo Time		Time feature was recorded. Used to match with photo.

Visible Bedrock (bdrkline.shp and bdrkpts.shp)

Bedrock was an attribute that could be recorded as part of several kinds of features. For instance, it was possible to record bedrock at the toe of an eroding bank, on the bed of the channel in a channel reach, as a type of grade break, or as a separate feature. During post-processing, all features that contained bedrock were copied into a separate file (actually two files, one for point features and one for line features). Since the bedrock features were obtained from other features which are present in other inventory shape files, they often overlap the features they were derived from. This is a particularly large amount of overlap with the Change in Channel Grade database, since rock sills across the channel often result in abrupt changes in the channel profile. No attributes were coded into the GIS database for bedrock since it was generally compiled from other feature types.

References:

Rosgen, Dave, 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

APPENDIX B

Biological Resources Inventory

Prepared for:

Phase II Waterway Management Plan
for
San Luis Obispo County Zone 9
Flood Control and Water Conservation District
and
City of San Luis Obispo

Prepared by:

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Environmental Services

January 2002

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Background Research/Studies

This Appendix describes the existing biological resources found within the study reaches of San Luis Obispo Creek, East Fork of San Luis Obispo Creek, Prefumo Creek, Stenner Creek, Brizziolari Creek and See Canyon Creek. The information in this Appendix is a compilation of botanical, wildlife, and fisheries data gathered during the Phase II creek inventory and from previous biological surveys along San Luis Obispo (SLO) Creek and its tributaries. The primary literature sources reviewed include:

- Biological resources assessment and impact analysis for the SLO Creek Water Reuse Project (Fugro West 1995);
- SLO Creek Restoration Plan (SLO Land Conservancy 1988);
- SLO Creek steelhead habitat inventory (Cleveland 1996);
- Stream Corridor Management Plan for SLO Creek Phase I Study Area (Questa 1997), and;
- SLO Creek Watershed Hydrologic Survey (SLOLC 1996).

Several Biological Assessments and Environmental Determinations for projects located along the SLO Creek riparian corridor were also reviewed.

Phase I Inventory Methods

Vegetative resources were mapped in Phase I using 21 vegetative series from the nomenclature of Sawyer and Keeler-Wolf (1995). The Reaches 8, 9, 10, 14, 17, and 19 of SLO Creek and tributaries were characterized in the Phase I study utilizing the following procedures:

- Extensive review of regional and local data sources and previous Environmental Determinations prepared for other proposed projects in the vicinity of SLO Creek and tributaries.
- Use of available aerial photography to identify limits of existing riparian vegetation.
- Ground-based confirmation of limits of riparian vegetation identified through aerial photographs.
- Canvassing of study areas during months of January and February of 1997 in order to characterize plant series' and enhancement opportunities.
- Visual estimation of cover values for herbaceous, shrub and tree layers.
- The analysis and compilation of existing data and field data, which consist of series-based maps of the riparian corridor (Plate III) and tables outlining cover values and enhancement opportunities (Appendix III).

Phase I creek reaches were inventoried for steelhead trout habitat following guidelines presented in the second edition of the *California Almonid Stream Habitat Restoration Manual (Flossi and Reynols, 1991).* The habitat types delineated were pools, riffles and flatwaters.

Phase II Inventory Methods
The baseline biological data for the Phase II study was inventoried in the field using a Trimble XR GPS unit. Creating an appropriate data dictionary was based upon review of the Phase I inventory and refined in consultation with Zone 9 and participating agencies. The resulting inventory included the following components: streams, pools, undercut banks, trees, shrubs, grasses, exotics, sensitive species and cultural resources. The methodology used in recording data for each of these resources is described below. It is important to note that although this has been termed a biological inventory, there are many components of the biological community of San Luis Obispo Creek and its tributaries that were not mapped or investigated within the scope of the Phase II study.

The data collected during field inventory was compiled in GIS (Geographic Information System) to be available for a variety of mapping and planning endeavors. The GIS data is available through a Cal Poly website at *http://midnight.calpoly.edu/gist/slo_creek* and through the City of San Luis Obispo Engineering Department.

Streams
Streams were recorded as line features using the GPS unit. The water edge at both banks was walked and recorded by the GPS. The field technician began by walking upstream along the left bank to collect the attributes (characteristics) of the stream channel. Walking upstream was required in order to more easily observe instream features as walking downstream would cause turbidity to impair visibility of the attributes. Attributes that were recorded in the field are as follows:

- Type (glide, riffle, or run)
- Substrate (silt/clay, sand, gravel, cobble, boulder, bedrock, or man-made)
- Gradient (low, high, or cascade)
- Depth (<0.5m, 0.5-1m, 1-2m, or >2m)

The line of the right bank was recorded while walking downstream. These two line features established a general width of the creek. The stream type observed in the field was based on the definitions described in the U.S. Forest Service's *Stream Habitat Classification and Inventory Procedures for Northern California, Fish Habitat Relationships Technical Bulletin, No. One (no date).*

Classifying substrate proved more subjective. Many sections of creek consisted of a mixed assortment of substrate. For the purposes of this inventory, the substrate recorded was the predominant type present. In many instances, silt covered the substrate. If silt caused the substrate to become more than 80% embedded the substrate was classified as silt/clay, otherwise it was classified according to the underlying substrate. Cobble was distinguished from gravel if the substrate was generally larger than 1 inch in diameter.

Stream gradient classification was also based on the above-mentioned manual.

Stream depth was estimated and generalized throughout the stream type. Often, mapping the stream required traversing under heavy riparian canopy that eliminated satellite reception and disabled the GPS unit function for varying lengths of creek. Aerial photographs and field notes were used during such occurrences to provide a characterization of the stream.

Pools

Pools were recorded with the GPS unit as two point features. The first point was the downstream end of the pool, while the second point was recorded at the upstream end of the pool. As with the stream feature, pools were recorded while walking upstream in order to decrease the likelihood of silting the pool and impairing observation of the pool attributes. Pool attributes recorded in the field are as follows:

- Width
- Type (backwater, confluence, corner, dammed, lateral scour, mid-channel, plunge, pocket, or secondary channel)
- Substrate (clay, silt, sand, gravel, cobble, claystone, bedrock, or man-made)
- Depth (<0.5m, 0.5 - 1m, 1 – 2m, or >2m)
- Cause (bedrock, root wad, log, or man-made)
- Shade cover (80% +, 50-79%, 25-49%, or <25%)
- Emergent vegetation (yes or no)

The width of the pool was estimated in the field and not measured directly. The pool type observed in the field was based on the definitions described in the U.S. Forest Service's *Stream Habitat Classification and Inventory Procedures for Northern California.* Substrate found in the pools was evaluated in the same way that was described for streams, above.

The depth of the pools was also estimated and placed within one of the four depth ranges provided by the GPS data dictionary. The cause of the pools was also based on the Habitat Classification manual referred to above. The percentage of shade cover a pool had was estimated as the percentage of the pool under the canopy if looking straight down from directly above the pool. Emergent vegetation was noted simply as present or absent.

Photographs were taken of most pools. Every attempt was made to take the photographs from the downstream end of the pool. However, when vegetation or lighting obstructed the view of the pool an alternative angle was used. Accuracy was diminished in some instances by the inability to access GPS satellites signals due to the thick canopy. Aerial photographs were used in the field to help accurately fill in the gaps in GPS data.

Undercut Banks

Undercut banks were also recorded as two points representing the downstream and upstream ends of the undercut bank.

Trees

Tree species were recorded as area features with the GPS unit. The field technician recorded tree features by walking around individuals and groups of trees. In locations where the technician was unable to walk around the tree area, aerial photographs were used to identify the extent of the area during post-processing. Accuracy was diminished in some instances by the inability to access signals from satellites due to the thick canopy. Aerial photographs were used in the field to help accurately fill in the gaps in GPS data. Attributes of the tree features recorded in the field are as follows:

- Type (arroyo willow, black cottonwood, box elder, black walnut, coast live oak, California sycamore, eucalyptus, Hinds walnut, Monterey cypress, Monterey pine, mixed willow, pepper tree, California bay, or ornamental)
- Percent cover (80% +, 50-79%, 25-49%, or <25%).

The species specifically identified by type in the GPS unit were chosen for consistency with the Phase I inventory. The Phase II tree inventory differs from that of Phase I in that tree features were not recorded as tree "series", but as individuals and stands of trees. The ornamental option was added to identify tree species, other than those specifically named that are horticultural varieties not native to the watershed.

Shrubs

Shrubs were recorded as area features with the GPS unit. The field technician recorded shrub features by walking around individuals and groups of shrubs. In locations where the technician was unable to walk around the shrub area, aerial photographs were used to identify the extent of the area during post-processing. Attributes of the shrub features recorded in the field are as follows:

- Type (California sagebrush, coyote bush, other shrub, or ornamental
- Other ID (type in the shrub species)
- Percent cover (80% +, 50-79%, 25-49%, or <25%)

The ornamental type was added to identify shrub species that are horticultural varieties not native to the watershed. Accuracy was diminished in some instances by the inability to access signals from satellites due to the thick canopy. Aerial photographs were used in the field to help accurately fill in the gaps in GPS data.

Grasses

Grasses were recorded as area features with the GPS unit. Attributes of the grass features recorded in the field are as follows:

- Type (perennial-introduced, perennial-native, serpentine, annual-introduced, annual-native, crops, and agricultural use)
- Percent cover (80% +, 50-79%, 25-49%, or <25%)

Grass areas were only recorded when grass was the primary vegetation type of an area or when an area contained a native grass component. Some areas within the watershed exhibit crop or agricultural use to the edge of the stream. For this reason, crops and agricultural use were added to the collection dictionary. Kikuyu grass was recorded as an exotic species due to its aggressive nature and the need to address its eradication.

Exotic Species

Exotic species were recorded as point and line features using the GPS unit. Isolated individual occurrences were typically recorded as point features, whereas large areas of exotics were recorded as lines showing the extent of coverage. Attributes of the exotic species recorded in the field are as follows:

- Type (Arundo, cape ivy, castor bean, or other)
- Other ID (exotic species name)
- Percent cover (80% +, 50-79%, 25-49%, or <25%)

Arundo, cape ivy, and castor bean are specifically addressed because they were identified as the primary exotic species in the watershed. However, the "Other ID" field allowed us to type in other exotic species that occurred throughout the watershed. Typically, exotic species that have groundcover habits, such as cape ivy, Vinca, kikuyu grass and English ivy, were recorded as line features. The length of the line delineates their upstream and downstream extents.

Special-status Species

A few of the special-status species in the watershed were specifically included in the inventory. These included the California red-legged frog, southern steelhead, southwestern pond turtle, two-striped garter snake, tidewater goby, and southwestern willow flycatcher. Sightings of these species were recorded as point features when observed. The number individuals of each species observed at any particular point was recorded. Age class was also noted for red-legged frog and steelhead. The only special-status animal species observed during the inventory were southwestern pond turtle and southern steelhead.

Cultural Resources

Cultural resources were recorded as point features with the GPS unit. This feature was included in the event that any obvious signs of cultural or historic resources were encountered. This inventory effort was not intended to serve as a comprehensive survey of the riparian corridor. The types of cultural resources in the data dictionary were as follows:

- shell midden,
- dark-oily soil,
- modified chert or obsidian
- bones, rock mortar, groundstone
- homeless camp
- building remains

The only type from this list that was observed and recorded was homeless camp. Homeless camp was included at the request of the City.

Habitats - Vegetation Classification Overview

Riparian vegetation within the San Luis Obispo Creek watershed was classified and mapped during the Phase I inventory (Questa 1997) using the vegetative series nomenclature of Sawyer and Keeler-Wolf (1995). In total, 21 vegetative series were identified during the Phase I effort. The following discussion approaches classification of vegetation in a somewhat different manner, using the classification system authored by the California

Department of Fish and Game (R. Holland 1986) and the system used by the USFWS (Cowardin et al. 1979). Both of these classification systems are more broad-brushed than Sawyer and Keeler-Wolf, resulting in fewer classified community types. Using these two classification references, six habitat types were identified in association with the San Luis Obispo Creek riparian corridor, including: 1) Riverine, 2) Freshwater Marsh, 3) Riparian Forest, 4) Riparian Scrub, 5) Southern Coastal Salt Marsh, and 6) Ruderal/Disturbed. Descriptions of these habitats, as found in the SLO Creek watershed, are provided below.

Habitat Types

Riverine Habitat

The streambed areas of San Luis Obispo Creek and its major tributaries are classified as Riverine habitat. Riverine habitat includes both the active flowing channel and associated gravel/sand floodplain areas. Seasonally, this habitat type supports emergent hydrophytes (water loving plants) such as watercress (*Rorippa nasturtium-aquaticum*), bulrush (*Scirpus* spp.), and cattail (*Typha latifolia*). Such vegetated areas are often classified as jurisdictional wetlands and are regulated by the U.S. Army Corps of Engineers. Upper watershed areas have relatively steep stream gradients and higher flow velocities, while lower riverine habitats have slower water velocities and well-developed floodplains. Substrate within this habitat type is typically variable, and may consist of bedrock, clay, cobbles, gravels, and sand.

Freshwater Marsh Habitat

Freshwater marsh communities typically occur in nutrient-rich mineral soils that are saturated throughout most of the year. These communities are found in locations containing slow-moving or stagnant shallow water and a high water table (R. Holland 1986). Such sites commonly occur around springs, seeps, stream channels, and depressional areas that accumulate runoff from surrounding areas. Standing water does not have to be present throughout the entire year, since the water table is so close to the soil surface that it can be tapped in the dry season by hydrophytic plants.

Plant species diversity within freshwater marsh areas of the watershed is moderate to high, and this habitat type typically exhibits dense vegetative coverage. Various plant species observed in areas of freshwater marsh containing saturated soils or surface water include arroyo willow (*Salix lasiolepis*), cattail, barnyard grass (*Echinocloa crus-galli*), water smartweed (*Polygonum punctatum*), California bulrush (*Scirpus californicus*), saltgrass (*Distichlis spicata*), brown-headed rush (*Juncus phaeocephalus*), umbrella sedge (*Cyperus eragrostis*), watercress, spikerush (*Eleocharis macrostachya*), seep monkeyflower (*Mimulus guttatus*), and duckweed (*Lemna* spp.). Additional species typical of the study areas include mugwort (*Artemisia douglasiana*), horsetail and scouring rush (*Equisetum* spp.), and stinging nettle (*Urtica* spp.). A good example of freshwater marsh habitat may be seen within the lower reaches of the East Fork of San Luis Obispo Creek (Morro Group 2001a).

Riparian Forest Habitat

Riparian forest habitat consists of moderate to dense closed-canopy broadleaf vegetation that closely follows streambank contours. Dominant species and canopy density varies with elevation and topography along the riparian corridor. The overall structure of the riparian community found within the study areas is composed of an assemblage of native and introduced tree species. Species characteristic of the overstory layer include endemic species such as tree and shrub forms of willows (*Salix lasiolepis*, *S. lucida* ssp. *lasiandra*, and *S. laevigata*), California sycamore (*Platanus racemosa*), black walnut (*Juglans hindsii* ssp. *hindsii*), coast live oak (*Quercus agrifolia*), California bay (*Umbellularia californica*), Fremont cottonwood (*Populus fremontii*), black cottonwood (*P. balsamifera* ssp. *trichocarpa*), Monterey pine (*Pinus radiata*), Monterey cypress (*Cupressus marocarpa*), white alder (*Alnus rhombifolia*), big-leaf maple (*Acer macrophyllum*), and box elder (*Acer negundo* ssp. *californica*). Non-native, naturally reproducing trees commonly found within the watershed include eucalyptus (*Eucalyptus* spp.), black locust (*Robina pseudoacacia*), pepper tree (*Schinus molle*), phoenix palm (*Phoenix canariensis*), and tree of heaven (*Ailanthus altissima*). Urban areas of the watershed typically also contain a large number of ornamental tree species. This is the dominant streamside habitat type within the SLO Creek watershed at those locations not subject to urban encroachment or severe cattle grazing. Good examples of riparian forest habitat are evident on the upper SLO Creek mainstem near Cuesta Park.

Riparian Scrub Habitat

Riparian scrub communities are characterized as scrubby streamside thickets dominated by willows that occur along frequently inundated lands along perennial and intermittent rivers and streams, or in areas where the water table is at or near the ground surface (R. Holland 1986). These communities are considered sensitive by CDFG and frequently qualify as wetland, thereby also falling under Corps jurisdiction. Riparian scrub is distributed throughout the San Luis Obispo Creek watershed). This community type typically occurs adjacent to flowing stream channels or seasonally flooded arroyos, or in depressional areas located close to ground water. The overstory of the riparian scrub community is typically dominated by dense arroyo willow. Characteristic native shrub species include coffeeberry (*Rhamnus californica*), wild rose (*Rosa californica*), toyon (*Heteromeles arbutifolia*), elderberry (*Sambucus mexicana*), poison oak (*Toxicodendron diversilobium*), virgin's bower (*Clematis ligustifolia*), coyote brush (*Baccharis pilularis*), mule fat (*B. salicifolia*), California sagebrush (*Artemisia californica*), fuchsia-flowered gooseberry (*Ribes speciosum*) and blackberry (*Rubus ursinus*).

Exotic shrub species found within the watershed include castor bean (*Ricinus communis*), giant reed (*Arundo donax*), tree tobacco (*Nicotiana glauca*), Scotch broom (*Cytisus scoparius*), cultivated Himilayan blackberry (*Rubus discolor*), cocklebur (*Xanthium* spp.), Cape ivy (*Delairea odorata*), poison hemlock (*Conium maculatum*), sweet fennel (*Foeniculum vulgare*), and Japanese honeysuckle (*Lonicera japonica*). Riparian scrub communities often are dominated by hydrophytes and as such, may be classified as jurisdictional wetland habitat regulated by the Corps. This habitat type is common within the SLO Creek watershed, with good examples evident on the SLO Creek mainstem near the South Higuera Street bridge (Morro Group 2001b).

Southern Coastal Salt Marsh

This community typically occurs near the confluence of creeks and seawater, in areas protected from wave action. These habitats typically exhibit a characteristic zonation of plant types based on depth and duration of inundation by salt water. Coastal salt marsh vegetation consists primarily of low-growing, salt tolerant, herbaceous perennial plants. Species consist of perennial, emergent, herbaceous monocots, including sedges (*Carex spp*), saltgrass, rushes (*Juncus* spp.), frankenia (*Frankenia grandiflora*), fleshy jaumea (*Jaumea carnosa*), pickleweed (*Salicornia virginica*), and cattails. Southern coastal salt marsh may be classified as jurisdictional wetland habitat regulated by the Corps. This habitat type occurs patchily within the tidally influenced portion of SLO Creek below the Marre Dam.

Ruderal/Disturbed Habitat

Ruderal vegetation (disturbed habitat) is found in areas that have been significantly altered by agriculture, construction, or other land-clearing activities. Ruderal habitats often occur in abandoned agricultural fields, along roadsides, and in other areas experiencing severe ground surface disturbance. Ruderal areas are present throughout the lower portions of the watershed, particularly in urbanized areas. Representative species at these locations include summer mustard (*Hirschfeldia incana*), poison hemlock, kikuyu grass (*Pennisetum clandestinum*), *Vinca*, Italian thistle (*Carduus pycnocephalus*), giant reed, bristly ox-tongue (*Picris echioides)*, and castor bean. Exotic species commonly found within the herbaceous layer consist of periwinkle (*Vinca major*), Cape ivy, bristly ox-tongue, English ivy (*Hedera helix*), Bermuda buttercup (*Oxalis pes-caprae*), rabbitsfoot grass (*Polypogon monspeliensis*), and Bermuda grass (*Cynodon dactylon*). These species often intergrade with Riparian Scrub habitat.

Extensive areas containing exotic species are present throughout the watershed. Generally, these plants are ornamental, agricultural or weedy species that have escaped and become naturalized. These invasive plant species often have no natural predator and therefore have the ability to out compete native species for valuable habitat. This displacement of native plant species degrades overall riparian habitat quality. Tree species that negatively impact native habitat include eucalyptus, black locust, and tree of heaven. Shrubs include giant reed, castor bean, sweet fennel, poison hemlock, and Scotch broom. Herbs include Cape ivy, periwinkle, bristly ox-tongue, and Japanese honeysuckle.

Sensitive Communities and Species

Sensitive species are plants and animals that are either listed as endangered or threatened under the Federal or California Endangered Species Acts, rare under the California Native Plant Protection Act, or considered to be rare (but not formally listed) by resource agencies, professional organizations (e.g., Audubon Society, CNPS, The Wildlife Society), and the scientific community. For the purposes of this project, sensitive species are defined in Appendix A. Sensitive communities are those habitats or plant associations considered rare by the CDFG (R. Holland 1986).

The following sections address those sensitive communities and species known from, or with a reasonable chance to occur within, the SLO Creek watershed. The primary source consulted was the California Natural Diversity Database (NDDB) for the San Luis Obispo (NDDB 2000a), Pismo Beach (NDDB 2000b), and Lopez Mountain (NDDB 2001) quadrangles. Other sources include the documents listed at the beginning this Appendix B. Table B-1 identifies the name and legal status of sensitive taxa revealed during this search, and a narrative discussion follows.

Sensitive Plant Communities

Two rare plant communities (R. Holland 1986) were mapped by the NDDB (2000a, 2000b) within the SLO Creek watershed, including Coastal and Valley Freshwater Marsh, and Serpentine Bunchgrass. Three addition CDFG rare habitats are also present within the watershed. These include Northern Coastal Salt Marsh, Central Coast Arroyo Willow Riparian Forest, and Central Coast Riparian Scrub. All of these habitats are recognized by the CDFG as "rare" based on past and present habitat degradation and land conversion practices.

Northern Coastal Salt Marsh

Northern Coastal Salt Marsh habitat is defined by the CDFG (R. Holland 1986) as those salt marsh habitats ranging from the Oregon border southward to Point Conception, Santa Barbara County, California. This habitat type is highly productive, and is typically composed of herbaceous, salt-tolerant species. Regular tidal inundation is a physical requirement of this habitat type, which has been reduced in distribution historically by intensive seaport development, particularly in Humboldt Bay, Tomales Bay, Elkhorn Slough, Morro Bay, and San Francisco Bay (R. Holland 1986). Northern Coastal Salt Marsh habitat is restricted to isolated patches and narrow strips within the lower portions of Reach 1 of SLO Creek. Representative species within Reach 1 include pickleweed (*Salicornia virginica*) and saltgrass (*Distichlis spicata*).

Central Coast Arroyo Willow Riparian Forest

This habitat type is typified by dense, low, closed-canopy, broadleafed, winter deciduous riparian forests dominated by arroyo willow (*Salix lasiolepis*). Other willow species such as red willow (*S. laevigata*) and yellow willow (*S. lasiandra*) typically are found in association with this habitat type. Central Coast Arroyo Willow Riparian Forest (CCAWRF) habitat is distributed along low-gradient stream corridors from coastal Monterey to Santa Barbara. Within the SLO Creek watershed, this habitat type is widely distributed through most reaches of the SLO Creek mainstem, and within most SLO Creek tributaries. Within Reach 1, tidal influences have limited the distribution of CCAWRF habitat to the area near Marre Dam.

Central Coast Riparian Scrub

Similar to CCAWRF habitat (previous section), Central Coast Riparian Scrub (CCRS) habitat is widely distributed within the SLO Creek watershed, and is ubiquitous within all SLO Creek tributaries and mainstem reaches other than Reach 1. This habitat generally consists of a scrubby streamside thicket dominated by any of several willow species. R. Holland (1986) considers CCRS habitat an early seral community, later developing to riparian forest habitats. Characteristic species include willows (*Salix* spp.) and coyote brush (*Baccharis pilularis*).

Coastal and Valley Freshwater Marsh

Coastal and Valley Freshwater Marsh (CVFWM) habitat is typically dominated by perennial, emergent monocots, often forming completely closed canopies. This habitat type is characteristic of permanently flooded freshwater sites without significant current. The NDDB (2000a) maps CVFWM habitat in association with Laguna Lake within the Prefumo Creek sub-watershed. An expansive area of CVFWM habitat exists near the lower portions of the East Fork near its confluence with SLO Creek, with hydrology supplied by the East Fork and several groundwater seeps flowing downward from the serpentine ridge south of confluence area (Morro Group 2000a). The CDFG (R. Holland 1986) considers CVFWM habitat as sensitive in California primarily due to farmland conversion and other large-scale mechanisms of habitat loss.

Serpentine Bunchgrass

Serpentine Bunchgrass is characteristically open grassland dominated by native, perennial bunchgrasses with typically low vegetative cover. Within the study area, the dominant species is purple needle-grass (*Nassella pulchra*). The NDDB (2000a) maps this community type above the Cal Poly campus in association with Brizziolari Creek. A good example of serpentine bunchgrass habitat can be seen at the base of the serpentine outcrop immediately south of the confluence of the East Fork with SLO Creek (Morro Group 2000a).

Sensitive Plant Species

Thirteen sensitive plant species are known to be present within or adjacent to riparian areas of the watershed (refer to Table B-1). Most of the species listed are considered serpentine associates or serpentine endemics. Individual species accounts, described below, are based largely on Skinner and Pavlik (1994), Hoover (1970), and Hickman (1993). Occurrence data are primarily derived from the NDDB and from the Cal Flora Occurrence Database (www.calflora.org), unless noted otherwise in text.

TABLE B-1
Sensitive Vegetation with the Potential to Occur in the San Luis Obispo Creek Riparian Corridor

Scientific Name	Common Name	Legal Status Federal/State/CNPS/RED
Communities		
	Northern Coastal Salt Marsh	CDFG Rare
	Central Coast Arroyo Willow Riparian	CDFG Rare
	Central Coast Riparian Scrub	CDFG Rare
	Coastal/Valley Freshwater Marsh	CDFG Rare
	Serpentine Bunchgrass	CDFG Rare
Plants		
Arctostaphylos pechoensis	Pecho manzanita	FSC/--/1B/2-2-3
Arctostaphylos wellsii	Wells's manzanita	--/--/1B/2-3-3
Calochortus obispoensis	San Luis mariposa lily	--/--/1B/2-2-3
Carex obispoensis	San Luis Obispo sedge	--/--/1B/2-2-3
Chorizanthe brewerii	Brewer's spineflower	--/--/1B/3-1-3
Cirsium fontinale var. *obispoense*	Chorro Creek bog thistle	FE/SE/1B/3-2-3
Dudleya abramsii ssp. *bettinae*	San Luis Obispo serpentine dudleya	FSC/--/1B/3-2-3
Dudleya abramsii ssp. *murina*	San Luis Obispo dudleya	--/--/1B/2-1-3
Centromadia parryi ssp. *congdonii*	Congdon's tarplant	FSC/--/1B/3-3-3
Layia jonesii	Jones's layia	FSC/--/1B/3-2-3
Sanicula maritima	adobe sanicle	FSC/SR/1B/3-3-3
Senecio aphanactis	rayless ragwort	--/--/2/3-2-1
Streptanthus albidus var. *peramoenus*	most beautiful jewel-flower	FSC/--/1B/2-2-3
FE: federally endangered **FSC**: federal species of concern **SE**: California endangered **SR**: California rare *California Native Plant Society (CNPS):* **List 1B** = rare in California and elsewhere. **List 2** = rare in California	*CNPS Rare-Endangerment-Distribution*: **Rare**: 1 = rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time; 2) distributed in a limited number of occurrences, occasionally more if each occurrence is small; 3) distributed in one to several highly restricted occurrences, or present in such small numbers that it is seldom reported.	CNPS R-E-D (continued): **Endangerment**: 1) not endangered; 2) endangered in a portion of its range; 3) endangered throughout a portion of its range. **Distribution**: 1) more or less widespread outside California; 2) rare outside California; 3) endemic to California.

Table B-2 presents the occurrences of sensitive habitats and plant species in the study reaches. Central coast arroyo willow riparian forest and Central Coast riparian scrub, both sensitive habitats are prevalent throughout all of the creek reaches. The potential for occurrence of a sensitive plant species is indicated where reach conditions/habitat are particularly suitable for that species.

TABLE B-2
Sensitive Habitats & Plant Species Occurring in the Study Reaches

Sensitive Habitats	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**	**Reach 12**	**Reach 13**	**Reach 14**	**Reach 15**	**Reach 16**	**Reach 17**	**Reach 18**	**Reach 19**	**Reach 20**	**Reach 21**	**Reach 22**	**Reach 23**	**Reach 24**	**Old Garden Creek**
Northern Coastal Salt Marsh	x																								
Central Coast Arroyo Willow Riparian Forest	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Central Coast Riparian Scrub	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Coastal and Valley Freshwater Marsh															x	x						x			
Serpentine Bunchgrass																x									
Sensitive Plant Species																									
Pecho manzanita		p																					p		
Wells's manzanita	x	x																							
San Luis mariposa lily													p	x									p		
San Luis Obispo sedge															p			p							
Brewer's spineflower													x	x								x	x		
Chorro Creek bog thistle																x									
San Luis Obispo serpentine dudleya																x									
San Luis Obispo dudleya									x																
Congdon's tarplant																									
Jones's layia						x	x									x	x	x							
adobe sanicle																	x	x							
rayless ragwort									x				x	x											
most beautiful jewel-flower											x	x	x	x									x		

x indicates record/sighting in CNDDB
p indicates the potential to occur in this reach

Pecho Manzanita (*Arctostaphylos pechoensis*)
Pecho manzanita is known from the western portion of the Santa Lucia Range, from Coon Creek, and from See Canyon. This species is endemic to siliceous shale of San Luis Obispo County, occurring primarily in closed cone coniferous forests, chaparral, and coastal scrub communities. The typical flowering period for this species is January through March. Pecho manzanita is a federal special concern species that is considered very rare (RED 2-2-3) by the CNPS. The NDDB (2000a, 2000b) maps pecho manzanita along Prefumo Canyon Road, and within the San Miguelito Creek drainage between See Canyon and Davis Canyon.

Wells's Manzanita (*Arctostaphylos wellsii*)
This San Luis Obispo County endemic shrub is included on CNPS List 1B, but does not currently have any state or federal status. It has an R-E-D code of 2-3-3 (very rare). Wells's manzanita occurs in the San Luis Range from upper Coon Creek in Montana de Oro State Park to Arroyo Grande and Nipomo. The main populations of this species are found in the sandstone hills between the San Luis Valley and the ocean. The NDDB (2000b) maps this species along Avila Beach Road, near Sycamore Mineral Springs.

San Luis Mariposa Lily (*Calochortus obispoensis*)
San Luis mariposa lily is a perennial, herbaceous member of the lily family that is endemic to San Luis Obispo County, ranging from Cuesta Pass south to Arroyo Grande. The San Luis mariposa lily is known from chaparral, coastal scrub, grassland, and freshwater seep habitats of dry, serpentine soils. This species blooms from May to July. The California Native Plant Society (CNPS) assigns this species to List 1B, 2-2-3 R-E-D. The NDDB and Cal Flora list 48 historical occurrences of this species, with the majority located on west Cuesta Ridge, upper SLO Creek near Reservoir Canyon, upper Stenner Creek, and upper Chorro Creek. An additional occurrence is mapped in the Froom Creek region.

San Luis Obispo Sedge (*Carex obispoensis*)
San Luis Obispo sedge is a perennial (rhizomatous) herb that is native and endemic to California. This species chiefly occurs on steep, serpentine-derived hillsides in association with chaparral and coastal sage scrub habitats, and flowers from April to June. The CNPS considers this species as rare (List 1B, 2-2-3 R-E-D). Cal Flora lists 34 historical occurrences of this species, with the majority of these from west Cuesta Ridge, San Simeon, Cerro Alto, and the Prefumo Creek region. In addition, the NDDB (2000a) maps this species near the headwaters of Stenner Creek. Suitable habitat for this species is present within areas of the watershed containing serpentine soils.

Brewer's Spineflower (*Chorizanthe brewerii*)
Brewer's spineflower occurs in closed-cone coniferous forest, chaparral, cismontane woodland, and coastal scrub habitats, primarily on serpentinite substrates. The NDDB and Cal Flora list 48 historical occurrences of this species, with the majority located on west Cuesta Ridge, upper SLO Creek in Reservoir Canyon, Stenner

Creek, and Chorro Creek. Suitable habitat for this species is present within areas of the watershed containing serpentine soils. The CNPS considers this species as rare (List 1B, 3-1-3 R-E-D).

Chorro Creek Bog Thistle (*Cirsium fontinale* var. *obispoense*)
The Chorro Creek bog thistle, a San Luis Obispo County endemic, occurs primarily in association with serpentine seeps located in chaparral and cismontane woodland communities. This fairly tall (to 6.5 feet) perennial herb flowers primarily from February to July. It is ranked by CNPS as extremely rare (List 1B, 3-2-3 R-E-D). It is listed as both State and Federally Endangered. Chorro Creek bog thistle is mapped by the NDDB and Cal Flora as occurring along Prefumo Creek. Fugro (1995) reports occurrences of this species from Laguna Lake and Froom Creek.

San Luis Obispo Serpentine Dudleya (*Dudleya abramsii* ssp. *bettinae*)
San Luis Obispo serpentine dudleya is a succulent, perennial herb and a San Luis Obispo County endemic that is distributed within the San Luis Obispo, Morro Bay North, Cayucos, and Morro Bay South quadrangles. It is typically associated with coastal scrub and valley foothill grassland communities on serpentine soils, and blooms from May to July. It is ranked by the CNPS as extremely rare (List 1B, 3-2-3 R-E-D), and is listed by the federal government as a Species of Concern. Cal Flora catalogs 17 historical occurrences of this species, with most from Morro Bay and Cayucos. However, an occurrence was mapped in 1994 on "glider hill", a serpentine outcropping directly behind (west of) Madonna Inn.

San Luis Obispo Dudleya (*Dudleya abramsii* ssp. *murina*)
San Luis Obispo dudleya flowers from May to June, and is a serpentine endemic to California that is typically found in chaparral and foothill woodland habitats. It is considered rare by the CNPS (List 1B, 2-1-3 R-E-D). Similar to *D. a. bettinae*, San Luis Obispo dudleya is not mapped on the NDDB (2000b) Pismo Beach quadrangle. Cal Flora catalogs 10 historical occurrences of this species, with most from Cuesta Park (north San Luis Obispo City), and a single occurrence on Cerro San Luis in 1950.

Congdon's Tarplant (*Centromadia parryi* ssp. *congdonii*)
Congdon's tarplant is endemic to California, occurring primarily within annual grassland habitats containing alkaline soils. Throughout San Luis Obispo County this species has been documented within low valleys located just west of the City of San Luis Obispo (Hoover 1970). This annual herb flowers from June through November. Congdon's tarplant is a federal special concern species considered by the CNPS as extremely rare (RED 3-3-3). The NDDB (2000a) maps this species as occurring near Laguna Lake.

Jones's Layia (*Layia jonesii*)
Jones's layia is an annual herb found on serpentine or clay-based chaparral and valley grassland habitats. Within San Luis Obispo County, this species is known to range primarily from the Cayucos area south to San Luis Obispo. It is a California endemic, with flowering generally occurring in March to May. Jones's layia is a

Federal Species of Special Concern, and is considered extremely rare by the CNPS (List 1B, 3-2-3 R-E-D). Cal Flora maps 33 occurrences throughout San Luis Obispo City and Morro Bay. Particularly, occurrences are mapped along south Higuera Street and near Laguna Lake.

Adobe Sanicle (*Sanicula maritima*)
Adobe sanicle is a San Luis Obispo County endemic. It is a federal concern and state rare species considered by the CNPS as extremely rare (3-3-3). Adobe sanicle is typically restricted to highly localized, seasonally wet areas located near the coast, and is generally found in association with grassland communities. The NDDB (2000a) maps this species on the low hills and valleys located west of San Luis Obispo City, and specifically, near Laguna Lake.

Rayless Ragwort (*Senecio aphanactis*)
Rayless ragwort is an annual herb that occurs in cismontane woodland and coastal scrub habitats, on alkaline soils (Skinner and Pavlik 1994). The typical flowering period for this species is from January through April. The NDDB (2000a) documents this species as occurring just east of the City of San Luis Obispo near Highway 101, in the vicinity of Madonna Road, and near the headwaters of SLO Creek. The CNPS considers this species as extremely rare (RED 3-2-1).

Most Beautiful Jewel-flower (*Streptanthus albidus* ssp. *peramoenus*)
Most beautiful jewel-flower is an annual herb that occurs in chaparral and grassland habitats, primarily on serpentine substrates (Skinner and Pavlik 1994). This species typically blooms from April through June. The California Native Plant Society (CNPS) assigns this species to List 1B, 2-2-3 R-E-D. The NDDB and Cal Flora document 22 historical occurrences throughout San Luis Obispo County, including Brizziolari, Stenner, Prefumo, and SLO creeks.

Sensitive Wildlife Species
The NDDB (2000a, 2000b, 2001) and environmental documents prepared within the SLO Creek watershed indicate the occurrence, or the reasonable potential for occurrence, of 13 sensitive animal species within the study area (Table B-3). These include: Cooper's hawk (*Accipiter cooperi*); pallid bat (*Antrozous pallidus*); southwestern pond turtle (*Clemmys marmorata pallida*); monarch butterfly (*Danaus plexippus*); yellow warbler (*Dendroica petechia*); willow flycatcher (*Empidonax traillii*); tidewater goby (*Eucyclogobius newberryi*); yellow-breasted chat (*Icteria virens*); southern steelhead trout (*Oncorhynchus mykiss irideus*); California red-legged frog (*Rana aurora draytonii*); California spotted owl (*Strix occidentalis* ssp. *occidentalis*; Coast Range newt (*Taricha torosa torosa*); and two-striped garter snake (*Thamnophis hammondii*). Known occurrences of these species, and the potential for occurrence by reach, are summarized within Table B-4. The potential for occurrence of a particular species noted within Table B-4 was based on the presence of suitable habitat, as defined by Burt and Grossenheider (1976), Remsen (1978), Robbins et al. (1983), and Zeiner at al. (1990). Individual species accounts, described below, are based on the same authoritative sources unless noted otherwise.

TABLE B-3
Sensitive Wildlife Species with the potential to occur
In the SLO Creek Watershed

Scientific Name	Common Name	Legal Status[a] Federal/State/CDFG
Accipiter cooperi	Cooper's hawk (nesting)	--/--/CSC
Antrozous pallidus	pallid bat	--/--/CSC
Clemmys marmorata pallida	southwestern pond turtle	FSC/--/CSC,P
Danaus plexippus	monarch butterfly (wintering)	--/--/*
Dendroica petechia	yellow warbler (nesting)	--/--/CSC
Empidonax traillii	willow flycatcher (nesting)	--/SE/--
Eucyclogobius newberryi	tidewater goby	FE/--/CSC,P
Icteria virens	yellow-breasted chat (nesting)	--/--/CSC
Oncorhynchus mykiss irideus	southern steelhead trout**	FT/--/CSC
Rana aurora draytonii	California red-legged frog	FT/--/CSC,P
Strix occidentalis	California spotted owl	FSC/--/CSC
Taricha torosa torosa	Coast Range newt	--/--/CSC
Thamnophis hammondii	two-striped garter snake	--/--/CSC,P

FE: Federally Endangered
FT: Federally Threatened
FSC: Federal Special Concern
SE: State Endangered
CSC: California Special Concern
P: CDFG Protected

*Restricted range in California

**south/central evolutionary significant unit (ESU)

Table B-4 presents the occurrences of sensitive wildlife species in the study reaches. The potential for occurrence of a sensitive wildlife species is indicated where reach habitat is available for that species.

TABLE B-4
Occurrence of Sensitive Wildlife Species by Study Reach

Sensitive Wildlife	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20	Reach 21	Reach 22	Reach 23	Reach 24	Old Garden Creek
southern steelhead	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	p	p	x	x	x	x	x	x	x
southwestern pond turtle	p	x	x	p	p	p	x	p	p			p	p	p	x	p	p	p	p	p	p	p	x		p
monarch butterfly	p	p				p	p	p	p	x	p	p	p	p	p	p		x	p	p	p	p	p		
tidewater goby	x																								
two-striped garter snake																x									
pallid bat	x					x	x			p	x	p	p			x									
California red-legged frog	x													x			x								
Coast range newt													x	x										p	p
yellow warbler	p	p	p	p	p	p	p							p	p	p		p				p		p	
yellow-breasted chat	p	p	p	p	p	p	p							p	p	p		p				p		p	
Cooper's hawk	p	p	p	p	p	p	p							p	p	p		p				p		p	
California spotted owl																								x	
willow flycatcher	p	p	p	p	p	p	p							p	p	p		p				p		p	

x indicates record/sighting in CNDDB
0 indicates an actual sighting during Morro Group Phase II GPS data collection
p indicates the potential to occur in this reach (see text for rationale)

<u>Cooper's Hawk (*Accipter cooperi*)</u>
Cooper's hawk is a fairly large accipter hawk that ranges throughout the United States and is widely distributed throughout California. This species is a resident of San Luis Obispo County, nesting and foraging in and near deciduous riparian areas. Cooper's hawk is rarely found in areas without dense tree stands or patchy woodland habitat. Breeding occurs March to August, peaking May to July. Incubation lasts about 36 days, and young are independent eight weeks thereafter (Baicich and Harrision 1997). California considers Cooper's hawk a Species of Special Concern, based on a reduction in breeding numbers in recent years. These reductions are reportedly due to destruction of lowland riparian habitat, and direct/indirect human disturbance at nest sites. Suitable habitat is present throughout the SLO Creek watershed where dense, relatively undisturbed riparian forest habitat persists.

<u>Pallid Bat (*Antrozous pallidus*)</u>
The pallid bat is a locally common species of low elevations in California that is distributed throughout the western and southwestern United States, southward into Mexico. In California, this species is found statewide except for higher elevations of the Cascade and Sierra Nevada ranges. Pallid bats establish day roosts in caves,

crevices, mines, and occasionally in hollow trees and buildings. Day roosts are selected in locations that protect pallid bats from high temperatures. Night roosts are often in more open sites such as porches and open buildings. This species mates from October to February, with a litter of two pups (typically) born during April through July (peaking May through June). Young are weaned in approximately seven weeks, and are flying freely by July to August. Pallid bats are very sensitive to disturbance of roosting sites, as such sites are important for metabolic economy, juvenile growth, and consumption of prey. California considers pallid bat a Species of Special Concern. Several bridges over SLO Creek are known to support day and/or night roosting pallid bats (Morro Group 1998, 2001b).

Southwestern Pond Turtle (*Clemmys marmorata pallida*)
The southwestern pond turtle (SWPT) ranges discontinuously from Monterey Bay southward through the coast ranges to Baja, Mexico (Hunt 1994). It prefers quiet waters of ponds, small lakes, streams, and marshes, and requires basking sites such as partially submerged logs, rocks, mats of floating vegetation, or open mud banks. The SWPT will often inhabit reaches of streams that contain deep pools, with depths greater than three feet (Stebbins 1972). They are typically found in the largest and deepest pools along streams containing suitable basking sites, including fallen trees and boulders. They also tend to congregate along portions of streams containing abundant underwater cover or areas containing escape routes beneath the water surface such as undercut banks, tangles of roots, and submerged logs (Hunt 1994). Overland movements up to 5 km have been recorded, and these are thought to be in response to adverse environmental circumstances (e.g., drought), or normal movements within home ranges (D. Holland 1994). Along the central coast, mating occurs during April to May, and eggs (3 to 11) are typically laid from March through August within nests constructed in sandy banks. Incubation of eggs may range to approximately three months, with young turtles reaching sexual maturity in about eight years. Southwestern pond turtles are considered omnivores, feeding on vegetation, insects, fishes, frogs, and carrion.

The SWPT is designated as a Federal Special Concern species, and is considered Protected and a Special Concern Species by the CDFG. D. Holland (1994) estimates that 80 to 85% of the turtle populations (including both SWPT and northwestern pond turtle, *C. m. marmorata*) in California have been eliminated primarily due to land conversion, collecting, disease, non-native predators, urbanization, and flood control practices. Pond turtles are known to occur throughout the San Luis Obispo Creek corridor and many of its tributaries (Fugro 1995), with specific occurrences known from upper Stenner Creek and SLO Creek near the East Fork confluence (Havlik *in litt*., Morro Group 2000a).

Monarch Butterfly (*Danaus plexippus*)
Monarch butterfly uses *Eucalyptus* woodland, as well as other habitat types, for winter roost sites and has been observed to roost in a variety of areas throughout the Los Osos, Morro Bay, and San Luis Obispo regions. Primary roost sites include Montana de Oro and Morro Bay state parks, and scattered areas throughout the communities of Los Osos and Morro Bay. The over-wintering habitats for this

species are of special concern and protected by the CDFG. The NDDB (2000a) maps wintering occurrences of monarch butterfly in the Prefumo Creek drainage, and within the SLO Creek corridor near the Madonna Road Bridge.

Yellow Warbler (*Dendroica petechia*)

Yellow warblers are migratory and are broadly distributed throughout North America, though their California distribution is largely restricted to the northern and coastal portions of the State, and the Sierra Nevada foothills. Within San Luis Obispo County, this species is a fairly common summer transient of deciduous riparian habitats. Breeding and nesting of yellow warbler typically occurs from mid-April to early August, with peak activity occurring in June. Eggs (typically 3 to 6) are incubated for approximately 11 days, and young fledge approximately 9 to 12 days thereafter. The nesting lifestage of yellow warbler is considered sensitive (California Special Concern) by CDFG. Brood parasitism by brown-headed cowbirds has reportedly reduced numbers of this species statewide, though predation and destruction/clearing of riparian habitat is also implicated in population declines of this species. Suitable habitat for this species exists throughout the SLO Creek watershed within riparian scrub habitats.

Willow Flycatcher (*Empidonax traillii*)

Willow flycatcher is a small, migratory passerine that ranges across North America, and is a rare spring transient and an uncommon summer/fall migrant to San Luis Obispo County. This species more commonly is found as a summer resident within mountainous wet meadow and montane riparian habitats of the Sierra Nevada and Cascade ranges after migrating from winter habitat in Central and South America. Dense willow thickets are required for nesting and roosting, with peak egg laying occurring in June. Young fledge within 13 to 14 days. Willow flycatcher is considered a California Species of Concern, primarily due to destruction of riparian scrub habitat and to cowbird brood parasitism. No nesting records of this species exist within San Luis Obispo County (T. Edell, Caltrans biologist, pers. comm.), though riparian areas of the SLO Creek watershed could provide suitable habitat.

Tidewater Goby (*Eucyclogobius newberryi*)

The tidewater goby is a small (to 50 mm), native species found along the Pacific coast of California from Humboldt County south to San Diego County (Moyle 1976). While most gobies are strictly marine fishes, the tidewater goby is one of two California goby species found in and near freshwater for a significant portion of its life. In coastal streams, gobies are usually found in slow moving reaches or within pools away from excessive current. Spawning generally occurs from April through June. Tidewater gobies are present within Reach 1 of SLO Creek, and are relatively abundant immediately downstream of the Marre Dam (Swenson 1995).

Yellow-breasted Chat (*Ictera virens*)
The yellow-breasted chat is a migratory species distributed throughout the United States, though it is noted as an uncommon summer resident of the coast and Sierra Nevada foothills of California. Preferred habitat for cover, foraging, and nesting consists of willow riparian thickets, with dense understory cover. In San Luis Obispo County, observations of yellow-breasted chat are limited to uncommon occurrences from May to mid-August, concurrent with their breeding period, which peaks in June. Eggs (3 to 6 typically) are incubated for 11 to 15 days, with chicks fledging 8 to 11 days thereafter. The nesting lifestage of yellow-breasted chat is considered sensitive by the CDFG, and this species is listed as a California Special Concern species. Habitat loss and cowbird brood parasitism (similar to yellow warbler, above) are implicated in population declines. No nesting records for this species exist in the watershed (T. Edell, Caltrans biologist, pers. comm.), though riparian scrub habitats of the SLO Creek watershed could provide migratory habitat (resting/feeding).

Southern Steelhead Trout (*Oncorhynchus mykiss irideus*)
Steelhead are known as the anadromous form of rainbow trout (McEwan and Jackson 1996). Steelhead historically ranged from Alaska southward to the California-Mexico border, though current data suggest that the Ventura River is presently the southernmost drainage supporting substantial steelhead runs. Periodically, steelhead are reported within the Santa Clara River and Malibu Creek. Southern steelhead are important in that they represent the southernmost portion of the native steelhead range in North America, having ecologically and physiologically adapted to seasonally intermittent, coastal California streams.

Optimal habitat for steelhead throughout its entire range on the Pacific Coast can generally be characterized by clear, cool water with abundant instream cover (i.e., submerged branches, rocks, logs), well-vegetated stream margins, relatively stable water flow, and a 1:1 pool-to-riffle ratio (Raleigh et al. 1984). However, steelhead are occasionally found in reaches of streams containing habitat that would be considered less than optimal. Steelhead within the central coast region begin moving up coastal drainages (including SLO Creek) following the first substantial rainfall of the fall season. Spawning typically occurs in the spring in riffle areas that consist of clean, coarse gravels (Moore 1980). Deposited eggs incubate for approximately 3 to 4 weeks, with hatched fry rearing within the gravel interstices for an additional 2 to 3 weeks. Emergent fry rear at the stream margins near overhanging vegetation. Juveniles (smolts), after rearing for 1 to 3 years within freshwater, and post-spawning adults migrate out to the ocean from March to July, depending on streamflows. Therefore, juvenile steelhead can be found within SLO Creek at all times of the year, while adults are likely to be found from approximately February to July.

All populations of steelhead occurring within the South-Central California Coast Evolutionary Significant Unit (ESU) Region—which is defined as that geographic region north of the Santa Maria River, northward to (and including) the Pajaro River (and it's tributaries), Santa Cruz County—were listed as Federally Threatened by the National Marine Fisheries Service (NMFS) in August 1997. San Luis Obispo Creek (including its major tributaries) was recently listed by the NMFS as critical habitat for this species (Federal Register 2000). Southern steelhead trout are also considered a California Special Concern species. The NMFS lists habitat deterioration due to sedimentation and flooding related to land management practices, and potential genetic interaction with hatchery rainbow trout, as risk factors to steelhead within this ESU. Southern steelhead trout are distributed throughout the San Luis Creek watershed, including most of it's major tributaries. The extent of steelhead distribution within the San Luis Obispo Creek watershed is summarized in SLOLC (2002).

California Red-legged Frog (*Rana aurora draytonii*)
The California red-legged frog historically ranged from Marin County southward to northern Baja California. Presently, Monterey, San Luis Obispo, and Santa Barbara counties support the largest remaining CRLF populations within the State. CRLFs prefer aquatic habitats with little or no flow, the presence of surface water to at least early June, surface water depths to at least 2.3 feet, and the presence of fairly sturdy underwater supports such as cattails. The largest densities of this subspecies are typically associated with dense stands of overhanging willows and an intermixed fringe of sturdy emergent vegetation.

CRLF typically breed from January to July, with peak breeding occurring in February. Eggs are attached to subsurface vegetation, and hatched tadpoles require 11 to 20 weeks to metamorphose. It is estimated that only 1% of eggs actually reach adulthood. This species was formally listed by the USFWS as Federally threatened in 1996, and is considered a California Special Concern species, and Protected species, by the CDFG. Riparian habitat degradation, urbanization, predation by bullfrogs, and historic market harvesting has all reportedly contributed to population declines in this species.

Suitable habitat as described above does exist within the watershed. However, CRLF have often been observed in unsuitable habitat (concrete ponds, roadside ditches) and the presence of water indicates that CRLF may be encountered. Documented populations of CRLF are located in Prefumo Canyon, and in Gragg Canyon. No CRLF sightings have been reported on the mainstem of San Luis Obispo Creek.

California Spotted Owl (*Strix occidentalis occidentalis*)
The California spotted owl has been documented in riparian woodlands of upper See Canyon, within the San Miguelito Creek sub-watershed. Suitable habitat includes dense, multilayered forests. Summer roosts generally include dense forest canopies on north-facing slopes, while winter roosts generally include oak forestland. Usually nest in tree cavities or broken tops of trees. Noted as an uncommon resident of San Luis Obispo County (Edell et al. 1985), and unlikely to be very abundant within the study area.

Coast Range Newt (*Taricha torosa torosa*)

California newts (*T. torosa*) consist of two subspecies: Coast Range newt and Sierra newt. The former ranges discontinuously along the coast of California from Mendocino County to San Diego County. Optimum habitats reportedly consist of valley-foothill hardwood forest in association with rivers, creeks, ponds, and lakes. Coast Range newts have both terrestrial and aquatic life history phases. Adults are largely inactive, aestivating within subterranean refuges during most of the year. Following the first rains of fall, adults migrate to water, with mating occurring from September to May. Adhesive egg masses are deposited on submergent vegetation and rocks from May to June, with larvae hatching 5 to 7 weeks thereafter. Larvae transform to adults during the summer or fall of their first year. Sexual maturity is reached at approximately the end of the first year. Post-metamorphic juveniles and adults eat earthworms, snails, slugs, sowbugs, and insects. Adults within breeding ponds eat insects, crustaceans, and snails, and the eggs of other amphibians and trout, as well as eggs of their own species. The CDFG considers those populations of *T. torosa torosa* distributed from San Luis Obispo County southward as California Special Concern species. Riparian degradation related to urban development has likely contributed to population declines. This species is seasonally abundant within the upper reaches of several San Luis Obispo County creeks, including SLO Creek near Cuesta Grade, Morro Creek near Cerro Alto campground, and the uppermost reaches of Toro Creek (J. Tupen, Morro Group biologist, pers. obs.).

Two-Striped Garter Snake (*Thamnophis hammondii*)

The two-striped garter snake is a highly aquatic species, and is associated with semi-permanent to permanent freshwater habitats containing substantial emergent vegetation. It is also typically found in perennial pools containing frogs and fish, which are their primary prey (Zeiner et al. 1988). This species is considered a California Special Concern Species, and is protected by the CDFG. Suitable habitat for this species exists throughout the San Luis Obispo Creek watershed.

Reach by Reach Conditions

The following descriptions of individual creek reaches are compiled from the Phase I and II San Luis Obispo Creek studies and the literature and studies noted in Section 1 – Background and Section IV – References. An overview of the vegetative occurring in the study area is presented in Table B-5 – Reach-by-Reach Vegetation Summary. A summary of instream habitat characteristics is presented in Table B-6.

TABLE B-5
Reach-by-Reach Vegetation Summary*

Creek	Reach	Tree Species	Shrub Species	Grass Species	Exotic Species
San Luis Obispo Creek	1	Arroyo willow	Black sage	Perennial-intro.	Cape ivy
		Black cottonwood	Blackberry		Castor bean
		California bay	Coyote bush		Kikuyu
		California sycamore	Holly-leaf cherry		Mustard
		Coast live oak	Poison oak		Pampas grass
		Eucalyptus	Toyon		Vinca
		Hinds walnut			
		Mixed willow			
		Ornamental			
		Pepper Tree			
	2	Black cottonwood	None Recorded	None Recorded	Arundo
		Box elder			Cape ivy
		California sycamore			Castor bean
		Coast live oak			Cocklebur
		Eucalyptus			
		Hinds walnut			
		Mixed willow			
	3	Black cottonwood	None Recorded	None Recorded	Arundo
		Box elder			Cape ivy
		Hinds walnut			Castor bean
		Mixed willow			
	4	Box elder	Blackberry	None Recorded	Arundo
		California sycamore	California wild rose		Cape ivy
		Hinds walnut	Coyote bush		Castor bean
		Mixed willow			Hemlock
		Ornamental			Kikuyu
	5	Arroyo willow	None Recorded	None Recorded	Arundo
		Black cottonwood			Cape ivy
		Box elder			Castor bean
		California sycamore			Cocklebur
		Hinds walnut			Fennel
		Mixed willow			Hemlock
		Ornamental			Mustard
		Pepper tree			
	6	Box elder	Blackberry	Perennial-native	Arundo
		California bay	Coyote bush		Cape ivy
		California sycamore			Castor bean
		Eucalyptus			Cocklebur
		Hinds walnut			Fennel
		Mixed willow			Hemlock
		Monterey pine			Iceplant
		Ornamental			Kikuyu
		Pepper tree			Mustard
					Ox-tongue
					Scotch broom
					Smilo grass
					Star thistle
					Tree tobacco

Creek	Reach	Tree Species	Shrub Species	Grass Species	Exotic Species
San Luis Obispo Creek	7	Black cottonwood	Blackberry	None Recorded	Arundo
		Box elder			Cape ivy
		California sycamore			Castor bean
		Coast live oak			Cocklebur
		Eucalyptus			Fennel
		Hinds walnut			Hemlock
		Mixed willow			Kikuyu
		Ornamental			Mustard
					Sweet clover
	8	Arroyo willow	Coyote bush	Perennial - intro	Castor bean
		Eucalyptus			
		Hinds walnut			
		Mixed willow			
		Primary successional			
	9	Arroyo willow		Perennial - intro	Castor bean
		Black cottonwood			Groundcover
		California sycamore			Ornamentals
		Eucalyptus			
		Hinids walnut			
		Mixed willow			
		Monterey cypress			
		Monterey pine			
	10	Arroyo willow			Castor bean
		Black cottonwood			Ornamentals
		California sycamore			
		Eucalyptus			
		Mixed willow			
		Montery pine			
	11	Arroyo willow	Blackberry	None Recorded	Cape ivy
		Black cottonwood	California wild rose		English ivy
		Black locust	Coffeeberry		Fennel
		Black walnut	Coyote bush		Himalayan berry
		California sycamore	Elderberry		Honeysuckle
		Coast live oak	Ornamental		Ipomoea
		Eucalyptus	Poison oak		Kikuyu
		Hinds walnut	Snowberry		Vinca
		Mixed willow			
		Monterey pine			
		Ornamental			
		Pepper tree			
	12	Arroyo willow	Elderberry	None Recorded	English ivy
		Black walnut	Poison oak		Kikuyu
		California sycamore	Toyon		Pampas grass
		Coast live oak			Pyrocantha
		Eucalyptus			Scotch broom
		Mixed willow			Vinca
		Monterey pine			
		Ornamental			
		Pepper tree			
		Arroyo willow	Coyote bush	Perennial-intro	Arundo

Creek	Reach	Tree Species	Shrub Species	Grass Species	Exotic Species
San Luis Obispo Creek	13	Black cottonwood	Elderberry	Perennial-native	English ivy
		Black walnut	Poison oak		Honeysuckle
		California bay	Toyon		Kikuyu
		California sycamore			Pampas grass
		Coast live oak			Scotch broom
		Eucalyptus			Vinca
		Monterey pine			
		Ornamental			
		Pepper tree			
		Arroyo willow	California sagebrush	Perennial - intro	Groundcover
	14	Black cottonwood	coyote bush		
		California sycamore			
		Coast live oak			
		Eucalyptus			
East Fork of San Luis Obispo Creek	15	Eucalyptus	blackberry	Perennial-intro	castor bean
		Hinds walnut			hemlock
		Mixed willow			mustard
	16	Arroyo willow	blackberry	Perennial-intro	cocklebur
		Black walnut		Perennial-native	hemlock
		Eucalyptus			kikuyu
		Hinds walnut			mustard
		Mixed willow			ox-tongue
					teasal
Prefumo Creek	17	Arroyo willow	Coyote bush	Perennial - intro	
		Black locust			
		California sycamore			
		Coast live oak			
		Mixed willow			
	18	Eucalyptus	blackberry	Perennial-intro	Arundo
		Hinds walnut			English ivy
		Mixed willow			Kikuyu
		Ornamental			Pampas grass
					Phalaris
					Phoenix palm
					Vinca
Stenner Creek	19	Arroyo willow	None Recorded	None Recorded	Cape ivy
		Black walnut			Castor bean
		California bay			English ivy
		California sycamore			Himalaya berry
		Eucalyptus			Phoenix palm
		Ornamental			Vinca
	20	Arroyo willow	Blackberry	Perennial-intro	Arundo
		Black walnut			Cape ivy
		Box elder			Castor bean
		California sycamore			English ivy
		Coast live oak			Himalaya berry
		Eucalyptus			Kikuyu
		Monterey cypress			Phoenix palm
		Monterey pine			Vinca
		Ornamental			

Creek	Reach	Tree Species	Shrub Species	Grass Species	Exotic Species
Stenner Creek	21	Arroyo willow	Blackberry	None Recorded	Cape ivy
		Black cottonwood	Poison oak		Castor bean
		Black locust			English ivy
		Black walnut			Kikuyu
		Box elder			Pampas grass
		California bay			Phoenix palm
		California sycamore			Vinca
		Coast live oak			
		Eucalyptus			
		Hinds walnut			
		Mixed willow			
		Ornamental			
		Pepper tree			
	22	Arroyo willow	Blackberry	Perennial-intro	Arundo
		Black cottonwood	Coffeeberry		Cape ivy
		Black locust	Coyote bush		Castor bean
		Black walnut	Poison oak		Cocklebur
		California bay	Toyon		Fennel
		California sycamore			Kikuyu
		Coast live oak			Phoenix palm
		Eucalyptus			Scotch broom
		Mixed willow			Vinca
		Ornamental			
		Pepper tree			
Brizziolari Creek	23	Arroyo willow	Coffeeberry	Perennial-intro	Cape ivy
		Black cottonwood	Coyote bush		Castor bean
		California bay	Elderberry		Cocklebur
		California sycamore			Fennel
		Coast live oak			Grapevine
		Eucalyptus			Kikuyu
		Mixed willow			Pampas
		Ornamental			Phoenix palm
		Pepper tree			
See Canyon Creek	24	Arroyo willow	Coffeeberry	None recorded	unknown
		Black walnut	Coyote brush		
		Coast live oak	Elderberry		
		Mixed willow			
		Sycamore			

* plants listed are taken from both Phase I and Phase II observations and inventories

TABLE B-6
Instream Habitat Characteristics

Reach ID	Reach Location	Reach Length in km (ft)	Habitats (#) P	R	FW	Habitats (%) P	R	FW	Pools #/km	Length (m)
SLO Creek 1	Mouth to Lower SLBD Bridge	2.98 (9770.6)	2	0	1	1.1	0	98.9	0.67	16.8
SLO Creek 2	Lower SLBD Bridge to Ontario Rd.	1.65 (5413)	28	0	31	51.8	0	48.2	16.7	18.1
SLO Creek 3	Ontario to Upper SLBD Bridge	1.61 (5298.5)	29	2	33	34.1	1.8	64.2	18.0	19.0
SLO Creek 4	Upper SLBD Bridge to wood bridge	1.10 (3618.5)	12	6	17	27.3	9.4	63.3	10.9	25.1
SLO Creek 5	Wood bridge to 2nd wood bridge	2.07 (6784.5)	27	8	43	18.4	7.9	73.7	13.0	14.1
SLO Creek 6	2nd wood bridge to SHSB	0.95 (3126)	10	2	20	13.4	2.8	83.8	10.5	12.8
SLO Creek 7	SHSB to LOVR Bridge	1.82 (5984.5)	27	6	34	18.7	6.0	75.3	14.8	12.6
SLO Creek 8	LOVR to Prado Rd	2.16 (7073)	33	1	61	15.4	0.7	83.9	15.3	10.1
SLO Creek 9	Prado Rd to Madonna Rd	1.63 (5355)	15	1	153	6.5	0.2	93.3	9.2	8.1
SLO Creek 10	Madonna to Stenner Cr	1.24 (4083)	8	2	28	4.7	2.9	92.4	6.5	7.3
SLO Creek 11	Stenner Cr to California St Bridge	2.47 (8108)	6	9	64	1.3	6.4	92.4	2.4	5.2
SLO Creek 12	Cal St Bridge to Andrews St Bridge	0.23 (770)	2	1	6	6.0	4.8	89.2	8.7	7.0
SLO Creek 13	Andrews St. to 101 overpass at Cuesta Park	1.22 (4006)	6	3	25	8.3	3.0	88.7	4.9	17.0
SLO Creek 14	Cuesta Park to Stagecoach Rd	4.70 (15427)	9	3	51	0.8	2.3	96.9	1.9	4.5
East Fork 15	East Fork to Santa Fe Rd	1.65 (5420.9)	3	10	18	1.4	15.1	83.5	1.8	7.5
East Fork 16	Confluence to Acacia Creek	2.72 (8936.3)	6	4	13	5.5	2.9	91.6	2.2	25.1
Prefumo Creek 17	Laguna Lake inlet to SLO City limits	1.86 (6105)	10	6	18	4.5	2.7	92.7	5.4	27.6
Prefumo Creek 18	SLO Creek confluence to Laguna Lake outlet	1.9 (6237)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Stenner Creek 19	Confluence to Chorro St.	0.28 (761.2)	1	3	4	2.0	37.3	60.7	3.5	4.7
Stenner Creek 20	Chorro St. to Santa Rosa St.	0.68 (2240.5)	6	11	15	6.3	30.7	63.0	8.8	7.2
Stenner Creek 21	Santa Rosa St. to Brizziolari confl.	0.76 (2507.2)	7	14	20	4.3	26.5	69.2	9.2	4.7
Stenner Creek 22	Brizziolari confl. to Stenner Ck Road	2.19 (7191.9)	21	20	28	7.0	20.7	72.3	9.6	7.3
Brizziolari Cr. 23	Confluence to back of bldgs	1.79 (5867.1)	8	4	14	3.3	5.5	91.2	4.5	7.4
San Miguelito Cr. 24	Not surveyed for instream character									
Old Garden Cr.	Confluence to Foothill	1.75 (5727.7)	8	7	13	2.8	12.7	84.5	4.6	6.3

Reach 1 – San Luis Obispo Creek

Reach 1 is 3 km (9,771 ft) in length, and is unique among all areas treated within the present study in that it is subject to tidal influence, and therefore, partly saline in water chemistry. A sheet pile dam (Marre Dam) constructed in the 1960's, approximately mid-way through this reach, separates the brackish portion of Reach 1 (below dam) from the freshwater portion above the dam to the bridge. The majority of Reach 1 below the dam flows through the Avila Beach Resort Golf Club. Historically, San Luis Obispo Creek upstream to the lower San Luis Bay Drive Bridge (reach boundary) was subject to tidal influence, and estuarine species such as starry flounder (*Platichthys stellatus*) and shiner perch (*Cymatogaster aggregata*) were periodically observed from the bridge platform (Kresja, pers. comm.). Construction of the dam, proposed as necessary to prevent salt intrusion into agricultural well points, functionally truncated the size of the San Luis Obispo Creek estuary habitat.

Presently, streamside vegetation within the portion of Reach 1 below Marre Dam is dominated by a dense, mixed willow stand immediately downflow of the dam. However, the majority of this portion of Reach 1 is fairly degraded, with no substantial riparian component throughout the golf course property. Vegetation within this lower portion of Reach 1 consists largely of herbaceous species, including non-native grasses, pickleweed, and saltgrass. Above Marre Dam, the riparian corridor is relatively intact. Dominant tree species include arroyo willow, coast live oak, black cottonwood, and California sycamore. The shrub layer is dominated by coyote brush, with toyon, poison oak, black sage (*Salvia mellifera*), and holly-leafed cherry (*Prunus ilicifolia*). Exotics are fairly abundant within Reach 1, with representative species including castor bean, pampas grass (*Cortaderia selloana*), cape ivy, *Vinca*, summer mustard, and kikuyu grass.

The entirety of Reach 1 can be considered a uniform, somewhat characterless flatwater, with only two pools inventoried during mapping efforts in 2001. Marre Dam appears to indicate the only discernable stream gradient change within this reach, with an elevational difference on either side of the dam of approximately 1m during low tide events. During such events, a fairly deep (~2m) pool exists immediately downflow and adjacent to Marre Dam. This pool is parallel to the sheetpile dam alignment, and presumably is formed and maintained by dam overtopping during high-flow events. Tidewater gobies (*Eucylogobius newberryi*), listed by the USFWS as federally endangered in 1994, were present within this pool during surveys conducted by Ramona Swenson in July 1995 (Swenson 1995). Several small (<2m long, 1m deep) lateral scour pools were present in the San Luis Obispo Creek mainstem within 100m downstream of the dam during a June 2001 site visit (J. Tupen, pers. obs.). No fish were observed within those pools at that time.

Reach 2 - San Luis Obispo Creek

Reach 2 is located from lower San Luis Bay Drive Bridge upstream to Ontario Road, a distance of 1.65 km (5,413 ft). The lowest 183 m (600 ft) of Reach 2 is subject to pooling from the downstream Marre Dam impoundment (SLOLC 1996). Major streamside development within this reach includes cabanas associated with Sycamore Mineral Springs, Avila Hot Springs, and Avila R/V Park and Resort. Agricultural orchards (apples) are also present immediately upstream of the bridge. The riparian habitat of Reach 2 is characterized by a multi-layered and polytypic mix of native species. Large California sycamores and black cottonwoods are abundant. This hardwood dominated tree layer is replaced with mixed willows near the Ontario Road Bridge, where Cleveland (1996) noted that the creek channel was “choked” with willows. Cape ivy is abundant throughout the reach, and *Arundo* is common near the bridge.

The instream habitat of Reach 2 is afforded substantial shade by the dense riparian vegetation. Cleveland (1996) noted that 51.8% (of the total reach length) of Reach 2 consisted of pool features, with 48.2% characterized as flatwaters. No riffles were inventoried within this reach. Overall, Cleveland inventoried 28 pools within Reach 2, for a pool #/reach length ratio of approximately 16.7 pools/km (second highest ratio within watershed). The mean pool length within this reach was 18.1 m, with most of the pools identified as root wad enhanced- or bedrock formed-lateral scour pools (Cleveland, 1996). The confluence of San Miguelito Creek (See Canyon Creek) is located within the lower portion of Reach 2.

Reach 3 - San Luis Obispo Creek

Reach 3 is located from Ontario Road upstream to the upper San Luis Bay Drive Bridge, a distance of 1.61 km (5,299 ft). This reach is largely undeveloped and rural, with some active cattle grazing evident. Several large-parcel residences are present, as is an R/V Park near the Ontario Road Bridge. Excessive bank erosion and slumping was reported by Cleveland (1996), presumably due to cattle grazing practices. The riparian canopy of Reach 3 is dominated by mixed willows, with box elder, Hinds walnut (*Juglans hindsii*), and black cottonwood also present. Mature sycamores are absent from Reach 3, reportedly reflecting historic channelization activities (SLOLC 1996). Shrub and herbaceous components are scarce to nonexistent, perhaps reflecting grazing pressure over time. Exotics include thick cape ivy, with castor bean and *Arundo* also noted.

The instream habitat of Reach 3 is similar in composition to that of Reach 2, with 29 pools inventoried over the extent of the reach for a ratio of 18 pools/km (highest pool ratio in watershed). Overall, 34.1% of Reach 3 consisted of pool features and 64.2% was characterized as flatwater habitat. Riffles composed less than 2% of the total habitat of Reach 3. Mean pool length within this reach was 19.0 m, with most of the pools identified as log enhanced- or root wad enhanced-lateral scour pools (Cleveland 1996). Cleveland (1996) also noted the existence of a gently sloped (4.1:50 ft) fish ladder within Reach 3 near Highway 101.

Reach 4 - San Luis Obispo Creek

Reach 4 is located from the upper San Luis Bay Drive Bridge upstream to a wooden bridge located on the DeVincenzo property, a distance of approximately 1 km (3,619 ft). Land use within this reach is largely agricultural, with active apple orchards dominating the land areas west of San Luis Obispo Creek. The riparian canopy of Reach 4 consists of mixed willows, Hinds walnut, and California sycamore. Shrub species include California wild rose, California blackberry, and coyote brush. Herbaceous, understory vegetation is scarce. Riparian vegetation is generally more degraded in the lower portions of the reach, relative to the upper reach areas (SLOLC 1996). Reach 4 is particularly infested with cape ivy, with castor bean, *Arundo*, poison hemlock, and kikuyu grass also present. The Land Conservancy has pursued ivy eradication efforts on the right bank of Reach 4.

Twelve pools, six riffles, and 17 flatwater habitats were mapped by Cleveland (1996) within Reach 4, resulting in a derived pool frequency of nearly 11 pools/km. As such, approximately 27% of Reach 4 consisted of pool features, with 63.3% characterized as flatwater habitat and 9.4% mapped as riffle habitat. This riffle percentage was the highest noted within the watershed, and likely reflects a relatively large proportion of the overall stream gradient change (slope) within San Luis Obispo Creek. Mean pool length within this reach was 25.1 m (greatest in watershed), with most of the pools identified as log enhanced lateral scour pools (Cleveland 1996). Mid-channel pools and root wad enhanced lateral scour pools were also noted within this reach, as was a single, boulder-formed lateral scour pool (actually formed by concrete rubble along the stream bank). The SLOLC (1996) noted that lower portions of Reach 4 were historically channelized/straightened.

Reach 5 - San Luis Obispo Creek

Reach 5 is 2.07 km (6,785 ft) long, and is located from the wooden bridge on the DeVincenzo property upstream to a wooden agricultural bridge on the Bunnell property. Land use within Reach 5 reach is largely agricultural farming, with active cattle grazing present also. The riparian canopy of Reach 5 consists of mixed willows, Hinds walnut, black cottonwood, and California sycamore, with single-trunk hardwoods more common in the lower portion of the reach. Shrub species and herbaceous species were not conspicuous components of the Reach 5 riparian community. This reach, like most reaches within the lower San Luis Obispo Creek watershed, harbors an assortment of introduced, noxious plant species, including cape ivy, castor bean, *Arundo*, poison hemlock, cocklebur, summer mustard, and fennel. The confluence of Davenport Creek is located within the upper portion of Reach 5.

The instream habitat of Reach 5 consists of approximately 18% pools, 8% riffles, and 74% flatwaters, with an overall pool frequency of 13/km. Pool lengths averaged approximately 14 m within this reach. The frequency of riffle habitat within Reach 5 (similar to Reach 4) indicates a relatively large proportion of the overall stream gradient change within the watershed. Pool habitats within Reach 5 consisted largely of root wad enhanced lateral scour pools, with log enhanced- and boulder formed-lateral scour pools also present. A single, clay-formed, mid-channel pool was identified in the central portion of Reach 5

Reach 6 - San Luis Obispo Creek

The 0.95 km (3,126 ft) Reach 6 of San Luis Obispo Creek is located from the wooden agricultural bridge on the Bunnell property upstream to the South Higuera Street Bridge. Land use within this reach is largely agricultural, with field crops and cattle grazing present. The creek corridor is constricted within Reach 6, largely due to construction of South Higuera Street and Highway 101, and also due to agricultural encroachment. The riparian canopy of Reach 6 is dominated by mixed willows, with Hinds walnut and Monterey pine also present. Shrub species include California blackberry and coyote brush. Native, perennial grasses were present within the herbaceous understory vegetation. Reach 6 was observed to support the widest diversity (though not necessarily greatest abundance) of exotics and noxious, weedy species within the surveyed watershed areas. Dominants included castor bean and cape ivy, though the following weedy species were also noted: *Arundo*, tree tobacco, Scotch broom, ice plant (*Carpobrotus edulis)*, fennel, yellow star thistle (*Centaurea solstitialis*), poison hemlock, kikuyu grass, summer mustard, cocklebur, bristly ox-tongue, and smilo grass (*Piptatherum miliaceum*).

Nearly 84% of the instream habitat areas of Reach 6 was characterized as flatwaters, with pools and riffles composing 13% and 3% of the remaining habitats, respectively. The pool frequency ratio within this reach was 10.5/km, with an average size pool of approximately 13 m in length. Of the 10 pools identified within Reach 6, nine were root wad enhanced- or boulder formed lateral scour pools, and one was a log enhanced lateral scour pool (Cleveland 1996). No mid-channel pools were evident within this reach during 1995 survey efforts. The East Fork of San Luis Obispo Creek joins the mainstem near the upper portion of Reach 6. The SLOLC (1996) notes that a portion of Reach 6 adjacent to Higuera Street was historically moved to its present alignment to facilitate the construction of Highway 101.

Reach 7 - San Luis Obispo Creek

Reach 7 is 1.82 km (5,985 ft) long, and is located from the South Higuera Street Bridge upstream to the Los Osos Valley Road (LOVR) Bridge. Land use within Reach 7 reach is largely agricultural, with most farming activity near the lower portions of the reach. The riparian canopy of Reach 7 consists largely of mixed willows, with Hinds walnut, black cottonwood, California sycamore, and *Eucalyptus* also present. Shrub species and herbaceous species were not conspicuous components of the Reach 7 riparian community, though California blackberry is somewhat abundant. Similar to Reach 6, the lower portion of the Reach 7 channel is constricted by urban encroachment and agricultural practices, and riparian vegetation is consequently less dense than areas near the LOVR Bridge. Non-native vegetation within this reach included cape ivy, castor bean, *Arundo*, poison hemlock, yellow sweet clover (*Melilotus officinalis*), cocklebur, summer mustard, kikuyu grass, and fennel. The channel within the upper portions of Reach 7 is wide relative to lower portions, and is more heavily infested with *Arundo* and cape ivy than other Reach 7 areas.

The instream habitat of Reach 7 consists of 18.7% pools, 6% riffles, and 75.3% flatwaters, with an overall pool frequency of nearly 15/km. Pool lengths averaged approximately 13 m within this reach. Pool habitats within Reach 7 consisted largely of bedrock formed lateral scour pools, with log enhanced- and root wad enhanced lateral scour pools also present. Two boulder-formed lateral scour pools and a single, mid-channel pool were also mapped by Cleveland (1996) within this reach. The mainstem channel was braided in two locations during survey work in 1995.

Reach 8 - San Luis Obispo Creek

Reach 8 is located from the Los Osos Valley Road Bridge upstream to the Prado Road Bridge, a distance of 2.16 km (7,073 ft). Land use within this reach includes commercial and residential development, and the San Luis Obispo Water Treatment Facility. Some agriculture usage is present near the upper portions of Reach 8 near Prado Road. The riparian corridor ranges in width from 5-15 m (Questa 1997), with arroyo willow and Hinds walnut dominating the sparse canopy vegetation. Understory species consist largely of exotics, such as castor bean and *Arundo*, with coyote brush also mapped as an important streamside component. Windrow vegetation atop the creek bank includes *Eucalyptus* and cypress. The SLOLC (1996) notes that periodic removal of vegetation for flood control purposes has exacerbated bank erosion problems within this reach.

Approximately 84% of Reach 8 was characterized as flatwater habitat by Cleveland (1996), with pools and riffles composing 15% and 1% of the remaining habitats, respectively. The pool frequency ratio within Reach 8 was 15.3/km, with the average size pool being approximately 10 m in length. Of the pools identified within Reach 8, most were classified as root wad enhanced- and bedrock formed lateral scour pools. Several log enhanced- and boulder-formed lateral scour pools were also inventoried within this reach, as was a single corner pool feature near the central portion of the reach. Prefumo Creek joins the mainstem near the lower portion of Reach 8. Gabions and rock rip rap revetments are present along the streambank at several location to stabilize actively eroding slopes. Reach 8 was identified by Questa (1997) as the reach most in need of bank erosion control measures, relative to other reaches in the watershed. A large portion of Reach 8 (between LOVR and the WWTP) was excavated to a 40 m wide floodplain in the 1970's for flood control (Questa 1997).

Reach 9 - San Luis Obispo Creek

Reach 9 is located from the Prado Road bridge upstream to the Madonna Road Bridge, a distance of 1.63 km (5,355 ft). Land use within this reach is largely urban, with the mainstem channel constricted between commercial development to the east and Highway 101 to the west. Several mobile home parks are located at or near the top of the bank of San Luis Obispo Creek. Riparian zone width and vegetation composition within this reach is similar to that of Reach 8, but significantly less dense. Riparian vegetation along this reach has been removed or degraded by encroaching development (SLOLC 1996). Several serpentine outcrops were noted by Cleveland (1996), and Questa (1997) identified several plant species of concern potentially occurring within this reach, including San Luis Obispo dudleya (*Dudleya murina)* and San Luis mariposa lily (*Calochortus simulans*). Several areas of severe streambank erosion are present within this reach, particularly near the former RRM Design building and the present Elks Lodge. Channel constrictions caused by *Arundo* infestations were noted immediately downstream of the Madonna Road Bridge (SLOLC 1996).

Cleveland (1996) characterized just over 93% of Reach 9 as flatwater habitat (second highest in watershed), probably reflecting the poor condition of creek habitat and general bank instability issues within the reach. Pools and riffles comprised 6.5% and 0.2% of the surveyed habitats, respectively. The pool frequency ratio within Reach 9 was 9.2/km, with the average size pool being 8.1 m in length. Of the pools identified within Reach 9, most were classified as root wad enhanced, bedrock formed, or boulder formed lateral scour pools. Concrete apron, slabs, and rubble, and rock rip rap revetments are present along the streambank at several locations to stabilize actively eroding slopes. A low flow barrier to fish passage was noted by Cleveland (1996) as occurring just upstream of Padre Liquor (near intersection of Prado Road and South Higuera Street).

Reach 10 - San Luis Obispo Creek

Reach 10 is located from the Madonna Road bridge upstream to the confluence of Stenner Creek (behind Four Seasons Outfitters on Higuera Street), a distance of 1.24 km (4,083 ft). Land use within this reach is largely urban, with both commercial and residential development encroaching on the creek corridor. The riparian corridor ranges in width from 15-35 m (Questa 1997), with mixed willows and *Eucalyptus* dominating the canopy vegetation. Understory species consist largely of exotics, such as *Arundo*, castor bean, and cape ivy.

Approximately 92% of Reach 10 is classified as flatwater habitat, with pools and riffles composing nearly 5% and 3% of the remaining instream habitat areas, respectively. The pool frequency ratio within Reach 10 was 6.5/km, which represents one of the lowest frequencies noted within the watershed. Of the eight pools, averaging 7.3 m in length, identified within Reach 10, three were classified as root wad enhanced lateral scour pools, and five were classified as bedrock formed lateral scour pools. Concrete rip-rap and sack revetments, and gabions are abundant along the streambank at several locations, apparently reflecting attempts to stabilize actively eroding slopes adjacent to residential and commercial developments.

Reach 11 - San Luis Obispo Creek

Reach 11 is 2.47 km (8,108 ft) long, and is located from the Stenner Creek confluence upstream to the California Street Bridge. Land use within Reach 11 is almost entirely developed urban, as this reach passes directly through downtown San Luis Obispo. At several sections within the reach, San Luis Obispo Creek is passed beneath the City via tunnels, closed bridges, and culverts. Riparian vegetation within these areas is not surprisingly absent. Within those areas subject to sunlight, California sycamore, Eucalyptus, arroyo willow, and mixed willow canopies dominate riparian vegetation. Ornamental species are abundant. Shrub understory species, where present, include coyote brush, poison oak, blue elderberry (*Sambucus mexicana*), and California wild rose. Exotics are abundant within Reach 11, with species including cape ivy, English ivy, *Vinca*, kikuyu grass, fennel, *Arundo*, and Himalayan blackberry. Several revegetation projects are evident along this reach.

The instream habitat of Reach 11 consists of approximately 1% pool, 6% riffles, and 92% flatwaters, with an overall pool frequency of 2.4/km (second lowest in watershed). Pool lengths averaged approximately 5.2 m within this reach. Of the six pools identified within this reach by Cleveland (1996), three were bedrock formed lateral scour pools and three were boulder formed lateral scour pools. Much, if not most, of the bank slopes within this reach are armored in some fashion (SLOLC 1996).

Reach 12 - San Luis Obispo Creek

The 0.23 km (770 ft) Reach 12 of San Luis Obispo Creek consists of a bedrock located between the California Street bridge and the (upstream) Andrews Street foot bridge. Land use within this reach is also urban, with residential development often occurring at the hinge (top) of the streambank. California sycamore, ornamentals, coast live oak, and arroyo willow dominate the riparian canopy vegetation, while toyon, poison oak, and blue elderberry compose the shrub understory. Herbaceous species were not a conspicuous component of the Reach 12 riparian corridor. English ivy and *Vinca* are the most abundant exotics within this reach, though Scotch broom, pampas grass, kikuyu grass, and *Pyracantha* were also noted.

The instream habitat of Reach 12 consisted of 6% pools, undoubtedly reflecting the abundance of bedrock substrate. Riffle habitat and flatwaters comprised approximately 5% and 89% of the instream habitat, respectively. The pool frequency ratio within this reach was 8.7/km, with the average size pool being approximately 7 m in length. Two pools identified within this reach were both classified as mid-channel pools, also reflecting the hard rock composition of this reach.

Reach 13 - San Luis Obispo Creek

Reach 13 is 1.22 km (4,006 ft) long, and is located from the Andrews Street Bridge upstream to the Highway 101 culvert above Cuesta Park. Land use within this reach is a mix of urban and agricultural development, with the latter use largely related to grazing on Cal Poly lands in the upper watershed. A canopy of California sycamore (particularly near Cuesta Park), coast live oak, arroyo willow, *Eucalyptus*, and various ornamentals dominate the riparian vegetation within Reach 13. Blue elderberry, coyote brush, toyon, and poison oak form the shrub component, and while both native and non-native perennial grass species dominate the herbaceous layer. Scotch broom, English ivy, and *Vinca* are the dominant exotics in this reach.

The instream habitat of Reach 13 consists of 8.3% pool, 3% riffles, and 88.7% flatwaters, with an overall pool frequency of nearly 5/km. Pool lengths averaged approximately 17 m within this reach. Of the six pools identified within this reach by Cleveland (1996), three were mid-channel pools, two were dammed pools, and one was classified as a bedrock formed lateral scour pool. Gabion baskets are present at several locations to stabilize eroding banks, and water is being pumped (extracted) by various landowners to irrigate landscapes (SLOLC 1996).

Reach 14 - San Luis Obispo Creek

Reach 14, the final reach inventoried within the San Luis Obispo Creek drainage, is 4.70 km (15,427 ft) long, and is located from the Highway 101 culvert above Cuesta Park upstream to the Stagecoach Road culvert beneath Highway 101. Land use within this reach is largely agricultural, with field crops and cattle grazing both evident. The riparian corridor within Reach 14 is dominated by a canopy of California sycamore in the lower and upper portions of the reach, and by coast live oak within the central portions of the reach near Reservoir Canyon. The relatively dense canopy vegetation excludes the development of a dense shrub understory. Introduced perennial grasses form the dominant herbaceous component of the Reach 14 riparian community.

The instream habitat of Reach 14 consists of approximately 1% pool, 2% riffles, and 97% flatwaters, with an overall pool frequency of nearly 2/km. Pool lengths averaged approximately 4.5 m within this reach. Root wad enhanced lateral scour pools were most abundant within the reach (n = 5), relative to other pool types. The four remaining pools identified by Cleveland (1996) within Reach 14 were a log-enhanced lateral scour pool; bedrock formed lateral scour pool, a plunge pool, and a dammed pool.

Reach 15 – East Fork of San Luis Obispo Creek

The East Fork of SLO Creek is the largest sub-watershed within the SLO Creek watershed. The confluence of the East Fork with the mainstem of San Luis Obispo Creek is located near Higuera Street at the southernmost limits of the City of San Luis Obispo. Acacia Creek is a tributary to the East Fork, with its confluence point located approximately 0.4-km (0.25-mile) south of Buckley Road. Reach 15 is that approximately 1.65km (5,421 feet) portion of Acacia Creek between this confluence point and Santa Fe Road. Land use within Reach 15 is largely agricultural and historic industrial use associated with the Unocal Tank Farm. The riparian corridor of Acacia Creek throughout this reach is consequently narrowed, with dominant species including various willows and Hinds walnut. Blackberry and non-native grasses form the riparian understory. Exotics found within Reach 15 include perennial mustard, poison hemlock, and castor bean.

The instream habitat of Reach 15 consists of approximately 1% pool, 15% riffles, and 84% flatwaters, with an overall pool frequency of nearly 2/km. Pool lengths averaged approximately 7.5 m within this reach. This reach was not included in the Cleveland (1996) survey, and specific habitat classifications are not available.

Reach 16 - East Fork of San Luis Obispo Creek

Reach 16 is that 2.72km (8,936 ft) portion of the East Fork drainage from the confluence of San Luis Obispo Creek upstream to the Acacia Creek confluence point. Similar to Reach 15, the riparian corridor of this portion of the East Fork has been degraded through time by past and present agricultural practices. Canopy-forming riparian vegetation within the lower East Fork is scant to non-existent, reflecting agricultural practices and historic stream channelization activities (Morro Group 2000b). Rather, this section is characterized as a seasonal freshwater marsh. Dominant mid-channel vegetation includes tule (*Scirpus acutus*) and cattail, with streamside vegetation composed of a diverse mixture of noxious, weedy species. These exotics include fennel, bristly ox-tongue, common sow thistle (*Sonchus oleraceaus*), cocklebur, and poison hemlock. Surface flows within the lower East Fork are seasonally intermittent.

The instream habitat of Reach 16 is severely degraded, also reflecting past land use practices. The channel is incised, and the retreating banks provide a continuing source of sedimentation and turbidity. Concrete debris has been dumped at the confluence of the East Fork with San Luis Obispo Creek in an attempt to halt the active headcutting (erosion) within the East Fork (Morro Group 2000b). Instream features consist of approximately 5.5% pools, 3% riffles, and 92% flatwaters, with an overall pool frequency of 2.2/km. Pool lengths averaged 25 m within this reach.

Reach 17 - Prefumo Creek

Prefumo Creek, a tributary to SLO Creek draining the Irish Hills west of San Luis Obispo, was inventoried from its confluence point with San Luis Obispo Creek near the intersection of Los Osos Valley Road and U.S. Highway 101, upstream to the western City limits of San Luis Obispo along Prefumo Canyon Road. Reach 17 is that portion of Prefumo Creek originating at the Laguna Lake inflow, upstream 1.86km (6,105 ft) to the western City limits boundary. Chaparral dominates the headwater region vegetation, with riparian species including arroyo willow, California sycamore, black locust, coast live oak, and coyote brush. Land use in this area is mainly residential suburban, with some agricultural use present also.

Cattle grazing in the upper watershed and in the lowlands near Foothill Blvd and Los Osos Valley Road has contributed to soil erosion and consequent sedimentation within Prefumo Creek. Laguna Lake, located at the approximate midpoint of the Prefumo Creek drainage corridor, acts as a settling pond for sediment originating in these upstream regions, reducing sedimentation to the mainstem of SLO Creek. Instream features within Reach 17 consist of 4.5% pools, 2.7% riffles, and 92.7% flatwaters, with an overall pool frequency of 5.4/km. Pool lengths averaged 27.6m within this reach. All mapped pool features within Reach 17 were boulder-formed lateral scour pools, and were formed around boulders, logs, or rootwads. Recent stream restoration projects within this reach conducted by the Land Conservancy of San Luis Obispo County should restore headwater region access to southern steelhead trout.

Reach 18 - Prefumo Creek

Reach 18 is that 1.9km (6,237 ft) portion of the Prefumo Creek drainage located between the Laguna Lake outflow near Madonna Road, downstream to the San Luis Obispo Creek confluence. Within this reach, the riparian corridor of Prefumo Creek is constrained and narrowed by existing agricultural operations, and both residential and commercial development. Eucalyptus forms the dominant canopy species in the upper portions of Reach 18 south of Madonna Road, with mixed willows present near the lower areas of the reach. Exotic vegetation is abundant within Reach 18, with dominants including *Arundo*, kikuyu grass, *Vinca*, English ivy, and pampas grass. Escaped ornamental species are abundant near the residential development south of Madonna Road and east of Los Osos Valley Road.

Instream habitat features within the 1.49km section of Prefumo Creek located between Calle Joaquin and the lake outflow were surveyed by Morro Group. Five pool features (one plunge, three mid-channel, and one lateral scour) ranging in length from 13m to 22m (average 17.4m) were located within this area, for a pool frequency of 3.4/km. The lowest portion of this reach between Highway 101 and the San Luis Obispo Creek confluence was surveyed by Cleveland in 1997 as part of the Phase I studies. Two pools were reported by Questa (1997) within this lowest section, but it is difficult to determine from the record if these pools were located on the San Luis Obispo Creek mainstem or the lowest section of Prefumo Creek.

Reach 19 - Stenner Creek
Reach 19 of Stenner Creek is 0.28 km (761 ft) long, and is located from the San Luis Obispo Creek confluence point near south Marsh Street, upstream to the Chorro Street Bridge. Land use within this reach is entirely urban residential, with Stenner Creek abutting numerous residences. Urban encroachment has resulted in the artificial channelization of portions of this reach, with the consequent reduction of riparian vegetation. Streamside vegetation within this reach, where it does occur, consists of a diverse mixture of canopy-forming species, including *Eucalyptus*, black walnut, California sycamore, and arroyo willow. Shrub and herbaceous understory species are sparse. Escaped ornamental vegetation (*Vinca* and English ivy) dominates the exotic flora of this reach, with castor bean, cape ivy, Phoenix palm, and Himalayan blackberry also present

The instream habitat of Reach 19 consists of 2% pool, 37.3% riffles, and 60.7% flatwaters, with an overall pool frequency of 3.5/km. Pool lengths averaged approximately 5 m within this reach. The relatively high frequency of riffle habitat within this reach, relative to the SLO Creek mainstem, likely reflects differences in stream gradients between drainages. The SLOLC (1996) noted that flows within the lower portions of Stenner Creek are flashy, and that urban encroachment has contributed to significant pollutant loading in the lower Stenner Creek watershed.

Reach 20 - Stenner Creek
Reach 20 is 0.68 km (2,241 ft) long, and is located from the Chorro Street Bridge upstream to the Santa Rosa Street Bridge. Similar to Reach 19, this reach is intensively developed with residences, and the Stenner Creek corridor is consequently narrowed and sometimes channelized. Streamside canopy-forming vegetation within this reach consists of arroyo willow, various ornamentals, black cottonwood, *Eucalyptus*, California sycamore, and black walnut. California blackberry forms the dominant herbaceous understory throughout Reach 20. Exotics are abundant and similar in composition to those of Reach 19, though kikuyu grass seems to be the dominant exotic species. Instream habitat features of Reach 20 included 6.3% pools, 30.7% riffles, and 63% flatwaters, with an overall pool frequency of nearly 9/km. Pool lengths averaged approximately 7 m within this reach.

Reach 21 - Stenner Creek
Reach 21 is a 0.76 km (2507 ft) long section located from the Santa Rosa Street Bridge upstream to the Brizziolari Creek confluence point. Land use within this reach is a combination of commercial development, agricultural orchards, and row crops, with most of this reach passing through the lower Cal Poly property. Riparian vegetation includes arroyo willow, California sycamore, black walnut, coast live oak, *Eucalyptus*, and various ornamentals. Poison oak and California blackberry form the dominant understory flora.

Exotic vegetation is abundant and similar to Reach 20, with English ivy dominating. The instream habitat of Reach 21 consists of 4.3% pools, 26.5% riffles, and 69.2% flatwaters, with an overall pool frequency of 9.2/km. Pool lengths averaged approximately 5 m within this reach.

Reach 22 - Stenner Creek

Reach 22 is a 2.19 km (7,192 ft) long section located from the Brizziolari Creek confluence point upstream to Stenner Creek Road. Land use within this reach is almost entirely agricultural, with cattle ranching and row crop agriculture both present (SLOLC 1996). The entirety of this reach is within Cal Poly land holdings. Canopy-forming riparian species include coast live oak, California sycamore, arroyo willow, and *Eucalyptus*. Poison oak, California blackberry, coffeeberry, coyote brush, and toyon form the shrub understory, while perennial introduced grass species dominate the herbaceous cover. Exotics are abundant and similar in composition to other reaches within the watershed, with the addition of fennel, cocklebur, and Scotch broom. Instream features consist of 7% pools, 20.7% riffles, and 72.3% flatwaters, with an overall pool frequency of 9.6/km. Pool lengths averaged approximately 7 m within this reach.

Reach 23 - Brizziolari Creek

Brizziolari Creek, another tributary to Stenner Creek, was inventoried from its confluence point for an upstream distance of 1.79 km (5,867 ft). Land use within this sub-watershed is largely used for agriculture and cattle grazing associated with Cal Poly. While the riparian vegetation is generally in good condition, cattle entering the stream channel have eroded significant areas of streambank, contributing to excessive siltation. Instream features consist of approximately 3% pools, 6% riffles, and 91% flatwaters, with an overall pool frequency of 4.5/km. Pool lengths averaged approximately 7 m within this reach.

Reach 24 - San Miguelito (See Canyon) Creek

Reach 24 is the approximately 4km (13,200 ft) lowest portion of San Miguelito Creek. This drainage and it's associated sub-watershed are more rural and less developed than other tributaries to San Luis Obispo Creek. Land use is largely agricultural within the lowlands nearest San Luis Bay Drive, with residential development scattered throughout the lower and middle portions of the watershed. Streambank erosion exists along the lower portions of Reach 24 where See Canyon Road has encroached upon the drainage alignment. Dominant vegetation includes walnut, mixed oak, and sycamore canopies along the creek corridor, with mixed chaparral dominating the upper watershed land areas (SLOLC 1996). Instream habitats were not quantified by Cleveland (1996). However, the rural nature of this sub-watershed and the relatively undisturbed condition of its riparian corridor (SLOLC 1988) led SLOLC (1996, pg. 56) to note that "[San Miguelito Creek is] one of the best sub-watersheds for fish." San Miguelito Creek is reportedly one of the few tributaries to San Luis Obispo Creek providing both spawning and rearing habitat for southern steelhead trout (SLOLC 1988), with upstream migration impeded only by a dam located in the highest reaches of the watershed (SLOLC 2002).

Old Garden Creek

Old Garden Creek, a tributary to Stenner Creek, was inventoried from its confluence point to Foothill Blvd. for an upstream distance of 1.75 km (5,728 ft). Land use is largely urban residential, with Garden Creek forming a significant part of the landscape feature of many San Luis Obispo City residents. Riparian vegetation is sparse to non-existent due to urban encroachment. Grass lawns and ornamental vegetation are common along the streambank hinge. Similar to Stenner Creek, urban pollutant loading is a problem within this drainage. Instream features consist of approximately 3% pools, 13% riffles, and 85% flatwaters, with an overall pool frequency of 4.6/km. Pool lengths averaged approximately 6 m within this reach.

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APPENDIX C

Hydraulic and Hydrologic Report

HYDROLOGY AND HYDRAULIC STUDIES

This section summarizes the hydrologic and hydraulic analysis techniques used to determine design flow rates and water surface elevations. It provides information on the approach, methodology, and calibration of the models used to analyze and develop the flood management alternatives.

C-1.0 Watershed Hydrology

The purpose of hydrologic modeling on this project was to define design flow rates in San Luis Obispo Creek and its major tributaries for storms of various recurrence interval, ranging from the 2-year to the 100-year storm. This information will form the basis for the design and evaluation of flood management alternatives within the basin.

C-1.1 Hydrologic Modeling Approach

Questa's modeling approach has been to create a theoretical watershed runoff model using the U.S. Army Corps of Engineers' Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) computer modeling package. HMS is similar in computational ability to the old HEC-1 computer model but has a graphical user interface and allows for more detailed rainfall infiltration modeling and for greater GIS compatibility.

The model is composed of three components; watershed sub-basins, stream flow routing reaches, and modeled precipitation events. The watershed sub-basin component mimics the physical characteristics of the watershed including the relationship between precipitation and runoff. The flow routing component describes how flow moves from the upper reaches of the watershed to the mouth and determines the relative timing of this runoff. The precipitation component describes precisely how much rainfall occurs on each watershed sub-basin at each model time step.

The San Luis Obispo Creek Watershed above the mouth is approximately 217 square kilometers (84 square miles) in area. The topographic variability is quite impressive. Elevations vary from sea level to over 800 meters (2600 feet) along the crest of the Cuesta Ridge, in the Santa Lucia Mountains. No point in the watershed is more than 22 km (14 mi) from the coast. Storms coming off the Pacific Ocean are pushed over the mountains, tending to create widely varying rainfall patterns within the watershed. Precipitation in the lower Southeastern portions of the watershed can be less than half of that in the higher Northern portions. Flow in San Luis Obispo Creek can respond very quickly to short high intensity rainfall bursts. Floods in San Luis Obispo Creek tend to be of high magnitude and relatively short duration.

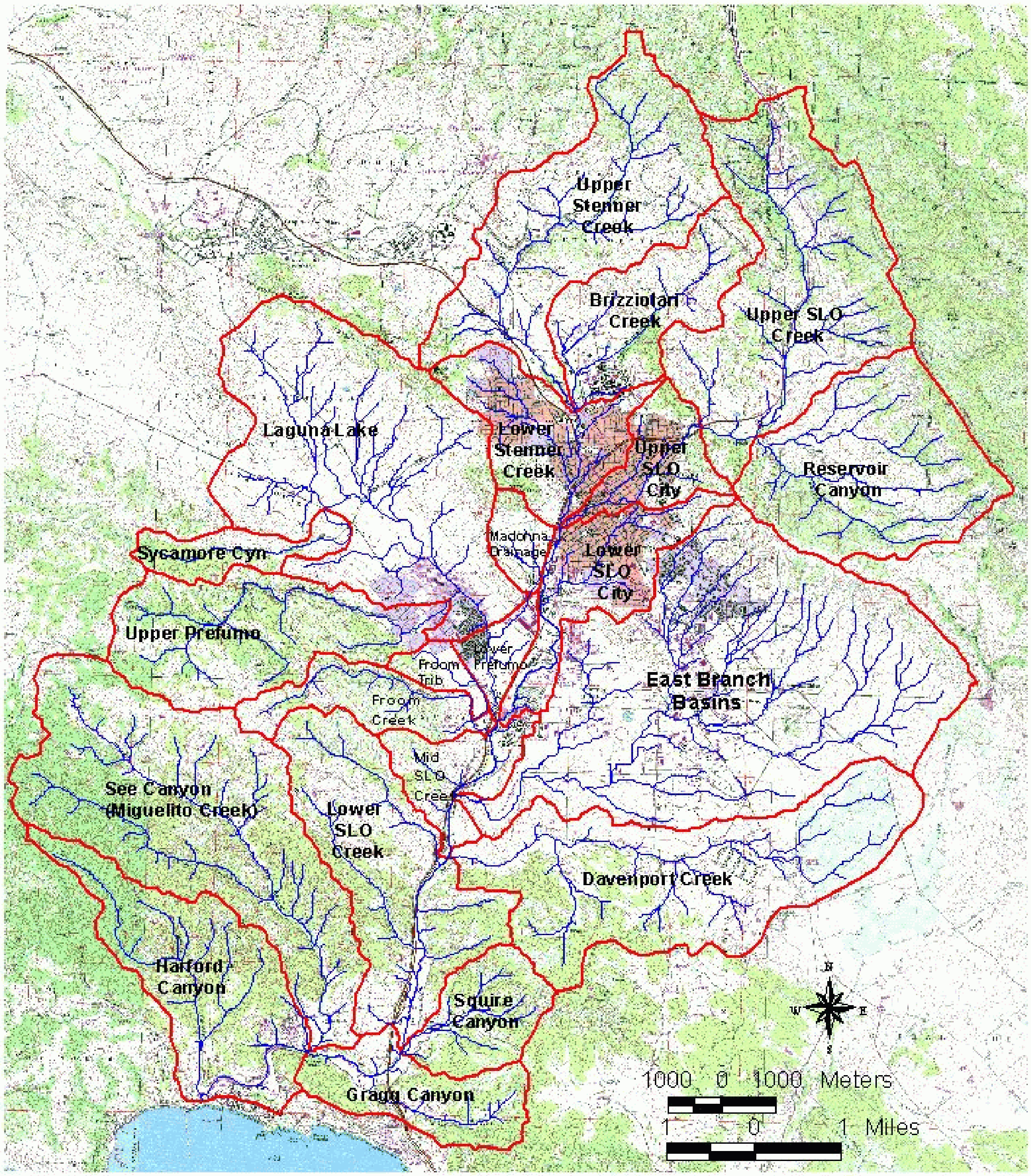

Figure C-1. Watershed Sub-Basin Boundaries

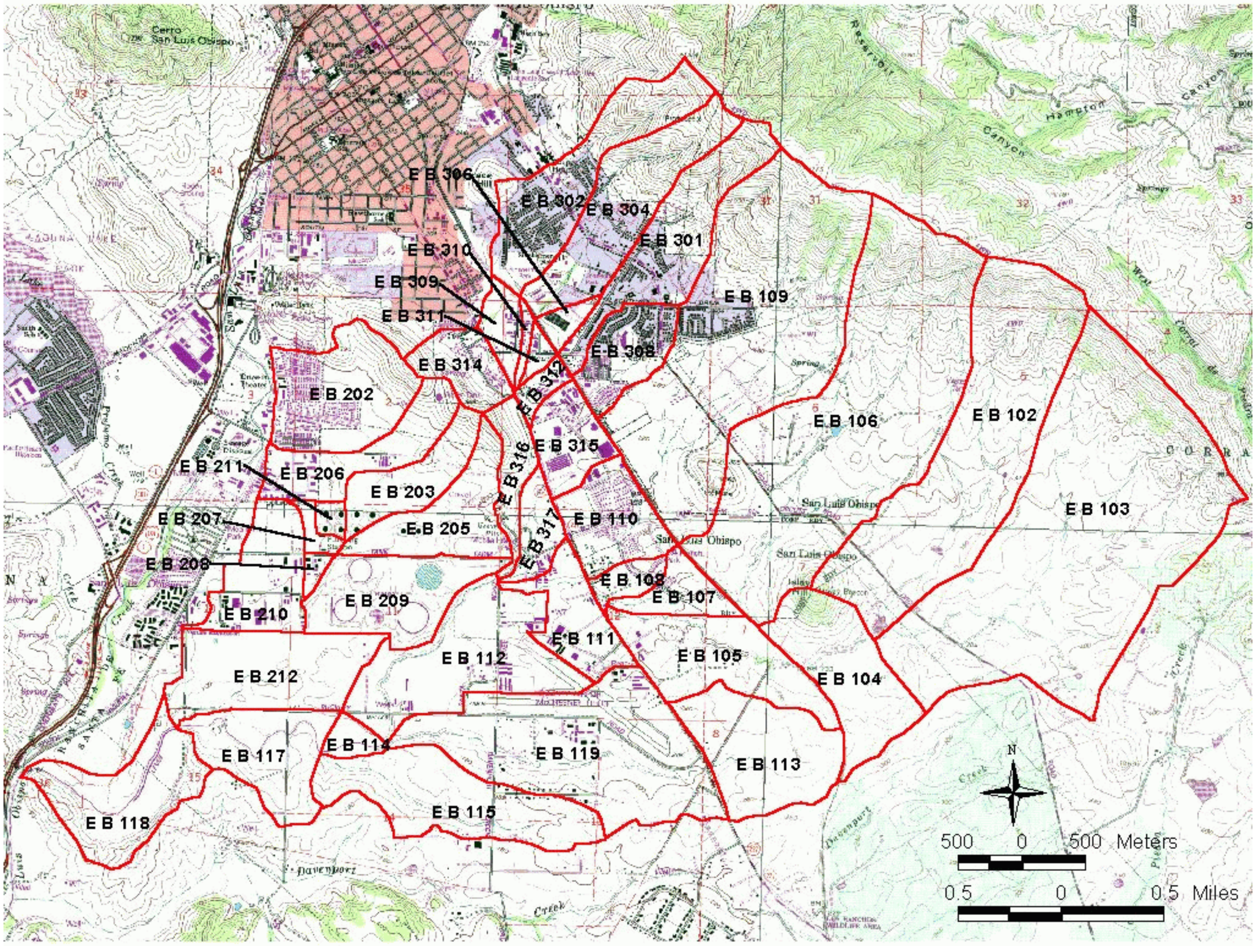

Figure C-2. Sub-basin delineation along the East Branch of San Luis Obispo Creek follows the *City of San Luis Obispo Storm Drain Master Plan* (Boyle Engineering Corporation, 1999).

C-1.2 Watershed Model

The watershed model was formed by splitting the watershed into 61 individual sub-basins (**Figure C-1**). To maintain consistency with the recently published *San Luis Obispo Storm Drainage Master Plan* (Boyle Engineering Corporation, 1999), basin boundaries within the watershed of the East Fork of San Luis Obispo Creek were taken from that report. The SCS loss-rate and the SCS unit hydrograph methods were used to determine runoff hydrographs from each of the sub-basins, based on a set of 24-hour design storms.

Loss-rate

In the SCS loss-rate method, infiltration properities of a basin are described by a runoff curve number. Curve numbers (CN) range from 1 to 100, with lower values denoting less runoff for a given precipitation total than higher values. The SCS curve number was typically calculated as a function of land use and soil hydrologic characteristics, according to Natural Resources Conservation Service (NRCS) recommendations outlined in Technical Report 55 (TR55) (Soil Conservation Service, 1975).

For this study, the goal was to develop runoff curve numbers representing four separate watershed conditions: pre-European settlement, historic circa 1960 conditions, existing conditions, and future conditions assuming general plan build-out. An individual runoff curve number map was created for each of the four watershed conditions. While it is possible to model changes in land use by changing an "impervious surface" variable in the SCS method, rather than by changing the curve number itself, this technique was not used as part of this study. Changes in curve number were the only way that change in infiltration characteristics over time were modeled.

The soil map shown in **Figure C-3** is based on published NRCS data, and is applicable for all four watershed conditions. Land use was determined using a combination of USGS quadrangle maps, recent aerial photography, city and county general plan land use maps, and several GIS vegetation coverages for the watershed. A future conditions land-use map (**Figure C-4**) was created by merging the city and county general plan land use maps and correlating the land use categories in those maps with land use categories defined by the NRCS (Soil Conservation Service, 1975). In the few locations where city and county data overlapped, the city land use category superceded the county category unless the city category was "open space," where the county map was assumed to be more representative. In areas zoned "open space," "agriculture," and "rural land," vegetation maps were overlain on top of the zoning map to better characterize those areas. Since only existing conditions vegetation maps were available, this technique assumes that vegetation characteristics in the rural parts of the watershed have been and will remain fairly constant over time.

Existing conditions land use was determined by comparing the general plan land use categories with recent aerial photography. Where the general plan land use did not appear to represent existing conditions as interpreted from a current aerial photograph, the land use category was changed to be more appropriate. This was most common directly south of San Luis Obispo.

Some areas zoned suburban or rural residential appeared on the aerial photographs to have not yet achieved total buildout. These areas were given the mean curve number between the most extensive existing vegetation type in the area and the curve number representing future general plan conditions.

There were two special cases where the existing condition land use was significantly less developed than the general plan buildout, and where simple averaging of undeveloped and post-buildout curve numbers would not be representative. These areas were See Canyon's area of "rural residential" zoning and the area of "suburban" zoning in Squire canyon. For See Canyon, we assumed that good condition brush characterized 75% of the basin and rural residential 25%. We weighted the curve numbers for these two categories accordingly. For Squire Canyon, we assumed that the existing condition was similar to the much less dense rural residential category, with 2-acre lots, and used that SCS category. Where areas were partly zoned suburban and partly grassland, we assumed that a rural residential 2-ac lot zoning was representative of existing conditions.

A similar method was used to define circa 1963 land use. This time, instead of adjusting general plan build-out curve numbers based on recent aerial photography, the general plan conditions were modified using a 1963 USGS quadrangle map. Where conditions on the historic USGS quadrangle differed from the general plan, a best estimate of the 1960's land use was made.

For pre-European settlement conditions, a curve number of 67.2 (calibrated), representing the average for undeveloped sub-basins in the existing conditions model, was applied to all sub-basins that in the 1960 model contained significant development. Essentially, this represents removing the city of San Luis Obispo and replacing it with land use that currently exists outside of the city limits. Otherwise, the pre-European settlement model is identical to the circa 1960 model.

Sub-basin curve numbers ranged from 61 to 79 (calibrated) and were typically lower in the upper portions of the watershed (**Table C-1**).

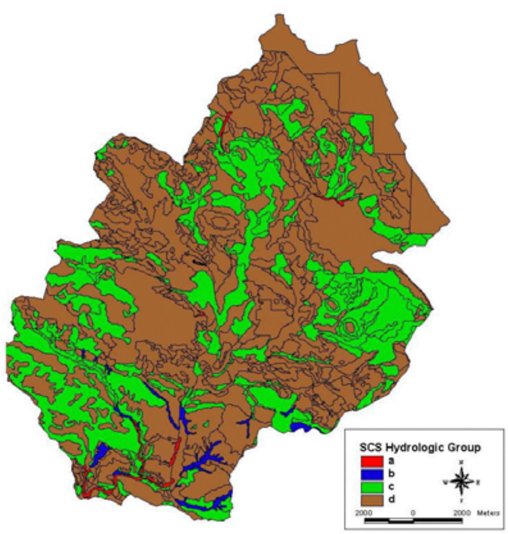

Figure C-3. Soil Hydrologic Groups.

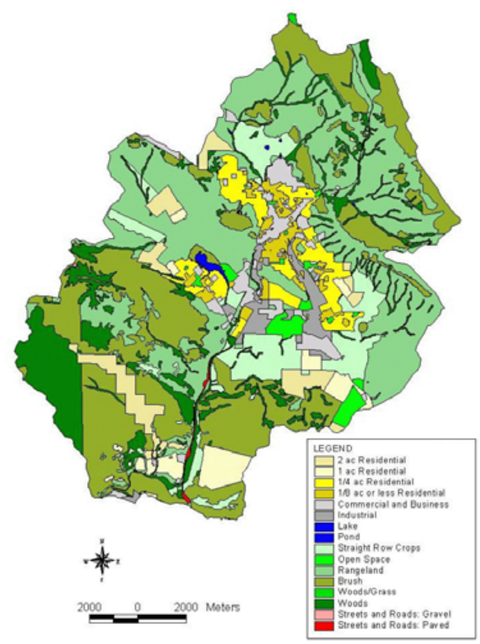

Figure C-4. NRCS Land Use Categories.

Table C-1. Loss Rate Parameters

Basin	Basin Area (km2)	Uncalibrated Existing Conditions SCS Curve Number	Calibrated Existing Conditions SCS Curve Number	Calibrated Future Conditions SCS Curve Number	Calibrated Historic 1965 Conditions SCS Curve Number	Calibrated Pre-European Settlement SCS Curve Number
Brizziolari Creek	7.28	83.7	71.2	71.2	70.7	67.2
Davenport Creek	17.97	77.1	65.6	65.6	65.9	65.9
Gragg Canyon	5.11	73.0	62.1	62.0	61.4	61.4
Froom Creek	7.57	76.1	64.7	64.8	67.8	67.2
Froom Tributary	1.12	82.2	69.9	74.3	67.8	67.2
Harford Canyon	11.09	70.3	59.7	60.1	59.5	59.5
Laguna Lake	21.69	83.4	70.9	70.9	70.7	67.2
Lower Prefumo	1.64	88.4	75.1	75.7	67.8	67.2
Lower SLO City	6.01	88.9	75.6	75.6	74.5	67.2
Lower SLO Creek	13.54	76.9	65.3	65.1	64.7	64.7
Lower Stenner	6.44	85.6	72.7	73.1	72.1	67.2
Madonna Drainage	1.56	82.7	70.3	70.3	67.8	67.2
Mid SLO Creek	3.57	81.5	69.3	69.3	67.8	67.2
Miguelito Creek	21.01	71.6	60.8	62.0	60.8	60.8
Reservoir Canyo	12.51	78.3	66.5	66.5	66.5	66.5
Squire Canyon	4.18	76.4	65.0	66.1	61.4	61.4
Sycamore Canyon	2.72	76.1	64.7	64.6	64.7	64.7
Upper Prefumo	10.46	75.8	64.4	64.4	64.1	64.1
Upper SLO City	3.45	87.5	74.4	74.5	74.0	67.2
Upper SLO Creek	17.15	78.6	66.8	66.8	66.8	66.8
Upper Stenner	15.01	80.5	68.5	68.5	68.3	67.2
E B 102	2.29	78.7	66.9	66.9	66.9	66.9
E B 103	4.193	79.3	67.4	67.4	67.4	67.2
E B 104	0.912	80.9	68.7	68.7	68.7	67.2
E B 105	0.837	85.8	72.9	72.9	72.0	67.2
E B 106	3.577	82.1	69.8	69.7	70.4	67.2
E B 107	0.282	85.4	72.6	72.6	71.4	67.2
E B 108	0.127	84.0	71.4	71.4	71.9	67.2
E B 109	2.968	82.7	70.3	70.3	71.0	67.2
E B 110	0.518	89.5	76.1	76.2	73.8	67.2
E B 111	0.458	92.8	78.9	78.9	74.8	67.2
E B 112	1.083	89.4	76.0	75.6	75.6	67.2
E B 113	0.909	89.0	75.6	75.6	75.5	67.2
E B 114	0.041	85.8	72.9	72.9	72.9	67.2
E B 115	1.031	86.3	73.4	73.5	75.5	67.2
E B 117	0.671	86.0	73.1	73.1	73.1	67.2
E B 118	1.054	82.0	69.7	69.7	69.8	67.2
E B 119	0.86	89.0	75.7	76.2	76.2	67.2
E B 202	0.86	86.8	73.8	74.6	73.0	67.2
E B 203	0.448	84.3	71.7	75.5	72.6	67.2
E B 205	0.606	83.7	71.1	73.7	75.4	67.2
E B 206	0.534	86.9	73.9	75.9	72.1	67.2
E B 207	0.085	84.1	71.5	80.3	76.8	67.2
E B 208	0.06	92.9	79.0	79.0	76.7	67.2
E B 209	0.751	84.2	71.6	68.1	78.1	67.2
E B 210	0.58	89.1	75.7	78.1	73.4	67.2
E B 211	0.06	84.0	71.4	80.7	78.2	67.2
E B 212	0.899	88.2	75.0	75.0	75.1	67.2
E B 301	0.904	84.9	72.2	72.6	72.4	67.2
E B 302	0.979	85.7	72.9	72.8	73.1	67.2
E B 304	0.907	85.8	72.9	72.9	72.2	67.2
E B 306	0.08	91.9	78.1	78.6	75.6	67.2
E B 308	0.433	85.9	73.0	73.8	73.6	67.2
E B 309	0.176	90.6	77.0	78.2	74.4	67.2
E B 310	0.049	87.9	74.7	78.7	70.1	67.2
E B 311	0.054	88.4	75.2	79.1	75.0	67.2
E B 312	0.106	88.9	75.5	79.0	72.7	67.2
E B 314	0.368	87.9	74.7	74.7	74.6	67.2
E B 315	0.365	92.9	78.9	78.9	75.4	67.2
E B 316	0.233	83.8	71.3	71.6	70.8	67.2
E B 317	0.238	90.5	76.9	76.7	75.5	67.2

The *initial abstraction* represents the amount of water temporarily stored in puddles, on plant stems, in the soil, etc., before runoff begins. It is related to the runoff curve number but can vary from this relationship depending on how recently the watershed experienced a significant rainfall event. For this study, the initial abstraction was initially assumed to follow an empirical relationship with the runoff curve number as described by **Equation C-1**.

Eq. C-1

$$I_a = 0.2\left(\frac{1000}{CN} - 10\right)$$

Values of initial abstraction ranged from 0.48 to 0.69 in, but were adjusted down 50 percent after model calibration. Because the purpose of the modeling is to predict the runoff from relatively large design storm events, and because the most intense rainfall in the design storm occurs 12 hours after the storm begins, the initial abstraction is usually “filled” long before the most intense design rainfall occurs. This makes initial abstraction a less important variable for our purposes than the curve number. It would be more important if the purpose of the modeling was to predict peak flow rates from less intense, shorter duration storms.

Hydrograph Transformation

The SCS unit hydrograph method was used to transform excess rainfall into runoff at the outlet of any given basin.

Lag time is the difference in time between the center of mass of excess rainfall and the time at which flow from that sub-basin peaks. It is the only required input parameter for the SCS unit hydrograph transformation. Lag time is often calculated as a function subbasin geometry according to the following form:

Eq. C-2

$$T_{lag} = C_t * \left(\frac{(L * L_{ca})}{\sqrt{S}}\right)^m$$

where:

C_t = empirical coefficient
= 24*N where N is a basin roughness coefficient (Nolte and Associates, 1977)
L = the maximum flow length in a basin, in mi.
S = the average slope along the maximum flow length pathway
L_{ca} = the distance from the basin outlet to the centroid
m = lag exponent.

For the sub-basins in the East Branch of San Luis Obispo Creek, lag parameters were taken from the *City of San Luis Obispo Storm Drain Master Plan* (Boyle Engineering Corporation, 1999). For the remaining basins, two sets of coefficients were used. For the two urbanized basins in the watershed–Upper SLO City and Lower SLO City–coefficients derived by the US Army Corps of engineers for 100% urbanized watersheds in the Tulsa Oklahoma area were used (Boss International, 1999). These are $C_t = 0.59$ and $m = 0.30$. For all other basins outside the East Branch watershed, coefficients derived by Riverside County, California for foothill areas were used. Here, $C_t = 0.72$ (i.e. N = 0.03) and m = 0.38. Time lag for each of the sub-basins is listed in **Table C-2**.

As part of the model verification process, the unit hydrograph used by George S. Nolte and Associates (1977) was substituted for the SCS Unit Hydrograph Method. The difference in peak flow rates and timing was negligible–on the order of 2-3 percent.

Base Flow

Base flow from each sub-basin was determined by looking at the daily-average flow rates at the stream gauge that operated on San Luis Obispo Creek near Avila until 1986. A conservative estimate was made by assuming that base flow in the creek during a large storm would be similar to the base flow in the creek that was observed over the week following the storm of March 2, 1983. The average base flow for this time period, omitting days when rainfall occurred, was approximately 14 cms (500 cfs). Divided over the upstream area of 207 km^2 (80 mi^2) this gives an average base flow rate of 0.067 cms/km^2 (6.3 cfs/mi^2), which was then applied to each sub-basin.

This base flow rate is significantly higher than the long term average winter-season flow rate in San Luis Obispo creek, and is intended to represent the base flow in the creek during a series of wet storms. It is much greater than any likely wintertime releases from the City of San Luis Obispo Water Reclamation Facility, which discharges into San Luis Obispo Creek downstream from the Prado Road Bridge.

C-1.3 Flow Routing

Runoff from individual sub-basins is routed through the system using the Muskingum-Cunge 8-point routing technique. This technique uses a rough approximation of a channel cross section, including the floodplain, along with representative roughness values, to evaluate the effects of channel and floodplain storage on the flood hydrograph as it passes downstream through the reach.

Highway 101 crosses San Luis Obispo Creek at two locations near the upstream city limits, once just below Cuesta Park, and once just above Cuesta Park. These culverts have been observed to cause ponding upstream of the respective highway embankments during large storms, which could cause a significant amount of attenuation of flood peak flow rates. The backwater behind each of these culverts was modeled using reservoir routing techniques available in HEC-HMS. A computer hydraulic model was created for each of these culverts using HEC-RAS (as described in Section B-2 of this appendix). A flow versus upstream water surface elevation curve for each culvert was obtained from the model. Elevation versus water surface area curves were obtained from the LIDAR survey flown as part of this project for the lower culvert and from the 1994 City of San Luis Obispo 10-m DEM for the upper culvert. Note that the 10-m DEM is more accurate than the 100-ft DEM currently supported by the City. It was flow by Golden State Aerials in 1994, has a 10 meter horizontal spacing between points, and has a vertical accuracy on the order of 0.6 to 0.76 m (2 to 2.5 ft) (Baragona, pers. comm, 2001). The LiDAR accuracy is on the order of 0.15 m (0.5 ft).

Another important routing area was Laguna Lake in the Prefumo Creek watershed. Laguna Lake was modeled as a reservoir using the Modified Puls method. The stage elevation curve for the lake was obtained from a combination of an existing 10-m Digital Elevation Model (DEM) of the San Luis Obispo Creek watershed and an aerial laser topographinc (LIDAR) survey performed as part of the WMP. (See the WMP for more details). The stage-discharge curve for the reservoir, which empties into lower Prefumo Creek through two 2.13 m x 3.05 m (7 ft x 10 ft) concrete box culverts and one 2.13 m x 4.27 m (7 ft x 14 ft) concrete box culvert under Madonna Road, was obtained by setting up a HEC-RAS backwater model of the culvert and stream system in that area.

Some of Laguna Lake's flood storage volume would likely already be used at the start of a peak 24-hour rainfall event. A conservative starting water surface elevation for the 10-year, 25-year, 50-year, and 100-year storms was obtained by developing a separate simplified rainfall-runoff model of the watershed above the lake and then running an 8-day storm corresponding to the desired recurrence interval through the watershed and lake on an hourly time increment. The simplified model used a constant infiltration rate of 0.13 in/hr, which was reported by George S. Nolte and Associates (1977) to be appropriate for long-term detention analysis. The highest lake elevation from the given design 8-day storm was used as the starting water surface elevation for the 24-hour design storm. The rainfall depth for the 8-day storms was obtained by a statistical analysis of the each year's highest 8-day precipitation total as recorded at the San Luis Obispo Cal Poly rain gage, for the 1948 to 2001 water years. The highest total, 21.8 in, occurred from January 19 to January 26, 1969. The statistical results, as fit to a Gamma probability distribution function, are shown in **Figure C-5**. The precipitation pattern for the 8-day storm was based on the January 19 to 26, 1969 storm as recorded at the Huasna, California gage (the only hourly gage record currently available for that storm). This gage is located approximately 30 km (20 mi) southeast of San Luis Obispo.

C-1.4 Precipitation

The 24-hour design storm precipitation was based on *NOAA Atlas II, Precipitation-Frequency Atlas of the Western United States*. Because of the significant topographic variation within the watershed, two separate 24-hour design storms for each recurrence interval were synthesized, one for the lower portions of the watershed (those basins with a mean elevation below 200 meters) and one for the upper portions (mean elevation 200 meters or greater), based on typical depth-duration-frequency numbers taken from the *NOAA Atlas II* (National Oceanic and Atmospheric Administration, 1973). **Table C-3** lists the depth-duration-frequency values used for developing the design storms. **Figure C-6** shows the basins with mean elevations above 200 meters.

Table C-3. Design Depth-Duration-Frequency Values

For Basins Below 200-m in mean elevation:

	Rainfall (mm) at various durations and frequencies				
Duration	**100-year**	**50-year**	**25-year**	**10-year**	**2-year**
5 min	11.7	10.5	9.3	7.9	5.0
10 min	18.2	16.3	14.4	12.2	7.7
15 min	23.1	20.7	18.2	15.5	9.8
1 hr	40.5	36.3	32.0	27.2	17.1
2 hr	55.2	49.6	45.0	37.7	24.0
3 hr	69.1	62.1	57.4	47.7	30.5
6 hr	101.6	91.4	86.4	71.1	45.7
12 hr	135.9	128.3	115.6	94.0	64.8
24 hr	170.2	165.1	144.8	116.8	83.8

For Basins Above 200-m in mean elevation:

	Rainfall (mm) at various durations and frequencies				
Duration	**100-year**	**50-year**	**25-year**	**10-year**	**2-year**
5 min	12.2	11.2	10.0	8.6	5.6
10 min	19.0	17.4	15.5	13.4	8.7
15 min	24.1	22.0	19.7	16.9	11.0
1 hr	42.2	38.6	34.5	29.7	19.3
2 hr	59.5	54.9	48.2	41.5	27.5
3 hr	76.0	70.5	61.2	52.7	35.2
6 hr	114.3	106.7	91.4	78.7	53.3
12 hr	158.8	146.1	125.7	106.7	73.7
24 hr	203.2	185.4	160.0	134.6	94.0

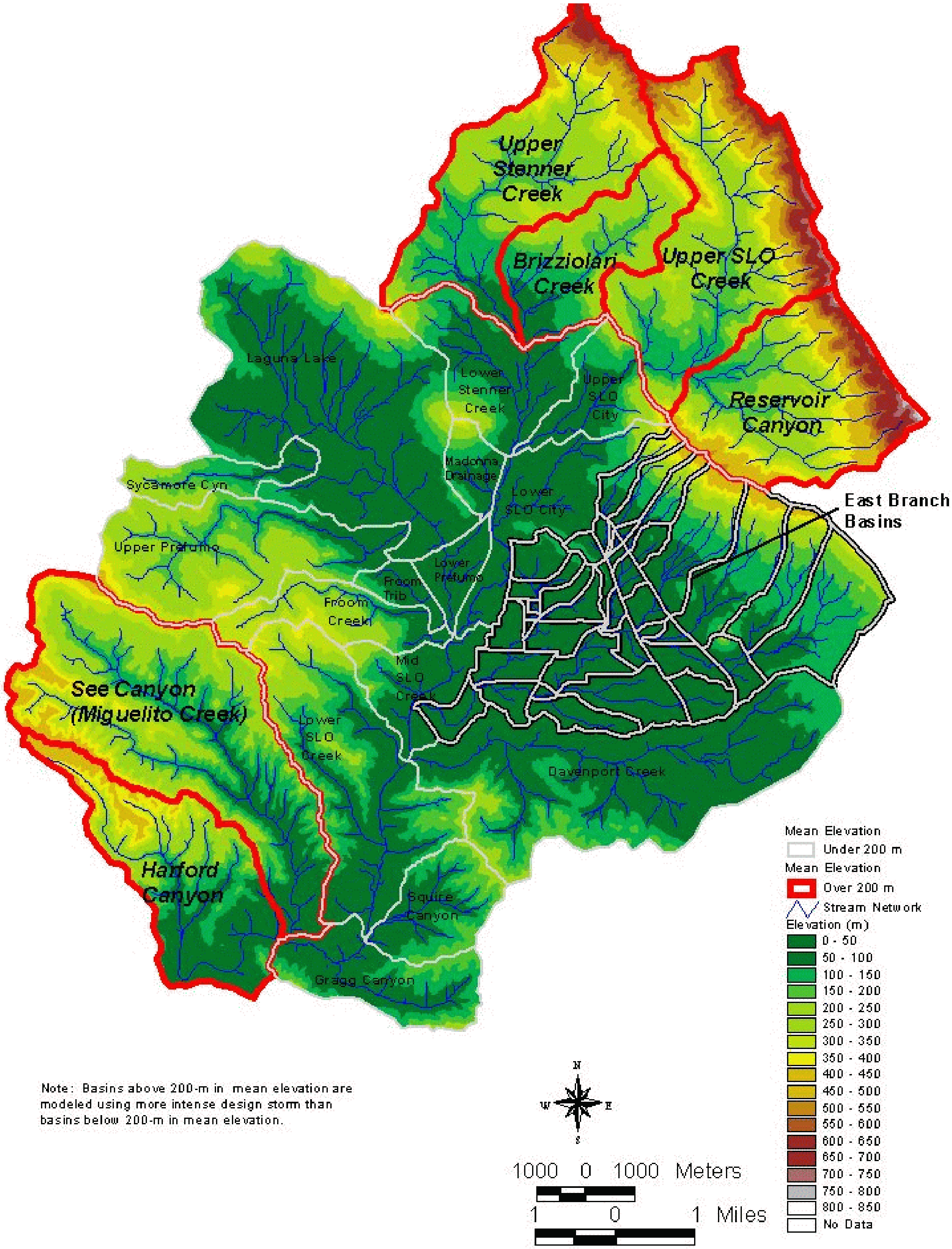

Figure C-6. Higher Intensity Design Storm Locations

Hypothetical design storms generated using this method give precipitation distributions that are appropriate for individual points but not for large areas. For areas much larger than a few square kilometers, the fact that the storm must travel from one portion of the basin to the next prevents the most intense rainfall from occurring all at once. In other words, while it may be raining heavily at point A, at the same time, it is only lightly raining at point B, and the totals at point B may never reach those of point A during that particular storm event. The further apart A is from B, the more pronounced this effect. Because both A and B contribute flow to the lower portions of the creek, flow rates there are lower than if the storm at A was occurring simultaneously at B.

To account for this phenomenon, a correction factor must be applied to the design storms derived using NOAA data. This factor reduces the storm precipitation based on the area of upstream contributory watershed. While there is a fairly simple way to handle this in HEC-1, the current version of HMS does not include this ability. Consequently, we derived four different design storms, each of which would give a conservative approximation of this effect for a selected set of points along the stream system. The depth-area curve used to make the reduction was taken from *NOAA Atlas II* (**Figure C-7**).

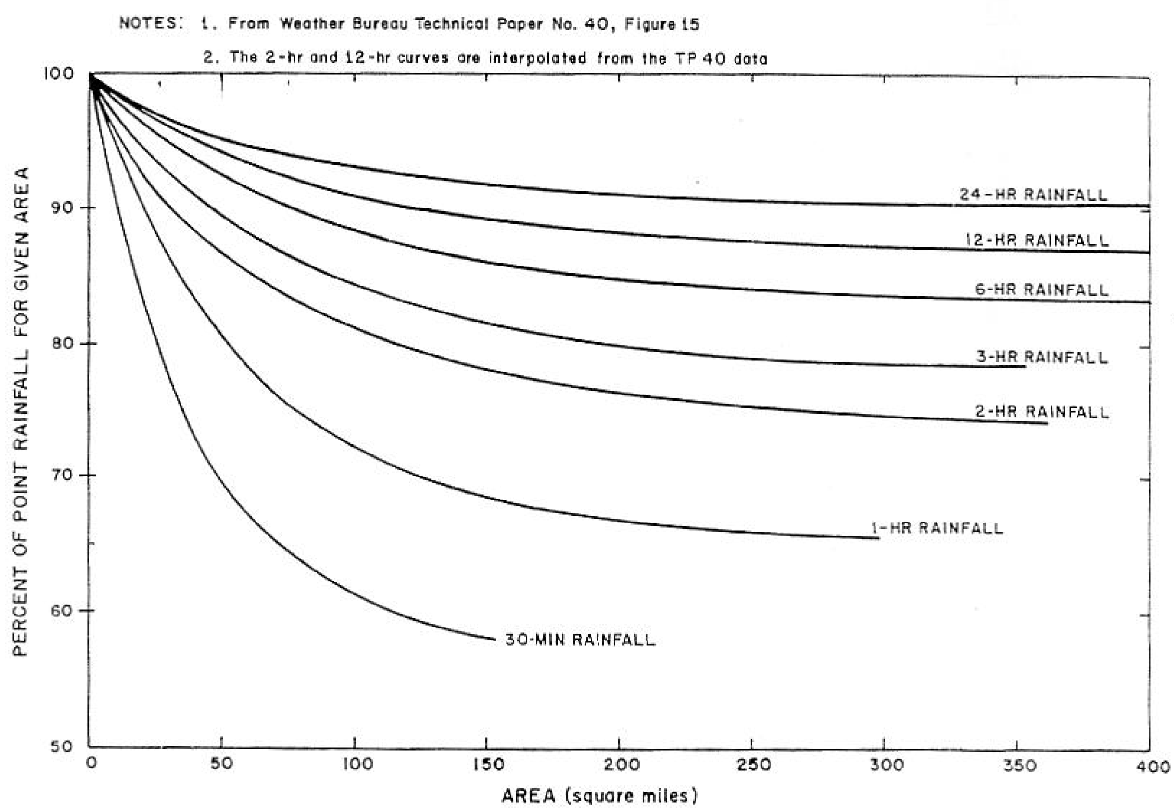

Figure C-7. Depth-Area curves used for developing design storms for larger watershed areas.

The first storm size was set equal to the area of each individual sub-basin. This storm (Storm A) is appropriate along all tributaries of San Luis Obispo Creek before their confluence with San Luis Obispo Creek, as well as for Upper San Luis Obispo Creek before the confluence with Stenner Creek. The second storm (Storm B) was given a size based on the combined area of the Stenner and San Luis Obispo Creek basins above the Stenner/San Luis Obispo Creek confluence (61.8 km^2, 23.9 mi^2). It is appropriate for computing flow in San Luis Obispo Creek from the confluence with Stenner Creek downstream to the confluence with the East Branch of San Luis Obispo Creek. The third storm (Storm C) was given a size based on the combined area of the Main Stem of San Luis Obispo Creek and the East Branch of San Luis Obispo Creek at the Main Stem/East Branch confluence (133.9 km^2, 51.7 mi^2). This storm is appropriate for computing flow in San Luis Obispo Creek from the East Branch confluence downstream to the mouth of the Gragg Canyon tributary. The fourth storm (Storm D) was given a size equal to the entire San Luis Obispo Creek watershed above the confluence with Miguelito Creek (See Canyon, 174.7 km^2, 67.5 mi^2). It is appropriate to use this storm from the mouth of the Gragg Canyon Tributary downstream to the mouth of San Luis Obispo Creek. The depth-area reduction factors used for each storm size are listed in **Table C-4**.

Table C-4. Depth-Area Reduction Factors

Duration	Storm A (12 km^2)	Storm B (62 km^2)	Storm C (133 km^2)	Storm D (175 km^2)
5 min	0.94	0.79	0.69	0.66
10 min	0.94	0.79	0.69	0.66
15 min	0.94	0.79	0.69	0.66
1 hr	0.97	0.88	0.8	0.77
2 hr	0.98	0.91	0.85	0.82
3 hr	0.99	0.94	0.9	0.88
6 hr	0.99	0.96	0.93	0.91
12 hr	1.00	0.96	0.94	0.92
24 hr	1.00	0.97	0.95	0.94

C-2 Hydraulic Model

Project flood management alternatives were analyzed using the U.S. Army Corps of Engineers Hydraulic Engineering Center–River Analysis System (HEC-RAS) version 3.0. HEC-RAS is a one-dimensional hydraulic computer modeling system that is used to predict flood water surface elevations at approximately evenly spaced cross-sections, oriented perpendicular to the predominate flow direction and distributed throughout the modeled reach. The predicted water surface elevations are then compared to the elevation of the top of channel banks and of the floodplain (and buildings) to determine flood break-out points and outline the extent and depth of flood water for various flood flow recurence intervals (i.e. 10-year, 100-year flows).

C-2.1 Data Requirements

The input requirements for the model include stream flow rates, the geometry of various hydraulic structures such as bridges and culverts, topographic information along a set of relatively evenly spaced cross-sections oriented perpendicular to the predominant flow direction, channel roughness estimates (such as flow resistance) along each cross-section, and a water surface elevation at the downstream boundary of the model.

Section C-1 of this appendix describes the rainfall-runoff modeling methods used to define stream flow rates used in this study. Field surveys and as-built drawings were used to define the hydraulic structures such as bridges and culverts.

The topographic information for this project was obtained using LIDAR technology. LIDAR is a system where a laser beam mounted on an aircraft is shot at the ground from the air. The signal produced when the laser beam hits the ground can be used to measure the distance from the aircraft and the ground. This, combined with a global positioning system (GPS) receiver on the aircraft and some post-processing that corrects for signal returns coming from objects not directly on the ground surface can be used to produce a map of ground spot elevations. The raw LIDAR points, which for our survey were spaced approximately 2-meters apart, are then used to create a gridded surface map (at 5-meter spacing for this project) of the channel and floodplain topography.

For this project, the grid produced from the LIDAR was not dense enough to fully characterize the channel bed. Even the 2-meter spacing between raw points was not sufficient in certain locations to fully define the channel. Consequently, a second LIDAR flight, this time with a raw point spacing of less than 1 meter, was performed in the spring of 2000 to densify the channel. Raw points from this and from the original LIDAR survey were used to develop the surface used for hydraulic modeling between channel banks. Outside of the channel banks, the original 5-meter grid was used

Because the post-processing that corrects for vegetation and buildings can remove a significant number of points at some locations where the stream channel bed is obscured by dense vegetation, it was necessary for us to directly inspect the raw point coverage to determine where the LIDAR survey had resulted in a dense point coverage in the channel bed. We drew our cross-sections at locations where the raw data points existed all the way across the stream bed. Also, since bridges can obscure the channel bed from the LIDAR instrumentation, we augmented the LIDAR survey with physical surveys taken in the field at all bridges in the study reach (with the exception of those bridges along the East Branch of San Luis Obispo Creek, where information was taken directly from the HEC-RAS model developed for the area by Boyle Engineering Corporation as part of the Airport Area Specific Plan).

Channel roughness was estimated in the field by comparing published roughness values for various photographed channels with the condition of the local channel (from bank-top to bank-top). Roughness in the floodplain areas outside the stream banks was estimated by creating a map of representative regions using digital orthophotography of the site and coding these representative regions with appropriate values based on published Corps of Engineers guidelines (U.S. Army Corps of Engineers, 2001). Where buildings provide significant obstruction to flood flow, especially through the downtown district of San Luis Obispo and on the east side of Higuera street south of downtown, very high roughness values on the order of 1.0 to 2.0 were used to represent the composite effect of bed roughness across streets and lawns and the obstructing effects of the buildings. Streets in built-up areas that run parallel to the creek channel were coded with low roughness values in order to represent the increased flood flow conveyance these zones provide. **Table C-5** shows the typical roughness values used in the model.

Table C-5. Typical Manning's Roughness Values.

Land Use	Roughness Value
Overbank Areas	
Typical Built up Areas	0.07-0.15
Fields	0.035
Orchard	0.06
Riparian Scrub/Forest	0.09-0.1
Suburban Areas	0.06
Open Streets	0.025
Upland Woodland/Chaparral	0.07
Downtown SLO Commercial Buildings *	1.0-2.0
Stream Channels	
San Luis Obispo Creek Through City	0.045-0.065
San Luis Obispo Creek Below City Limits	0.06-0.07
San Luis Obispo Creek at Avila Golf Course	0.03-0.045
Stenner Creek	0.05-0.065
Brizziolari Creek	0.055-0.06
Prefumo Creek	0.06-0.07

* Downtown commercial buildings were coded with extremely high roughness to effectively block all flow from being conveyed through them. Overbank flow in those areas was allowed to travel down individual streets, which were coded with a roughness of 0.025.

The downstream boundary condition for the model was taken as the highest recorded tide at Port SanLuis, approximately 1.6 km (1 mi) west of the mouth of San Luis Obispo Creek. This water surface elevation was observed on January 18, 1973, during one of the largest storms on record for the region. It is approximately 0.73 meters (2.40 ft) above Mean Higher High Water (MHHW) at this location. A sensitivity analysis performed on this variable showed that the downstream boundary only influenced the model significantly for several hundred meters upstream of the mouth and had no impact on the model above the coffer dam upstream of the Avila Golf Course, about 2 km above the mouth.

C-2.2 Flow Splits

There are several points in the watershed where flow splits out of the main channel and spills across a roadway or berm, leaving the main channel for a significant distance. Specifically, this occurs on Stenner Creek above Foothill Boulevard and again at Murray and Santa Rosa Streets, and on San Luis Obispo Creek across Highway 101 at several locations in the vicinity of Madonna Road. At these specific locations, some of the assumptions made in producing a 1-dimensional model are violated, and a different modeling technique must be used. We used the broad crested weir equation to calculate the amount of flow lost from the main channel at these locations. A separate reach was defined in the HEC-RAS model for the overflow areas until they finally meet up with a modeled creek reach downstream of the breakout point.

C-2.3 Undercity Culvert

In Downtown San Luis Obispo, San Luis Obispo Creek runs for about 370 m (1200 ft) through a completely enclosed structure referred to here as the undercity culvert. According to a U.S. Army Corps of Engineers report (U.S. Army Corps of Engineers, 1985), the culvert has a capacity of 127 cms (4500 cfs). This is not sufficient to pass even a 25-year flow event, according to our hydrology model results. Flow in San Luis Obispo Creek was observed in1973 to split out of the channel upstream of the culvert and to re-enter the channel over 1 km (0.6 mi) downstream, along Higuera Street.

To model the undercity culvert in HEC-RAS, the capacity determined by the Corps of Engineers was assumed to represent the condition just before flow spills out of the channel immediately upstream of the culvert. For flow rates less than the culvert capacity, the culvert was modeled as a rectangular box whose dimensions and characteristics were calibrated so that a 127-cms (4500-cfs) flow just overtopped the channel at the upstream end. For flow rates greater than the culvert capacity, the model was made more stable by simply removing the culvert and modeling an overland flow rate equal to the total design flow minus the 127-cms (4500-cfs) culvert capacity.

C-3 Model Calibration

Regardless of the amount of detail incorporated into the model, calibration against real data must occur before results can be verified and used reliably. Calibration of the hydrologic and hydraulic models was performed using NEXRAD radar rainfall totals and high water marks observed for the storm of March 9 to 11, 1995.

C-3.1 Calibration Storm

One of the challenges of modeling the rainfall along California's Central Coast is the strong orographic influence the Coast Ranges have on precipitation totals. While rainfall for the March 1995 storm was recorded at numerous rain gauges throughout the basin, only six rain gauges in the immediate vicinity of the San Luis Obispo Creek Watershed recorded rainfall on the15-minute (or shorter) time intervals necessary for the hydrology model (**Figure C-8**). The difference between the lowest and highest rainfall total for the March 1995 storm was just over 100% of the lowest gauge total. These gauges were deemed insufficient to fully characterize the magnitude of the storm in certain parts of the watershed, especially where orographic effects would have acted to increase precipitation beyond what the valley floor experienced.

Figure C-9 shows cumulative rainfall at each of six recording rainfall gauges in the watershed. Peak recorded 24-hour totals ranged from 9.39 cm (3.69 in) at the Cuesta Ridge gauge to 21.56 cm (8.49 in) at the Santa Margarita Booster gauge, just north of the northern watershed boundary near the crest of Cuesta Ridge, while peak 48-hour totals ranged from 13.20 cm (5.20 in) at the Cuesta Ridge gauge to 29.76 cm (11.71 in) at the Santa Margarita Booster gauge. The rainfall totals at the county-maintained Cuesta Ridge gauge were significantly lower than at any of the other gauges and are likely in error–especially considering the much higher totals recorded a few miles away at the Santa Margarita Booster gauge. The Cuesta Ridge data were not used in any technical analysis. The next lowest totals were at the SoCal Gas gauge, near the San Luis Obispo Airport, with a 12.12 cm (4.77 in) 24 hr-total and a 14.29 cm (5.62 in) 48-hour total. Because of the wide variability in precipitation totals from gauge to gauge and because of uncertainty in the reliability of the county-maintained Cuesta Ridge gauge (and, by extension, at the other county-maintained gauge at Davis Peak), a more detailed method of modeling rainfall for the March 1995 storm was required.

To provide a more complete picture of rainfall for the March 1995 Storm, archival NEXRAD meteorologic radar information for the time period in question was used to develop a detailed set of rainfall information, on 15-minute time steps, for each basin in the watershed model. The meteorologic analysis, performed by NEXRAIN corporation, involved calibrating radar return information with gauged rainfall intensities so that the NEXRAIN dataset was consistent with gauged information. Gauges outside the San Luis Obispo Creek watershed were used for this rainfall calibration process. Data was first computed on a 2-km by 2-km grid, and then averaged by sub-basin. Totals for the peak 24-hour period ranged from 16.81 cm (6.62 in) for the Davenport Creek sub-basin to 33.20 cm (13.11 in) for the Harford Canyon sub-basin. A complete 48 hour period was not covered by the NEXRAIN dataset. The entire NEXRAIN dataset can be found in the HEC-HMS hydrology model, which is published on CD along with this document.

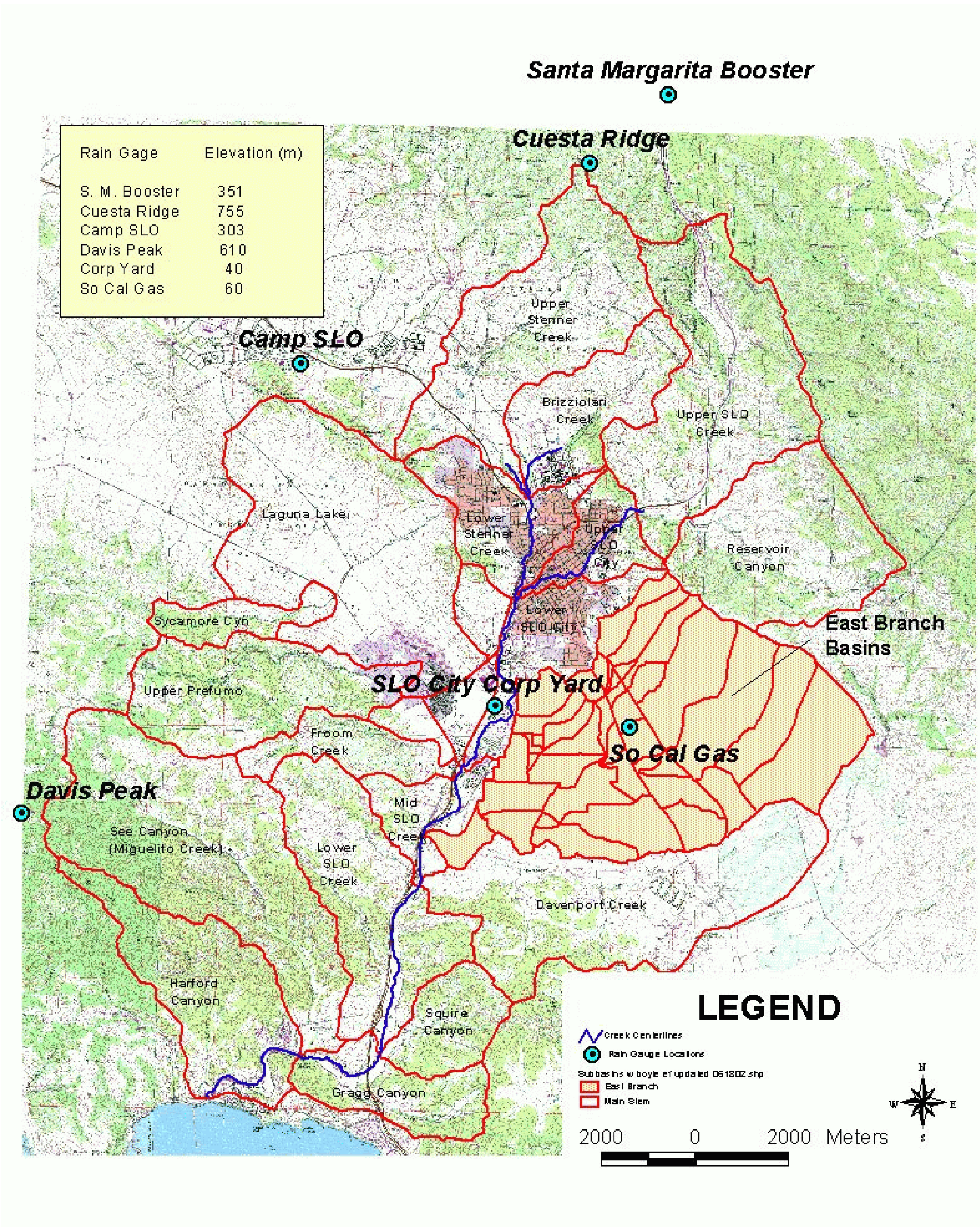

Figure C-8. Precipitation gauge Locations

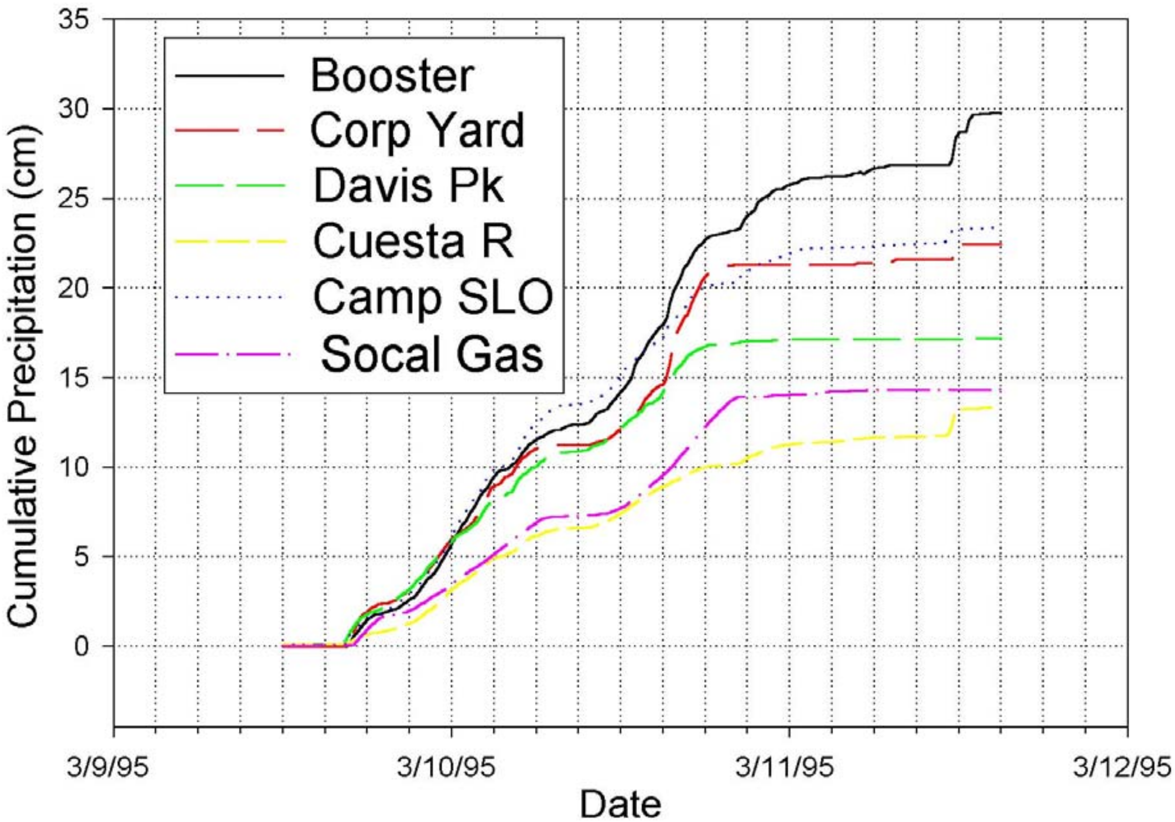

Figure C-9. Rain gauge record, March 9 to 11, 1995.

C-3.2 High Water Marks

Historically, at least two stream gauges existed in the San Luis Obispo Creek Watershed that would have been capable of recording flood peaks. One was located on lower San Luis Obispo Creek near Avila, and the other was located on Upper San Luis Obispo Creek, in San Luis Obispo. Unfortunately, both of these gauges were put out of service in 1992. Since that time, the city of San Luis Obispo has re-installed a gauge on Upper San Luis Obispo Creek. However, there is no gauge record for the 1995 water year.

The best records available for describing the effects of the March 1995 storm are in the form of high water marks surveyed at various points throughout the basin. Some of these high water marks were surveyed immediately after the storm, while others were derived later based on photographs taken near the flood peak. A summary of the available marks is shown in **Table C-6**

.

Table C-6. Hydrology Model Calibration Points.

Observed Mark Location	Source	NAVD 88 Elevation (m)	Reliability [1]	Back-Calculated Flow (m^3/s)	Uncalibrated HMS Flow (m^3/s)	Calibrated HMS Flow (m^3/s)
Sycamore Mineral Springs ~St 3342	Colleen Snyder, Sycamore Employee	9.21-9.36	A	450-500	655	571
Ontario Road ~St 4370	Dan Erdman, County Engineer	9.88	A	490	655	571
Below Sycamore Mineral Springs [2]	Church Water Consultants	multiple points	A	n/a	n/a	n/a
Caltrans Yard, ~St 15646	Caltrans Employee/City Survey	47.67	A	210	293	268
McNamera, ~St 16712	Property Owner/City Survey	53.33	A	325	271	247
Nipomo Bridge, 17431	Photo/LIDAR	58.4	B	140	161	148
Dana Street, ~St 17180	Photo/LIDAR	55.8	B	143	161	148
Upper Stenner Creek @ Radio Tower	Cal Poly Student Survey	N/A	C	62	64	58
Stenner Creek 300m above Nipomo	Cal Poly Student Survey	N/A	C	78	118	106
Brizziolari Creek Above Cal Poly	Cal Poly Student Survey	N/A	C	26	33	30

[1] Reliability is used here to denote the quality of the survey used to determine the high water mark. For an "A" rating, the datum o
the mark must be correctly known and have been surveyed professionally. For a "B" rating, the location of the mark is precisely known, bu
the elevation of the nearest surface visible on the LIDAR survey is used as a vertical datum. Neither the precise location nor elevatio
of the "C" marks is known. These were taken from a senior project prepared by a Cal Poly student in 1995. Some manipulatio
of the data in the student report was required to allow the data to be used for this study
[2] Points surveyed by Church Water Consultands were too numerous to back-calculate flows individually. They were used as model validation. See Figure B-1

C-3.3 Calibration Technique and Results

Because no reliable stream gauge data was available for the March 1995 storm, the best way to check the results of the rainfall-runoff model against reality was to use the hydraulic model to back-calculate flow rates from recorded high water marks, and to then check whether the rainfall-runoff model produced these flow rates for the March 1995 storm. This raises the question of how we could computed reliable flow rates using the hydraulic model that itself had not been checked against reality. The reality check for the hydraulic model came from trying to make high water marks for any given region consistent with one another. This was accomplished by adjusting channel roughness assumptions until the high water marks produced consistent flow rates.

Without any calibration, the rainfall-runoff model gave fairly high runoff results **(Table C-6).** To achieve the best fit possible, the SCS curve number parameter was reduced by 15% across the entire model. The 15% reduction was applied to all basins of all watershed models, including the pre-European settlement model, the 1965 conditions model, the existing conditions model, and the future conditions model.

Figure C-10 shows the position of a set of high water marks taken on San Luis Obispo Creek near the lower San Luis Bay Drive Bridge with respect to the modeled water surface elevation for the March 1995 flow (after calibration). **Figure C-11** shows observed and calibrated high water model results on San Luis Obispo Creek near the confluence with Stenner Creek. The agreement between the high water marks from this data set and the modeled water surface is relatively good. The most error between the predicted and observed water surface within the City of San Luis Obispo occurred at the Marsh Street Bridge, where the observed flood elevation was approximately 0.6 m (2 ft) above the modeled flood elevation. The most likely reason for this discrepancy is the tendency for the Marsh Street Bridge to collect debris during a large storm event. Due to their unpredictable nature, the HEC-RAS model does not account for debris blockages (In general, bridges known to be prone to debris blockage should be monitored during large storm events, and any debris blocking the bridge opening should be removed.) It is likely that debris raised the flood elevation at the Marsh Street Bridge above the level that would have occurred if no debris had been present.

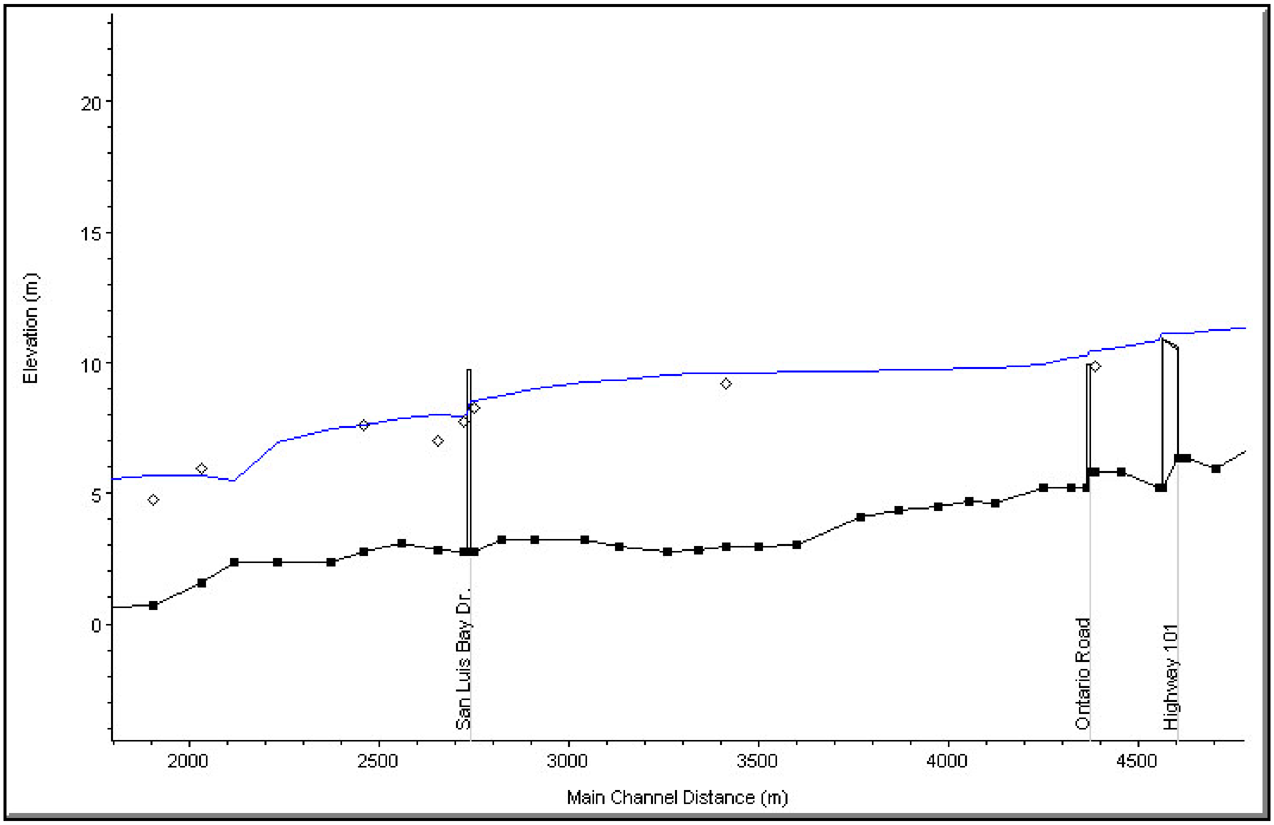

Figure C-10. Observed high water marks (black diamonds) compared with calibrated modeled water surface (blue line) for March 11, 1995 storm, near Avila Beach.

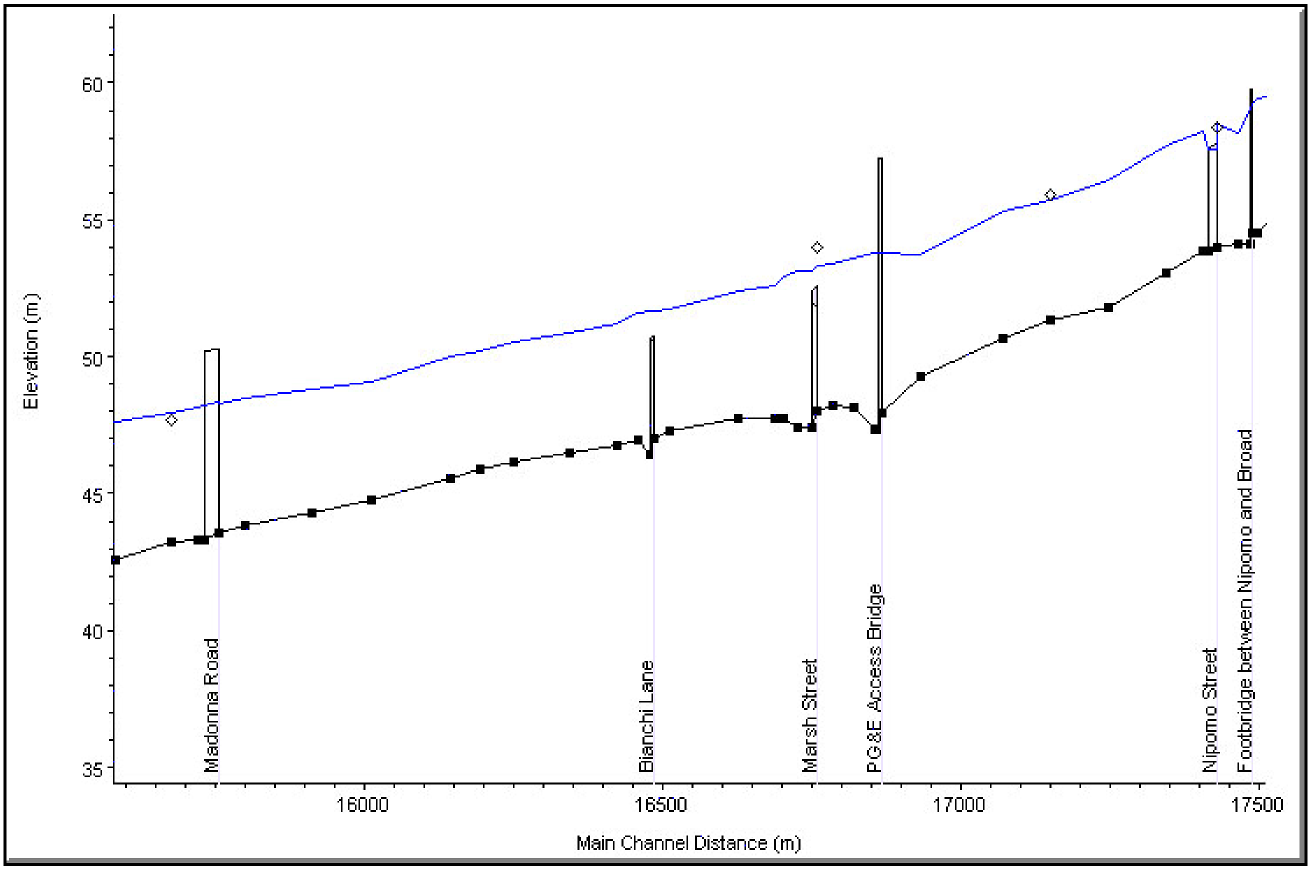

Figure C-11. Observed High Water Marks (black diamonds) compared with calibrated modeled water surface (blue line) for March 11, 1995 storm, within San Luis Obispo City Limits.

C-4 Results of the Hydrologic and Hydraulic Modeling

The results of the hydrologic model at various locations in the watershed are shown in **Table C-7**. Modeled water surface elevation profiles are included in at the end of this Appendix and are numbered **CP-1** (Appendix C/Profile #) through **CP-24**.

One of the objectives of this study was to evaluate the impact that development within the upper areas of the watershed has had on flood flow rates lower in the watershed. Typically, increasing impervious surface areas within a watershed increases flood risk downstream. To test this, design precipitation events were run through each of the four models (i.e. prehistoric, historic 1963, existing, and general plan buildout conditions). The results are shown in **Table C-8**. These results show very little change in peak flow rates from prehistoric conditions to existing conditions. This is primarily due to the presence of the two crossings of Highway 101 over San Luis Obispo Creek at Cuesta Park, above San Luis Obispo. The highway embankment at these locations acts as a dam, holding back the highest storm peaks. Were it not for the highway, increases in impervious surface throughout the watershed would likely have caused an increase of between about 4 and 7 percent, depending on recurrence interval and location in the watershed. Most of this effect likely occurred fairly early in this century, at least before the 1960's. However, the construction of the two Highway 101 crossings of San Luis Obispo Creek at Cuesta Park has essentially negated this increase.

Table C-7. Selected Hydrology Model Results for Existing Watershed Conditions

				Flow Rates (m^3/s)					
Creek	**Station**	**Description**	**Storm Size**	**Q100**	**Q50**	**Q25**	**Q10**	**Q2**	**1995 Flow**
SLO	20627	Cuesta Park	A	176	166	147	123	71	136
SLO	19319	At California Boulevard	A	190	179	160	133	79	148
SLO	16935	At Stenner Creek Confluence	B	354	319	274	220	119	247
SLO	15583	At Meadow Creek Confluence	B	378	341	292	231	127	268
SLO	12148	At Prefumo Creek Confluence	B	433	389	333	258	142	323
SLO	11897	At Froom Creek Confluence	B	444	398	342	264	145	333
SLO	10182	At E. Branch Confluence	C	538	476	412	309	165	468
SLO	9159	At Davenport Creek Confluence	C	596	525	455	338	179	516
SLO	4929	At Squire Creek Confluence	C	624	548	478	353	185	559
SLO	4554	At Gragg Canyon Confluence	C	632	555	485	357	186	570
SLO	3131	At Miguelito Creek Confluence	D	671	589	506	374	194	639
SLO	214	At Harford Canyon Confluence	D	686	603	513	376	191	669
Prefumo	1906	Laguna Lake Outlet	A	58	48	40	28	17	49
Prefumo	1385	At Drainage from Madonna Plaza	A	60	50	42	29	18	51
Prefumo [1]	432	At Calle Joaquin	A	71	62	51	35	21	56
Stenner		Above Brizziolari Creek	A	106	93	76	59	30	58
Stenner	2449	At Brizziolari Creek Confluence	A	166	146	120	93	48	85
Stenner	976	At Garden Creek Confluence	A	206	181	149	115	58	106
Brizziolari	n/a	Entire Sub-basin	A	70	62	51	40	21	30
Orcutt	2416	At Orcutt Road	A	6.2	5.5	4.6	3.4	1.7	2.8
Orcutt	1079	At Broad Street	A	12	11	9	6.9	3.5	5.2
Orcutt	583	At Confluence with Acacia Creek	A	15	14	11	8.6	4.3	6.6
Acacia	1877	At Orcutt Road	A	11	10	8.2	6.2	3.2	5.9
Acacia	1593	At Broad Street	A	40	35	29	22	11	22
Acacia	489	At Confluence with East Branch	A	42	37	30	23	11	23
East Branch SLO	6685	Above Acacia Creek Confluence	A	115	101	83	61	29	81
East Branch SLO	5984	Below Acacia Creek Confluence	A	154	136	112	83	40	107
East Branch SLO	4040		A	178	157	130	96	47	116
East Branch SLO	3425	Below Airport Tributary Confluence	A	186	164	136	100	49	120
East Branch SLO	1834	Below Tank Farm Creek Confluence	A	212	187	155	114	56	136
East Branch SLO	740	At Mouth	A	215	189	158	116	57	139

[1] Includes "Froom Tributary" basin, which during low flow drains to Froom Creek.
Inclusion of this basin results in conservative flow estimate where Prefumo Creek crosses under U.S. 101.

A more detailed analysis of these results and their flood management implications is available in

Table C-8. Impact of Changes in Land Use and Watershed Development on Flow Rates

Estimated Pre-Settlement Conditions	Flow Rates (m^3/s) Q10	Q100	% Change from Pre-Settlement Q10	Q100
SLO Creek Below Stenner Conf.	235	430	n/a	n/a
SLO Creek at Mouth	360	690	n/a	n/a
1963 Conditions				
SLO Creek Below Stenner Conf.	218	352	-7.2%	-18.1%
SLO Creek at Mouth	375	685	4.2%	-0.7%
Existing Conditions				
SLO Creek Below Stenner Conf.	220	354	-6.4%	-17.7%
SLO Creek at Mouth	376	686	4.4%	-0.6%
Existing Conditions, Discounting Detention at 101[1]				
SLO Creek Below Stenner Conf.	248	448	5.5%	4.2%
SLO Creek at Mouth	385	726	6.9%	5.2%
General Plan Buildout Conditions [2]				
SLO Creek Below Stenner Conf.	220	354	-6.4%	-17.7%
SLO Creek at Mouth	378	685	5.0%	-0.7%

[1] Currently Highway 101 at Cuesta Park provides some flood protection. These runs ignore this protection.

[2] Assumes Highway 101 at Cuesta Park is in its existing configuration. It may be possible to augmen the protection provided by the highway embankment. See Flood Management Alternatives Section

Section 5.4 of the Waterway Management Plan Report.

C-5 Comparison with Previous Studies

One of the motivating factors for the San Luis Obispo Waterway Management Plan (WMP) has been the frequent flooding that has occurred on San Luis Obispo Creek. It is believed that previous studies have inadequately predicted the relatively frequent occurrence of flooding in the area, especially in the Mid-Higuera area and along Stenner Creek.

C-5.1 1974 Corps of Engineers/Nolte/FEMA Study.

Since the 1970's, the definitive study on flow in the San Luis Obispo Creek watershed has been the 1974 U.S. Army Corps of Engineers floodplain study of San Luis Obispo Creek (U.S. Army Corps of Engineers, 1974). This study was updated in 1977 by George S. Nolte and Associates to predict flow rates at recurrence intervals other than the 100-year event. The Nolte study was used by FEMA for its Flood Insurace Study of the area (FEMA 1978).

The Corps/Nolte/FEMA study involved the construction of a theoretical watershed model similar in nature to that used for the current study. As in the current study, the Corps/Nolte/FEMA study split the watershed into a set of small sub-basins. A theoretical equation was used to predict rainfall losses for each sub-basin. Then a unit hygrograph was used to translate the rainfall excess (that not lost using the loss equation) into a runoff hydrograph. The hydrograph was then routed downstream from the outlet of each sub-basin in a similar way to the model described in this report.

The precipitation model used in the Corps/Nolte/FEMA study was very different than that used in the WMP, however. Instead of modeling a specific design precipitation event at each recurrence interval (i.e. a 10-year or 100-year 24-hour design storm) as was done for the WMP, the Corps/Nolte/FEMA study used an actual recorded rainfall event (in this case, the January 19, 1973 event) to define a storm that theoretically represented the maximum precipitation possible for a given part of the watershed. The process involved defining precipitation contours for the 1973 event, which was centered over the Irish Hills near the Prefumo Creek watershed, and then developing a way to re-center the storm over any given basin. The temporal distribution for the storm was determined from two recording rain gauges and was computed on 15-minute intervals.

The runoff occurring from the theoretical maximum possible precipitation event (which was derived from but different than the 1973 event), when centered over a given basin, was termed the standard project flood (SPF). The SPF has no direct relationship with a given recurrence interval. To develop such a relationship, a second watershed model was developed for the nearby Arroyo Grande Creek watershed, which at that time had a gauge with a 28-year record (prior to the construction of Lopez Dam) that had been analyzed statistically to determine a 100-year flow rate. At that gauge, the statistically-determined 100-year flood event was 63% of the SPF. This fraction was then assumed to apply to San Luis Obispo Creek watershed. The 100-year flow rate for any given basin in the San Luis Obispo Creek Watershed was found by multiplying the SPF for that basin by 0.63.

To determine flow rates at more frequent recurrence intervals, the Nolte study used a regional regression analysis of six nearby watersheds to define a set of regional flood frequency curves, which state the ratio of the 50-, 25-, and 10-year events to the 100-year event as a function of drainage area. These relationships were used to define flow rates at recurrence intervals other than the 100-year event in the San Luis Obispo Creek Watershed.

Flow rates from the Nolte study were used by FEMA to develop a backwater hydraulic model of San Luis Obispo Creek and tributaries within the City Limits of San Luis Obispo. The results of this model were used to develop the current FEMA flood plain map. This model was very similar conceptually to the HEC-RAS model employed by the current study

(WMP) to develop flood water surface elevations and flood plain information. However, advances in computer technology allow the current (WMP) model to use additional, more tightly spaced cross sections and more detailed floodplain topography and roughness information.

C-5.2 1999 U.S. Army Corps of Engineers Statistical Analysis of Local Stream Gauges

Serious flooding throughout the Central Coast of California in 1995 and 1997 prompted the U.S. Army Corps of Engineers to perform a flood frequency study at certain local gauges in 1999 as part of a larger study of San Luis Obispo and Monterey Counties. This study applied traditional flood frequency statistical analysis at several gauges in the watershed. The results are listed in **Table C-9**.

C-5.3 1999 U.S. Army Corps of Engineers Regional Statistical Analysis

After performing their analysis of specific gauges (Section B-5.2), the U.S. Army Corps of Engineers performed a regional flood frequency analysis using stream gauge data at various locations along the Central California Coast. This study resulted in a set of equations that predict flow rates at given recurrence intervals as a function of drainage area, mean annual rainfall, length of time of concentration, and length of "blue line" streams within the sub-basin on the appropriate USGS quadrangle map (U.S. Army Corps of Engineers, 1999b). The results at a few select points within the San Luis Obispo Creek watershed are listed in **Table C-9**. In general, this method resulted in lower flow rates than the analysis of specific gauges within the San Luis Obispo Creek watershed (Section B-5.2).

C-*5.4 Discussion of Differences From Previous Studies*

While the WMP model generally shows higher flow rates at all recurrence intervals than the previous studies (with the possible exception of the Corps of Engineers individual gauge analysis), the most important differences occur for frequent (i.e. 25-year or shorter) recurrence interval storms (**Table C-9**). The WMP model shows on the order of twice the flow rate from the Corps/Nolte/FEMA model at the 10-year event, while the difference is far less at the 100-year event. The one exception to the WMP results being higher than the Corps/Nolte/FEMA results is on San Luis Obispo Creek just above the confluence with Stenner Creek (point 2 in Table B-9). This occurs because the Corps/Nolte/FEMA model did not consider the detention provided by the Highway 101 culverts at Cuesta Park (Section C-1.3). In general, since the current model results in higher flow rates for frequent storms than the previous USACE/Nolte/FEMA model, its use will result in a more conservative flood management design.

The Corps of Engineer's individual gauge analysis is difficult to interpret. It shows a greater flow rate at the 100-year event on Stenner Creek than on lower San Luis Obispo Creek near Avila. In general, its results are higher than the current hydrology model results except at the gauge near Avila. It appears likely that the Avila Gauge may have mis-recorded high flow rates and should be dismissed. The fact that the Avila gauge was used by the Corps of Engineers for its regional regression analysis could help explain why the regional regression analysis predicts lower flow rates than either the current model or the Corps/Nolte/FEMA model. Additionally, work Questa performed for the County of San Luis Obispo (Questa Engineering Corporation, 2000) identified an error in one of the other gauge records used in the Corps gauge analysis (The Main Street gauge on Santa Rosa Creek in Cambria appears to have missed the peak of the crucial March 1995 flood event). Because of the uncertainties associated with the gauge record, further application of the 1999 Corps of Engineers hydrology studies to the San Luis Obispo Watershed should be undertaken only cautiously.

In summary, the WMP model generally predicts higher flow values than the other studies. Its use would consequently be expected to result in relatively conservative flood management designs. In any case, the development and calibration procedures for the WMP model used the most current technology and data available and should represent the most accurate and complete flow and flood plain information of any of the studies reviewed here.

Table C-9. Comparison of Modeled Flow Results with Other Studies

	Upstream Drainage Area		10-Year Flow		100-Year Flow	
	sq. mi	sq. km	m³/s	cfs	m³/s	cfs
Questa/Zone 9 Model						
1 SLO Creek Above City Limits (above Res. Cyn)	6.6	17.1	64	2300	117	4100
2 SLO Creek Above Stenner Creek Confluence	12.8	33.2	133	4700	190	6700
3 Stenner Creek Above Brizziolari Creek Confluence	5.8	15.0	59	2100	106	3700
4 Stenner Creek Above SLO Creek Confluence	11.1	28.7	115	4100	206	7300
5 SLO Creek At Squire Canyon	70	181.3	353	12500	624	22000
FEMA Flood Insurance Study						
1 SLO Creek Above City Limits (above Res. Cyn)	–	–	–	–	–	–
2 SLO Creek at Higuera Street (above Stenner conf.) [1]	12.6	32.6	71	2500	221	7800
3 Stenner Creek Above Brizziolari Creek Confluence [1]	5.7	14.8	31	1100	102	3600
4 Stenner Creek at Broad Street (above SLO conf.) [1]	10.8	28.0	59	2100	190	6700
5 SLO Creek above See Canyon [2]	64.6	167.3	119	4200	561	19800
Corps of Engineers Analysis of Individual Gage Record [3]						
1 SLO Creek "Near San Luis Obispo" (above Res. Cyn) [3]	5.27	13.6	46	1640	167	5900
2 SLO Creek Above Stenner Creek Confluence	–	–	–	–		–
3 Stenner Creek at Cal Poly (above Briz. conf.) [3]	5.5	14.2	76	2680	282	9950
4 Stenner Creek Above Confluence with SLO Creek	–	–	–	–		–
5 Lower San Luis Obispo Creek Near Avila [3]	67.7	175.3	146	5140	272	9620
Corps of Engineers Regional Regression Equation						
1 SLO Creek "Near San Luis Obispo" (above Res. Cyn) [3]	5.27	13.6	–	–	130	4608
2 SLO Creek Above Stenner Creek Confluence [4]	13.03	33.7	42	1500	136	4800
3 Stenner Creek at Cal Poly (above Briz. conf.) [3]	5.5	14.2	–	–	210	7427
4 Stenner Creek Above SLO Creek Confluence [4]	11.01	28.5	40	1400	108	3800
5 Lower San Luis Obispo Creek Near Avila [3]	67.7	175.3	–	–	485	17131

[1] Federal Emergency Management Agency. Flood Insurance Study: City of San Luis Obispo, California. October 1978.

[2] George S. Nolte and Associates. Flood Control and Drainage Master Plan for the San Luis Obispo Creek Watershed. 1977.

[3] U. S. Army Corps of Engineers, Los Angeles District. Part II Discharge-Frequency Analysis: Report on Hydrologic Analysis of San Luis Obispo, Santa Rosa, and Arroyo Grande Creeks.October 1999.

[4] U. S. Army Corps of Engineers, Los Angeles District. Part I Regional Discharge-Frequency Analysis: Interim Report on Hydrologic Analysis of San Luis Obispo, Santa Rosa, and Arroyo Grande Creeks. June 1999.

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APPENDIX D

PROJECT ALTERNATIVES

This Appendix discusses project alternatives that were reviewed and evaluated by the Zone 9 Advisory Committee in selecting the recommended or Preferred Project. As with the Preferred Project, project alternatives consist of a functional grouping of a number of discrete project actions that would address local flooding problems separately along various reaches of SLO Creek. Three groupings of projects or alternatives were evaluated from a technical, environmental, and cost perspective. They include:

- **Alternative 1- Design Modifications to the Preferred Project**. A technically and financially viable Design Alternative that could be constructed at a lower cost than the preferred project, but that has greater environmental impacts.

- **Alternative 2- Low Cost/Low Impact Alternative** that would provide limited additional flood protection.

- **Alternative 3- Projects Not Considered Feasible and Not Evaluated Further**. This consists of project components that were not considered technically or financially feasible and were not evaluated further.

In addition to these alternatives, non-structural flood control options are discussed in this section.

D1.0 Alternative 1- Design Modifications to the Preferred Project

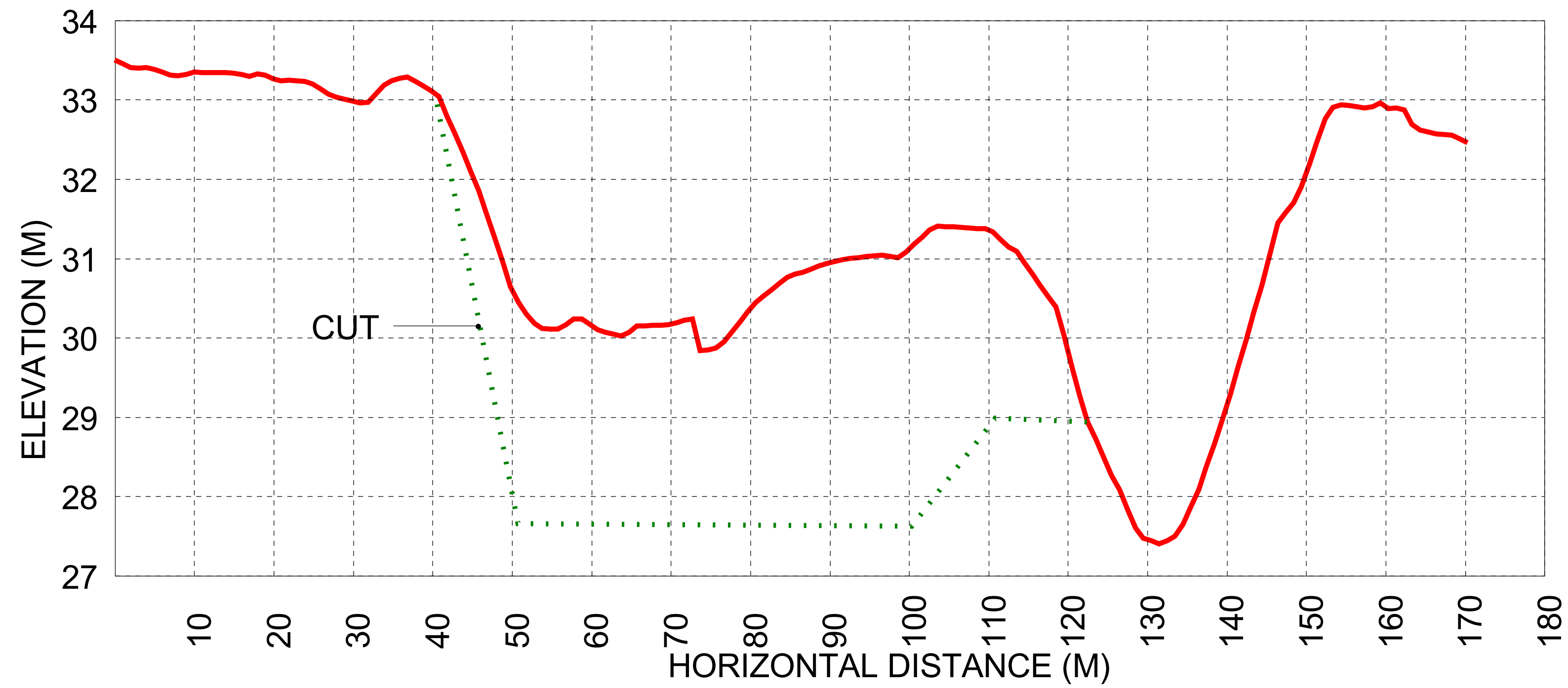
Alternative 1 (**Figure D-1)** represents structural projects that would provide a similar or higher level of flood protection as compared to the Preferred Project, but channel environment disturbance would be higher. Construction costs would generally be lower, because less land would need to be purchased for channel widening than the Preferred Project with bypass channels. This alternative evolved from discussions and review of the preferred project by the Zone 9 Advisory Committee. It represents an alternative that could be constructed with less overall costs than the Preferred Project, but with higher environmental impacts.

All of the main elements of the Preferred Project would be included in Alternative 1 (Stenner Creek bridge replacement, Cuesta Park detention enhancement, channel maintenance in Mid-Higuera); however, several of the components have modified designs that may differ in their environmental impacts and in costs of construction, as compared to the Preferred Project. Modified design components include:

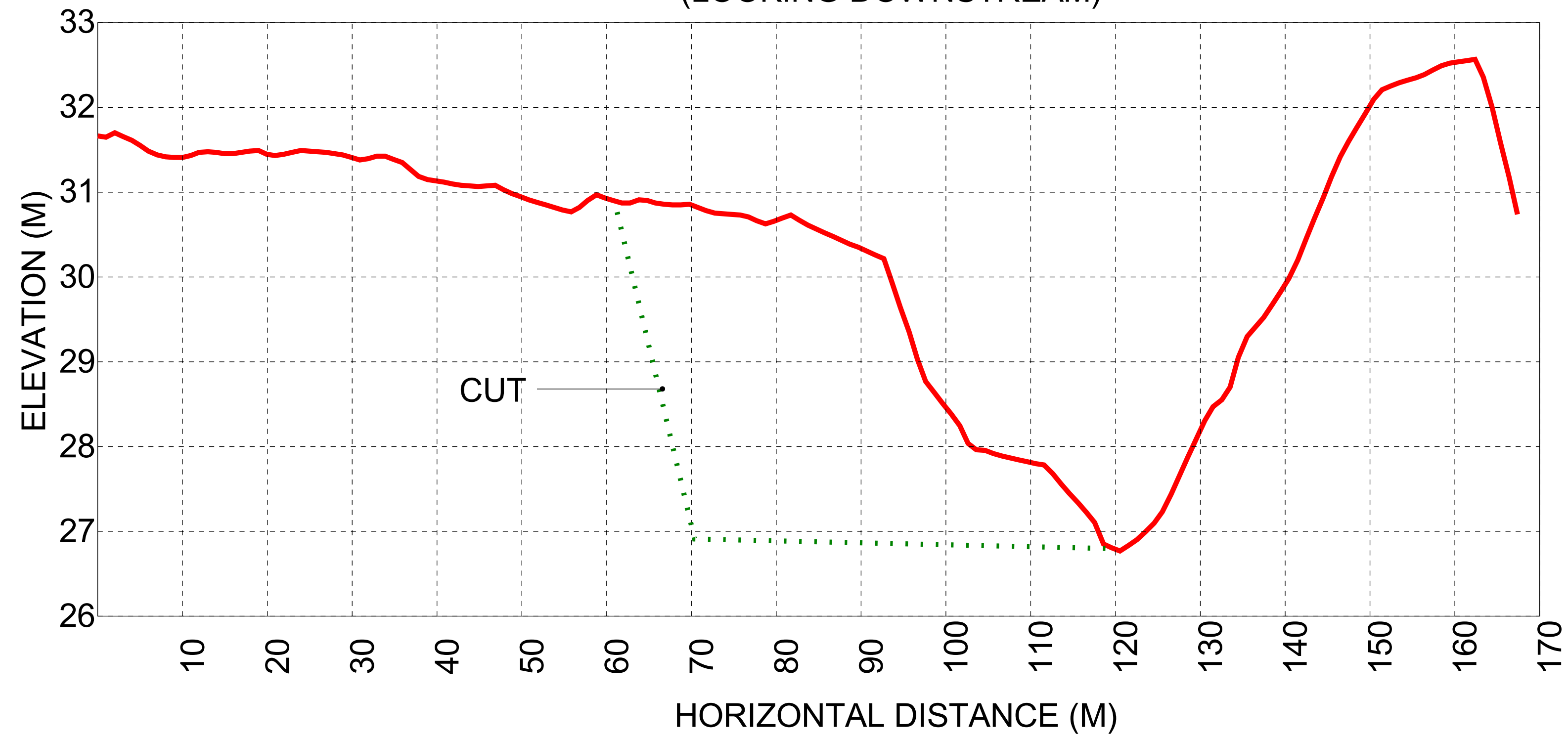
- **Widen SLO/Prefumo Creek Confluence** near Los Osos Valley Road, just below the confluence of Prefumo and San Luis Obispo Creeks, to prevent flow from backing up onto highway 101 and into Prefumo Creek on the west side of the Highway, (instead of the bypass channel of the Preferred Project).

- **Channel Widening Between Cemetery above Elks Lane and WTTP below Prado Road.** This would include replacement of the Preferred Project bypass channel with a channel-widening project from above Elks Lane downstream to

CROSS SECTION A-A'
(LOOKING DOWNSTREAM)



CROSS SECTION B-B'
(LOOKING DOWNSTREAM)



City of San Luis Obispo PUBLIC WORKS DEPARTMENT	**LOVR Design Alternative** **SLO Phase II Waterway Management Plan** QUESTA ENGINEERING CORPORATION	**Figure** **D-1**

Prado Road. The widened channel would be designed to provide 100-year protection for the adjacent mainly undeveloped floodplain and would prevent flow from spilling across Highway 101 and flooding the historic floodplain on the west side of the highway at the 100-year event.

- **Floodplain Excavation in Mid-Higuera Area.** This would include a floodplain bypass channel excavation within the Mid-Higuera Business District, similar to the Preferred Project. However, the initial channel excavation work just below the Marsh Street Bridge would occur on the east bank downstream to just below the Bianchi Lane Bridge, and not on the west side at the Madonna Company construction yard.

D.1.1 Widen SLO/Prefumo Creek Confluence

This design alternative to the Preferred Project would widen San Luis Obispo Creek near LOVR to increase local capacity and reduce backwater flooding on Prefumo Creek and Highway 101. This project would provide protection up to the 100-year flood. It would be constructed instead of the bypass channel proposed as the Preferred Project, as a lesser-cost alternative. The existing arch culvert where LOVR crosses SLO Creek is sufficient to pass the 100-year flood, so no new bridge would be required.

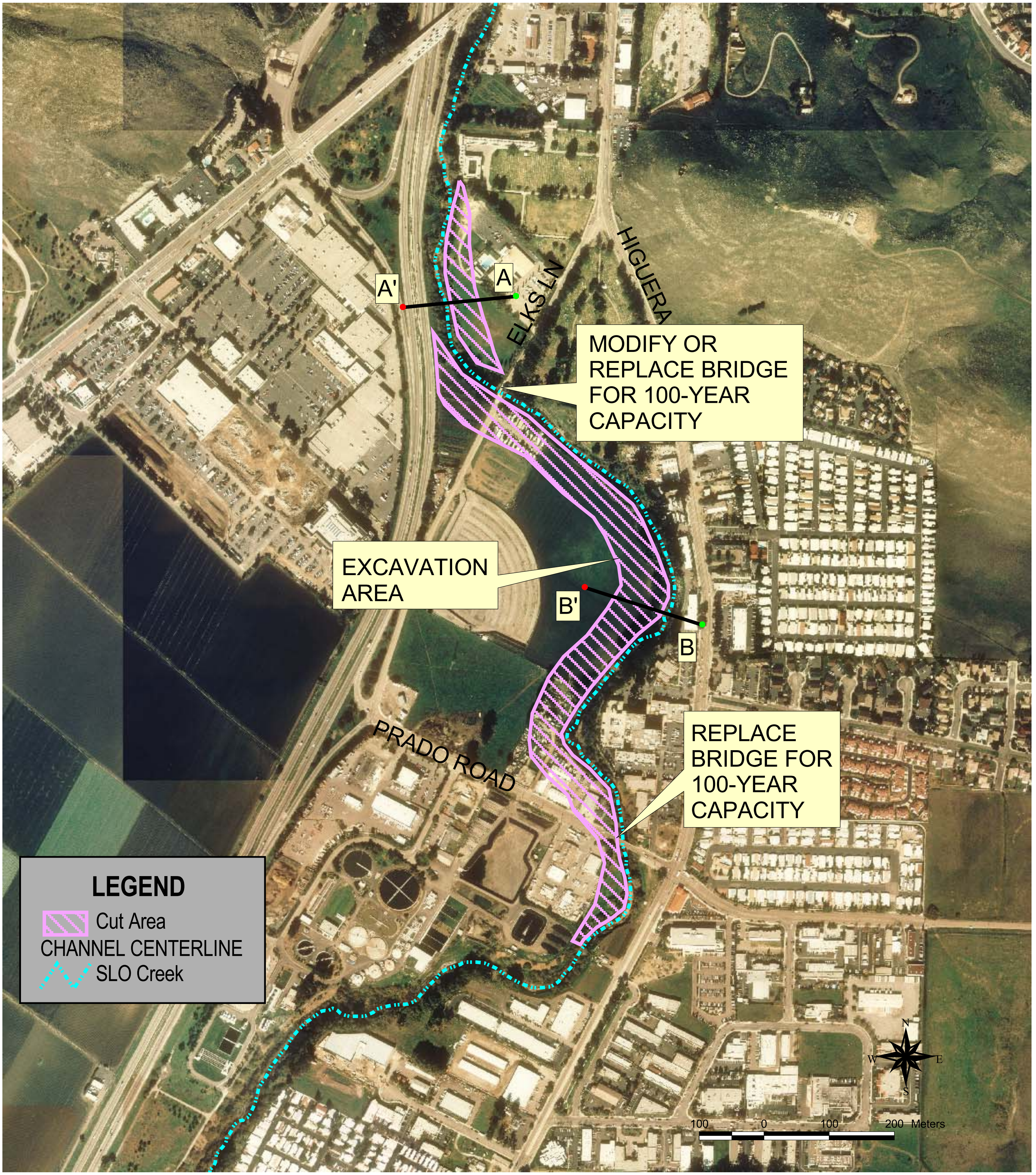
Channel widening would focus on the east bank, and would extend downstream from the LOVR crossing of SLO Creek about 250 meters. The upper channel would be widened and deepened at the location of the existing bypass channel (see Section A-A' in Figure D-1). The bed of the bypass channel would be near the existing streambed.

Additional lowering of the water surface elevations in Prefumo Creek would also be achieved in this reach by managing the existing dense vegetation, as in the Preferred Project. This would involve thinning and limbing up the willows, and inter-planting with single trunk species such as sycamores and cottonwoods. The work would be focused on Prefumo Creek below Calle Joaquin. Replacing the Prefumo Creek culverts under Highway 101 and the Highway 101 onramp are also included as part of this project, as with the Preferred Project.

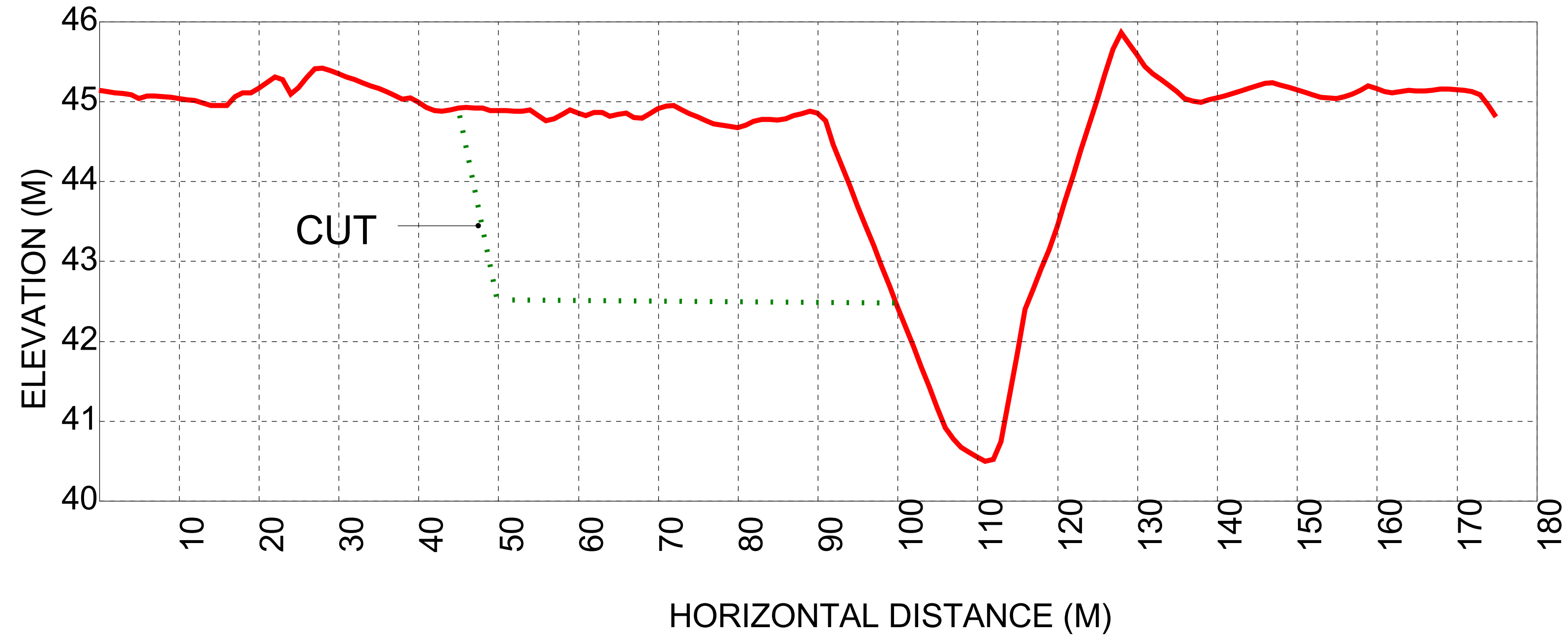
D.1.2 Channel Widening Between Cemetery above Elks Lane and WTTP below Prado Road

Increased flood flow conveyance to meet an increased Design Flow goal of a 100-year recurrence interval flood would be provided on SLO Creek by channel enlargement, generally on the east bank (**Figure D-2**). An in-channel bench or floodplain terrace would be constructed about 1/3 of the way up the bank, just above the 2-year flow line, or OHW. The floodplain terrace would be planted to native riparian trees and shrubs.

This Design Flow is greater than the proposed DDM Design Flow of 50-year



CROSS SECTION A-A'
(LOOKING DOWNSTREAM)



CROSS SECTION B-B'
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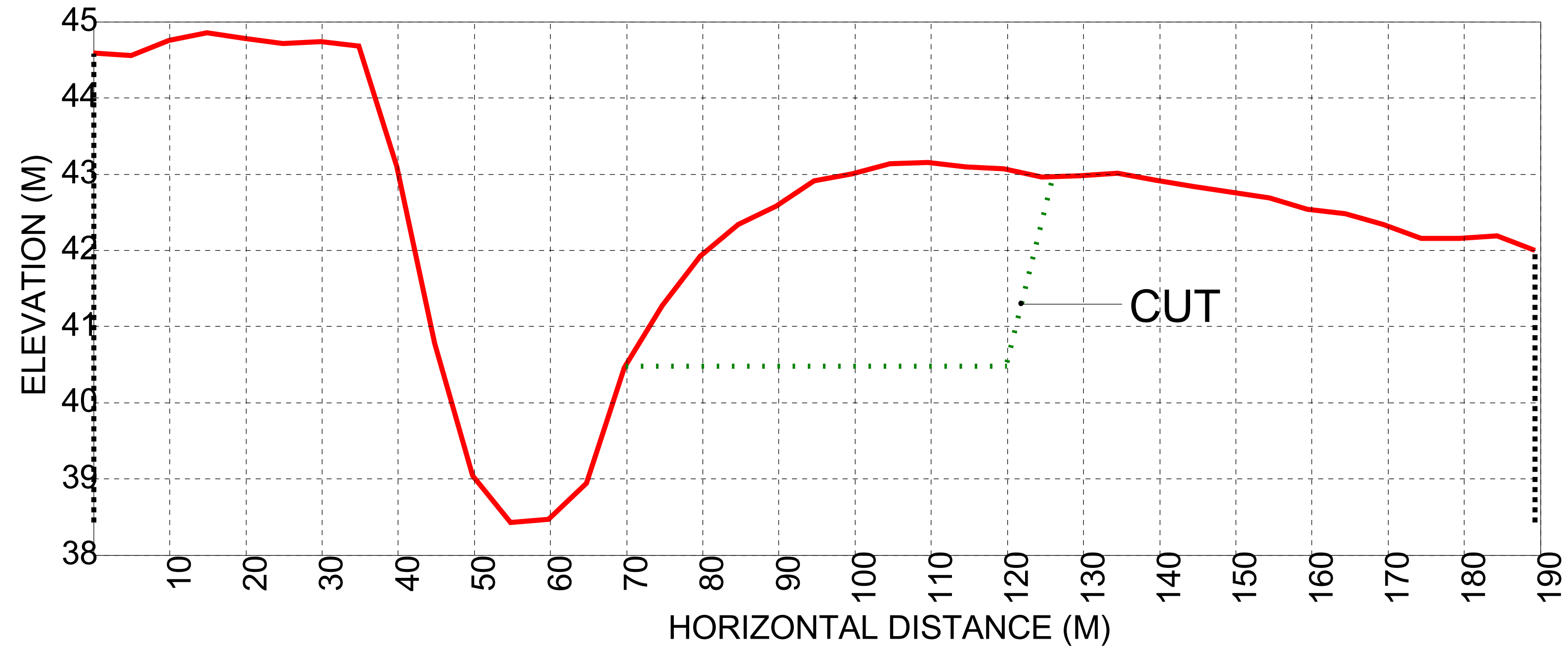


city of san luis obispo
PUBLIC WORKS DEPARTMENT

Elks Lane Design Alternative

SLO Phase II
Waterway Management Plan

QUESTA ENGINEERING CORPORATION

Figure

D-2

protection. However, the 100-year Design Flow can be achieved through this reach with little increase in project cost over the 50-year Design Flow, when using a channel terrace excavation approach.

The primary difference in cost and environmental impact between a 50-year and a 100-year design are the replacement of the Prado Road bridge and slightly greater excavation width (and volume), Since the additional excavation would occur on floodplain uplands (grasslands), there is also little increase in impacts to the riparian corridor, as compared to a 50-year terrace project

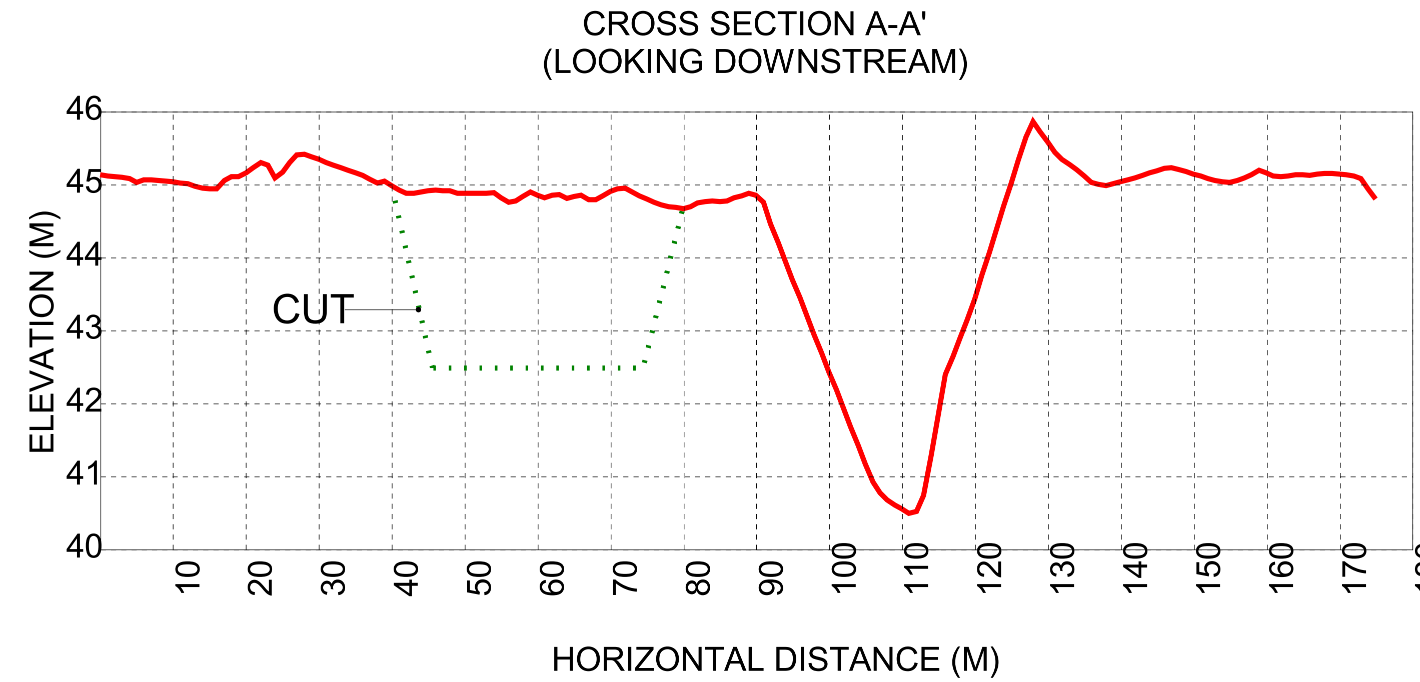
The depth of excavation (below existing floodplain ground surface) would be kept at 2 to 3 meters (7 to 10 feet), beginning about 2 meters (7 feet) above the existing creek bed, to minimize impacts to the existing riparian corridor and maintain summer low flows. The width of the in-channel terrace would vary from about 30 meters (100 feet) to about 50 meters (165 feet). Some 300 lineal meters (1,000 feet) of upper creek bank and bank top would be impacted by the channel-widening project. In some areas the toe of the existing bank would need to be stabilized by planted rock rip-rap.

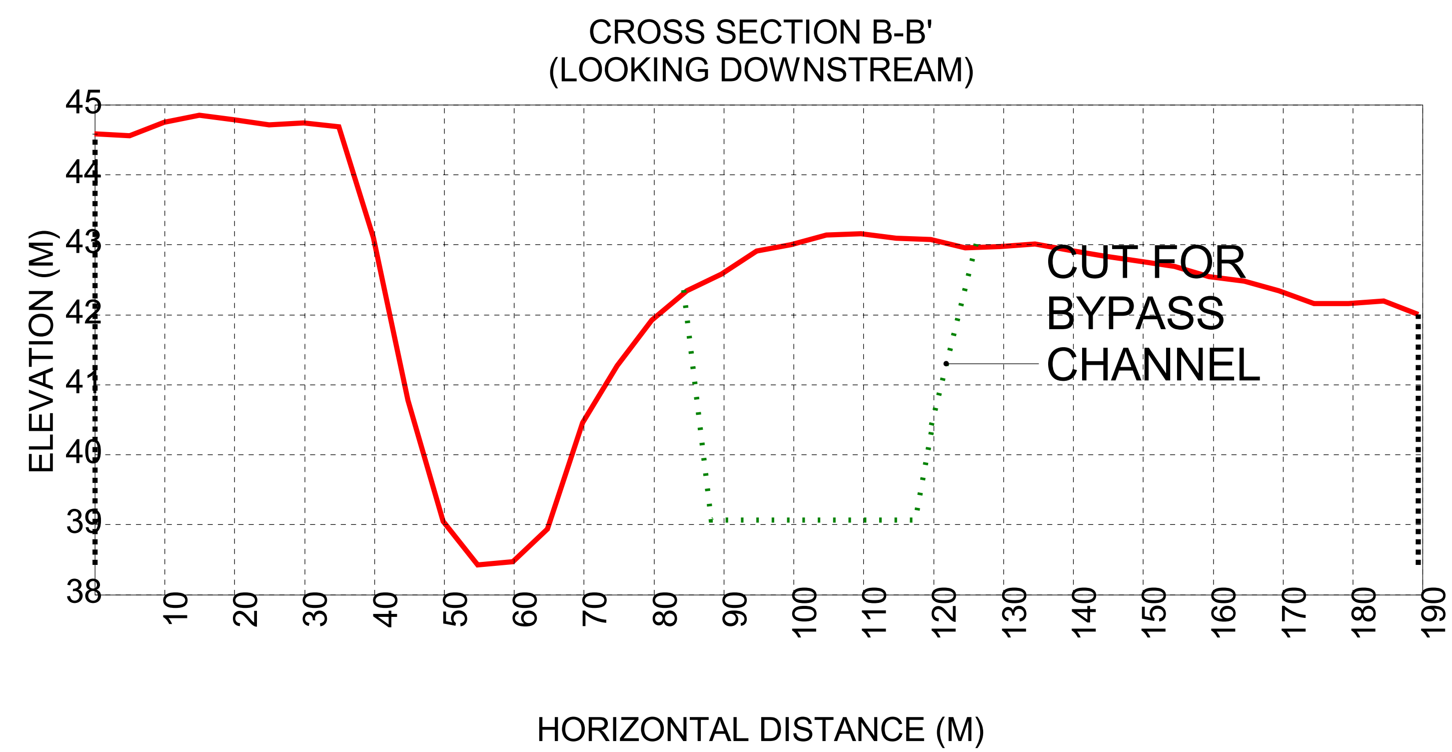
At certain locations, it will be necessary to construct a levee or berm along the west bank of the creek, especially near Elks Lane where flow currently leaves the stream channel. Any levees would have minimal impact on upstream water surface elevations since the channel capacity upstream of the levees would have increased due to the channel widening. The project will also require constructing a vertical retaining wall along about 120 meters (1400 feet) of creek channel in the area adjacent to the Mausoleum, as there is insufficient room for either a bypass or a terrace project in this area. Other project elements would include bank stabilization using planted rip-rap immediately downstream of Madonna road, and replacement of the Prado Road Bridge.

The advantage of channel widening over a bypass channel system is in lower construction costs, as less right-of-way would need to be acquired, and the amount of excavation and grading is reduced.

D.1.3 Floodplain Excavation in Mid-Higuera Area

This component of **Alternative 1 (Figure D-3)** would combine the channel maintenance and bank vegetation management along San Luis Obispo Creek between Marsh Street and Madonna Road similar to that described in the Preferred Project, including the excavation of an secondary overflow flood pathway (a large, shallow bypass channel) on the floodplain on the west side of the creek. However, the design would be modified in this alternative to focus channel excavation on the east side, from the Marsh Street Bridge to just downstream of Bianchi Lane Bridge, instead of through the Madonna Construction Company's yard. The 24 to 30 meter (80-100 feet) wide, bench or terrace would extend about 250 meters (825 feet) downstream of Marsh Street Bridge.





city of san luis obispo PUBLIC WORKS DEPARTMENT	**Elks Lane By-Pass** **SLO Creek Phase II Waterway Management Plan** QUESTA ENGINEERING CORPORATION	**Figure** **WMP 6-3**

D.2 Alternative 2- Low Cost/Low Impact Alternative

Alternative 2 represents a lower level of flood protection than the Preferred Project and the other project alternatives evaluated. Several of the individual project elements of this alternative are similar to the smaller components of the Preferred Project; but the more extensive channel modifications and floodplain bypass channel excavation components have been eliminated. For the most part, the projects associated with Alternative 2 would be restricted to specific channel constrictions or breakout points along San Luis Obispo and Stenner Creeks. Alternative 2 includes the following:

- Minor excavation and a revised vegetation management program along the reach of San Luis Obispo Creek between Marsh Street and Madonna Road.
- Replacing three bridges on Stenner Creek, as in the Preferred Project.
- Improving flood detention storage on San Luis Obispo Creek above Cuesta Park, as in the Preferred Project.

D.2.1 Channel Management Program

The proposed Channel Management Program of the Preferred Project would be retained in Alternative 2. However the amount of thinning and limbing work would be more conservative and scaled back substantially. Management would involve reducing the channel roughness of the creek banks for increased flow conveyance by very selectively thinning and limbing up the willows, and inter-planting taller growing, single-trunk native trees higher upon the creek banks. Sycamores and cottonwoods are favored. These would eventually shade out the shorter willows on the lower banks. In the short term, the lower branches on existing willows would be limbed and clumps of willows would be thinned down in volume and total number of stems during an annual maintenance visit. Any large gaps in the canopy would be inter-planted with tall, straight, tree forming species. Work would focus on willow management along the lower channel banks and planting trees and shrubs on the upper bank and bank top area.

The selective willow management program of the Preferred Project would remove most willow branches that are as low or lower than 6 feet, (maintenance crew could walk under the branches) except where over-hanging important pool areas. Under this alternative, willow branches would typically be limbed up only to 3 or 4 feet (maintenance crew would need to stoop to get under the tree branches).

Vegetation management would be completed in phases and take 5-7 years to become effective; however each year some important net reduction in channel flow resistance would be accomplished. Annual channel maintenance would be accomplished within the conditions of the overall Stream Maintenance and Management Program (SMMP).

A program of active channel vegetation maintenance will have some modest benefits in this stream reach, reducing flood water surface elevations for the 10-year flood event by an estimated 0.1 to 0.2 meters, (0.3 to 0.6 foot), depending on location within the reach. However, the Design Flow Goal of a 20-year level of protection for this stream segment cannot be achieved with this alternative (and the other components).

D.2.2 Marsh Street Floodway Terrace

An additional component of Alternative 2 would entail excavation of a floodway terrace on the creek's east bank immediately downstream of Marsh Street bridge (at the McNamara Real Estate building property) as in the Preferred Project. Work on the east bank would involve removing 2-3 meters (7-10 feet) of soil in a zone extending eastward to Higuera Street 24 to30 meters wide (80 to 100 feet) and south past Bianchi Lane 250 meters (825 feet). In addition, some minor improvements to the channel upstream of Marsh Street Bridge would be included to reduce the effects of sediment and debris blockage of the bridge barrels. Implementation of this aspect of **Alternative 2** results in a predicted drop in water surface elevations of 0.28 m (0.9 ft) at the Marsh Street Bridge, but has little direct benefit elsewhere in the reach.

D.2.3 Replace Stenner Creek Bridges

As with the Preferred Alternative, the three undersized bridges on Stenner Creek (at Foothill, Murray, and Santa Rosa Streets) would be replaced as a component of Alternative 2.

Note: Geotechnical failure of the embankment for the Foothill Avenue Bridge in Winter 2001 has necessitated the replacement of that bridge for non-flood related reasons. Work began in April 2001.

D.2.4 Detention Storage on San Luis Obispo Creek above Cuesta Park

The detention storage flood control benefits of the undersized culvert at Cuesta Park would be enhanced as a component of this project, as in the Preferred Project.

D.3 Alternative 3 - Projects Not Considered Feasible and Not Evaluated Further

In preparing the flood management section of the WMP, a large number of flood control concepts were initially evaluated as a "long-list" of possible flood management alternatives. A number of these were considered earlier in the 1977 Nolte studies, by the Corps of Engineers, or by Shaff and Wheeler in the late 1980's. Upon further analysis by the project study team, these were not considered feasible, either from a technical, cost, or environmental and permitting difficulty perspective. These conceptual projects were eliminated in developing the "short-list" of project alternatives and were recommended by the Zone 9 Advisory Committee to be placed in the category of "Not Considered Feasible, and Not Evaluated Further". They are described here to provide a point of cost comparison to other alternatives and to document for future reference purposes that this alternative was considered in a preliminary fashion.

The projects, which were reviewed and determined to be infeasible, included:

Buried Bypass Culverts

- A buried bypass culvert around the downtown business district, running down Pacific Street or down Meadow Creek

Floodwalls

- Floodwalls along the east bank of San Luis Obispo Creek from Nipomo Street to Madonna
- A set of levees/floodwalls along both creek banks above Prado Road combined with property acquisition of floodplain areas on the stream side of the floodwalls
- A set of small levees/berms to prevent flow from spilling across Highway 101 between Madonna and Prado Roads
- Construction of a floodwall near Andrews Street/San Luis

Significant Channel Enlargement

- Significantly widening the channel of San Luis Obispo Creek between Marsh Street and Madonna Road to provide 50-year flood capacity

Flood Detention Basins

- Upper Stenner Creek
- Upper SLO Creek

D.3.1 Bypass Culverts

Buried Bypass Culvert, Downtown Business District. Downtown San Luis Obispo currently floods at between the 20- and 25- year recurrence interval because of low channel capacity and insufficient capacity of the large culvert (often termed the under city culvert) under Higuera Street between Osos and Chorro Streets. Replacing the under city culvert, increasing its capacity, or protecting the downtown area with levees or floodwalls are not technically feasible alternatives. Consequently, the only large-scale alternatives besides or in addition to detention for protecting downtown San Luis Obispo involves diverting a portion of the flow in excess of the under city culvert capacity into a bypass system.

Pacific Street Bypass Culvert. A buried concrete box culvert could be installed down Pacific Street, starting above Santa Rosa Street and re-entering the creek below the lower Marsh Street Bridge. The culvert would be approximately 3.7 m (12 ft) wide by 3.7 m (12 ft) deep for 100-year protection or 3.7 m (12 ft) wide by 2.4 m (8 ft) deep for 25-year protection. Since the excavation depth is not significantly different between a 25-year and 100-year project, the 100-year project would have the most advantageous cost-benefit ratio. For environmental reasons, a specialized inlet structure would need to be designed that prevented low flow and ordinary wet-season runoff from entering the bypass without reducing the structure's capacity at high flow events. The design of such a structure would require a very detailed hydraulic model and possibly a physical modeling study to ensure adequate performance.

This project would entail major excavation and the relocation of all utilities within Pacific Street. The excavation would take up most of the street width and would preclude all use of the street during construction (estimated to take at least a year). Construction could be phased so that the entire street would not be torn up at once. Several large sewer collection, water, and gas distribution lines would be crossed by the project, as would several fiber optic cables. These utilities would need to be removed and replaced where they cross the culvert alignment.

Costs for this project are highly dependent on soil conditions and the shoring requirements of the excavation. Two different shoring techniques, sheet piles (least expensive) and soldier beams (most expensive), were used for cost estimating purposes to get a range within which the costs might occur. Utility relocation is included in the estimates.

Project engineers concluded (and the Zone 9 Advisory Committee concurred) that the buried culvert bypass project would not be feasible because of high costs (in excess of $20,000,000.00) relative to benefits, and the severe disruption that would occur to businesses located along Pacific Street.

Meadow Creek Bypass. An alternative solution to the Pacific Street Bypass for bypassing flow around downtown San Luis Obispo would be to install an open channel bypass down the current alignment of Meadow Creek, which flows from near the intersection of Islay and Toro Streets, through Meadow Park, and into San Luis Obispo Creek just below Madonna Road.

Currently, parts of this alignment are open channel, while other parts are contained within a buried storm water conduit. The City does not own an easement along this alignment; so acquiring property rights from the existing owners would be one of the more expensive aspects of the project. In addition, approximately 20 buildings would need to be acquired and moved or demolished for the project to proceed.

Because of the channel slope down the Meadow Creek alignment, flow velocities would require a concrete channel lining. To minimize the channel's footprint, a rectangular channel with dimensions of 20 feet wide by 10 feet deep would be the most efficient design.

Similar to the Pacific Street Bypass**,** a specialized inlet structure would need to be constructed at the upper end of the bypass, which would be near Johnson Avenue. The design of this structure would require detailed study.

While this project would extend further downstream than the Pacific Street Bypass, it would primarily benefit downtown San Luis Obispo. San Luis Obispo Creek would still experience relatively frequent flooding below the confluence with Stenner Creek even with a bypass in place.

Because of the high cost, (estimated to exceed $37,000,000.00) the lack of an existing easement, disruption of existing businesses, and major impacts to a creek, this alternative is not considered feasible.

D3.3 Floodwalls

Floodwalls along Mid-Higuera Reach. San Luis Obispo Creek between the Nipomo Street and Madonna Road bridges has less than a 10-year event channel capacity in many places. This is one of the first areas along San Luis Obispo Creek to experience flooding. Flooding occurs in the commercial area east of the creek and portions of Highway 101 near Madonna Road, when the channel overtops. Once the flood overtops Highway 101, water spills across the highway and flows on the west side of Highway 101 downstream to Prefumo Creek, where it returns to the main creek channel.

This alternative would contain flood flows between Highway 101 and a floodwall to be constructed along the creek's east bank. A floodwall would be installed along Highway 101 near Madonna Road to prevent flow from spilling across the highway.

Currently, when flow overtops the creek banks, Higuera Street becomes a relatively unobstructed pathway for floodwaters. If the conveyance represented by Higuera Street and the rest of the floodplain was removed and the flow was forced back into the creek by a floodwall, water surface elevations for a given storm would increase in the upstream direction above existing levels. To contain even a 25-year event behind floodwalls, the walls would need to be between 1.5 and 2 m (4.9 and 6.6 ft) high (somewhat less at upper end) and extend for the entire distance between Madonna Road and Nipomo Street. To contain a 50-year event, add 0.25 m (0.8 ft) to the height, and for a 100-year event, add 0.5 m (1.6 ft). Total wall height along San Luis Obispo Creek in the Mid-Higuera reach would than range to nearly 2.5 meters (8.2 feet).

The increase in upstream water surface elevation from Mid-Higuera floodwall construction would be approximately 1 m (3.3 ft) at the upper end of the wall, near Nipomo Street, for a 100-year flood, and 0.3 to 0.4 m (1 to 1.3 ft) for a 25-year event. This would represent a significant increase in flooding along Dana Street below Nipomo (just upstream of the confluence of Stenner and San Luis Obispo Creeks). Furthermore, preventing flow from spilling across Highway 101 near Madonna Road would force additional flow into San Luis Obispo Creek downstream of Madonna Road beyond what is currently experienced, increasing flood depths downstream. Finally, by placing a continuous barrier along the creek, local runoff from average-sized storms may not be able to find its way into the creek as easily as it currently does, potentially causing local flooding problems on the city side of the floodwalls. These impacts would require significant flood proofing mitigation, including purchasing and moving some buildings, elevating buildings, and wet flood proofing. The increases in water surface elevation are most pronounced at the 50- and 100- year events. They may make achieving anything higher than 25-year protection infeasible or unacceptable.

It is not possible to place a floodwall across a roadway. Instead, the roadway must be elevated to the required wall height. This would be a problem where the wall alignment crosses Marsh Street and the PG&E Bridge, just upstream of Marsh Street. The Marsh Street Bridge would need to be replaced with a higher structure. Work would also need to be done on the PG&E Bridge, though it probably would not require replacement. In any case, the Marsh Street Bridge will need to be elevated by the several meters. This would then require a significant road elevation project along Higuera Street to avoid exceeding maximum road slopes.

Currently, floods in this area rise slowly enough for people to escape the floodwaters. Holding back flood flows behind a floodwall or levee creates some risk of catastrophic failure. Failure of the wall would release a sudden flood wave that could cause loss of life. If the floodwalls are designed to provide protection only for relatively frequent storms (i.e. the 25-year event), it will be especially important to design them to perform safely when flow overtops the wall. Furthermore, if the floodwalls are designed to be overtopped on a relatively frequent basis, it will be important to consider how flow on the east (city) side of the walls would return to the stream channel. Because of these constraints, Mid-Higuera floodwalls are considered infeasible.

<u>Floodwalls along Highway 101/Elevate Prado Road Onramp to Highway 101</u>. Under existing conditions, flow in San Luis Obispo Creek spills across Highway 101 at several locations starting just above the 10-year event. Flow leaves San Luis Obispo Creek beginning just upstream of Madonna Road and continues to flow across Highway 101 to below Prado Road. Flow returns to the creek near the confluence with Prefumo Creek, near Los Osos Valley Road. Several 1 to1.5 m (3.3 to 4.9 ft) high floodwalls could be built at select locations on the east side of Highway 101 to prevent flow from crossing the highway. The onramp from Prado Road to Highway 101 is at one of the low points where flow leaves the creek. This interchange would need to be elevated to the same height as the floodwall.

This project would increase floodwater surface elevations along San Luis Obispo Creek by containing all of the flow in the main creek channel. The increases in flood depths would vary depending on location and storm size. An estimate for this flood depth increase is as much as 1 m (3.3 ft) at the 100-year event and 0.6 m (2 ft) at the 25-year event below Prado Road. Upstream of Madonna Road, the increase in flood depths would be approximately 5 cm (2 in) for a 100-year event and 3 cm (1 in) for a 25-year event.

Because some of these increases could occur in areas that currently do not experience flooding or areas that would become prone to flooding given these water surface elevation increases, other structural projects or local flood proofing would be required as mitigation to make this project feasible. On the east side of the creek, upstream of Prado Road, a floodwall would need to be constructed along the creek bank top to prevent increased water depths from spilling across Higuera Street. Without this floodwall, overflow could potentially cross a drainage divide and flood parts of the tank farm tributary of the East Branch of San Luis Obispo Creek. Another floodwall on the east bank of the creek, below Prado Road, could be constructed to prevent flooding of the existing trailer park there.

The City corporation yard located south of Prado Road is a mobilization area for flood emergency response. Consequently, increased flood protection for this area is critical. This alternative would provide increased protection to the corporation yard during a 100-year storm, along with providing flood incident access from Highway 101. However, it could increase flooding depths in the adjacent Waste Water Treatment Plant (WWTP) and on the floodplains upstream of Prado Road. It would not be possible to protect the WWTP using floodwalls or levees without significant increases in upstream flooding depths. Consequently, this project assumes that only local flood proofing alternatives will be used to protect critical structures at the WWTP, such as raising berms and elevating some utilities and material storage areas. Floodwater would be allowed to flow through open areas of the plant.

Floodwalls/Levees near Prado Road. The hydraulic analysis shows that under existing conditions, flow from San Luis Obispo Creek leaves the main creek channel near Elks Lane and flows overland through the drive-in theater, across Prado Road, into the City's corporation yard and waste water treatment plant (WWTP), and then crosses Highway 101 or flows back into the main creek channel. This begins to occur at less than a 10-year recurrence interval storm. Below the WWTP and above the confluence with Prefumo Creek, the channel has approximately a 100-year capacity, except at the trailer park west of Higuera Street, which would begin to experience flooding at approximately a 25-year event (assuming all flow in San Luis Obispo Creek is kept on the east side of Highway 101).

The city corporation yard is a mobilization area for flood emergency response. Consequently, flood protection for this area is critical. This alternative involves protecting the corporation yard and WWTP by installing floodwalls/levees upstream of Prado road (or alternatively raising Prado Road itself), so that the flow that currently crosses Prado Road onto these sites is contained within the creek channel.

By preventing flow from freely crossing an area that currently provides flood flow conveyance, this alternative significantly raises the water surface elevation upstream of Prado Road. This rise in water surface is enough that the Prado Road Bridge would need to be replaced with a new structure several meters higher than the existing bridge. Levees would need to be installed between Highway 101 and the creek from Prado Road to above Elks Lane, and some elevation of parts of Elks Lane itself would be necessary. Because of increased flooding from floodwall construction and high mitigation costs, this alternative was not considered feasible.

Andrews/San Luis Drive Floodwall. During events larger than about a 25-year storm, hydraulic analysis shows that San Luis Obispo Creek overtops its banks along San Luis Drive above Andrews Street. Some of the lost flow re-enters at Andrews Street, and the rest flows down San Luis Drive to re-enter the creek near California Boulevard. Below Andrews Street, the creek has the capacity to convey a 100-year storm, including the flow that currently runs down San Luis Drive. This project would utilize a low floodwall or earthen berm to prevent flow from leaving the main creek channel.

The floodwall would extend from the Andrews Street footbridge upstream for approximately 190 m (620 ft), through existing residents' rear yards. The wall would be between 0.6 and 1 m (2.0 and 3.3 ft) high for 100-year protection. For 50-year protection, placing soil berms at select low locations would likely be sufficient, although a detailed topographic survey would need to be performed to confirm this. Members of the project team met with residents of the Andrews Street neighborhood where the project would be built. Given the minor flooding that occurs here, and project aesthetic considerations, the neighborhood representatives did not support the project.

D.3.4 Significant Channel Enlargement

Channel Widening Between Marsh Street and Madonna Road. Flood protection for the Mid-Higuera Business district could be obtained by significantly widening the channel throughout the entire reach from Marsh Street downstream to below Madonna Road. For 100 -year protections, the channel would need to be widened about 25 to 30 meters (82 to 98 feet) or more. The bed of the widened channel would be about 2 m (6.6 ft) above the existing channel bed so that work within the existing channel would be minimized. At several locations within the Mid-Higuera Business District, existing structures and right-of-way would need to be purchased. The bridge at Madonna Road would need some modification, or an additional bypass bridge under Madonna Road would need to be constructed on what is currently Caltrans property. Downstream of the Caltrans yard, near the confluence with Meadow Creek, it is probably not possible to provide 100-year flooding protection because of the local constriction formed by the Mausoleum at the cemetery.
The project would entail the removal of most of the upper-bank and bank-top riparian vegetation within the project reach. Due to its high costs and relatively high environmental impact, and its relatively modest benefits, it was dropped from further consideration.

D.3.5 Flood Detention Basins

Upper Stenner Creek Detention Basin. Schaff and Wheeler's 1989 detention basin feasibility study (CITE) indicated that detention in the upper Stenner Creek area would require a large dam (about 50 or more feet high) due to the steep nature of the stream channel. No potential projects were found to have a positive cost-benefit ratio, and the environmental impacts of such a large dam on steel head fisheries would certainly make permitting such a project exceedingly difficult. Based on costs and adverse environmental impacts, a detention basin on upper Stenner Creek was not considered feasible.

Upper SLO Creek Detention Basin. Schaff and Wheeler (1989), and Nolte (1977) also investigated the feasibility of constructing a flood detention facility on upper SLO Creek above Cuesta Park and near Reservoir Canyon. As with the Stenner Creel detention basin, it was concluded that the cost: benefit ratio was not favorable and adverse environmental impacts would make permitting of the project difficult.

D.4 Non-Structural Flood Control Alternatives

One of the main elements of the WMP is the development of new Policies and Programs for floodplain management. This is proposed to be implemented by adopting Special Floodplain Management Zones for the Mid-Higuera area, and the undeveloped lands along Prefumo and SLO Creeks downstream of Madonna Road. New Policies include prohibition of structures that block flood flow and return flow pathways in the Mid-Higuera area, and the proposed No Net Fill policy below Madonna Road. Demonstration of "No Adverse Impact" is required throughout the watershed, using the new Zone 9 computer hydrology/hydraulic models.

Alternatives to these proposed regulations include 1) **designation of a regulatory floodway** along portions of SLO Creek, 2) **prohibition of new development** or redevelopment on low recurrence interval (10-year or 25-year) floodplains, and 3) an expanded program of **flood prone property acquisition.**

D4.1 Floodway Regulation

Many communities with published FEMA floodplain maps have a special zone along a creek or river shown on the map that is termed a "floodway". This portion of the floodplain is where the highest flood velocities and greatest flood depths usually occur, and where buildings and their occupants are most at risk. This is also where development or encroachment can have the greatest effect on upstream or downstream flooding. Where a Floodway has been designated on a FEMA map, FEMA regulations adopted by communities usually prohibit any encroachment or obstructions within this regulated zone.

The FEMA maps covering the majority of the City of SLO do not show a regulatory floodway. A floodway is shown on the Flood Insurance Rate Map or FIRM for the portion of the creek that was enlarged in 1972 between downstream of Prado Road to LOVR. If the FIRM maps did delineate floodways within SLO, large portions of the community, especially in the Mid-Higuera area, would be included within it, making remodeling or redevelopment very difficult, if not impossible.

Although there are technical difficulties to precisely defining a regulatory floodway along many reaches of SLO creek, because of the degree of build-out, it is possible to do so using the new Zone 9 hydraulic model. As an alternative to the proposed floodplain management regulations included in the Preferred Plan, a regulatory floodway could be delineated along SLO Creek and its major tributaries that would preclude new encroachment into the floodway, and make rebuilding or remodeling difficult. This would require acceptance by FEMA of the hydrology and hydraulic studies completed for the project, the issuance of revised floodplain maps, and the adoption of a regulatory floodway ordinance by the City and County. This would be a major departure from current City Policy (included in the Preferred Plan) that permits building replacement in potential floodways along creeks, provided that building elevation or flood proofing measures are incorporated into the design, the buildings occupy a similar footprint, and building shadowing and other techniques are used to maximize flood conveyance and minimize flow obstruction.

D.4.2 Floodplain Development and Redevelopment Prohibition

FEMA regulations currently allow development within a 100-year floodplain, provided that the bottom floor elevation of habitable buildings are (usually) one- to two-feet above the 100-year flood, and that any fill, including the buildings themselves, do not raise water surface elevations more than 1 foot.

Some communities have adopted regulations that do not allow development on vacant land within an active floodplain, or do not allow rebuilding of damaged buildings, or redevelopment within these flood prone areas. Usually a program of public purchase of lands that becomes for sale, or voluntary purchase of lands by a government entity is used to implement this policy and avoid a "taking" issue. Over time, as more lands are purchased, the lands often become parks or greenways along the creek or river. Acquisition by eminent domain is possible, but seldom used, and is typically not funded by agency grant programs.

The City of San Luis Obispo and SLO County could adopt such a Policy as a more stringent alternative means of floodplain regulation than is proposed in the Preferred Project. The regulations could cover only property downstream of Marsh Street, or Madonna Road, and/or only the 10-year floodplain in these areas. Considering the large amount of property within the 100-year floodplain, both developed and undeveloped, it would not be practical or economically feasible for the community to purchase all buildings or vacant lands that could be developed within the limits of the 100-year flood, or even the 25-year flood along SLO or Stenner Creeks.

In order to avoid condemning property and disrupting businesses, the City could have a program in place (and funding available) to purchase vacant property that is voluntarily put up for sale, or property that is substantially damaged (as defined by FEMA) and that should not be rebuilt or remodeled according to the new regulations. Generally such a program of voluntary purchase of buildings in the most active portions of the floodplain is only gradually successful over time, depending on property turnover, the repetitiveness of flooding, and flood damage.

D.4.3 Flood-prone Property Acquisition

An expanded version of the Preferred Project Non-structural flood management alternative could include a significantly larger program of acquisition of property in floodprone areas. This was evaluated as part of early planning for the Mid-Higuera Specific Plan. The expanded floodplain acquisition program alternative could include widespread acquisition of developed properties in the Mid-Higuera area, such as the mobile home park at Bianchi Lane, and the residential housing in the South Street – Brooke Street area of lower Mid-Higuera, as well as other properties on lower Stenner Creek. The program could also include vacant property acquisition in the Elks Lane area, as well as purchase of development rights along lower SLO Creek in the unincorporated area below LOVR. Such an alternative would be very costly (tens of millions of dollars), and would not be consistent with the current City General Plan.

D.4.3 Other Regulatory Alternatives

As discussed in Section 5.0, the City of San Luis Obispo has established modest creek setbacks or buffer zones along all of its major creeks, but the County has no specific setback policy along SLO Creek in unincorporated areas. As a regulatory alternative the City could update its creek setback ordinance and create new Creek Development Standards that would apply to the kinds of land uses allowed within the setback zone. For instance different standards may apply to various creek reaches depending on the condition and biological value of the creek and its management needs. A larger setback might be needed along floodprone properties or areas with unstable banks, to allow for construction and repair of facilities. Different development standards may also be applied to urban infill lots than to larger parcels where the creek is in a more natural setting. Development standards might include design conditions on fencing, allowable parking structures, landscaping, , etc. The modification of creek setback and development standards could also be coordinated between the City and County in this Alternative, to include SLO Creek and other blue-lined or named creek tributaries.