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PILARCITOS CREEK
RESTORATION PLAN

Prepared for

Regional Water Quality Control Board
Department of Fish & Game

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1. INTRODUCTION

Pilarcitos Creek watershed in San Mateo County, California (Figure 1) is a significant resource for diverse interests including water supply, waste management, agriculture, and fisheries. There are five major tributaries contributing flow to Pilarcitos Creek—including Nuff Creek, Corinda Los Trancos Creek, and Apanolio Creek from the north and Madonna Creek and Arroyo Leon from the south. Pilarcitos Creek originates in the steep coastal mountains and then flows through lower gradient floodplain areas and the City of Half Moon Bay before reaching its estuary and the Pacific Ocean.

On October 29, 1992, failure of a debris dam downstream of the BFI Ox Mountain Landfill in Corinda Los Trancos Creek contributed massive quantities of sediment to Pilarcitos Creek. Downstream of the confluence with Corinda Los Trancos Creek, the sediment destroyed habitat by covering riffles and filling pools, and by creating a flat and shallow sandy substrate (Marston, 1993). A settlement between the State and BFI initiated a trust fund for restoration activities that led to the current restoration effort in Pilarcitos Creek watershed. The restoration fund is administered by two lead agencies: the California Department of Fish and Game and the Regional Water Quality Control Board. A citizens advisory committee was created to provide input to the planning process. This Watershed Restoration Plan for Pilarcitos Creek was developed in coordination with the two lead agencies and the advisory committee and is the first step toward restoration in the watershed. This restoration plan was developed by Philip Williams & Associates, Ltd., with Habitat Restoration Group. Prunuske Chatham, Inc. prepared the cost estimates and participated in landowner outreach. Callander Associates facilitated a public meeting and prepared newsletters.

The major issues of concern in Pilarcitos Creek and its tributaries include: 1) reduced streamflows; 2) degraded fish habitat; 3) bank erosion, and loss of riparian vegetation and habitat; 4) watershed erosion and channel sedimentation; and 5) exotic vegetation. Addressing landowners concerns is a critical element of the Pilarcitos Creek Restoration Plan. For example, the plan provides non-regulatory recommendations to landowners to increase bank stability while enhancing the ecosystem. This Watershed Restoration Plan describes the technical studies which document the issues of concern, and prioritizes alternatives that may be implemented for the restoration effort. The term "restoration" is meant to describe activities that significantly enhance the physical or biological attributes of the watershed in the long-term.

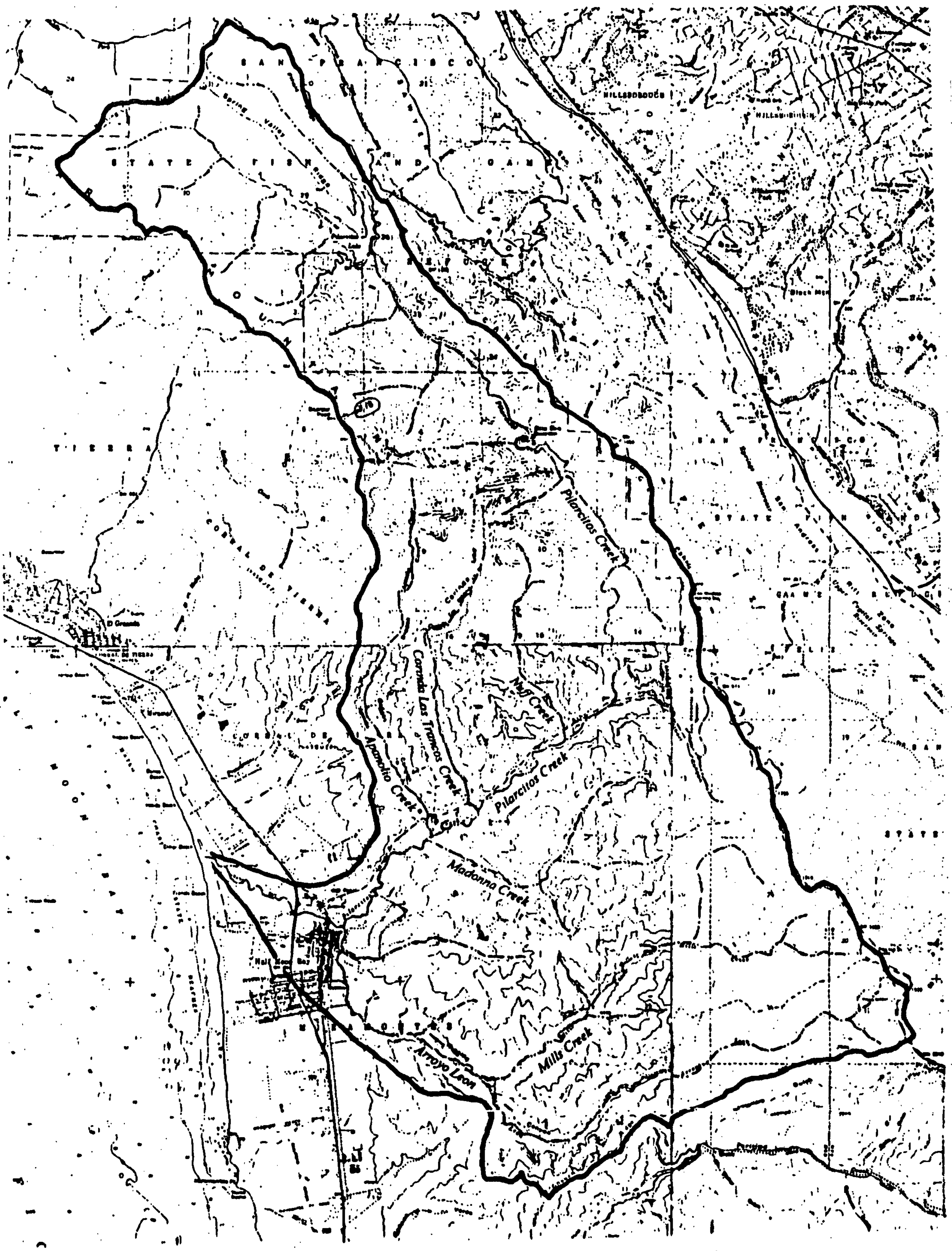

figure 1

Pilarcitos Creek Watershed

Source: USGS, 1973

1.1 SCOPE OF PILARCITOS CREEK WATERSHED RESTORATION PLAN

This Restoration Plan includes a guide to restoration projects in the Pilarcitos Creek watershed. We present a vision of a natural watershed to describe what the watershed would look like if all the restoration goals were accomplished in the long-term. The major problems and critical issues in the watershed are identified in the existing conditions section of the plan. Understanding the dominant geomorphic and hydrologic processes of erosion and sedimentation, and the existing fisheries, vegetation and sensitive wildlife conditions provides the basis for developing the opportunities and constraints and multi-objective alternatives. The evaluation of existing physical and biologic conditions in the Pilarcitos Creek watershed was conducted using available technical data supplemented by field reconnaissance. A limitation of this study was the lack of detailed available data on sediment transport and fisheries in individual tributaries, and the lack of access to some private property within the watershed.

The plan takes a watershed approach toward developing alternatives to reduce sedimentation in the creeks, enhance fish migration and rearing and riparian habitat, and to provide educational resources. The alternatives are grouped and prioritized within each tributary watershed. Prioritization of the alternatives is based on significance in restoring habitat, the probability of long term success, the potential for public education, feasibility, reliance on future maintenance, and cost. We recommend several projects which may be adopted and implemented with the funds available for this restoration project. Some of the projects described in this plan may be implemented through future restoration grants. The next phase of work for the Pilarcitos Creek watershed Restoration Plan will be to design and implement the specific restoration projects selected by the citizens advisory committee and the project administrators.

1.2 VISION OF A NATURAL WATERSHED

1.2.1 A Watershed Approach

A watershed may be viewed as an open system, with inputs of rainfall, sunlight, and human activity; outputs include stream discharge, sediment, agricultural products, etc. The Pilarcitos Creek watershed includes the hillslopes, the channel network and the floodplain. Viewing the watershed this way allows us to understand how natural processes and human activities in the upper portion of the watershed affect the lower portions of the watershed. The Pilarcitos Creek Restoration Project takes a watershed approach in order to evaluate existing conditions and to develop alternatives. The following two sections describe the physical processes and the biologic characteristics of a natural watershed. This watershed restoration plan attempts to restore ecosystem function to the extent possible. However, because of existing constraints and land use activities (described in Section 5) within the Pilarcitos Creek watershed, as well as the limitation of available funds, the current restoration project only attempts to achieve a portion of his vision. In the long-term, this plan provides the framework for future restoration activities.

1.2.2 Natural Geomorphic and Hydrologic Processes

A restored Pilarcitos Creek watershed system would produce sediment in the steep headwaters and transport that material downstream to the ocean. Over the long-term, geomorphic and hydrologic processes would adjust to natural geologic and land use changes, all the components of the system mutually adjust and affect the other components of the system. These adjustments would tend toward a delicate balance called "dynamic equilibrium." "Dynamic equilibrium" is defined as a state of balance which is maintained by dynamic adjustments, or fluctuations in flow and sediment supply, around the average condition of the system. Pilarcitos Creek is dynamic and does not stay in a static position over time. Dynamic equilibrium is measured over the long-term, as the watershed system evolves.

A restored Pilarcitos Creek would maintain a dynamic equilibrium between flow of water and the movement of sediment. The balance would be achieved through the adjustment of fluvial variables such as the creek width, depth, slope, velocity, roughness, and the flow and sediment discharge. When the flow or sediment discharge change, the other variables adjust to accommodate the new condition. In a restored well vegetated watershed with limited water diversions, the volume of fine sediment contributed to the stream systems would be reduced, while the flow rates would be increased.

In a restored watershed, the floodplain would be an integral part of the creek. The floodplain is a geomorphic feature formed over time by the river during successive floods. In a restored watershed a portion of the floodplain would be inundated every few years. The flow that fills the channel to the top of bank is called the channel forming flow (or the dominant discharge). This moderate and relatively frequent flood is responsible for creating the characteristic morphology (size and shape) of the channel. The morphology of Pilarcitos Creek would be created and maintained as meanders migrate downstream through the floodplain. In alluvial reaches, the channel tends to meander and migrate across the floodplain, eroding the bank on the outside of the bend and depositing sediment on the inside of the bend. The process of meander migration is an integral part of the dynamic equilibrium. In a restored system, the riparian zone would be well vegetated and wide enough to accommodate meander processes. Riparian vegetation would stabilize the banks and minimize erosion and fine sediment contribution to the creek, while providing habitat.

1.2.3 Natural Fisheries, Vegetation, and Wildlife Resources

Ideally, the restored riparian plant communities in the Pilarcitos creek watershed would have a high diversity of native plant species and little or no invasive non-native plant species. The riparian vegetation would have a well-developed vegetation structure consisting of three layers: a riparian tree over story, a shrub layer, and a dense herbaceous layer with no bare ground. The presence of these layers would provide structural diversity and niches for wildlife. The native riparian habitat would provide a very high wildlife species diversity and abundance. The tree canopy and shrubs would be used by a variety of insectivorous birds, including nesting and foraging by neo-tropical migrants. Larger trees would be used by nesting raptors and as denning sites for some mammals; under story plant leaf litter, and downed woody debris would provide important habitat structure for granivorous and leaf litter, foraging birds, reptiles, amphibians and small mammals.

The tree over-story would have dense vegetative cover that provides shade for the creek. The shade would promote cool water temperatures and therefore, benefit fish and aquatic habitat. There would be high vegetative cover for wildlife use, both for forage and concealment. The creek banks would also be well vegetated, so the banks would be stabilized and there would be little or no erosion during major flow events. The vegetated riparian corridor would range in width from about 50 feet in the upper watershed, to about 500 feet in the lower stream reaches.

Good fisheries habitat would consist of improved salmonid rearing and spawning conditions. Stream substrate would have a greatly reduced fine sediment and a preponderance of gravel which would enhance cover, aquatic food production, and spawning success. Stream canopy closure would be provided by native tree species and instream woody cover would be abundant. There would be perennial flow to the lagoon in March through May for smolt outmigration and adult salmonid access to upper Pilarcitos, Mills, Arroyo Leon, and Apanolio Creeks for rearing and spawning. The two large Arroyo Leon irrigation ponds would have adequate water releases to insure upstream adult passage and spring smolt outmigration, and would maintain water levels adequate for juvenile steelhead rearing until the first heavy fall rains.

2. EXISTING WATERSHED CONDITIONS

2.1 IMPACTS OF LAND USE ACTIVITIES IN PILARCITOS CREEK WATERSHED

Land use activities that affect the physical and biologic components of habitat in the watershed include: 1) the municipal and agricultural water diversions; 2) the Ox Mountain Landfill in Corinda Los Trancos Creek; 3) agriculture; 4) road maintenance practices; 5) quarries; and 6) both urban and residential development. Dams, municipal and agricultural water diversions, and pumped wells reduce the streamflow in Pilarcitos Creek. Low seasonal flow (or no flow) degrades fish and aquatic habitat. Potential sediment sources in Pilarcitos Creek watershed related to human activities include:

- *Agriculture* — Approximately 400 acres of floodplain and hillslopes are cultivated for agriculture within the Pilarcitos Creek watershed. Top soil eroded from the farmed area by sheet erosion is carried toward creek. In areas where there is no buffer, the sediment contribution from agriculture may be high. Bank erosion rates increase where riparian vegetation has been removed for agricultural land reclamation. Agricultural practices may also degrade water quality in the creek.

- *Road Related Erosion* — Maintenance and clearing of roads including paved and unpaved roads during and immediately after storms contributes fine sediment to Pilarcitos Creek. Steep road cuts on Highway 92 and Higgins Road provide a sediment source.

- *BFI Sanitary Landfill, Debris Basins* — Debris basins downstream of the land fill in Corinda Los Trancos failed in 1992, thus contributing a large volume of fine sediment to Pilarcitos Creek. Flow downstream of the landfill is more turbid than flow in other adjacent tributaries. Water quality is degraded downstream of the landfill.

- *Nuff Creek Quarry* — Soil erosion from the 40-acre quarry is partially contained within debris dams below the quarry. However, some sediment reaches Pilarcitos Creek.

- *Urban and Residential Development* — The construction phase of urban and residential development may increase surface erosion and fine sedimentation of Pilarcitos Creek and estuary. In addition, development and construction of impervious surfaces increases runoff and peak flood discharge. This in turn increases channel width and depth and accelerated bank erosion.

2.2 GEOMORPHOLOGY

Geomorphic issues in the Pilarcitos Creek watershed (Figure 1) are related to defining the sources and sinks of sediment. Abundant sand and fine sediment reaches the main channel in Pilarcitos Creek, modifies stream habitat conditions by reducing the stable substrate and pool habitat, and decreasing oxygen availability within the spawning substrate. The increased fine sediments in Pilarcitos Creek result from both hillslope and bank erosion. The source of fine sand in the lower portions of Pilarcitos Creek are derived from the weathered Montara Granodiorite which outcrops in the headwaters of Pilarcitos Creek, Nuff Creek, Corinda Los Trancos Creek, and Apanolio Creek. The 1992 failure of a debris dam downstream of the Ox Mountain Landfill contributed approximately 20,200 yd^3 of fine sediment to Pilarcitos Creek.

No detailed data are available that quantify sediment erosion, transport, and deposition in the Pilarcitos Creek watershed. Portions of the watershed have been evaluated in some detail, including Apanolio Creek, Corinda Los Trancos, and Nuff Creek (HLA, 1989; Final EIS on the Ox Mountain Sanitary Landfill Apanolio Canyon Expansion Site, prepared for the COE). To gain an understanding of the erosion and sedimentation characteristics in Pilarcitos Creek, the following methods were used:

- review of aerial photographs and geologic maps of the watershed;
- field reconnaissance;
- review of available reports and documents describing regional erosion rates and processes.

The results of this evaluation of erosion and sedimentation provides an overview of the major geomorphic processes and sources of sediment (see Figure 16) that are a constraint to watershed restoration. Estimates of watershed sediment yield based on other central California watersheds provides an estimate for the order of magnitude of the sediment problem. Finally, the estimate of watershed sediment yield is compared to an estimate of the sediment yield from agricultural areas in the watershed. Results of this comparison are described in Section 2.2.3.

2.2.1 Sediment Erosion Processes And Sources

The dominant hillslope erosion processes in a basin are influenced by factors such as: 1) climate (including rainfall intensity, duration, and amount); 2) vegetation; 3) geology (including rock type and topography); 4) soil character; and 5) land use history. The geologic structure and lithology in the Pilarcitos Creek watershed affects its sediment yield. The headwaters of Pilarcitos Creek flow along the north-northwest trending Pilarcitos Creek fault. Numerous landslides along the fault have contributed to sediment trapped upstream of Pilarcitos and Stone Dams and to downstream reaches of Pilarcitos Creek. Bedrock in the northern part of the watershed consists of Granitic rocks, clayey sandstone, sandstone, shale, and mudstone, and rocks of the erodible Franciscan Assemblage (mapped by Wentworth *et al.*, 1985). The coarse sand and fine gravel bed material present along much of Pilarcitos Creek is derived from the eroded Granitic rocks. Bedrock in the southern part of the basin consists of shale, mudstone, sandstone, and clayey sandstone. Alluvium fills the valleys of the main channel and some of the tributaries of Pilarcitos Creek. Alluvium and marine deposits form the coastal terrace. Hillslopes range from very steep (>70%) in the headwaters of tributaries) to very gentle to flat (0-5%) in the a valley bottoms (Mark *et al.*, 1988). The high volume of fine sediment in Pilarcitos Creek and its tributaries results from the combination of erodible bedrock, steep slopes, and land use practices.

Hillslope erosion processes in the Pilarcitos Creek watershed include landslides and soil slips, gullies, soil creep, and sheet erosion. Sheet erosion is common on agricultural fields where vegetation is denuded between rows. Channel bank erosion in Pilarcitos Creek and its tributaries also contributes sediment downstream. During most years (with relatively low rainfall), not all of the sediment eroded from hillslopes is contributed to the stream channel: rather, mobilized sediment goes into storage on the lower parts of slopes, or in channels, gully beds and banks. During wet years, more of the sediment eroded from hillslopes is likely to reach the creeks. For example, in a study of a small coastal basin in Marin County (for the period between 1971 and 1974), Lehre (1982) estimated that about 50% of the sediment mobilized on hillslopes reached the channel. Most of this removal of sediment from hillslope storage takes place during storms with recurrence intervals greater than 10-15 years. The following discussion provides a general description of sediment erosion processes in the Pilarcitos Creek watershed.

Landslides

A common type of landslide in the Pilarcitos Creek watershed are shallow slides called soil slips. Typical soil slips triggered by the 1982 storm in the San Francisco Bay Region originated on steep slopes (26 to 40 degrees; Ellen *et al.*, 1988). Soil from these scars was mobilized as debris flows and contributed sediment to the creeks at the base of the slopes. These soil slips occurred following the intense rainfall in 1982 in locations where water was concentrated—commonly in swales or colluvial hollows. Figure 2 shows the distribution of landslides mapped following the 1982 storm in the San Francisco Bay Region as an example of erosion patterns following a large storm (USGS, 1988; Plate 7). The Figure shows one large landslide on Arroyo Leon downstream of the confluence with Mills Creek and two other large landslides on Pilarcitos Creek near Pilarcitos Lake. Large landslides such as these may provide a significant amount of sediment, however they are difficult to repair because of the steep terrain, poor accessability and the dynamic nature of the feature. The distribution and concentration of debris flows mapped following the 1982 storm are shown on Figure 3 (USGS, 1988; Plate 8). Numerous debris flows occurred on the ridge between Mills Creek and Arroyo Leon (up to 28 debris flows per square kilometer) and in the upper portion of Pilarcitos Creek near Pilarcitos Lake (up to 20 debris flows per square kilometer).

figure 2

Sites of Landslide-Damage Distribution in the San Francisco Bay Region for the January 3-5, 1982 Storm

Source: USGS, 1988, Plate 14

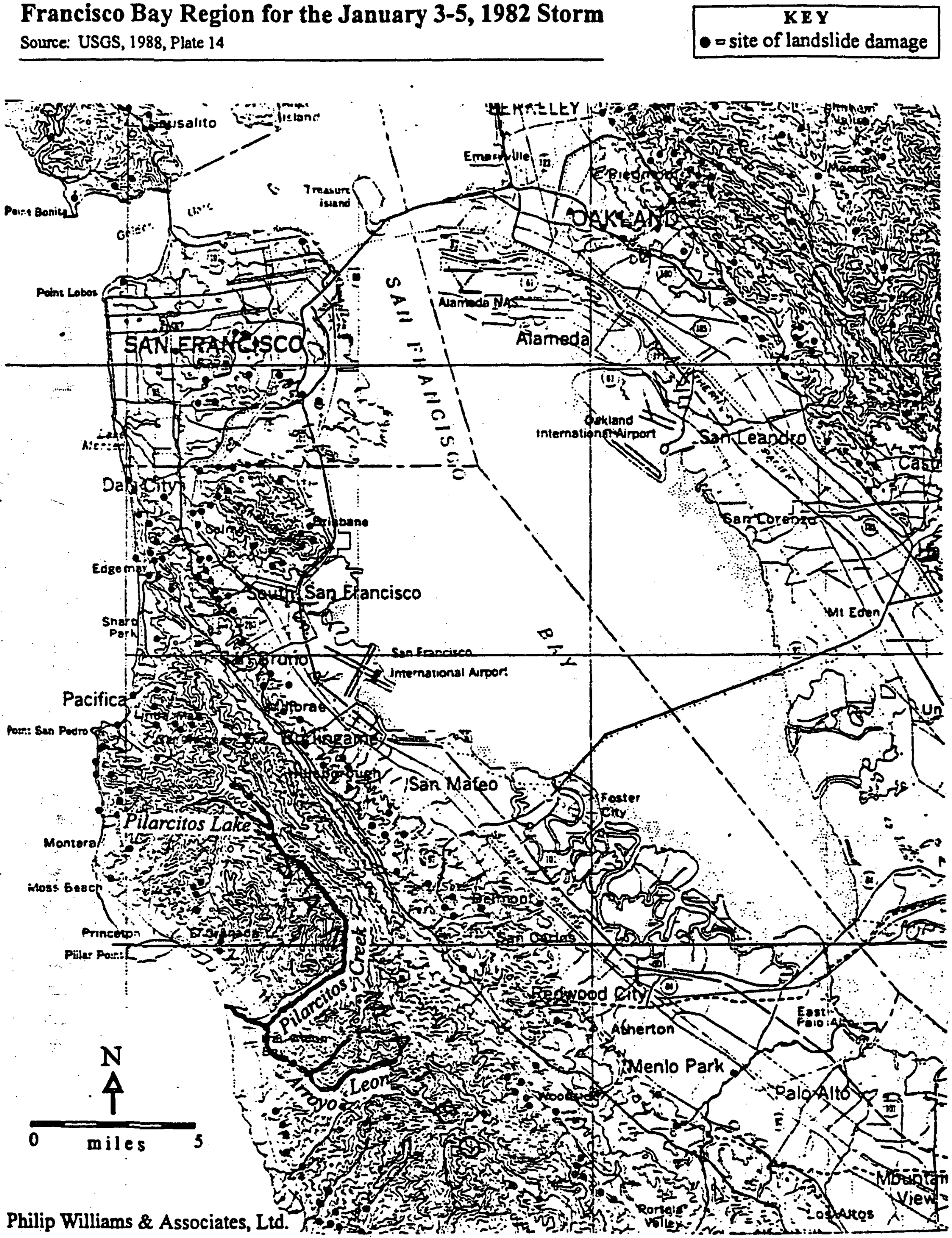

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figure 3

Distribution and Concentration of Debris Flows and Other Landslides, San Mateo County

Source: USGS, 1988, Plate 8

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Gullies

Gullies are usually found in colluvial material on hillslopes as a result of extreme storms or removal of vegetation (Selby, 1982). Gullies cut headward and transport sediment toward the creek at the bottom of the valleys. Gullying is accelerated where runoff is concentrated; it accelerates where tracks and trails go directly upslope—at culvert outfalls—and where roads and trails have inadequate water-breaks (Wahrhaftig, 1974). Some gullies are present on hillslopes in swales and are unrelated to roads. These gullies may due to concentration of runoff and be associated with prior landuse practices: These include grazing, which caused soil compaction, removal of vegetation, and concentration of runoff. Large gullies were observed following the January 1995 storm on southwest facing hillslopes in the Arroyo Leon tributary.

Soil Creep

Creep is a slow and continuous mass movement process whereby hillslope soil and colluvium move downslope under the force of gravity. Creep is caused by: 1) the expansion and contraction due to freezing and thawing, wetting and drying, or 2) is a result of biotic processes—for example, animal burrows and any disturbance involving vegetation, such as a tree throw (when a tree falls over and the roots pull up and disturb soil). Landscapes affected by creep have rounded ridge crests and broadly convex slopes.

Sheet Erosion

Sheet erosion is effective in contributing sediment downslope on unvegetated slopes. Most of the slopes in the Pilarcitos Creek watershed are vegetated with the exception of the unplanted floodplain agricultural areas and some hillslope agricultural areas adjacent to Pilarcitos Creek. Vegetation limits sheet erosion by: 1) insulating soil from the direct effects of running water and rainfall impact; 2) increasing soil strength from root binding; 3) reducing overland flow by promoting porous soil structure and infiltration; and by 4) reducing overland flow velocity and therefore the capacity of the flow to entrain and transport soil particles (Statham, 1977). Sheet erosion is also dependent on the magnitude and intensity of rainfall.

Different kinds of vegetation have been shown to affect rates of transport by sheet erosion—especially in agricultural areas. Ellison (1945) found that a cover of organic litter such as crop residue could significantly reduce soil loss in run-off. Rates of sheet erosion are increased by several orders of magnitude in tilled and cropped areas (Statham, 1977). The presence of a cover crop during the rainy season significantly reduces the potential for erosion.

Bank Erosion

Bank erosion is a natural processes which occurs as river flow exerts a force on the bed and the banks of the channel. In a meandering channel, such as the main channel of Pilarcitos Creek, erosion occurs on the outside of channel bends and deposition occurs on the inside of bends as the channel migrates in the floodplain over time. Figure 4 shows changes in channel morphology in Pilarcitos Creek from 1943-1980. Channel meanders present in 1943 were straightened for agricultural reclamation by 1956. These locations are now experiencing bank erosion as the channel attempts to re-establish its meandering character. The process of erosion may be accelerated by land use activities which increase runoff and peak flow or which remove riparian vegetation, or by periodic releases from upstream dams. Cooke and Reeves (1976) suggest that incision common to many coastal California streams results from grazing during the last century. Episodic channel widening in response to incision is common as the creek adjusts toward a new stable condition. In incised streams, such as the tributaries to Pilarcitos Creek, flow undercuts the toe of the bank during storms, causing bank failure. Bank erosion is accelerated by channel incision due to prior land use practices such as grazing which compacted soil and increased overland flow and peak stream discharges over the past century. As the main channel incises, tributaries incise to meet the new base level at their confluences. It is likely that the main channel of Pilarcitos Creek and its tributaries will experience episodic bank failure until a new equilibrium channel geometry is attained. Numerous bank failures were observed on Mills and Pilarcitos Creeks after the January and March 1995 storms.

2.2.2 <u>Watershed Sediment Yield</u>

Methods to estimate watershed sediment yield range from detailed field investigations of nearby watersheds to regionalization methods. There are currently no detailed data from the Pilarcitos Creek watershed. In this study, we compare the results of a widely used regional methods to the results of sediment yield estimates from intensive field investigation of sediment erosion and deposition processes and rates conducted in other central coast watersheds (Lehre, 1982; Reneau, 1988; Reneau *et al.*, 1990; and Wilson *et al.*, 1989). Although these investigations do not extend into the study area, they are representative of the central coast watershed—such as Pilarcitos Creek—that has a Mediterranean climate, is underlain by the Franciscan Assemblage and other erosive bedrock, and is vegetated by grass, chaparral, and forest. The following order of magnitude estimates can be used to help identify the magnitude of likely sediment problems in the watershed.

figure 4

Changes in Channel Morphology of Pilarcitos Creek, 1943 - 1980

N

0 1000 2000 feet

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Marin County Hillslope Erosion Field Studies

Estimates of sediment yield from Lone Tree Creek basin in Marin County and other nearby basins are probably similar to the sediment mobilization and the sediment reaching the channel for Pilarcitos Creek. Lehre (1982) estimates that the long term sediment yield in Lone Tree basin is 135 tons/ square mile/ year. Reneau (1988) estimated sediment yield from two locations in Lone Tree basin range as 50 and 72 tons/square mile/year while sediment yield from San Pedro Ridge ranged from 10 to 80 tons/square mile/year. These studies may be used as the low end of the range of an order of magnitude estimate of the volume of sediment contributed from the Pilarcitos Creek watershed.

Reservoir Sedimentation Studies

Sedimentation studies have been conducted in numerous reservoirs in the San Francisco Bay Area including Crystal Springs Reservoir in San Mateo County (Brown and Jackson, 1973) and St. Mary's Reservoir in Contra Costa County (Flaxman, 1972). The mean annual sediment yield measured in Crystal Springs Reservoir was 2,300 tons/ square mile/ year. The mean annual sediment yield measured in St. Mary's Reservoir was 1,500 tons/square mile/year. These values represent sediment yields from the upper portions of watershed which are steeper and produce more sediment than the lower portions of basins which may be urbanized. Sediment trapped in these reservoirs represent the middle to upper end of the range of an order of magnitude estimate of the volume of sediment contributed from the Pilarcitos Creek watershed.

Measured Basins and Estimates of Sediment Yield in the San Francisco Bay Area

Brown and Jackson (1973) conducted a sediment study of south and central San Francisco Bay by measuring sediment yield at USGS gaging stations on three Creeks. The average sediment yield on Colma Creek south of San Francisco for the period between 1966 and 1970 was 5,138 tons/square mile/year. The average sediment yield for San Francisquito Creek at Stanford for the period between 1962 and 1969 was 657 tons/square mile/year. An estimate of the sediment yield measured in Alameda Creek near Niles for the period between 1957 and 1970 was 198 tons/square mile/year. The average sediment yield form these three field studies is about 2,000 tons/square mile/year.

SCS conducted studies on Upper Penitencia Creek (SCS, 1984a) and Lower Silver Creek (1984b) in Santa Clara County using the Universal Soil Loss Equation (USLE). These studies estimated sheet and rill erosion as well as streambank and gully erosion, and the estimates contained much uncertainty (Northwest Hydraulic Consultants, 1990). The sediment yield estimate for Upper Penitencia Creek is 2,835 tons/square mile/year and the estimate for Lower Silver Creek is 595 tons/square mile/year. PWA (1993) estimated the arithmetic average for computed sediment yields for the Upper Guadalupe River based on upland basins in Coastal

California near San Jose, California, to be about 1,600 tons/square mile/year while Water Engineering & Technology, Inc. (WET, 1991) estimated the arithmetic average for computed sediment yields for the Lower Guadalupe River to be about 1,840 tons/square mile/year.

Estuary Studies

Estuary studies conducted in the area provide some estimates of basin sediment yields. An estimate of sediment yield from Redwood Creek Basin (Marin County) was developed from the quantity of sediment deposited in wetlands at the mouth of Redwood Creek between 1981 and the present (PWA *et al.*, 1994). Results of this study suggest that the historical sediment yield that led to the filling of the lagoon was 270 tons/square mile/ year. This historical value represents the period when grazing occurred in the watershed and is a minimum value since part of the sediment load would have been washed out to sea.

Regional Correlations

The SCS (1969) developed a map of sediment yield rates for the western United States. This map provides an estimate of the sediment yield for the Pilarcitos Creek area of about 425 tons/square mile/year. This estimate is not intended for design purposes, but provides a range of the regional value of sediment yield.

Another regional estimate of the average sediment yield for California reported in Dunne and Leopold (1978; Table 17-2) is 1,300 tons/square mile/year with a range between 80 and 5,570 tons/square mile/year. This estimate is also very broad and is included to illustrate the range in possible estimates.

Pacific Southwest Inter-Agency Committee (PSIAC) Method

The PSIAC method is a regional method that may be used to estimate sediment yields in the Pacific Southwest. The method gives a broad estimate of sediment yield and is intended for planning purposes rather than detailed studies. The method is most accurate for basins greater than 10 square miles and provides a general estimate of sediment yield to compare to field studies in nearby watersheds. Factors used in determining the sediment yield are 1) geology, 2) soils, 3) climate, 4) runoff, 5) topography, 6) ground cover, 7) land use, 8) upland erosion, and 9) channel erosion and sediment transport (Table 1).

TABLE 1. PSIAC Regional Sediment Yield Method

Factors		Description of Sediment Yield Level
A	surface geology (5)	rocks of medium hardness; moderately weathered and fractured
B	soils (5)	medium textured soil
C	climate (5)	storms of moderate duration and intensity
D	runoff (5)	moderate peak flows, moderate volume of flow per unit area
E	topography (20)	steep upland slopes (>30%), high relief; some floodplain development
F	ground cover (-10)	area completely protected by vegetation, rock fragments, litter. Little opportunity for rainfall to reach erodible material (excluding agricultural areas)
G	land use (0)	less than 25% cultivated; less than 50% intensively grazed; ordinary road and other construction
H	upland erosion (10)	less than 25% of the area characterized by rill, gully, or landslide erosion
I	channel erosion (25)	eroding banks with active degradation

Using the PSIAC method, the total rating is 65 which corresponds to a sediment yield estimate of about 980 to 1,950 tons/square mile/year. This is a very generalized estimate which can be used for planning purposed only. The method is not sensitive to comparisons of the effect of farming in the basins because when the factor F, Ground Cover, is changed to the next category (with a value of 0, the total basin rating changes from 65 to 55, and is still classified as having a sediment yield between 390 and 980 tons/square mile/year). The specific field studies would be more accurate than the regional PSIAC method.

Summary of Sediment Yield Estimates for Pilarcitos Creek Watershed

Table 2 summarizes the results of the methods discussed to estimate sediment yield from the Pilarcitos Creek watershed. The Regional Correlations and the PSIAC method are relatively insensitive compared to the other methods used. The range of sediment yield estimates on Table 2 shows the large variation in estimates. Long-term site-specific measurements would be needed to quantify sediment yields or to construct a sediment budget for individual tributaries in the Pilarcitos Creek watershed.

TABLE 2. Estimates of Sediment Yield from Regional Studies and Near-by Basins

Location	Sediment Yield (tons/mi²/yr)	Data Source
Marin County		
Lone Tree Basin	135	Lehre (1982)
Lone Tree Basin	50-72	Reneau (1988)
San Pedro Ridge	10-80	Reneau (1988)
Reservoir Sedimentation		
Crystal Springs Reservoir	2,300	Brown and Jackson (1973)
St. Marys Reservoir	1,500	Flaxman (1972)
South San Francisco Bay Area		
Colma Creek	5,138	Brown and Jackson (1973)
San Francisquito Creek	657	Brown and Jackson (1973)
Alameda Creek	198	Brown and Jackson (1973)
Upper Penitencia Creek	2,835	SCS (1984a)
Lower Silver Creek	595	SCS (1984b)
Upper Guadalupe River	1,600	PWA (1993)
Lower Guadalupe River	1,840	WET (1991)
Estuary Studies		
Redwood Creek Basin	270	PWA *et al.* (1994)
Regional Correlations	425	SCS (1969)
	1,300	Dunne and Leopold 91978)
PSIAC Method	980-1,950	PSIAC (1968)

2.2.3 Sediment Yield From Agricultural Areas

The Universal Soil Loss Equation (USLE) can be used to estimate the increased sediment load from the farmed floodplain areas in the study area. The USLE is a predictive equation which estimates the soil loss by sheet and rill erosion in relatively flat lying areas where field data is not available (Wischmeier and Smith, 1979). The method is not designed to estimate sediment yields in mountainous areas, but it is applicable to the flat lying farmed floodplain areas adjacent Pilarcitos Creek and its tributaries. The USLE is appropriate for areas of less than a few square miles. The USLE is:

$$A = RKLSCP$$

where	*A*	=	soil loss (in tons/acre/year)
	R	=	rainfall erositivity index
	K	=	soil erodibility index
	L	=	hillslope-length factor
	S	=	hillslope gradient factor
	C	=	cropping management factor
	P	=	erosion control practice factor.

Typical values for central California are reported in Table 3. Although the results will vary depending on the factors chosen in the equation, the method is useful to compare the impacts of different land use and to estimate the relative contribution of various land use activities to total watershed erosion. The R factor is based on data from a contour map in Wischmeier and Smith (1979). The K factor is based on the soil type. The LS factor is based on hillslope topography and is particularly difficult to estimate because the topographic map available for this study is at a scale of 1:24,000. The C factor includes the effect of vegetative cover, the sequence of crops in rotation, the stage of the crop, tillage practices and residue management. The P factor varies with such techniques as contour cultivation, strip cropping, and terracing.

TABLE 3. Universal Soil Loss Equation Factors
USLE = R K LS C P = A in tons/acre/year

	R	K	LS	C	P
Bare Soil	50	0.37	0.10	1.0	1.0
Floodplain Agriculture	50	0.37	0.10	0.26	0.80
Natural Vegetated Floodplain	50	0.37	0.10	0.001	0.10

Estimated erosion rates for the various land uses in the basin using the USLE are reported in Table 4. The table provides an estimate of the sediment yield expected if these areas were left in there natural state in order to evaluate the impacts of the various types of landuse. Although the total sediment yield from floodplain agricultural activities is higher than the assumed yield if the floodplain were natural riparian vegetation, it is small compared to the estimated basin yield. However, since agricultural practices tend to contribute silt to the creek, modification of agricultural practices could improve water quality in Pilarcitos Creek.

TABLE 4. Watershed Areas and Sediment Yield from Agricultural Area using USLE

Tributary Name	Tributary Area		Approximate Agricultural Area* (acres)	Sediment Yield from Agricultural Area (tons/year)
	(acres)	($miles^2$)		
Mills Creek	2,450	3.8	—	—
Arroyo Leon	3,315	5.2	115	44
Madonna Creek	1,045	1.6	40	15
Albert Canyon	790	1.2	—	—
Pilarcitos Creek (upstream of Hwy. 92)	6,220	9.7	30	10
Pilarcitos Creek (between Hwy. 92 and estuary)	1,805	2.8	120	46
Nuff Creek	670	1.1	—	—
Corinda Los Trancos	570	0.9	15	6
Apanolio Creek	1,255	2.0	80	30

* Area cultivated estimated from 1992 aerial photograph

2.3 HYDROLOGY

Hydrologic data for the Pilarcitos Creek watershed were developed from USGS gaging station data at the Pilarcitos Creek at Half Moon Bay Station (gaging station #11162630). The period of record for the gage is from 1966 to present. Although the gaging station has moved 800 feet upstream to its present location (downstream of Highway 1) in 1983, the entire record is treated collectively because the two locations are close together. Figure 5 shows the flood frequency relationship and Figure 6 shows the flow duration curve. Table 5 reports mean monthly rainfall and mean monthly flows at Half Moon Bay.

figure 5

Flood Frequency Curve
Pilaracitos Creek at Half Moon Bay (1967 - 1993)

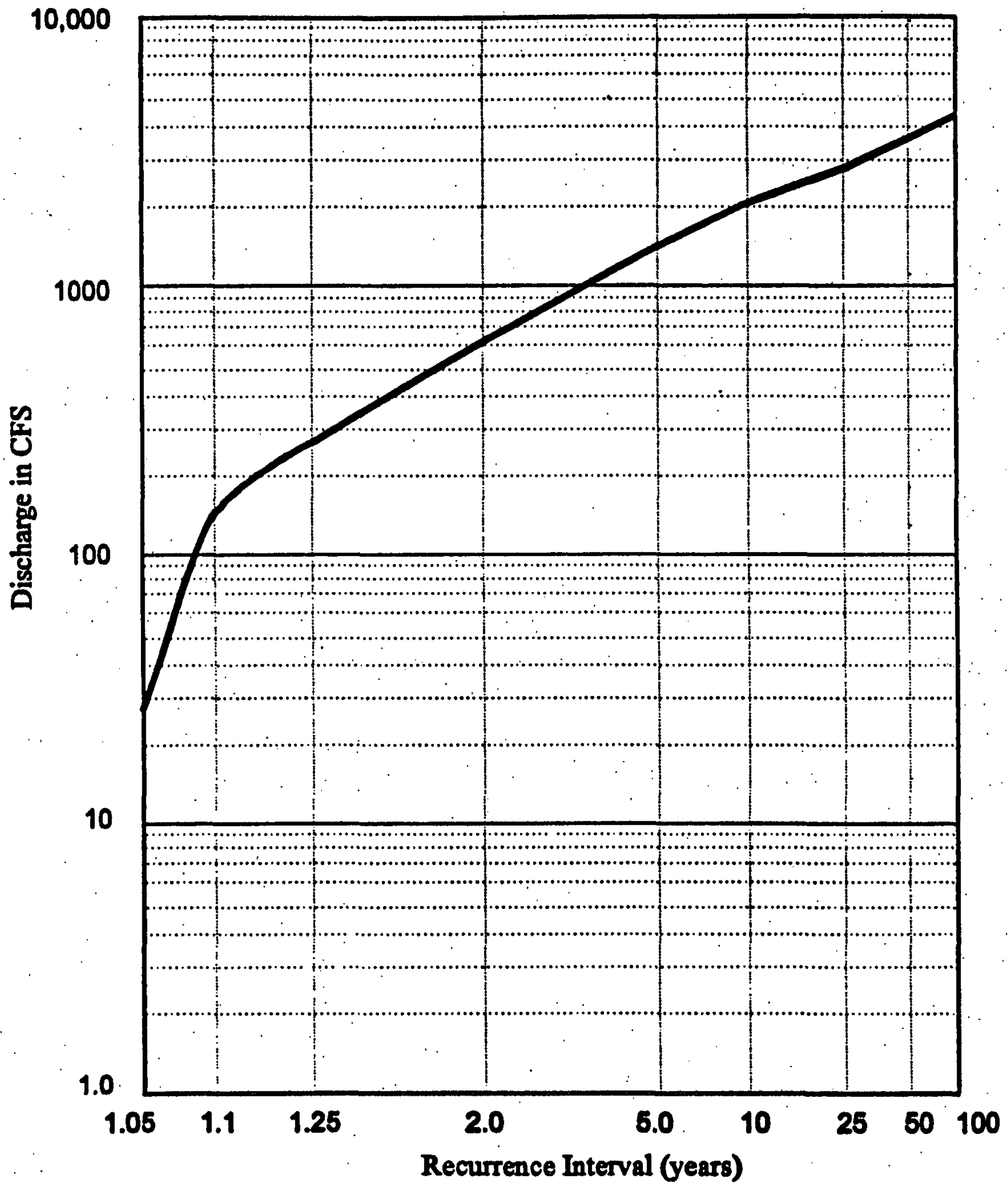


figure 6

Flow Duration Curve
Pilaracitos Creek at Half Moon Bay (1967 - 1993)

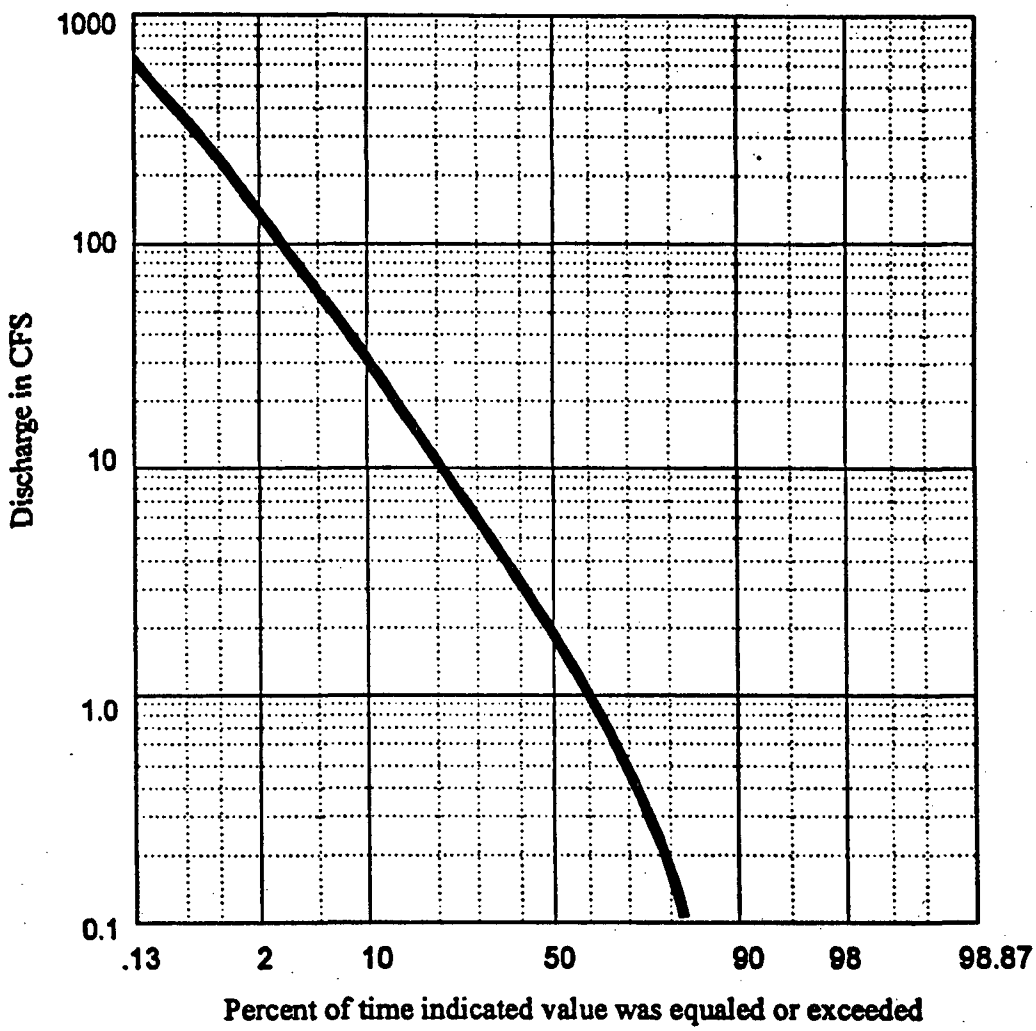


TABLE 5. Mean Monthly Precipitation at Half Moon Bay, San Mateo County

Month	Mean Monthly Precipitation* (inches)	Pilarcitos Creek @ Half Moon Bay; Mean Monthly Flow (cfs)
October	1.69	1.22
November	3.21	6.23
December	4.52	16.92
January	5.11	39.50
February	4.02	41.45
March	4.04	39.16
April	1.85	20.16
May	0.59	5.63
June	0.26	1.97
July	0.11	0.90
August	0.21	0.53
September	0.44	0.35
Total Average	26.05	14.50

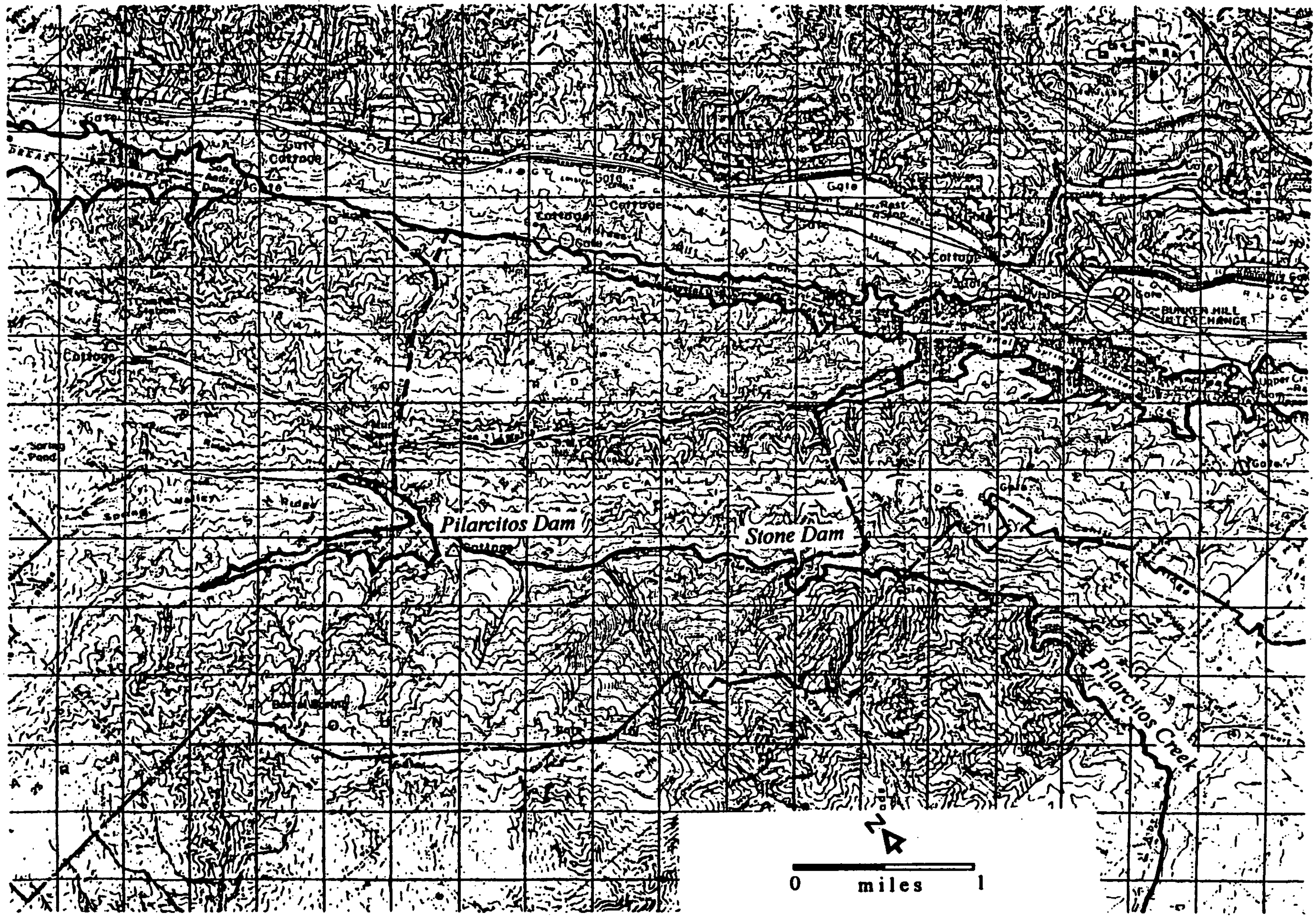
* Period of Record: 1951-1952, 1954-1972, 1974-1984,1986-1987, 1989-1993
Elevation: 11 feet NGVD

2.3.1 Water Rights

Water in the Pilarcitos Creek watershed is used by the San Francisco Water Department, the Coastside County Water District, the Colony Golf Course, local floodplain agriculture and domestic users. Water is the essential component of the riparian habitat in Pilarcitos Creek. Figure 7 shows the Pilarcitos Creek Water Supply System currently used by the San Francisco Water Department which diverts water from the upper portion of Pilarcitos Creek at Pilarcitos Dam and Stone Dam. The coastside Water District pumps approximately five wells between Stone Dam and the confluence with Albert Canyon for use in the City of Half Moon Bay and other communities on the mid-coast of San Mateo County. Figure 8 shows a San Francisco Water Department map of riparian rights along Pilarcitos Creek. As a result of current upstream water diversions and municipal, domestic, and agricultural pumping, the lower portion of Pilarcitos Creek is dry on average 59 days per year. The following summarizes the permitted water use in the Pilarcitos Creek watershed (EOA, 1990):

figure 7

Pilarcitos Creek Water Supply Systems, Source: San Francisco Water Supply



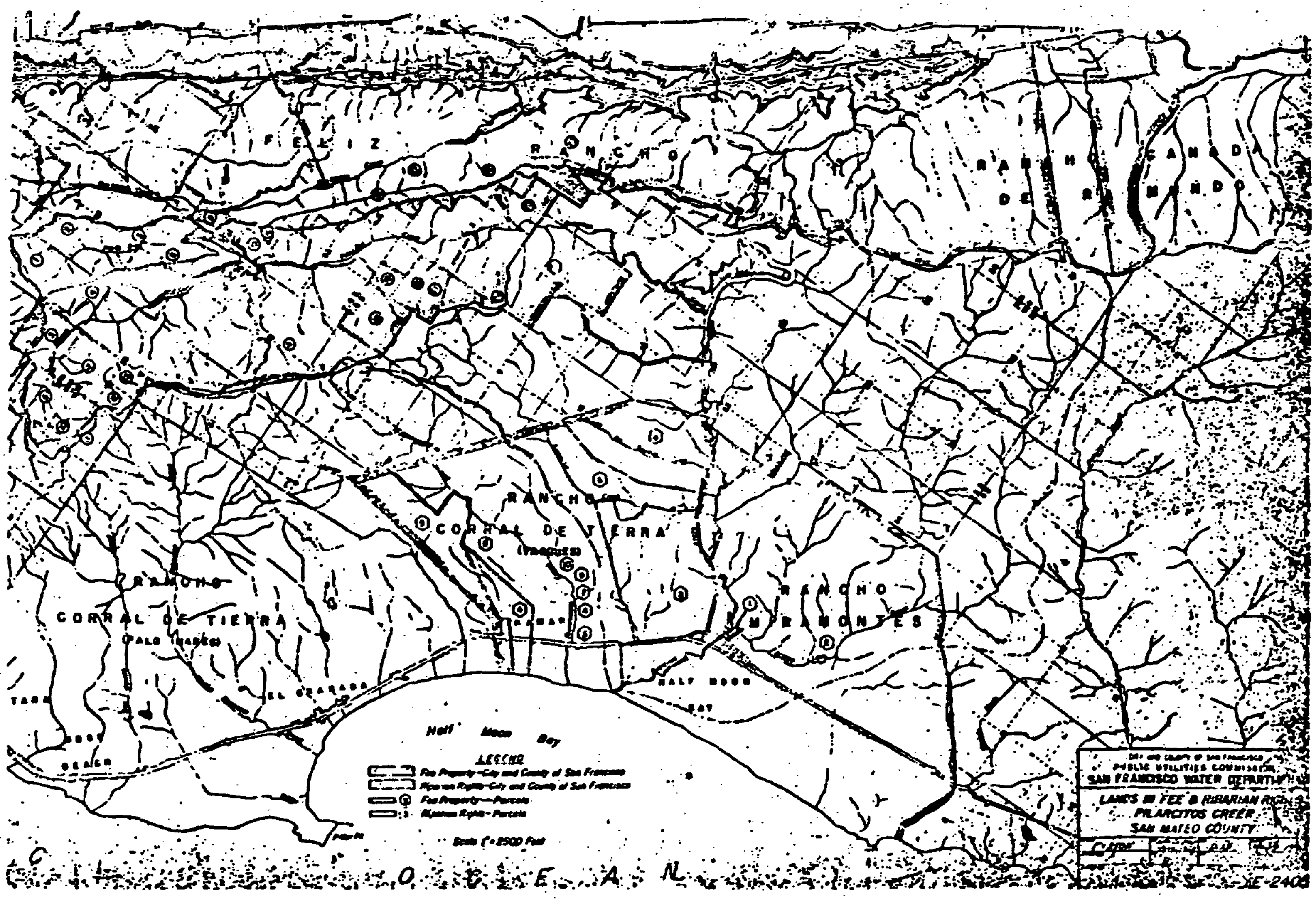


figure 8

Lands in Fee & Riparian Rights, Pilarcitos Creek

Source: San Francisco Water Department

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- San Francisco Water Department diverts approximately 4,800 acre-feet/year for use outside the watershed (some is sold to Coastside County Water District);

- Coastside County Water District operates a series of infiltration wells and has an appropriative right to divert up to 448 acre-feet/year between November 1 and March 31 each year. About 218 acre-feet/year are removed on the average—with less during drought years since the wells rely on infiltration;

- The amount of permitted appropriative diversions in the watershed total about 1,133 acre-feet/year. Most appropriative users are prohibited by conditions in their permit or licences from diverting water during the summer. The amount of riparian diversion and pre-1914 appropriative diversions are reported in statements filed with the State Water Resources Control Board (SWRCB) as 3,604 acre-feet/year. Appendix A summarizes these permitted diversions filed with the SWRCB as reported by EOA (1990); and

- Groundwater use from domestic wells is estimated at 336 acre-feet/year.

In addition to the permitted water uses, there appears to be numerous unpermitted diversions throughout the watershed (see Figure 15). Currently, there is no consistent long-term streamflow data available that records the effect of the various permitted and unpermitted diversions in Pilarcitos Creek.

A 1990 study by EOA, Inc., identified flow augmentation as a primary element necessary for watershed restoration in Pilarcitos Creek. EOA reports an informal Department of Fish and Game recommendation of increasing summertime flows to at least 2 cfs (or 1,445 acre-feet/year; or 1.3 million gallons per day) to provide permanent summer flow. The feasibility study discussed several alternatives for augmenting streamflow for fish habitat enhancement. These alternatives included:

- Constructing a dam in Albert Canyon to supply water during the dry season;

- Purchasing water from the San Francisco Water Department;

- Purchasing water rights from riparian or appropriative users;

- Using reclaimed wastewater for direct discharge to the creek downstream of the Coastside County Water District wells;

- Utilizing local groundwater; or

- Using reclaimed water to offset current use and allow that amount of water to be released to Pilarcitos creek.

A dam in Albert Canyon is not considered because of the environmental degradation associated with dam construction. Utilization of local groundwater is not considered as it is assumed that pumping groundwater in the watershed would reduce streamflow before adding the flow back to the creek. Purchasing water or water rights does not appear feasible in the long-term within the constraints of the current project funding and current water user needs. Reclaimed water is likely to become an option in the future, and construction of a tertiary treatment plant should be promoted. In the alternatives for this restoration plan (Section 7), we propose that a working group, comprised of the water users, discuss water use and needs, conservation strategies, water "wheeling" (or one district's trading water with another) and reduction of agricultural pollutants.

2.3.2 Water Quality

Few data are available to characterize the water quality of Pilarcitos Creek. In June 1994, staff of the Regional Water Quality Control Board collected samples at five stations along the mainstem and analyzed them for a broad array of water quality parameters. Figure 9 illustrates collection sites and Table 6 shows the most interesting data. Most of the constituents analyzed were below the level of detection. However, some pesticides and fertilizers were detected.

The data indicate a general deterioration in water quality in the downstream direction. Three heavy metals (Ba, Cd and Cu) were present in detectable concentrations at Station 1. Although the source of these metals may be anthropogenic, their concentrations are low enough that they are not of concern. It is important to note that the concentration of metals is correlated with both sodium (Na) and electrical conductivity (EC). This suggests that the increase of heavy metals is a part of the downstream increase of dissolved solids rather than a point source of pollution along the creek. The increase in dissolved solids downstream may be related to return flows from irrigation or to evapotranspiration along the stream.

figure 9

Locations of Surface Samples Collected June 30, 1994

Source: USGS

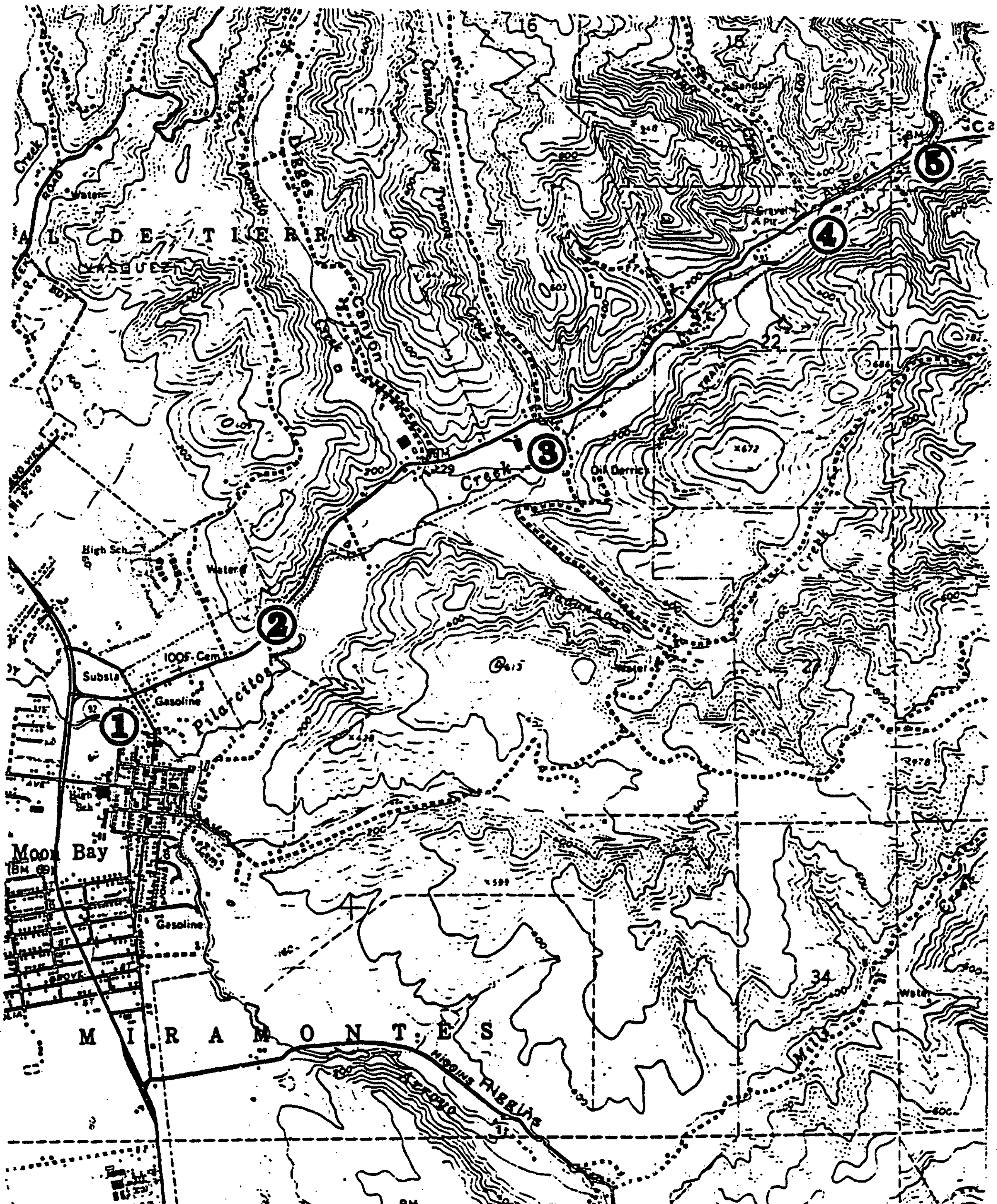

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TABLE 6. Pilarcitos Creek Water Quality Data, June 1994

		Station				
		1	2	3	4	5
Ba	µg/l	110	120	90	70	70
Cd	µg/l	0.9	nd	nd		
Cu	µg/l	0.7	0.4	nd		
Na	mg/l	81	80	48	38	34
E.C.	µmhos/cm	0.89	0.86	0.66	0.56	0.52
Tot. PO_4	µg/l	500	200	<100	<100	<100
TKN	µg/l	500	600	500	300	400
Fecal Col	MPN/100 ml	79	540	1600	220	79
Endosulfan	µg/l	0.02	0.13	nd	nd	nd

The concentration of Endosulfan sulfate at Station 2 exceeds the EPA water quality criteria for protection of aquatic organisms. The source is somewhere between stations 2 and 3.* There is a decrease in concentration between Station 2 and Station 1. This could result from: a) uptake or breakdown of the pesticide in the stream; b) dilution; or c) downstream travel time.

The concentration of nutrients—especially phosphorus—also increases downstream. This may be due to the use of agricultural fertilizer. Concentrations of 500 µg/l (0.5 mg/l) are sufficient to stimulate algae growth. Night-time uptake of oxygen by algae (as well as other plants) may deplete dissolved oxygen.

Fecal coliform concentrations are high along the stream—especially at Station 3. The concentrations exceed EPA criteria for aquatic recreation (200 per 100 ml based on a mean of 5 samples) at Stations 2, 3 and 4. Additional samples are needed to confirm these findings. Note that other water quality parameters at Station 3 do not indicate contamination. Domestic animals are the most likely source of bacterial contamination.

Data from two surface water quality samples are available for Corinda Los Trancos Creek, downstream of the landfill, from February, 1986 (following a period of unusually heavy rainfall), and May 1987 (Table 7). The concentration of nitrate-nitrogen is very high (10 mg/l)—and reaches the EPA limit for drinking water. This concentration would stimulate algae growth and almost certainly is anthropogenic. The presence of asbestos is also surprising.

TABLE 7. Surface Data for Corinda Los Trancos Creek[a]
Source: HLA, 1989

Parameter	Sampling Station[b]	
	S-4[b] February 27, 1986	S-4[c] August, 1987
Specific Conductance (µmhos/cm)	370	—
pH (standard units)	7.9	—
Total Dissolved Solids	230	—
Bicarbonate Alkalinity	120	—
Hardness	—	150
Calcium	—	40
Copper	—	<0.1
Fluoride	0.16	—
Iron	9.5	—
Magnesium	12.0	—
Manganese	0.58	—
Sodium	45	—
Zinc	<0.05	—
Sulfate	38	—
Chloride	—	37
Nitrate (as N)	—	10
Asbestos (fibers/1)	—	500
Total Coliform (MPN/1)	—	≥1600

a All values expressed as mg/l, except where noted
b Data Source: Purcell, Rhoades and Associates, May 21, 1986, in HLA, 1989
c Data Source: Purcell, Rhoades and Associates, August 26, 1987, in HLA, 1989

2.4 FISHERIES

2.4.1 Fisheries Resources Literature Review

Available fisheries resources literature were reviewed. In addition, portions of Apanolio, Arroyo Leon, Mills, and Pilarcitos Creeks were observed during a reconnaissance level field investigation over two days.

Fish Species Composition

There is limited information regarding the fisheries resources of the Pilarcitos Creek watershed. Most of the information on fisheries resources in the Pilarcitos Creek watershed comes from stream surveys conducted by the California Department of Fish and Game (CDFG). These stream surveys include data on the general habitat conditions, riparian vegetation, and observations of fish. Few quantitative electroshocking surveys have been conducted, but the few that do exist include sampling by CDFG (Ulmer, 1987), and consultants (Osterling, 1989; WESCO, 1989) in Apanolio Creek. The U.S. Fish and Wildlife Service (USFWS) conducted one stream survey of Pilarcitos Creek in 1988. However, the National Marine Fisheries Service (NMFS) does not have fisheries information for the Pilarcitos Creek watershed. Smith (1991) electroshocked at four sites upstream of Stone Dam— an impassable barrier—in 1991. In order to assess the impact of the BFI sediment spill, CDFG (Marston, 1993) sampled Pilarcitos Creek up- and downstream of Corinda Los Trancos Creek in November 1992.

In Pilarcitos Creek, both rainbow and steelhead trout have been observed in several stream surveys—predominantly in the upper reaches, upstream of primary agricultural land use. Rainbow and steelhead trout (*Oncorhynchus mykiss*) were observed during CDFG stream surveys in 1987, 1988 and 1992. In addition, sculpin (prickly and coastrange [*cotlus asper* and *C. aleuticus*]) and sticklebacks (*Gasterosteus aculeatus*) have been observed in Pilarcitos Creek.

Few of the tributaries of Pilarcitos Creek have been surveyed or sampled. Rainbow and steelhead trout were observed in Mills Creek (CDFG, 1987), Arroyo Leon (CDFG, 1985; 1987), and in Apanolio Creek (CDFG, 1987; 1987; 1988; 1989; Smith, 1990). A sculpin was observed in Arroyo Leon in 1987 (CDFG, 1987).

Migration Barriers

Migration barriers in the Pilarcitos Creek watershed are illustrated on Figure 10. In Pilarcitos Creek, the Stone Dam on San Francisco Water Company property blocks migrating anadromous steelhead: the dam is the upstream migration limit. Pilarcitos Creek is dry an average of 59 days per year at the USGS gaging station on the lower portion of the creek (EOA, 1990). This could represent a barrier for both adult upstream migration and juvenile downstream migration. Since adults swim upstream in response to storm flows, low streamflows may represent a more significant barrier for downstream migrating juveniles in the late spring and early summer.

Apanolio Creek has three potential barriers downstream of BFI property (Smith, 1990). The furthermost downstream barrier, the Bongard Diversion Dam, is impassable for upstream migration during most flow conditions. Due to high velocities, the culverts at the Bongard Pond may represent a migration barrier. The drop below the culvert on the Gossett property is another potential barrier. Gossett's flashboard dam is no longer in use, but did represent a potential barrier through 1990.

Arroyo Leon has four potential barriers on the mainstem, a barrier on the tributary Mills Creek, and potential migration barriers created by inadequate flow during smolt migration periods. On mainstem Arroyo Leon, potential barriers exist at the two large (20 feet high) flashboard dams on the Half Moon Bay Heritage Co. and two smaller flashboard dams upstream. However, these flashboard dams may not present migration barriers if the flashboards are removed during the adult migration period. On Mills Creek, scour downstream of the historic bridge has created a potential migration barrier.

Habitat Conditions

Stream surveys, including recent CDFG surveys (1992) on Arroyo Leon and portions of Pilarcitos Creek, indicate that low summer streamflows and numerous diversions are a major constraint on steelhead habitat. Substrates in most surveyed stream sections are dominated by sand. In some stream sections, riparian vegetation has been removed. Loss of riparian vegetation can result in increased stream temperatures, loss of escape cover for fish and amphibians, and changes in habitat types.

2.4.2 Fisheries Resources Field Inventory and Electroshocking

Field surveys were conducted within the watershed during the weeks of October 21 and 28, 1995 in order to inventory stream conditions on accessible streams. Stream surveys consisted of walking up or downstream recording fisheries habitat conditions in field notebooks. Spawning substrate presence and quality, available rearing habitat (including amount and forms of escape cover), and percentage estimates of habitat types were documented. The following were noted during surveys:

- stream channel widths and depths (using measuring rods in increments of tenths of feet);

- riparian canopy closure percentages (using a densitometer);

- stream gradient (measured with a clinometer); and

- barriers and water diversions, fish, and restoration opportunities.

Distances surveyed were approximated by using a clicker for every ten feet walked instream. Representative and unique areas were recorded as potential electroshock sampling sites. Each surveyed tributary was divided into reaches based on differing fisheries habitat and stream channel characteristics (Figure 10).

Electroshock fish sampling was conducted November 6th through 9th by using a Model Type VII Smith Root electroshocker to gain information on species composition, age classes, abundance, and distribution. Stations were blocked using nets at the upstream and downstream ends of pools, riffles, and runs sampled. Captured fish were held in a live car until depletion sampling was completed. Rainbow and steelhead trout (rt/sth) fork lengths were measured in 5 mm increments and their age groups were separated by length/frequency. The larger young of the year (yoy) (greater than approximately 75 mm) will likely become large enough to smolt by the spring of 1996 and were included in "smolt-sized" fish density. Surveyors also tallied prickly sculpin and three spine stickleback. Data forms were completed for each site to record station location, fish species information, and stream habitat characteristics. Electroshocking site locations are shown on Figure 10.

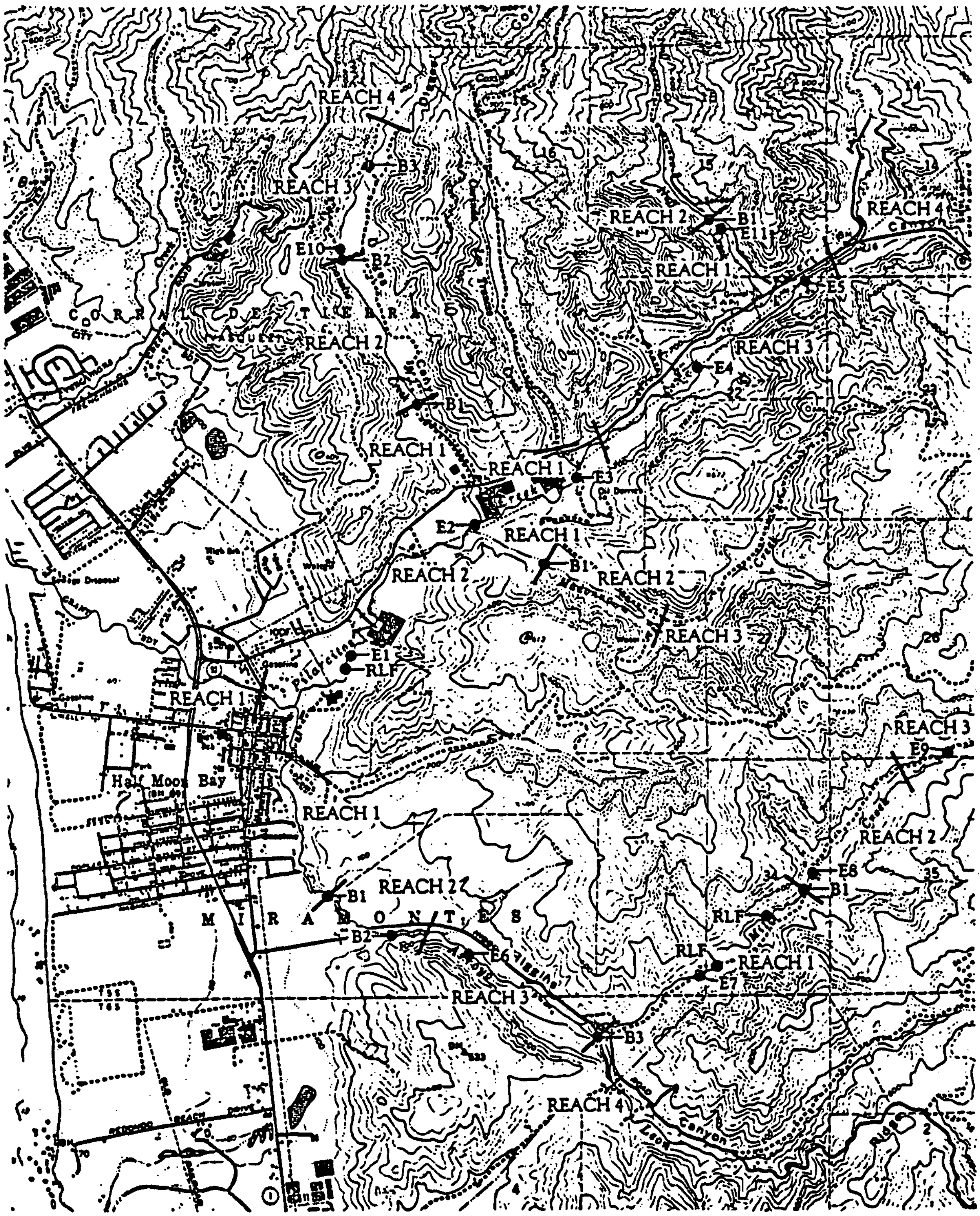
Both the fisheries habitat field survey and electrofishing surveys were conducted prior to any major rainfall events in fall 1995. However, this field work was also performed after higher than average rainfall the previous year (1994-95). This may account for the substantially higher than average fall streamflows noted during the field surveys.

The survey encompassed approximately 7.2 miles of the Pilarcitos Creek watershed—including Pilarcitos, Arroyo Leon, Mills, Madonna, Apanolio, Corinda Los Trancos, and Nuff Creeks. Eleven sites were sampled by electroshocking.

Overview of 1995 Habitat/Fish Evaluation

Tables 8 and 9 summarize electroshocking results for substrate compositions and densities of rt/sth. Table 10 rates fisheries habitat conditions in the Pilarcitos Creek watershed. Table 11 compares the Pilarcitos Creek watershed to four other streams in San Mateo County.

Stream substrate throughout the Pilarcitos watershed is dominated by sand (Table 8). Even at the best sites, sand generally dominated pools and runs; spawning gravels contained large amounts of sand. Sand from erodible granitic and sandy soils results in poor spawning conditions throughout much of the watershed (Table 10). Sand also limits the extent and depth of pools and results in fewer aquatic insects as food for fish. Even at relatively undisturbed sites, such as Pilarcitos Creek above Stone Dan (Smith, 1991), sandy substrate constrains stream habitat values.



LEGEND

E1	Electroshocking Sites
B1	Fish Migration Barriers
RLF	Red-legged Frog Sitings

0 2,000' 4,000'

N

figure 10

Fisheries and Wildlife Map

Source: The Habitat Restoration Group

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TABLE 8. Substrate Composition (percent) at Electroshock Sites in Pilarcitos Creek Watershed, November 1995

Stream, Reach and Electroshock Site	Organics/ Silt	Sand (<2 to 5 mm)	Gravel (GR) (5 to 75 mm)	Gravel/Cobble (75 to 225 mm)	Cobble/Boulders (>225 mm)
PILARCITOS					
Reach 2, #1					
Pool	25	70	5		
Riffle		40	60		
Run	10	75	15		
Reach 2, #2					
Pool	65	20	15		
Riffle\Run	10	15	70	5	
Reach 2, #3					
Pool	20	65	15		
Riffle	10	25	65		
Run	5	15	70		10
Reach 3, #4					
Pool	50	25	25		
Riffle	15	10	75		
Run	35	40	25		
Reach 3, #5					
Pool	25	50	25		
Riffle	5	20	50	25	
Run	10	40	25	25	
ARROYO LEON					
Reach 3, #6					
Pool	45	30	15	10	
Riffle	10	10	25	55	
Run	5	70	15	10	
MILLS					
Reach 1, #7					
Pool	60	35	5		
Riffle	10	25	38	26	1
Run	4	6	85	4	1
Reach 2, #8					

TABLE 8 (continued)

Stream, Reach and Electroshock Site	Organics/ Silt	Sand (<2 to 5 mm)	Gravel (GR) (5 to 75 mm)	Gravel/Cobble (75 to 225 mm)	Cobble/Boulders (>225 mm)
Pool	40	37	22	1	
Riffle	2	5	42	51	
Run					
Reach 3, #9					
Pool	40	40	5		15
Riffle/Run		5		15	80
APANOLIO					
Reach 3, #10					
Pool	25	75			
Riffle/Run	15	50	35		

TABLE 9. **Distances (Feet) and Types of Habitat Sampled and Densities of YOY and Smolt-sized (Age 1+ to 2+ and YOY >75mm) Steelhead per 100 Feet at Electroshock Sites in Pilarcitos Creek Watershed in November 1995**

Stream, Reach, and Electroshock Site	Distances Sampled	Percent Habitat Composition			Rt/Sth Density/100 Feet		Total Density Ranking
		Pool	Riffle	Run	YOY	Smolt-sized	
PILARCITOS							
Reach 2, #1	91	33	18	49	0	0	10th
Reach 2, #2	66	39		*61	0	15	9th
Reach 2, #3	52	37	34	29	2	22	6th
Reach 3, #4	88	34	33	33	20	22	5th
Reach 3, #5	73	16	55	29	32	12	4th
ARROYO LEON							
Reach 3, #6	105	52	29	19	0	19	8th
MILLS							
Reach 1, #7	77.5	22	46	32	37	14	2nd
Reach 2, #8	67	37	63	0	24	26	3rd
Reach 3, #9	50	30		*70	12	10	7th
APANOLIO							
Reach 3, #10	35	24		*76	29	23	1st

* Percentage for a Riffle/Run habitat

1995 Densities in Other San Mateo and Northern Santa Cruz Counties for Comparison

Stream, Reach, and Site	Rt/Sth Density/100 Feet	
	YOY	Smolt-sized
GAZOS	54	28
WADDELL	54	39
SCOTT	75	25

TABLE 10. Steelhead Rearing, Spawning, and Migration Conditions for Stream Reaches in Pilarcitos Creek Watershed

Stream and Reach	Steelhead		Migration		Number of Barriers	Number of Diversions Noted
	Rearing	Spawning	Up	Down		
PILARCITOS						
Reach 1	Poor	Poor	Good	Fair-Good	0	0
Reach 2	Poor-Fair	Fair	Good	Fair-Good	0	7
Reach 3	Fair	Fair	Good	Fair-Good	0	6
Reach 4*	?	?	Good	Fair-Good	1	?
ARROYO LEON						
Reach 1	None-Poor	Poor	Good	Poor	0	0
Reach 2 (ponds)	None-Good	Poor	Good	Poor	2	2
Reach 3	Fair	Poor	Good	Poor	0	0
Reach 4*	?	-	None	Poor	1	?
MILLS						
Reach 1	Fair-Good	Poor	Good	Poor	1	0
Reach 2	Fair-Good	Fair	None	Poor	0	0
Reach 3	Poor	Fair-Poor	None	Poor	?	1 known
MADONNA						
Reach 1	Poor	Poor	Fair	Fair-Good	0	0
Reach 2	Poor-Good	Poor	None	Fair	1	1
APANOLIO						
Reach 1**	Fair	Poor	Good	Fair-Good	0	0
Reach 2**	Fair	Poor	Poor	Fair-Good	2	2
Reach 3	Fair-Good	Poor-Fair	Poor	Fair-Good	1	0
Reach 4**	Fair	Poor	Poor	Fair-Good	?	?
NUFF						
Reach 1	Poor	Poor	?	Fair	?	?
Reach 2	Poor	Poor	None	Fair	1 known	?

* Not surveyed — no landowner access.
** Based on past survey information from 1990.

TABLE 11. **Comparison of Fisheries Habitat Conditions Within Four Other San Mateo County Streams**

Stream and Reach	Steelhead/Rainbow Trout		Migration	
	Rearing	Spawning	Up	Down
GAZOS	Fair-Good	Fair	Good	Good
PESCADERO				
Lagoon	Poor-Excellent	Fair	Good	Good
To mile 3	Fair	Fair	Good	Good-Fair
Above mile 3	Fair-Very Good	Fair-Good	Good	Good-Fair
PURISIMA	Good-Very Good	Fair-Good	None	Good
SAN GREGORIO				
Lagoon	Fair-Excellent	None	Good	Good
Above Lagoon	Fair-Very Good	Fair-Good	Good	Good

High streamflows are needed in sandy watersheds in order to support good populations of steelhead: high streamflows produce adequate depth, insect production and, overhead cover (as turbulence). Unfortunately, the Pilarcitos watershed is not only sandy, but most stream sections have low flows in average or dry years as well. Currently, no minimum flows are released from Stone Dam on Upper Pilarcitos Creek during the summer months. Likewise, diversions for agricultural use are common year-round throughout the watershed (Table 10).

Upstream barriers to adult migration in Apanolio and Arroyo Leon watersheds are obvious and modifiable. A more subtle migration problem is low April and May flows in dry years. These may block outmigrating smolts at shallow riffles or by early formation of a sandbar at the mouth. In dry and average years, the operation of dams and diversions on lower Arroyo Leon probably restrict or block smolt downstream migration.

On Pilarcitos Creek, stream habitat (Tables 8 and 10) and fish abundance (Table 9) generally increased upstream. The site sampled on Apanolio Creek and the two lower sites on Mills Creek also had relatively high fish densities for the watershed (Table 9). However, these "best" sites still had combined steelhead densities about *half* of the *average* steelhead density on 28 sites on Gazos, Waddell, and Scott Creeks (Table 9) in 1995. Ponds on Apanolio Creek and Arroyo Leon do offer important *potential* steelhead rearing habitat. Nuff and Madonna Creeks and Corinda Los Trancos Creek are significant sources of summer streamflow to Pilarcitos creek and sandy sediment.

In most years, Pilarcitos Creek is dry near the mouth and no summer lagoon forms. However, if summer streamflows reach the mouth Pilarcitos Creek (as they did in 1995), a lagoon can form in summer as the beach develops.

Overall, in comparison to other streams in San Mateo County (Table 11) and Santa Cruz County (Table 9), Pilarcitos Creek watershed has only modest steelhead habitat (Table 9). The majority of the listed streams also have coho salmon populations or could support restored coho populations.

Pilarcitos Creek

Approximately 4.1 miles of Pilarcitos Creek fisheries habitat were surveyed from Elmar Beach upstream to a private bridge east of Half Moon Bay Nursery. Three stream reaches are designated on Figure 10; surveyors were denied access to a fourth reach, upstream of the nursery. Due to restricted access for salmonids above Stone Dam, the portion of the creek on San Francisco Water Department (SFWD) lands (upstream of Stone Dam) was not surveyed in October/November 1995. A visual survey of this section was conducted with SFWD personnel in late spring 1995. Because of limited restoration opportunities, and an on-going resource management plan by SFWD, further field surveys were not deemed necessary.

Locations of the reaches on Pilarcitos Creek are as follows:

Reach 1 begins 0.2 miles downstream of the footbridge on the Elmar Beach trail and extends upstream 1.4 miles to the Main Street bridge. Reach 2 begins at the Main Street bridge and extends upstream 1.8 miles to a vehicular bridge 0.3 miles east of Obester Winery (at the east end of a tree farm). Reach 3 starts at the vehicular bridge and extends upstream 0.9 miles to the second bridge east of Half Moon Bay Nursery (Figure 10). Reach 4 is the unsurveyed section from Half Moon Bay Nursery upstream to Stone Dam; a survey of the Coastside County Water District property in Reach 4 will be conducted in 1996. Reach 5 lies between Stone Dam and Pilarcitos Reservoir and was surveyed in 1991 (Smith, 1991).

All three reaches are characterized by sand banks and a stream gradient that averaged 0.5 to 1 percent. Reaches 2 and 3 had the following similarities:

- a well-confined stream channel and streamflow of approximately 1 cubic foot per second (cfs) in late October 1995;
- streambanks that averaged approximately 8 feet in height that are overgrown with Himalaya berry/German ivy;

- dominant riparian trees of alder and willow as well as boulders, overhanging vegetation, and both large and small woody debris; and

- some undercut banks that provide natural escape cover for migrating and rearing fish and juvenile rainbow and steelhead trout (rt/sth) and three spine sticklebacks.

Three sites in Reach 2 and two sites in Reach 3 were selected for fish sampling by electroshocking (Figure 10).

Reach 1 — Pilarcitos Creek

The wetted stream channel ranged from 7 to 25 feet wide, with an average width of 8 to 10 feet. The stream channel ranged from slightly (at the beach) to moderately confined (beginning 0.5 miles upstream). Total channel width ranged from 20 to 60 feet. Streambank heights varied from almost 0 at the beach to 20 feet in some areas upstream. Stream habitats consisted of 20 percent pools, 5 percent riffles, and 75 percent runs. Pools were shallow and small with depths that ranged from 0.5 to 2 feet and averaged 0.6 to 0.7 feet. Substrate consisted of fine and course sand for the first 0.5 miles. Upstream of that point some small gravel (25 to 75 millimeters [mm]) and 75 to 150 mm gravel/cobble appeared. However, fine sediment was still the dominant substrate. Suitable spawning gravel was not identified within Reach 1. Stream canopy closure averaged 75 to 80 percent after it appeared 0.2 miles from the start of the survey. Juvenile rt/sth were not observed within Reach 1. Streamflow was approximately 3 cfs. However, this survey was conducted following a release of approximately 8 cfs out of Arroyo Leon the prior evening. As field surveyors approached the Main Street Bridge and confluence of Arroyo Leon on October 31, 1995, the water turbidity had increased, also indicating that higher than normal flows were probably being released from dammed ponds on Arroyo Leon.

Pilarcitos Creek and Frenchman's Creek (a watershed to the north), both flowed into a common lagoon in 1995. The common area of the lagoon was dry at the time of this survey in early November, 1995. During the late fall/early winter of 1995/1996, the sandbar was breached at the Venice Beach Access and Pilarcitos Creek entered the Pacific Ocean.

This reach was not sampled by electroshocker because fish were not observed during the survey nor were rt/sth captured upstream at electroshock Site 1.

Reach 2 — Pilarcitos Creek

Apanolio, Arroyo Leon, Corinda Los Trancos, and Madonna Creeks join Pilarcitos Creek within Reach 2 (Figure 10). The wetted stream channel ranged from 2 to 15 feet wide, with an average width of 5 to 6 feet. Total channel width varied from 8 to 20 feet. Stream habitats consisted of 40 percent pools, 20 percent riffles, 35 percent runs, and 5 percent glides. Although the percentage of pools was relatively high, pools were shallow and small with depths that ranged from 0.5 to 3.5 feet and averaged 0.7 to 0.8 feet. Scour was either very concentrated or occurred as slight lateral scour throughout the habitat. Natural escape cover within pools was poor to fair for migrating and rearing fish. Spawning gravel was limited with substrate embeddedness being at least 30 percent (Table 8). However, several potential spawning locations upstream of Apanolio Creek were noted. One of the potential spawning areas had a substrate composition of 30 percent sand, 25 percent gravel under 25 mm, 20 percent 25 to 50 mm gravel, 20 percent 50 to 75 mm gravel, and 5 percent 75 to 150 mm gravel/cobble. Stream canopy closure averaged between 70 and 75 percent. However, the width of vegetative riparian zones was relatively narrow. At least seven water diversions were noted. A juvenile red-legged frog was found within this reach.

The uppermost 0.3 miles of Reach 2 has been altered by riparian vegetation removal resulting in extensive summer growth of watercress within the channel. Overall, stream characteristics appeared the same as the remainder of Reach 2, except those relating to canopy. Instream emergent vegetation provided good cover for fish. However, the lack of riparian canopy probably increases summer stream temperatures significantly.

Three sites were selected to be electroshocked within Reach 2 (Figure 10). Site 1 was located 0.3 miles upstream of the confluence with Arroyo Leon, Site 2 was located between the Madonna Creek and Apanolio Creek confluences, and Site 3 was located between Apanolio Creek and Corinda Los Trancos Creek confluences.

No fish were captured at Site 1. However, one 64 to 76 mm rt/sth (rt/sth) was missed during sampling effort within the pool. Overall rt/sth yoy densities were very low within Reach 2. Smolt-sized rt/sth densities were higher (Table 9). Threespine sticklebacks were captured; sticklebacks were numerous at Site 2.

Reach 3 — Pilarcitos Creek

Nuff Creek joins Pilarcitos Creek within this reach. The average wetted stream channel width was 6 to 7 feet. Total channel widths ranged from 7 to 42 feet. Stream habitats consisted of 40 percent pools, 20 percent riffles, 30 percent runs, and 10 percent glides. Pools were somewhat deeper, on average, than those encountered in Reach 2 with depths averaging 0.8 to 1 foot. Natural escape cover within pools was better than Reach 2, but still only fair for migrating and rearing fish. Spawning gravel was limited with substrate embeddedness of 40 to 50 percent due to a significant component of course sand and fine sediment (Table 8). Larger substrate sizes were found compared to downstream with 150 to 225 mm cobble and some boulders present. Stream canopy closure was good, averaging between 80 and 85 percent. At least six water diversions were noted. There was a 500-600 foot section of creek within this reach that was atypical of the three reaches of Pilarcitos Creek surveyed. The atypical section was less confined with a wider flood plain and had a few redwood trees contributing to stream canopy.

Two sites were sampled for fish by electroshocking in Reach 3. Site 4 was located at Cozzolino Park, behind the Cozzolino Nursery (the atypical stream section mentioned in the above reach summary) and Site 5 was located at the bridge east of Half Moon Bay Nursery (Figure 10). Rainbow and steelhead trout yoy were much more dense in Reach 3 than Reach 2 and smolt-sized rt/sth had similar densities to Reach 2 (Table 9). Threespine sticklebacks were also captured at Sites 4 and 5.

Reach 4 — Pilarcitos Creek

Reach 4 of Pilarcitos Creek was not surveyed as access was denied by a private landowner. A fisheries study was conducted during spring 1995 on the Coastside County Water District property to Stone Dam Reservoir. However, because this information may be used in a legal action it was not available for review. Existing conditions of this section of Pilarcitos Creek are unknown at this time.

Reach 5 — Pilarcitos Creek

Despite the generally undisturbed watershed conditions between Stone and Pilarcitos Dams, the streambed was dominated by sand. Streamflows in summer are maintained at near 1 cfs as part of San Francisco Water Department's overall water operations, but poor substrate and pool development constrain rainbow trout numbers and size.

Arroyo Leon

Approximately 0.8 miles of Arroyo Leon were surveyed and divided into three reaches. A fourth reach, upstream of the barrier near the mouth of Mills Creek, was not surveyed in October because access was denied by private landowners. In February 1996, Jennifer Nelson (CDFG) spot- checked the upper portion of Reach 4.

Reach 1 of Arroyo Leon began at the confluence with Pilarcitos Creek and extended upstream to the first dam barrier (0.1 - 0.2 miles downstream of Higgins Road). A total of 0.6 miles was surveyed within this reach—0.4 miles from the mouth upstream and 0.2 miles from the end of Arnold Way at the apartment complex upstream to the first dam barrier. Reach 2 consisted of dam barriers one and two and their associated ponds (approximately 0.5 miles) (Figure 3). Reach 3 extended approximately 0.9 miles upstream of Reach 2 to a third barrier on Arroyo Leon. Approximately 0.2 miles was spot checked. Steep, inaccessible banks, overgrown with poison oak, limited access into Reach 3 . Reaches 1 and 3 were characterized by a well-confined stream channel, streambanks ranging in height from eight to twenty-five feet. The lack of spawning gravel was due to large amounts of fine sediment that caused embeddedness (or buried) of the gravel substrate (Table 8). One site was selected for electroshocking in Reach 3. HRG will conduct surveys in Reach 4 of Arroyo Leon in 1996.

Reach 1 — Arroyo Leon

Streamflow was approximately 0.2 cfs and the wetted channel width ranged from 5 to 6 feet wide where there was water flow. Stream channel width ranged from 5 to 20 feet with an average width of 13 feet. Riffle/run habitat was dominant in this reach. Pools were small and shallow with a range of 0.5 to 3 feet depth. Natural escape cover within pools was generally lacking for migrating and rearing fish. However, when present the forms of cover included overhanging vegetation, small woody debris, and some undercut banks. Stream canopy closure averaged between 70 and 75 percent, and stream gradient averaged between 0.5 and 1 percent. Numerous Threespine sticklebacks, two sculpin, and several juvenile rt/sth were observed within Reach 1. Reach 1 of Arroyo Leon was not sampled by electrofishing.

Reach 2 — Arroyo Leon

Two barriers to fish migration exist within Reach 2 (Figure 10). The first is a cement dam that is approximately 25 feet high and creates a 23 foot wide channel below. Water level in the lake was 2.5 to 3 feet below the spillway. The pond above the dam was 175 to 200 feet wide and about 950 feet long extending to a culvert at Higgins road. The second barrier is a cement dam and pond above Higgins Road. These two ponds are drained in the fall via slide gates (per California Division of Dams and Safety regulations), thus providing access for adult Steelhead migrating upstream and downstream. However, the gates are currently closed in the late winter or early spring which creates difficulty for Steelhead smolts migrating downstream during spring months. Reach 2 was not sampled by electrofishing.

Reach 3 — Arroyo Leon

The wetted stream channel ranged from 2.5 to 15 feet wide. Stream habitats consisted of 65 to 75 percent pools and 25 to 35 percent riffles/runs. Pools averaged approximately 2 feet deep with a maximum of 4 feet. Natural escape cover within pools was good for migrating and rearing fish. Forms of cover included depth, large woody debris, small woody debris, and an abundance of undercut banks (as much as 4 feet). Streamflow was approximately 2.5 cfs. Stream canopy closure averaged between 75 and 85 percent, and stream gradient was approximately 1.5 percent. Juvenile rt/sth were observed within Reach 3. A small seasonal flash board dam in Reach 3 represents a possible barrier to fish passage if the boards are not removed in winter and spring.

Reach 3 of Arroyo Leon was electrofished at one site (Site 6) approximately 0.5 miles upstream of Higgins road crossing. The density of yoy and smolt-sized rt/sth was low. However, yoy were fast-growing and large and were therefore classified as smolt-sized (Table 9). Prickly sculpin were also captured.

Reach 4 — Arroyo Leon

A culvert upstream of the Mills Creek confluence is a fourth barrier. This culvert is 4.5 feet high with an apron at the base (Figure 10). The habitat immediately upstream of the culvert is dominated by sand. However, the substrates in the upstream portion of the reach had abundant gravel and cobble in February 1996 (Nelson, pers. comm., 1996).

Mills Creek

A total of 1.6 miles of Mills Creek was surveyed and divided into two reaches. A third reach was designated upstream of Reach 2 (Figure 10). Reach 1 of Mills Creek began at the confluence with Arroyo Leon and extends upstream approximately 1.4 miles to the old stone bridge barrier. Access was difficult in the lower 0.3 miles due to steep vegetated banks, thus the survey began 0.3 miles downstream of the first bridge crossing the creek within the State Park. Reach 2 of Mills Creek extends upstream of the old stone bridge for 0.5 miles. Reach 3 was the section of the creek upstream of Reach 2 and was spot checked and observed where an electroshocking site was chosen. The total distance of Mills Creek surveyed was adequate to gain an understanding of the overall stream conditions.

Similarities found within the two reaches surveyed included: stream habitat composition of 50 percent pools, 40 percent riffles, 10 percent runs; a dense riparian canopy closure of 80 to 85 percent; and natural escape cover in the form of depth, large woody debris, small woody debris, and undercut banks. Three sites, one in each reach, were selected for electroshocking (Figure 10).

Reach 1 — Mills Creek

The wetted stream channel ranged from 2 to 14 feet wide, and averaged 6 to 7 feet. The stream channel was well-confined. Pool depths ranged from 0.5 to 4 feet and averaged 1 to 1.5 feet. Most pools provided good juvenile rearing and adult holding habitat with abundant natural escape cover (most notable were the numerous undercut banks, with one undercut measuring 6 feet). The largest pool encountered was 14 feet wide, 32 feet long and 2.5 feet deep. Potential spawning habitat was noted in several areas but was of poor quality: the substrate embeddedness ranged from 30 to as high as 50 percent due to a heavy component of fine sediment (Table 8). Some bedrock was present in this tributary—a characteristic found only in the reach and on Madonna Creek. Stream gradient averaged between 1 and 1.5 percent. Juvenile rt/sth were observed throughout Reach 1 and possible red-legged frog sightings were documented (Figure 10). The old stone bridge at the end of this reach acts as a fish migration barrier. The vertical drop from the 20 foot long by 12 foot wide cement bridge foundation within the creek was 7.5 feet to the water surface below. The dimensions of the pool below were 20 feet long, 23 feet wide, and 1 foot deep. There is a maximum depth of 2.5 feet off to the side of the drop.

One site (Site 7) was sampled for fish by electroshocking in Reach 1 at the first bridge within the State Park (Figure 10). Like the two other reaches of Mill Creek, rainbow and steelhead trout yoy were generally small indicating slow growth but had the highest density of sites electroshocked in the watershed. However, smolt-sized fish had low densities (Table 9). No other fish species were captured.

Reach 2 — Mills Creek

The wetted stream channel in Reach 2 averaged 7 feet. The stream channel was less confined with a wider flood plain (maximum 22 foot width) than in Reach 1. Pool depths ranged from 0.5 to 3.5 feet and averaged about 1 foot. The largest pool encountered was 14 by 21 feet wide, with a 2.5 feet depth. Most pools provided good juvenile rearing and adult holding habitat. Juvenile rt/sth were observed throughout Reach 2; however, fish appeared less numerous than in Reach 1. Spawning gravel was present at several locations. Fine sediment content was less than Reach 1, but was still high, with substrate embeddedness averaging 30 percent (Table 8). Stream gradient averaged approximately 1 percent.

One site (Site 8) was selected for electrofishing within Reach 2 upstream of the stone bridge barrier (Figure 10). Smolt-sized rt/sth had highest densities in the portion of the watershed electroshocked and yoy were of average density, comparatively (Tables 9 and 10). No other fish species were captured.

Reach 3 — Mills Creek

Reach 3 is that section of Mills Creek upstream of the surveyed area. Stream characteristics observed from electroshock sampling included: 7 to 15 foot high streambanks with alder as the dominant riparian tree, approximately 4 percent stream gradient, 75 to 80 percent canopy closure, and larger instream substrate. There were no spawning gravels in this area (Table 8).

One site (Site 9) was electroshocked in Reach 3 below three water tanks approximately one mile above the bridge near the park residence. Both yoy and smolt-sized rt/sth densities were very low at Site 3 (Table 9).

Madonna Creek

Portions of Madonna Creek, equaling approximately 0.2 miles, were spot checked walking downstream from the first bridge located approximately one mile upstream of the Pilarcitos Creek confluence on Peninsula Open Space Trust (POST) lands.

The creek was divided into two reaches. A third reach designated as the upstream area was not surveyed as access was denied by private landowners. Reach 1 extends from the confluence with Pilarcitos Creek upstream approximately 0.3 miles where there was a barrier to fish migration. Reach 2 extended upstream of this barrier for approximately 0.5 miles to the first bridge. Access was difficult for both reaches due to steep vegetated banks, deep pools without bank access, and downed riparian vegetation within the creek. Madonna Creek was not sampled by electroshocking because of its low potential for salmonid fisheries. This is due to the barrier and low streamflow (observed even during a wet year).

Reach 1 — Madonna Creek

Reach 1 provides little fish habitat due to a lack of pools and spawning gravel. Fine sediment was abundant and the stream channel was dry except for isolated shallow pools. Approximately 0.3 mile upstream of Pilarcitos Creek there is fish migration barrier consisting of a concrete/wood dam with a steep wood spillway that drops approximately 25 feet into the creek below (Figure 10).

Reach 2 — Madonna Creek

There is a pond formed above the barrier that creates potential fisheries rearing habitat. The canyon above the pond is well-shaded and the dominant habitat type above the diversion was pools. Threespine stickleback observed within Reach 2.

Streamflow varied from isolated pockets of water to deep pools and flowing riffles. Spawning gravel was not found as the stream bottom was dominated by fine sediment. One section of this reach was characterized by bedrock walls, a constricted channel, sand/bedrock substrate, and large, deep pools with intervening riffles.

Near the upstream end of Reach 2 (at the bridge) there was a 30 foot drop in elevation caused by erosion where concrete slabs were placed into the creek. Concrete slabs were present in the channel for approximately 600 feet.

A significant restoration effort would have to take place within Madonna Creek in order to create suitable salmonid fisheries habitat.

Apanolio Creek

Apanolio Creek is divided into four reaches. Reach 1 extends from the mouth upstream approximately 0.5 miles to the first barrier. Reach 2 extends upstream to a second barrier (approximately 0.6 miles). Reach 3 extends upstream of the second barrier approximately 0.5 miles to the BFI property boundary. This was the only section surveyed as further access was denied by private landowners. Reaches 1-3 were surveyed in 1990 (Smith, 1990). Reach 4 is the BFI property above the surveyed Reach 3 (Figure 10). One site within Reach 3 was sampled by electroshocking in 1995.

Reach 1 — Apanolio Creek

In 1995, this area was not surveyed as access was denied by private landowners. In 1990, the streambed was dominated by sand, pool development was limited and spawning sites were scarce. A diversion dam barrier (Figure 10) exists at the upstream end of this reach. It makes upstream access extremely difficult for adult salmonids: they must make a 5-foot jump to an apron and then a second 4.5-foot jump or swim through an opening in the bottom of the structure.

Reach 2 — Apanolio Creek

This reach was also unable to be surveyed in 1995 due to lack of landowner permission. In 1990, habitat was shallow and sandy, despite relatively good summer streamflow. A large barrier is located at the upstream end of this reach. A 15 foot long apron exists downstream of a 50 foot long inclined culvert that goes through the dam. The apron limits depth into the mouth of the culvert and the inclined culvert presents velocity problems for migrating steelhead.

Reach 3 — Apanolio Creek

Apanolio Creek was surveyed in 1995 by walking from the north end of the Gossett property downstream 0.5 miles. Wetted stream channel width averaged 3 to 4 feet. The stream channel was well-confined. There were several areas where the total stream width was 20 to 24 feet; however, the total channel width averaged 6 to 7 feet. Stream habitat percentages were approximately 30 to 40 percent pools and 60 to 70 percent riffle/runs. Pool depths ranged from 0.5 to 1.1 feet and averaged 0.5 or 0.6 feet. Pools were small, shallow and lacking cover. Cover, when present, was dominated by undercut banks and woody debris. There were several locations where potential spawning gravel was seen; however, embeddedness was approximately 50 percent due to high fine sediment content (Table 8). Streamflow was approximately 0.5 cfs. Stream canopy was good, averaging 80 to 85 percent. The upper 300 feet of the reach has a 2 to 3 percent gradient; however, overall stream gradient averaged approximately 1 to 1.5 percent. There was a barrier to fish migration located approximately 0.25 miles downstream of the BFI property boundary. The stream flowed out of a 4 by 4 foot cement box culvert (3.5 foot drop) over cement slabs that created a steep cascade consisting of a 10-foot drop over 38 feet. Approximately three feet of downcutting has occurred since 1989. Juvenile rt/sth were not observed upstream of this barrier.

One site (Site 10) was electroshocked at the southern end of Reach 3 (Figure 10). Young of the year and smolt-sized rt/sth were quite dense (Table 9). Fish densities within Apanolio Creek were the highest for both yoy and smolt-sized salmonids when compared to all sites electroshocked within the watershed; however, the pool electroshocked was one of the best observed within the surveyed Reach 3. The Bongard pond (at the downstream boundary of Reach 3) provides good potential rearing habitat for juvenile steelhead.

Corinda Los Trancos Creek

Corinda Los Trancos Creek was divided into two reaches. The first reach extended from the mouth to Highway 92 and the second was upstream of this point. Corinda Los Trancos Creek was not sampled by electroshocking because it was largely inaccessible and has low quality salmonid fisheries habitat.

Reach 1 — Corinda Los Trancos Creek

Total stream channel width ranged from 4 to 10 feet and averaged approximately 5 to 6 feet. The wetted stream channel ranged from 1 to 2 feet. Stream substrate was dominated by fine sediment, while the riparian zone was sparsely vegetated. Four yoy/yearling rt/sth were observed within this stream section.

Reach 2 — Corinda Los Trancos Creek

Reach 2 was not surveyed as property access was denied.

Nuff Creek

Two reaches have been designated for Nuff Creek. Reach 1 extended from the mouth upstream approximately 0.5 miles to the culvert barrier at the Pilarcitos Quarry. Reach 2 extended upstream of the culvert barrier. A spot check with the electroshocker within Reach 1 was conducted.

Reach 1 — Nuff Creek

Nuff Creek was spot checked below the Pilarcitos Quarry. Wetted stream channel was shallow, approximate 3 to 4 feet wide, with a stream bottom composed primarily of fine sediment. Stream channel was well-confined and entrenched within a steep canyon. Fish habitat was limited; fish have not been known to reside in Nuff Creek for at least thirty years (personal communication with Pilarcitos Quarry owner). Eucalyptus was the dominant riparian tree.

The Pilarcitos Quarry on Nuff Creek is approximately 0.5 miles upstream of the mouth. Though the quarry property, Nuff Creek flows through a 5.5 foot culvert (barrier) for 0.25 miles. Water is diverted from Nuff Creek for a trout farm in this section (personal communication with Quarry owner).

A limited spot check (Site 11) with the electroshocker was conducted within a small pool and a riffle/run habitat downstream of the quarry (Figure 10). Fish were not captured or seen.

Reach 2 — Nuff Creek

Reach 2 was the unsurveyed portion of the creek above the Quarry.

A significant effort in restoration would have to take place within Nuff Creek in order to create suitable salmonid fisheries habitat.

2.5 VEGETATION

2.5.1 Introduction

The purpose of the vegetation resources study was to evaluate the existing riparian vegetation resources within the watershed for restoration and enhancement opportunities. The study focused on the control of invasive, non-native plant species and revegetation with native plant species. Severe concentrations of invasive non-native species (German ivy and poison hemlock) lower the habitat value of the riparian corridors by out-competing native riparian plant species. These species can also cover large areas of ground, and therefore, inhibit the potential for re-establishment or germination of desired native plant species. A secondary task was identify any occurrences or potential habitat for special-status plant species within the riparian corridors. Due to the limited field surveys (3 days for accessible portions of the watershed) and the time of year in which the surveys were conducted, the present study should not be considered as a focused survey for special status species.

2.5.2 Methods

Review of Available Technical Data

A comprehensive search was made for all of the available published and unpublished information on the vegetation resources in the watershed. The following literature was reviewed for information on the vegetation resources of the Pilarcitos Watershed: Local Coastal Program- Policies, County of San Mateo (August 1992); County of San Mateo Feasibility Study for the Pilarcitos Watershed Restoration Program (EOA, Inc., 1990); County of San Mateo General Plan (1986); City and County of San Francisco Peninsula Watershed Management Program (1984); Biological Assessment of the Mills Creek Riparian Corridor (Cheng and McBride, 1992); and the California Department of Fish and Game (CDFG), Stream Surveys of Pilarcitos Creek 1977, 1985, 1988, and 1992. As appropriate, information from these resources was incorporated into the existing conditions text.

Electronic Inventories

In order to review significant vegetation resources in the Pilarcitos Watershed, two electronic data bases were accessed to determine recorded occurrences of sensitive plant communities and sensitive species present within the watershed. The California Native Plant Society's (CNPS) Inventory of Rare and Endangered Vascular Plants (1994) and the California Department of Fish and Game Natural Diversity Data Base (NDDB) "Rare Finds" (1995) were searched for the three main USGS quadrangles that occur within the watershed: Half Moon Bay, Montara Mountain, and Woodside quadrangles.

Aerial Photograph Interpretation

Orthophoto maps (County of San Mateo; scale 1 inch = 400 feet, 1/1/82) were reviewed to evaluate the extent and composition of the riparian vegetation along the creeks within the watershed. Prior to the field surveys, the general location of the riparian corridor and what appeared to be groves of eucalyptus trees were marked on the aerial maps to be ground-truthed (traversed) in the field.

Reconnaissance Surveys

Three days of reconnaissance surveys were performed on July 5, August 31, and September 21, 1995 along portions of the riparian corridors and marsh habitats associated with the following creeks within the Pilarcitos Watershed: Apanolio Creek, Arroyo Leon, Corinda Los Trancos Creek, Mills Creek, Madonna Creek, Nuff Creek, and Pilarcitos Creek. Riparian areas were surveyed for habitat value and species composition, focusing on the presence of dominant species, sensitive species (special status), and invasive non-native species. Field surveys were conducted over a three-month period due to the length of time needed to obtain permission from property owners for access.

During the three days of reconnaissance surveys the following vegetation resources were mapped onto the County orthophoto aerial maps: the major types of riparian habitat, groves of invasive non-native tree species (e.g., eucalyptus, pine); and significant concentrations of herbaceous, invasive non-native species (e.g., German ivy, poison hemlock).

Riparian areas that were ground-truthed were limited to lands where authorization for entry had been approved. Areas that were not authorized by private landowners, and therefore not surveyed in the field, were: 1) Corinda Los Trancos Creek north of the entrance to the land fill owned by Browning Ferris Industries (BFI), 2) the portion Apanolio Creek owned by Ron Bongard and the upper portion of Apanolio Creek owned by BFI, 3) portions of Pilarcitos Creek owned by Cleo Sare, the upstream portion of Madonna Creek past the old ranch houses, 4) the upstream portion of Arroyo Leon owned by DHL Shipping and other private landowners, and 5) the portion of the Arroyo Leon riparian corridor owned by Mr. Giovanoni. In general, throughout the watershed, riparian areas under private ownership that had not been contacted or had not given permission for access were surveyed as was possible from vantage points on public roads. Limited visibility prevented detailed characterization of the vegetation in these areas— but it was possible to determine the general nature of the tree overstory in some of these areas.

2.5.3 Existing Conditions

Apanolio Creek

The location of the Apanolio Creek riparian corridor is depicted in Figure 1. The creek runs from north to south, converging with Pilarcitos Creek in Albert's Canyon south of Highway 92. Field reconnaissance was limited to the portion of the creek that is privately owned by Gil Gossett, a long-time resident of the area.

Riparian Vegetation. Willow-Alder riparian forest is the main type of riparian plant community found along this portion of Apanolio Creek. The tree overstory is dominated by red alder (*Alnus rubra*), arroyo willow (*Salix lasiolepis*), and yellow willow (*Salix lasiandra*) with scattered trees of blue gum eucalyptus (*Eucalyptus globulus*), California buckeye (*Aesculus californicus*), Douglas fir (*Pseudotsuga menzesii)*, and Monterey cypress (*Cupressus macrocarpa*). The shrub layer is dominated by California blackberry (*Rubus ursinus*), poison oak (*Toxicodendron diversilobum*), thimbleberry (*Rubus parviflorus* var. *velutinus*), and coast elderberry (*Sambucus callicarpa*). Additional shrub species include coffeeberry (*Rhamnus californica*) lizard tail (*Eriophyllum staechadifolium*) and common snowberry (*Symphoricarpos albus* var. *laevigatus*). The herbaceous understory tends to be densely distributed and is dominated by stinging nettle (*Urtica* *holosericea* var. *dioica*), western sword fern (*Polystichum munitum*), poison hemlock (*Conium maculatum*), and bull thistle (*Cirsium vulgare*).

According to Mr. Gossett (pers. comm., Aug. 1995), the uppermost reach (owned by BFI) in the headwaters of the creek is an environmentally significant area due to the presence of a rain forest supported by the large amounts of fog drip occurring at the ridge top. A videotape on Apanolio Creek and the upper rain forest has been recorded.

Extent of Invasive Non-native Plant Species. Portions of the native riparian forest have been displaced by invasive, non-native blue gum eucalyptus trees which are out-competing the native riparian vegetation and lowering the wildlife habitat value of the riparian corridor. Herbaceous invasive, non-native species observed within the riparian corridor include: German ivy (*Senecio mikanioides*), poison hemlock, bull thistle, bristly ox-tongue (*Picris echioides*), black mustard (*Hirschfeldia incana*), Italian thistle (*Carduus pycnocephalus*), milk thistle (*Silybum marianum*), periwinkle (*Vinca major*) and wandering Jew (*Tradescantia fluminensis*). Large patches (several hundred feet long) of German ivy and poison hemlock occur within the corridor. The majority of the German ivy is located downstream of the Gossett residence. A large patch (approximately 200 feet by 30 feet) of wandering Jew was observed on the Gossett property near the barn and out-buildings. A patch of pampas grass was also noted northwest of the reservoir on the Gossett property. The locations of the eucalyptus groves and other areas having significant concentrations of invasive non-native species are depicted in Figures 11 and 13.

It appears from the aerial photograph that there are no groves of eucalyptus trees in the upper areas of the riparian corridor. However, areas of non-native trees may occur. In the lower reaches of the creek near Highway 92 on the Bongard property, the aerial photograph shows several significant groves of eucalyptus trees located within the riparian corridor.

Arroyo Leon

Arroyo Leon is the second largest creek within the watershed. Its location is depicted in Figure 1. Arroyo Leon flows from the southeast, converging with Pilarcitos Creek within the City of Half Moon Bay. Within the city, the creek has been influenced by urban activities and much of its banks front residential yards. Debris and refuse are common, and in some areas garden escapes such as non-native Monterey pine (*Pinus radiata*) and garden nasturtium (*Tropaeolum majus*) have invaded the riparian corridor. Within the city limits, field reconnaissance was limited to observations from bridges and public roads. Field surveys also included portions of the riparian corridor as visible from Higgins Canyon Road. Since permission was not obtained, field surveys were not performed in the upper reaches of Arroyo Leon, as these areas are private parcels accessed by a private road.

figure 11

Locations of Riparian Communities and Eucalyptus Groves

Sheet 1 of 2 | *Source: The Habitat Restoration Group*

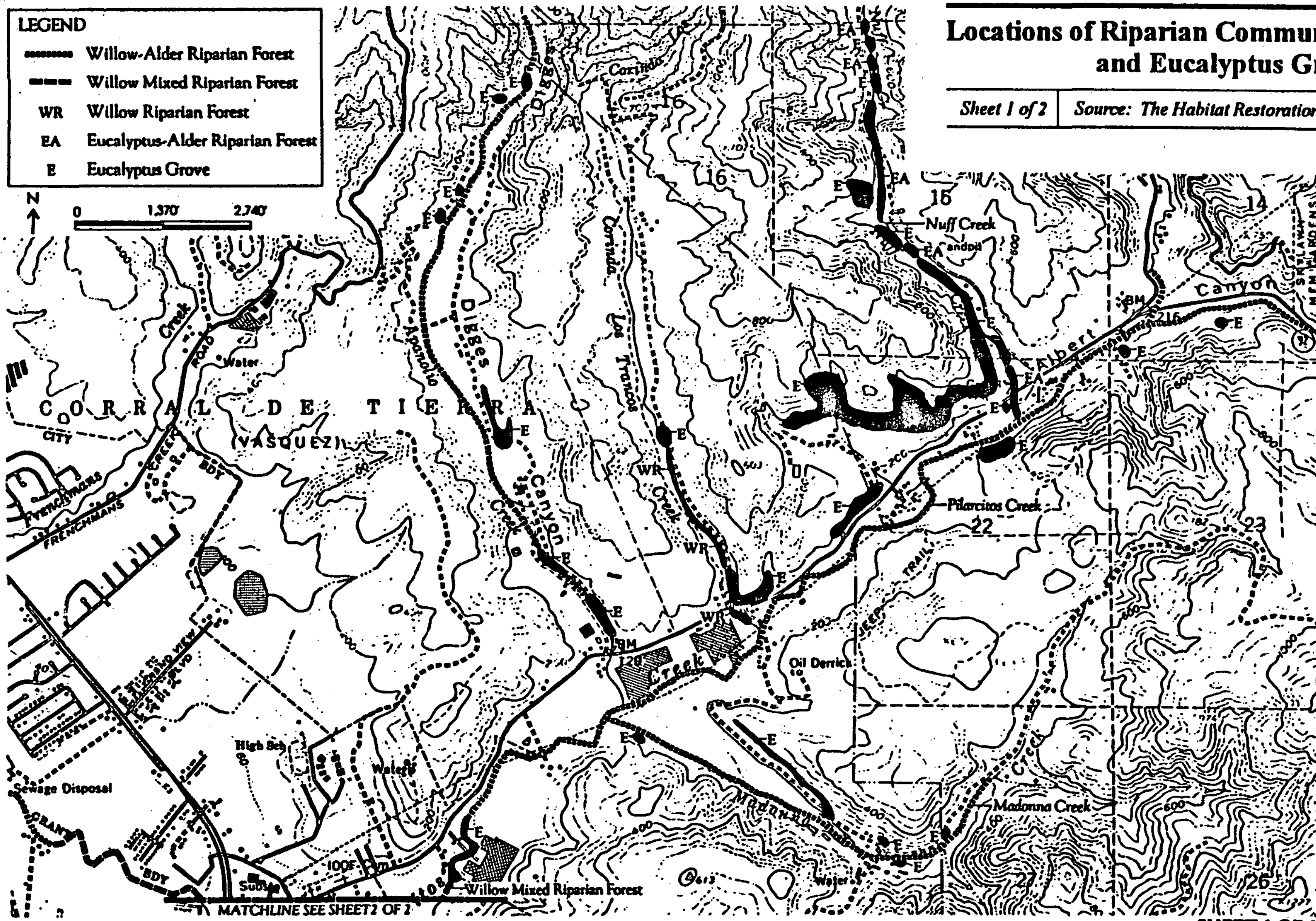
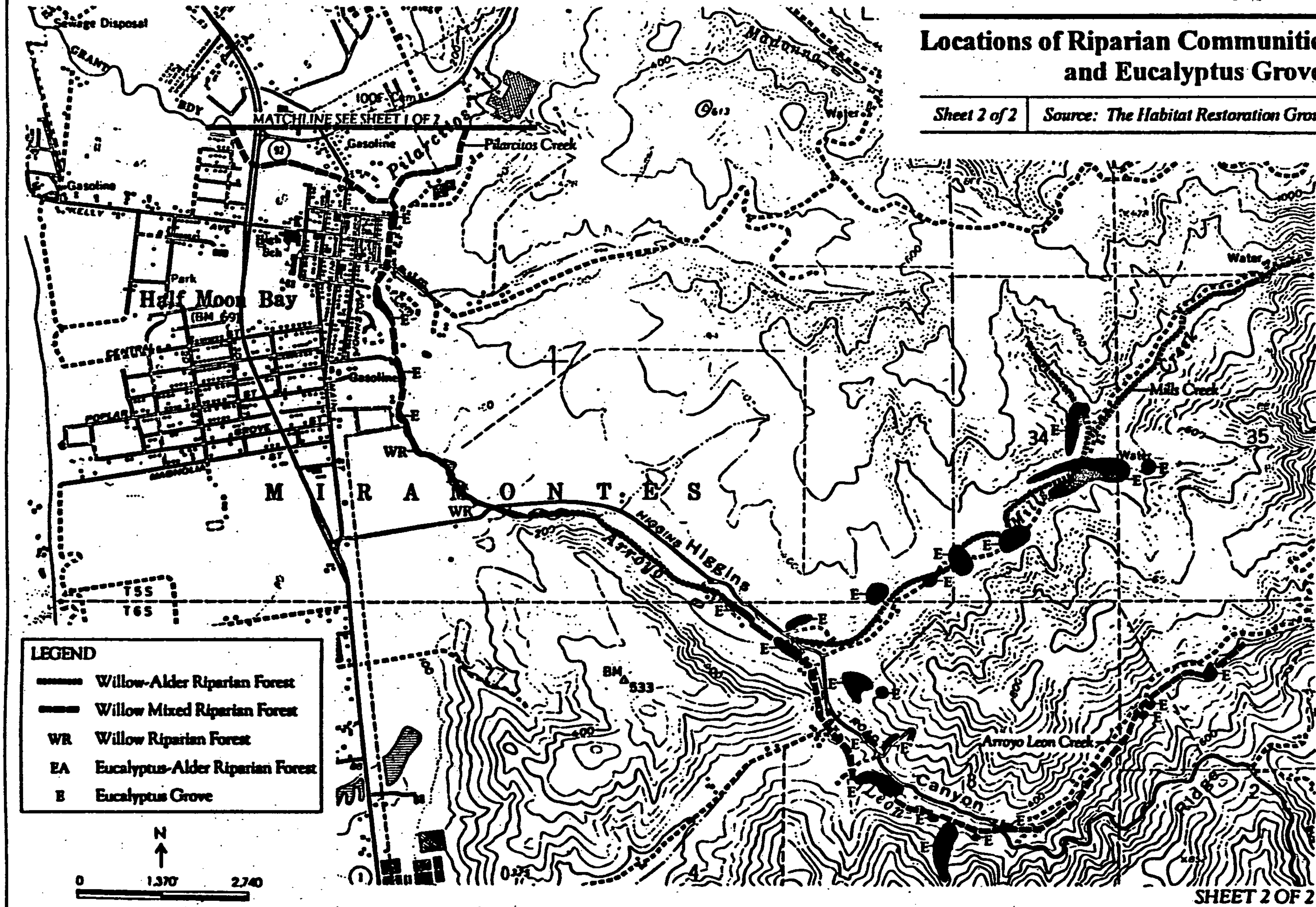


figure 12

Locations of Riparian Communities and Eucalyptus Groves

Sheet 2 of 2 | *Source: The Habitat Restoration Group*



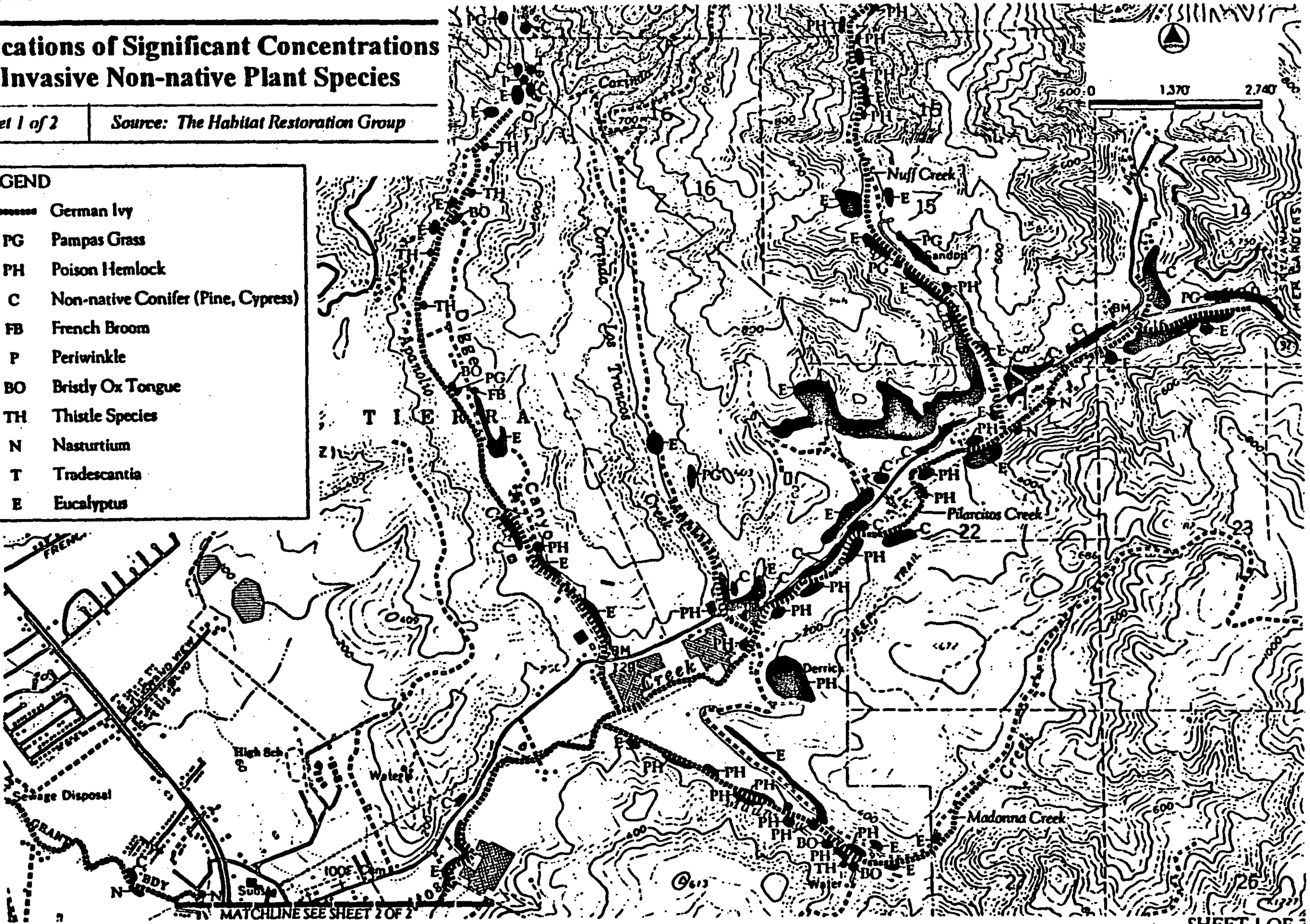
Philip Williams & Associates, Ltd.

figure 13

Locations of Significant Concentrations of Invasive Non-native Plant Species

Sheet 1 of 2 | *Source: The Habitat Restoration Group*

LEGEND	
▪▪▪▪▪▪▪▪	German Ivy
PG	Pampas Grass
PH	Poison Hemlock
C	Non-native Conifer (Pine, Cypress)
FB	French Broom
P	Periwinkle
BO	Bristly Ox Tongue
TH	Thistle Species
N	Nasturtium
T	Tradescantia
E	Eucalyptus



Riparian Vegetation. Willow mixed riparian forest is the predominant riparian plant community found along the lower reaches of Arroyo Leon near the City of Half Moon Bay. The tree overstory is dominated by arroyo willow and yellow willow. There are also occasional red alder, Monterey pine, and blue gum eucalyptus trees. The shrub layer is dominated by California blackberry and poison oak. Additional shrub species include coast elderberry and coyote brush (*Baccharis pilularis*). The herbaceous understory is primarily composed of invasive non-native plant species (see discussion below). Native herbaceous species observed include: mugwort (*Artemisia douglasiana*), bedstraw (*Galium* sp.), wild cucumber (*Marah fabaceus*), and bugle hedge nettle (*Stachys ajugoides* var. *ajugoides*).

The riparian corridor further upstream along Higgins Canyon Road has more red alders present and is therefore classified as willow-alder riparian forest (Figure 1). Proceeding eastward on Higgins Canyon Road along the riparian corridor, blue gum eucalyptus trees become more prevalent compared to the lower reaches. Upstream of the confluence with Mills Creek, willow mixed riparian forest is predominant.

Extent of Invasive Non-native Plant Species. Portions of the native riparian forest have been displaced by invasive, non-native blue gum eucalyptus trees which are out-competing the native riparian vegetation. Significant groves of blue gum eucalyptus occur in the vicinity of the confluence of Arroyo Leon and Mills Creek (Figure 12). Scattered areas of pampas grass and French broom (*Genista monspessulana*) were also observed near this area (Figure 14). Patches of French broom were also observed near the junction of Higgins Canyon Road and Purisima Road. Herbaceous invasive, non-native species observed within the riparian corridor include: German ivy, garden nasturtium, poison hemlock, bull thistle, bristly ox-tongue (*Picris echioides*), black mustard (*Hirschfeldia incana*), Italian thistle (*Carduus pycnocephalus*), milk thistle (*Silybum marianum*). Large expanses of German ivy and poison hemlock occur within the corridor. German ivy is a significant problem, extending from the lower reaches in the City of Half Moon Bay inland to the intersection of Higgins Canyon Road and Purisima Road. The locations of the eucalyptus groves and other areas having significant concentrations of invasive non-native species are depicted in Figures 12 and 14.

Corinda Los Trancos Creek

The location of the creek is depicted in Figure 1. This creek follows a north-south alignment, converging with Pilarcitos Creek in Albert's Canyon south of Highway 92. The portion of the creek above Highway 92 is owned and managed by Browning Ferris Industries, Inc. Permission for access was denied above Highway 92. Therefore, field reconnaissance was limited to the lowest portion of the creek that extends from Highway 92 near the Obester Winery to the confluence with Pilarcitos Creek. This portion of the creek has been modified by agricultural practices and consists of a rock-lined ditch which converges with Pilarcitos Creek adjacent to agricultural lands. The rock-lined ditch interferes with the establishment and growth of vegetation on the banks of the creek.

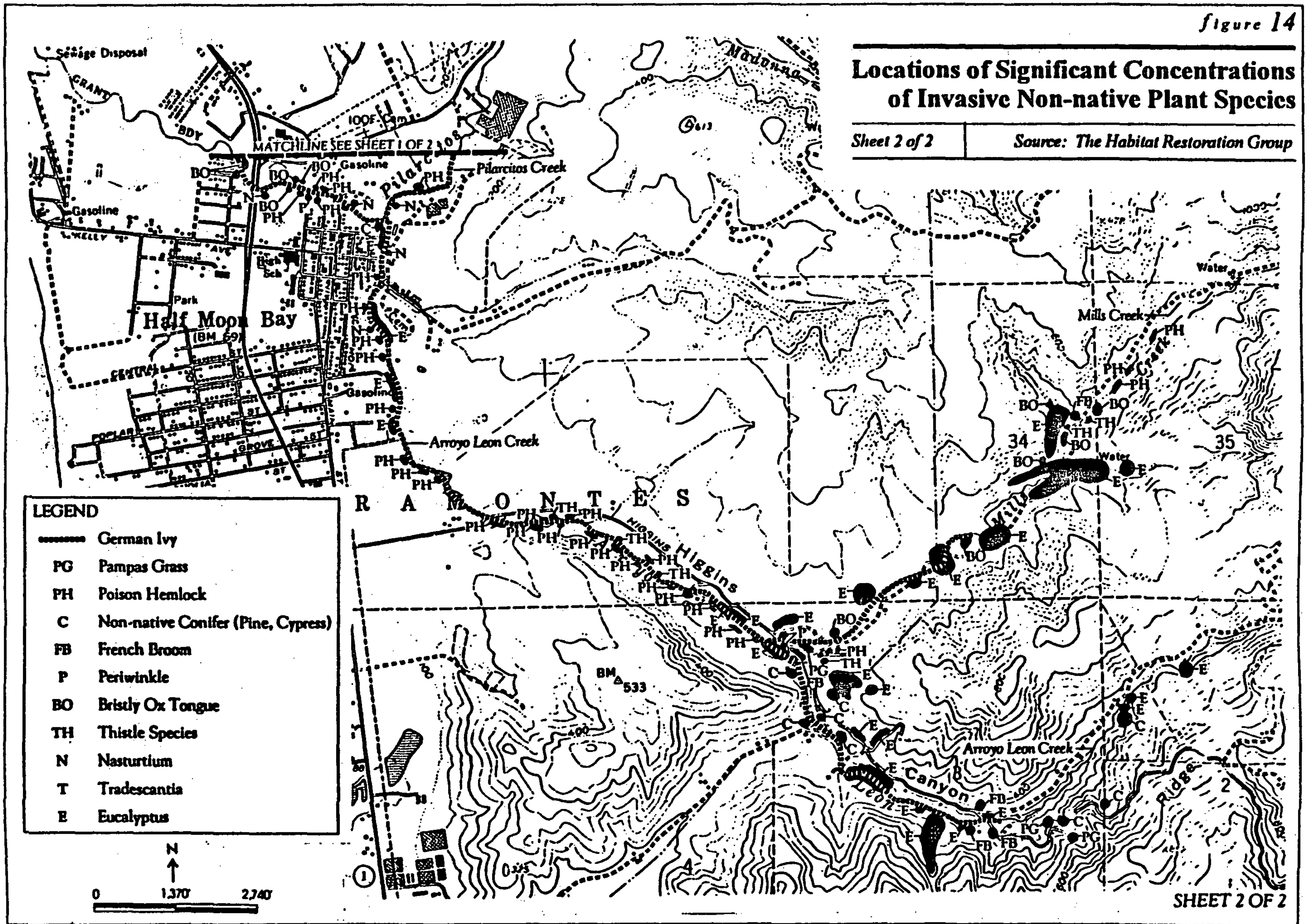


figure 14

Locations of Significant Concentrations of Invasive Non-native Plant Species

Sheet 2 of 2 | *Source: The Habitat Restoration Group*

Philip Williams & Associates, Ltd.

Riparian Vegetation. The value of the riparian habitat along this portion of the creek is low due to disturbance by human activities and the presence of non-native species. The plant community present is willow riparian forest. The sparse tree overstory is dominated by arroyo willow and yellow willow and there are several non-native Monterey cypress trees. The shrub layer is mainly comprised of coast elderberry, poison oak and California blackberry.

Extent of Invasive Non-Native Plant Species. The most significant invasive, non-native species present along this portion of the creek is German ivy. This species is found along most of the riparian corridor surveyed, and is particularly severe near the confluence with Pilarcitos Creek—where it is smothering the native riparian understory vegetation and interfering with tree growth. Poison hemlock is also prevalent and pampas grass was observed by the landfill entrance. The locations of the non-native trees and other areas having significant concentrations of invasive non-native species are depicted in Figures 11 and 13.

The uppermost reaches of Corinda Los Trancos Creek need to be ground-truthed as it is difficult to determine from the aerial photograph whether some of the tree groves in the riparian corridor are composed of conifer or blue gum eucalyptus trees.

Madonna Creek

The location of the riparian corridor is depicted in Figure 1. Madonna Creek converges from the southeast into Pilarcitos Creek. The lower reach of Madonna Creek from its confluence with Pilarcitos Creek to just upstream of the old ranch buildings (approximately 1 mile from Pilarcitos Creek) is owned by Peninsula Open Space Trust (POST), a private non-profit corporation. Field reconnaissance was limited to this portion of the creek. Agricultural fields occur along lower portions of the reach.

Riparian Vegetation. Willow-alder riparian forest is the major type of riparian plant community found along this portion of Madonna Creek. The tree overstory is dominated by red alder, arroyo willow and yellow willow. There are also occasional blue gum eucalyptus trees scattered along the riparian corridor. The shrub layer is dominated by California blackberry, poison oak, and coast elderberry. Additional shrub species include coffeeberry, thimbleberry and creek dogwood. The herbaceous understory is primarily composed of invasive non-native plant species (see discussion below).

Extent of Invasive Non-native Plant Species. Occasional blue gum eucalyptus trees have invaded the riparian corridor. There is also a long row of eucalyptus trees lining the road that parallels creek outside the riparian corridor. Poison hemlock and German ivy are the most abundant invasive non-native species. The poison hemlock is common along the top of the creek bank—especially in areas where the tree overstory is sparsely distributed. The following non-natives were also observed to be prevalent in the vicinity of the lower reservoir: bristly ox-tongue, black mustard, wild radish (*Raphanus sativus*), milk thistle and bull thistle. The locations of the non-native trees and other areas having significant concentrations of invasive non-native species are depicted in Figures 11 and 13.

It appears from the aerial photograph that the riparian corridor located upstream from the portion of the creek managed by POST has several large eucalyptus groves, including a grove near the headwaters of Madonna Creek. The extent of non-native species should be verified once access is permitted.

Mills Creek

The location of the Mills Creek riparian corridor is depicted in Figure 1. Field reconnaissance was limited to the portion of the creek known as Burleigh Murray Ranch State Park that is owned and managed by the State of California Department of Parks and Recreation. A short portion (about 1,000 feet) between the confluence of Mills Creek with Arroyo Leon and the State boundary is privately owned; access was not granted.

Riparian Vegetation. Willow-alder riparian forest is the predominant riparian plant community found along Mills Creek. The tree overstory is dominated by red alder, yellow willow, and arroyo willow with scattered trees of blue gum eucalyptus, California buckeye, Douglas fir, and Monterey cypress. The shrub layer is dominated by California blackberry, poison oak, and coast elderberry. Additional shrub species include: thimbleberry, cream bush (*Holodiscus discolor*), creek dogwood (*Cornus californica*), snowberry and twinberry (*Lonicera involucrata* var. *ledebourii*). The herbaceous understory tends to be densely distributed and is dominated by stinging nettle, sword fern, poison hemlock, and bull thistle.

According to the Resource Ecologist for the State Park (J. Ferreira pers. comm., 1995), there are no known occurrences of special status plant species within the Park. She feels that while there is the potential for such species, there have been no focused surveys to verify their presence or absence.

Extent of Invasive Non-native Plant Species. Portions of the native riparian forest have been displaced by invasive, non-native blue gum eucalyptus trees which are out-competing the native riparian vegetation and lowering the wildlife habitat value of the riparian corridor. Eleven significant stands of blue gum eucalyptus have been documented and evaluated during a biotic assessment of the Mills Creek riparian corridor conducted in 1992. The locations of these stands are shown in Figure 12. Further information on these eucalyptus stands is found in the Cheng and McBride report.

Other invasive non-native species observed during the 1995 reconnaissance surveys include: German ivy, poison hemlock, bristly ox-tongue, bull thistle, milk thistle, fennel (*Foeniculum vulgare*), and French broom. German ivy was noted to be abundant on the lower portion of Mills Creek near the confluence with Arroyo Leon. Scattered occurrences were also observed, extending upstream to the historic dairy barn. Fennel and poison hemlock are more abundant where there are openings in the tree canopy to provide sunlight. Areas supporting significant concentrations of invasive species are depicted in Figure 14.

Nuff Creek

The location of the Nuff Creek riparian corridor is shown in Figure 1. The riparian survey was limited to portions of the creek leased by Pilarcitos Quarry. The upper reaches were not surveyed, because at a distance, they did not appear to need restoration; the upper reaches are more pristine in nature in comparison to portions of the creek by the quarry operations. Also, the quarry site creates a barrier to fish passage. The upper reaches were not surveyed because projects for improved fisheries habitat are not likely to be implemented upstream of the quarry operations.

Riparian Vegetation. In the portion of the creek downstream from quarry operations, the native willow - alder riparian forest has been out-competed and replaced by non-native blue gum eucalyptus and, therefore, is classified as eucalyptus-alder riparian forest (Figure 11). Blue gum eucalyptus trees are growing within the creek channel. In the uppermost reaches, the tree overstory appears to be composed of primarily native species, being dominated by red alder and willow trees.

In areas dominated by blue gum eucalyptus, the shrub and herbaceous understory is minimal and consists mainly of scattered vegetation, dominated by poison oak. In areas where the tree overstory is dominated by arroyo willow and red alder, there is a higher diversity of native and non-native plant species in the riparian understory, including: California blackberry, bugle hedge nettle, stinging nettle, sword fern, poison hemlock, and bull thistle.

Extent of Invasive Non-native Plant Species. Between Highway 92 and the quarry mining operations and buildings, the tree overstory of riparian corridor has been invaded by invasive, non-native tree species, predominantly blue gum eucalyptus. Non-native Monterey pine and Monterey cypress are also found within the riparian corridor. In the vicinity of the quarry operations, the disturbed landscape has become dominated by pampas grass. Other herbaceous non-native species observed were: German ivy, Italian thistle, bull thistle and poison hemlock. Extensive areas of German ivy occur approximately 1,200 feet upstream of the quarry operations. Farther upstream (approximately 2,800 feet from quarry operations) in open areas along Nuff Creek there are extensive patches of poison hemlock. Areas supporting significant concentrations of invasive species are depicted in Figure 13.

It appears from the aerial photograph that there are no eucalyptus groves in the upper reaches, upstream of where the creek bends to the east, by the poison hemlock areas noted above.

Pilarcitos Creek

Pilarcitos Creek is the largest drainage in the watershed. As indicated on Figure 1, it flows westward through Albert Canyon, entering the Pacific Ocean at Francis State Beach. The upper reaches of Pilarcitos Creek are owned by Cleo Sare and the Coastside County Water District (CCWD). These areas were not surveyed during the present study.

Riparian Vegetation. Willow riparian forest is the main type of riparian plant community found west of Highway 1 along the lower reaches of Pilarcitos Creek. The tree overstory is dominated by arroyo willow and yellow willow. There are also occasional red alder, Monterey pine, and blue gum eucalyptus trees. The shrub layer is sparse, being dominated by California blackberry and poison oak. Additional shrub species include coast elderberry and coyote brush (*Baccharis pilularis*). The herbaceous understory is primarily composed of invasive non-native plant species (see discussion below). Native herbaceous species observed include: mugwort (*Artemisia douglasiana*), bedstraw (*Galium* sp.), wild cucumber (*Marah fabaceus*), and bugle hedge nettle (*Stachys ajugoides* var. *ajugoides*).

In the vicinity of Francis State Park, the herbaceous understory also includes native plant species that are adapted to coastal conditions including: beach sagewort (*Artemisia pycnocephala*), lizard tail, sand verbena (*Abronia latifolia*), and sea rocket (*Cakile maritima*). Upstream of Highway 1, the riparian corridor along Highway 92 (Albert Canyon Road) has more red alders and therefore, the plant community has been designated as willow - alder riparian forest (Figure 11).

Extent of Invasive Non-native Plant Species. Portions of the native riparian forest have been displaced by invasive, non-native blue gum eucalyptus trees which are out-competing the native riparian vegetation. Significant groves of blue gum eucalyptus are prevalent within and adjacent to the riparian corridor (Figure 11). As one proceeds east above the town of Half Moon Bay, blue gum eucalyptus and other non-native trees (i.e., Monterey pine and Monterey cypress) are more abundant compared to lower reaches. Herbaceous invasive, non-native species observed within the riparian corridor were: German ivy (*Senecio mikanioides*), garden nasturtium, poison hemlock, bull thistle, bristly ox-tongue (*Picris echioides*), black mustard (*Hirschfeldia incana*), Italian thistle (*Carduus pycnocephalus*), milk thistle (*Silybum marianum*). Large expanses of German ivy and poison hemlock occur within the corridor. German ivy is a significant problem, extending from the coast, throughout the City of Half Moon Bay and easterly to upper reaches of Pilarcitos Creek. The locations of the eucalyptus groves and other areas having significant concentrations of invasive non-native species are depicted in Figure 13.

It appears from the aerial photograph that there are several large eucalyptus groves and a non-native Christmas tree farm in the vicinity of where Pilarcitos Creek crosses County Road No. 108. It is likely that additional eucalyptus groves occur in the riparian corridor upstream from the Christmas tree farm and on adjacent east-facing slopes. Ground-truthing is needed to verify the extent of non-native tree species on the

Sare property. The uppermost reaches of Pilarcitos Creek that are managed by Coastside County Water District are assumed to be more pristine in nature and dominated by native vegetation.

2.5.4 Sensitive Plant Species and Communities

Sensitive Plant Communities

The riparian corridors and wetlands found along the creeks within the Pilarcitos Watershed are considered sensitive habitats by the San Mateo County Local Coastal Program (LCP) (1992) and the County of San Mateo General Plan (1986). Sensitive habitats are areas where the vegetation, water, or fish and wildlife resources provide valuable plant and animal habitats. Riparian habitat is recognized as a significant and limited resource due to the reduction of this habitat type over the last hundred years from urban and agricultural development. Riparian vegetation provides forage and nesting habitat for a wide variety of wildlife species—many of which are not found in other habitats. The San Mateo County LCP (1992) defines riparian corridors by the "limit of riparian vegetation." Such a corridor must contain at least 50% cover of the following native plant species: red alder, jaumea, pickleweed, big-leaf maple, narrow-leaf cattail, arroyo willow, broad-leaf cattail, horsetail, creek dogwood, black cottonwood, and box elder.

Riparian and wetland habitats are subject to the San Mateo County grading ordinance and State and Federal regulations under the Section 1601-1603 of the California Fish and Game Code and Section 404 of the Federal Clean Water Act. Vegetation removal and stream alteration are subject to one or more permits from the above agencies.

Plant Species of Concern

Results from the NDDB and CNPS electronic data bases show that there are three sensitive plant species with recorded occurrences in the Pilarcitos Watershed: western leatherwood (*Dirca occidentalis*), fragrant fritillary (*Fritillaria liliacea*), and Hickman's cinquefoil (*Potentilla hickmanii*). Fragrant fritillary has been observed in Spring Valley near the headwaters of Pilarcitos Creek. All three of these species are on the CNPS List of 1B plants. List 1B plants are considered rare throughout their range. Fragrant fritillary has no State listing and is federally designated as C2: threat and/or distribution data are insufficient to support Federal listing.

According to the NDDB, Hickman's cinquefoil was last seen in the Montara Mountain quadrangle in 1933. This species is listed as State endangered (CE) and is federally listed as C1, enough data on file to support Federal listing. The County of San Mateo General Plan (1986) considers Hickman's cinquefoil to be extinct or extirpated. These data bases and the San Mateo General Plan should be updated and amended as there has been a recent sighting (October 1995) of Hickman's cinquefoil adjacent to a right-of-way owned by the California Department of Transportation. The area is located to the south of the Pilarcitos Creek watershed (J. Ferreira, 1995). This is the first documented sighting of this rare species in San Mateo County since 1933.

No occurrences of special status species were observed during the field surveys conducted for the present study. However, as noted above, field surveys were not conducted during the blooming periods, and were limited to only portions of the riparian corridors along the major creeks and only in the immediate riparian corridors (within 25 feet of each bank). Therefore, these surveys should not be considered as comprehensive surveys of the entire watershed.

2.5.5 Effects of Introduced Plants upon Wildlife and Fish Habitat

Eucalyptus affects fish and wildlife habitat in several ways. The evergreen foliage prevents the growth of algae in the stream in late fall and spring, when native streamside trees (e.g., willows and alders) have shed their leaves. Algae is important as a food base to support aquatic insects, which serve as food for fish and amphibians. The other possible food base is leaves, but eucalyptus leaves, with their poisonous oils, are nearly useless compared to the nutritious willows and alders they replace. A chemical in eucalyptus leaves also apparently prevents the development of understory plants, which could reduce erosion and stream sedimentation, provide leaves as food for aquatic insects, and provide hiding cover for streamside wildlife (i.e., red-legged frog and San Francisco garter snake).

Dense stands of German ivy destroy plants useful as food for aquatic insects and wildlife and prevent the development of overhanging vegetation as fish hiding cover. They also provide poor habitat for red-legged frog and garter snake, since the ivy rarely provides a good mix of escape cover and basking habitat.

2.6 SENSITIVE WILDLIFE

2.6.1 Existing Conditions—Wildlife Resources

The riparian community is clearly one of the most important wildlife habitats in North America. The relatively small amount of total area representative of riparian systems provides a strikingly disproportionate amount of habitat for wildlife. Some of the highest breeding bird densities in the continental United States have been reported from riparian zones. In many areas, nearly 50 percent of the avifauna are primarily associated with and/or reach their greatest concentration in riparian systems. Riparian systems provide habitat for 83 percent of the amphibian and 40 percent of the reptile species comprising the native herpetofauna of California. Although impacted in parts from encroaching urban development, agricultural activities, or non-native vegetation, Pilarcitos Creek Watershed riparian corridors also provide high value wildlife habitat.

Although wildlife field surveys were not conducted as part of this project (except observations for sensitive, threatened, or endangered reptile and amphibian species), the following description is based on literature review and knowledge of nearby central coast willow-alder riparian systems.

Amphibians and Reptiles

Amphibians and reptiles represent important ecological components of riparian communities, where they may reach high densities (Brode & Bury, 1984). Many species are permanent residents of the riparian zone, while others are transient or temporal visitors.

Amphibians. Amphibians are expected to be more numerous and diverse in this habitat than elsewhere in the watershed. Most species require the aquatic environments found in riparian habitats in order to complete their life cycle, while others seek the mesic conditions underneath fallen logs and woodland debris for breeding and refuge.

Aquatic-breeding species which occur in this habitat include California newt (*Taricha torosa*), western toad (*Bufo boreas*), and Pacific treefrog (*Pseudacris regilla*). The moist ground conditions and abundant sources of cover (e.g., dead and down woody material and forest litter) offer suitable habitat for several species which do not require surface water for reproduction. These include Ensatina (*Ensatina eschscholtzii*), California slender salamander (*Batrachoseps attenuatus*), and black salamander (*Aneides flavipunctatus*). Black salamanders are predicted to be common along the stream margins.

The potential for presence of California red-legged frog (*Rana aurora draytonii*) and western pond turtle (*Clemmys marmorata*), two sensitive species, is discussed below under Sensitive Species.

Reptiles. The presence of water together with the tree canopy cover and downed woody material contribute to make this habitat suitable for many reptile species associated with mesic environments. Many species of adjacent habitats are likely to be found also in the riparian habitats of the study area. Species typical of aquatic environments that are likely to occur include common garter snake (*Thamnophis sirtalis*), western terrestrial garter snake (*T. elegans*), and western aquatic garter snake (*T. couchii*). Additionally, species that occur more commonly near streams include common kingsnake (*Lampropeltis getulus)*, mountain kingsnake (*L. zonata*), and sharp-tailed snake (*Contia tenuis*). The potential presence of the endangered San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) is discussed below under Sensitive Species.

Birds

Willow-Alder Riparian Habitat. The number of bird species that use riparian woodlands is greater than for any other habitat type in California (Miller, 1951). At least 100 species are known to use this type of habitat in California for food and cover (Gaines, 1977). The reasons for this include the presence of water, the abundant food supply generated by the high productivity of plant life, the variety of ecological niches created by the vertical stratification of the habitat, edge effects, and the interface between aquatic and adjacent terrestrial habitats. Seventy-five percent of the bird species known or predicted to next in the study area are expected to do so in the riparian habitat.

Birds are the most numerous and diverse group of vertebrate species occurring in the study area. Birds using the riparian habitat can be categorized into four groups based on their seasonal occurrence: permanent residents, breeding migrants, overwintering migrants, and transients (i.e., migrants passing through during spring and/or fall). As a result of many factors (e.g., migratory and local movements, reproduction, mortality, seasonally changing habitat requirements), bird populations are distinctly different from season-to-season (Brinson *et al*, 1981).

Resident bird species occurring in this habitat include California Quail (*callipepla californica*), Mourning Dove (*Zenaida macroura*), Anna's Hummingbird (*Calypte anna*), Downy Woodpecker (*Picoides pubescens*), Steller's Jay (*Cyanocitta stelleri*), Scrub Jay (*Aphelocoma coerlescens*), Chestnut-backed Chickadee (*Parus rufescens*), Bushtit (*Psaltriparus minimus*), Bewick's Wren (*Thryomanes bewickii*), American Robin (*Turdus migratorius*), Wrentit (*Chamaea fasciata*), Rufous-sided Towhee (*Pipilo erythropthalmus*), Song Sparrow (*Melospiza melodia*), House Finch (*czrpodacus mexicana*), and American Goldfinch (*carduelis tristis*). Many of these species have a complex seasonal status, with sub-populations comprised of residents, breeding migrants, wintering migrants, and transients (e.g., American Robin and Northern Flicker), while other species are very sedentary (e.g., Hutton's Vireo and Rufous-sided Towhee). All of these resident species are known or expected to nest in this habitat within the study area, although most use other adjacent habitats as well.

Migrant species which breed in the study area's riparian habitat include Allen's Hummingbird (*Selasphorus sasin*), Pacific-slope Flycatcher (*Empidonax difficilis*), Violet-green Swallow (*Tachycineta thalassina*), Swainson's Thrush (*Catharus ustulatus*), Warbling Vireo (*Vireo gilvus*), Orange-crowned Warbler (*Vermivora celata*), Wilson's Warbler (*Wilsonia pusilla*), Black-headed Grosbeak (*Pheuticus melanoicephalus*), and Brown-headed Cowbird (*Mologhrus ater*). Most of these species nest only in this habitat in the immediate vicinity of the study area.

Eucalyptus Forest. This habitat is used by several species which prefer tall canopy trees or dense cover, although many of the bird species which normally occur in a native riparian forest are not expected to occur in this habitat. The Eucalyptus provide good nest sites for raptors (e.g., Red-shouldered Hawk, Red-tailed

Hawk, and Great Horned Owl). Blue gum eucalyptus trees, which flower during the winter season, provide food (i.e., nectar and insect attraction) for some wildlife species. These species include Allen's hummingbird, Pacific slope flycatcher, American robin, and house finch.

Mammals

Most of the mammalian species predicted to occur in this habitat are year-round residents. While some of these are more numerous in adjacent grassland and scrub habitats, many are dependent on riparian ecosystems. The moist ground conditions found in the riparian corridor are especially suitable for insectivorous mammals (e.g., shrews and moles). Cover and shade provided by the canopy and understory, and the presence of water make this habitat suitable as a refuge for many mammal species using the more xeric adjacent areas. The corridor may function as a important passage for the movement of larger mammals (e.g., deer); however, its value as an avenue for wildlife travel has probably been reduced by development adjacent to the riparian habitat.

Mammal species expected to occur in this habitat include Virginia Opossum (*Didelphis virginiana*), ornate Shrew (*Sorex ornatus*), Trowbridge's Shrew (*Sorex trowbridgii*), Broad-footed Mole (*Scapanus latimanus*), Brush Rabbit (*Sylvilagus bachmani*), Western Harvest Mouse (*Reithrodontomys megalotis*), Deer Mouse (*Peromyscus maniculatus*), coyote (*Canis latrans*), Raccoon (*Procyon loor*), Long-tailed Weasel (*Mustela frenata*), Striped Skunk (*Mephitis*), and Black-tailed Deer (*Odocoileus hemionus*).

2.6.2 <u>Sensitive Fish and Wildlife Species</u>

Based upon a review of California Natural Diversity Data Base records (CNDDB, 1995), CDF&G records, other available literature and our own field reconnaissance, the following sensitive species have been reported or could potentially occur in the Pilarcitos Creek riparian system. Habitat for these species should be considered for maintenance, restoration, and enhancement as part of other measures recommended for aquatic or riparian enhancement in the plan. It should also be noted that habitat for these species can be adversely affected during construction of restoration measures; therefore, proper precautions need to be taken to ensure habitat is preserved or mitigated.

The San Francisco garter snake is a federal and state endangered species, and the tidewater goby (*Eucyclogobius newberryi*) is a federal endangered species. The California redlegged frog is a federal threatened species. The western pond turtle is a category 2 (insufficient information) candidate for federal listing. Coho salmon (silver salmon) (*Oncorhynchus Kisutch*) were proposed for listing as a threatened species by the National Marine Fisheries Service (NMFS) and south of San Francisco were listed as Endangered by the State of California. Steelhead are proposed by NMFS as endangered in central and southern California. The western snowy plover is a federally threatened species and a state species of special concern. Although the present restoration efforts will not necessarily target all of the previously mentioned species, restoration actions for one species should not be taken which adversely impact status or restoration potential of other species.

San Francisco Garter Snake

San Francisco garter snakes are found almost exclusively in San Mateo County and require pond, marsh, or stream habitats. A major requirement is good populations of tree frogs and redlegged frogs, the major prey for the garter snakes. Wetland habitats where introduced bullfrogs (*Rana catesbeiana*) have become established usually lose their San Francisco garter snake populations, because bullfrogs are unsuitable prey (chemical defenses and large size) and also tend to eliminate redlegged frogs and reduce tree frogs. In addition to aquatic habitat suitable for their preferred prey, San Francisco garter snakes also require open basking habitat near or within the wetland and hibernation sites in upland habitat. No San Francisco garter snakes were found during fisheries field surveys.

Tidewater Goby

Tidewater gobies are weak-swimming fishes which seldom exceed 2 inches in length. They occur only in lagoons at the mouths of coastal California streams, and are apparently not now present in Pilarcitos Creek. Gobies are tolerant of a wide range of salinities and water quality conditions, but in small streams they can persist only if the stream mouth has protected, marshy backwaters so the gobies are not washed to sea during large floods. Channelization of stream mouths and excessive sedimentation have eliminated tidewater gobies from a majority of their former sites in California. Even in healthy tidewater goby populations numbers decline drastically during winter, when lagoons are drained and scoured by winter storms. However, they can become extremely abundant in summer after the sandbar dams the stream mouths and creates calm, productive summer lagoons. Summer populations can be impacted by artificial sandbar breaching, which reduces the size of goby habitat and exposes them to tidal action. Because gobies are poor swimmers, they are rarely able to move far through the ocean; recolonization from other coastal streams is unlikely to restore most extirpated populations unless the stream mouths are very close. The nearest known population to Pilarcitos Creek is in San Gregorio Creek.

Redlegged Frog

Redlegged frogs are most abundant in ponds or slower portions of streams. They hibernate away from flowing streams in winter, and spend considerable time within dense riparian habitat throughout the year.

Loss of stream side vegetation results in the loss of redlegged frogs, apparently due to increased temperatures and/or much greater vulnerability to predators. Development of the tadpole larvae takes much of the summer, so redlegged frogs cannot use temporary winter ponds as can fast-developing toads and tree frogs. The major threats to redlegged frogs within the slow-water, permanent habitats they need are the introduction or invasion of predatory fish (such as largemouth bass [*Micropterus salmoides*] or green sunfish [*Lepomis cyanellus*]) or bullfrogs. Redlegged frogs have almost been eliminated in the central valley and most other inland habitats by habitat changes and by bullfrogs and predatory fish. They still remain common in relatively undisturbed coastal watersheds which have been isolated from the impacts of predatory fish and bullfrogs. Three apparent sightings of red legged frogs were made during 1995 field surveys (see Figure 10).

Western Pond Turtle

Western pond turtles share many of the habitat requirements and threats of redlegged frogs, and the two were proposed for federal endangered species listing in the same petition. Although they prefer slow pools and ponds as habitat most of the year, pond turtles also need suitable (usually more open) adjacent upland habitat for winter hibernation and for nesting. Predatory fish and bullfrogs also prey on young turtles and can prevent replacement in turtle populations. The impact may not become apparent for years, as pond turtles can live for more than 25 years; even apparently abundant populations may be doomed, aging, remnant populations. No pond turtles were found during 1995 field surveys; however, suitable habitat conditions do exist in some reaches of Pilarcitos Creek and tributaries.

Steelhead

Steelhead appear anatomically identical to rainbow trout, but differ in their migratory instincts. They are anadromous fish which means they spend part of their lives in the ocean but spawn in their natal fresh water stream. They are native to Pacific coastal streams from Alaska to southern California. Suitable spawning and rearing habitat, as well as suitable upstream passage for adult fish and downstream passage for juveniles migrating to the ocean for the first time (smolts) is required for steelhead. Upstream passage can be blocked by natural falls and low streamflows or by man-made structures, such as road culverts or seasonal or permanent dams. Since adult steelhead migrate upstream with winter storms, some access from the ocean is usually provided for waiting fish, even in drought years. Barriers requiring high or complex jumps, however, may be complete barriers or restrict passage to only the largest storms. Removal of significant barriers, especially lower in the watershed, often offer the most cost effective way to increase steelhead populations. A one-time effort at barrier removal or modification may provide permanent access to miles of suitable spawning and rearing habitat. However, in many cases, the effect is to replace a resident rainbow trout population with a migratory steelhead population.

Downstream passage by smolts can also be affected by poor passage structures at seasonal dams. However, since steelhead smolts primarily migrate to the ocean over an extended period in late March through May, low spring streamflows can produce substantial passage problems. Even if the lower portions of streams do not completely dry during the migration period, low streamflows can result in shallow riffles, sandbar formation at the stream mouth, and high water temperatures, preventing or restricting much of the smolt outmigration. In streams with low spring streamflow (due to dry watersheds, percolating streambeds, or diversions) passage for smolt migration is often the one factor which limits steelhead population abundance or even prevents the maintenance of a migratory rainbow trout population.

Spawning steelhead require gravel substrates large enough to resist scour and to provide for water and oxygen flow through the substrate and small enough to allow the female to dig a nest (redd) with her body and tail (ideal spawning substrate size: from 0.6 to 10.2 cm). Streams dominated by sandy substrate may have low hatching success due to reduced gravel permeability, intra-gravel water flow, and dissolved oxygen during embryonic development (Daykin 1965, Cooper 1965). Frequent loss of redds by late winter storms may also result. However, relatively few nests (of several thousand eggs each) have to be successful to saturate a small stream with steelhead fry. Therefore, small streams with only rare patches of good quality spawning gravels can still provide adequate spawning success; steelhead are good at finding and using the best available spawning sites. Steelhead spawn from January to late April, and even in years of heavy winter storms the nests of late-spawning fish survive flood scour. A substantial portion (10-25%) of spawning steelhead survive to spawn 1 or more additional times. Ideal water temperatures for successful spawning have been found to be between 39 to 40°F; however, steelhead have been known to spawn in water as cold as 39°F and as warm as 55°F. The most common spawning site is a pool tail where the surface water breaks into a riffle. They normally spawn in water 4 to 54 inches deep with velocities of 2 to 5 feet per second. Incubation of steelhead eggs within the gravel nest (redd) can take from 20 days at 60°F to 80 days at 40 °F. Disease susceptibility of eggs increases with warmer stream temperatures.

Steelhead rear in streams until they become large enough to smolt (usually 5-8 inches). In most central coast streams the low streamflows of summer prevent much growth after June, and most steelhead require two years of stream residence to become smolt-sized. Young-of-year steelhead can use all types of habitat, but often grow best in riffles or at heads of pools, where they can feed in fast water on drifting insects. Overwintering habitat and summer rearing habitat for yearling steelhead is primarily in pools with good escape cover (undercut banks, logs, and root wads). Important juvenile steelhead survival factors such as food production, pool depth and cover are reduced within streams containing high fine sediment levels. Optimal water temperatures for rearing should be between 55° and 65°F, depending upon available food. At higher temperatures food demands increase and steelhead grow slowly or starve if food is not abundant. The upper lethal limit is approximately 75° F. Habitat for yearling fish is most likely to limit the production of smolt-sized fish in the majority of small streams.

If good conditions for feeding are available throughout the summer, young steelhead will grow continuously and reach smolt size in one year. Such conditions occur in partially-shaded streams with high summer streamflow or in productive ponds or lagoons, if water temperature and dissolved oxygen conditions are not too harsh. These habitats may make up only a small portion of total rearing habitat, however they can produce many of the smolts due to the fast growth experienced within the productive waters. For example, the lagoons at Pescadero and Waddell creeks may in some years produce a majority of the watershed smolts.

The estuary/lagoon at the mouth of the stream is potentially a very important habitat feature for steelhead populations, even when it does not provide for summer rearing. Smolts entering the ocean must adjust to salt water, and many fail to make the adjustment or are weakened and lost to predators. Deeper estuaries with a mixture of salt and fresh water allow smolts to gradually adjust, resulting in much higher survival during the transition. Where lagoons have no brackish embayment in spring, many of the stream-produced smolts probably die. This is especially true of the smaller fish, which have a more difficult transition. A poor watershed with a good lagoon may outproduce a good watershed with no spring or summer lagoon.

Coho Salmon

Coho salmon share many of the habitat requirements of steelhead, but differ significantly in that they require cool pools for rearing, spawn earlier in winter (December to February), and die after maturing whether they successfully spawn or not. The rearing requirements mean that coho will only maintain themselves in streams with extensive flat, but cool, habitat. Most of the stream habitat in the central coast is either relatively steep and cool or else flat, sandy and warm. Few streams south of San Francisco offer much coho rearing habitat. Early winter spawning by coho means that nests are frequency exposed to, and destroyed by, subsequent winter storms, especially in streams with sandy, easily-scoured substrate. The rigid life history of coho, with death after maturation and with all wild females maturing at 3 years, means that coho can be eliminated by droughts or severe floods, which eliminate individual year classes. The very limited amount of suitable rearing habitat and the likelihood of frequent access problems presently precludes the Pilarcitos Creek watershed from maintaining a coho population.

Snowy Plover

Snowy plovers are small pale-colored shorebirds that forage for invertebrates in intertidal zones and above high tide lines. Western snowy plovers are found on the Pacific coast between southern Washington and southern Baja California. Plovers breed in small depressions on beaches from mid-March to August. Nesting sites have experienced a 62 percent decline in California, largely due to human disturbance of nests and predation of adults, chicks, and eggs by pets, crows, ravens, and red foxes. Nesting has been previously documented at Half Moon Bay beaches near the mouth of Pilarcitos Creek, between Frenchmen's Creek and Kelly Avenue (USFWS 1995).

2.7 SUMMARY OF EXISTING WATERSHED CONDITIONS

2.7.1 Geomorphology and Hydrology

The main geomorphic and hydrologic problems in the watershed are related to watershed erosion, channel sedimentation, and reduced streamflow. The bedrock geology in the watershed consists of easily erodible granitic rocks in the headwaters of Apanolio, Corinda Los Trancos, Nuff, and Pilarcitos Creek. This weathered granitic rock is the source of much of the sand in Pilarcitos Creek. The upper portion of Pilarcitos Creek flows along the Pilarcitos Fault which divides the granitic rocks from erodible Franciscan Formation rocks, (the Franciscan rocks are also a source of fine sediment to Pilarcitos Creek). The tributaries joining Pilarcitos Creek from the south—Madonna Creek, Mills Creek and Arroyo Leon flow through sandstones, mudstones, and shales provide less fine sediment than the tributaries to the north, but sand is still present in their channels. The upper portions of the tributaries have steep hillslopes and are prone to erosion.

Land use activities that accelerate the rate of hillslope and bank erosion include agriculture, road construction and maintenance practices, and construction for urban development (Figure 16). Erosion usually occurs when vegetation is disturbed, and bare soil is exposed. Unpaved roads throughout the watershed and eroding road cuts are sources of fine sediment. Landslides are common in the headwaters of Pilarcitos Creek upstream of Highway 92, and gullies are present on the south facing slopes in the Arroyo Leon basin. A landslide above Highway 92 in Albert Canyon may be the result of concentrated runoff from an unpaved road above the slide or artificial steepening of the slope related to the Highway 92 road cut.

Although there is a large supply of fine sediment to Pilarcitos Creek and its tributaries from watershed erosion, there is evidence of channel incision throughout the watershed. Fine sediment is easily transported during floods, and does not prevent incision. Incision in the tributaries and in the main channel of Pilarcitos Creek is illustrated by elevation drops downstream of bridges, culverts, dams, or other water diversion structures. The incision is caused by dams that trap the coarse sediment, by increases in peak discharge or water releases from dams, and from past landuse practices such as grazing. The drop downstream of Corinda Los Trancos is probably related to an increase in runoff as a result of the impervious BFI Ox Mountain Landfill while the drop downstream of bridges and culverts in Mills Creek and Arroyo Leon are probably related to historic grazing and road and residential development.

Bank erosion is pervasive throughout the watershed. While bank erosion is a natural process that occurs as creeks evolve and create their valleys and pattern through incision and meandering, recent incision and bank erosion rates are clearly accelerated. Incision increases bank heights and the potential for erosion. Removal or disturbance of riparian vegetation also increases bank instability. Most of the tributaries and the main channel of Pilarcitos Creek have steep or vertical banks that are undercut or show evidence of bank erosion. Riparian vegetation provides root strength and helps resist erosion. In locations where riparian vegetation is absent or sparse, erosion is a accelerated. Well-vegetated riparian zones slow the rate of bank erosion, because after one tree is undercut or eroded, another is behind it to offer resistance.

On Pilarcitos Creek downstream of Highway 92, a reach of the channel was straightened in the past. This reach is likely to erode at an accelerated rate in the future as the channel morphology adjusts to the disturbance caused by channel straightening. Structural approaches to bank stabilization fix the channel in one location and do not allow the natural process of meander migration to occur. The disruption of this process causes other river adjustments that accelerate bank erosion upstream of the hard structure.

Streamflow in Pilarcitos Creek is reduced due to dams and water diversions, and groundwater pumping adjacent to the creek. Reduced flow damages fish habitat by 1) allowing pools and riffles to fill with sediment and 2) reducing flows sufficient for rearing or migration. During dry years, there is not enough flow to transport even fine sand from the creeks. As a result, pools fill in and the coarser substrate is buried. Fish growth and rearing takes place during the spring and summer when there is often little or no flow in Pilarcitos Creek. The issues related to water use and streamflow on Pilarcitos Creek are complicated by the diversity and number of water users, the economics and politics related to water use, and the current lack of coordination between users.

Very little data are available reporting water quality in the watershed. The major source of pollution is the fine sediment eroded from disturbed hillslopes, floodplains, and channel banks. Other sources of pollutants may include leachate from the BFI Ox Mountain Landfill, fertilizers and pesticides used for agriculture, and hydrocarbons and heavy metals from the highway and roads.

2.7.2 Fisheries

Stream substrate throughout the Pilarcitos watershed is dominated by sand (Table 8). Even at the best sites, sand generally dominates pools and runs, and spawning gravels contain abundant sand. The abundance of sand, from erodible granitic and sandy soils, results in poor spawning conditions in much of the watershed (Table 10). Sand also limits the extent and depth of pools and the abundance of aquatic insects as food for fish. Even at relatively undisturbed sites, such as Pilarcitos Creek above Stone Dam (Smith, 1991), sandy substrate is a constraint on stream habitat.

In sandy watersheds high streamflows are needed to produce adequate depth, insect production and overhead cover (as turbulence) to support good populations of steelhead. Unfortunately, the Pilarcitos watershed is not only sandy, but most stream sections have low flows in average or dry years. No minimum summer flows are presently released in summer from Stone Dam on Upper Pilarcitos Creek, and diversions for agricultural use are common throughout the watershed (Table 10).

Upstream barriers to adult migration in Apanolio and Arroyo Leon Watersheds are obvious and modifiable. A more subtle migration problem is low April and May flows in dry years, which may block outmigrating smolts at shallow riffles or allow formation of a sandbar at the mouth. In dry and average years, the operation of dams and diversions on lower Arroyo Leon probably restricts or block smolt downstream migration.

On Pilarcitos Creek stream habitat (Tables 8 and 10) and fish abundance (Table 9) generally increased upstream. The single sampled site on Apanolio Creek and the two lower sites on Mills Creek also had relatively high fish densities for the watershed (Table 9). However, these "best" sites still had combined steelhead densities half of the average steelhead density on 28 sites on Gazos, Waddell, and Scott Creeks (Table 9) in 1995. Ponds on Apanolio and Arroyo Leon do offer important potential steelhead rearing habitat.

Nuff, Madonna and Corinda Los Trancos Creeks are significant primarily as sources of some summer streamflow to Pilarcitos creek and as major sources of sandy sediment.

At the mouth of Pilarcitos Creek a lagoon can form in summer as the beach develops, if summer streamflows reach the mouth, as they did in 1995. In most years Pilarcitos Creek is dry near the mouth and no summer lagoon forms.

Overall, Pilarcitos Creek watershed has only modest steelhead habitat (Table 9) compared to other streams in San Mateo County (Table 11) and Santa Cruz County (Table 9). Most of the other listed streams also presently have coho salmon populations or could potentially support restored coho populations.

2.7.3 Vegetation

The vegetation resources of the riparian corridors of the major creeks in the watershed were investigated in early fall 1995. The purpose of the study was to evaluate the vegetation resources of the watershed for restoration and enhancement opportunities. Field reconnaissance surveys and extensive review of environmental documents were performed. The extent of known occurrences of sensitive botanical resources was investigated by using two electronic inventories: California Department of Fish and Game Natural Diversity Data Base (1995) and the California Native Plant Society's Inventory of Rare and Endangered Vascular Plants (1994). During the field surveys, the types of riparian habitats and significant concentrations of invasive non-natives were mapped onto orthophoto maps available from the County of San Mateo.

The field surveys found five basic types of woody riparian habitat: willow-alder riparian forest, willow mixed riparian forest, willow riparian forest, eucalyptus-alder riparian forest, and eucalyptus groves. These riparian habitats have been disturbed and reduced in size by urban and agricultural practices. The disturbance has resulted in the establishment and spread of invasive species (e.g., eucalyptus trees, German ivy, pampas grass, and poison hemlock). The eucalyptus trees are significantly displacing native tree overstory species, and in some areas eucalyptus forests have established. Under the eucalyptus trees, the shrub and herbaceous layers tend to be sparsely distributed, which contributes to soil erosion and sedimentation of the creeks. The majority of the understory vegetation observed was dominated by non-native species. Streamside eucalyptus also reduces aquatic insect production, reducing food for fish. German ivy is significantly lowering the riparian habitat value by congesting the channel edges and creek banks and by out-competing native vegetation. Ivy reduces habitat for red-legged frog, western pond turtle, and San Francisco garter snake. German ivy has already reached epidemic proportions in the main stem of Pilarcitos Creek.

Vegetation management is important for restoring the watershed, both for improved wildlife habitat and for improved fisheries habitat. The extent of invasive non-native species must be significantly reduced in order to re-establish a diverse assemblage of native riparian plant and animal species. Increased biodiversity will contribute to stabilizing the watershed in terms of the ecosystem as a whole.

3. CRITICAL WATERSHED ISSUES

3.1 REDUCED STREAMFLOW

Diversions, dams, wells, and in-channel irrigation or stock ponds reduce streamflow in Pilarcitos Creek and its tributaries. During most years, available flows are not transporting sand and finer sediment out of the creek system.

3.2 DEGRADED FISH HABITAT

Barriers to fish migration and degraded water quality negatively affect fish habitat. In addition, sand substrate limits spawning and rearing habitat by covering riffles. Rearing takes place during the summer when there is often little or no streamflow in the Pilarcitos Creek system.

3.3 LOSS OF RIPARIAN VEGETATION AND HABITAT AND BANK EROSION

Narrowing of the riparian corridor in the Pilarcitos Creek watershed results in a lack of food sources for fish and wildlife and limits woody debris recruitment that could create more complex pool habitat. The removal of riparian vegetation and channel incision throughout the watershed leads to bank erosion.

3.4 WATERSHED EROSION AND CHANNEL SEDIMENTATION

Hillslope erosion and channel sedimentation is high in Pilarcitos Creek watershed due to the natural geology with steep hill slopes and erodible weathered bedrock. Historic human activities such as grazing, road construction, and agricultural clearing also contribute fine material to the stream channels. Fine sediment contributed to the channel affects fish habitat.

3.5 EXOTIC VEGETATION

Exotic overstory (eucalyptus) and understory (German ivy) vegetation prohibits the recruitment of new native vegetation. A dense overstory of eucalyptus, common in the watershed, eliminates native understory. Bare ground is more susceptible to erosion and can contribute sediment to the creek at an increased rate.

3.6 LANDOWNER CONCERNS

Addressing landowners concerns is a critical element of the Pilarcitos Creek Restoration Plan. Specific issues to address include respecting landowner privacy and time constraints, and minimizing landowner liability and maintenance.

4. RESTORATION GOALS

GOAL 1. Improve Degraded Habitat and Passage Conditions for Adult and Juvenile Salmonids

- Increase summer and fall streamflows to Pilarcitos Creek and its estuary through voluntary measures. Increase late summer and fall flows to at least 2 cfs.

- Modify barriers to anadromous fish migration on Apanolio, Pilarcitos, Arroyo Leon and Mills Creeks.

- Reduce fine sediment load from watershed.

GOAL 2. Improve Degraded Wildlife Habitat, Native Species Biodiversity, and Natural Resource Values

- Remove exotic trees, shrubs, and herbaceous species and replace with native species.

- Increase the proportion of native plant species by planting self-sustaining native vegetation which requires little or minimal maintenance in the long term (i.e., capable of self-regeneration without continued dependence on irrigation, soil amendments, or fertilizer.

- Replant native riparian vegetation on bare streambanks to increase stability and improve esthetic quality of riparian corridor.

- Restore and enhance riparian habitat for plant and animal species of special status.

GOAL 3. Enhance Stability of Riparian Corridor

- Provide guidelines for consistent bank stabilization treatments that restore the dynamic equilibrium of the creek on public and private land in the Pilarcitos Creek watershed.

- Integrate biologic value into treatment designs that accommodate natural geomorphic processes.

- Develop best management practices to minimize erosion in the short and long-term, with vegetation cover or other surface erosion control measures.

GOAL 4. Minimize Flood Hazard

- Allow sufficient channel capacity to accommodate vegetation within bank stabilization design.

GOAL 5. Improve Water Quality

- Provide a riparian buffer between Pilarcitos Creek and urban and agricultural land uses.

- Control pollution at the source.

GOAL 6. Provide Educational Resources, Especially for Riparian and Agricultural Landowners

- Increase community awareness of watershed processes and habitat through newsletters, riparian and agricultural landowner outreach and educational workshops.

- Provide resource lists for interested science teachers in the watershed.

- Develop a long-term monitoring and reporting program to evaluate the success of the restoration projects and to adjust treatments based on the monitoring results.

5. CONSTRAINTS AND OPPORTUNITIES

5.1 CONSTRAINTS

Watershed constraints are illustrated on Figures 10-17. Each tributary to Pilarcitos Creek is evaluated in order to determine what factors constrain the restoration project. Table 12 illustrates which constraints occur within specific tributary basins in the Pilarcitos Creek watershed. Pilarcitos Creek is described as Upper Pilarcitos Creek (upstream of Highway 92) and Lower Pilarcitos Creek (downstream of Highway 92).

- *Streamflow*— Diversions, dams, near-channel wells, and irrigation or stock ponds reduce streamflow in Pilarcitos Creek and its tributaries (Figure 15). Lower Pilarcitos Creek is dry on average 59 day of the year, and flows are often too low to transport fine sediment out of the system. In addition, growth and rearing takes place during the spring and summer when there is often little or no flow in Pilarcitos Creek and its tributaries.

- *Flooding* — Flooding occurs on Pilarcitos Creek downstream of Stone Dam during wet years (such as the winter of 1995) when water flows over the spillway of the dam. Flooding and sedimentation also occurred in 1992 following the failure of a debris dam on Corinda Los Trancos Creek downstream of the BFI landfill.

- *Water Quality* — Water quality can be affected by land use activities such as leachate from the BFI landfill, nutrients and pesticides used for agriculture, hydrocarbons from roads and highways, fine sediment from watershed disturbances, and urban development. Degraded water quality negatively affects fish habitat and constrains options for well sites and diversions.

- *Sand Substrate* — The soils of the watershed highly erodible and contribute to poor substrate conditions in streams. Sand substrate limits spawning and rearing habitat by covering riffles and filling pools.

- *Fish Barriers* — Numerous barriers to fish migration exist in the Pilarcitos Creek watershed (Figure 10). Barriers to fish migration restrict or prevent steelhead use of upper stream sections, although resident rainbow trout may be present.

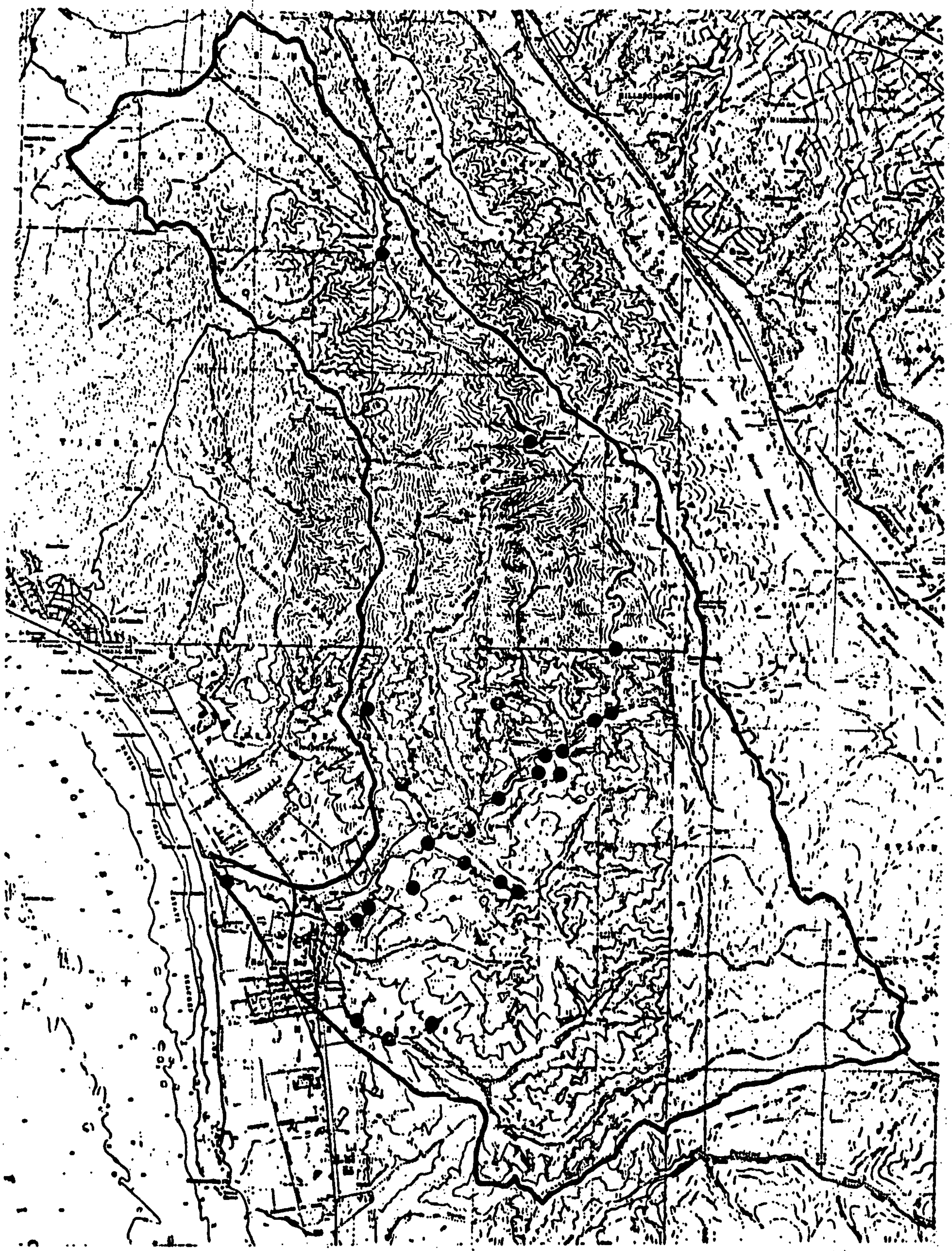


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figure 15

Water Diversions
Pilarcitos Creek Watershed

Source: USGS, 1973 #1021

Philip Williams & Associates, Ltd.

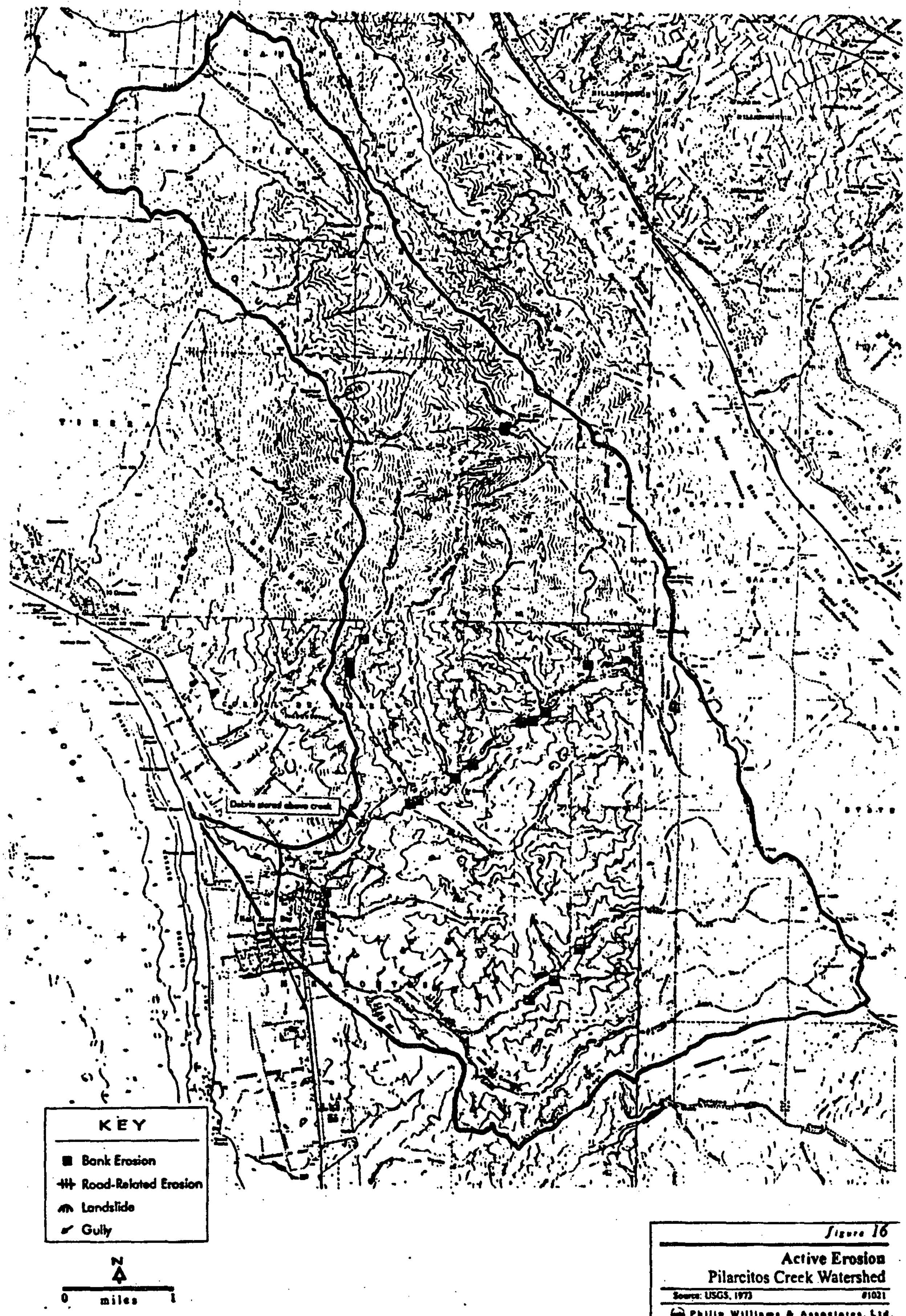

Figure 16

Active Erosion
Pilarcitos Creek Watershed

Source: USGS, 1973 #1021

Philip Williams & Associates, Ltd.

figure 17

Constraints
Pilarcitos Creek Watershed

Source: USGS, 1973 #1031

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TABLE 12. Summary of Constraints

Sub-watershed	Drainage Area (mi^2)	Wells, Diversions or Dams	Instream flow Limited	Flooding	Water Quality	Sand Substrate	Fish Barriers	Bank Erosion	Existing Bank Protection	Channel Incision	Hillslope Erosion	Agricultural Practices	Exotic Vegetation	Other Land use	Bridges, Culverts & Roads	Institutional (Permits)
Apanolio Creek	2.0	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔	✔	✔
Corinda Los Trancos Creek	0.9		✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Nuff Creek	1.1		✔			✔	✔			✔			✔	✔	✔	✔
Upper Pilarcitos Creek	9.7	✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	✔	✔	✔
Lower Pilarcitos Creek	2.8	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Albert Canyon	1.2									✔	✔		✔	✔	✔	✔
Madonna Creek	1.6	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔	✔	✔
Mill Creek	3.8					✔	✔	✔		✔	✔		✔		✔	✔
Arroyo Leon	5.2	✔	✔			✔	✔	✔		✔	✔	✔	✔	✔	✔	✔
Estuary			✔		✔	✔							✔		✔	✔

- *Bank Erosion* — Bank erosion is pervasive throughout Pilarcitos Creek and its tributaries (Figure 16). Bank erosion results from erodible bank material, disturbance of the riparian vegetation and invasion of the riparian corridor by on-native plants, such as eucalyptus.

- *Existing Bank Protection* — Existing bank protection structures disrupt the natural process of meander migration and may cause erosion upstream and downstream of the structure. Some hard structures (such as the rip-rap near the mouth of Corinda Los Trancos) lack habitat value, unless specific provisions to integrate vegetation are made in the design.

- *Channel Incision* — Many of the tributaries to Pilarcitos Creek exhibit signs of incision, or downcutting of the bed of the channel. Incision may be caused by 1) trapping coarse sediment behind dams and diversion structures, 2) because increase in peak flows due to removal of vegetation and development of the watershed, and 3) historic grazing that compacted soils and increased runoff. Incision is also pronounced downstream of culverts at road crossings. Incision increases bank heights and steepness and accelerates bank erosion. The larger channel size and capacity decrease the frequency of overbank flooding.

- *Hillslope Erosion* — Hillslope erosion such as landslides and gullies is extensive in the watershed, especially along the Pilarcitos Fault in Upper Pilarcitos Creek. Gullys are present on southwest facing slopes in the Arroyo Leon Watershed.

- *Agricultural Practices* — Land clearing for agriculture often extends to the top of bank without providing a buffer between agricultural practices and the creek. Bare ground in agricultural areas contributes fine sediment to the creek. Fertilizers and pesticides can runoff to the creek and degrade water quality.

- *Private Property* — An overall constraint to managing the watershed's restoration projects is the reluctance of some property owners to participate in the program. Educational workshops should promote benefits of the watershed restoration project to private landowners. Incentives should be developed to encourage all property owners to participate in the project over the next five years. Many of the restoration alternatives (i.e., control of invasive species) need a systemic approach, and do not recognize property boundaries. Private landowner cooperation is needed to allow fish passage through and/or around existing fish migration barriers.

- *Exotic Vegetation* — The removal of invasive non-native plant species will be constrained by the ubiquitous nature of invasive species present within the watershed, particularly eucalyptus, German ivy and poison hemlock (Figures 11-14). These species are so prevalent that cooperative agreements must be made between adjacent landowners. If there is no cooperation, then the invasive species will continue to have a seed source and control/efforts would be futile.

- *Other Land Use* — The BFI landfill in the headwaters of Corinda Los Trancos Creek contributes sediment and degrades water quality in Pilarcitos Creek (Figure 17). Urbanization in Half Moon Bay and the watershed could require additional water from Pilarcitos Creek, contribute pollutants to the creek, and increase peak discharges to downstream areas.

- *Bridges, Culverts, and Roads* — Incision downstream of fixed bridge and culvert crossings creates fish migration barriers (Figure 17). Road cuts contribute sediment to Pilarcitos Creek and its tributaries. Road maintenance practices—such as clearing debris from roads during storms and pushing it to the shoulder above the creek—contribute to the sediment problem in Pilarcitos Creek.

- *Institutional*— The restoration projects can be constrained by the County permit process. Depending on a given project and the current land use, restoration projects will be subject to County approval and permitting (e.g., coastal development permit). Summer fishing is presently allowed on Arroyo Leon.

5.2 OPPORTUNITIES

Opportunities to enhance the riparian corridors in the Pilarcitos watershed include improvement of the habitat value of the vegetation for fisheries and wildlife use, and a reduction in sedimentation. Table 13 illustrates where opportunities occur within the Pilarcitos Creek watershed.

- *Increase Streamflow* — Streamflows could be increased through voluntary agreements between all of the water users in the Pilarcitos Creek watershed. Increased flows would improve fisheries rearing habitat conditions and migration.

- *Follow Water Release Contingency Plan* — The Water Release Contingency Plan for releases from San Francisco Water Department Dams could be closely followed to reduce downstream flood damages.

- *Modify Fish Barriers* — Barrier modification could provide adult salmonids access to upstream portions of several tributaries such as Mill Creek and Apanolio Creek.

TABLE 13. Summary of Opportunities

Sub-watershed	Drainage Area (mi^2)	Increase Streamflow	Follow Water Release Contingency Plan	Modify Fish Barriers	Stabilize Banks or Hillslopes	Promote Setback and Riparian Buffer	Remove exotic vegetation & replace w/natives	Minimize Disturbance	Maintain Paved and Unpaved Roads	Modify Highway Maintenance Practices	Facilitate Permit Process	Provide Educational Resources	Regulate Fishing
Apanolio Creek	2.0	✔		✔	✔	✔	✔	✔	✔		✔	✔	✔
Corinda Los Trancos Creek	0.9				✔	✔		✔	✔		✔	✔	
Nuff Creek	1.1					✔		✔	✔		✔	✔	
Upper Pilarcitos Creek	9.7	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔
Lower Pilarcitos Creek	2.8	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔
Albert Canyon	1.2									✔	✔	✔	
Madonna Creek	1.6	✔		✔	✔	✔	✔	✔	✔		✔	✔	
Mill Creek	3.8			✔	✔		✔	✔	✔		✔	✔	✔
Arroyo Leon	5.2	✔		✔	✔	✔	✔	✔	✔		✔	✔	✔
Estuary		✔				✔	✔	✔			✔	✔	

- *Stabilize Banks or Hillslopes* — Stabilizing streambanks and hillslopes would reduce the volume of fine sediment contributed to the Pilarcitos Creek watershed. Streambank stability could be improved by planting riparian vegetation, or by using bio-technical treatments that enhance habitat value and that do not inhibit the geomorphic processes of the creek. Hillslope gullys could be repaired.

- *Remove Exotic Vegetation and Replace with Native Vegetation* — Increase the proportion of native plant species through the phased removal of invasive non-native species (e.g., German ivy and eucalyptus trees) and the replacement with native riparian vegetation. The costs of removal could be off-set by the sale of the felled eucalyptus for firewood and wood pulp. In portions of the riparian corridor with little tree overstory—such as a portion of Pilarcitos Creek above the confluence with Corinda Los Trancos—native tree species may be planted to provide more shade for improved fish habitat. Vegetation management on private lands would be pursuant to purchasing land or obtaining conservation easements from willing landowners.

- *Promote Setback and Riparian Buffer* — A setback from the creek with a riparian buffer would reduce the volume of sediment, nutrients, and other pollutants reaching the creek while adding important riparian habitat. Existing San Mateo County Ordinances should be enforced. The establishment of buffers of setbacks from the riparian corridor would be pursuant to purchasing land or obtaining conservation easements from willing landowners. Vegetation management on private lands would be pursuant to purchasing land or obtaining conservation easements from willing landowners.

- *Minimize Disturbance* — Vegetation disturbance and road construction increase erosion rates and add sediment to the creeks. Disturbance could be minimized to reduce the sediment supplied to the Pilarcitos Creek watershed.

- *Modify Road and Highway Maintenance Practices* — Unpaved and paved roads could be maintained so that water is not concentrated. This will aid in reducing erosion on unpaved roads, and on down slope areas. Caltrans could modify its road maintenance practices on Highway 92 that contribute sediment to Pilarcitos Creek. A new debris basin could be constructed and maintained down slope of the landslide above Highway 92 in Albert Canyon.

- *Facilitate Permit Process* — San Mateo County could facilitate the permit process.

- *Provide Educational Resources* — A resource list could be provided to local educators, and workshops could be held for agricultural landowners to aid in reducing sediment and pollutants to the creeks. Educational workshops should promote benefits of bank stabilization and management of sediment and pesticides on agricultural land. Potential labor sources for implementing the restoration projects include the California Conservation Corps (CCC), student environmental groups from nearby high schools and universities, members of the local chapter of the California Native Plant Society, and volunteers from the Half Moon Bay community. With guidance from a fisheries biologist, future monitoring of aquatic habitat and fish populations can be conducted by community members or school programs and have significant educational value.

- ***Regulate Fishing*** — The California Department of Fish and Game could regulate fishing in Pilarcitos Creek and its tributaries in order to enhance survival of anadromous fish especially if migration barriers are modified to allow upstream passage.

6.1 BANK AND HILLSLOPE STABILIZATION

Bank stabilization in the context of watershed restoration should be conducted at a scale that reduces fine sediment supply to Pilarcitos Creek and significantly improves habitat. In order to be successful in the long-term, bank stabilization efforts would coincide with other watershed restoration activities such as modification of the barriers to fish migration or designation of a riparian corridor. A riparian corridor would be wide enough to accommodate the geomorphic process of meander migration, while providing riparian habitat and a buffer from agriculture activities. Watershed issues of streamflow, channel incision, bank erosion, and fishery and habitat restoration must be looked at holistically in order to be successful in the long-term. Restoration of a stable riparian corridor throughout the watershed would provide long-term benefits to fish habitat while local structural techniques require long-term maintenance and management.

Bank stabilization conducted at the scale of individual bank failures or along property lines does not significantly reduce the watershed's fine sediment load, and may actually cause further erosion at their edges (depending on the method selected). For this reason, the restoration project promotes bank stabilization methods that extend along the length of a geomorphic feature, such as a meander, or between two tributaries. Individual landowners could use the following stabilization methods on a smaller scale to protect property and enhance habitat in the short-term.

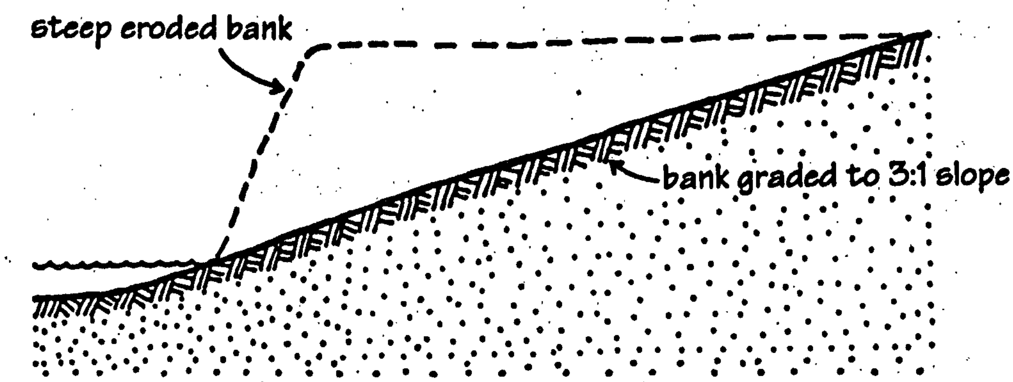
Grading Techniques

Grading the channel banks back to a stable slope or creating a new lower floodplain at the elevation of the dominant discharge (lower than the existing floodplain elevation) increases bank stability, and allows for easier establishment of vegetation (Gray and Leiser, 1989). Grading increases channel capacity and can allow for planting new vegetation on the banks while minimizing flood hazard. Grading can be used in combination with all of the vegetative, deflection, and armoring techniques. Grading should be done at the scale of a reach. (A reach is defined as the entire length of a geomorphic feature such as a meander, or between hard structures that fix the channel morphology.) Grading to a stable slope is most appropriate where there is no existing riparian vegetation that would be disturbed by the site work. The two techniques listed are illustrated in Figure 18.

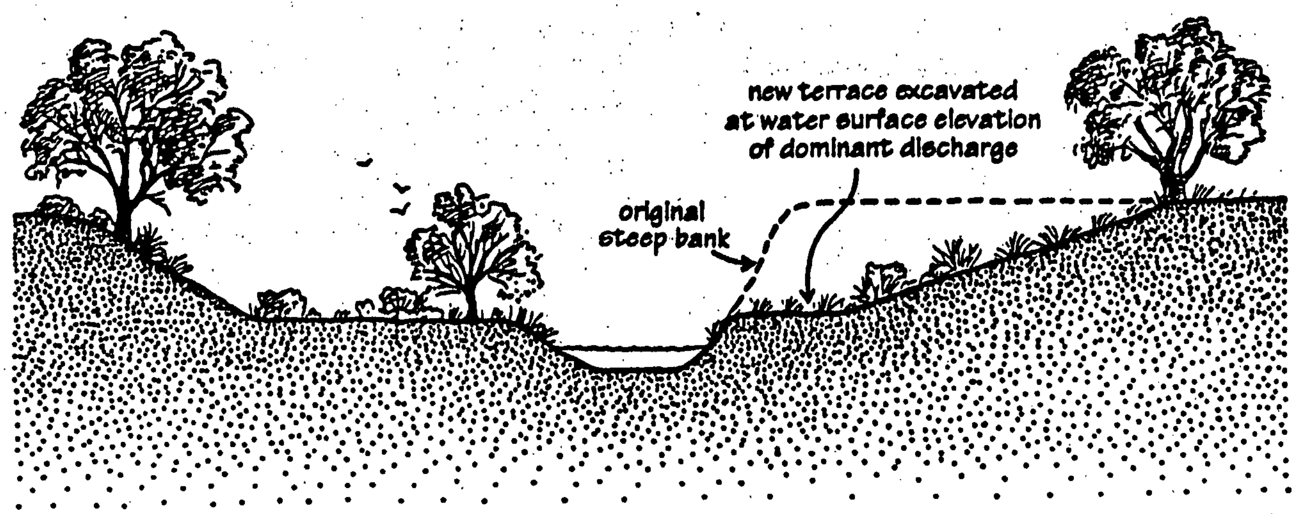
- Stable Gradient (at 3:1 or lower slope)
- Terraced Bank

Grading Techniques

Stable Gradient



Terraced Bank



Vegetative Techniques

Vegetation may be used to stabilize banks (Chatham, 1995; Flosi and Reynolds, 1994; Gray and Leiser, 1989; Sotir and Gray, 1989). Vegetation slows flow velocity and reduces shear stress on the bank. Roots bind soil together and increase the strength of the bank and its resistance to erosion. Use of vegetation for bank stability is sometimes called "bioengineering." There are numerous benefits to using vegetative techniques in increasing streambank stability:

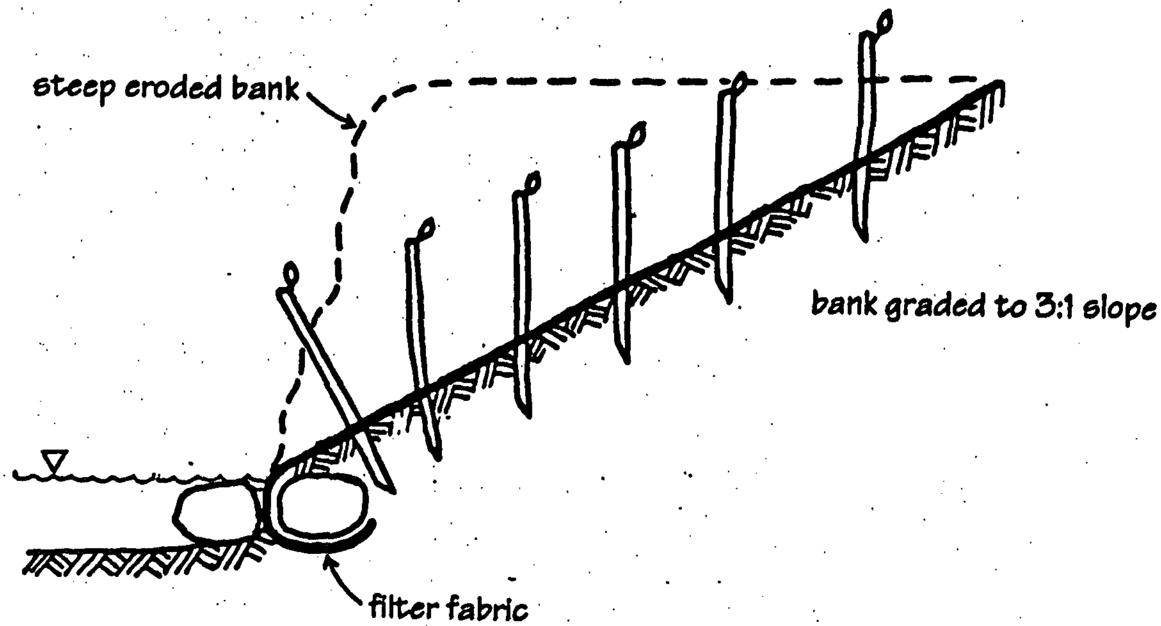
- Vegetation provides habitat value on the banks, and overhanging trees provide shade that reduces water temperatures and improves water quality;
- Vegetative techniques are flexible, and allow the geomorphic process of meander migration to occur;
- Vegetative techniques are self-repairing;
- Vegetative techniques are relatively inexpensive compared to structural bank repair techniques (although it may be more labor intensive initially);
- Vegetation can filter debris from floodwater and prevent it from damaging structures on the floodplain;
- Vegetative techniques allow for a focus on areas with poor vegetation since repair of already failed banks is more difficult and more expensive;
- Vegetative techniques do not deflect flow to the extent that hard structures do, and therefore, do not accelerate bank erosion across the channel, or upstream or downstream.

Bank stabilization using vegetative techniques benefits landowners by reducing the loss of land to bank erosion. Vegetative techniques such as planting live willow cuttings are relatively inexpensive and could be accomplished by cooperative landowners. Monitoring bank conditions before and after treatment with a vegetative or combination technique is recommended to provide feedback for future designs. The type of vegetation that is appropriate for Pilarcitos Creek is described in Section 6.3. In some areas where banks are not vertical live cuttings can be planted to stabilize banks. Vertical banks however, would need to be graded. When vegetative techniques are combined with grading, they should be implemented on the scale of a reach, rather than piecemeal along the channel. The following vegetative techniques are illustrated in Figures 19 and 20.

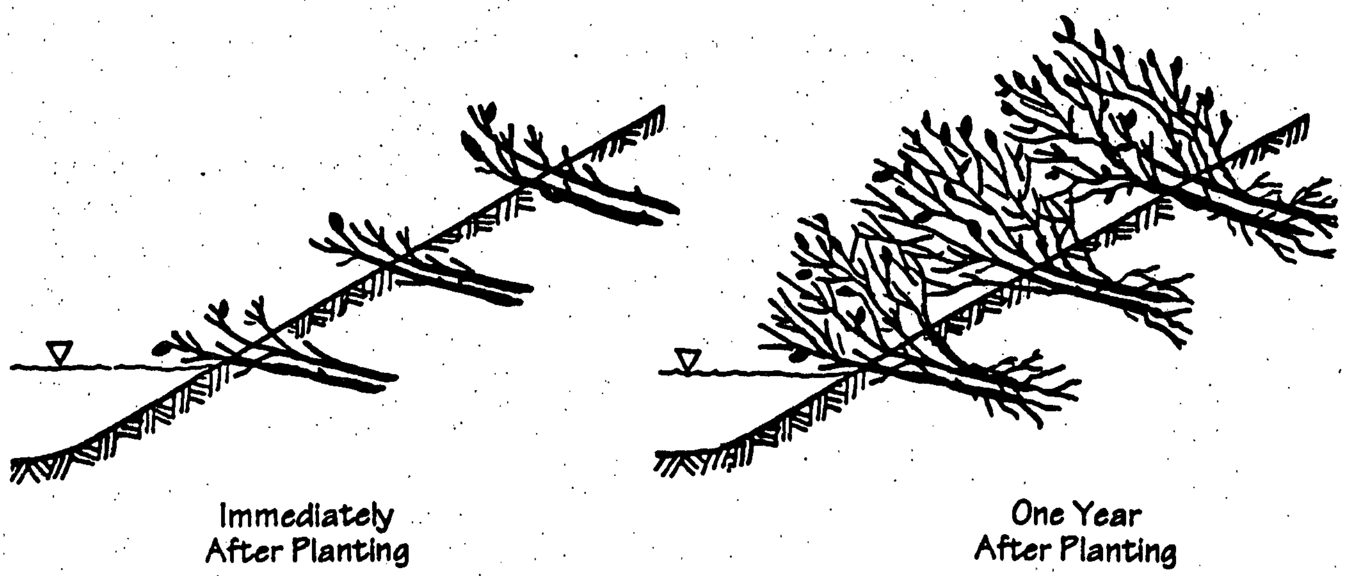
- Live Willow Cuttings (Live Stakes)
- Brush Layers
- Willow Wattles
- Live Fence

Vegetative Techniques

Live Stakes

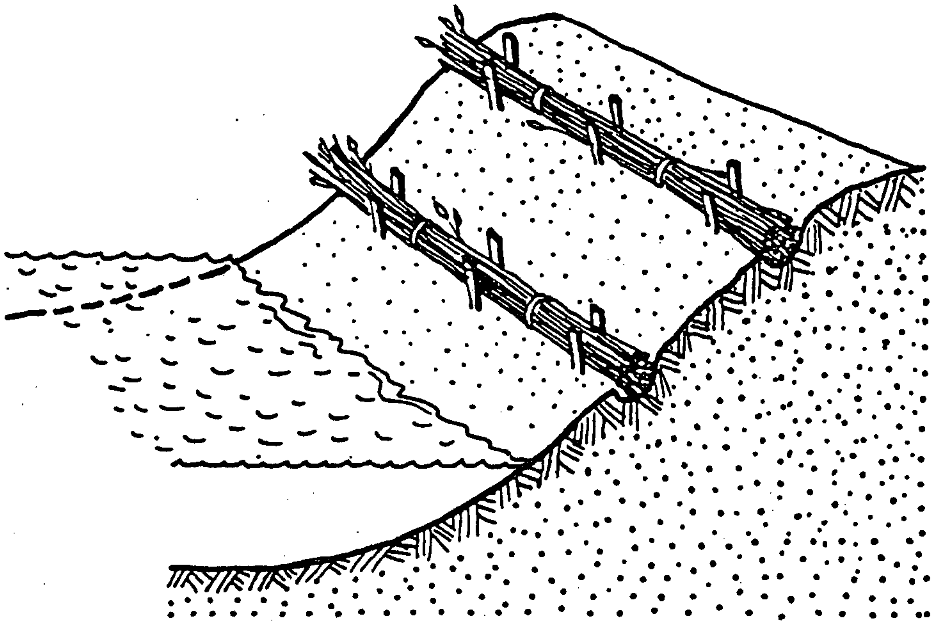


Brush Layers

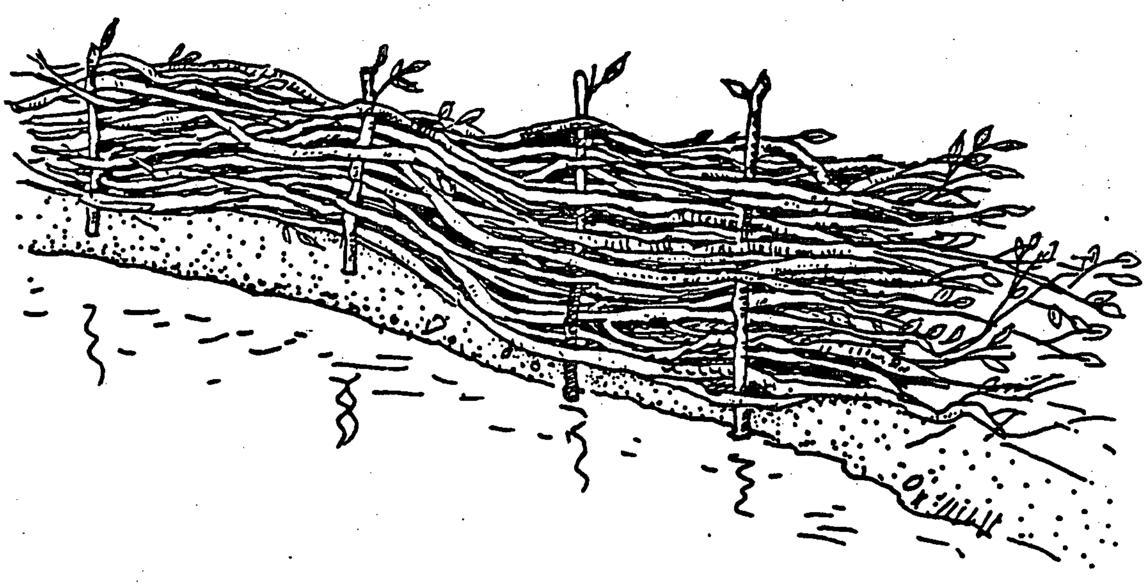


Vegetative Techniques

Willow Wattles



Live Fence



Flow Deflectors

Flow deflectors can be used to protect eroding banks, minimize erosion and encourage deposition of sediment at the toe of the slope (Flosi and Reynolds, 1994; Sotir and Nunnally, 1995). The height of the deflector corresponds to a designated design flow, such as the dominant discharge. In Pilarcitos Creek, other treatments should be used in combination with flow deflectors, since the sandy banks adjacent to and above the deflectors would still be subject to erosion. A project site that includes bank stabilization treatment should extend through a reach of channel. Two types of deflectors are illustrated on Figure 21.

- Vegetated Dikes
- Log Wing Deflectors

Bank Armor

It may be necessary to use hard erosion control structures in some locations to protect infrastructure (for example at bridge abutments) or residences where vegetation alone does not provide enough strength. Vegetation should be used in combination with large rocks or logs to effectively protect sensitive structures or infrastructure while providing habitat value (Haltiner, 1995; Flosi and Reynolds, 1994; Rosgen, 1991; Gray and Leiser, 1989). Structural or "hard" bank erosion control techniques such as logs, walls, and rock or concrete intended to fix the river in one location, affect river processes by deflecting flow energy to the opposite bank and by limiting meander migration. Meander migration is a response of the river to varying sediment and flow discharges over time; fixing the channel in one location prevents the river from adjusting its width, depth, slope and morphology to maintain a balance. A hard structure on one bank may deflect flow, causing erosion on the opposite bank, and at the upstream and downstream transitions. Rock must be large enough to remain in place during a designated design flood, and both rocks and logs must be tied into the bank and bed to prevent undercutting of the structure. Hard structures may fail when incision lowers the bed elevation after construction. A geotextile fabric or gravel blanket prevents soil underlying armor from being washed out. Four types of bank armor that allow for incorporation of vegetation in the design are illustrated in Figures 22 and 23.

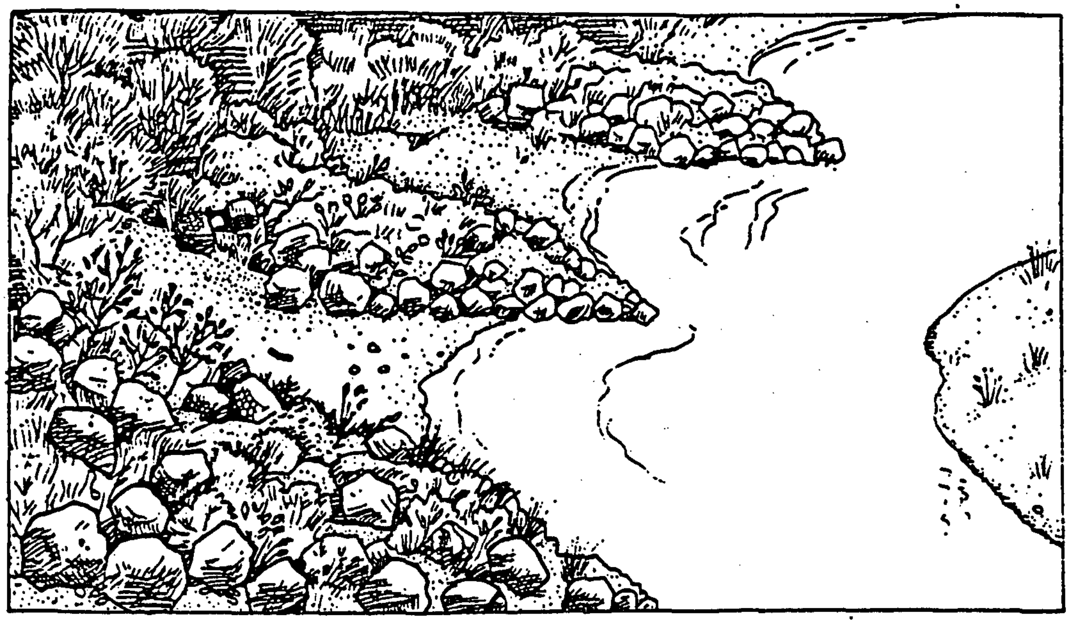
- Log bank Armor
- Log Crib Wall
- Planted Rock
- Rocks and Logs

Gully Stabilization

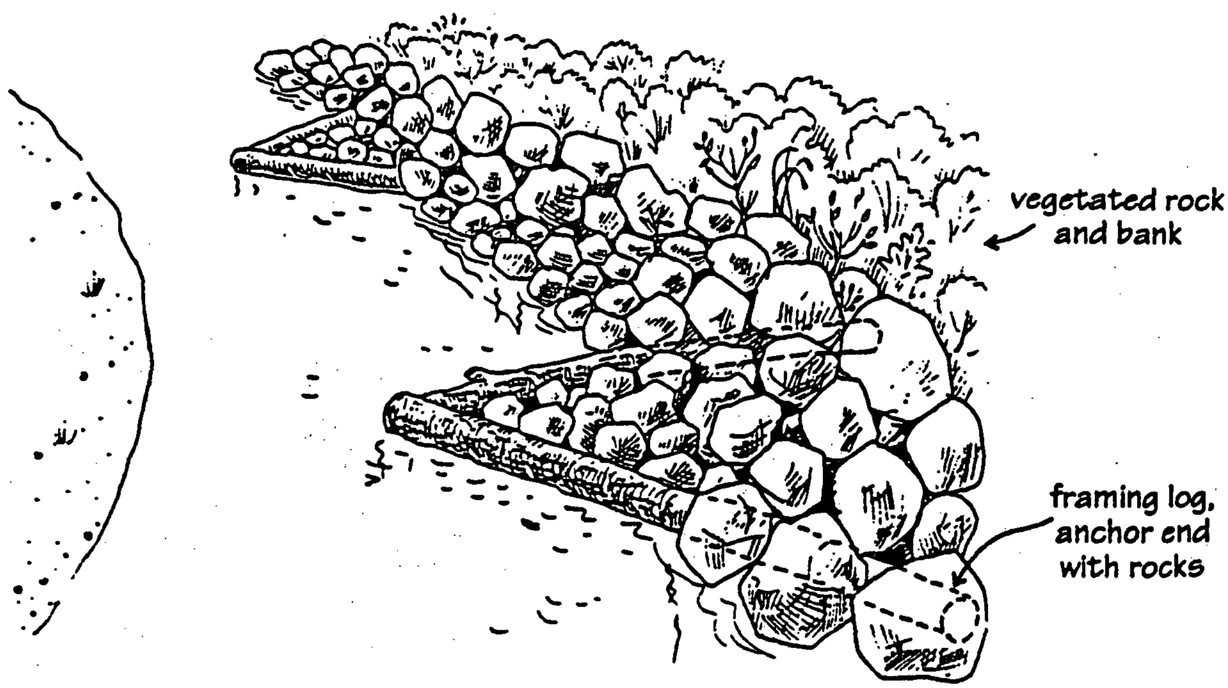
Stabilization of gullies involves stopping both the headward and downward incision. Methods for gully repair are described in Prunuske (1987). Stopping the erosion involves diverting the source of water away

Flow Deflectors

Vegetated Dikes

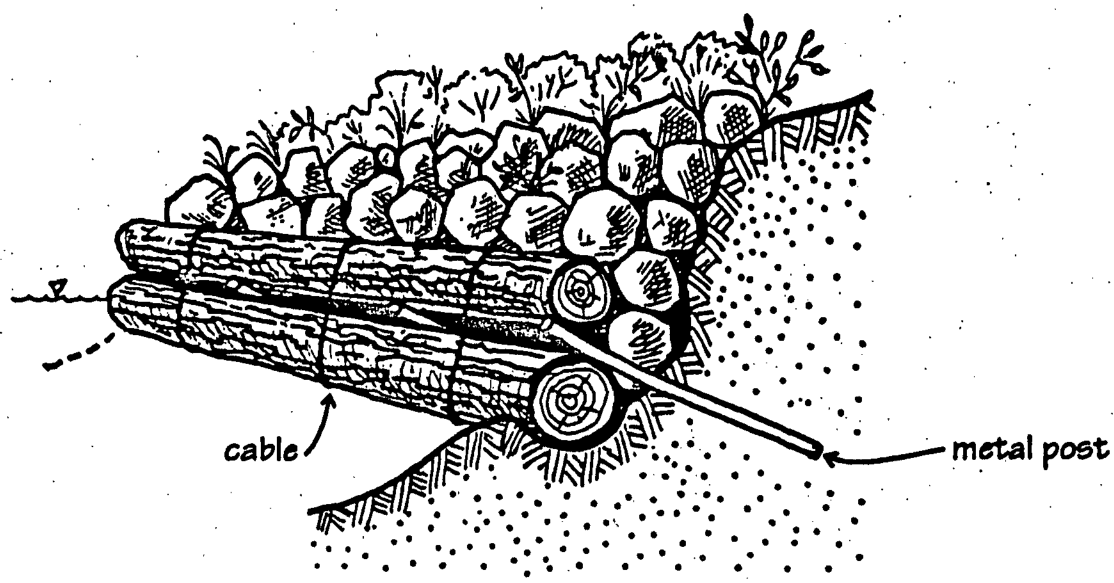


Log Wing Deflectors

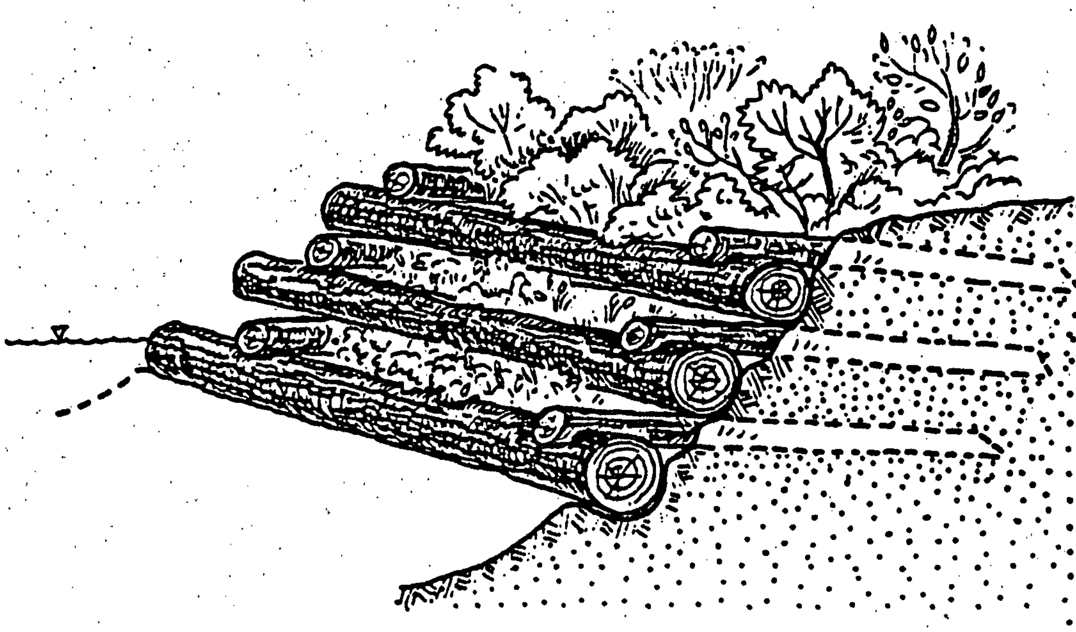


Bank Armor

Log Bank Armor

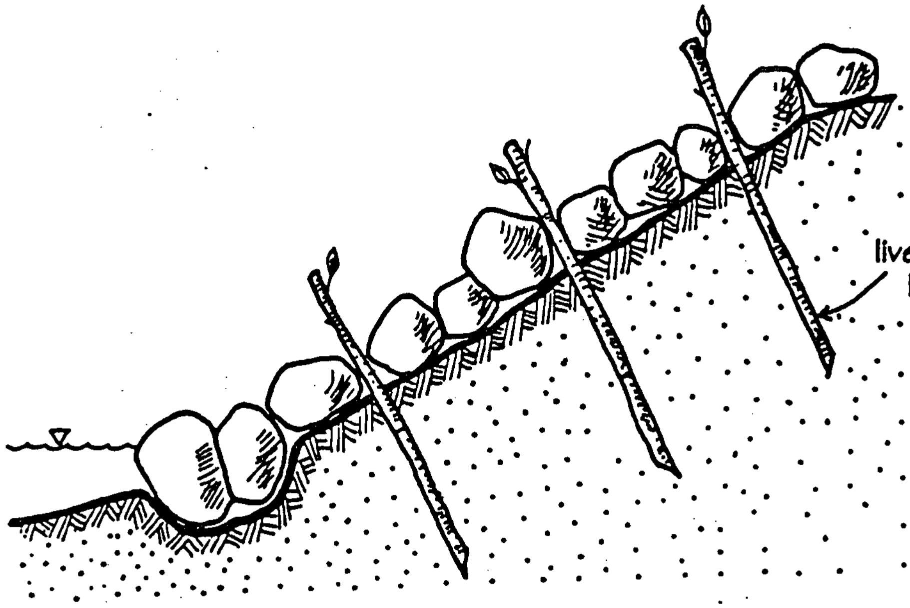


Log Crib Wall

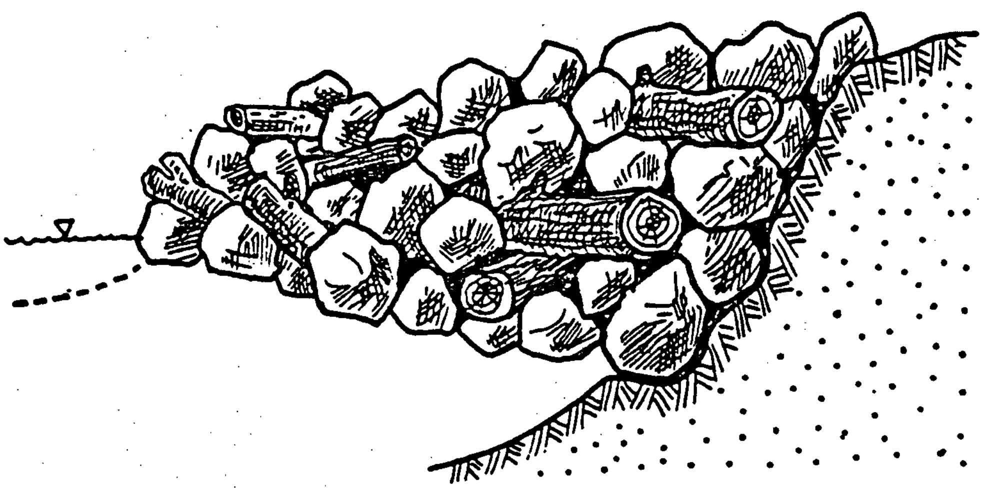


Bank Armor

Planted Rock



Rocks and Logs



from the gully, stopping the headcutting, raising the bed to stop the downcutting (using rock or wood check dams), grading banks to a stable slope, and planting vegetation. Gully stabilization is difficult on steep slopes, such as those in the Arroyo Leon and Mills Creek basins. Stabilization or repair of gullies is relatively expensive, and should only be attempted if the gully adds large volumes of sediment to the tributaries.

Guidelines for Bank Stabilization

- Apply bank stabilization treatments on the scale of a reach. A reach is defined as the length of channel that extends through entire geomorphic feature, such as a meander, to the confluence with a tributary, or between two structures that fix the channel position, such as a bridge or culvert crossing.

- Use vegetative methods for bank stabilization instead of hard structures where possible. Hard structures should not be used to stabilize banks where vegetative methods could be successfully used instead. The benefit of using vegetative techniques as the first approach is they provide bank strength and resistance to erosion. Vegetation is flexible and the stream can still meander naturally without disturbing geomorphic processes upstream or downstream.

- Minimize upstream or downstream impacts of techniques that utilize rock or logs by using vegetation to reduce flow velocity and potential scour. Bank stabilization treatments should not increase erosion potential on upstream, downstream, or opposite banks.

- Create flexible bank stabilization treatments that accommodate the potential for future incision.

- Add vegetation to the channel opposite any structures which may deflect flow. This will minimize the effects of using armor in combination with vegetation.

- Provide additional strength to poorly vegetated banks with little riparian buffer - which have not yet failed - using vegetative techniques. Aggressive riparian planting on banks that have not yet eroded to vertical, or grading and planting on banks would benefit streambank stability and water quality.

- Promote a setback, or riparian buffer adjacent to the channel to minimize the rate of bank erosion. The width of the riparian buffer should be related to the width of the meander corridor of the river. and the optimum width of riparian vegetation As bank erosion occurs and individual trees fall into the creek, a riparian buffer would provide additional resistance to reduce the erosion rate.

- Minimize flood hazard associated with increasing bank vegetation by increasing channel capacity. This can be accomplished by grading vertical banks to a 3:1 slope or creating a terrace adjacent to the channel before planting.

- Use permeable filter fabric on graded slopes to prevent flow from undercutting planted vegetation or armor.

- Stabilize the toe of the bank using rock, logs, or deflectors as part of the treatment where unconsolidated vertical banks could be undercut.

- To prevent future channel incision from undercutting the new bank stabilization structure, use vortex weirs as grade control structures that allow for fish migration. A vortex weir with large boulders placed so that flow can pass between them above the bed of the channel helps minimize bed erosion. Traditional approaches to grade control using concrete or grouted rock are not recommended because over time, they could become a new barrier to fish migration.

- Encourage landowners to protect riparian vegetation in order to minimize bank erosion, and to replant vegetation where it has been removed.

6.2 FISH HABITAT ENHANCEMENT

The stream channels in the watershed are characterized by incision and sandy banks. For this reason, extensive use of fisheries enhancement structures (e.g., wood cover and boulder/log weirs) is not recommended. The most beneficial projects for fisheries in this watershed would be those focused on modification of barriers, increased streamflows, reduced sediment supply, and establishment of a native vegetation canopy. The goal of barrier modification is to provide passage past obstructions that impede upstream migration of salmonids. Modification of downstream barriers must occur before modification of upstream barriers.

Instream Structures

Because of the steep sandy banks throughout the watershed, wood cover or log weirs added to the channel are likely to be undercut and wash out. Bank protection (see Section 6.1) in bends can produce some scour and provide cover for juvenile steelhead. Boulder weirs, sometimes called "Vortex weirs" (with the "V" pointing upstream with spaces between the boulders and with boulder height lower in the center of the channel) can scour summer pools and produce gravel deposition at the pool tail crest. In sandy streams the boulders must be carefully placed to avoid bank erosion and to ensure that the boulders stay in place. The abundant sediment in the watershed will reduce the size of the pools produced and also result in wide seasonal variation in the pool depth and size. If attempted, a small pilot project (about 5-10 widely spaced structures) should be constructed to first determine the amount of habitat produced in a channel with a heavy sand sediment load.

On Pilarcitos Creek, success would be most likely upstream of Corinda Los Trancos where coarser substrate is more common. However, because of the large supply of fine material, even at that location, there will probably be only limited habitat improvement from instream structures.

Fish Ladder Barrier Modification

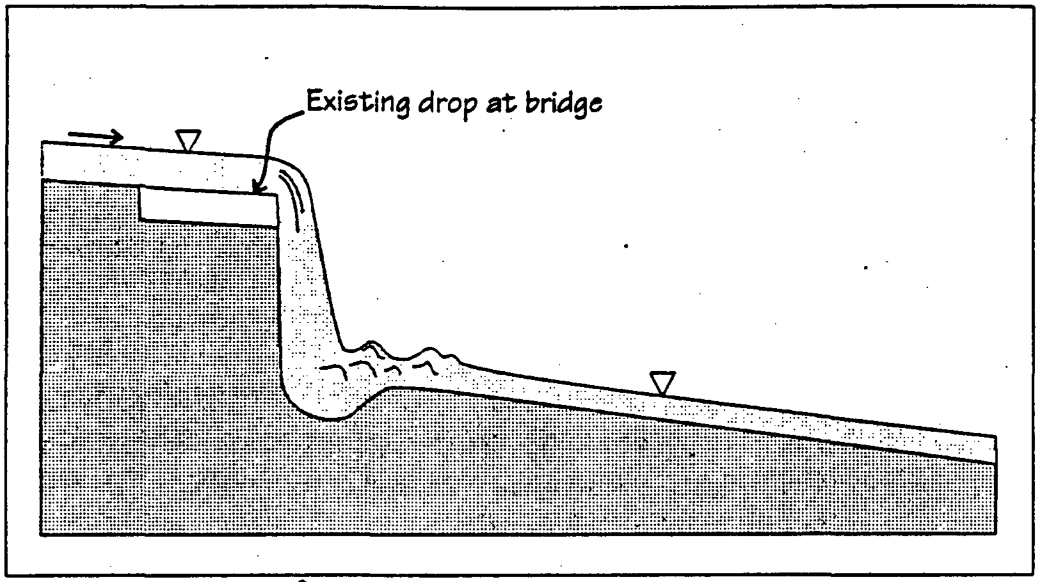
Fish ladders or fishways generally consist of a flume with baffles or a series of step-pool sequences that slow the velocity sufficiently so that a fish can swim upstream. This type of structure consists of a series of vertical partitions installed at intervals down the length of the flume. Water flows over the top of the partitions, each slightly lower than the one upstream creating a series of steps and pools (Flosi and Reynolds, 1994). These structures are prone to blockage with debris and require regular maintenance. Fish ladders are also possible poaching sites.

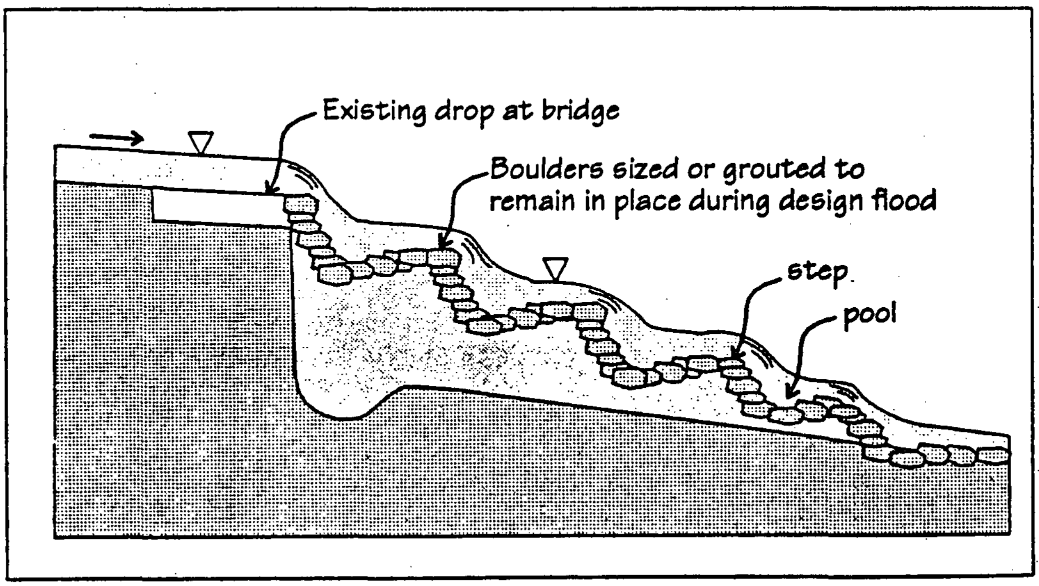
Boulder Step-Pool Sequence Barrier Modification

Existing fish migration barriers may be modified using a boulder step-pool sequence that extend across the entire width of the channel (Figure 24). The boulders are placed downstream of the barrier to imitate a series of short drops with rapidly flowing water and pools where the fish may rest. These features have aesthetic appeal because they form the channel morphology and may be integrated with re-vegetation and bank restoration. A benefit of this type of structure is that the original barrier does not need to be removed, and therefore, the elevation bed of the channel upstream and downstream of the structure will not change. The boulder steps should be placed in a series of steps descending from the top of the dam toward the channel downstream. The gradient of the boulder steps should not exceed about 10 percent. When carefully constructed, the step-pool can provide passage over a wide range of flows without regular maintenance and debris removal.

figure 24

Schematic Longitudinal Profile Showing Modification of Drop to a Series of Boulder Steps





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6.3 REMOVAL OF EXOTIC VEGETATION AND RE-VEGETATION WITH NATIVE PLANT SPECIES

The approach to the proposed restoration projects will consist of four main phases: a detailed pre-project site survey (site analysis), a landowner education program, project implementation, and a follow-up monitoring phase for a period of up to five years.

Pre-project Surveys

Due to the variable existing conditions throughout the watershed, each restoration project will need to be evaluated on a site-by-site basis. The pre-project survey would include observations on the extent of invasive non-native species; appropriate native species for revegetation; potential for natural recruitment of native species; shade, slope, soil texture, nutrients, and moisture content; and potential soil erosion problems. The pre-project surveys will also evaluate the site for fisheries habitat, including downed woody vegetation on or near the creek and existing shade. In certain cases, eucalyptus trees provide needed shade; therefore, phased removal of the eucalyptus trees and replanting of native riparian species may be needed to maintain shade levels. In some cases, there may be landowner or public opposition to tree removal. Educational workshops should reiterate the negative aspects of retaining eucalyptus trees (see Section 6.3 - Exotics Removal) and landowners and the public should be reassured that there will be a phased removal of trees, and replanting with native vegetation that enhances wildlife use. The information gathered during the pre-project survey will be used as a guide for developing the tasks required to implement a given project.

Landowner Education Program

Prior to any vegetation removal, an effort will be made to inform the public about the benefits of removing non-native vegetation in order to restore habitat for native plants and the animals which depend upon them. A mailing explaining the projects should be sent prior to any work, and informal signs should be installed at visible vegetation removal and revegetation sites.

Exotics Removal

The control of invasive non-native plant species is a needed component of the Pilarcitos Creek watershed Restoration plan. Invasive plant species (e.g., pampas grass, German ivy, and French broom) have several detrimental effects on the environment. According to Warner (1993), they cause:

1. The loss of habitat for native plant species through plant competition;

2. The loss of ecological relationships (i.e., loss of food and shelter for wildlife and loss of microclimates for insects and plants);

3. Disruption of soil fungi and microorganisms relationships with plants;

4. Disruption of nutrient cycles;

5. Decrease in biodiversity;

6. The loss of aesthetic and recreational values of native plant communities;

7. Economic losses due to the conversion of timberland to less valuable vegetation types; and

8. The potential of certain exotic plants to contribute to the intensity of wildfires.

Occasionally, there is concern by the public that tree removal has negative impacts on the environment, and that it is unsightly. Before implementing tree removal, landowners and the public should be reassured that removal will be phased to minimize local impacts, that a revegetation plan is in place, and that replanting with native species will enhance wildlife use.

Currently, invasive non-native plant species are displacing and out-competing native vegetation throughout the watershed. The elimination of invasive species would encourage an increase in the number and diversity of native plant species. Of particular concern are infestations of eucalyptus, German ivy, pampas grass, and French broom. German ivy is considered to be the most invasive and most problematic in the riparian corridors of the watershed. This species has spread throughout much of the watershed, and is especially prevalent along Pilarcitos Creek and Arroyo Leon. For example, near the confluence of Pilarcitos and Corinda Los Trancos Creeks, German ivy has become strongly established and is displacing the native vegetation. This species grows as a vine that forms extensive patches that smother native vegetation. German ivy also prevents the establishment of native plants by covering the creek banks and channel edges.

Due to the sensitive nature of the riparian habitats, the use of herbicides will be minimized, unless safe, selective herbicides become available. In addition, the Regional Water Quality Control Board discourages herbicide use in riparian areas. Therefore, mechanical and manual methods are recommended. For more information on the control of invasive species see Appendix B.

Priority Ranking

The invasive non-native species in the watershed have been assigned a Priority Ranking of 1 or 2 (Table 14). Priority 1 non-native species are considered very high priority, being the most invasive and in need of control or eradication. Priority 1 species are usually perennial and spread aggressively. The Priority 1 species observed in the watershed include German ivy, pampas grass, blue gum eucalyptus, and French broom. These species are recommended for removal/control within Years 1 through 5 of the watershed restoration program. Priority 2 species are considered high priority, as they are aggressive and may create large stands. Given site conditions, these species are not considered as invasive as Priority 1 species. These species are often annuals or biennials. Examples of Priority 2 species include poison hemlock, bull thistle, milk thistle, bristly ox-tongue, and garden nasturtium. Bull thistle and poison hemlock have been designated as Priority 2 species because their locations are limited to areas that are not likely to expand significantly in the next 3 to 4 years. Priority 2 species should be removed once Priority 1 species are under control and have either been contained or significantly reduced, depending on the particular species.

Guidelines for Revegetation

After removal of non-native species, native riparian species should be planted, as needed. Suggested tree species are arroyo willow, yellow willow, and red alder. Understory shrub and herbaceous species could include California blackberry, coast elderberry, thimbleberry, creek dogwood, red flowering current, California bee plant, and hedge nettle. Willows can be planted from cuttings taken in mid-winter, while shrubs and herbaceous species may be contract grown from locally collected material in containers (i.e., leach tubes) and planted prior to first heavy rains in the fall. Any bare ground exposed between the time exotics are removed and native species are replanted and established and should receive appropriate erosion control treatment. A specific exotics removal and revegetation plan should be prepared to guide operations at each restoration site.

TABLE 14. Invasive Non-native Plant Species in the Pilarcitos Creek Watershed*

Common Name	Scientific Name
PRIORITY 1 NON-NATIVES	
Pampas Grass	*Cortaderia jubata*
Blue Gum Eucalyptus	*Eucalyptus globulus*
French Broom	*Genista monspessulana*
German Ivy	*Senecio mikanioides*
Bull Thistle	*Cirsium vulgare*

TABLE 14 (continued)

Common Name	Scientific Name
PRIORITY 2 NON-NATIVES	
Poison Hemlock	*Conium maculatum*
Milk Thistle	*Silybum marianum*
Italian Thistle	*Carduus pycnocephalus*
Bristly Ox-tongue	*Picris echioides*
Garden Nasturtium	*Tropaeolum majus*
Wandering Jew	*Tradescantia fluminensis*
Periwinkle	*Vinca major*
Fennel	*Foeniculum vulgare*
Mustard	*Brassica* ssp.

* This is a partial list, especially for Priority 2 species. This should be refined after more field inventory work in each restoration area.

The general revegetation guidelines presented below are subject to refinement during the pre-project surveys for a particular restoration site. Table 15 lists plant species that are appropriate for riparian revegetation in the Pilarcitos Creek watershed. This is a master list which will be modified according to the native plant species in the project's vicinity and the types of propagules available.

TABLE 15. Plant Species Appropriate For Riparian Revegetation in The Pilarcitos Creek watershed*

Common Name	Scientific Name
Trees:	
Arroyo Willow	*Salix lasiolepis*
California Bay	*Umbellularia californica*
California Buckeye	*Aesculus californicus*
Coast Live Oak**	*Quercus agrifolia*
Red Alder**	*Alnus rubra*
Yellow Willow	*Salix lucida* ssp. *lasiandra*
Shrubs:	
California Blackberry**	*Rubus ursinus*
California Rose**	*Rosa californica*

Table 15 (continued)

Common Name	Scientific Name
Coast Elderberry**	*Sambucus callicarpa*
Coffeeberry**	*Rhamnus californica*
Common Snowberry	*Symphoricarpos albus* var. *laevigatus*
Coyote Brush	*Baccharis pilularis*
Ocean Spray**	*Holodiscus discolor*
Creek side Dogwood**	*Cornus californica*
Red Flowering Current**	*Ribes sanguineum* var. *glutinosum*
Thimbleberry**	*Rubus parviflorus*
Toyon**	*Heteromeles arbutifolia*
Herbs and Grasses:	
California Bee-plant**	*Scrophularia californica*
Common Tarweed	*Madia sativa*
Cow Parsnip	*Heracleum lanatum*
Five-Finger Fern	*Adiantum pedatum* var. *aleuticum*
Footsteps-of-Spring	*Sanicula arctopoides*
Fringe Cups	*Tellima grandiflora*
Giant Chain Fern	*Woodwardia fimbriata*
Hairy Wood Sorrel	*Oxalis albicans* ssp. *pilosa*
Hedge Nettle	*Stachys* ssp.
Lindley's Annual Lupine**	*Lupinus bicolor*
Mugwort	*Artemisia douglasiana*
Pacific Starflower	*Trientalis latifolia*
Purple Needlegrass	*Nassella pulchra*
Rush	*Juncus* ssp.
Sneezeweed	*Helenium puberulum*
Sword Fern	*Polystichum munitum*
Western Wild Rye	*Elymus glaucus*
Wild Strawberry**	*Fragaria californica*
Yarrow**	*Achillea millefolium* var. *californica*
Yellow Bush Lupine**	*Lupinus arboreus* var. *arboreus*

* This general palette of riparian plant species should be refined during the pre-project survey, according to the native vegetation present in the vicinity of a given project site.

** Plants that attract birds, butterflies, and other wildlife (have berries, seeds, or nectar).

Genetic Guidelines

To the maximum extent possible, seed and other types of propagation material should be collected on-site in order to preserve the existing gene pool. An exception to this will be the use of cereal barley for immediate interim erosion control if on-site collected material is not yet available. Barley has been selected because it does not readily reseed, therefore, it will not inhibit later permanent revegetation efforts.

Guidelines have been developed to preserve local gene pools that have resulted from a species adapting to its particular environment (Guinon, 1992). Some of the major principles are summarized below:

1. Collect local, native propagules from the site to be restored; do not purchase from nurseries unless the origin of the stock is certified.

2. If there are not enough native species to collect from on the restoration site, collect from closely adjacent native populations of similar ecology and physiography (geographic proximity is not enough). To insure this, collection should be done within the Pilarcitos Creek watershed.

3. Collect from a large number of individuals (donors), especially when genetic variability within stands is large.

4. If it is not possible to collect enough local material, find a nursery that keeps records of plant origins. State or federal nurseries, or native plant societies may have local stock.

Propagule Collection

A revegetation specialist should oversee a propagule collection program for native riparian plant species. With supervision, the collection of propagation materials such as seeds, cuttings, and rhizomes is a task that may be performed by volunteers from the community. The propagation materials should be collected within the riparian corridor of the same creek as the revegetation site. During the growing season, the riparian corridor should be checked every 2 to 3 weeks to collect seeds as they ripen. Table 15 serves as a guide for species that are appropriate for collection. Hardwood cuttings of willow trees may be taken in midwinter and planted directly. Salvage of rhizomes or whole plants of species such as California blackberry and wild rose typically occur in December. Care should be taken to prevent excessive harvest of all species; therefore, the collection of seed, cuttings, etc. should be limited to 10 to 20% of the existing population of the species collected. The collected materials may be sent to a native plant nursery for contract growing of container plants (i.e., plugs, leach tubes, 4-inch pots, one-gallon tree pots). A portion of the collected seed may be processed and stored until early fall and broadcast seeded.

Site Preparation

Proper site preparation is an important component of revegetation success. Prior to planting a given restoration site, the site will need to be prepared including: removing invasive non-native species, leveling uneven contours, and clearing inorganic debris. Application of chemical fertilizer is not recommended, as fertilizer may encourage weeds.

Erosion Control Measures

In some cases, erosion control will be necessary, depending on the amount of soil disturbance left from exotics removal. Barren disturbed areas greater than eight feet across should be seeded the first fall after the disturbance to take advantage of fall/winter rains for germination and plant establishment. Ideally, the seed mix should contain seeds of locally collected native herb and grass species. This may not be possible in all areas due to insufficient amounts of locally collected seed. If a purchased erosion control mix is used, the species should be compatible with future plantings of native, on-site collected seed. For example, cereal barley (*Hordeum vulgare*) does not compete with native vegetation, as it is a short-lived species. In problem areas, hay bales, scattered sterile hay, or wood chips may provide short-term erosion control until native vegetation becomes established.

Plant Installation

The amount of planting needed will depend on several factors, including: the proportion of native vegetative cover; the level of disturbance remaining from exotics removal; and the potential of native plant species to naturally recruit or re-establish at the site. A revegetation specialist should develop a revegetation plan and determine planting densities, according to the results of the pre-project surveys of the particular restoration area. Generally, collected seed is hand broadcast d in early fall and container grown stock is planted in late fall or early winter, depending on local precipitation. Container plantings should be watered after installation. Supplemental irrigation may be necessary for several years after planting.

Monitoring

After exotic vegetation removal and replanting of native riparian species, the restoration site should be monitored to determine whether objectives are achieved. The monitoring of the restoration projects would consist of both quantitative and qualitative methods. The monitoring program should assess a range of performance indicators that adequately describe the functioning of the riparian system. Vegetative monitoring parameters should assess: species diversity, species composition, absolute vegetative cover, extent of invasive non-native species, the extent of natural recruitment, and existing or potential soil erosion. Photo documentation (before and after) is also recommended as a means of tracking project success. The monitoring results will be evaluated annually to determine if additional restoration measures are needed. A brief monitoring report will document success and recommend new or refined methods for project implementation, as needed.

7. ALTERNATIVE RESTORATION PROJECTS

The following sections describe the site specific alternatives identified in each tributary in the Pilarcitos Creek watershed. Alternative projects are also identified for the estuary, and for educational activities. These alternatives are based on the field reconnaissance of the watershed, discussions with the Advisory Committee, and comments received during a public meeting.

7.1 MILLS CREEK AND ARROYO LEON

1. **Increase early spring water releases from two existing in-channel irrigation ponds on Arroyo Leon upstream and downstream of Higgins Road and maintain minimum water levels in the ponds throughout the summer and fall.** This can be accomplished by management (under the long-term supervision of DFG), or by construction or enlargement of an off channel pond:

   - Manage diversions to maintain flows adequate for smolt out-migration in April and May. Manage summer depth in existing ponds to enhance rearing habitat. Provide fish passage over or around when slide gates are closed and alter overflow design to prevent injury to migrating smolts.

   - Create or enlarge an existing off-channel irrigation pond to provide flexibility in the use of the on-channel irrigation ponds. Water could be pumped from Arroyo Leon during the wet season, and stored in the off channel pond. This would reduce the draw down of the on-channel ponds in the late summer and maintain rearing habitat until the fall rains.

2. **Modify fish barrier downstream of historic bridge on Mills Creek in the State Park to provide fish passage using a step-pool sequence or a fish ladder and install Washington Baffles under the bridge.** Because the stone bridge crossing poses a barrier to fish passage, a demonstration project has already been proposed to modify the structure to allow fish passage.

3. **Modify the fish barrier on Mills Creek about 2 miles upstream of the historic bridge (near the water tanks).** This flash board dam system could be managed to provide upstream passage of adults and downstream passage of smolts.

4. **Modify fish barrier downstream of culvert under private culvert on Arroyo Leon.** A private culvert crossing that failed during the winter of 1995 offers the opportunity to modify the existing

fish migration barrier at the culvert outfall below the bridge. A boulder step-pool sequence or fish ladder could be constructed.

5. **Remove exotic vegetation and replace with native vegetation.** The areas where construction disturbance has occurred and non-native species have been removed will need to be revegetated with native vegetation using the species and techniques described in Section 6.3.

- **Eucalyptus Removal.** Due to willing cooperation of State Parks and the large infestation of eucalyptus within Burleigh Murray Ranch State Park, a pilot eucalyptus removal program would be designed for Mills Creek. However, the approach will have general guidelines that would be appropriate for the rest of the creeks in the watershed. First priority for removal would be eucalyptus saplings and then mature trees that are growing directly adjacent to the channel. As labor and funding allow, additional trees outside the creek channel, but within the riparian corridor would be removed. Tree removal should be phased so that existing tree canopies and light regimes (fish shade) are not radically altered prior to re-establishment of a native riparian canopy.

  As a general guideline, it is best to start removing eucalyptus trees located in the uppermost locations of the creek where they occur and then proceed downstream to lower elevation trees. This helps to remove seed and vegetative sources from upper areas that would otherwise travel downstream and recolonize. As soon as a tree is cut, an herbicide should be applied to the cut stump to prevent crown sprouting. For additional information on the control of this species, see Appendix B. Some of the harvested trees would be marketable for pulp or firewood; however, much of the small branches and foliage "slash" would need to be chipped and left in the project vicinity. Disposal of chips could pose a challenge. At Burleigh Murray State Park, the chips may provide useful trail material, whereas in other areas they could be made available to homeowners as garden mulch. The tree removal program should be evaluated for effectiveness, and refined as needed for eucalyptus removal in other portions of the watershed.

  Eucalyptus trees provide needed shade; therefore, phased removal of the eucalyptus trees and replanting of native riparian species may be needed to maintain shade levels. In some cases, there may be landowner or public opposition to tree removal. Educational workshops should reiterate the negative aspects of retaining eucalyptus trees and landowners and the public should be reassured that there will be a phased removal of trees, and replanting with native vegetation that enhances wildlife use.

- **Remove German Ivy from Arroyo Leon and Mills Creek.** German ivy has severely infested most of Arroyo Leon and is out-competing the native vegetation. To a lesser extent, it is also establishing on Mills Creek. German ivy plants that are growing in the channel or on the toe of the creek banks are the highest priority for removal. The removal of German ivy is likely to require on-going control efforts and intensive manual labor. Control measures should be monitored yearly for effectiveness with follow-up plant removal as needed. All removed plant material should be bagged and removed from the site. With appropriate supervision and direction, the California Conservation Corps or student volunteer groups might be suitable labor sources for this task.

- **Eradicate French Broom along Mills Creek and Arroyo Leon.** French broom is becoming established along a portion of Mills Creek and along Higgins Canyon Road, adjacent to the riparian corridor of Arroyo Leon upstream of the confluence with Mills Creek along Higgins Canyon Road. Any noted plants should be removed as soon as possible, while areas supporting this species are still small and manageable. The removal of French broom is suited to manual control methods (e.g., hand pulling or wrenching). A tool called a Weed Wrench has been specifically developed for controlling this invasive non-native species. For more information on controlling French broom, see Appendix B. As discussed above, control measures for French broom should be monitored yearly for effectiveness with follow-up plant removal, as needed. With direction and supervision, the California Conservation Corps or student volunteer groups could be suitable labor sources for this project.

6. **Stabilize eroding creek banks as described in Section 6.1.** Bank erosion is pervasive in Arroyo Leon and Mills Creek. Some of the most severe locations of erosion are mapped on Figure 16. Bank stabilization should be done on the scale of a reach, where a reach is defined as the length of channel through a meander, or between two bridges. The first priority for areas for bank stabilization is the reach adjacent to the proposed demonstration project at the historic bridge. Stabilization of the disturbance to the riparian corridor during construction of the demonstration project is addressed withing the current design. Additional native vegetation could be planted higher on the banks. Reaches of channel extending upstream and downstream of mapped active bank erosion could also be stabilized using grading and vegetative techniques. Grading would be needed because the channel is incised, and banks are steep or vertical. Figure 16 shows active erosion about 1,400 feet upstream of the demonstration project, near the unnamed confluence with Mills Creek downstream of the Historic Bridge, and upstream of a road crossing. Bank stabilization could be conducted along these reaches and extend through geomorphic features, to bridges, or to confluences with tributaries. Even though some portions of the banks are not currently eroding, most of the

banks are steep. To achieve watershed restoration over the long-term in Mills Creek, the length of bank stabilization should be 500-1,000 feet. Small stabilization lengths addressing current active erosion would not significantly benefit habitat. Future comprehensive bank stabilization should start in the upstream portion of the watershed and continue downstream.

On Arroyo Leon, steep eroding banks exceed 20 feet in some locations (for example near Higgins Road). Grading in combination with other treatments would be needed in order to stabilize the banks in these areas. This may not be possible, however, since a 3:1 slope would push the top of bank back by about 60 feet. Live stakes could be used where bank slope is more gentle to increase stability and habitat in other reaches.

7. **Maintain paved and unpaved roads.** Roads should be graded and maintained so that water does not concentrate and cut rills on the roads or hillslopes. Debris eroding from road cuts should not be allowed to enter the creeks.

8. **Stabilize gullies that contribute sediment to creeks.** A present there are approximately 5 large gullies in the Arroyo Leon and 2 in the Mills Creek basin that contribute sediment to the tributaries. The size and quantity of gullies is likely to change in the next few winters as it has in the past two, and a final field evaluation should occur as part of the implementation process. Gullies could be repaired by creating a series of check dams and planting vegetation.

Recommendations to be Accomplished Outside of Restoration Project

- **Promote setback and riparian buffer.** The San Mateo County LCP delineates a buffer to protect riparian habitat in the coastal zone. These recommendations should be promoted throughout the watershed to enhance riparian habitat. Riparian landowner education could emphasize the benefits of riparian protection to minimize loss of land. A dense zone of riparian vegetation will minimize bank erosion because even after one tree is eroded from the bank, numerous other trees and their root systems would offer resistance to erosion. A buffer also filters out fine sediment and pollutants from agricultural activities.

  Riparian protection may also be achieved by purchasing a conservation easement from a willing landowner. A conservation easement is a tool for acquiring open space with less than full-fee purchase, whereby a public agency buys only certain specific rights from the landowner. These may be positive rights (providing the public with the opportunity to hunt, fish, hike or ride over the land), or they may be restrictive rights (limiting the uses to which the landowner may devote the land in the future).

- **Regulate fishing.** If the barriers to migration are removed, the Department of Fish and Game could close the stream to summer fishing to protect rearing steelhead, as is done on all other steelhead streams.

7.2 ALTERNATIVES FOR APANOLIO CREEK

1. **Modify lower fish barrier downstream of the Bongard water diversion pipe to create fish passage.** The lower fish barrier must be modified to allow migration prior to modification of the other upstream barriers. The barrier could be modified using a boulder step-pool sequence or a fish ladder.

2. **Modify middle fish barrier at the Bongard water storage pond.** The barrier is both a drop below the culvert through the dam and the length and slope of the culvert itself. A boulder step-pool sequence could be constructed below the culvert. The culvert could be retrofitted using Washington Baffles to slow the velocity of flow through the culvert.

3. **Modify upper fish barrier downstream of the Gossett road crossing.** The barrier could be modified by constructing a boulder step-pool sequence that extends across the entire width of the channel downstream of the road.

4. **Dredge old diversion pond on Apanolio Creek (upstream of upper barrier) to provide rearing habitat.** If all three of the downstream barriers on Apanolio Creek are modified, the old diversion pond upstream could be dredged to provide summer rearing habitat. With the present rate of sedimentation, however , this would require on-going maintenance.

5. **Remove exotic vegetation and replace with native vegetation.** Eucalyptus removal could be accomplished as described in Section 7.1. Remove exotic German Ivy in Apanolio Creek and replace with Native Vegetation. German ivy is establishing on the lower portions Apanolio Creek. Removal of German Ivy is described in Section 7.1.

   Control Periwinkle and Spiderwort along Apanolio Creek. A secondary priority is to manually remove the patches of periwinkle and spiderwort located near the barns owned by Gil Gossett before they spread to rest of the riparian corridor. Due to the vining habit of these species, control methods will be similar to those used for German ivy. If eradication is not feasible due to budget constraints, then at a minimum these species should be contained to their present location. Existing boundaries should be marked in the field. The use of volunteers would be appropriate for this small-sized project. The effectiveness of the control measures should be monitored on an annual basis.

6. **Stabilize eroding creek banks.** Bank heights exceed 10 feet in most locations, and erosion is common along Apanolio Creek. Stabilization methods are described in Section 6. A priority for bank stabilization are reaches of channel extending upstream and downstream of the proposed barrier modification projects. The three bank erosion sites on Apanolio Creek mapped on Figure 16 would be contained within this work. To achieve restoration over the long-term, bank treatment including grading to a stable slope should extend upstream and downstream at least 1,000 feet of the lower and middle barrier modifications and about 500 feet upstream and downstream of the upper modification. Small stabilization projects at sites of current active erosion would not significantly reduce sediment supply, although it would enhance habitat. Live stakes could be used where bank slope is more gentle to increase stability and habitat in other reaches. Future comprehensive bank stabilization in the watershed should start upstream and continue in downstream reaches.

7. Maintain unpaved roads. An unpaved road that follows Apanolio Creek from Highway 92 to the headwaters of the tributary could be maintained to avoid erosion and creek sedimentation.

Recommendations to be Accomplished Outside of Restoration Project

- Promote setback and riparian buffer as described in Section 7.1.
- Apanolio Creek is already closed to fishing; this policy should be maintained.

7.3 ALTERNATIVES FOR PILARCITOS CREEK

1. **Increase streamflow in Pilarcitos Creek.** In order to accomplish this by voluntary means, a "Pilarcitos Creek Water Users Working Group" could be formed. The goal of this group would be to increase streamflow to provide adequate habitat for fish rearing and migration. The working group would include representatives of the San Francisco Water Department, Coastside Water District, individual property owners; agricultural lessors, or others that depend on water from Pilarcitos Creek. Biologists informed about the water needs of fish would also be part of this group. The group would:

   - define their interests and water use needs;
   - develop long-term water conservation and water use reduction strategies;
   - develop alternative agricultural practices that minimize pesticides, herbicides, and fertilizers to minimize adverse impacts to water quality;

- identify gaps in available data;

- develop a long-term monitoring and enforcement agreement.

The working group could discuss minimum flows and the timing of flows. The desired streamflow increase has not been quantified, but an IFIM (Instream Flow Incremental Methodology) study is not needed. Present rearing flows are sufficiently low that any modest increase (up to 2 cfs) in streamflow would increase steelhead abundance and growth in most years. Substrate conditions generally increase upstream in Pilarcitos Creek, so increased water in upstream reaches would have the most beneficial effect on steelhead abundance.

Other issues which could be addressed by the working group could include increasing flows downstream of Stone Dam; reduced pumping from the Coastside wells; management of water diversions from Pilarcitos Creek, use of tertiary treated wastewater (after the treatment plant is upgraded) for agricultural and landscape (for example for the Colony golf course) irrigation, or to increase streamflow; and water "wheeling;" agreements between districts to trade water. Concerns related to the potential for additional releases in the Upper part of Pilarcitos Creek to be diverted for agricultural or domestic use downstream— and not being available to enhance flows for fish habitat could be discussed by the working group. In order to develop a long-term monitoring and enforcement agreement the working group would need to develop a stream gaging network. This network would provide streamflow data in tributaries (where there is currently little data), and upstream and downstream of diversions in the main channel. Detailed flow monitoring is the only way to assess the accuracy of water usage information. Monitoring could be conduced by a public agency such as RWQCB, DFG or the RCD.

Because the restoration funds cannot be spent on litigation, these measures must be voluntary, and have the cooperation of all of the water users that affect streamflow. A facilitator for a group like this would ideally be from a public agency, such as RWQCB, DFG, RCD, or the Farm Bureau. It is likely that other alternatives that increase streamflows would involve litigation.

Discussions are currently underway between the San Francisco Water Department and the Coastside Water District to modify the present water supply system that pipes water from Stone Dam to the Coastside system. The proposal to route water in the Pilarcitos Creek Channel from Stone Dam to the Coastside infiltration wells field would provide approximately 2 miles of improved summer rearing habitat in Upper Pilarcitos Creek. This type of agreement, that increases flow in parts of the watershed, is one component of the complex actions that could provide adequate flows for fish migration and rearing in the future.

2. **Remove exotic riparian vegetation and replace with native vegetation.** Eucalyptus removal is described in Section 7.1. Upstream of the Confluence with Corinda Los Trancos Creek a section of Pilarcitos (Figure 11), is devoid of trees. The channel and creek banks are severely invaded by German ivy that has displaced the native vegetation, making it difficult for native trees to become established. To a lesser extent, poison hemlock and thistle species are present. A tree overstory is needed to provide shade/cover for fish habitat. The German ivy vines are so thick in some areas that they physically obstruct the channel and may interfere with fish passage. A two phased approach for restoration is recommended. The first phase would consist of controlling the invasive non-native species present. Due to the sensitive nature of the riparian corridor, it is best if manual methods (e.g., hand pulling) are used to remove German ivy and poison hemlock from the channel and then proceed up the banks to the full width of the riparian corridor, as labor and funding allow. This is highly labor intensive and will require on-going control efforts on a yearly basis. This species is highly invasive and spreads from small stem fragments. Monitoring the control efforts will determine whether the control measures are effective and whether the rate of natural recruitment of native plant species is adequate. Although some recruitment of native willow and alder saplings is occurring, it is likely that active revegetation using willow and red alder will be necessary. In some cases, a detailed plan should be prepared prior to exotics removal and revegetation. For more information on controlling poison hemlock and thistle species, see Appendix B.

Remove German ivy within the Main stem of Pilarcitos Creek. The main stem of Pilarcitos Creek is the most infested riparian corridor in the watershed. The first areas proposed for German ivy removal are those lands owned or managed by persons that have authorized surveys and restoration projects on their property. As of October 1995, such areas are lands managed by California State Parks (at Francis State Beach), Jim Cozzolino, POST, and the Half Moon Bay Nursery. German ivy is found in epidemic proportions throughout the main stem of Pilarcitos Creek, and spreads easily throughout the riparian system. In terms of creating improved fisheries habitat, the creek channel and the toe of the banks should be cleared of German ivy first to promote fish passage in the creek. Plants may be manually pulled and dug out, removing both above and below ground plant parts. For the removal program to be effective, additional property owners must be contacted and given incentives to participate in the program so removal may be performed along the entire main stem, contributing to the re-establishment of native plant species to provide shade for fisheries habitat. Due to the severity of the problem and the difficulty of eradicating this species, it is like that yearly, on-going control efforts will be required; therefore, periodic removal costs should be factored into the annual budget for the watershed restoration program.

Control bristle ox-tongue, poison hemlock, garden nasturtium, black mustard, fennel, and bull thistle — Priority 2 Invasive Species. As labor and funding allow, these Priority 2, non-native species should be controlled within the riparian corridors of the watershed. Garden nasturtium is a significant problem within the City of Half Moon Bay. It co-exists with German ivy as a vine, smothering native vegetation. Methods of manual control are appropriate for Priority 2 invasive species. Garden nasturtium is easily removed by hand pulling. Plants should be removed before they set seed. Control will be labor intensive and should be monitored for effectiveness with follow-up plant removal as needed. With supervision, the California Conservation Corps and community volunteers could be suitable labor sources for this task. For more information on controlling Priority 2 invasive, see Appendix B.

Remove pampas grass along Highway 92 upstream from Half Moon Bay Nursery. The landslide on the south-facing slope along Highway 92 in Albert's Canyon has been invaded by pampas grass and a large population of this Priority 2 species has become established. Due to the proximity of these plants to Pilarcitos Creek, they pose a constant source of seed that may spread into the riparian corridor. Pampas grass plants within and adjacent to the riparian corridor should be controlled to the maximum extent possible. Many of the plants are on a steep road cut and are inaccessible or dangerous to remove. For steep areas outside the riparian corridor, alternative removal methods should be considered. This could include use of mountain climbing equipment and backpacks for herbicide application.

3. **Stabilize eroding creek banks.** Bank height in Pilarcitos Creek ranges from about 10 to 20 feet in the reach between Highway 92 and the estuary. Stabilization of banks using grading and vegetative methods combined with a dense riparian buffer on the floodplain would help the creek achieve a dynamic equilibrium over the long-term. Hard structures should not be used unless necessary to protect infrastructure. Bank stabilization projects should be conducted on the scale of a reach, where the length of one meander feature is up to 1,000 feet. Priority should be given to reaches about 1,000 feet upstream and downstream of the confluence with Apanolio and Nuff Creeks. An additional eroding area exists on Pilarcitos Creek upstream of Highway 92 (see Figure 16). Addressing current active erosion in small lengths does not significantly reduce fine sediment contributed to Pilarcitos Creek. Individual property owners could be encouraged to use vegetative techniques to protect property and enhance habitat in the short-term. Future comprehensive bank stabilization should begin at the upstream portion of the watershed and continue downstream.

4. **Maintain paved and unpaved roads.** Unpaved roads through the agricultural areas on the floodplain of Pilarcitos Creek are common. These roads could be maintained to avoid erosion and creek sedimentation.

5. **Modify the fish barrier created by Stone Dam.** This barrier could be modified using a fish ladder. Construction of a fish ladder at Stone Dam on Upper Pilarcitos Creek would allow adult steelhead access to the stream between Stone Dam and Pilarcitos Reservoir. Good summer streamflows are maintained in that stretch of stream as part of the overall San Francisco Water Department water operations. However, stream substrate is sandy and the stream lacks deep pools (Smith, 1991). A

fish ladder would be relatively expensive, considering the present habitat conditions above Stone Dam. In addition, minimum bypass flows are presently not required at Stone Dam, so in dry years, passage flows for smolts in April and May would not be available.

6. **Conduct a pilot project of vortex weir installations between Corinda Los Trancos Creek and Highway 92 to investigate the potential benefit for pool development and spawning gravel entrapment.** Benefits may be limited by the heavy sediment load and careful installation will be required to prevent bank erosion. Addition of spawning gravel in Pilarcitos Creek is unlikely to be remain in place and the weirs must prove successful at trapping gravel, despite the heavy sand sediment load. Monitoring will provide data to determine if these weirs should be attempted over a larger scale.

Recommendations to be Accomplished Outside of Restoration Project

- **Modify Caltrans maintenance practices to reduce sediment contribution from Highway 92.** Debris cleared form the highway should be disposed of in an appropriate location that will not contribute sediment to Pilarcitos Creek. Debris from the active landslide in Albert Canyon on the south facing slope above Highway 92 should be trapped in a debris basin and disposed of in an appropriate location.

- **Promote setback and riparian buffer as described in Section 7.1.** The width of the riparian buffer should be as wide as possible to accommodate the meanders (meander amplitude is approximately 200 to 400 feet) although current land use would constrain the width available. In areas where Pilarcitos Creek has been straightened and the riparian corridor narrowed in the past, the riparian buffer should be wider than it currently is, since it is likely that the creek will attempt to re-establish its width and meandering pattern over time.

- **Fishing is already regulated in Pilarcitos Creek upstream of Highway 1; this policy should be maintained.**

7.4 ALTERNATIVES FOR ESTUARY

1. **Create summer habitat for red-legged frogs and the San Francisco garter snake** (by increasing low flows to estuary—Section 7.3).

2. **Reduce disturbance from recreational use (re-route horse trail).** **In the vicinity of the wooden pedestrian bridge, an existing horse trail passes directly upstream of the Pilarcitos Creek** estuary. The horse manure negatively affects water quality and lowers the value of the fisheries habitat. Horse activity has also reduced the extent of native willow vegetative cover compared to past levels (J. Ferreira, pers. comm, 1995). The main task would be to construct a new bridge for horse use.

3. **Remove exotic vegetation and replant with native vegetation in the Pilarcitos Estuary (and the Riparian Corridor in Francis Beach State Park).** Invasive non-native plants are lowering the riparian habitat value within the Francis Beach State Park. Invasive exotics include German ivy and bristly ox-tongue. The restoration project would have two main tasks: 1) removal of invasive exotics, and 2) revegetation with willow trees. The control of invasive non-native plant species would primarily rely on manual methods. Volunteers from the community or the California Conservation Corps are potential labor sources.

7.5 ALTERNATIVES FOR MADONNA CREEK

1. **Remove exotic riparian vegetation and replace with native vegetation.** Eucalyptus Removal is discussed in Section 7.1. German ivy is establishing on lower portions of Madonna Creek. German ivy removal on Madonna Creek would be similar to that described in Section 7.3. The existing downstream pond (about 3,500 feet upstream of the confluence with Pilarcitos Creek) is poorly vegetated and the majority of the vegetation is non-native. To improve the habitat value of the reservoir and its adjacent surroundings, restoration will require the control of non-native plant species, primarily poison hemlock, black mustard, milk thistle, bristly ox-tongue, and fennel. After or concurrently with the removal of these species, there should be active revegetation of the area with arroyo willow, yellow willow, blackberry, and creek side dogwood to improve the habitat for wildlife.

   In addition to restoring the reservoir area, the remaining portion of the corridor managed by POST should be restored by removing invasive species. Scattered eucalyptus trees in the corridor should be removed as described in Section 7. As funding and labor sources allow, the eucalyptus grove lining the access road should also be removed to avoid future spread into the riparian corridor.

2. **Stabilize creek banks.** The downstream pond is a barrier to fish migration, therefore extensive bank stabilization projects are not warranted. However, eroding banks downstream of the lower pond could be stabilized using live stakes to reduce sediment impacts to Pilarcitos Creek.

3. **Maintain unpaved roads.** Unpaved roads could be maintained to prevent sediment from entering the tributary.

Recommendations to be Accomplished Outside of Restoration Project

- **Promote setback and riparian buffer as described in Section 7.1.**

7.6 ALTERNATIVES FOR NUFF CREEK

1. **Remove Eucalyptus Trees, German Ivy, and Pampas Grass.** Eucalyptus trees, German ivy, and pampas grass plants have invaded the riparian corridor along Nuff Creek, and are prevalent in the vicinity of Pilarcitos Quarry. Eucalyptus, German ivy, and pampas grass are considered Priority 1 invasive non-native species and have top priority for removal. The County of San Mateo has requested that the quarry implement a strategic eradication plan for the infestation of blue gum eucalyptus and pampas grass on the quarry property. The County has recommended that a Registered Professional Forester put together a timber harvest plan and that tree harvesting be done only during periods of low flow, typically July through September.

As a condition of the Pilarcitos Quarry Surface Mining Permit (SMP 84-1) and the Coastal Development Permit, the County of San Mateo has requested that the applicant remove eucalyptus saplings that are three inches or less in diameter from the channel of Nuff Creek in order to curtail the spread of trees within the riparian corridor. No tree cutting permit would need to be obtained for removing eucalyptus trees (Sam Herzberg pers. comm, 1995).

Several sizable areas of German ivy occur upstream of the center of quarry operations (Figure 11). In some areas, the German ivy dominates the riparian corridor, and extends into the adjoining woodland. Removal of German ivy upstream of the quarry operations would help to enhance the riparian corridor for wildlife use by reopening areas for native vegetation. Manual methods of removal are recommended due to the sensitive nature of the riparian corridor. Any detected plants of German ivy should be hand pulled and underground portions dug out. All removed plant material should be bagged and removed for the restoration site, as stem fragments may produce new plants. Control will be difficult and labor intensive and should be monitored yearly for effectiveness with follow-up plant removal and revegetation as needed. The California Conservation Corps could be a suitable labor source for this task.

Any pampas grass noted within the riparian corridor should be removed by manual methods. The use of herbicides should be avoided due to close proximity to the creek. Well-established plants should be removed first as they have the highest reproductive potential due to their prolific seed heads. For more information on controlling pampas grass and German ivy see Appendix B. The effectiveness of removing the eucalyptus trees, German ivy, and pampas grass from the Nuff Creek riparian corridor should be monitored on an annual basis and surviving target species removed.

The disturbed mining area of Pilarcitos Quarry (outside the riparian corridor) has been invaded by pampas grass, and a large population of this species has become established. Due to the proximity of these plants to the riparian corridor, they pose a constant source of seed that may spread into the riparian corridor. Pampas grass plants within and adjacent to the riparian corridor should be controlled to the maximum extent possible. Many of the plants in the mining area are located on very steep slopes and, therefore, are inaccessible or dangerous to remove. For steep areas outside the riparian corridor, it is recommended that the feasibility of using backpack mounted sprayers for herbicide application be investigated. However, vegetation on steep slopes should not be removed unless careful erosion control measures are implemented and native species are replanted.

Recommendations to be Accomplished Outside of Restoration Project

- Promote setback and riparian buffer as described in Section 7.1.
- Maintain debris basins downstream of the quarry operations that trap sediment from upstream as currently required.
- Maintain unpaved roads.

7.7 ALTERNATIVES FOR CORINDA LOS TRANCOS CREEK

1. **Stabilize eroding creek banks and restore riparian habitat in the lower portion of Corinda Los Trancos Creek where erosion took place during the BFI sediment spill.** Rip-rap was used for erosion control, downstream of Highway 92, but no riparian habitat was established. Riparian trees could be planted in this area to provide habitat.

2. **Remove exotic riparian vegetation and replace with native vegetation.** Eucalyptus Removal is discussed in Section 7.1. Restoration will require control of non-native plant species (primarily poison hemlock and German ivy) and active revegetation of the area with arroyo willow, yellow willow, and creek side dogwood to improve the habitat for wildlife.

Recommendations to be Accomplished Outside of Restoration Project

- **Stabilize eroding creek banks upstream of Highway 92.** Bank erosion in Corinda Los Trancos is severe and habitat would be improved by continued stabilization and re-vegetation of banks.

- **Create setback and riparian buffer as described in Section 7.1.**

- **Maintain unpaved roads to reduce sediment supply to downstream areas.**

- **Control leaching from landfill to minimize downstream water quality degradation.**

7.8 EDUCATIONAL ALTERNATIVES

1. **Provide resources for workshops for landowner education.** Workshops to educate riparian and agricultural landowners and residents could be facilitated by the local RCD, Farm Bureau, San Mateo County, or the Half Moon Bay Public Works Department. Restoration funds may be used for this purpose. Topics of relevance to the restoration plan include:

- The role of riparian vegetation for fish habitat and bank stabilization;
- Improving water quality by reducing pesticides, herbicides, and by minimizing erosion;
- Water conservation;
- Control measures for invasive non-native plant species;
- Long-term channel maintenance plans;
- Monitoring restoration projects.

Recommendations to be Accomplished Outside of Restoration Project

Provide resource list for interested science teachers in the watershed. The following list of resources could be used by local elementary or secondary school educators to propose an age-appropriate scientific program. The following list of resources could aid in the design of curriculum and watershed activities, however, the restoration fund cannot be used for classroom activities.

— Kids in Creeks: A Creek Exploration and Restoration Program—San Francisco Estuary Institute. A 20 hour K-12 teacher training workshop with teaching materials developed for the local creek. A special workshop could be developed for Pilarcitos Creek watershed. Contact: Kathy Kramer (510) 231-9539 ex 211.

— Salmon and Trout Education Program—Monterey Bay Salmon and Trout Project. Educational materials and activities for salmon and trout life cycles and habitat. Contact: Matt McCaslin (408) 426-3600 or (408) 426-6165.

— Teaching About Watersheds—San Francisco Estuary Institute and the Department of Biological Sciences CSU Hayward. A conference with symposia, workshops a curriculum fair and field trips for educators to effectively teach about watersheds. Contact: San Francisco Estuary Institute (510) 231-9539.

— State Parks—Local educators could coordinate with the program State Parks is currently developing in the Pilarcitos Creek watershed. Contact: Heidi Horvitz (415) 726-8819.

— Water Education Foundation Materials and Publications—Background information on western water issues including a water conservation video and classroom materials for grades 4-12. Contact: Water Education Foundation (916) 444-6240.

— Hands on Save Our Streams—Izaak Walton League. Grade 1-12 teacher's manual to help students make a difference in protecting their environment. Contact: Karen Firehock, IWLA (301) 548-010.

— California Aquatic Science Education Consortium—Learning Activities for Youth Groups, Age 10-15: "Water Inspectors, Examining H_2O;" "Fresh Water Guardians, Defending Our Precious Supply;" Creek Watchers, Exploring the Worlds of Creeks and Streams. Contact: Graduate School of Education, UCSB (805) 893-2739.

— Global Rivers Environmental Educations Network (GREEN)—Designs Watershed Workshops to help educators develop watershed education programs. Topics include monitoring from chemical or biological attributes. Special workshop could be developed for Pilarcitos Creek watershed for a fee. Contact: Lisa Bryce Lewis (206) 5228489 or (313) 761-8142.

— Britannica Science System—FOSS Integrated with Multimedia Materials produced by UC California Lawrence Hall of Science. Earth Science Modules with activities for Earth Materials, Water, and Landforms. Contact: Britannica Educational Corporation, 310 South Michigan Avenue, Chicago Il 60604.

- Shorebird Nature Center Teachers Packet—City of Berkeley. Field trip and pre-and post- trip survey questions. Contact: Shorebird Nature Center (510) 644-8623.

- Pescadero High School Biology Teacher. Contact: Steve Maskel (415) 879-0274.

- San Mateo County Environmental Health Storm Water Program. Contact: Dwane O'Donnel (415) 363-4708.

- Coyote Creek Riparian Station—Community Creek Watch and Adult Training. Contacts: Mike Rigney and Karen Cotter (408) 262-9204.

- San Mateo County Fish &Wildlife Committee. Contact: Jerry Hearn (415) 851-2718, (415) 325-1584.

- Department of Fish and Game Aquatic Project Wild. Contacts: Ms. Rebecca Miller (916) 653-6132.

- UC Sea Grant Extension Program. Contact: Jodi Cassel (415) 871-7559

Organize Clean-up Program on Pilarcitos Creek and Arroyo Leon within the City of Half Moon Bay. Specific areas in need of clean-up were observed along Pilarcitos Creek downstream of Highway 1 adjacent to residential areas and along Arroyo Leon from Kelly Ave to Magnolia Street. The garbage, debris, and yard clippings lower habitat value of the creek. Clean-up should be on-going, and involve the city residents as part of a volunteer program. The restoration project cannot fund these activities.

8. MONITORING AND MAINTENANCE RECOMMENDATIONS

Maintenance of restoration projects should be based on monitoring data collected in the project area, and upstream and downstream reaches. Data should be collected at least once a year for the first five years following construction. During years with only small floods, monitoring activities should take place following the last rains in spring. During years with one or more moderate or small floods, measurements should be taken after every flood. Long-term monitoring is encouraged as an educational tool to learn about the benefits of watershed restoration. Most of the monitoring activities may be conducted with volunteers under guidance of a geomorphologist or biologist. A brief report summarizing the results of the physical and biologic monitoring should document the evolution of the sites over time. The summary should also recommend any required maintenance.

8.1 GEOMORPHIC AND HYDROLOGIC MONITORING

Physical monitoring requirements of the restoration projects should include surveyed channel cross-sections, longitudinal profiles, bed material measurements, geomorphic maps, and periodic discharge measurements.

Cross-sections. Surveyed channel cross-sections should be located at permanently monumented sites upstream, downstream and within the project area. Cross-sections should extend from the top of bank to the opposite top of bank and show the morphology of the channel including the portion below the water surface. Cross-sections should be consistently located over geomorphic features such as at the head of riffles, across the deepest part of pools, or across particular types of channel bars when possible. Survey notes should describe geomorphic features including top and base of bank, edges of bars, thalweg (the deepest part of the channel), and sediment characteristics. All cross-section elevations should be tied into a benchmark referenced to NGVD.

Longitudinal Profile. A longitudinal profile should extend from upstream of the project area to downstream of the project area. Profile points should be surveyed in the thalweg, and be detailed enough to illustrate the channel morphology. Distance measurements should be based on River Mile upstream of the Ocean, or continue to a permanent or reproducible location marker such as a bridge. Distance should be measured along the centerline of the channel (not the meandering low flow channel). Profile elevations should referenced to NGVD.

Geomorphic Maps and Photo Documentation. Geomorphic maps may be constructed using a tape and compass for the project reaches to illustrate channel morphology. Maps should illustrate bed and bank characteristics of the channel and particle size. Photographs of the project sites should be taken before construction, and again during each monitoring session.

Hydrology and Sediment Transport. If no gaging station is located near the study reach, velocity and discharge measurements are required to establish a rating curve. These measurements should always be taken at the same stable cross-section and should be measured over a range of flows. Discharge and bed material measurements including suspended and bedload transport measurements are useful as an educational tool to compare sediment yield from tributaries with differing land use practices.

8.2 FISHERIES MONITORING

Monitor Fish Ladders. If fish ladders or boulder-weirs are installed on Apanolio, Arroyo Leon and/or Mills Creeks, a fisheries biologist will need to complete the following steps during the first winter:

- monitor for clogging caused by debris;
- monitor a variety of flows to ensure adequate upstream fish passage; and
- correct any design problems.

Furthermore, a long-term monitoring plan should designate responsibility for long-term monitoring and maintenance.

Monitor Vortex Weirs. If vortex weirs are installed on Pilarcitos Creek in order to produce pools and provide for gravel deposition at the pool tail crest, a fisheries biologist will need to:

- inventory sites before construction;
- monitor the extent and type of habitat during and after the first winter; and
- check for structure failures (boulder movement) and installation problems (bank failures) over the long term.

Monitor Ponds. During the first average to dry rainfall year, the water levels and water quality (temperature, dissolved oxygen) need to be monitored in the ponds on Arroyo Leon and Apanolio Creek—from late summer and through the fall. Water level monitoring requires installing staff gages on the upstream side of each dam. Water quality and temperature monitoring in ponds is described below.

Monitor Streamflow. Streamflow is a major constraint on steelhead abundance in the watershed. There is only one streamflow USGS gage in the Pilarcitos Watershed, located near Highway 1. Past records show no flow at the gage during the late summer in most years and there no record of flow conditions elsewhere in the watershed. Automatic recording gages are expensive to install and operate. Instead, qualitative or semi-quantitative flow monitoring by volunteers could provide useful information on flow conditions. Department of Parks and Recreation personnel (or volunteers) could record the sandbar's opening and closure at the stream mouth. As part of fish passage devices, staff gages and/or notched weirs can be installed at the following locations: 1) the culvert upstream of Mills Creek on Arroyo Leon; 2) the historical bridge on Mills Creek; and 3) the downstream barrier on Apanolio Creek. Weirs and staff gages could also be installed at: 1) the Highway 92 bridges; 2) on Pilarcitos and Nuff Creeks; 3) on Corinda Los Trancos; and 4) the Highway 92 bridges on Nuff, Apanolio, and Corrinda Los Trancos Creeks; and 5) at a downstream Half Moon Bay bridge crossing on Arroyo Leon. Staff gages will allow both landowners and volunteers to monitor summer and fall low flows, if stage-discharge curves are developed. Flow records will provide a long-term record of when stream sections run dry or when flows run too low to provide for adult or smolt passage. These records could be kept permanently at the Resource Conservation District office or some other suitable location.

Monitor Temperature, Water Quality and Substrate. During the fall semester, age-appropriate school classes could monitor steam water temperatures in the watershed with maximum-minimum thermometers (or HOBO temperature recorders). (The monitoring of stream water quality with pH, nitrate, phosphate, dissolved oxygen and other educational test kits is unlikely to provide useful information as these parameters are not a significant problem for stream water quality in the watershed.) It is important to monitor substrate percent composition and pool depth—but changes are subtle and difficult to observe; photographs at representative sites can provide valuable long-term records.

8.3 VEGETATION MONITORING

Photodocumentation. Prior to any restoration efforts, the baseline conditions at the restoration site should be documented by a series of panoramic photographs and documenting the locations from which the photographs were taken. The locations from which the photographs are taken should be mapped on a topographic map and staked in the field in order to establish permanent photo stations. On an annual basis sin spring, photographs should be reshot from these photo stations as a means of tracking changes in vegetative cover, species composition, and the amount of bare ground. It is anticipated that landowners or interested volunteer groups will take the photos.

Monitoring of Exotics Removal. On an annual basis in spring, there should be field surveys for invasive non-native species in restoration areas where Priority 1 Species have been removed. The surveys will evaluate whether control measures have been effective, and whether additional removal of invasive species is needed. Problem areas should be mapped and flagged in the field, as appropriate. Seeds of French broom remain viable in the soil for many years, and previously cut stems of German ivy or stumps of eucalyptus will resprout.

As a reasonable goals, by the end of three to five years of control efforts, Priority 1 invasive non-native species (Table 14) should not exceed 10% (all Priority 1 Species combined) of the total absolute vegetative cover of the restoration area.

Monitoring of Revegetation Efforts. For three to five years after planting, a given revegetation area should be monitored on an annual basis in the spring. The monitoring should be supervised by a revegetation specialists that has demonstrated experience in revegetation monitoring; however, volunteers from the community or college students can assist with the field work and data collection. The monitoring should evaluate shifts in species composition, number of native species (species richness), revegetation success, absolute vegetative cover, and erosion potential. Notes on browse damage and weeds should also be recorded.

In general, by the end of five years after planting, at least 60% of the area should be vegetated and a minimum of four native plant species represented. For steep areas planted for erosion control, 80% total vegetative cover is preferred. If the proportion of native species and vegetative cover are not showing an increasing trend, remedial measures and alternative management practices should be implemented. To measure revegetation success, a survival count according to species may be conducted for installed containers such as one-gallons or leach tubes. Observational notes are more appropriate for seeded areas. The types of species used for revegetation may need to be refined, depending on which species prove to be strong performers.

Monitoring of Natural Recruitment. The level of natural recruitment of native plant species within each restoration area should be documented through reconnaissance-level field surveys. The survey should be performed by a botanist who is familiar with the native species in the Pilarcitos watershed. The rate of natural recruitment will vary, depending on the native vegetation density. The results of these surveys will serve as guide to determine which areas will require additional active revegetation.

9. COST ESTIMATES OF POTENTIAL PROJECTS

Tables 16 through 24 show cost estimates for the various alternatives described in Section 7. The costs estimates provide a high and low range and will depend on the final design adopted for implementation. The estimates provided are used in Section 10 to assign priorities to the potential restoration project alternatives.

TABLE 16. Cost Estimate for Mills Creek and Arroyo Leon *

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Modify Irrigation Ponds			
	a. Management			
	b. Construction	$250,000	$500,000	We roughly estimated that a 25 acre foot storage dam would require approximately $320,000 to design and build.
2	Modify Barrier at Historic Bridge on Mills Creek	$66,000		
3	Modify Barrier 2 miles upstream on Mills Creek	$5,000	$50,000	PCI has virtually no information on this barrier
4	Modify Barrier at Arroyo Leon Culvert	$54,000		
5	Stabilize Banks at Historic Bridge on Mills Creek			
5.1	Reslope, no toe protection, cover with erosion control blanket, reseed, reveg with willows, no establishment period	$3,000 per 100 linear feet of bank	$15,000 per 100 linear feet of bank	Soil disposal is on site, access is good, market wages (not prevailing wages), assumes max bank height of 20'.
5.2	Willow wall with toe rock toe protection	$8,000 per 100 linear feet of bank	$20,000 per 100 linear feet of bank	Soil disposal is on site, access is good, market wages (not prevailing wages), assumes max bank height of 20'.
5.3	Rock and willow slope protection with vertical toe	$9,000 per 100 linear feet of bank	$20,000 per 100 linear feet of bank	Soil disposal is on site, access is good, market wages (not prevailing wages), assumes max bank height of 20'.
5.4	Install willow sprigs	$1,000 per 1000 feet of channel	$2,500 per 1000 feet of channel	Install sprigs (18" long, 12" in ground) within 5 feet of thalweg elevation of channel. Approximate spacing of 10' by 3'. Costs assume no establishment period maintenance.
6	Remove Exotic Eucalyptus and Replace with Native Species			

*Note: These cost estimates prepared by Prunuske-Chatham are general in nature. They are intended to assist in setting priorities and for estimating program budgets. Except for Items 2 and 4 in Mills Creek and Arroyo Leon, there are no plans, dimensions or drawings.

TABLE 16 (continued)

Alternative		Approx Low Cost	Approx High Cost	Comments
6.1	Remove Eucalyptus	$50,000	$1,000,000	Approximately 53 acres. Low cost assumes that substantially all material is larger than 5" and accessible by tractor and truck and that stands of eucalyptus are several acres each. No clean-up of slash or road restoration required. The high estimate assumes most material is under 5", slash will have to be piled and burned, temporary skid trails and roads will have to be removed, some areas do not allow tractor access and stands are small and scattered.
6.2	Install and Establish Native Species	$250,000	$700,000	Approximately 53 acres total. Low cost assumes that 50% of revegetation is with native grasses and 50% with riparian forest, all areas are tractor accessible, and herbicides can be used to prepare the site. High cost estimate assumes 80% of revegetation is riparian shrubs and trees requiring a strong 3 year establishment period. No herbicide use.
7	Maintain Unpaved Roads			
	Install concrete wet crossing (ford)	$1,700 per wet crossing	$4,000 per wet crossing	Replaces culvert. Wet crossings do not plug during stormy weather.
	Recut road grade to improve drainage	$3 per cubic yard of earth moved	$20 per cubic yard of earth moved	
	Grade road for removing ruts	$600 per mile	$2,000 per mile	
8	Stabilize Banks			
	Mills Creek at Road Crossing			See Item 5 above.
	Arroyo Leon at Ponds			See Item 5 above.
9	Stabilize Gullies			We expect that repairing the major gullies in the Mills Creek Watershed would be a low six figure number.

TABLE 16 (continued)

Alternative		Approx Low Cost	Approx High Cost	Comments
	Install Loose rock headcut control	$2,000 each	$12,000 each	Typically 1 to 3 needed per gully. Assumes truck and equipment access is available.
	Install loose rock check dam	$2,000 each	$12,000 each	Many may be needed per gully, depends on slope and length of gully, soil type and presence of bed rock, and landuse such as livestock or cultivation.
10	Stabilize Remaining Banks			See Item 5 above.
11	Remove Exotics and Replace with Native Species			
11.1	German Ivy	$100,000	$300,000	23 acres total. The low end of the cost range assumes the use of herbicides, that ivy is in large contiguous stands and native grass revegetation is needed. The high end of the cost range assumes the use of labor only, that no herbicides are used, sites are discontinuous and small and substantial riparian forest revegetation is needed.
11.2	French Broom	$4,000	$15,000	Total of 0.3 acres. Low cost assumes native grass reseeding, herbicides can be used and slash can be burned on site. High costs assumes no herbicide, native grass revegetation with a 2 year establishment period.

TABLE 17. Cost Estimate for Apanolio Creek *

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Modify Lower Fish Barrier	$35,000	$60,000	
2	Modify Middle Fish Barrier	$15,000	$50,000	
3	Modify Upper Fish Barrier	$35,000	$60,000	
4	Stabilize Banks at Barrier Modification Projects			See Item 5 under Mills Creek and Arroyo Leon. Also, depending on the site conditions, the passage barrier may provide adequate bank stability.
5	Remove Exotic Eucalyptus and Replace with Native Species	$35,000	$140,000	7.0 acres total. See Items 6.1 and 6.2 under ills Creek and Arroyo Leon for additional comment.
6	Maintain Unpaved Roads			See Item 7 under Mills Creek and Arroyo Leon.
7	Dredge Old Diversion Pond	$6 per cubic yard	$25 per cubic yard	The low cost assumes good access and disposal of the material on site. The high end of the cost range assumes that the material will have to be hauled less than 20 miles.
8	Stabilize Remaining Banks			See Item 5 under Mills Creek and Arroyo Leon.
9	Remove Exotics and Replace with Native Species	$8,000	$35,000	3.4 acres total. See comments at Apanolio Creek Items 11.1 and 11.2.

*Note: These cost estimates prepared by Prunuske-Chatham are general in nature. They are intended to assist in setting priorities and for estimating program budgets. Except for Items 2 and 4 in Mills Creek and Arroyo Leon, there are no plans, dimensions or drawings.

TABLE 18. Cost Estimate for Pilarcitos Creek *

Alternative	Approx Low Cost	Approx High Cost	Comments
1 Increase Instream Flow — Stone Dam to Wells			
2 Stabilize Banks			
a. Upstream and Downstream of Apanolio Creek			See Item 5 under Mills Creek and Arroyo Leon.
b. Upstream and Downstream of Nuff Creek			See Item 5 under Mills Creek and Arroyo Leon.
c. Upstream of Corinda Los Trancos Creek			See Item 5 under Mills Creek and Arroyo Leon.
d. Upstream of Highway 92			See Item 5 under Mills Creek and Arroyo Leon.
3 Remove Exotic Eucalyptus and Replace with Native Species	$150,000	$400,000	24 acres total. Includes groves along Hwy. 92. See Items 6.1 and 6.2 under Mills Creek and Arroyo Leon.
4 Maintain paved and Unpaved Roads			See Item 7 under Mills Creek and Arroyo Leon.
5 Install Vortex Weirs	$2,500	$10,000	
6 Modify Fish Barrier at Stone Dam	$80,000	$120,000	Stone dam is approx 30 feet high.
7 Increase Instream Flow — Wells to Estuary			
8 Stabilize Remaining Banks			See Item 5 under Mills Creek and Arroyo Leon.
9 Remove Exotics and Replace with Native Species	$120,000	$400,000	30 acres of German ivy. See additional comments at Mills Creek and Arroyo Leon Item 11.1.

*Note: These cost estimates prepared by Prunuske-Chatham are general in nature. They are intended to assist in setting priorities and for estimating program budgets. Except for Items 2 and 4 in Mills Creek and Arroyo Leon, there are no plans, dimensions or drawings.

TABLE 19. Cost Estimate for Estuary*

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Reduce Disturbance (Construct New Horse Bridge)	$50,000	$100,000	The low cost estimate assumes a medium weight capacity one span bridge shorter than 70 feet. The high cost estimate assumes a two span bridge each span less than 70 feet.
2	Remove Exotics and Replant with Native Species			Included with Pilarcitos Creek.

TABLE 20. Cost Estimate for Madonna Creek*

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Stabilize Banks			See Item 5 under Mills Creek and Arroyo Leon.
2	Maintain Unpaved Roads			See Item 7 under Mills Creek and Arroyo Leon.
3	Remove Exotic Eucalyptus and Replant with Native Species	$30,000	$100,000	6 acres total. Includes trees along road. see Item 6 under Mills Creek and Arroyo Leon.
4	Remove other Exotics and Replant with Native Species	$16,000	$50,000	4 acres of German ivy. See Item 11 under Mills Creek and Arroyo Leon.

TABLE 21. Cost Estimate for Nuff Creek*

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Remove Exotic Eucalyptus and Replant with Native Species	$120,000	$250,000	12 acres. See Item 6 under Mills Creek and Arroyo Leon.
2	Remove Other Exotics and Replant with Native Species	$40,000	$100,000	9 acres of German ivy and pampas grass. See Item 11 under Mills Creek and Arroyo Leon.

*Note: These cost estimates prepared by Prunuske-Chatham are general in nature. They are intended to assist in setting priorities and for estimating program budgets. Except for Items 2 and 4 in Mills Creek and Arroyo Leon, there are no plans, dimensions or drawings.

TABLE 22. Cost Estimate for Corinda Los Trancos *

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Restore Riparian Habitat Downstream of Highway 92	$5,000 per acre	$20,000 per acre	The low end of the range assumes a favorable site condition with a minimal one year establishment period. The high end assumes a challenging site condition and strong establishment period maintenance regime for 3 years.
2	Remove Exotics and Replant with Native Species	$35,000	$100,000	3.5 acres. See Item 6.1 and 6.2 under Mills Creek and Arroyo Leon.

* Note: These cost estimates are general in nature. They are intended to assist in setting priorities and for estimating program budgets. Except for Items 2 and 4 in Mills Creek and Arroyo Leon, there are no plans, dimensions or drawings.

TABLE 23. Cost Estimate for Education

Alternative		Approx Low Cost	Approx High Cost	Comments
1	Provide Resources for Workshops	$5,000	$10,000	Cost per workshop

TABLE 24. Cost Estimate for Monitoring

Alternative		Approximate Annual Cost *	Comments
1	Monitor Fish Barrier		
	Cross-sections	$500	2 cross-sections per barrier
	Longitudinal Profile	$500	assume 200 ft
	Photo Documentation	$50	at monumented sections
	Geomorphic Map	$250	using as-built as base map
	Stream Gaging	$3,200	installation and monitoring; 5 days
	Temperature	$570	using HOBO temp. $70 per instrument; data analysis
	Revegetation & Natural Recruitment	$4,000	per acre
	Sediment Transport	$5,500	monitoring at same time as stream gaging
	Total	$14,570	
2	Monitor Vortex Weirs	$4,500	visual inspection and pre- and post-installation electroshocking
	Total	$4,500	
3	Monitor Fish Ladders	$1,500	visual inspection/per ladder; 5 days
	Total	$1,500	
4	Monitor Bank Stabilization		
	Cross-sections	$5,000	10 cross-sections
	Longitudinal Profile	$1,000	per mile reach of channel
	Photo Documentation	$50	at monumented stations
	Geomorphic Map	$500	using as-built as base map
	Stream Gaging	$3,200	installation and monitoring; 5 days
	Revegetation & Natural Recruitment	$4,000	per acre
	Sediment Transport	$5,500	monitoring at same time as stream gaging
	Total	$19,250	

* Costs reflect maximum estimates on a per structure basis. If more than one structure is monitored, costs would be reduced. Costs reflect monitoring by trained professional.

10. ASSIGNING PRIORITIES TO POTENTIAL RESTORATION PROJECTS

10.1 1996 DEMONSTRATION PROJECT

Design drawings and construction specifications for modification of the fish barrier downstream of the historic bridge on Mills Creek in the State Park are complete (Prunuske Chatham, February 1996). This demonstration project will modify the fish barrier downstream by providing fish passage using a step-pool sequence or a fish ladder. This project was chosen by the Pilarcitos Creek Advisory Committee for early rapid implementation because:

- the project will allow fish migration to several miles of habitat in the upper portion of Mills Creek, and is likely to be successful in the long-term;
- State Parks is interested in the project and integrating it with its own long-term goals;
- the project may be integrated with other restoration project alternatives such as bank stabilization, removal of exotic vegetation and replanting with native vegetation, modification of the small barrier about 2 miles upstream of the bridge, and improved road maintenance;
- the project is on public land and will be accessible, and may be used in education of the public about watershed restoration, and the physical and biologic processes, and human activities that degrade the watershed.

In order to ensure the success of the barrier modification in Mills Creek, the two irrigation ponds downstream on Arroyo Leon must be managed to allow upstream migration of adults and downstream migration of smolts (as described in Section 7.1).

10.2 FUTURE PROJECTS — 1996 TO 2000

Priorities for restoration project alternatives for the Pilarcitos Creek watershed were assigned on the basis of several factors:

- significance with respect to fish migration or rearing, riparian habitat, or reducing creek sedimentation;

- probability of long-term success (i.e., is the degraded condition reversible?);
- potential to integrate with other restoration projects in the tributary;
- potential for educating the public about watershed processes;
- feasibility (including landowner willingness, ease of permit process, access);
- extent of future maintenance required for projects;
- cost effectiveness.

The intent of the watershed restoration project is to use the available funds wisely, and to create the most habitat benefit for the least cost. For example, alternatives that are expensive and require long-term maintenance have a lower ranking relative to other projects that can be implemented for less cost and that require less maintenance. The following ranking relies on an understanding of the long and short-term physical and biological benefits that would be accomplished through the restoration projects.

The highest priority was given to modification to barriers of fish migration and landowner education. Bank erosion and non-native species are pervasive throughout the watershed. In order for bank stabilization or removal of non-native species and revegetation with native species to have a significant effect on fish or wildlife habitat these alternatives would need to be implemented on a sub-watershed scale, or throughout each tributary. Current funds available are insufficient to allow for implementation of these restoration alternatives on this scale. However, as future funding becomes available, bank stabilization and removal of non-natives and revegetation with native species should be implemented based on quality of fish habitat to be improved. For example, if the fish barriers are modified in Mills Creek to open the upper watershed as fish habitat, a priority place to stabilize banks and to remove non-native species would be areas upstream of the barrier.

A ranking of alternatives for each tributary, the estuary, and for education is illustrated in Tables 25-32. The tables are ordered so that those with the most value are listed first. Emphasis is placed on fish habitat in the Arroyo Leon, Mills Creek and Apanolio Creek watershed because they create the most habitat for the least cost. The projects with the highest priority that could be completed within the available funding (using the approximate high costs) include:

- Modification of the fish barrier at the Historic Bridge crossing in the State Park in Mills Creek;

- Modification of a small barrier about 2 miles upstream of the Historic Bridge on Mills Creek;

- Construction of off-channel irrigation ponds near Higgins Canyon Road on Arroyo Leon;

- Modification of the fish barrier at the private culvert crossing on Arroyo Leon upstream of the confluence with Mills Creek;

- Modification of the lower, middle, and upper fish barrier on Apanolio Creek;

- Funding educational resources for riparian and agricultural landowners;

- Conduct a pilot project of vortex weir installation in Pilarcitos Creek (downstream of Highway 92) and monitor to determine the extent of pool development and gravel entrapment;

- Install staff gages on ponds and bridges. Determine stage-discharge relationships, and purchase temperature recorders to allow volunteers to monitor pond levels, streamflow, and water temperatures;

- Remove Eucalyptus at sites where the value of the removed wood will pay for removal and revegetation of the sites.

Other projects could be implemented using any remaining funds, through future grant funds, or through volunteer efforts. For example, willow cuttings could be planted throughout many reaches within the watershed.

TABLE 25. ***Mills Creek and Arroyo Leon*** **— Prioritization of Alternatives**

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Modify Irrigation Ponds									
	a. Management	H			M	H	M	M	H	--
	b. Construction	H			M	H	L	M	H	H
2.	Modify Barrier at Historic Bridge on Mills Creek	H			H	H	H	H	M	M
3.	Modify Barrier 2 miles upstream on Mills Creek	H			H	H	L	H	L	L
4.	Modify Barrier at Arroyo Leon Culvert	H			H	M	L	L	M	M
5.	Stabilize Banks at Historic Bridge on Mills Creek		M	M	H	H	M	H	M	M
6.	Remove Exotic Eucalyptus and Replace with Native Species	L	H	L	H	H	H	H	H	M
7.	Maintain Unpaved Roads			M	M	L	M	M	H	M
8.	Stabilize Banks									
	Mills Creek at Road Crossing		M	M	M	M	M	M	M	M
	Arroyo Leon at Ponds		M	M	L	M	M	L	M	H
9.	Stabilize Remaining Banks		M	H	H	H	M	L	M	H
10.	Stabilize Gullies			M		L	M	L	M	H
11.	Remove Exotics and Replace with Native Species									
	German Ivy		H		M	H	M	L	H	H
	French Broom		H		M	H	M	L	H	H

TABLE 26. *Education* — Prioritization of Alternatives

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Provide Resources for Workshops						H			L

TABLE 27. ***Apanolio Creek*** **— Prioritization of Alternatives**

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Modify Lower Fish Barrier	H			H	H	L	M	M	M
2.	Modify Middle Fish Barrier	H			H	H	L	M	M	M
3.	Modify Upper Fish Barrier	H			H	H	L	M	M	M
4.	Stabilize Banks at Barrier Modification Projects	L	M	M	H	H	L	M	M	M
5.	Remove Exotic Eucalyptus and Replace with Native Species		H	L	M	H	L	M	H	M
6.	Maintain Unpaved Roads			M	M	L	H	M	H	M
7.	Dredge Old Diversion Pond	M				H	L	H	H	L
8.	Stabilize Remaining Banks	L	M	H	H	M	L	L	M	H
9.	Remove Exotics and Replace with Native Species									
	Periwinkle		H		M	H	L	L	H	H
	Spiderwort		H		M	H	L	L	H	H

TABLE 28. ***Pilarcitos Creek*** **— Prioritization of Alternatives**

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Increase Instream Flow — Stone Dam to Wells	H			H	H	H	H	M	--*
2.	Stabilize Banks									
	a. Upstream and Downstream of Apanolio Creek	L	M	M	H	H	H	H	M	M
	b. Upstream and Downstream of Nuff Creek	L	M	M	H	H	H	H	M	M
	c. Upstream of Corinda Los Trancos Creek	L	M	M	H	H	H	H	M	M
	d. Upstream of Highway 92	L	M	M	H	H	H	H	M	M
3.	Remove Exotic Eucalyptus and Replace with Native Species	L	H	L	M	M	H	H	H	M
4.	Maintain Paved and Unpaved Roads			H		M	H	M	H	--
5.	Install Vortex Weirs	M			M	H	H	M	M	M
6.	Modify Fish Barrier at Stone Dam	M			L	M	H	M	H	H
7.	Increase Instream Flow—Wells to Estuary—as part of water users group.	H			L	H	H	L	H	--**
9.	Stabilize Remaining Banks	L	M	H	H	M	M	L	M	H
8.	Remove Exotics and Replace with Native Species									
	German Ivy		H		M	M	M	L	H	H
	Other Exotic Vegetation		H		M	M	M	L	H	H

* Assuming SF Water Department and Coastside Water District come to an agreement.

** Assuming voluntary agreements are reached.

TABLE 29. *Estuary* — Prioritization of Alternatives

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Reduce Disturbance (Construct New Horse Bridge)		H	M	H	H	H	H	M	H
2.	Remove Exotics and Replant with Native Species									
	German Ivy		H		M	H	H	M	H	H
	Ox-Tongue		H		M	H	H	M	H	H
3.	Increase Instream Flow to Estuary	H			L	H	H	L	H	H

TABLE 30. ***Madonna Creek* — Prioritization of Alternatives**

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Stabilize Banks	L	M	M	M	L	L	M	M	M
2.	Maintain Unpaved Roads			M	M	L	H	M	H	—
3.	Remove Exotic Eucalyptus and Replant with Native Species		M	L		L	L	M	H	M
4.	Remove Other Exotics and Replant with Native Species		M	L	M	L	L	L	H	H

TABLE 31. ***Nuff Creek* — Prioritization of Alternatives**

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Remove Exotic Eucalyptus and Replant with Native Species		M	L	M	L	L	M	H	M
2.	Remove Other Exotics and Replant with Native Species		M	L	M	L	L	L	H	H

TABLE 32. *Corinda Los Trancos* — Prioritization of Alternatives

Priority	Alternative	Enhance Fish Migration or Rearing	Enhance Riparian Habitat	Reduce Sedimentation	Probability of Long-term Success	Potential to Integrate with Other Alternatives	Potential for Education	Feasibility	Future Maintenance Requirements	Cost
1.	Restore Riparian Habitat Downstream of Highway 92		H	M	M	L	M	M	H	M
2.	Remove Exotics and Replant with Native Species		H	L	M	L	L	L	H	H

11. CONCLUSIONS

This restoration plan for Pilarcitos Creek Watershed takes a watershed approach to understand how natural processes and human activities have created the existing physical and biologic characteristics. The critical watershed issues are identified as:

- reduced streamflow;
- degraded fish habitat;
- loss of riparian vegetation and habitat and bank erosion;
- watershed erosion and channel sedimentation;
- exotic vegetation; and
- landowner concerns.

The existing watershed conditions and restoration constraints and opportunities were used to develop preliminary alternatives for discussion with the Advisory Group, the Project Administrators, and the Public. This plan presents refined alternatives that are prioritized based on their significance in restoring habitat, probability of success, potential for education, feasibility, maintenance required, and cost. The following conclusions summarize the existing watershed conditions that led to the need for a plan. Conclusions describing the restoration plan follow.

EXISTING WATERSHED CONDITIONS IN PILARCITOS CREEK

Streamflow in Pilarcitos Creek is reduced due to dams and water diversions, and groundwater pumping from the aquifer adjacent to the creek. Issues related to water and streamflow on Pilarcitos Creek are complicated by the diversity and number of water users and the current lack of coordination and planning in the watershed.

The bedrock geology is the source of sand to the Pilarcitos Creek watershed. The bedrock geology in Pilarcitos Creek watershed consists of erodible granitic rocks in the headwaters of Apanolio, Corinda Los Trancos, Nuff and Pilarcitos Creeks. This weathered granitic rock is the source of much of the sand in Pilarcitos creek. There are numerous landslide scars on the hillslopes above the channel in Pilarcitos Creek (upstream of Highway 92). The sandstones, mudstones, and shales in Arroyo Leon, Mills, and Madonna Creek are also a source for sand. Active gullies are numerous on southwest facing hillslopes in Arroyo Leon and Mills Creek.

Erosion is accelerated when vegetation is disturbed on steep hill slopes or on the channel banks. Bare soil on agricultural fields, unpaved roads and driveways, and road cuts are a source of sediment to Pilarcitos Creek. The active landslide in Albert Canyon may be related to the steep road cut above Highway 92 or to concentrated runoff from the unpaved road above the slide.

Most of the tributaries and the main channel of Pilarcitos Creek show evidence of channel incision. Incision accelerates bank erosion, and creates barriers to fish migration.

Bank erosion is pervasive throughout the Pilarcitos Creek watershed. Bank erosion is a natural process, but rates are accelerated from disturbance to vegetation, channel incision, or straightening of meanders. Structural approaches to bank stabilization fix the channel in one location and do not allow the natural process of meander migration to occur. The disruption of this process causes other adjustments that accelerate bank erosion upstream of the hard structure.

The main source of water pollution in Pilarcitos Creek is the fine sediment eroded in the watershed. Other potential sources of pollutants are from agricultural practices (pesticides and fertilizers), the BFI landfill, and urban activities.

Stream substrate throughout the Pilarcitos Creek watershed is dominated by sand. Even at the best sites in the watershed, sand is present in spawning gravels in riffles and dominates pools and runs. The abundance of sand results in poor spawning conditions, limits the extent and depth of pools, and results in fewer aquatic insects as food for fish.

Stream flows are reduced because of dams and numerous diversions. In dry years there is little or no flow in Pilarcitos Creek. In sandy streams, high streamflows are needed to produce adequate depth, insect production, and cover to support populations of steelhead.

Barriers to adult migration and to out migrating smolt degrade fish habitat in Pilarcitos Creek watershed. Barriers to adult migration exist in Arroyo Leon, Mills Creek, and Apanolio Creek. Barriers to out-migration in April and May form in dry years at shallow riffles or at the mouth of Pilarcitos Creek. In average or dry years, the operation of dams and diversions probably restricts or blocks smolt downstream migration on lower Arroyo Leon.

Stream habitat and fish abundance are generally the greatest in the upper reaches of Pilarcitos Creek. Two other sites in the watershed - Apanolio Creek and lower Mills Creek also had relatively high fish densities. Nuff and Madonna Creeks and Corinda Los Trancos Creek offer little habitat, but are a source of some summer streamflow to Pilarcitos Creek. However, these best sites only have steelhead densities about half the average density in other nearby coastal streams (such as Gazos Waddell, and Scott Creeks). Overall, the Pilarcitos Creek watershed has only modest steelhead habitat compared to other streams in San Mateo and Santa Cruz Counties. Most of these other streams presently have coho salmon populations that could potentially support restore coho populations.

In most years Pilarcitos Creek is dry near the mouth and no summer lagoon forms. In wet years, such as 1995, when summer Stream flows reach the mouth, the Pilarcitos Creek estuary forms a lagoon in summer as the barrier beach develops.

Riparian habitat has been disturbed and reduced in size by urban and agricultural activities. The disturbance has resulted in establishment and spread of invasive species (eucalyptus trees, German ivy, pampas grass, and poison hemlock). Eucalyptus displace native tree species, and shrubs and herbaceous layers tend to be sparse. This leads to increased soil erosion under the eucalyptus.

RESTORATION PLAN FOR PILARCITOS CREEK

The highest priority projects include alternatives that remove barriers to fish migration and provide educational resources for landowners. Because bank erosion and non-native species are pervasive throughout the watershed, and although alternatives to reduce creek sedimentation and to enhance habitat through revegetation with native species are important, they are relatively expensive. Alternatives to reduce sedimentation and enhance habitat as described in the restoration plan can be implemented in the future as funding becomes available. The rational for recommending specific projects is discussed in detail in Section 10. The following projects are the most likely to significantly enhance fish habitat within the existing funding.

- Modification of the fish barrier at the Historic Bridge crossing in the State Park in Mills Creek;
- Modification of a small barrier about 2 miles upstream of the Historic Bridge on Mills Creek;
- Construction of off-channel irrigation ponds near Higgins Canyon Road on Arroyo Leon;
- Modification of the fish barrier at the private culvert crossing on Arroyo Leon upstream of the confluence with Mills Creek;

- Modification of the lower, middle, and upper fish barrier on Apanolio Creek;

- Funding educational resources for landowners;

- Conducting a pilot project of vortex weir installation in Pilarcitos Creek (downstream of Highway 92) and monitoring to determine the extent of pool development and gravel entrapment;

- Installing staff gages on ponds and bridges. Determine stage-discharge relationships and purchase temperature recorders to allow volunteers to monitor pond levels, streamflow, and water temperatures;

- Removing Eucalyptus at sites where the value of the removed wood will pay for removal and revegetation of the sites.

Fish migration barriers can be modified at sites on Arroyo Leon, Mills Creek, and Apanolio Creek. These modifications can provide adult salmonids access to upstream portions of the tributaries.

Streamflow could be increased through voluntary agreements between all of the water users in the Pilarcitos Creek. Increased streamflows in Pilarcitos Creek to the estuary would improve fisheries rearing habitat conditions and migration. A first step would be to create a water users group to identify water needs, develop long-term water conservation strategies, develop a long-term monitoring and enforcement agreement, and explore the use of tertiary treated wastewater in the future. Because the current restoration funds cannot be spent on litigation, a voluntary agreement between water users is essential to increase streamflow for fish habitat in Pilarcitos Creek.

Streamflow in Arroyo Leon can be increased through construction of an off-channel irrigation system. An alternative approach is possible for Arroyo Leon, by constructing off-channel storage for the major agricultural water user. Because there are fewer water users in Arroyo Leon than in Pilarcitos Creek, management of the water system for fish habitat through voluntary measures is more feasible.

Banks should be stabilized on the scale of a reach. A reach is defined as the length of channel through a meander, between bridges, or to a confluence with a tributary. Because bank erosion is pervasive in the watershed, the benefit of stabilizing one reach of eroding channel will be small relative to the magnitude of the sediment contribution of the entire basin. Although the entire bank may not be currently eroding, the entire length should be integrated into the design to avoid inconsistent approaches based on property boundaries. Piece-meal approaches are not effective in the long-term because they do not account for active geomorphic processes such as meander migration. Establishment of a riparian buffer with bank stabilization would allow for the evolution of a meander corridor, and bring Pilarcitos Creek closer toward the long-term restoration goals.

A riparian buffer adjacent to the channel should be promoted as part of the restoration effort. A buffer would minimize the rate of bank erosion and filter pollutants from the creeks. A dense riparian buffer would reduce the bank erosion rate, because even after one tree or shrub is eroded, other vegetation will remain and provide root strength and resistance to erosion.

Banks should be stabilized using vegetation instead of hard structures where possible. Vegetation provides strength to banks and helps minimizes erosion. Vegetation accommodates geomorphic processes such as meander migration and does not "fix" the channel in one locations. Steep or vertical streambanks should be graded to a gentle slope, and protected by dense planting of riparian vegetation. Biotechnical techniques that incorporate vegetation could be used where infrastructure is threatened.

Non-native vegetation should be removed and replaced with native species. Removal of invasive species and replanting with native vegetation to improve habitat should be done to the extent possible withing the existing funding, and continued in the future with volunteers and outside funding. The extent of invasive exotic species must be reduced in order to re-establish a diverse assemblage of native riparian plant and animal species. Increased biodiversity will contribute to stabilizing the watershed.

Monitoring of restoration site should be conducted. Monitoring is essential in ensuring that restoration projects function as predicted and in identifying any required maintenance. Monitoring should be conducted annually as part of the restoration project for a period of five years. Longer-term monitoring by a local agency or volunteers would provide data for future restoration efforts in the watershed.

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APPENDIX A

Permitted Appropriative Water Rights Diversions (Post 1914 Rights) and Statement of Water Diversions other than Post-1914 Appropriative Permits

PILARCITOS CREEK WATERSHED

PERMITTED APPROPRIATIVE WATER RIGHTS DIVERSIONS (POST 1914 RIGHTS)

NAME	APPLICATION NUMBER	LICENSED	PERIOD OF DIVERSION	NO. MONTHS DIVERTED	DIVERTED CFS	TOTAL ACRE-FEET	STORED AC-FT	DATE FILED	DATE COMPLETE USE
Pilarcitos Creek									
CCWD	18496	YES	11/01 – 03/31	5	1.5	448.0	0	1955	1955
CANADAS	22437	YES	04/01 – 11/01	7	0.06	25.0	0	1966	1969
GONSALVES	22854	YES	11/01 – 03/31	5		25.0	25	1967	1971
SKYLAWN	25198	NO	01/01 – 03/31	3		49.0	49	1976	1990
EVERGREEN	25407	NO	12/01 – 05/01	6		14.0	14	1977	1992
SKYLAWN	25748	YES	01/01 – 03/31	3		15.0	15	1978	1984
EVERGREEN	28075	NO	12/01 – 04/30	5		25.0	25	1984	1992
NURSERYMAN	29239	YES	11/01 – 05/01	6		14.0	14	1988	1993
					SUBTOTAL	615.0	142.0		
Apanalio Creek									
BONGARD	16819	YES	01/01 – 03/01	3		0.5	0.5	1955	1959
Nuff Creek									
LINTT	28121	NO	01/01 – 12/31	12	0.44	318.0	0	1984	1988
Arroyo Leon Creek									
CASSINELLI	25462	NO	12/01 – 04/30	5		49.0	49	1977	1992
CORADO	25463	NO	12/01 – 04/30	5		30.0	30	1977	1988
CASSINELLI	25464	YES	12/01 – 04/30	5		22.2	22.2	1977	1984
CASSINELLI	25465	YES	12/01 – 04/30	5		49.0	49	1977	1984
ANDREASON & TAT	28288	NO	11/01 – 03/31	5		49.0	49	1989	1984
					SUBTOTAL	199.2	199.2		
				TOTALS – ACRE-FEET		1132.7	341.7		

TOTAL OF 1132.7 ACRE-FEET DIVERTED PER YEAR

NOTE: STORAGE EQUALS AMOUNT THAT CAN BE DIVERTED ANNUALLY

TABLE 3

Source: EOA, 1990

PILARCITOS CREEK WATERSHED

STATEMENT OF WATER DIVERSIONS OTHER THAN POST 1914 APPROPRIATIVE PERMITS

NAME	STATEMENT NUMBER	PERIOD OF DIVERSION	NO. MONTHS DIVERTED	DIVERTED CFS	TOTAL ACRE-FEET	DATE FILED
Pilarcitos Creek						
SARE	661	03/01 – 10/31	8	0.28	133.3	1967
MICKLESON	2159	01/01 – 12/31	12	0.0135	9.6	1967
BERTA	6258	?	8	0.082	39.0	1970
SKYLAWN	9673	01/01 – 12/31	12	0.1	71.4	1978
SKYLAWN	11428	01/01 – 12/31	12	0.1	71.4	1984
COZZOLINO	12230	02/01 – 11/30	10	0.47	279.7	1985
REPETTO	12238	01/01 – 12/31	12	0.5	357.1	1988
NURSERYMAN	13154	04/01 – 11/30	8	0.25	119.0	1988
				SUBTOTAL	1080.6	
Apanalio Creek						
BONGARD	1617	01/01 – 12/31	12	0.7	499.9	1967
FAIGLE	13234	01/01 – 12/31	12	0.045	32.1	1989
				SUBTOTAL	532.0	
Nuff Creek						
DAVIS	1856	01/01 – 12/31	12	0.08	57.1	1967
DAVIS	1857	01/01 – 12/31	12	0.08	57.1	1967
				SUBTOTAL	114.3	
Arroyo Leon Creek						
THRIFT	1150	01/01 – 12/31	12	0.0002	0.1	1967
WAGNER	8861	01/01 – 12/31	12	0.0004	0.3	1978
CORADO, INC	9379	05/01 – 10/31	6	1	357.1	1977
CORADO, INC	9380	05/01 – 10/31	6	1	357.1	1977
CORADO, INC	9381	05/01 – 10/31	6	0.5	178.5	1977
CORADO, INC	9382	?	8	1	476.1	1977
CORADO, INC	9383	03/01 – 10/31	8	1	476.1	1978
WAEGNER	12205	01/01 – 12/31	12	0.045	32.1	1985
				SUBTOTAL	1877.4	
			TOTAL – ACRE-FEET		3604.2	

TOTAL OF 3604.2 ACRE-FEET DIVERTED PER YEAR

TABLE 4

Source: EOA, 1990