San Francisco Bay Regional Water Quality Control Board

Pescadero-Butano Watershed Sediment TMDL

Project Definition and Project Plan

[Pescadero Marsh and the Lagoon, 2010

www.Californiacoastline.org]

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Setenay Bozkurt Frucht

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INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) requires that states develop a list of water bodies that do not meet water quality standards ("impaired" water bodies) and develop plans to attain water quality standards in impaired water bodies. In California, State Water Resources Control Board and Regional Water Quality Control Boards are the principal agencies responsible for the coordination and control of water quality. The San Francisco Bay Regional Water Quality Control Board (Water Board) is the agency that exercises rulemaking and regulatory activities and is responsible for the development of water quality standards in the San Francisco Bay region. The Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) delineates these standards by identifying beneficial uses in the San Francisco Bay Region, numeric and narrative water quality objectives to protect these uses, and provisions to enhance and protect existing water quality. The Water Board develops Total Maximum Daily Loads (TMDLs), which are action plans that identify sources of pollutants and specify restoration and implementation actions to attain water quality objectives.

The Water Board, in 1998, formally identified water quality impairment for the Pescadero-Butano Watershed due to excessive sedimentation and determined that sedimentation in the watershed can most efficiently be addressed by undertaking a total maximum daily load (TMDL) project. This report provides the Project Plan for the Pescadero-Butano Sediment TMDL and includes a detailed compilation and review of existing data and a technical approach to address the impairment and attain water quality standards.

BASIS OF 303(d) LISTING

The 303(d) listing of the Pescadero-Butano watershed iwas based upon the consensus opinion of scientists and resource professionals, and was prompted by the loss of suitable habitat due to excessive sedimentation and the decline in populations of sensitive, threatened, or endangered aquatic species. The species of concern in the watershed include coho salmon (Oncorhynchus kisutch), steelhead trout (Oncorhynchus mykiss), tidewater goby (Eucyclogobius newberryi), red-legged frog (Rana aurora draytonii), and San Francisco garter snake (Thamnophis sirtalis tetrataenia).

Pescadero and Butano Creeks do not meet narrative water quality objectives because beneficial uses in the watershed are believed to be impaired by accelerated rates of erosion and sedimentation resulting from natural geologic and climatic processes augmented by human land use practices. In addition to excessive sedimentation, scientists have identified other factors that may be limiting populations of sensitive species. Such factors include recruitment and retention of woody debris, water withdrawal during critical low-flow periods, lagoon circulation and management, and water quality.

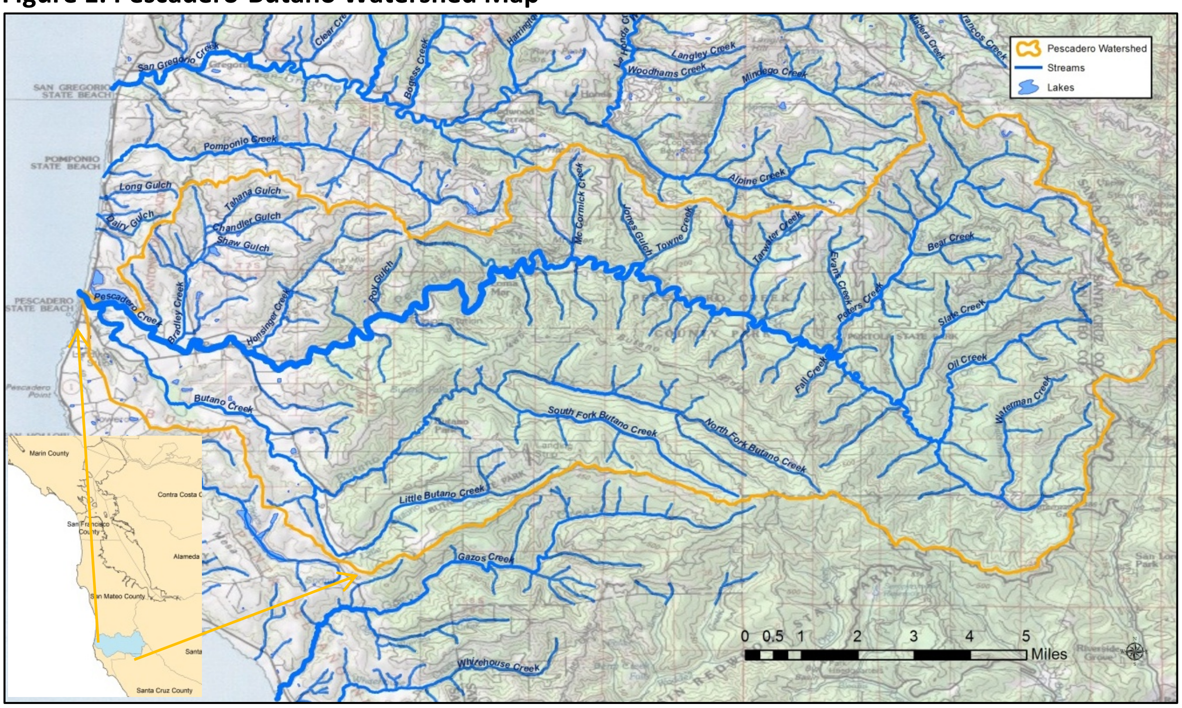
The narrative water quality objective for sediment states that suspended sediment loads and discharge rates shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. The narrative water quality objective for settleable material states that water shall not contain substances in concentrations that result in the deposition of material that cause nuisance or adversely affect beneficial uses.

Designated beneficial uses of water in the watershed include:

- Fish migration and spawning;
- Cold and warm freshwater habitats;
- Wildlife habitat;
- Preservation of rare and endangered species;
- Water supply (agricultural and municipal);
- Recreation (fishing swimming, and boating, etc.); and,
- Fresh and salt marsh habitat.

Beneficial uses adversely affected by excess sediment in the Pescadero and Butano Creeks are cold freshwater habitat, fish spawning and migration, preservation of rare and endangered species, and recreation.

Figure 1. Pescadero-Butano Watershed Map



Status of Anadromous Fish in the Watershed

As stated above, scientists and agency personnel working in the watershed believe that excessive sedimentation resulting from a combination of natural and human induced factors are the primary causes for the decline of the anadromous fish populations in Pescadero-Butano Creek Watershed.

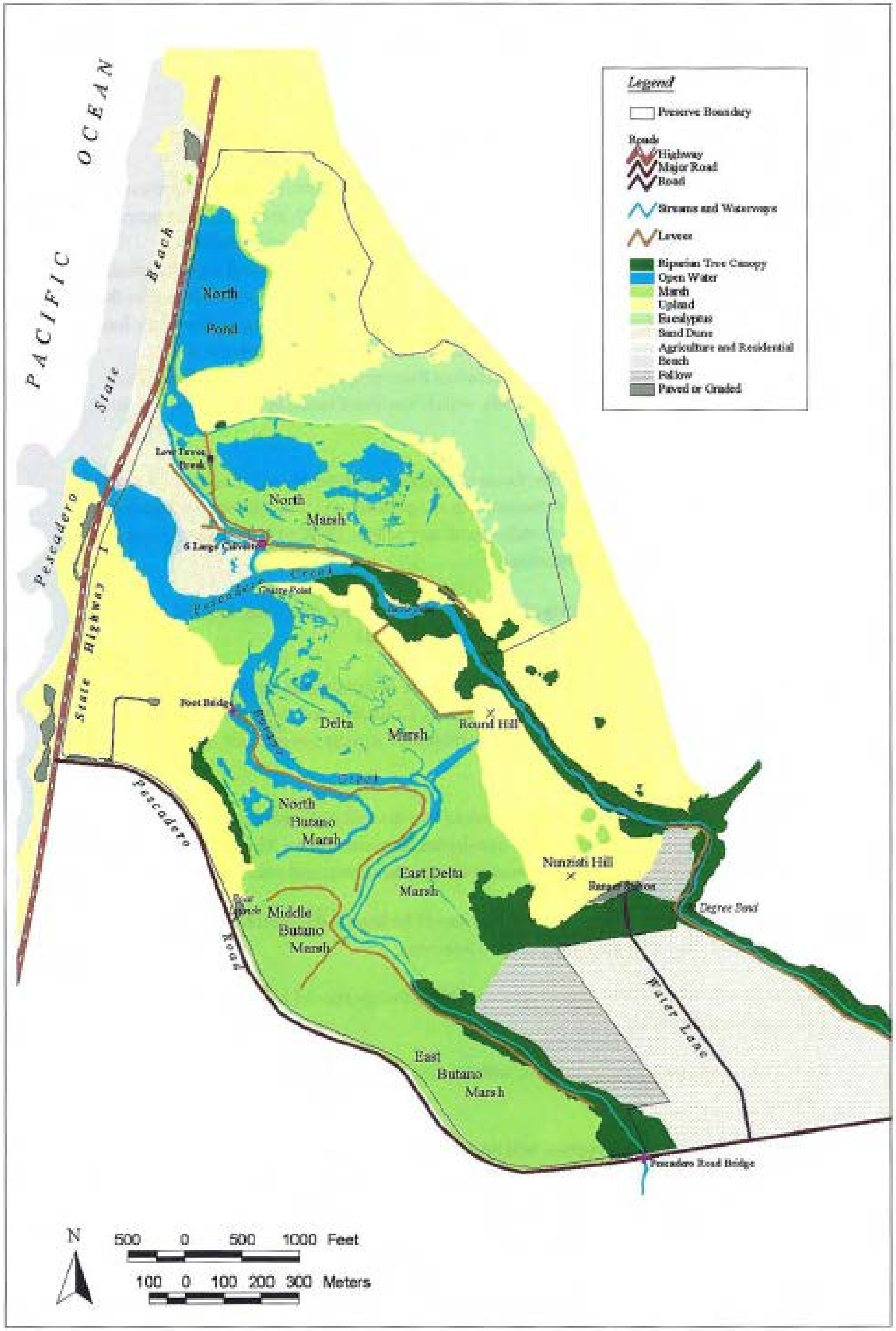
Historically, Pescadero Creek and many of its tributaries supported substantial runs of coho salmon. Although there is little definitive data on historic coho salmon abundance, the Department of Fish and Game has estimated that the San Mateo County coastal streams (Pescadero, San Gregorio, and Gazos Creeks) supported an annual run of approximately 1,000 adult coho during the early 1960's (Baker, 1998). Historic (pre-1850) abundance was undoubtedly much greater. In 1995, coho salmon south of San Francisco Bay were designated as a State 'Endangered' species. At the federal level, the Central California coast evolutionary significant unit (ESU) was listed as a 'Threatened' species under the Endangered Species Act in 1996. Presently, the Pescadero Creek watershed is not believed to support a viable self-sustained run of coho salmon, although a small remnant population of one brood year (1999…2002) may still exist (J. Smith, personal communication with Board staff, June 17, 2003). Extinction of the two (or three) brood years is believed to have occurred sometime in the 1970s (Baker, 1998).

Pescadero Marsh

Pescadero Marsh (Figure 2) provides habitat for the San Francisco garter snake, tidewater goby, and California red-legged frog. The availability of suitable habitat in the marsh for sensitive species is affected by variable natural factors, the legacy of land use changes in the marsh and watershed, and current management practices and restoration efforts. Diking, channelization, reclamation, and excessive sedimentation have dramatically altered the size and character of Pescadero Marsh over the past 150 years. Between 1900 and 1960 the size of the delta/open water area of the marsh decreased by over 50%, primarily due to reclamation of marshland for agriculture (Violis, 1979). Human alteration to geomorphic and hydrologic processes in Pescadero Marsh has dramatically reduced the availability of suitable habitat for sensitive species (Smith and Reis, 1997; J. Smith, personal communication with Board staff, June 17, 2003).

Tidewater gobies, which tolerate fresh or saltwater but avoid strongly tidal areas, are found in the lagoon following formation of the sandbar, as well as in non-tidal marsh habitats of Pescadero Marsh (Smith and Reis, 1997). In recent years the sandbar has been forming much later in the summer (August-October) than usual, delaying the timing of suitable habitat for tidewater gobies. The change in timing of sandbar formation is most likely a result of changes in the supply of sediment to the marsh and the transport capacity of flows. The restoration of tidal action to North Pond and North Marsh in 1995 reduced available habitat for tidewater gobies in areas where they were once common (op cit). San Francisco garter snakes rely on red-legged frogs for food, and also require freshwater habitat. San Francisco garter snakes are only observed in areas where red-legged frogs are abundant, such as the freshwater portions of North Marsh and the boundary of Middle and East Butano marshes (op cit).

Figure 2. Pescadero Marsh Land Cover and Place Names (from ESA, 2008)



California red-legged frogs use areas of the marsh that remain fresh through spring and mid-summer, such as East Butano marsh, the trout ponds, and portions of North marsh; they are limited by the drying and/or salinization of pond and marsh habitats during this period. The restoration of tidal action to North and Middle Butano marshes and North Pond effectively limits the value of these habitats to red-legged frogs.

Flooding

While not designated as a beneficial use, flooding, which is partly a result of the excess sedimentation, is an important issue for local residents. The main access route to the town of Pescadero, as well as surrounding farm and residential land, is routinely flooded during heavy winter storms. The magnitude and frequency of flooding has increased dramatically over the past few decades, as a direct result of the decreased channel capacity of Butano Creek and the marsh system (Cook, 2002).

PREVIOUS STUDIES

The Pescadero-Butano watershed and the Pescadero Marsh have been the subject of numerous academic studies and investigations by consulting firms in the last 30 years. The following is a list of studies that were reviewed and incorporated into our Project Definition:

- Abram, D.,Clarke, D. Jordan, E., and Salmon, P. 2006. Reconstructing the sediment history of Pescadero Lagoon- preliminary report (PDF). Liverpool, University of Liverpool: 4.
- Atkinson, Kristine A. 2010. Habitat Conditions and Steelhead Abundance and Growth in a California Lagoon. Paper 3746. http://scholarworks.sjsu.edu/etd_theses/3746
- Balance Hydrologics, Inc. 2003. Water Supply Alternatives, Fish Passage and Use, and Streambed Conditions at Memorial County Park, San Mateo County, California. Prepared for San Mateo County Parks and Recreation Division and California Department of Fish and Game.
- [Bergolar] Bergolar Geotechnical Consultants. 1988. Geotechnical Report, Pescadero Marsh, Pescadero State Beach, California. Prepared for the Office of the State Architect. 62 pp.
- [CEMAR] Center for Ecosystem Management and Restoration. 2010. Considerations for Restoration of the Pescadero Marsh. A Report Based upon the Proceedings of the December 2008 Public Forum Restoration of Pescadero Marsh: Identifying Problems and Exploring Solutions. Prepared for the Pescadero Marsh Working Group.
- Curry, Robert, R. Houghton, T. Kidwell, and P. Tang. 1985. Sediment and Hydrologic Analysis of Pescadero Marsh and its Watershed. Draft. University of California at Santa Cruz. Prepared for California Department of Parks and Recreation, Sacramento, CA.

- Donaldson, Eric T. 2011. Geomorphic Controls on Spatial Distributions of Cobbles and Boulders in Stream-Channel Networks. Master's Thesis. 112 pp.
- [DPR] California Department of Parks and Recreation. 1992. Pescadero Marsh Natural Preserve Hydrologic Enhancement Project.
- [ESA] Environmental Science Associates. 2002. Butano Creek Cross Sections Survey Report. Prepared for California Department of Parks and Recreation, San Francisco, CA.
- [ESA] Environmental Science Associates. 2004. Pescadero-Butano Watershed Assessment. Report by Environmental Science Associates, Pacific Watershed Associates, O'Connor Environmental, Albion Environmental and D. Jackson. Prepared for Monterey Bay National Marine Sanctuary Foundation, Monterey, CA.
- [ESA] Environmental Science Associates. 2008. Pescadero Marsh Restoration Assessment and Recommendations for Ecosystem Management. Prepared for California Department of Parks and Recreation, Half Moon Bay, CA.
- ESA PWA. 2011. Geomorphic Evolution of Pescadero Marsh: 1987-2011, Results of Field Monitoring and Data Collection 75 pp.
- Kamman Hydrology and Engineering, Inc. 2006. Data Synthesis and Hydrodynamic Model Development Feasibility Report for Pescadero Lagoon, San Mateo County, California.
- [PWA] Philip Williams & Associates. 1990. Pescadero Marsh Natural Preserve Hydrological Enhancement Plan. Prepared for California Department of Parks and Recreation.
- [PWA] Pacific Watershed Associates. 2004. Sediment source analysis for Pescadero-Butano watershed in Pescadero-Butano Watershed Assessment by ESA. p 6-1 to 6-54.
- [PWA] Pacific Watershed Associates. 2003. Sediment Assessment of Roads and Trails within the Pescadero/Memorial/San McDonald County Park Complex, Pescadero Creek Watershed, San Mateo County, CA.
- Sloan, Rebecca M. 2006. Ecological Investigations of a Fish Kill in Pescadero Lagoon, California. Paper 3032. http://scholarworks.sjsu.edu/etd_theses/3032
- Smith, Jerry J. 1990. The Effects of Sandbar Formation and Inflows on Aquatic Habitat and Fish Utilization in Pescadero, San Gregorio, Waddell and Pomponio Creek Estuary/Lagoon Systems, 1985-1989. Prepared for California Department of Parks and Recreation.
- Smith, Jerry J. and D.K. Reis. 1997. Pescadero Marsh Natural Preserve Salinity, Tidewater Goby and Red-Legged Frog Monitoring for 1995-1996. Prepared for California Department of Parks and Recreation.
- Smith Jerry J. 2008. Estuary/Lagoons as Habitat: Implications for the Pescadero Creek Estuary Complex. PowerPoint presentation. Pescadero Marsh Restoration Forum, December 9, 2008.
- Smith, Keenan A. 2009. Inorganic Chemical Oxygen Demand of Re-suspended Sediments in a Bar-Built Lagoon. Master's Theses. Paper 3346. http://scholarworks.sjsu.edu/etd_theses/3346

- Smith, Keenan A. 2009. Inorganic Chemical Oxygen Demand of Re-suspended Sediments in a Bar-Built Lagoon. Master's Theses. Paper 3346. http://scholarworks.sjsu.edu/etd_theses/3346
- [Swanson] Swanson Hydrology & Geomorphology. 2001. Hydrologic Issues regarding Management of Pescadero Marsh in light of Enhancement Projects completed in 1993 and 1997. Prepared for California Department of Parks and Recreation.
- Viollis, Frank S. 1979. The Evolution of Pescadero Marsh. Master's Thesis. San Francisco State University, San Francisco, CA.

PESCADERO-BUTANO WATERSHED SETTING

The Pescadero and Butano Creeks drain approximately 81 mi^2 of the Santa Cruz Mountains in western San Mateo and Santa Cruz Counties and enter the Pacific Ocean near the town of Pescadero (Figure 1). The watershed contains steep forested slopes, deep canyons with steep inner gorges, a coastal valley, and rolling hills and grasslands near the coast. While the Pescadero sub-watershed is 58 mi^2, the Butano sub-watershed is 23 mi^2.

Pescadero Marsh, a 320 acre brackish and freshwater wetland at the confluence of Pescadero Creek and Butano Creek (Figure 2), is one of the most significant coastal wetlands on the central California coast (Curry et al, 1985). It is composed of an estuary/seasonal freshwater lagoon, fresh and brackish water marshes, brackish water ponds, and riparian areas along stream channels (Smith and Reis, 1997).

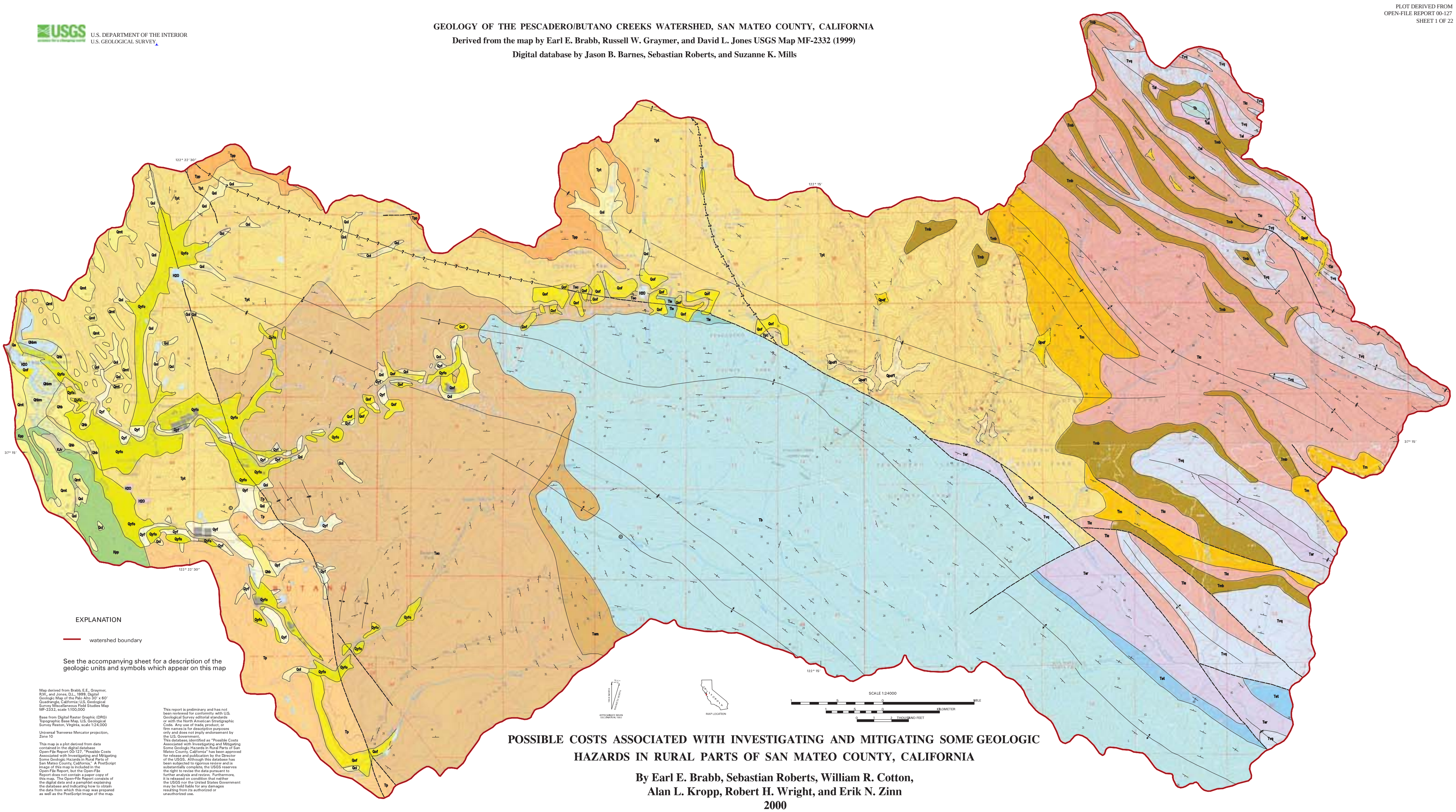
GEOLOGY AND SOILS

The evolution and current condition of the Pescadero-Butano watershed is tremendously influenced by regional and global geologic processes and controls including local bedrock, rising sea level, and faulting along the boundary between the Pacific and North American plates (Curry et al, 1985). The watershed is located in Santa Cruz Mountains within the Coast Ranges geomorphic province, an area of active tectonic deformation characterized by steep hillside terrain, frequent earthquakes, and fractured and weathered bedrock. Santa Cruz Mountains, bordered on the east by the San Andreas Fault system and on the west by the Pacific Ocean, is a tectonically active mountain range. In addition to the San Andreas Fault, there are two other northwest-trending faults that dissect the Santa Cruz Mountains: Pilarcitos and San Gregorio Faults (San Gregorio Fault Zone or SGFZ)(Figure 3). All these fault systems represent the active tectonic boundary between the Pacific and North American plates.

The basement rocks in the watershed are the Great Valley Complex (of the Pigeon Point Block) west of the SGFZ and the Salinian Complex (on the La Honda Block) east of the SGFZ. Both of these blocks have been carried northward from its place of origin to the south by San Andreas Fault's strike-slip fault movement. The Great Valley Complex west of the SGFZ consists of sandstones and conglomerates of the Upper Cretaceous (66 – 100 million years agoa) marine sedimentary rock that underlies the marine terrace deposits by the lower watershed. East of the SGFZ, the basement rocks are Cretaceous (approximately 92 million years ago) granitic rocks of the Salinian Complex (Sloan, 2006).

Overlying the basement rocks is a thick sequence of marine sedimentary rocks, including sandstone, shale, mudstone, and conglomerate, and some volcanic rocks (Figure 3); all of them ranging in age from Paleocene to Pliocene of Tertiary period (65 – 1.8 million years ago). Many of these sedimentary rock units are mechanically weak and highly susceptible to landsliding, debris flows, and gullying. This is clearly illustrated by the large occurrence of debris flows (shown in Figure 4 as black dots) triggered after the El Nino storms of January 1982.

Figure 3. Geologic Map of the Pescadero-Butano Watershed (from USGS, 2000)



The decomposition of the sedimentary rock units into their constituent materials (e.g. sand, silt, or clay) over time involves a combination of chemical weathering, biogenic processes (e.g. tree throw), landslides, and direct erosion of bedrock exposed in stream channels. In addition, larger fragments of these units (e.g. cobbles and gravels) are broken apart into finer materials in the stream channels through saltation and abrasion. All these processes contribute to the production of soils in the watershed. Soil that accumulates as colluvium in the hollows near the ridge crests is transported downstream via gullying and episodic landslides, which typically occur during large storm events. For instance, El Nino storms in January 1982 triggered over 900 debris flows in the Pescadero-Butano watershed (Figure 3, black dots)(Ellen et al. 1997). Mapping of the debris flows from prior storms indicates where landslides are likely to occur during a major rainstorm.

Figure 4. Debris Flows Triggered by the January 1982 Storm in the Pescadero-Butano Watershed

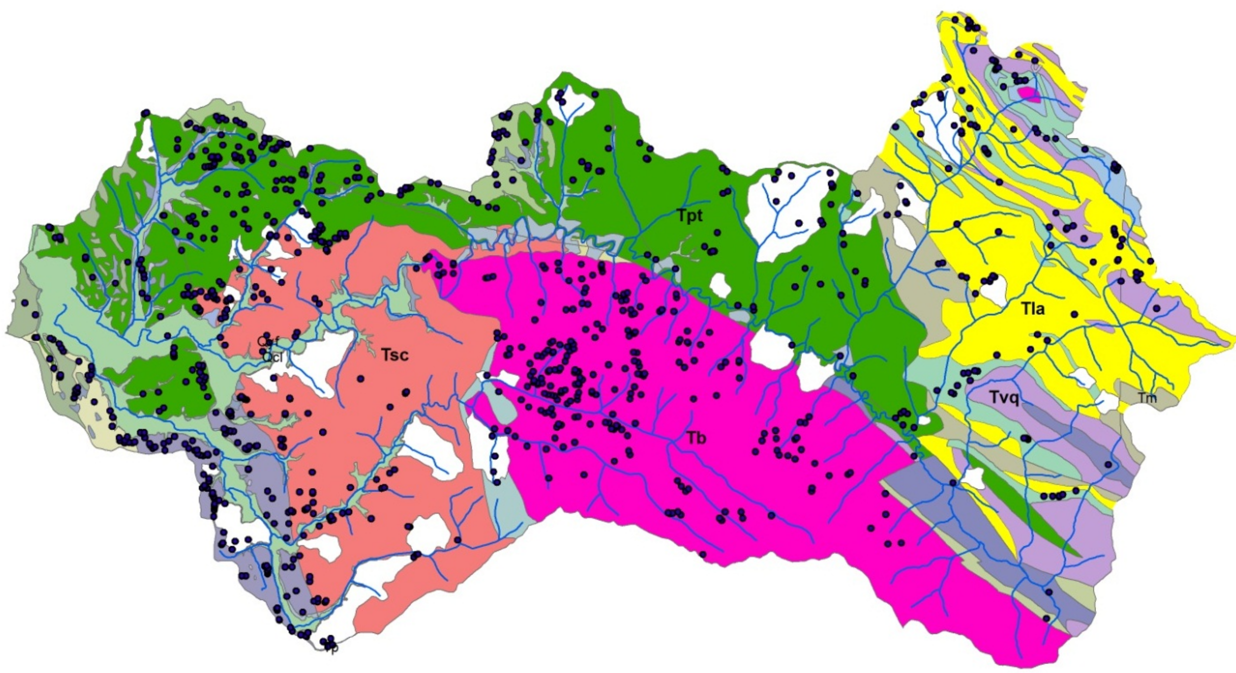


Table 1. Geologic Units in the Watershed and Their Erodibility (Brown, 1973)

Geologic Unit	Percentage of Watershed Area	Properties	Erodibility	Comments
Purisima Formation – Tahana Member (Tpt)	22%	Medium—to very fine-grained lithic sandstone and siltstone, with some silty mudstone	Moderate	No signs of active erosion where there is forest canopy; however, significant sheetwash erosion on grazed or deforested slopes
Butano Sandstone (Tb)	20%	Fine-grained, decomposes in exposures into friable fragments of many sizes. Exposures in canyons and roadcuts are commonly slumped	Very high	Steep slopes formed in this unit and the land use of the area that underlies make it a significant contributor of fluvial sediment
Santa Cruz Mudstone (Tsc)	16%	Medium- to thick-bedded, slides or slumps under adverse conditions	High	When saturated easily slumps
Lambert Shale (Tla)	11%	Thin- to medium-bedded, decomposes into friable fragments and fine, easily transported particles	Moderate (locally high)	Easily and deeply weathers
Vaqueros Sandstone (Tvq)	5%	Complexly fractured, laminated to very thick-bedded, decomposes into friable fragments and fine to very fine, easily transported particles	High (Locally very high)	Sheet erosion and numerous slides can occur during rainstorms. Evidences of severe erosion of this unit are not apparent on undisturbed slopes; however, disturbance make this unit immediately susceptible to accelerated erosion

CLIMATE AND HYDROLOGY

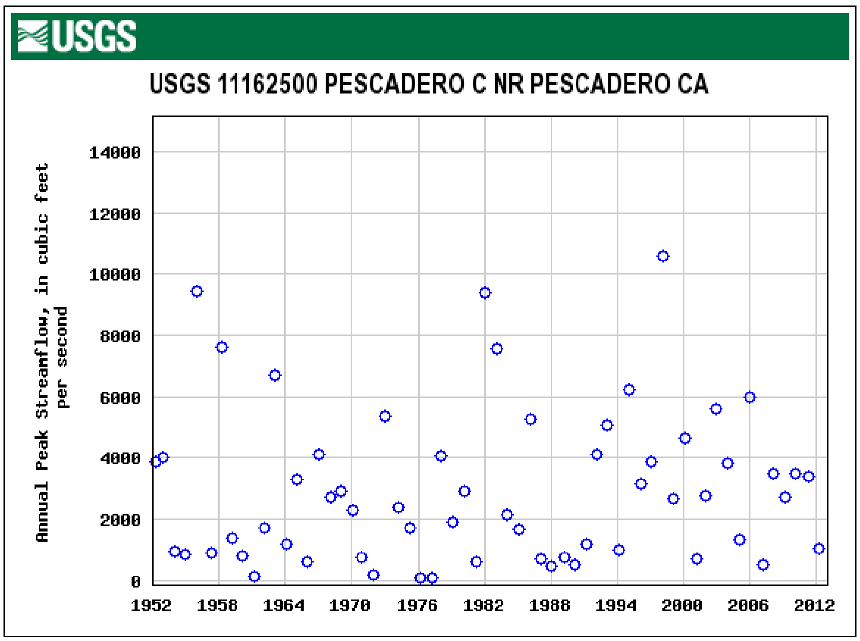
The Pescadero Creek watershed has a Mediterranean climate, moderated by the Pacific Ocean marine layer typical of the Central California Coast. The watershed experiences a mild, wet winter season which is typically from November to April and a warm, very dry summer season from May to October.

Westerly precipitation systems deliver rain to the watershed, which is impacted by orographic effects. The watershed averages approximately 40 inches of precipitation annually, with nearly 100% falling during the 6-month wet season. Anadromous fish have adapted to the strong seasonal hydrology of the region, migrating and spawning during the wet season and rearing over the summer in cold, deep pools.

Current problems in the Pescadero Creek watershed are directly related to the movement of water and sediment. Very large flood events are capable of tremendous sediment transport, and can have dramatic effects on aquatic habitat. The largest flood events for the period of record at the Pescadero

USGS gage (1951-present) are shown in Figure 5. The largest flood of record occurred in February 1998, with a peak flow of 10,600 cubic feet per second (cfs) at the Pescadero Creek gage. Figure 6 shows the annual runoff volumes (in acre-feet) from 1961 to 2011. The largest annual runoff volume of 118,900 acre-feet was recorded in 1983. The driest year on record was 1977 with an annual runoff volume of 1,250 ac-ft. We characterized recorded runoff volumes as dry, normal, and wet based on a simple ranking and subsequent identification of the 33rd and 66th percentiles. Years where runoff volumes exceed approximately 16,000 acre-feet and occur more than 66 percent of the time (two-thirds) are characterized as normal years. Years where runoff volumes are less than 16,000 acre-feet or exceed approximately 38,000 acre-feet (occur approximately one-third of the time) are characterized as dry and wet years, respectively.

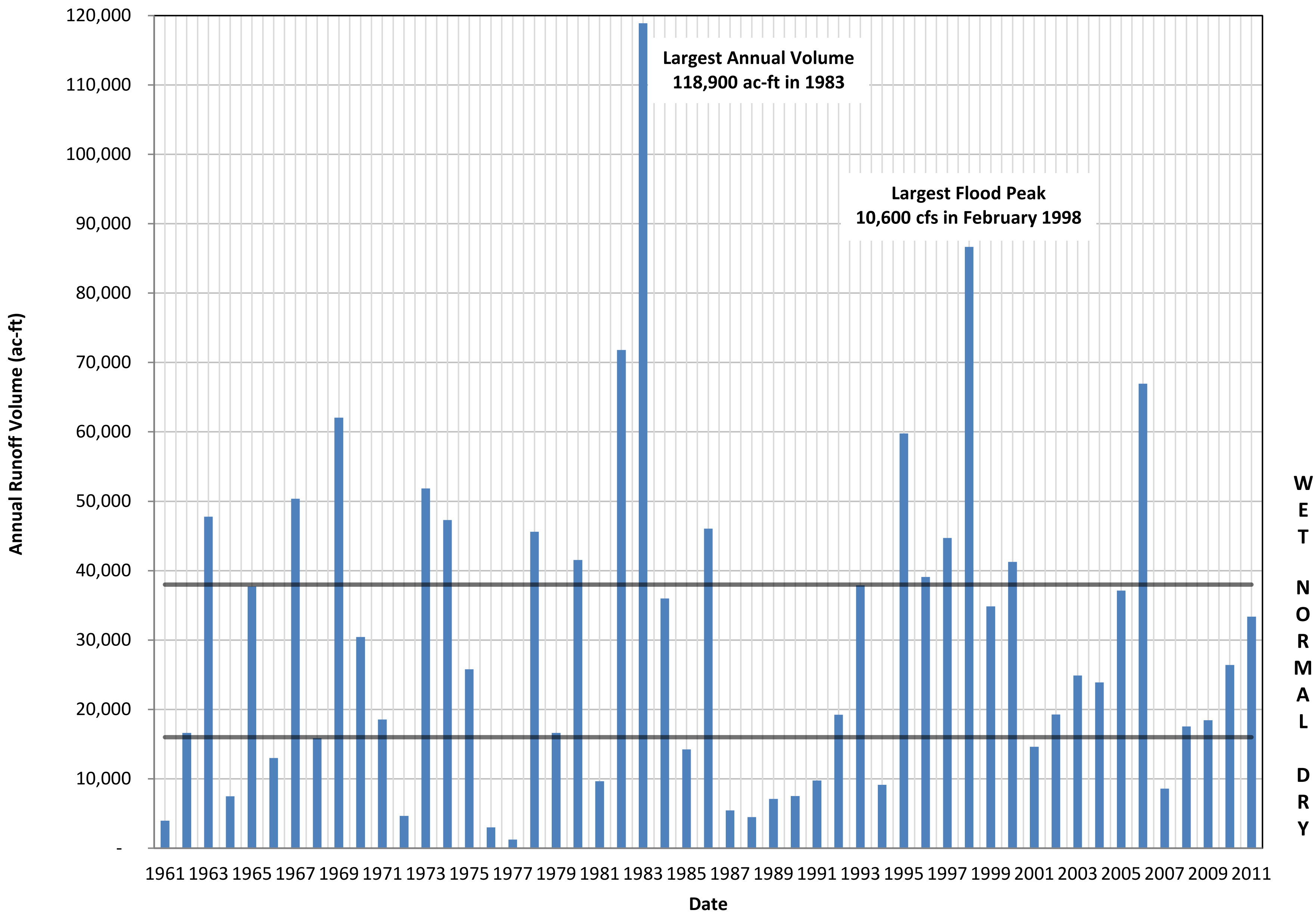
Figure 5. Annual Peak Flows at USGS Pescadero Creek Gauge 1952-2011



LAND USE HISTORY

Since the arrival of Mexican land-owners in 1820, Euro-American settlers in 1850, and European settlers in 1860, the Pescadero-Butano watershed has experienced the pervasive extraction of its natural resources, including fish, terrestrial wildlife, timber, water, ore minerals, and oil and gas over majority of its landscape. The dominant land uses in the watershed have involved extensive and intensive agricultural activities including ranching, dairy farming, and crop dry-farming since 1820, intensive timbering from 1850 to 1970, tourism and associated wildlife hunting and fishing from 1860 to 1940, and weekend tourism, camping, and hiking since about 1990 (Table 2).

Figure 6. Annual Runoff Volumes at USGS Pescadero Gauge (11162500)



During the period from 1850 to 1920, approximately 4,500 acres in the western most part of the watershed was used as grazing lands by the Mexican land owners. The same area was also used for ranching and dairy farming from the 1850s to 1920s. These activities additionally involved the conversion of the native vegetation on hillsides and along alluvial stream corridors over approximately 4,000 acres of the watershed in the 1850s, and the introduction of dozens of thousands of livestock (cows, sheep, and horses) to the newly cleared areas. The crop agricultural activities –including bean, flax, wheat, oats, and barley farming, involved reclamation of approximately 1,300 acres within swampy valley bottoms along Pescadero and Butano creeks by 1870. The associated hydrologic modifications in the 1880s and 1890s included building water diversions in the uplands, channelization, and the removal of in-channel large woody debris and riparian vegetation.

The early timbering activities, also referred to as 19th century logging, were very intensive during the period 1860 to 1890. These timbering activities involved the manual clear-cutting and downhill yarding of old-growth redwood and Douglas fir forests along easily accessible medium-order watercourses. In-channel skid roads and 19 on-channel shingle mill dams were built over 3,600 acres of the watershed employing oxen, mule and horse (later replaced by steam donkey engines) to skid logs along the intermittent watercourses, and operating seasonal splash dams to float timber logs along Pescadero Creek. The old form of clear-cutting from the 1800s and very early 1900s was an economic practice--cutting all that was usable to a sawmill. Since most timber at that time was large, old-growth timber, nearly all timber was usable--therefore all timber was cut. This total exploitation on the scale of many thousands of acres, in addition to the use of creeks as skid trails, roads, and flumes, left the region's forest resources in an apparent state of ruin.

Tourism and associated wildlife hunting and fishing activities escalated between 1860 to 1890 and lead to the massive extraction of coho salmon, steelhead trout, frogs, quail, rabbit, ground squirrel, deer, and grizzly bear. Prospecting for oil and gas, which took place in the uplands in the eastern part of the Pescadero-Butano watershed ended by 1890 and left behind over 250 mine shafts -150 of which are unaccounted for.

Table 2. Chronology of Significant Land Use Changes in the Pescadero-Butano Watershed

Date	Event
October 1769	Portola Expedition – first Spanish contact
1770 - 1822	Spanish period: grazing, introduction of non-native plants
1822 - 1848	Mexican period: land grants, livestock importation
1848 – 1868	Early American period: early logging, start of ranching and dairy farming, town of Pescadero established in 1856
1860s-1890s	First wave of heavy logging of redwoods in Pescadero and lower Butano, early agriculture including wheat, oat, barley, and flax farming
1920s-1930s	Construction of levees, channelization of Butano and Pescadero channels in marsh, farming in floodplains
1930s-1960s	Highest rates of marsh reclamation and agricultural expansion
1940	Construction of highway 1 bridge, temporary haul road built downstream of bridge
1950s-1970s	Post-WWII logging boom: road building and extensive bulldozer logging in old growth of North and South Forks Butano Creek
1960s	State of California begins to acquire property in Pescadero Marsh
	Entire flow of Butano Creek diverted during several summer seasons
	Second wave of logging in upper Pescadero (e.g. Slate, Oil Creeks)
1990s	Second wave of logging in North and South Forks Butano Creek
	Pescadero Marsh restoration projects

The period from 1920 to 1970 was marked by the severe mechanized deforestation of old- and second-growth redwood and Douglas fir forests. Industrial timbering activities took place on over 22,000 acres (or 43 percent) of the watershed. The following significant land use changes took place in the watershed in this period:

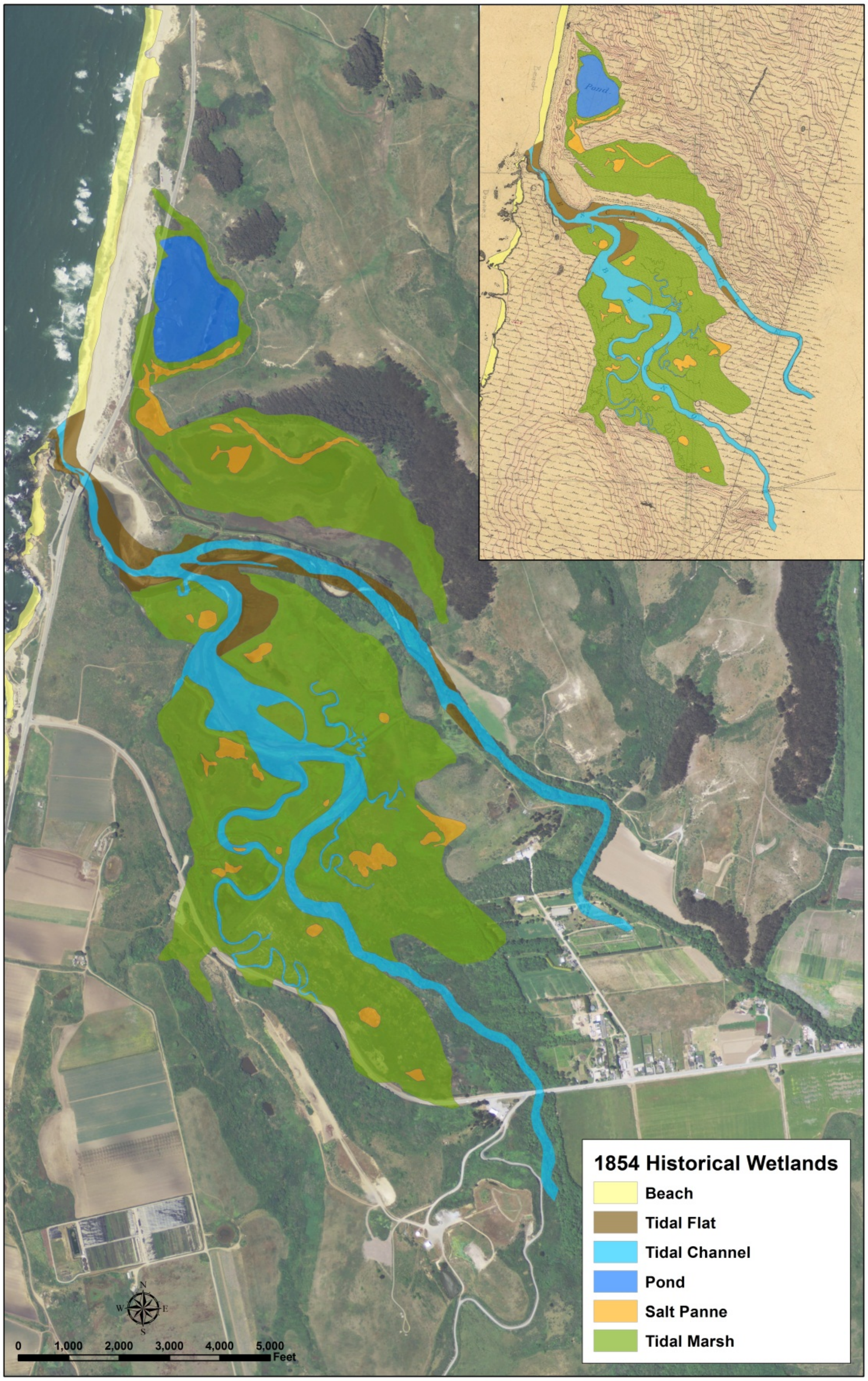
- Building of more than 250 miles of new unpaved haul roads and skid trails;
- Damming of ten small catchments (over an area of 1,300 acres) that drain the Butano Ridge;
- Construction of a major timber haul railroad and truck road along the canyon reach of Pescadero Creek;
- Conversion of mixed conifer-oak woodlands due to agricultural activities over 2,800 acres of the watershed area;
- Introduction of intensive irrigation crop agriculture in areas that were subject to ranching and dairy farming in the 19th century;
- Reclamation of land within Pescadero Marsh including the building of levees;
- Construction of Highway 1 across Pescadero Marsh; and,
- Establishment of several campgrounds for girl scouts, boy scouts, and public retreat sites along the canyon reaches of Pescadero and Butano creeks.

The following land use activities and changes took place in the period from 1970 to 2010:

- Significant reduction of industrial timbering activities to approximately 1,000 acres within the second- and third-growth redwood and Douglas fir forests;
- Creation of public lands;
- Introduction of seasonal camping and hiking tourism on over 27 percent of the watershed;
- Gradual decreases in intensive irrigation of crop agriculture;
- Increases in the management and abandoning of former ranching and agricultural areas in the west of the watershed; and,
- Limited conversion of former ranching areas to vineyard agriculture in the east of the watershed.

In spite of the fact that part of the land use activities that significantly impacted the watershed have been reduced compared to the period from 1850 to 1970s, the legacy impacts of previous anthropogenic actions in the watershed continue to manifest themselves in impairment due to excessive sedimentation and consequent impairment of habitat conditions for listed species.

Figure 7. Historic habitats of the Pescadero Marsh (digitized from the 1854 T-Sheet[1])



1 U.S. Coast Survey 1854 T-Sheet titled Punta Del Bolsa Northward to Tunitas Creek, CA

CONCEPTUAL MODEL FOR LAND USE DRIVEN HYDROLOGIC AND GEOMORPHIC CHANGES

The land use history outlined above triggered and sustained a profound hydrologic and geomorphic transformation across the entire Pescadero-Butano watershed, its channel network, and its estuary over the last 200 years.

There have been four major changes related to the sediment dynamics in the watershed that have completely altered the hydrologic, geomorphic, and subsequently, the ecologic functioning of the creeks and the marsh. These primary changes are listed below and shown in Figure 8:

- Increased in sediment delivery due to hillslope erosion triggered and exacerbated by land use practices including grazing, timber harvesting, and cultivation;
- Increased sediment delivery due to channel incision and bank erosion triggered and exacerbated by land use practices including channelization, cultivation, grazing, and wood removal;
- Elimination of sediment storage in alluvial valleys (formerly swampy meadows and floodplains) due to channel erosion and subsequent elimination of channel-floodplain connectivity;
- Reduced flushing of sediment out of the lagoon due to modification of the lagoon hydrology and sediment dynamics by draining and re-plumbing of the marsh, new Hwy 1 Bridge, reduced inflows due to channel diversions, and partially-implemented restoration projects in the 1990. The lagoon’s reduced ability to scour is exacerbated by increased sediment delivery.

The following is a conceptual outline of the major hydrologic and geomorphic elements of these key changes:

1. Increase in sediment delivery due to hillslope erosion

Conversion of native hillside vegetation, ranching, farming, and logging operations across a significant portion of the watershed resulted in a pronounced denudation (starting in about 1860) through surface erosion, gullying and mass wasting of the hillsides that delivered sediment to channels (Figures 9 and 10):

- An increase of approximately two-fold in the total sediment delivery to stream channels across the watershed that has persisted to present;
- The development of a remarkably dense gully network that expanded approximately three-fold since the 1940s over the grassland hillsides which are underlain by the Purisima Formation and which experience soil piping (Swanson et al., 1989);
- The clearcutting and tractor yarding using headwater channels as skid trails and roads; and
- The construction of the timber haul railroad/truck road in the 1940s and of more than 250 miles of new unpaved haul roads and skid trails.

Figure 8. Changes in the Hydrologic and Sediment dynamics in Pescadero-Butano Watershed

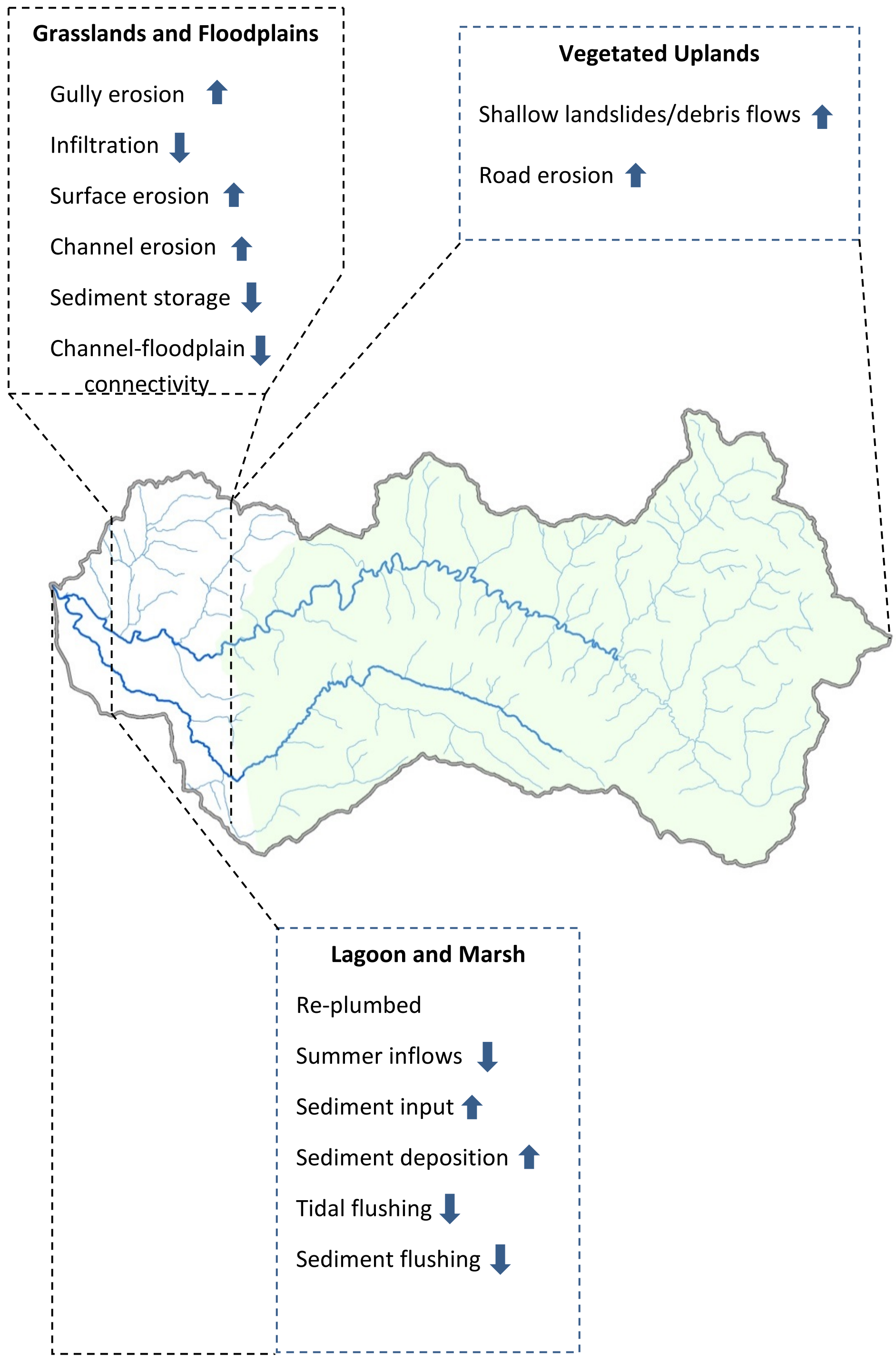
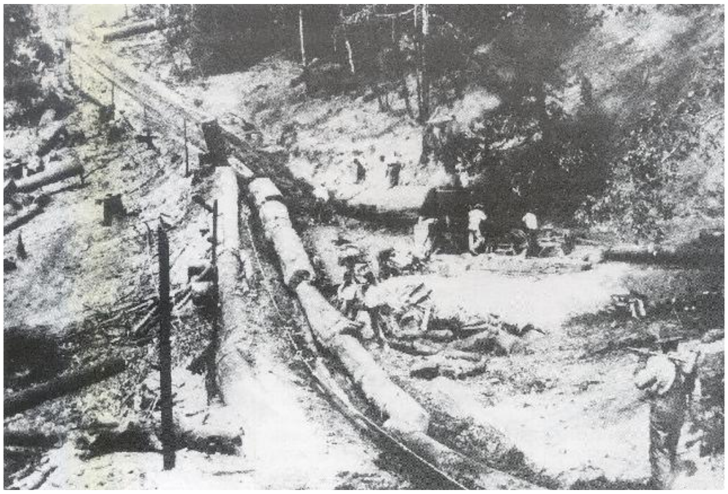


Figure 9. Historic photographs of logging operations in Pescadero-Butano watershed in 1940s illustrating the damaging impacts of the railroad and the use of creeks as skid trails, roads, and flumes.



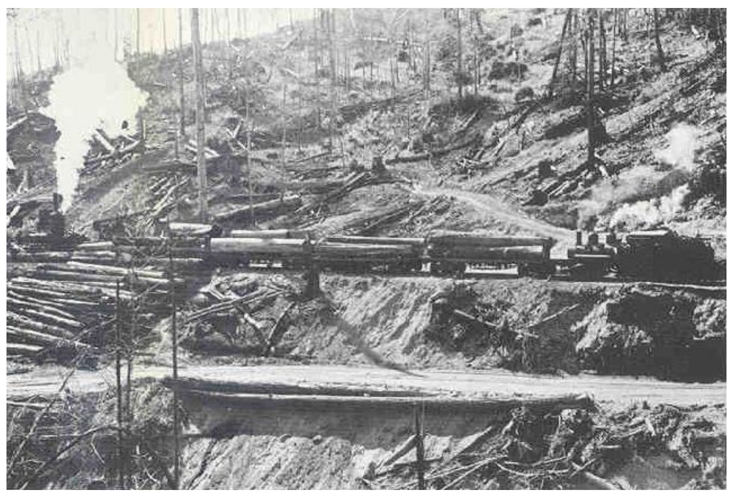


Figure 10. Key sediment sources in the watershed

Hillslope surface erosion and minor slumps on grazed and previously cultivated grasslands.

Large gully formation on the grazed slopes.

2. Increase in sediment delivery due to channel incision

Prior to disturbance, large extensive swampy meadows and floodplains occurred along lower Pescadero and lower Butano creeks adjacent to the marsh. Along Pescadero, the swampy meadows and floodplains were drained by 1870s. The same impact occurred approximately 50 years later along lower Butano Creek. Channelization of the formerly swampy meadows and floodplains resulted in increased connectivity of tributaries to the Pescadero and Butano Creeks and transformed the long-term geomorphic sediment sink landforms (such as Holocene valley fills and alluvial fans) to active sediment sources. Of note:

- The canyon reach of Pescadero Creek has incised by 6 to 12 feet during the first round of logging, likely as a result of the LWD removal and simplification of the channel to enable floating of logs. Many of the canyon reach tributaries (Bloomquist to Trestle) are now perched 6 to 12 feet;
- Splash dam logging, in-channel skidding, livestock trampling, and channel simplification on tributary's McCormick, Jones Gulch, Peters, Slate and Oil occurred primarily between 1860 and 1890;
- Pescadero Creek channel along the upper swampy meadows has incised by 15 feet or more since 1860 (Figure 11). In lower Butano Creek, the channel has incised by 25 feet or more since 1920 (Figure 12). Along Butano Creek incision in the canyon did not begin until after the late 1940s when wood (LWD) removal began in earnest.
- A transformation from channel incision to channel widening along Butano Creek since 2005. In many reaches of lower Butano, soft bedrock is now exposed on the bed and channels are beginning to rapidly widen as unconsolidated banks dominated by sand size material collapse, triggering systemic channel bank instability and increasing sediment delivery.

Figure 11. Anderson Bridge over Pescadero. Photographs showing the bridge prior to rebuilding in 1937 and at present, illustrating the extent of channel incision that took place in the last 100 years.

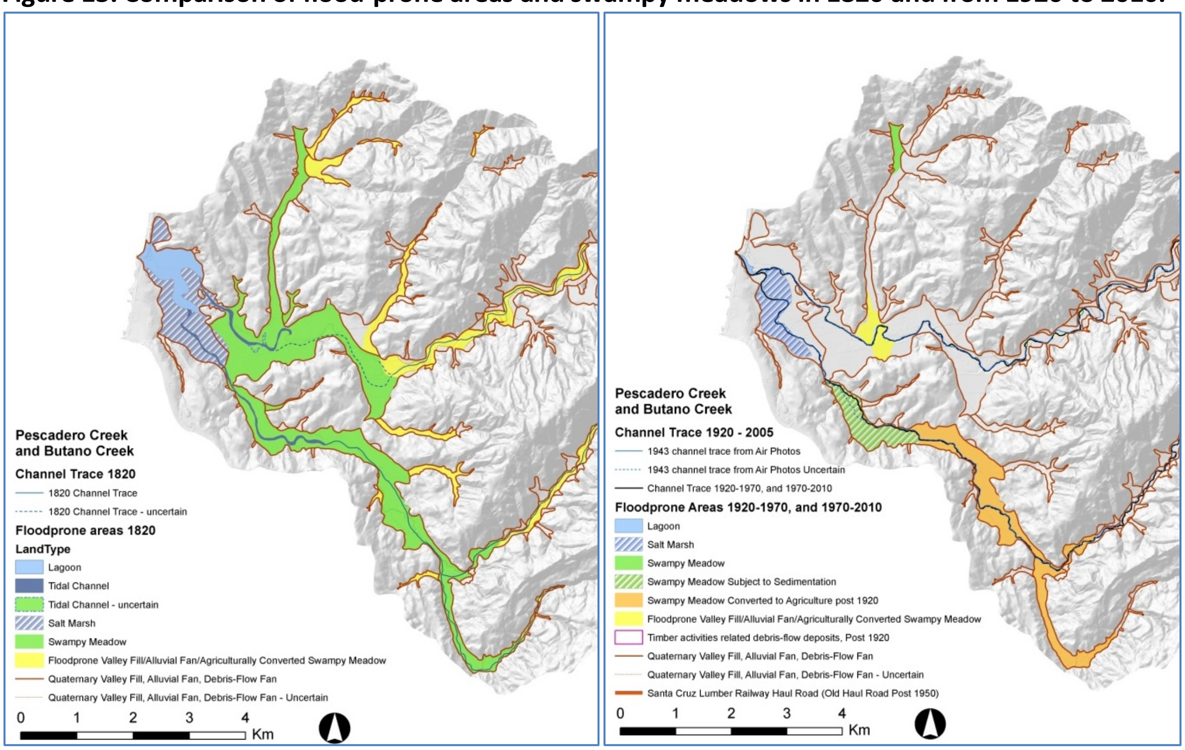
Figure 12. Incised Butano Creek channel

3. Elimination of sediment storage in alluvial valleys

The channelization and draining of the valley and associated channel incision resulted in the conversion of swampy meadows and floodplains that functioned as sediment storage areas to sediment production zones and efficient conduits that transport upstream sediment to lower channels and the marsh (Figures 13 and 14). Of note:

- Severe fragmentation of natural channel connectivity and channelization;
- 99 percent loss of swampy meadow valley floors (1,550 acres) by the 1870s and the abandonment of almost all of the natural floodplains (490 acres) by the 1940s;
- Channel incision and channelization took place along approximately 10 miles within the formerly swampy meadows and 7 miles within the alluvial-fan floodplains; and,
- Notable changes in the stream channel substrate: formerly fine-grained substrates within the alluvial valley floors have coarsened and formerly coarse-grained substrates within the uplands have become finer.

Figure 13. Comparison of flood-prone areas and swampy meadows in 1820 and from 1920 to 2010.



4. Changes in the hydraulic and sediment dynamics of Pescadero lagoon and marsh

Pescadero Marsh has been significantly altered due to land use changes in and around the Marsh and in the upper watershed as outlined above and in several other studies (Viollis 1979, Curry et al. 1985, ESA 2008). Specifically, the marsh was dredged, diked, and filled. Tidal flows were restricted by roads, a railroad crossing, channels, and other structures in the wetlands. Water circulation in the Marsh was altered and restricted by diversions and detentions. In addition, altered runoff patterns with increased flood peaks and reduced infiltration, water pollution by point and non-point sources, vegetation and soil disturbance in wetlands, upstream diversions reducing summer inflows, and exotic species have also affected the marsh (Figures 7 and 15). The new Highway 1 Bridge that was constructed in 1990 is thought to have significantly increased the elevation of the lagoon outlet.

All these alterations have resulted in the following changes to the Marsh:

- The transformation of the deep-water estuary into a shallow creek delta: it is estimated that at least half of the wetland area existing in the Marsh in 1900 was lost by 1960 (Viollis 1979);
- The deposition of up to 5 million tons of sediment within the Pescadero Marsh/Lagoon complex; and frequent flooding within the town of Pescadero since about 1940, most notably since 1990;
- The loss of 50 percent of the tidal reaches of the Pescadero and Butano creeks since 1820 involved a reduction from 1.9 to 0.7 mi on Pescadero Creek, and a reduction from 2.8 to 2.2 mi on Butano Creek; and
- A significant reduction in tidal prism from several hundred acre-feet to approximately 50 ac-ft (PWA, 1980 and ESA, 2011). The tidal prism has increased slightly (by approximately 10 percent) due to the 1990's restoration actions; however, sedimentation has reduced some of those gains to near pre-restoration levels.

The California Department of Parks and Recreation (DPR) owns and manages the Marsh. Between 1993 and 1997 DPR has implemented several restoration projects directed at restoring hydrologic functions and biological productivity (DPR 1992, ESA 2008, Swanson 2001, and CEMAR 2010). It has been hypothesized by some that the restoration projects have exacerbated deposition in the lagoon and marsh.

Figure 14. Lower Pescadero Creek channel in 1915.

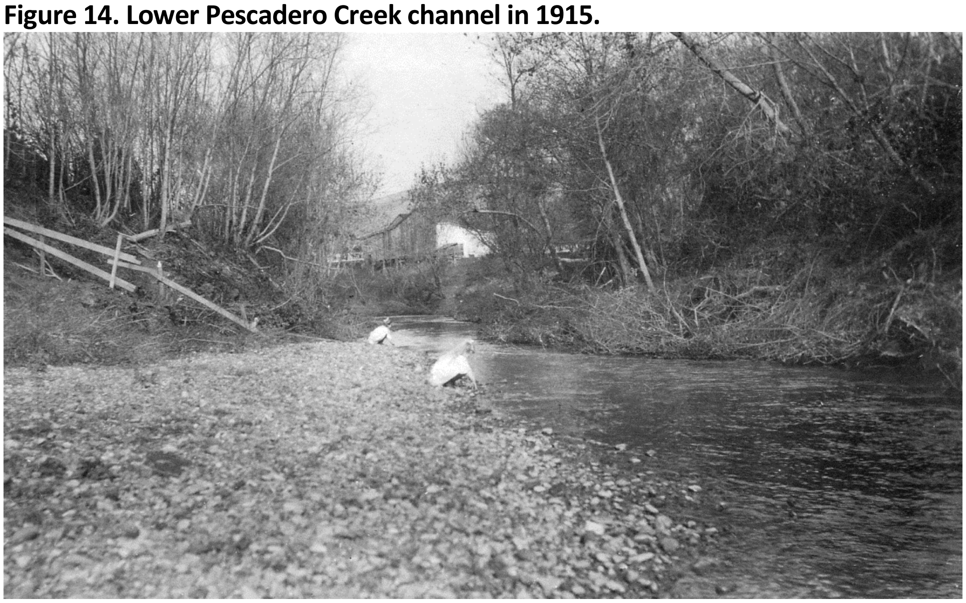


Figure 15. Historical lagoon and channel boundaries (digitized in red from the 1854 T-Sheet).

In summary, not only overall sediment input to the channels increased almost 100 percent over background rates but the sediment storage zones along the middle reaches have been eliminated and - more significantly, converted to sediment production zones. The lagoon, which is the most sensitive habitat for listed species, now receives more sediment from the grazed and cultivated grasslands, from landslides and road erosion in the upper watershed, and from increased channel incision and bank erosion along the formerly swampy meadow reaches. There is more sediment input to the channels which no longer is stored in the floodplains and is transported downstream into the estuary and deposits in the lagoon. If no action is taken, it is likely that channel erosion, hillslope erosion, sedimentation in Butano Creek downstream of the Pescadero Creek Road, and sedimentation in the lagoon will continue. Over the long term sea level rise will exacerbate lagoon sedimentation.

ANALYTICAL STRATEGY

In order to develop a total maximum daily load (TMDL) for sediment in the Pescadero-Butano watershed, we will investigate linkages between sediment inputs, transport, and storage supporting or impairing biological function, specifically salmonid population dynamics. The analytical strategy we will used to quantify the impact of excess erosion and sedimentation on fish populations incorporates two key elements:

1. Sediment Budget: to better understand the sources and transport of sediment in the watershed and to estimate loads associated with each source.
2. Limiting Factors Analysis: to better understand hypothesized linkages between sediment loads and habitat conditions. Changes in sediment supply, transport and storage conditions in the watershed resulted in the degradation of habitat conditions, which in turn have affected coho and steelhead population dynamics.

A sediment budget is an accounting of the sources and disposition of sediment as it travels form its point of origin to its eventual exit from a drainage basin. The sediment budget identifies the nature (natural or anthropogenic), magnitude, spatial distribution, and controllability of sediment sources in the watershed. Sediment production, transport, and storage elements and volumes are estimated based on existing data and studies, geomorphic reconnaissance and field data collection, review of available digital elevation models and aerial imagery, and interviews to document historical conditions. Maps, tables, and a summary write-up for the sediment budget were provided to the Water Board by our consultant Martin Trso. A synthesis of his analyses and a detailed report on the sediment budget is currently being developed.

Beneficial uses related to salmonid populations (cold freshwater habitat, fish migration, preservation of rare and endangered species, fish spawning) and other sensitive aquatic species are not being protected in the Pescadero-Butano watershed. The coho salmon population is on the brink of extinction, and several other threatened or endangered species are at risk due to loss of habitat and pool water quality. Excessive erosion and sedimentation are the primary factors impairing sensitive populations. Additional factors that contribute to the impairment are poor recruitment and retention of woody debris, water withdrawal and diversions during critical low-flow periods, and lagoon circulation and management. To understand the effects of past and current conditions on salmonid populations, a population dynamic model will be developed using RIPPLE, a digital terrain-based fish habitat distribution and population dynamics model.

RIPPLE integrates geomorphological information with aquatic habitat and biological data, and the anthropogenic factors affecting them, for an overall understanding of how these attributes affect salmon populations. Using the results of the RIPPLE model, we hope to assess current conditions quantitatively to help prioritize management actions, and evaluate restoration and conservation options under various scenarios to develop successful restoration strategies and measures.

WORKPLAN

Over the next couple of months, the Water Board staff will integrate and synthesize the results of all technical analyses conducted to date and will prepare a preliminary source assessment report. This report will provide details on the required TMDL components and the supporting information acquired over the last year.

Once the source assessment report is reviewed internally, we will start our stakeholder outreach efforts more formally by conducting public presentations on the sediment budget findings and limiting factors analysis. These presentations will be conducted along with the scientific experts and consultants who have been assisting us. We will also lead "creek walks" to illustrate on the ground our findings on channel incision and bank erosion processes and habitat issues. Our stakeholder outreach efforts will focus on interested, knowledgeable parties and those who will likely be required to undertake some action per the implementation plan. Stakeholder outreach efforts will start formally in the summer of 2013 and will continue throughout the TMDL development efforts.

Concurrently with the stakeholder outreach efforts, we will be completing the TMDL components including numeric targets, linkage analysis, and implementation actions. Our current understanding suggests that control of human caused sediment discharges will not be sufficient to achieve sediment water quality and therefore, protection of salmonid-related beneficial uses in the Pescadero-Butano watershed. Therefore, the implementation plan will likely need to evaluate a suite of actions to restore channel function, floodplain sediment storage, and estuary tidal prism to enhance circulation and sediment flushing out of the estuary into the ocean.

TMDL TIME SCHEDULE

Tasks	Completion Date
Data Collection and Analyses	
Data Collection and Modeling	June 2013
Conceptual Model	July 2013
Stakeholder Outreach	July 2013 to June 2015
Preliminary Project Report	
Source Assessment Report	September 2013
Preliminary Project Report	July 2014
Peer Review	
Peer Review Draft	August 2014
Staff Report	December 2014
Public Process	
Conduct CEQA Scoping	Mar 2014
Finalize Staff Report	May – September 2014
Public Comment Period	October-November 2014
Regulatory Action	
Planned Water Board Hearing	May 2015

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Personal

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