Total Maximum Daily Load for Sediment and Habitat Enhancement Plan for Pescadero-Butano Watershed

Staff Report

California Regional Water Quality Control Board

San Francisco Bay Region

by

Setenay Bozkurt Frucht

Mike Napolitano

James Ponton

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California Regional Water Quality Control Board, San Francisco Bay Region

1515 Clay Street, Suite 1400

Oakland, CA 94612

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CHAPTER 1

INTRODUCTION

Key Points

- Section 303(d) of the Clean Water Act requires states to compile a list of "impaired" water bodies that do not meet water quality standards.
- In 1998, the Water Board listed Pescadero and Butano Creeks as impaired by sedimentation. In addition, the creeks are impaired due to a lack of habitat complexity and connectivity.
- The impairment applies to Pescadero and Butano Creeks, as well as their tributaries.
- This report contains Water Board staff analyses and findings pertaining to these impairments and an Implementation Plan to address the impairments.

This Staff Report for the Pescadero-Butano Watershed Sediment Total Maximum Daily Load (TMDL) and Habitat Enhancement Plan presents the supporting documentation for a proposed Basin Plan amendment that will be considered by the San Francisco Bay Water Quality Control Board (Water Board) to restore water quality for sediment and habitat condition and to facilitate the recovery of listed populations of coho salmon and steelhead in the Pescadero-Butano watershed.

The Basin Plan is the Water Board's master planning document. It specifies designated beneficial uses of water (e.g., fish habitat, recreation, agricultural water supply), water quality objectives (parameters that can be evaluated to determine whether the designated uses are supported), and implementation plans and policies to achieve water quality standards. The Basin Plan amendment to address sediment and habitat impairments in Pescadero and Butano Creeks would establish an assimilative capacity for sediment, numeric targets that define attainment of water quality objectives for sedimentation and population and community ecology, and identifies implementation actions.

1.1. Background

The federal Clean Water Act requires California to adopt and enforce water quality standards to protect waters in the State. The Water Quality Control Plan (Basin Plan) for the San Francisco Bay region delineates these standards which include designated beneficial uses of water, numeric and narrative water quality objectives to protect those uses and provisions to enhance and protect existing water quality (antidegradation).

Designated beneficial uses of water for Pescadero and Butano Creeks include the following:

- Fish migration and spawning

- Cold and warm freshwater habitats
- Preservation of rare and endangered species
- Water supply (agricultural)
- Recreation (fishing, swimming, boating, etc.)
- Wildlife habitat

Beneficial uses adversely affected by excess sediment in the Pescadero and Butano Creeks are recreation (i.e., fishing), cold freshwater habitat, fish spawning and migration, and preservation of rare and endangered species. Section 303(d) of the Clean Water Act requires states to compile a list of "impaired" water bodes that do not meet water quality standards and to establish a TMDL to address the impairment. The 303(d) listing of the Pescadero-Butano Creek Watershed is prompted by the loss of suitable habitat and the decline in populations of sensitive aquatic species, especially salmonids, due to elevated sediment loads and excessive sedimentation. As described below, Pescadero Creek is not meeting narrative water quality objectives (Table 1). Excessive fine sediment has been documented throughout the watershed to embed spawning gravels and fill pools. Elevated sediment loads from the watershed have contributed to increased sedimentation in the Pescadero lagoon and marsh (estuary), however, the estuary still provides exceptional conditions for growth for the listed salmonids. Other species on the endangered list are also dependent on habitats within the Pescadero marsh and lagoon and include tidewater goby, San Francisco garter snake, and California red-legged frog.

In addition to elevated sediment loads and excessive sedimentation, the Pescadero-Butano watershed is also impaired by degraded habitat complexity and connectivity –a form of pollution—which results in non-attainment of the Basin Plan's water quality objective for Population and Community Ecology. Historical and ongoing channel incision degrades habitat complexity and connectivity, and it is widespread along both Pescadero and Butano Creeks. Channel incision reduces the frequency of gravel bars and pools, side channels and alcoves, and results in disconnection of the channel from its floodplain. These changes degrade the quality and quantity of habitat for federally-listed populations of coho salmon and steelhead.

This staff report presents the problems of sedimentation and channel incision, describes causes and sources, sets measurable values for target parameters related to achievement of narrative water quality objectives, and defines a course of action to restore water quality and habitat conditions.

1.2. TMDL Process

The Pescadero-Butano Watershed Sediment TMDL defines the allowable amount of sediment that can be discharged into the creeks while ensuring attainment of water quality standards. This TMDL is expressed as a mass per unit time, as well as a percentage of the natural background sediment delivery rate. The TMDL process includes compiling and considering available data and information, conducting appropriate analyses relevant to defining the impairment problem, identifying sources, and allocating responsibility for actions to resolve the impairment. In addition, the scientific basis of the Basin Plan amendment is subjected to external scientific peer review. This step is required under §57004 of the

Health and Safety Code, which specifies that an external review is required for work products that serve as the basis for a rule, "…establishing a regulatory level, standard, or other requirements for the protection of public health or the environment." Channel incision and the impacts on habitat complexity and connectivity, which are widespread in the watershed, is a controllable water quality factor. Channel incision is addressed separately from the TMDL with a set of numeric targets and management and restoration actions.

1.3. Document Organization

The sections of this staff report are as follows:

***Chapter 2. Problem Statement*.** Describes the relationships between the identified pollutant (sediment), applicable water quality objectives and beneficial uses, and current water quality conditions in Pescadero and Butano Creeks and their tributaries. The problem statement also describes factors limiting steelhead and coho salmon populations in the watershed.

Chapter 3. Pescadero-Butano Watershed Setting. Presents information about the physical setting of the watershed, including geology and soils, climate and hydrology.

Chapter 4. Two Centuries of Land Use Change. Presents an in-depth analysis of the impacts of historical land uses and the watershed response.

Chapter 5. Sediment Source Analysis. Presents the approach, methods, and results of the sediment source analysis. It is based on field measurements and/or models and estimations.

***Chapter 6. Numeric Targets*.** Defines the desired future condition of measurable indicators which when collectively achieved will ensure attainment of standards, including water quality objectives and protection of beneficial uses. Presents the rationale to support proposed targets.

Chapter 7. TMDL, Linkage Analysis and Allocations. Describes the linkages between sediment loads and habitat conditions, and therefore provides the rationale for estimating the assimilative capacity for sediment in Pescadero and Butano Creeks. Allocations are amounts of sediment allocated to each source category, including a margin of safety to account for uncertainty in estimating loads and assimilative capacity, and allowance for future growth.

***Chapter 8. Implementation Plan*.** Discusses actions and requirements needed to manage sediment sources and attain water quality standards and actions required to protect and/or enhance other stream habitat conditions.

Chapter 9. Regulatory Analysis. Contains legally required analyses of potential environmental impacts and costs that may be associated with the adoption of the proposed Basin Plan amendment.

CHAPTER 2

PROBLEM STATEMENT

Key Points

- Land-use activities have contributed to significantly elevated sediment delivery to channels; more than twice that of natural background rates.

- The substantial increase in sediment delivery has caused a significant increase in the amount of fine sediment deposited in streambeds, degrading spawning and rearing habitat for native fishes including listed populations of coho salmon and steelhead.

- Historical land-use disturbances also have caused the streambeds along Pescadero and Butano creeks to lower (incise) by more than ten feet in most channel reaches. These channel reaches are now disconnected from their floodplains.

- Prior to incision, about one-third of watershed sediment yield, including most of the gravel and sand, and some of the finer sediment, was deposited on floodplains and/or superimposed on alluvial fans along lower Pescadero and Butano creeks. The entire valley floor was a floodplain that was inundated frequently each wet season, creating extensive wetlands that provided high quality habitat for salmon, steelhead, and other species.

- Channel incision and associated bank erosion have converted floodplains and fans from significant sediment storage sites (sinks) into significant sediment sources. Also as a result of incision and a reduction in the amount of large woody debris in channels, habitat has been greatly simplified.

- Significant and persistent increases in sediment supply and loss of floodplains have contributed to an order-of-magnitude increase in the sedimentation rate in Pescadero Lagoon. There has been a substantial reduction in the depth and continuity of channels in the lagoon, which are likely adversely impacting steelhead smolt production.

- A substantial reduction in the rate of sediment yield to Pescadero Lagoon is necessary to maintain and/or enhance the depth and continuity of channel habitats within the lagoon.

2.1. Introduction

This chapter presents the problem statement which is the basis for the proposed Basin Plan amendment. It describes the relationship between the identified pollutant (sediment), applicable water quality standards, and current water quality conditions in the Pescadero-Butano watershed. Water quality standards include:

- A statement of beneficial water uses for a specified body of water
- Water quality objectives to protect those designated beneficial uses
- An anti-degradation policy, which requires that where water quality is better than needed to protect beneficial uses, those superior water quality conditions must be maintained

Water quality objectives for sediment and aquatic life, and relevant beneficial uses for Pescadero and Butano creeks are listed in Table 1. Narrative water quality objectives for sediment and settleable material are not met in the watershed because the percentage of fine sediment in the streambed[1] is elevated substantially above natural background, and the streambed is more mobile, contributing to the degradation of freshwater channel, floodplain, and estuarine habitats, and consequently to the decline of watershed salmonid populations listed under the Endangered Species Act. Pescadero and Butano creeks were placed on the 303(d) list of impaired water bodies initially in 1998 and the listing is sustained in the proposed 2016 303(d) list.

Elevated fine sediment deposition and loss of channel complexity and habitat in Pescadero and Butano creeks and their tributaries result not just from sediment supply increases, but also from fundamental alteration of channel sediment transport and storage processes. One of the largest human caused sediment sources is channel incision. In addition to its significance as a sediment source, incision also alters sediment transport and storage processes and obliterates the basic physical habitat structure of the channel, expressed by a substantial reduction in the frequency and area of gravel bars, riffles, side channels and sloughs, and disconnection of the channel from its floodplain. Channel incision is a controllable water quality factor that results in non-attainment of the narrative water quality objective for population and community ecology (Table 1). Inferred significant reductions in large woody debris (LWD) loading also substantially alter sediment transport and storage, and physical habitat structure. Our supporting rationale is as summarized below.

[1] When we refer to fine sediment in the streambed, we are referring primarily to sand (< 2mm) and lesser amounts of fine or very fine gravel (2 mm ≤ D ≤ 8 mm). These grain sizes constitute the bed material suspended load in gravel-bedded channel reaches that is transported either as bedload during smaller runoff events (that are greater the threshold for bed material transport), and/or as suspended load during larger runoff events.

Table 1. Water Quality Objectives and Sediment-Related Beneficial Use Categories

Beneficial Use Categories	Water Quality Objectives	
Cold Freshwater Habitat Fish Migration Preservation of Rare and Endangered Species Fish Spawning Wildlife Habitat Recreation	Turbidity	Increase from background <10% where natural turbidity is >50 NTU*
	Sediment	Suspended sediment load of surface waters shall not be altered in such a manner to cause a nuisance or adversely affect beneficial uses
	Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that cause a nuisance or adversely affect beneficial uses
	Suspended Material	Should not cause a nuisance or adversely affect beneficial uses
Cold Freshwater Habitat Fish Migration Preservation of Rare and Endangered Species Fish Spawning	**Population and Community Ecology**	All waters shall be maintained free of toxic substances in concentrations that are lethal to or that produce significant alterations in population or community ecology or receiving water biota. In addition, the health and life history characteristics of aquatic organisms in water affected by controllable water quality factors shall not differ significantly from those for the same waters on areas unaffected by controllable water quality factors
Note: Bold text indicates water quality objective is not being attained. *NTU Nephelometric Turbidity Unit		

Historical Declines in Coho Salmon and Steelhead Populations

Although steelhead have maintained a consistent presence in the watershed, considering the significant degradation of channel and lagoon habitat[2] that has occurred within the historical period (Chapter 4,

[2] Since the mid-1990s, large fish kills associated with natural breaching of Pescadero Lagoon have been documented in almost every year (Jankovitz,2016). In 2016, the lagoon breached on October 31-November, and is thought to have killed several hundred to more than one thousand robust juvenile steelhead (typical size 195-250 mm) that otherwise would have been expected to have very high ocean survival rates.

Balance Geo, 2015), it is likely that the watershed steelhead population has declined substantially. In Spanish, the word Pescadero means "fishing place" (Gudde, 1998). In fact, during the late nineteenth century coho salmon and steelhead populations were abundant enough to support a commercial fishery (Redding et al., 1872, as cited in Spence et al., 2011, pp. 71-72), and the Pescadero-Butano watershed was a popular destination for sport fishing (Rockwell, 1879, and Jordan, 1887, as cited in Spence et al., 2011, pp. 73-75). During this same period, Colonel A.S. Evans describes the fishing for "salmon-trout" in Pescadero Lagoon as follows:

> "… the best morning sport I have ever enjoyed in my life, and I have shot and fished from the Red River of the north to the Rio Grande, and from the Atlantic to the Pacific" (Evans, 1874, as quoted in Viollis, 1979, p. 88).

The above accounts are particularly notable considering the intensity and significance of land-use disturbances initiated two decades earlier, and still in-progress at the time of these writings, including extensive clear-cut logging and intensive grazing on hillslopes (Balance Geo, 2015), and also the construction of several sawmills on Pescadero Creek and its tributaries. For example, one sawmill located about three miles upstream of the lagoon was thought to completely block fish passage, and noted to be causing large fish kills from the tremendous quantities of sawdust being disposed directly into the stream (Redding, 1872, as cited in Spence et al., 2011, pp. 71-72, and Figure 4.5, p. 27).

Nevertheless, a few decades later in the early twentieth century, the California Department of Fish and Game (CDFG) indicated that Pescadero-Butano watershed still was an excellent steelhead stream and that it supported the largest steelhead run within San Mateo County (CDFG, 1912, as cited in Becker et al., 2010). CDFG's opinion also is supported by oral history accounts that document "great fishing" [for steelhead in the lagoon] and "boat houses ... at the eastern edge of the marsh … rented to fisherman for a dollar a day" (Oral History Interviews with Frank Bell and George Davis, as reported by Viollis, 1979, p. 88).

Almost a half-century later, in the early 1960s, the California Department of Fish and Game estimated that San Mateo County coastal streams, including Pescadero, Butano, San Gregorio, and Gazos combined, still supported estimated average spawning runs of 1,000 coho salmon and 5,000 steelhead (CDFG, 1967 as cited in Becker and Reining, 2008). Sport fishing continued to be popular.

However, by the late 1970s, CDFG concluded that the Pescadero-Butano coho run had been decimated or locally extirpated, in the wake of the severe drought of 1977 and 1978, "which exacerbated already poor habitat conditions" caused by intensive land-use disturbances (Anderson, 1995).

Spawner surveys conducted in recent years in the Pescadero-Butano watershed provide a basis for estimating that one-to-a-few-hundred adult steelhead returned to spawn in the Pescadero-Butano watershed in water years 2012, 2014, and 2015, and that several hundred to perhaps more than 1000 steelhead returned to spawn in water year 2013[3] (Jankovitz, 2012 and 2013; Goin, 2014 and 2015). For

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[3] Please note on average, about 20% of the total length of potential spawning habitat was surveyed. Therefore, using weighted average values for redd density, and an inferred ratio between the number of redds and adult steelhead, still results in fairly high uncertainty in estimating the number of returning adults. An additional

comparison, in defining population viability criteria, National Oceanic and Atmospheric Administration Fisheries states a low risk of extinction for the Pescadero-Butano steelhead population based on several parameters, including having an average annual spawning run of ≥ 2200 adults (Spence et al., 2012; NOAA Fisheries or NMFS, 2016).

Currently, coho salmon in the Central California Coastal Evolutionarily Significant Unit, including the Pescadero Creek population, are listed as endangered under the state and federal Endangered Species Act. Steelhead in the Central California Coastal Distinct Population Segment including the Pescadero-Butano population, are listed as threatened under the federal Endangered Species Act.

Significant Increase in Sediment Supply and Habitat Degradation via Channel Incision

Significant increases in sediment supply to channels and simplification and/or loss of freshwater channel and estuarine habitats have contributed to the decline of listed populations of salmonids, and other native species that are threatened or endangered, including tidewater goby, San Francisco garter snake, and California red-legged frog. In summary, intensive land-use related disturbances that occurred primarily in the mid-nineteenth through mid-twentieth centuries have caused fundamental alterations of sediment delivery to channels, and also to transport and storage of sediment within channels, and to sedimentation in the marsh and lagoon (Balance Geo, 2015, and Chapters 4 and 5 herein). These legacy disturbances have caused a persistent two-to-three-fold increase in total sediment supply to Pescadero Creek and its tributaries, and deep incision of most channels in alluvial valley reaches including much of Pescadero and Butano creeks[4] (Balance Geo, 2015, and Chapter 3 and 4 herein). During the historical period, as a result of channel and watershed disturbances, the streambeds along Pescadero and Butano creeks, in most locations, have lowered (incised) by several meters-or-more, and are now disconnected from their floodplains. Those disturbances include: a) connection of naturally disconnected tributary channels; b) relocation or straightening of reaches of the mainstem of Pescadero Creek; c) removal of large channel spanning debris jams on Pescadero and Butano creeks; d) clear-cut logging of old-growth forests; e) construction of mill dams; and f) intensive grazing and farming on hillslopes, which greatly increased runoff.

Prior to incision, about one-third of the total watershed sediment yield, including most of the gravel and sand, and some of the finer sediment, was deposited within floodplains and/or superimposed on alluvial fans along lower Pescadero and Butano creeks. The entire valley floor was a floodplain that was inundated many times during most wet seasons, creating and sustaining extensive wetlands (Balance Geo, 2015, Chapters 3 and 4 herein). Based on review of published literature these floodplains would have provided excellent rearing and refuge habitats for juvenile salmon and steelhead (Bustard and

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complicating factor exists related to determining whether potential spawning habitat in the Butano Creek sub-watershed remains accessible (except for very high water levels) to spawning adults under current conditions, which include complete filling of its channel within the Pescadero Lagoon.

[4] Deep incision occurs throughout the alluvial reaches of Pescadero and Butano creeks, except for the reach immediately upstream of Pescadero Creek Road in the "Willow Patch" and downstream of the road within the marsh (where the Butano Creek channel has disappeared) in response to substantial channel aggradation.

Narver, 1975; Nickelson et al., 1992a and b; Tschaplinski and Hartman, 1983; Swales and Levings, 1989; Solazzi et al, 2000). We also note that the loss of floodplain habitats is thought to be a primary factor in the decline of salmon populations throughout the Pacific Coastal Ecoregion[5] (Nickelson et al., 1992a, Beechie et al., 2001; Giannico and Hinch, 2003).

Channel incision within unconfined alluvial channel reaches, along Pescadero and Butano creeks, also has greatly increased the depth of flow during the annual flood while keeping the same width or narrowing the channel, and now the typical width-to-depth ratio is much less than 12-to-1, the minimum ratio that is required to facilitate bar formation in gravel-bedded channels (Jaeggi, 1983). This change occurring together with land-use related reductions in the amount and caliber of large woody debris in channels is inferred to have caused: a) a significant reduction in the frequency and extent of riffle and gravel bar habitats and the conversion of forced pool-riffle reaches to plane-bed reaches (Montgomery and Buffington, 1999); and b) a significant reduction in side channel habitats, that were formed via frequent channel avulsions prior to incision (Jerolmack and Mohrig, 2007; Collins et al. 2012).

Channel incision and much higher sediment supply also have interacted to contribute to a substantial reduction in the depth and continuity of channel habitats within the lagoon (Viollis, 1979; Curry, 1985; Largier et al., 2015)[6]. Channel incision, substantial increases in sediment supply, and also an inferred substantial reduction in the amount of large woody debris in channels have interacted to greatly diminish the quality and diversity of freshwater channel habitats.

Also, it is likely that there are fewer large fallen trees in channels as a result of logging of old-growth forests[7], intensive removal of debris from channels[8], and as a consequence of channel incision (e.g.,

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[5] Pescadero-Butano watershed is within the Pacific Coastal Ecoregion, which extends along the west coast of North America, south into the Santa Cruz Mountains (Naiman and Bilby, 1998, Figure 1.1, pp.6-7).

[6] Other factors may include effects of the Highway 1 Bridge configuration and/or historical levee construction (to allow agricultural cultivation to occur historically in portions of the marsh) in causing reductions in sediment transport capacity and/or in focusing sediment deposition over a smaller area (see Viollis, 1979; and Curry, 1985).

[7] For example, Lisle (2002, Figure 3) makes this point by comparing the size distribution of large woody debris in a channel draining an old-growth forest to the size distribution of an otherwise physically channel draining a second-growth redwood forest. Although we don't have a similarly detailed survey of large woody debris in the Pescadero Creek watershed, it is reasonable to infer that prior to clear-cut logging the median diameter of trees in the old-growth forests was substantially larger than in the second- or third-growth forests today. Larger, "key pieces" of wood are those that are big enough to resist entrainment, and therefore, they are integral to the establishment and stability of debris jams, which as a result can shape complex interconnected channel and floodplain habitats, as described by Collins et al. (2012).

[8] For example, along the mainstem of Butano Creek debris jams were removed in the 1920s to address frequent flooding of cabins built on the valley floor, once these cabins switched from being used seasonally to year-round residences (Al Solars, personal communication, as cited in Balance Geo, 2015). Also in the early 1990s, many debris jams were removed throughout the watershed, as part of an effort to reduce flooding and bank erosion (as described in Cook and Cook, 1997). Although poorly documented, it also is widely accepted that up until recent years, there were intensive efforts by watershed residents throughout the watershed to remove debris jams to salvage merchantable timber, reduce local flooding, and/or to address bank erosion concerns. Also, in the 1950s

incised channels are narrow and deep and as a result many fallen trees remain perched above the channel). Large trees and debris jams can store several decades or more of potential bedload supply in channels draining old-growth redwoods (Keller et al., 1995, pp.23-26); loss of trees and debris jams in the channels result in loss of in-channel sediment storage. The lack of large fallen trees in channels is a problem for fish because large trees force pools and bars to form, cause sediment to be sorted into discrete patches (that vary in grain size), and create side channels, islands, and floodplains (Collins et al., 2012). CDFW noted a lack of large woody debris during a number of the stream surveys in the watershed (CDFG 1994b, 1996a–c, and 1997). National Marine Fisheries Service (NMFS) (2012) identified the low amount of in-channel wood and poor shelter as two of the primary constraints to coho salmon adult, summer and winter rearing juvenile, and smolt life-stages in the Pescadero-Butano watershed. NMFS (2015) classified the existing habitat complexity, especially as related to large wood and shelter, as poor for steelhead in the Pescadero-Butano watershed.

Significant Increase in Sediment Supply and Elevated Levels of Fine Sediment Deposition in Freshwater Channels

Field studies and flume experiments that characterize sediment transport and deposition in gravel-bedded channels document that streambeds become finer in response to increases in sediment supply (Dietrich et al., 1989; Nolan and Marron, 1995; Lisle and Hilton, 1999; Cover et al., 2008). Although quantitative data characterizing streambed substrate conditions in the Pescadero-Butano watershed are limited, studies conducted in the nearby Napa River watershed, which has a similar range with regard to runoff and sediment supply, document a strong correlation therein between sediment supply and fine sediment deposition in streambeds (Water Board, 2009, Figure 14 and table 8). We infer that there has been a significant increase in the concentration of fine sediment deposited in streambeds in the watershed because of the large and persistent increase in sediment supply that has occurred (Balance Geo, 2015; ESA, 2004).

Also, habitat surveys conducted in the summer of 2003 in the Pescadero-Butano watershed identified abundant fine sediment deposition and lack of large woody debris (LWD) as the primary stressors for salmonid populations in freshwater channel habitats (ESA, 2004, pp. 2-13 through 2-15, and 8-14 through 8-16)[9].

Increase in Fine Sediment Deposition and Habitat Simplification and Their Effects on Salmonids

High levels of fine sediment deposition in the streambed can significantly reduce survival to emergence of incubating salmonid eggs/alevins (an alevin is a newly hatched fish still carrying its yolk sac) through:

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through 1970s, many debris jams were removed or modified by the California Department of Fish and Game because at that time they were perceived to be barriers to fish migration (Zatkin, 2002).

[9] The fisheries habitat assessment included within ESA (2004) was focused on freshwater channel reaches. Assessment of lagoon and marsh habitats was outside of the scope of this study.

a) Decreases in spawning gravel permeability and dissolved oxygen concentrations within the incubation site (McNeil, 1964; Chapman, 1988, pp. 4498-4503; Water Board, 2009, pp. 63-66);

b) Entombment of alevins (via infiltration of fine sediment into the redd that impedes the emergence of fry) (Phillips et al., 1975); and/or

c) Increased frequency and extent of streambed scour (Montgomery et al., 1996).

Rates of streambed mobility and reach-average values for streambed scour are strongly correlated (Haschenberger, 1999; Bigelow, 2005; May et al., 2009; and Shellberg et al., 2010). Streambed scour at spawning redds can be a significant source of mortality during incubation for coho salmon (McNeil, 1966; Montgomery et al., 1996; Shellberg, 2010). High rates of streambed mobility also have been linked to persistent reductions in the biomass of benthic macro-invertebrates (Matthaei and Townsend, 2000), suggesting there also could be the potential for reduced growth of juvenile salmonids in all freshwater life stages as a result of elevated rates of bed mobility.

For steelhead, smolt production may be limited, at least in part, by interstitial spaces in cobble-boulder substrate patches, which provide an important component of winter rearing habitat (Bustard and Narver, 1975; Stillwater Sciences, 2008, p. 57 and p. 63; Ligon et al., 2016). Cobble-boulder substrate patches capable of providing over-winter refuge habitat for juvenile steelhead are abundant within the Pescadero Butano watershed, and occur where debris flows are deposited in channels from watershed source regions underlain by hard bedrock types (Donaldson, 2011). Density and suitability of these interstitial spaces between the cobble-boulder substrate patches can be degraded by increases in the supply of sand and gravel delivered to the channel (see for example, Cover et al., 2008).

Scour of spawning gravel can be a significant source of mortality to the incubating eggs and larvae of salmon and trout species (Montgomery el al., 1996; Shellberg et al., 2010). The beds of natural gravel channels cut and fill during high flow events. How mobile the bed is deeply and how deeply it is scoured is a function of the force per unit area exerted by flowing water on the streambed, channel features that either concentrate or disperse flow energy (e.g., debris, vegetation, bedrock, gravel bars, etc.), and the abundance and sizes of sand and coarser sediment grains supplied to the channel (bedload). Human actions that increase bedload supply rate, and/or cause it to become finer, will also cause the streambed to become finer and increasing the rate of bedload transport through a channel reach (Dietrich et al., 1989). As bedload transport rate increases, so do the mean depth and/or spatial extent of streambed scour.

Finally, results from studies conducted elsewhere in the California Coast Range suggest that elevated levels of fine sediment deposition can have significant adverse effects on juvenile growth and survival during the summer rearing period (Suttle et al., 2004; Harvey et al., 2009).

Order-of-Magnitude Increase in the Sedimentation Rate in the Pescadero Lagoon and Marsh

Although the TMDL and implementation actions focus on the sediment impairment within the channel network upstream of the lagoon and does not include implementation actions specific to the lagoon and marsh, achievement of this TMDL is a necessary step to restore water quality and beneficial uses in the lagoon and marsh. This section describes the lagoon and marsh in order to provide for an understanding of the entire system.

Significant and persistent increases in sediment supply and loss of floodplains also have contributed to an order-of-magnitude increase in the sedimentation rate in Pescadero Lagoon (Berlogar, 1988; Viollis, 1979; Williams, 1990). As a result, there has been a substantial reduction in the depth and continuity of channels in the lagoon. Between approximately 1900 and 1960, over one-half of the open water volume within the marsh and lagoon was lost to sedimentation (Viollis, 1979) and Pescadero Lagoon has changed from an open-water estuary into a shallow-creek delta. There has been an additional average shallowing of the lagoon by about 1.3 feet since 1990 (Largier et al., 2015). Up to 4 million metric tons of sediment has been deposited in the marsh and lagoon system over the last hundred and fifty years (Chapter 5) as a result of upstream watershed disturbances and subsequent erosion, loss of floodplain storage in the valley, and land use disturbances and hydraulic modifications in the marsh.

These changes are hypothesized to adversely impact steelhead run size because: i) lagoons provide critical summer rearing habitat for steelhead and contribute to a major portion of watershed steelhead production (NMFS 2015); and ii) lagoon-reared juvenile steelhead achieve much larger size prior to ocean migration (as compared to the juvenile steelhead that rear exclusively in freshwater channel reaches), and therefore, the lagoon-reared steelhead smolts may dominate the population of adults that return from the ocean to spawn in the watershed, as has been demonstrated in the nearby Scott Creek watershed (Hayes et al. 2008; Hayes et al., 2011).

In addition to sedimentation, it is likely that other stressors including poor water quality in the lagoon (Largier et al., 2016, pp. 27-30), elevated and/or stressful stream temperatures (Spence et al., 2011, pp. 22-24), reduced freshwater inflows, and impediments and/or barriers to fish migration[10] may interact with sedimentation and habitat simplification to substantially diminish steelhead smolt production, fitness, and the diversity of life history variants, and also present substantial challenges to the re-establishment of a self-sustaining run of coho salmon.

[10] Barriers and/or impediments to salmonid passage include road crossings and dams identified along Pescadero and Butano creeks, and/or their tributaries.

Pescadero stream—Is three miles from Pompona [Pomponio] Creek, and **is a fine clear water trout stream**, empties into the sea about two miles below the town, and connects, one mile from the beach, with the **Butena River [Butano Creek], which is also a fine clear water trout stream running to the southeast; is about twenty feet wide, and six feet deep. For six miles this makes a fine resort for the salmon and silver salmon from the sea which frequent these waters, with other lesser sea fish, for the purpose of spawning.** From October to March, a wagon load of these beautiful fish, weighing from two to thirty pounds, are taken daily and sold all along the road, as high up as Spanishtown [Half Moon Bay], at seventy-five cents per pound. These fish are only taken during the spawning season, they being a deep water fish and go out to sea in March. Three miles up the Pescadero stream is Hayward's steam sawmill, and three miles further up is Anderson's sawmill, run by a turbine wheel, having a well-constructed dam, built of hewn logs, well secured right across the creek. The dam is twenty feet long and about ten feet high, built in eighteen hundred and sixty-two, and all the water from above passes through the sluiceway at the turbine wheel. As the water has never been half way up to the top of this dam, since it was built, no fish have ever passed. A sluicebox with stop waters in it for fish could be introduced through this dam near its base and outside the sluiceway for the wheel, this being the only place where the box could reach the water below, as all the rest of the bed of the stream is dry. Large quantities of sawdust and blocks are deposited in the stream below the dam; fish are found dead, their eyes eaten out by the strong poisonous acids in the water, and their bodies covered beneath the skin with disgusting blisters, like the small pox, whilst the inside is as black as ink. The waters are rendered at times wholly unfit for use…"

Captain E. Wakeman

Excerpts from 1st biennial report of the California Commissioner of Fisheries (Redding et al. 1872)

CHAPTER 3

PESCADERO-BUTANO WATERSHED SETTING

Key Points

- The 81 mi^2 Pescadero-Butano watershed is located in a tectonically active region and is underlain by poorly indurated and fractured assemblage of sedimentary rocks, which are generally prone to erosion. Tahana Member of the Purisima Formation, which underlies almost a quarter of the watershed, has very low slake durability and a very high susceptibility to erosion by water.
- The watershed experiences a Mediterranean climate. Precipitation averages between 20 inches to over 50 inches between the coast and higher elevations in the watershed.
- Stream gauge data shows that annual runoff is highly variable. Long-term average annual runoff is 30,000 acre-feet, with a median annual runoff rate of approximately 24,000 acre-feet, which means the average is higher due to some years of significantly high annual runoff.
- The Pescadero marsh and lagoon, located at the western terminus of the watershed transition seasonally from an open estuarine system to a closed lagoon system.

The Pescadero and Butano Creeks flow westerly and 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, is one of the most significant coastal wetlands on the central California coast (ESA 2004, 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.

3.1. Geology and Soils

The evolution and current condition of the Pescadero-Butano watershed is greatly 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 the 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 (SGFZ), which lies on the western end of the watershed, is a right-lateral strike-slip fault (the block on the west moves northward relative to the block on the east). Although its movement is dominantly strike-slip, locally it has uplifted segments of the coast. The SGFZ consists of two large active faults: the Coastways Fault and the Frijoles Fault. The Frijoles Fault is the main fault cutting across the lower part of the watershed primarily through the marsh. Rough locations of the fault are present on some maps of the area; however, no exact location is known as the Frijoles Fault is actually a system of smaller anastomosing fault lines (Mazzoni, 2003). The lower Butano Creek, which most likely flowed directly into the Pacific millions of years ago, may have been captured by the Frijoles, forcing it to run north and join up with Pescadero Creek. Based on its dimensions and late Quaternary activity, SGFZ appears to be a potential source of significant earthquakes (Petersen et al., 1996).

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 their 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 Ma) Pigeon Point Block, a marine sedimentary rock that underlies the marine terrace deposits by the lower watershed. East of the SGFZ, the basement rocks are Cretaceous (approximately 92 Ma) granitic rocks of the Salinian Complex (Sloan, 2006). Overlying the basement assemblage is a thick sequence of marine sedimentary rocks, including sandstone, shale, mudstone, and conglomerate, and some volcanic rocks; all of them ranging in age from Paleocene to Pliocene of Tertiary period (65 – 1.8 Ma) (Figure 2). Table 2 summarizes the stratigraphy and characteristics of the rock types that comprise the Pescadero-Butano watershed. Many of these sedimentary rock units are mechanically weak and highly susceptible to landsliding, debris flows, and gullying. Most notably, Purisima Formation, which underlies almost a quarter of the watershed, has a very low slake durability especially upon drying and rewetting and disaggregates (slakes), rendering channels or gullies underlain by this formation highly susceptible to fluvial erosion after wet-dry cycles.

The southeastern part of the watershed is underlain by the Butano Sandstone: very fine- to very coarse-grained sandstone interbedded with mudstone and shale. Conglomerate, containing boulders of granitic and metamorphic rocks and well-rounded cobbles and pebbles, is present in its lower part. Butano Sandstone is one of the two units in the watershed that provides gravel and cobble size materials to the streams. Part of this coarser material becomes finer (sand and silt sizes) through attrition as it travels downstream. Currently, a significant portion of gravels and larger size materials are trapped upstream of the Old Haul Road. The south central part of the watershed is underlain by Santa Cruz mudstone with moderate erodibility. The north central and northwestern part of the watershed is underlain by the Purisima foundation: medium- to very fine-grained sandstone and siltstone, with silty mudstone. The eastern part of the watershed, which is adjacent to the San Andreas Fault, has been subjected to more intense deformation. The area is characterized by extensive folding and highly fractured rocks, in a mix of units including volcanics, sandstones, shales, and mudstones, with a wide range of erodibility ratings (Brown, 1973). Some of the more prominent rocks in this area include the Lambert Shale, moderately well-cemented mudstone, siltstone, and claystone; Mindego Basalt, basaltic volcanic rock that commonly weathers spheroidally and is another source of gravel-sized material; and Monterey Formation, shale with chert, mudstone, siltstone, and sandstone (Brabb et al., 1998).

A study of the erosive behavior of the Tahana Member of the Purisima Formation showed that while the Butano sandstone and Purisima Formation have comparable tensile strengths, after one wet and dry cycle, the Butano sandstone maintains its original tensile strength, whereas the Purisima Formation loses so much strength that it disintegrates under its own submerged weight (Johnson and Finnegan, 2015). This very low slake durability of the Purisima Formation results in a very high susceptibility to erosion by clear water flows, particularly in Pescadero Creek. The differences between the erosive behavior of these rocks are linked to the difference in fluvial geomorphology in upper Butano Creek and within the canyon reach of Pescadero Creek, particularly with regard to differences in lateral erosion in these two streams. The study also showed that locally derived Purisima Formation rock makes up some of Pescadero Creek's bed load and is competent enough to become rounded during transport, but if it is abandoned above base-flow water levels, it will slake to small shards. This implies that most of the bed load in Pescadero Creek is made up of lithologies from upstream that do not slake (Johnson and Finnegan, 2015).

3.2. 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. The warmest temperatures typically occur during late summer. Average daily air temperatures range from 40°F to 75°F over a year.

There is a 2,400 foot rise in elevation from the lagoon to the rim of the drainage basin. This results in orographic precipitation, ranging on average from 20 inches of rain near the coast to over 50 inches at higher elevations. The average annual precipitation in the watershed is approximately 40 inches, with nearly 100 percent 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.

There are a number of gauging records available in the Pescadero-Butano watershed including:

- USGS Gauge 11162500 Pescadero Creek near Pescadero
- USGS Gauge 11162540 Butano Creek near Pescadero
- Balance Hydrologics records at the former Butano Creek gauge location
- CEMAR flow records on Pescadero (3 locations) and Honsinger Creeks

Table 2. Stratigraphic Properties of Geologic Units within the Pescadero-Butano Watershed (Brown, 1973)

Geologic Unit	Percentage of Watershed	Properties	Erodibility	Comments
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
Mindego Basalt (Tmb)	3.5%	Interstratified basaltic rocks, musdstone, sandstone, and carbonate rocks	Very low	
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
Purisima Formation – Tahana Member (Tpt)	22%	Medium—to very fine-grained lithic sandstone and siltstone, with some silty mudstone. Very low slake durability. Disintegrates easily after wet-dry cycles.	Moderate	No signs of active erosion where there is forest canopy; however, significant sheetwash erosion on grazed or deforested slopes. Competent enough to become rounded during transport, but if above base-flow levels, slakes to small shards. Drying of the rock and slaking allow for clear-water erosion of the formation; therefore, Pescadero Creek has a sinuous platform and is incising through the Purisima Formation.
Monterey Shale (Tm)	3%	Medium- to thick-bedded, decomposes into porcelaneous debris in exposures	Low (locally moderate)	Few signs of erosion?
Lambert Shale (Tla)	11%	Thin- to medium-bedded, decomposes into friable fragments and fine, easily transported particles	Moderate (locally high)	
Santa Cruz Mudstone (Tsc)	16%	Medium- to thick-bedded, slides or slumps under adverse conditions	High	When saturated easily slumps

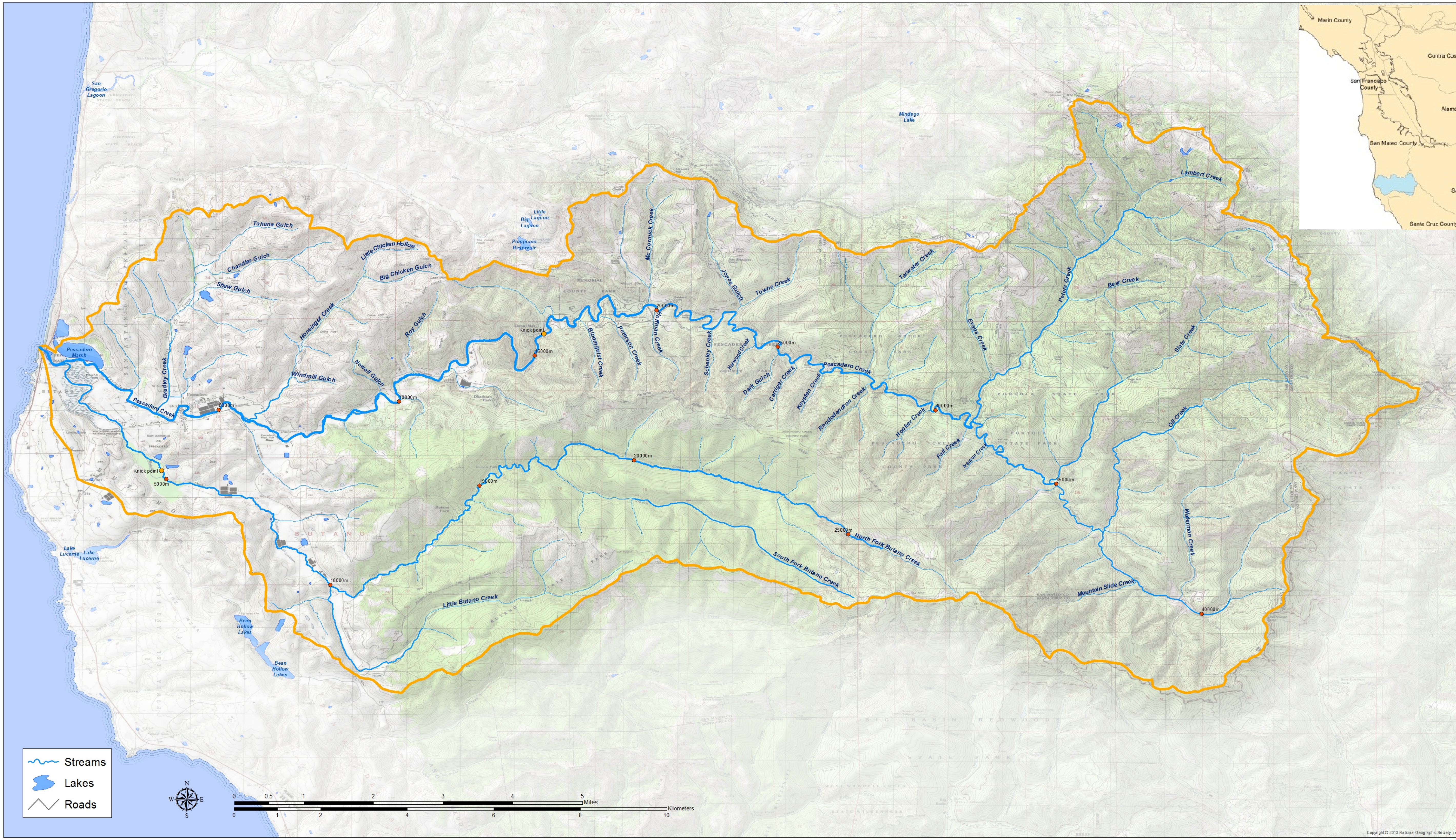


Figure 1 - Pescadero-Butano Watershed Map

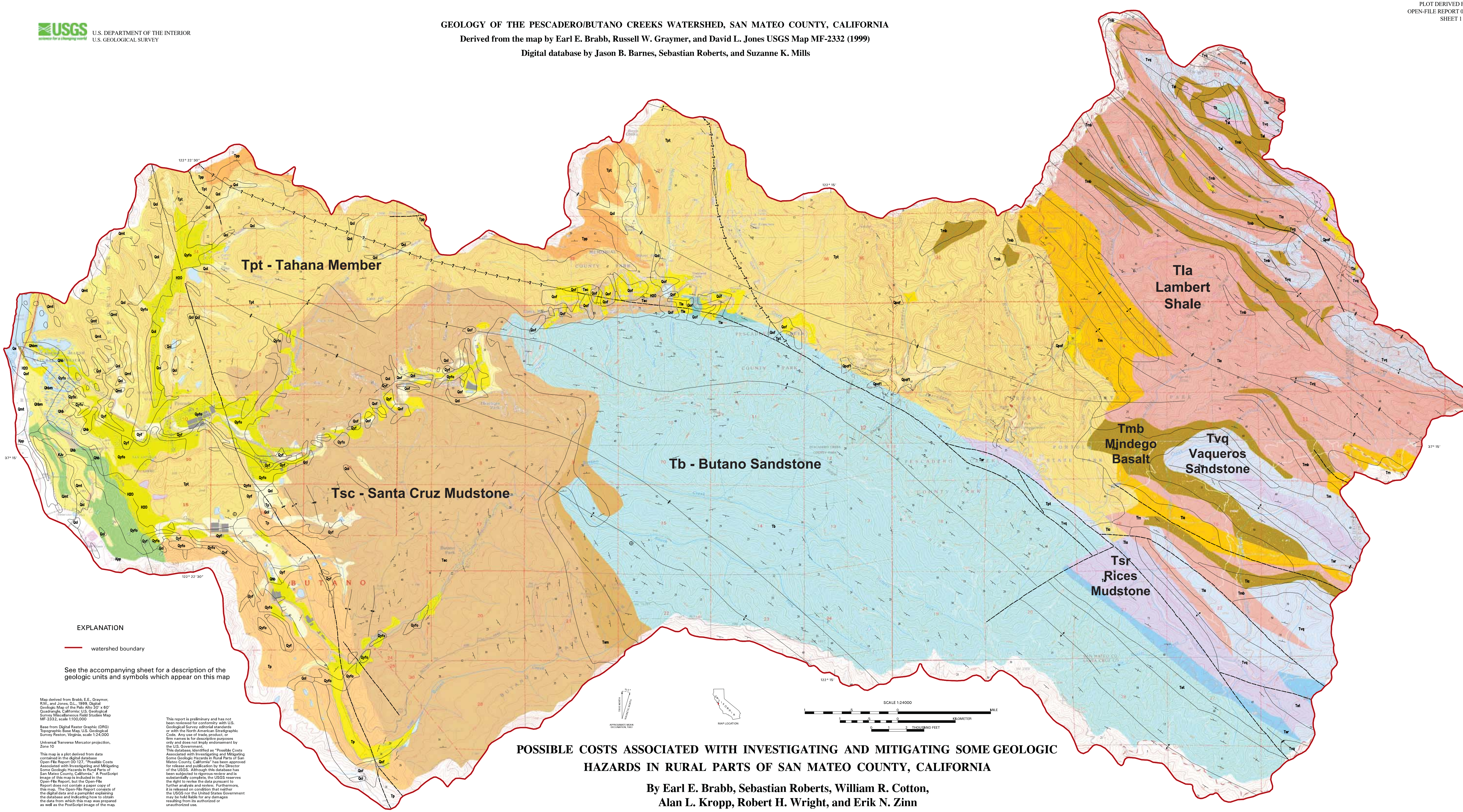
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGY OF THE PESCADERO/BUTANO CREEKS WATERSHED, SAN MATEO COUNTY, CALIFORNIA

Derived from the map by Earl E. Brabb, Russell W. Graymer, and David L. Jones USGS Map MF-2332 (1999)

Digital database by Jason B. Barnes, Sebastian Roberts, and Suzanne K. Mills

PLOT DERIVED FROM
OPEN-FILE REPORT 00-127
SHEET 1 OF 22



EXPLANATION

watershed boundary

See the accompanying sheet for a description of the geologic units and symbols which appear on this map

Map derived from Brabb, E.E., Graymer, R.W., and Jones, D.L., 1999, Digital Geologic Map of the Palo Alto 30′ x 60′ Quadrangle, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2332, scale 1:100,000

Base from Digital Raster Graphic (DRG) Topographic Base Map, U.S. Geological Survey Reston, Virginia, scale 1:24,000

Universal Tranverse Mercator projection, Zone 10

This map is a plot derived from data contained in the digital database Open-File Report 00-127, "Possible Costs Associated with Investigating and Mitigating Some Geologic Hazards in Rural Parts of San Mateo County, California." A PostScript image of this map is included in the Open-File Report, but the Open-File Report does not contain a paper copy of this map. The Open-File Report consists of the digital data and a pamphlet explaining the database and indicating how to obtain the data from which this map was prepared as well as the PostScript image of the map.

POSSIBLE COSTS ASSOCIATED WITH INVESTIGATING AND MITIGATING SOME GEOLOGIC HAZARDS IN RURAL PARTS OF SAN MATEO COUNTY, CALIFORNIA

By Earl E. Brabb, Sebastian Roberts, William R. Cotton, Alan L. Kropp, Robert H. Wright, and Erik N. Zinn
2000

Figure 2 - Geology of the Pescadero-Butano Watershed

The USGS Pescadero Creek gauge has the longer period of record, April 1951 to present (Table 3). It is located 5.3 mi upstream from the mouth and reflects surface runoff from the 45.9 mi^2 drainage area above the gauge. USGS ranked the records of "fair" quality except for flows below 20 cubic feet per second (cfs). The USGS Butano Creek gauge was located 2.2 mi upstream of Pescadero Creek Road and reflects an area of 18.9 mi^2. Data were collected between July 1, 1962 and October 7, 1974. Flow data for Butano Creek have been collected by Balance Hydrologics at the former USGS gauge location. Data have been collected since 2006 and include high flows (CBEC, 2014). Four gauging stations maintained by CEMAR were in operation since the winter of 2012 (CEMAR, 2014).

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 Table 3. The largest flood of record occurred in February 1998, with a peak flow of 10,600 cfs at the Pescadero Creek gage.

Several studies have developed flow frequency analyses of the Pescadero Creek gauge (Curry 1985, ESA 2004, CBEC, 2014). Table 3 below lists the largest peak flood events on record at the USGS Pescadero Creek gauge between 1952 and 2013 and it assigns, based on CBEC's analysis, a probability of being equaled or exceeded in any given year expressed as approximate recurrence interval. CBEC analyzed a 61-year flood peak data record, which is a sufficiently long data set to estimate statistical frequencies. Annual peak discharges were analyzed using a Pearson Type III distribution per Bulletin 17B guidelines of the Interagency Advisory Committee on Water Data (IACWD, 1982, p.8-21). Based on their analysis, the most recent flood event that occurred on February 15, 2009 with a peak flow of 2,710 cfs has approximately 2.4-year return interval or 42 percent probability of occurring in any giving year. This magnitude event is approximately the "bankfull event". The December 31, 2005 event with a flood peak of 5,980 cfs was similar in size to a 10-year event with an approximate return interval of 8.5 years (or 12 percent probability of occurring in any given year).

The USGS Butano Creek gauge (#11162540) that operated between July 1, 1962 and October 7, 1974 was historically located 2.2 mi upstream of Pescadero Road and drained a watershed area of 18.9 mi^2. CBEC (2014) compared flow measurements recorded at this gauge during the period from July 1962 to October 1974 to those recorded at the Pescadero gauge to develop a relationship/scaling factor between the two gauges. Their analysis of overlapping daily average flow data for the two gauges indicated a high correlation between the data sets. This allowed deriving a scaling factor of 0.4 based on drainage area ratio to synthesize Butano Creek flows. CBEC applied the 0.4 watershed ratio to Pescadero Creek flood frequency analysis to determine the corresponding flood events on Butano Creek (Table 4).

Curry (1985) developed empirical relationships using watershed area and area-elevation weighted precipitation to scale observed Pescadero Creek flood peak data to the peak of runoff of the sub-watersheds combined as the flow into the marsh (marsh inflow peak = 1.54 x gauge peak). They also found that runoff into the marsh is 1.7 times the value observed at the gauge. The difference in these two multipliers is due to differences in the time of concentration of peak runoff from the two sub-watersheds, as Butano Creek peaks ahead of Pescadero Creek (CBEC, 2014).

Table 3. Largest peak flow flood events on record (Water Year 1952-2013) at the USGS Pescadero Gage (11162500)

Rank	Date	Peak flow, Q (cfs)	Approximate recurrence interval (years)*
1	Feb 3, 1998	10,600	25-50
2	Dec 23, 1955	9,420	25
3	Jan 4, 1982	9,400	25
4	Apr 2, 1958	7,630	10-25
5	Jan 26, 1983	7,550	10-25
6	Jan 31, 1963	6,700	10
7	Jan 9, 1995	6,210	5-10
8	Dec 31, 2005	5,980	5-10
9	Dec 16, 2002	5,600	5-10
10	Jan 16, 1973	5,380	5-10
11	Feb 17, 1986	5,270	5-10
12	Jan 13, 1993	5,060	5
13	Dec 23, 2012	4,800	5
14	Feb 13, 2000	4,660	5
15	Jan 21, 1967	4,100	2-5
* A 5-year recurrence interval flood event has a 20% chance of being equaled or exceeded in any given year. A flood event that has a recurrence interval between 10- and 25-year has a 4% to 10% chance of being equaled or exceeded in any given year.			

Table 4. Magnitude and frequency of select flood events for Pescadero and Butano creeks (CBEC, 2014)

Return Interval	Peak Discharge (cfs)	
	Pescadero Creek*	Butano Creek**
2-year	2,175	870
5-year	4,824	1,930
10-year	6,900	2,760
* Pescadero Creek values are based on annual peak data record at USGS Pescadero Creek Gauge ** Butano Creek values were estimated by applying the 0.4 ratio of watershed areas to the Pescadero Creek discharge values		

Figure 3 shows the annual runoff from water year[11] 1961 to water year 2013 and illustrates that the flows are also highly variable from year to year. The long-term average annual runoff for the period of record is 30,000 acre-feet, whereas the median annual runoff is approximately 24,000 acre-feet. The

[11] The term "Water Year" is defined by USGS as the 12-month period starting in October 1st of any given year through September 30th of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

median annual runoff is the annual runoff 50 percent of the years and is a more meaningful measure of water availability. The discrepancy between the two values indicates the disproportionate effect of high values and suggests that there are more years with runoff less than the mean than there are years with runoff greater than the mean. The largest annual volume of 118,900 acre-feet was recorded in 1983 and the smallest annual volume of 1,250 was recorded in 1977. DWR (1966) extended Pescadero gauge record correlating with precipitation record and estimated annual runoff prior to the USGS gauge was installed. Their estimates show that average annual runoff for the period from 1900 to 1960 was approximately 31,500 acre-feet (DWR, 1966, p.70).

In order to compare different years and classify them as wet, normal, or dry, all the annual runoff volumes for the 53 years of record were ranked from lowest to highest value. The lower quartile was classified as dry and the upper quartile was classified as wet. The middle 50 percent of runoff values were classified as normal to allow a larger spread for “normal” years. Based on this classification, years with a runoff volume of less than 10,000 acre-feet were classified as dry and years with a runoff volume of greater than 42,000 acre-feet were classified as wet.

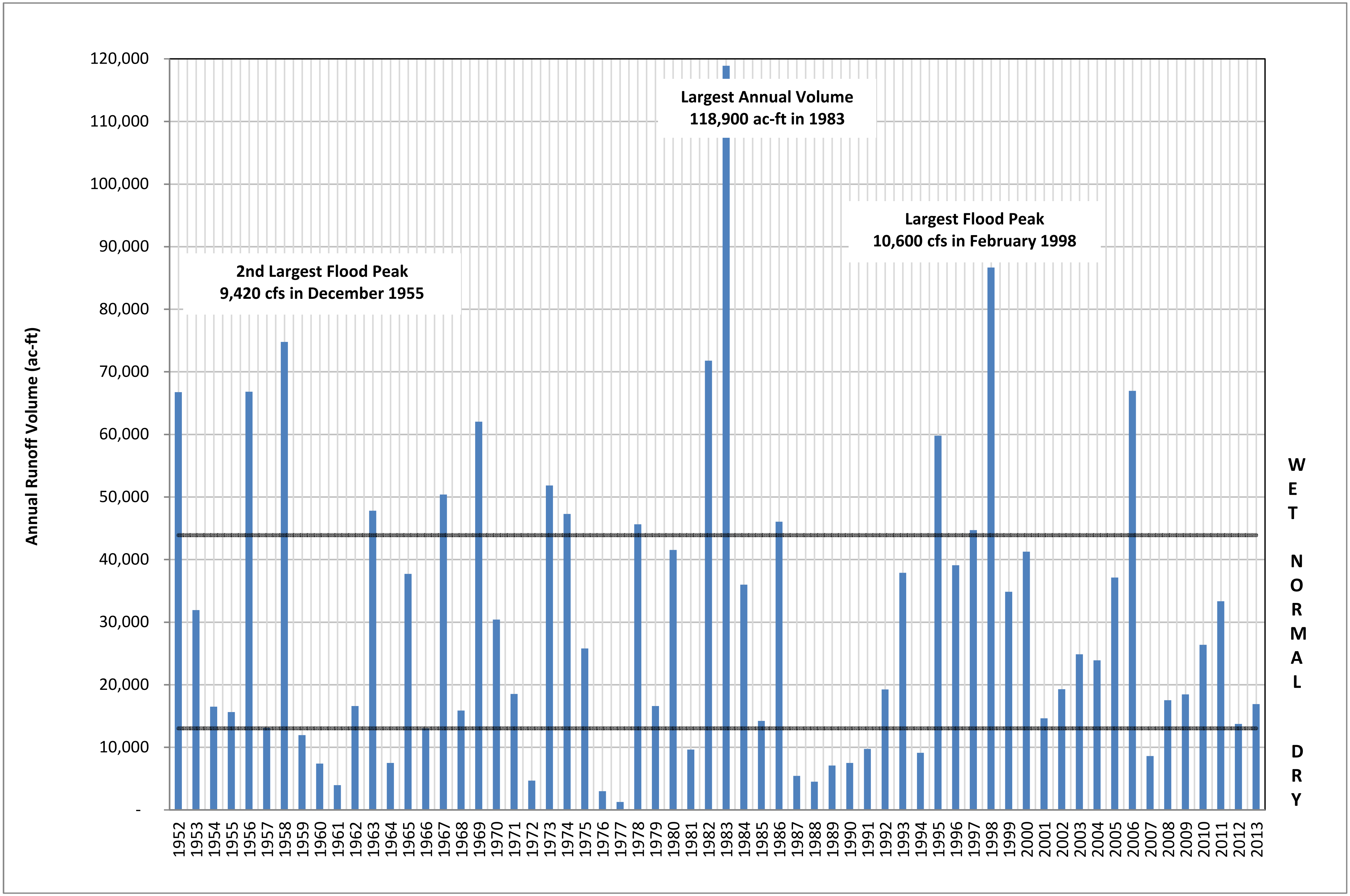


Figure 3 - Annual Runoff Volumes (ac-ft) at the USGS Pescadero Gauge (1952-2013)

CHAPTER 4

TWO CENTURIES OF LAND USE CHANGE:

INCISING CHANNELS, DISCONNECTED FLOODPLAINS, SHRINKING LAGOON

Key Points

- Sediment delivery to fish bearing channels has more than doubled as compared to natural background due primarily to historic land use activities including logging, grazing, roads, agriculture, and removal of wood from creeks.
- Pescadero and Butano creeks have incised up to 30 feet. Land use changes, channelization, and removal of wood from channels caused or contributed to channel incision, which in turn disconnected the creeks from their floodplains, and eliminated overbank flows and sediment storage on the floodplains and the valley.
- Prior to incision, floodplains incorporated diverse wetland habitats that provided excellent habitat for fish and aquatic wildlife.
- Channel incision and other channel management practices e.g., wood removal, also resulted in substantial simplification of channel habitat structure, which in turn adversely affected growth and survival of juvenile salmonids in all freshwater life stages.
- High sediment input combined with lack of storage in the channels and floodplains resulted in massive amounts of sediment delivered to the Pescadero estuary. Sedimentation rates in the Pescadero marsh and the lagoon increased by more than an order of magnitude.
- An order of magnitude increase in sedimentation in the estuary reduced the tidal prism to a quarter of its historic volume, decreased the available key nursery habitat for steelhead, and contributed to poor water quality problems that result in near-annual fish kills.
- In summary, prior to the European settlement of the watershed, creeks were largely clear-flowing, slower in the valley, and regulated by floodplains. Precipitation was largely held back by vegetation and wet meadows in the valley. Post-settlement land uses and channel disturbances have created a regime that is now far more energetic and prone to violent flooding because flows rush downstream in defined channels far more quickly and in larger volumes. Combined with the Mediterranean cycle of droughts and floods, this new creek regime is dominated by rushes of sediment, which essentially sandblast the habitat and its fauna. This drastic transformation in energy of the creeks underlies the dramatic rates of change that have been experienced.

4.1 Introduction

Pescadero-Butano watershed historically supported coho salmon and a steelhead fishery. Land use changes over the last two centuries have resulted in excessive erosion from the uplands and the channels, as well as accelerated sedimentation in the lagoon, leading to a reduction in the quality and quantity of instream habitat. Primary factors contributing to this habitat loss are attributable to adverse impacts of land and channel management practices, and the loss of instream channel structure necessary to maintain, and to efficiently store, sort, and transport delivered sediment.

This section briefly describes the recent history of human activity in the watershed and chronicles watershed and channel changes, and the geomorphic response to how these changes have changed how sediment is generated, transported, and stored in different parts of the watershed.

4.2. Historical Conditions in Pescadero and Butano Valleys

The Pescadero-Butano watershed is underlain by faults and weak, erodible rocks, and is surrounded by actively uplifting ranges in a Mediterranean climate. As such, it naturally generates large amounts of sediment. Most of the underlying geologic units, which consist of sandstone and siltstone, decompose readily into fine or friable sediment particles that are easily transported. In their downstream reaches, Pescadero and Butano creeks feature wide alluvial valleys and flatlands that historically functioned as wet meadows. Under natural conditions, the majority of sediment –especially sand-sized and coarser particles- were deposited in the wet meadows and alluvial valley or other depositional areas such as bars in stream channels or fans at the mouth of tributary streams. These large extensive wet meadows and floodplains functioned like a sponge, storing water and sediment during high flows, slowly releasing water to downstream reaches and recharging groundwater (Figure 5). A review of early maps, sketches, historic accounts of settlers, as well as topographic conditions, all point to a valley that was waterlogged and swampy with pockets of freshwater marshes and lagunas. The channels were not incised (Figure 6, Figure 7, and Figure 27. Brown Lithograph (1874) Showing the Hayward Mill Site on Pescadero Creek.) and the river bed was not much lower than the valley floor. Frequent flood waters spread onto adjacent floodplains, which were inundated during the annual flood, and perhaps much more frequently each wet season and which stayed wet for extended periods of time each year (Figure 5, 6, and 8).

While some of the tributary creeks maintained well-defined channels that connected to Pescadero Creek, some dissipated on the valley bottom or on alluvial fans. For instance, Bradley Creek (Figure 5) was mostly discontinuous, spreading out on the valley floor before reaching the mainstem channel with its own perennial pond and marsh identified as “Laguna” in an early map. This distributary characteristic reduced flood peaks downstream, recharged groundwater and freshwater wetlands, and deposited sediment to maintain the fertile valley. The entire valley provided an important watershed storage function by attenuating both flood flows and retaining sediments from the upper watershed.

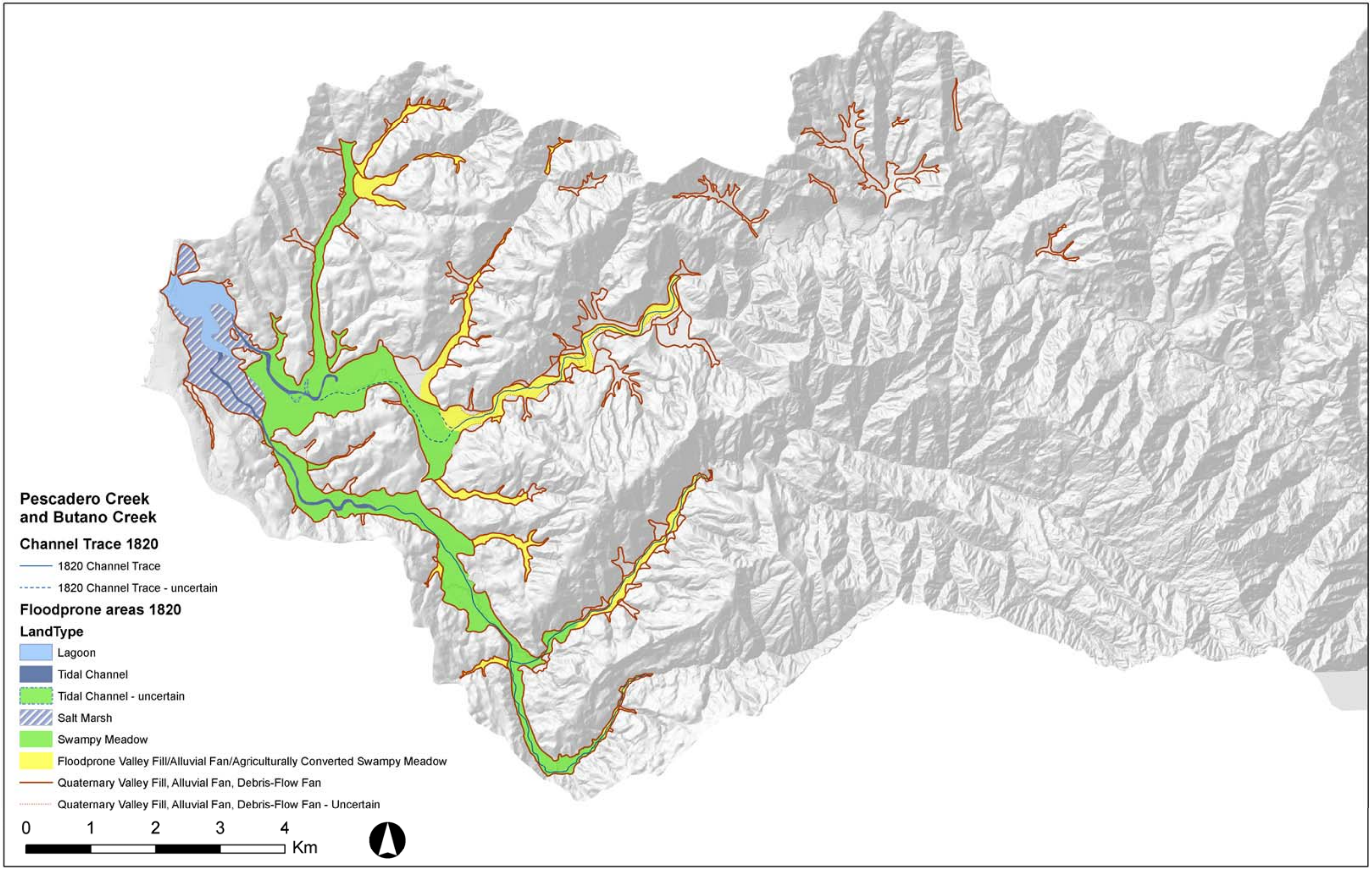


Figure 4 - Wet Meadows, Valleys, and Alluvial Fans in the Pescadero-Butano Watershed

In addition to maps, early settler accounts described cattle being stranded in mud and all early crops including wheat, barley, and oat being dry farmed. Dark organic-rich soils, which are indicative of wetland conditions during soil formation, are ubiquitous in both valleys. During the flood of December 1861, which is likely the historical flood of record,[12] the whole Pescadero valley was flooded. The Santa Cruz Sentinel reported: "At Pescadero the river overflowed its banks and flooded the whole bottom land." (ESA 2004).

The channels meandered through their alluvial valleys, migrating back and forth in a sinuous pattern across their floodplains. Figure 9 shows the historical alignments of Pescadero and Butano Creeks in their valleys. The main channels were unconfined, flooding almost the entire valley of more than 2,000 feet wide during high flows. There were several oxbows such as the one where the town of Pescadero was founded. The shifting of channels back and forth within the valley as they flowed downstream resulted in oxbow cutoffs, side channels, and other backwater areas of the main river channel. Large woody debris locally recruited in the channel or transported from upstream provided the physical structure needed to create hydrodynamic and topographic complexity. The result was an environment that supported salmonids.

The broad and frequently inundated floodplains of Pescadero and Butano valleys would have provided a tremendous amount of high quality winter rearing habitat for coho salmon in alcoves and side channels (Bustard and Narver, 1975; Nickelson et al., 1992a and b; Tschaplinski and Hartman, 1983). Floodplains also provide winter rearing and refuge habitat for juvenile steelhead (Swales and Levings, 1989; Solazzi et al., 2000; Stillwater Sciences, 2008), and essential habitat for many other native fish and wildlife species within the wet season and/or throughout the year. Prior to channel incision, the floodplains also likely supported more extensive riparian forests comprised of willows, alder, cottonwood, and live oak (as described by the early Spanish explorer, Friar Juan Crespi, in 1774, as quoted in ESA, 2004, p. 3-3) that would have provided abundant supply of large woody debris to the creeks, created additional forced pool-bar units and undercut banks with exposed/submerged roots. The poorly drained floodplains also would have enhanced the discharge of cold hyporheic flow into the creeks during the spring and dry season.

Large woody debris was likely the primary agent in shaping complex channel habitats (Abbe and Montgomery, 2003; Collins et al., 2012). Under natural conditions, debris jams can form a variety of habitats ranging from deep pools with good cover, gravel riffles, and well-shaded channel reaches that are connected to adjacent floodplains, alcoves, and side channels. Pacific salmonids have evolved to exploit these complex and interconnected habitats. Woody debris that is large enough to resist transport even during large floods (Figure 10) is the primary agent structuring interconnected habitats (Collins et al., 2012). Historically, large woody debris loading and the size of the largest pieces in the

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[12] 1861-62 was named the "Great Flood". Intense rainstorms that swept in from the Pacific Ocean began to pound central California on Christmas Eve in 1861 and continued virtually unabated for 43 days. In January 1862, rainfall at San Francisco was five times the average and in Los Angeles it was four times the average annual amount (Ingram, L.B. 2013.California Megaflood: Lessons from a Forgotten Catastrophe. Scientific American, January 1, 2013).

channels were high (much higher than at present) resulting in closely spaced debris jams and a higher frequency of pools and bars, and greater diversity of sediment patches in channel beds.

Figure 5. Part of the 1861 map by Chas. T. Healy and S.W. Smith titled A topographical map of the country known as the Rancho Pescadero in Santa Cruz Co.

Note the ponds identified as "Laguna" between Pescadero and Butano Creeks and along Bradley Creek pointing to freshwater wetlands in the valleys. Also, Bradley Creek has no surface drainage that conveys runoff and is shown as disappearing in the valley without reaching Pescadero Creek. The highly sinuous representation of Pescadero Creek may not reflect actual channel form. In May of 1861, the same year as this map, a description of the valley published in the Santa Cruz Sentinel stated: "A view of this valley from an elevated position cannot fail to strike the beholder with admiration. The perfectly level and fertile bottom land, covered with waving grain, interspersed with young orchards, and dotted with white buildings; the green hills which everywhere surround like sentinels, to guard it from the high winds that prevail on the coast, and the beautiful and clear stream of Pescadero, that winds through the whole length of the valley, makes a scene more lovely than any we had ever before looked upon." (from ESA 2004).

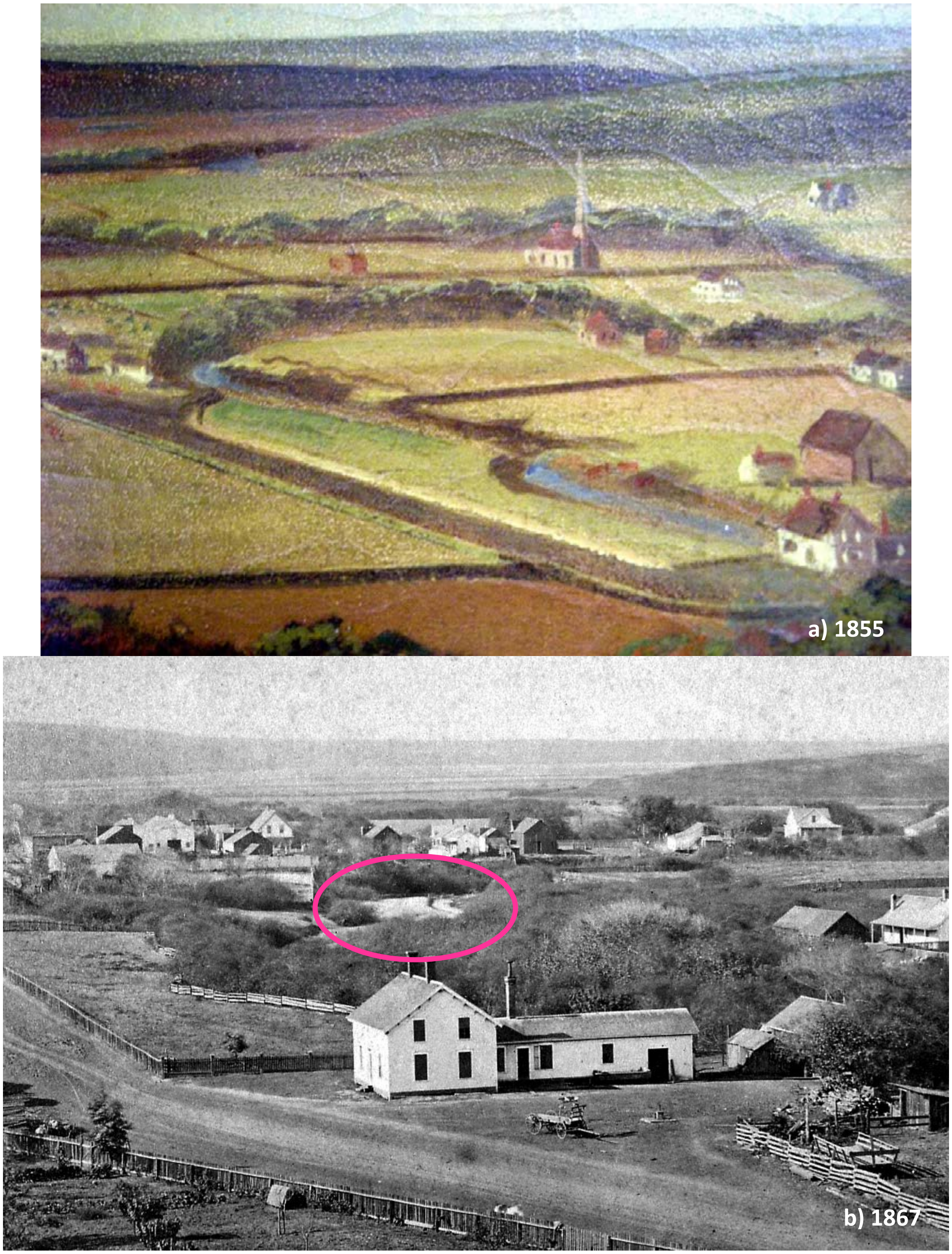

Figure 6. Pescadero Creek in the Vicinity of the Town: a)1855 Painting; and b)1867 Photograph.

Note the shallow, unconfined channel both upstream and downstream of the town. The channel appears to be less than 3 feet in height and is connected to its floodplain. The adjacent floodplain was likely inundated at least annually, and perhaps much more frequently each wet season. The banks are already showing signs of erosion and slump failures in a). Note the sediment deposited in the channel (likely a bar feature-encircled in pink).

Figure 7. Historic photographs of Pescadero Creek channel through the town in 1915 and 1920.

The channel was wide and shallow with low banks that flooded frequently, at least every 1 to 2 years. The channel was free to migrate creating alternating gravel bars and diverse aquatic and terrestrial habitats.

Sediment produced in the watershed due to erosion and delivered to channels consisted mainly of silts, sands, and gravels. The coarser material, or bedload, moves downstream in response to high winter flood events and majority of it was deposited where flow velocities slow down, either on alluvial fans or floodplains. The suspended load was more easily transported and could move all the way downstream to the marsh and the lagoon.

Downstream of wet meadows, Pescadero and Butano creeks entered their low-gradient coastal reaches forming a large 500 acre marsh and lagoon complex, which functioned as an area of deposition for a portion of the terrestrial sediments at the tidal interface. Sediments carried in the stream channels would largely deposit near the heads of the marshlands, where the channel gradients first become flat. Coarser sediments would deposit first, gradually getting finer as channels flowed downstream or overbank during larger winter runoff events. Finer sediments depositing in overbank flows created natural levees adjacent to channel banks. The 1854 map shows the natural levees along Pescadero Creek (Figure 12).

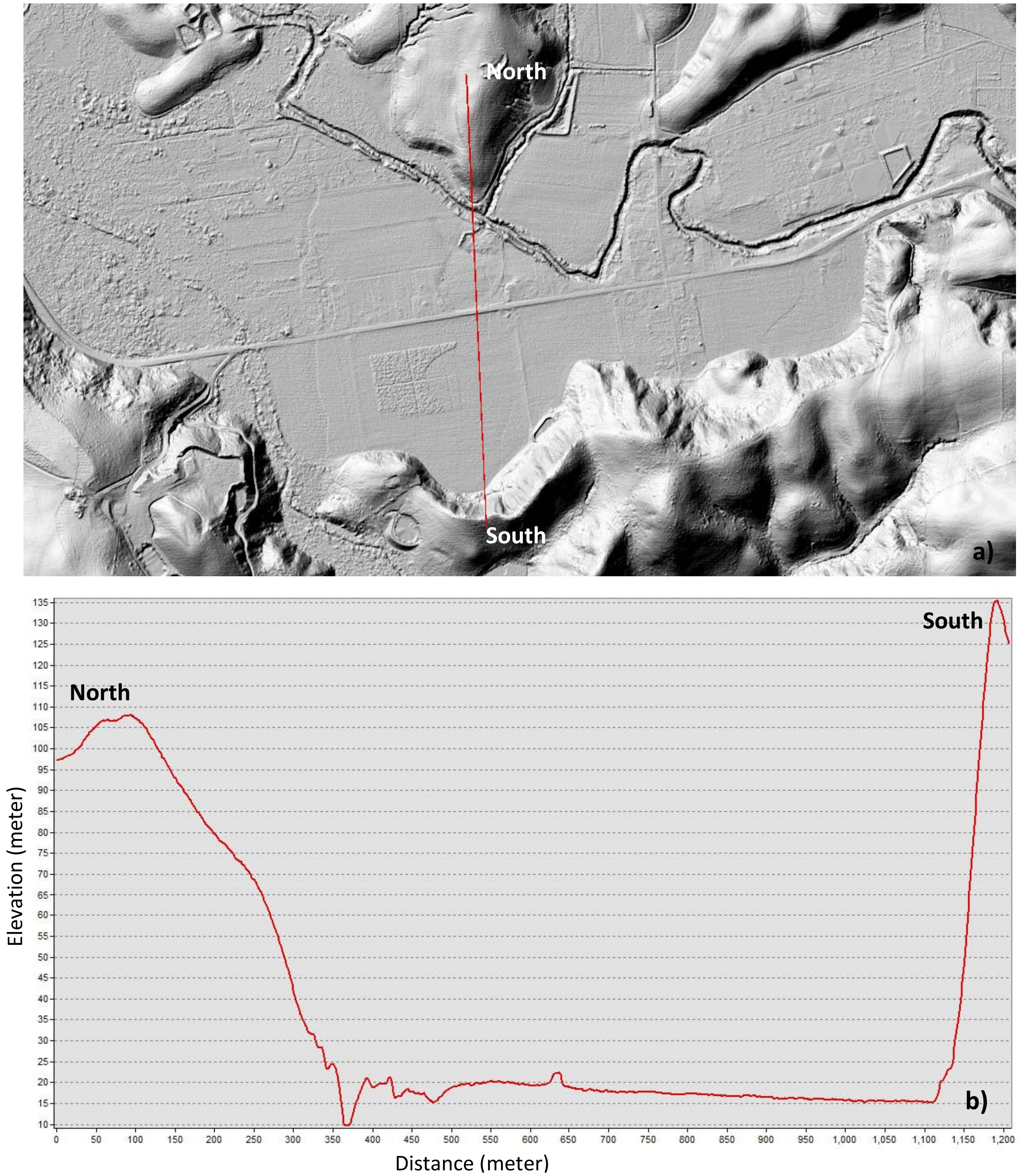

Figure 8. Location (a) and Profile View (b) of a Cross Section of Pescadero Valley Downstream of the Town.

Profile view looking towards upstream: while left bank is on the south of cross section, right bank is on the south. Pescadero Creek is on the northern end of the cross section (starting at station 350). Pescadero Creek Road can be seen as the elevated surface at station 630. On the left bank of Pescadero Creek, between stations 420 and 480, a couple of secondary channels can be observed. Note the valley elevations dropping away from the main channel toward the southern end of the valley, indicating an aggraded left floodplain built with overbank flows. Overbank flows leaving the Pescadero channel would flow south (before the road was constructed), inundate the valley, drain poorly, and create wet and swampy conditions.

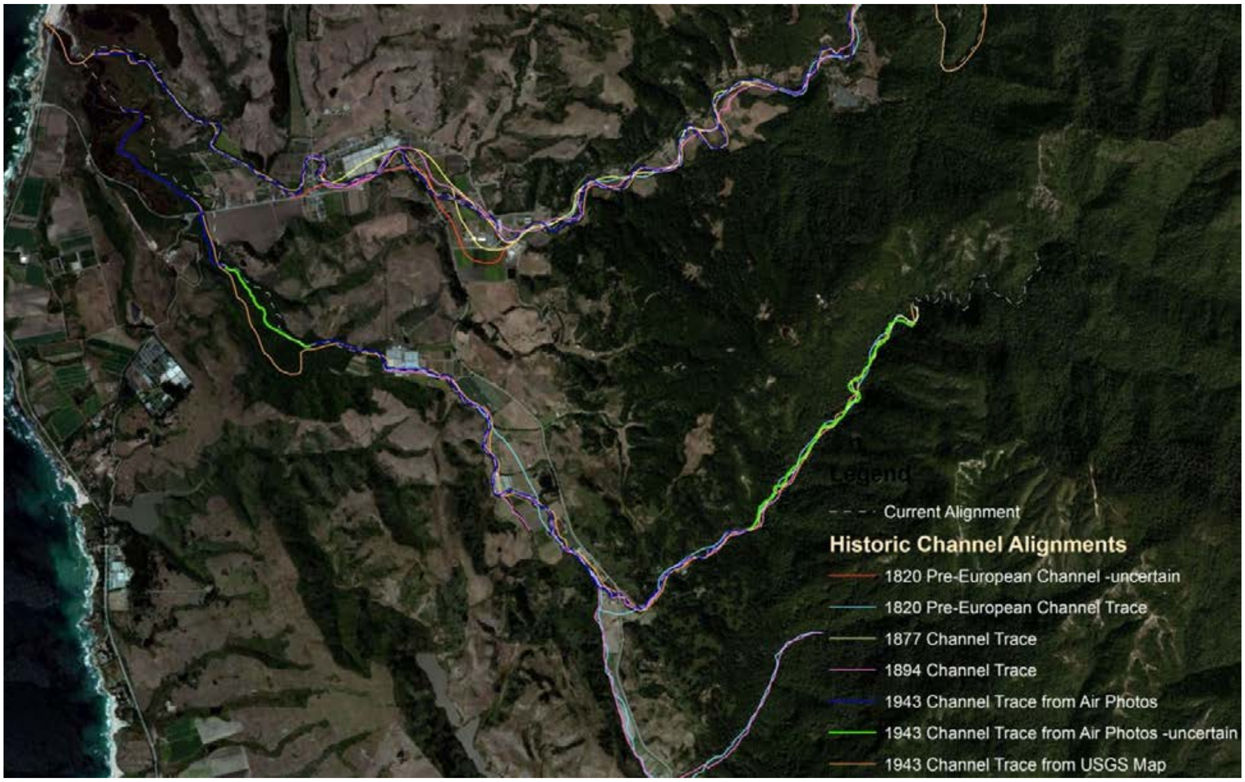

Figure 9. Historic Channel Alignments of Pescadero and Butano Creeks (BalanceGeo, 2015).

The historic channel alignments were mapped using historic maps, disenos, aerial photographs, as well as by conducting field work. Note the changing alignments over time and the large width of the meander corridor stretching from valley wall to valley wall. The main creek channel in early to mid-1800s was unconfined, flooding the more than 2,000 feet wide valley during high flows. There would have been oxbows such as the one where the town of Pescadero was established.

Figure 10. Upper Butano Creek, early 1900s. (Photo credit: Al Sollars).

Historically, large woody debris loading and the size of the largest pieces in the channels were high. Woody debris that is large enough to resist transport even during large floods as seen in this photograph is the primary agent structuring interconnected habitats (Collins et al., 2012).

The tidal portions of Pescadero and Butano channels were deep and wide, allowing intrusion of tidal waters to the town of Pescadero and all the way to the current location of Pescadero Creek Road bridge along Butano Creek. Indeed, historic maps from 1854 and 1861 indicate that Butano Creek was much deeper and wider than at present (see Figure 11 and Figure 12). The width of the channel was estimated at 100 feet (Williams, 1990) and its depth in 1970s was estimated to be 2 to 3 times deeper than in 1940s prior to the construction of Highway 1 Bridge (Viollis, 1979).

Pescadero lagoon was flooded during the Holocene marine transgression[13] (Viollis, 1979) and the drowned estuary infilled with sediment over the mid- and late-Holocene and a sand barrier formed across the mouth (Williams, 1990). Pescadero lagoon has persisted as a bar-built estuary for the past 3,000 years with a form that is similar to that of today; however, its exact shape and volume may have varied over time in response to large earthquakes, gradual changes in sea level, and sediment transport processes. Such high-magnitude/low-frequency events heavily influence back-barrier lagoon environments and therefore significantly impact their evolution (Woodroffe, 2002)[14]. The rate of sedimentation varies from year to year even in the absence of such catastrophic inputs: floods add a large quantity of sediment to the marsh and little sediment is transported during dry periods. In general, most sediment deposited in the valley and wet meadows and only residual sediment that was primarily suspended load was carried onto marshes where a portion of it was trapped by vegetation and deposited. Remaining finer sediments with low settling velocities discharged to the ocean.

The amount of sediment delivered to the marsh and the lagoon and sediment transport processes in the lagoon shape its morphology, which affects the estuarine processes by controlling the movement of water through the mouth and circulation patterns within the lagoon. The tidal prism,[15] the volume of flow in and out of the lagoon, determines whether or how long the mouth stays open. Prior to the European settlement the approximate effective tidal prism[16] of the Pescadero was estimated as 225 acre-feet based on the 1854 map (Williams, 1990). The current tidal prism is estimated at a quarter of historic tidal prism as 60 acre-feet (ESAPWA, 2011).

In its natural state, Pescadero marsh-lagoon complex supported large populations of many species of fish and wildlife (Viollis, 1979). In the 1870s, Pescadero was a favorite place for hunters and fishermen (Figure 13), who were attracted by trout, salmon, ducks, small game and bear (Viollis, 1979). It has been said that the Spanish named the town Pescadero, which may mean “fishing place” or “fishery”, due to the observations they made of the Indians frequenting the creeks with traps (Redwood City Tribune,

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[13] A marine transgression is a geologic event during which sea level rises relative to the land and the shoreline moves toward higher ground, resulting in flooding.

[14] Human activity also impacts the lagoon and the bar through the modification of morphology and hydrology while also indirectly impacting boundary conditions such as river flow and sediment production and delivery (Woodroffe, 2002).

[15] Tidal prism is calculated by subtracting the volume of water in the lagoon at low tide from the lagoon at high tide. Tidal prism partly regulates the opening and closing of the mouth and determines the effectiveness of the tidal flow for moving sediment through the lagoon.

[16] Calculation of the tidal prism in the lagoon is complicated by the sill formed at the mouth which keeps the lagoon from draining completely during low tide. The potential tidal prism would be between a low tide (-0.32 ft NAVD) and a high tide (5.68 ft NAVD) and would approximate 400 ac-ft. But since the sill limits drainage to 2.68 ft NAVD the effective tidal prism is estimated as 225 ac-ft.

June 9, 1960, as reported in Viollis, 1979). Pescadero Creek's steelhead abundance was noted in a 1912 letter which stated that Pescadero supported the largest steelhead run in the county historically (Leidy, 2005). The earliest observations of steelhead in Butano were stated in a 1930 report (Leidy, 2005).

Under natural conditions, sediment deposited within the lagoon comes from littoral (beach sands and coastal bluff sediments) and alluvial (stream borne) sources. The relative contribution of littoral and alluvial sources to sediment deposition depends on the amount of sediment supply and the transport capacity of creek flows, tidal currents, ocean waves, and internal windwaves to carry sediment into the lagoon. Littoral sediments come primarily from longshore transport of beach sand driven from dominant waves from northwest (Best and Griggs, 1991) and from sea cliffs and dune areas. Ocean waves move sand along the shore by rolling and dragging large particles along the bottom, and by stirring up smaller grained sand in the surf zone. At Pescadero, it is hypothesized that alluvial sediment is the primary source of beach sands because rocky headlands both north and south of the watershed prevent any significant longshore migration of sands to this site from other primary sources (Curry, 1985). In addition, the silty nature of the bedrock units comprising the sea cliffs precludes cliff erosion as a significant source of beach sands (Best and Griggs, 1991)[17]. Based on a hydrodynamic model of the lagoon, the littoral influence appears to be largely limited to the lower lagoon (Mark Stacey, personal communication, September 30, 2014). Therefore, the contribution of littoral sand to the lagoon has been limited and the finer-grained sand sizes would not be efficiently dispersed far into the lagoon, limiting its magnitude and extent.

[17] Pescadero-Butano watershed is within the Santa Cruz littoral cell. Best and Griggs (1991) determined that the littoral cut-off diameter, or the smallest grain size that will remain on the beach, for the Santa Cruz littoral cell is 0.18 mm.

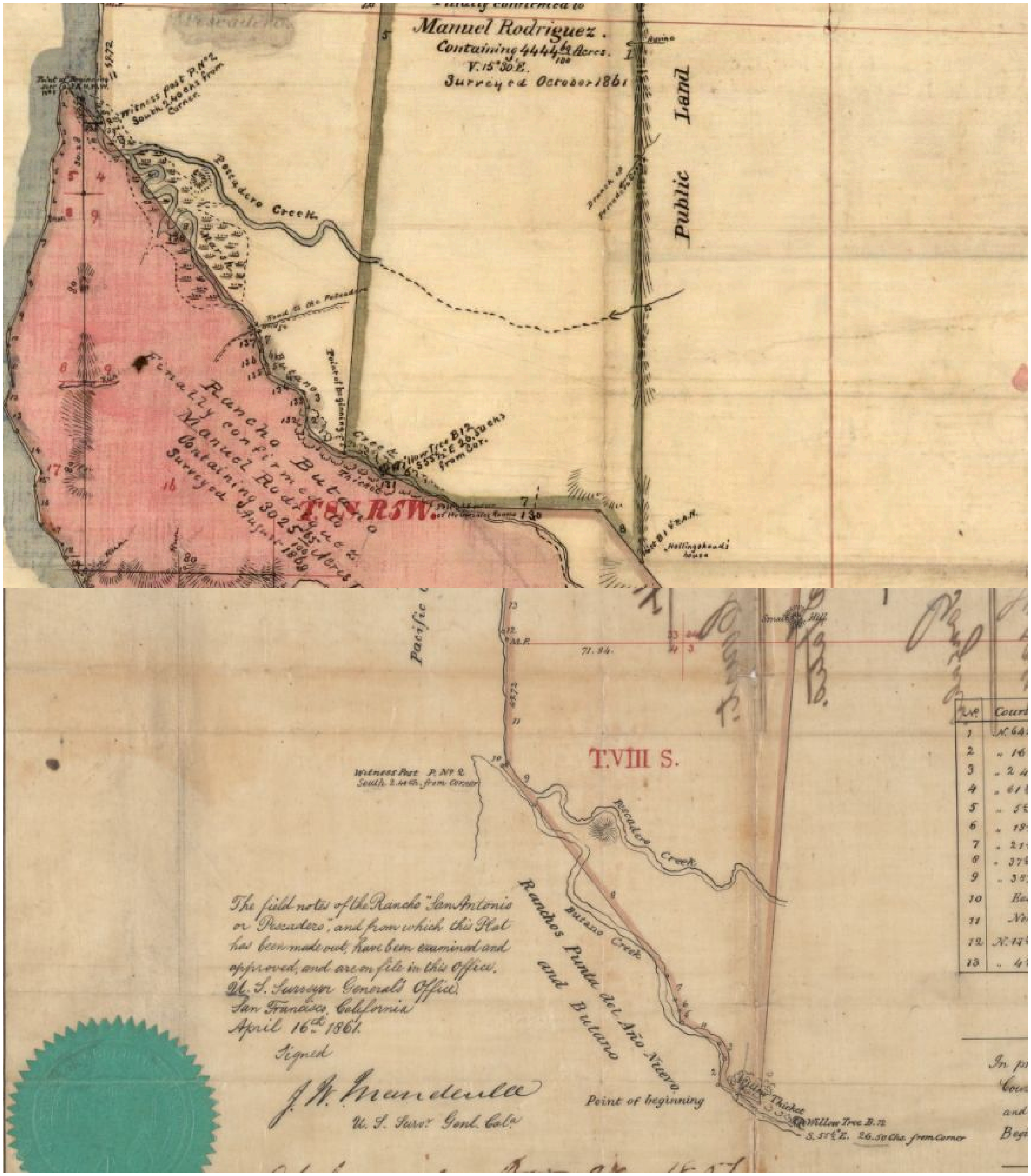

Figure 11. Excerpts from 1861 Gonzalez Hearing and 1861 Rodriguez Claim.

Note the "willow thicket" along Butano Creek identified in both maps. Rodriguez Claim illustrates the how wide the tidal Butano channel was.

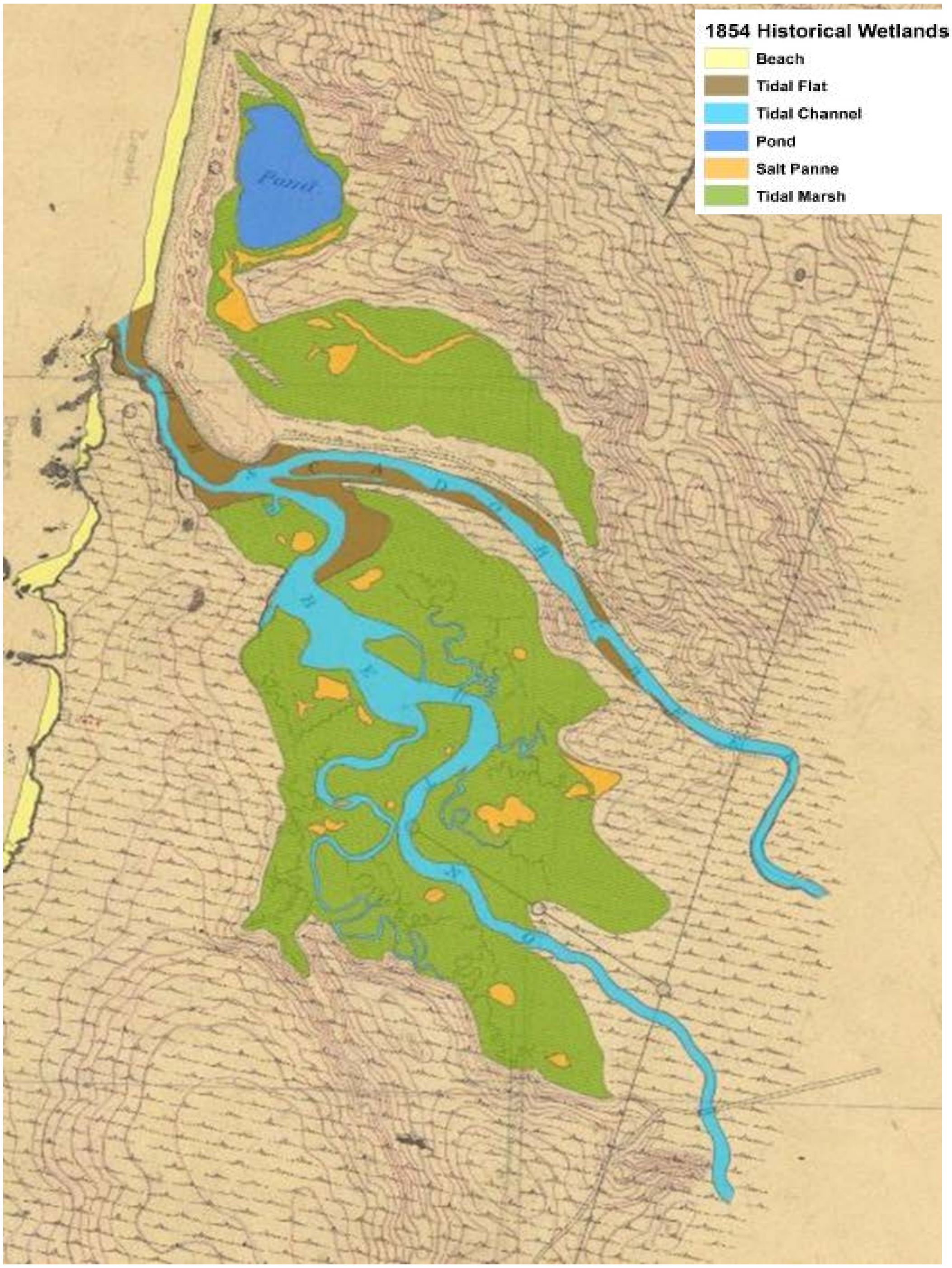

Figure 12. Historic Habitats of the Pescadero Lagoon and Marsh

Digitized from the 1854 T-Sheet. Note the larger marsh and extensive wetlands with well developed, wide tidal channels. A Williams (1990) report estimated that both Pescadero and Butano channels were 100 feet wide. The lagoon was much larger and deeper (Viollis, 1979; Curry, 1985). Viollis (1979) states that prior to Highway 1 bridge construction in 1941, the lagoon was 2-3 times deeper than in 1970s.

"Pescadero" is the Spanish for "fishery," and the name is indicative. The creeks which come down from the mountains all along this coast swarm with the spotted trout of California, and afford fine sport in the early part of the season. In places along their banks, the honeysuckle bushes and other shrubs and vines form a chapparal so dense that you must wade for miles to whip the stream; but one hundred, two hundred, or even three hundred trout are often basketed in a single day's fishing by one individual. It does not rain here from April until the last of November or December; but as the days become shorter, and the sun's rays less powerful, the evaporation which caused the streams to dwindle to mere strings of detached ponds decreases, and all over the State, especially in the Coast Range, the rivers commence to rise. Thompson, a hospitable landlord, took me down to the mouth of the Pescadero for a little sport. We sent a Mexican after worms for bait. The Mexican sent a negro, and we sent a Chinaman after the negro, and got them all at last. The row down the creek was short. We saw hundreds of mallards and teal **a)**

handsomest fish I ever caught. Eight- and ten-pounders are common, and they are the most delicious fish for frying or broiling which ever swam the sea. Great crabs came in also with the tide, and we dipped several of them out with our net. In two hours we corralled fourteen salmon-trout, losing several more by hooks breaking, and then, the slack-water coming on and the fish ceasing to bite with avidity, hoisted sail and went swiftly gliding back up the stream to the hotel. It was, all in all, the best morning's sport I have ever enjoyed in my life, and I have shot and fished from the Red River of the North to the Rio Grande, and from the Atlantic to the Pacific. **b)**

"The California angler can find on no spot above ground a fairer field for the display of his piscatory skill than the brooks flowing into Half Moon Bay, on the coast, some fifty miles below San Francisco. Parties of gentlemen from this city have recently met with extraordinary luck, and have brought back wagon loads of beautiful speckled trout. A week or two ago, four expert fishermen, after two days' sport, counted the number caught by the party, and found that they had captured two thousand of the finny inhabitants of these waters."

– Daily Alta, May 13, 1857

Figure 13. Historic Accounts of Pescadero Fishery

Figure 13-a) and b) are excerpts from *A la California, Sketch of life in the Golden State by Col. Albert S. Evans, published 1873, A.L. Bancroft & Company, San Francisco*. It is one of the many historic accounts illustrating that Pescadero marsh and lagoon supported large populations of many species of fish and wildlife. 13-c) Newspaper article from Daily Alta of May 13, 1857 describing trout fishing along San Mateo Coast.

4.3. History of Land Use in the Pescadero-Butano Watershed

The landscape of the Pescadero-Butano watershed has been, and continues to be, affected by regional uplift, folding, faulting, changes in vegetative cover, and fluvial processes that have occurred for millions of years. Costanoans, who lived in the area starting 3,000 years ago until the 1800s, burned and cleared land to remove protective cover for game animals and to plant grains. Within the last two centuries with the settlement of European-Americans, human impact on the landscape has included the construction of infrastructure for permanent settlements, farming, ranching, timber harvesting, and recreation.

Table 5 below shows a chronology of significant land use changes in the watershed.

The settlement and land use history of the Pescadero-Butano watershed has been previously studied and reported in several documents including but not limited to the following:

- Liles, T. 1994. Land-use history of the Pescadero Creek watershed, San Mateo County, California: 1848-1990. M.A. thesis, San Francisco State University. 205 p.
- Albion Environmental. 2004. History of the Pescadero-Butano watershed in Pescadero-Butano Watershed Assessment. Environmental Science Associates. 2004. pp 3-1 to 3-48
- San Mateo County Natural History Association (SMCNHA). 2009. European and American History on the San Mateo Coast. San Mateo Coast Sector Volunteer Study Guide. 9 p.

Figure 14. Photograph of the Town of Pescadero ca. 1890

Looking toward Bradley Creek watershed. Cows can be observed on the hills in the background of the photograph. The impacts of grazing were already becoming apparent as evident by gullies and signs of surface erosion on the hillslopes. Slump failures can also be seen along Bradley Creek. In the foreground, a smaller Pescadero Creek channel can be observed flowing first along the Pescadero Creek Road then making a right turn to flow along the Stage Road. Signs of bank erosion can also be observed on the right bank of Pescadero Creek channel.

Table 5. Chronology of significant land use changes in the Pescadero-Butano Watershed (BalanceGeo, 2015)

Date	Event
Pre-1820	"Natural" conditions
October 1769	Portola Expedition – first Spanish contact
1770 - 1820	Spanish period Grazing, introduction of non-native plants
1820 - 1850	Mexican period Land grants, livestock importation, conversion of hillside and streamside vegetation due to grazing (over an area of approximately 4,000 ac)
1850 - 1920	Early American period Early logging, start of ranching and dairy farming (over an area of approximately 4,500 ac)
1856	Town of Pescadero founded
1860s-1890s	First wave of heavy logging of redwoods in Pescadero and lower Butano (over an area of approximately 3,600 ac) Agriculture including wheat, oat, barley, and flax farming (over an area of approximately 1,300 ac)
1920 - 1970	Peak extent and intensity for all land uses
1920s-1930s	Construction of levees, channelization of Butano and Pescadero channels in marsh. Farming in floodplains
1930s-1960s	Intense marsh reclamation and agricultural expansion activities
1940	Construction of Highway 1 Bridge Temporary haul road built downstream of bridge
1930s-1970s	Post-WWII logging boom: road building and extensive bulldozer logging in old growth of North and South Forks Butano Creek (over an area of approximately 22,000 ac)
1960s	State of California begins to acquire property in Pescadero marsh
	Pescadero Road Bridge constructed in 1961
	Second wave of logging in upper Pescadero (e.g., Slate, Oil Creeks)
1970 - 2010	Second wave of logging in North and South Butano Creeks Pescadero marsh restoration projects

4.4. Watershed Response to Two Centuries of Change

The condition of the Pescadero-Butano watershed today reflects the cumulative impact of all the historical watershed development actions summarized in the preceding paragraphs. Based on our review[18] of the disturbance history of the watershed we conclude that although the Pescadero-Butano watershed generates large amounts of sediment, prior to European settlement of the watershed and subsequent land use disturbances, the natural drainage system ensured that much of that sediment was deposited on the alluvial fans, wet meadows, and floodplains. Channel modifications and land use changes in the last two centuries, while making the lower watershed more habitable and productive, have mobilized more sediment and eliminated natural sediment storage areas on the floodplains and have shifted the zone of deposition from the valley downstream to the lagoon. The primary changes in how the watershed generated, stored or moved sediment are as follows:

- Increased sediment delivery due to hillslope erosion triggered and exacerbated by land use practices including logging, grazing, and agricultural cultivation;
- Increased sediment delivery due to channel incision and bank erosion triggered and exacerbated by land use practices including channelization, wood removal, roads, agricultural cultivation, and grazing;
- Elimination of sediment storage in alluvial valleys due to channel incision and resultant disconnection of channels from their floodplains;
- Shifting of sediment storage from the wet meadows and floodplains to the Pescadero marsh-lagoon complex;
- Loss of volume of the lagoon and reduction in tidal prism of the lagoon and tidal channels transforming the deep water estuary into a shallow creek delta; and
- Reduced flushing of sediment out of the lagoon due to modifications of its hydrology by draining and re-plumbing of the marsh, the Highway 1 Bridge, reduced inflows due to upstream channel diversions, and partially-implemented restoration projects in the 1990s.

These significant changes have completely transformed the watershed and drastically altered the hydrologic, geomorphic, and subsequently, the ecologic functioning of the creeks and the marsh.

Grazing of rangelands in the western watershed was one the earliest land use practices (Figure 14). Intensive grazing has the potential to reduce ground cover vegetation density, change vegetation structure and species assemblage, and compact soils causing infiltration capacity and permeability to be reduced. These effects of grazing, in turn, may greatly increase overland flow runoff during storms, leading to significant increases in the rates of surface erosion. Intensive grazing can also increase peak rates of runoff and forms gullies during high intensity storm events. Our review of ground photographs from 1800s, paintings, and sketches suggest that the process of gullying was triggered around 1860 in the areas that naturally supported scrub/chaparral vegetative cover (Figure 15).

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[18] The analysis presented in this section was primarily synthesized by BalanceGeo (2015) and supported and/or complemented by ESA (2004) and Liles (1994).

Logging of the redwood forest started in mid-to-late 1800s and continued for a century. Logging happened in two distinct phases in the watershed (Figure 16):

i) Early logging activities in the second half of the 19th century; and
ii) Post World War II logging activities from 1930s through 1970s.

The early logging activities were intensive and involved manual clearcutting and downhill yarding of old-growth redwood and Douglas fir forests along easily accessible stream channels. Nineteen on-channel shingle mill dams were built (Figure 17, 18, and 19). Oxen, mule, horse, and later steam donkey engines, were employed to skid logs along the intermittent watercourses. Seasonal splash dams were put in place to float timber logs along Pescadero Creek. The old form of clearcutting in the 1800s and beginning of 1900s was an economic practice, which involved cutting all that was usable to a sawmill. Since most timber at that time was large, old-growth timber, nearly all timber was usable, and therefore all timber was cut. This amounted to total exploitation over many thousands of acres, and along with the use of creeks as skid trails, roads, and flumes, resulted in tremendous damage to the forestry resources in the region (Figure 19). Several tributaries to Pescadero Creek, including McCormick, Jones Gulch, Peters, Slate, and Oil, were significantly impacted due to splash-dam logging, in-channel skidding, livestock trampling, and channel simplification.

During the late 1880s, sawmills shifted to steam-powered circular saw, enabling cutting of more logs. By 1895, timber operations began using a combination of cable, steam energy, and animals to cut, load, and transport timber (Liles, 1994). The “steam donkey” engine and long cable provided a drive source and extension for tramways which could drag logs from distant points up or down a canyon. Before trees were cut, controlled fires removed unwanted sapwood, brush, and forest floor debris, leaving only the desired trees. This process significantly increased mass failures along hillslopes. Logs pulled through vegetation by steam donkeys also destroyed the soil and increased erosion. Due to the degradation of the land, it was sold cheaply after logging operations moved on to other areas (Liles, 1994).

The second phase of timber development began in the 1930s and incorporated heavy machinery. In order to meet the demand for finished timber products, timberlands were cleared at a rapid pace. After the clear cutting of the forest, everything remaining was burned. The slash-and-burn method made it easy for the big machines to haul the logs away. Without vegetation, massive landslides and slope failures were common after heavy rains (Lisle, 1994). Industrial timbering activities took place over 40 percent (22,000 acres) of the watershed and resulted in mechanized deforestation of old- and second-growth redwood and Douglas fir forests (Figure 20). Both phases of logging resulted in the following structural disturbances:

- 250 miles of new unpaved haul roads and skid trails were built;
- A major timber haul railroad and truck road, Old Haul Road, was constructed along the canyon reach of Pescadero Creek;
- Nineteen on-channel shingle mill dams were built;
- Dams were built on ten small tributaries (over an area of 1,300 acres) that drain the Butano Ridge; and
- 2,800 acres of mixed conifer-oak woodlands were converted to agricultural land.

Increased erosion and sediment delivery due to grazing, logging, and roads contributed to channel degradation. In addition, direct interventions to channels (e.g., ditching, wood removal, and channel relocation) also contributed to channel incision. Analysis of the ground photographs and paintings combined with field evidence indicate that channel incision was triggered around 1860 on Pescadero Creek (Figure 6 and Figure 7) and around 1920 on Butano Creek (Figure 21). Different reaches of the creeks incised as a result of different land use practices over different time frames. In the canyon reach of the creeks, incision[19] may have resulted from one or more of the following disturbances: logging of old-growth redwoods (increasing storm runoff); removal of large woody debris for salvage and to enable transport of logs (lowering local base level and subsequently steepening the slope). For instance, removal of woody debris within the Butano Fall residential tract in the 1930s contributed to significant degradation of Butano Creek in the alluvial fan reach.

Along Pescadero Creek, channel ditching in areas of shingle mills during the period from 1855 to 1920 steepened channel slopes locally and resulted in incision. In the alluvial fan reach, channel incision can be attributed to logging and associated agricultural conversion of the valley floor and all the consequent channel modifications. In the lower valley along the wet meadow reach, the following land use practices are the plausible drivers for incision: 1) ditching and draining of the valley floor to connect naturally disconnected tributaries; 2) relocation of some reaches; 3) channel straightening and ditching to reclaim the valley floors for agriculture from 1860s to 1970s; 4) salvage/snagging of large woody debris; and 5) removal of riparian vegetation for flood control purposes in the 1880s. Incision has resulted in loss of 1,500 acres of wet meadow valley floors and abandonment of 500 acres of floodplains due to loss of connectivity between the channels and floodplains during high flows. Figure 5 documents that Bradley Creek was naturally disconnected from Pescadero Creek, disappeared in an alluvial fan and freshwater wetlands shown as a “laguna”. Similarly, lower Honsinger Creek near its confluence with Pescadero Creek based on its straight and very deeply incised morphology, appears to have been ditched and straightened, suggesting it also may have been naturally disconnected.

Roads have contributed large amounts of sediment to channels in the watershed both in the historical period and currently. Paved and unpaved roads, driveways, trails, and footpaths collect and channel surface runoff, resulting in erosion and possible slope instability. Roads are a major source of erosion and sedimentation on most forest and ranch lands in the following ways (Weaver et al., 2014):

- Compacted road surfaces substantially increase the rate, volume, and locations of runoff;
- Road cuts and fills alter drainage pathways and the distribution of mass on the hillslope, often contributing to greater rates of landslide activity;
- Roads often can intercept and bring groundwater to the surface increasing the volume of runoff and erosion;
- Ditches concentrate storm runoff and can transport sediment to nearby channels;
- Road crossings over channels may be undersized for the conveyance of peak runoff rates and/or may be easily plugged by large debris during storms causing overtopping and/or diversion of

[19] In the canyon reach, incision refers to the evacuation from the channel bed of 6-12 feet deep valley fill (and not incision into bedrock).

channel flows, with resulting channel crossing erosion, and/or gully erosion through diversion of channel flows to another channel or hillslope location; and
- Lack of inspection and maintenance of drainage structures and unstable road fills along old, abandoned roads can also result in soil movement and sediment delivery to streams.

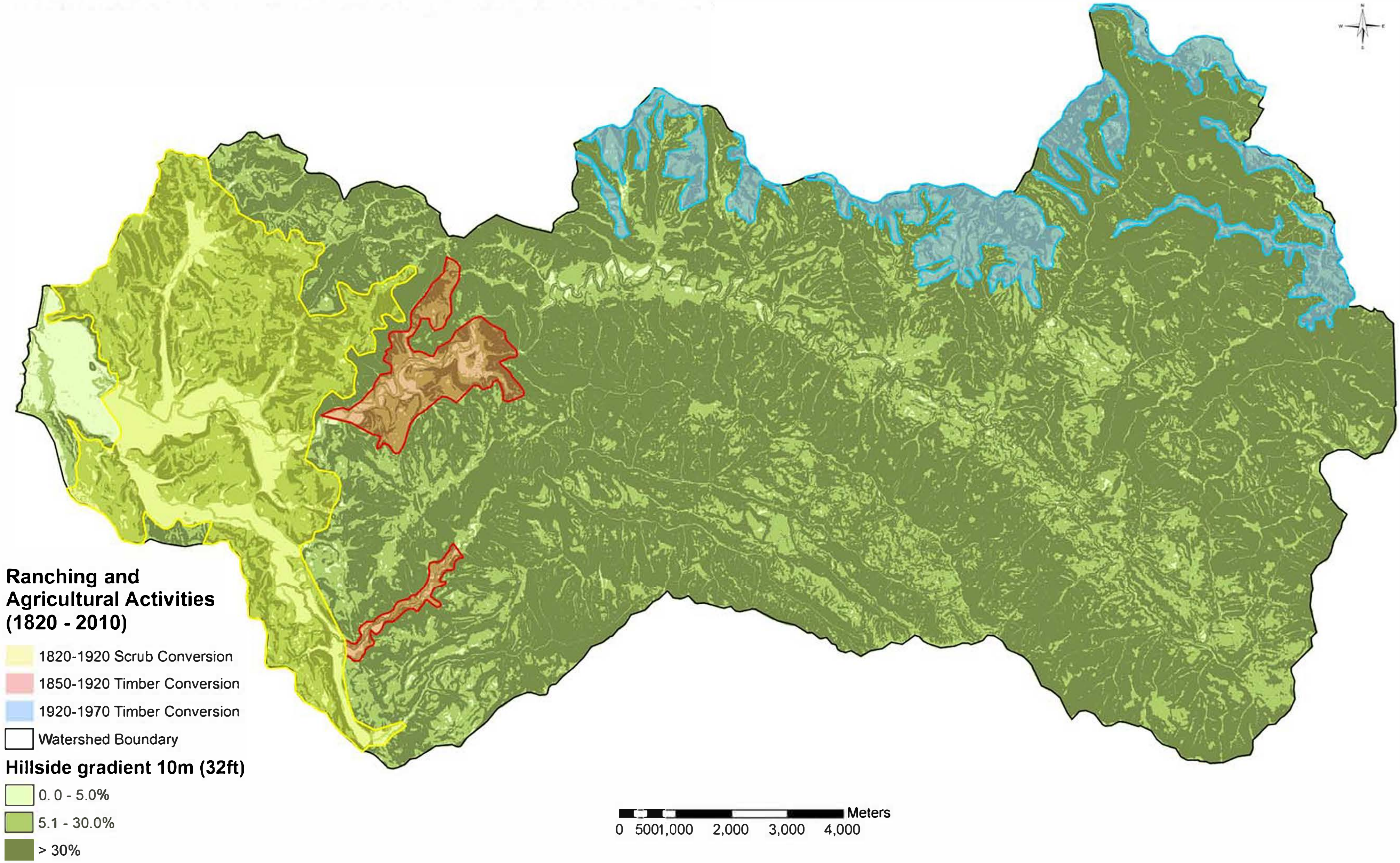

Figure 15 - Pescadero-Butano Watershed Ranching and Agricultural Areas

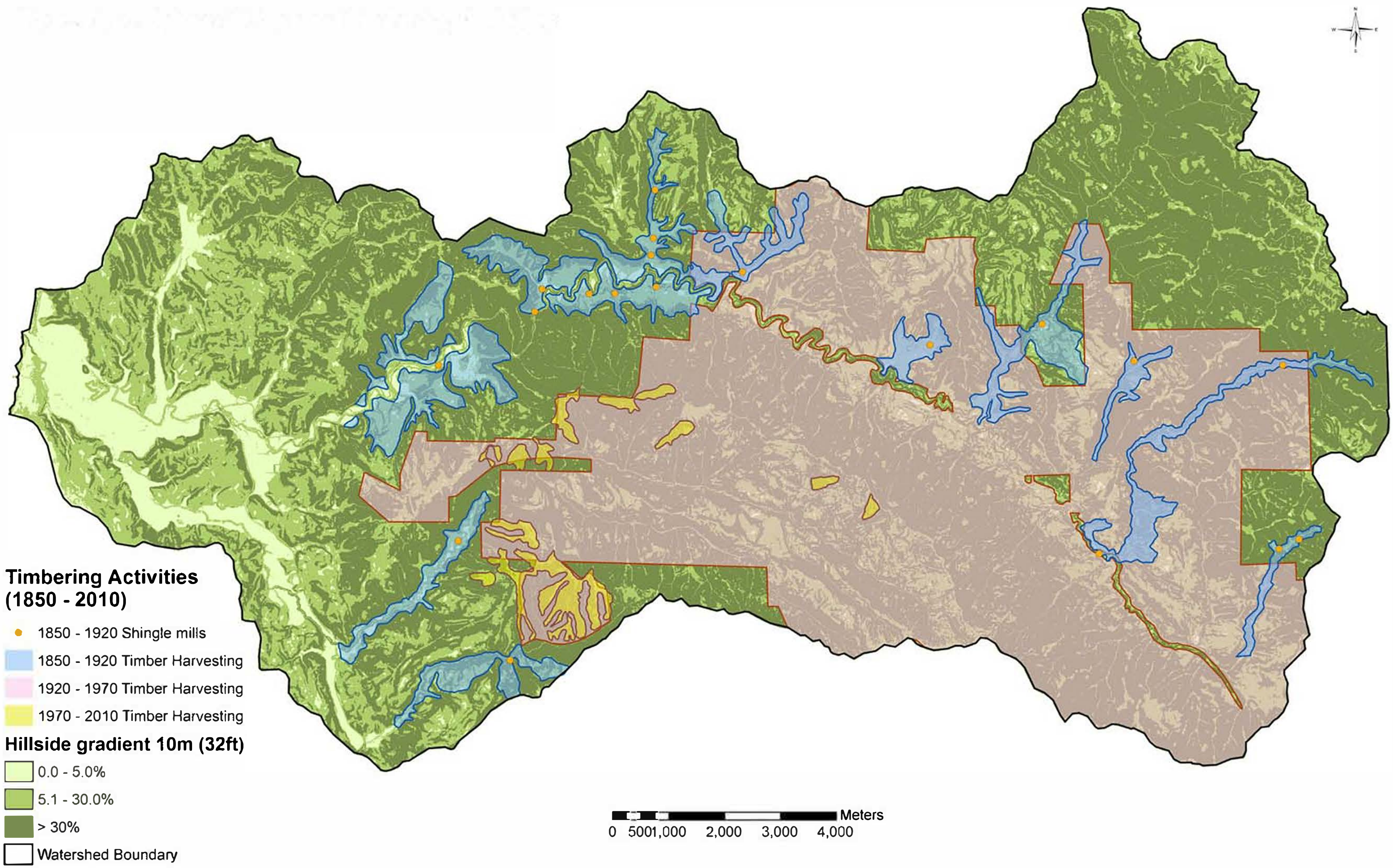

Figure 16 - Pescadero-Butano Watershed Timber Harvest Areas

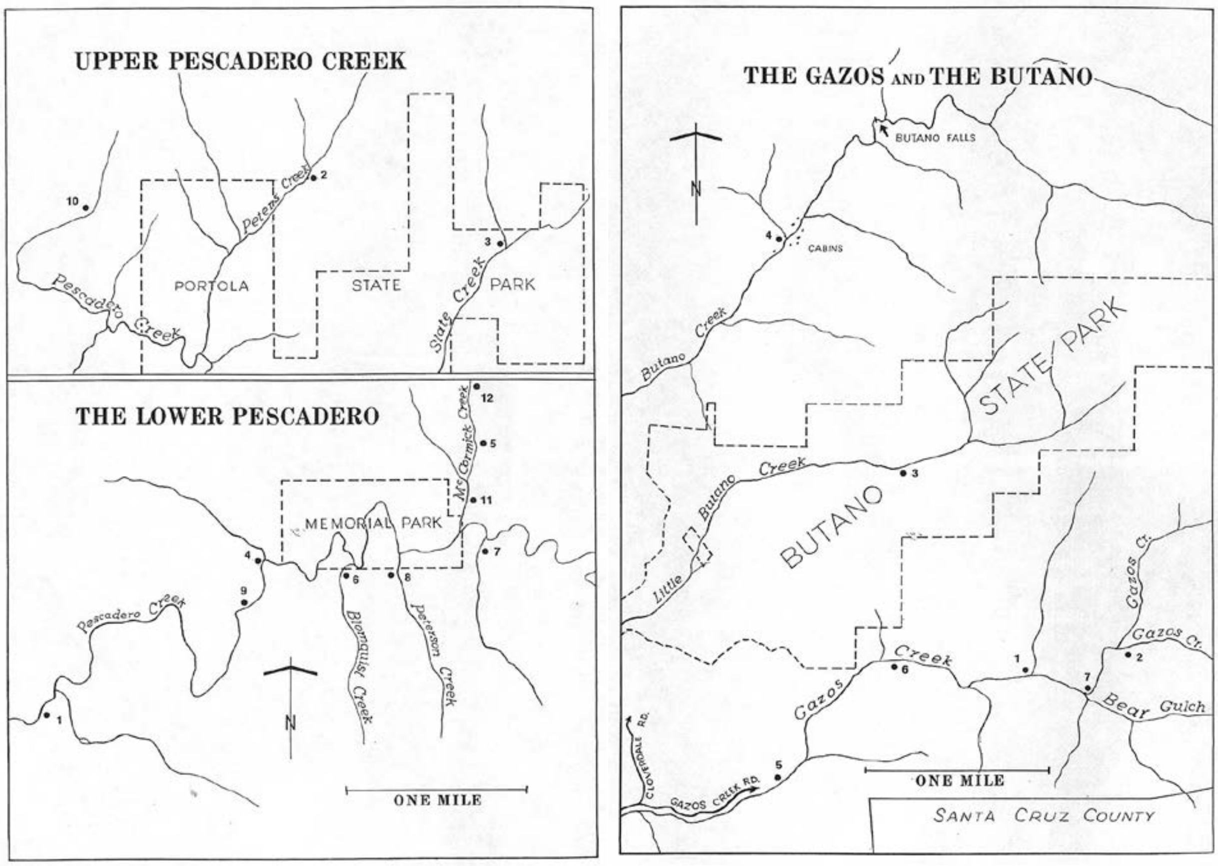

Figure 17. Shingle Mills on Pescadero (a) and Butano (b) Creeks

a) 1. Tuffley's Mill; Voris; B.Hayward (lumber and shingles), ca.1856-ca.1880. 2. Page Mill, 1867-1875. 3. Page Mill, new site, 1875-? 4. Anderson; Wurr Shingle Mill, 1869–1875. 5. A. Blomquist Shingle Mill, ?-1893. 6. Wurr Shingle Mill, ca. 1882-1887. 7. Wurr Shingle Mill, new site, 1887-1893; Blomquist to 1935. 8. Frank Blomquist Mill; Bloom, Peterson, 1904-1921. 9. Dudfield Mill, 1906-1912. 10. Moore, Fisher&Troupe (for Cal.Tie Co.) ca.1915. 11. Godeau Mill, ca.1923-ca.1930. 12. Haskins Shingle Mill, 1875. b) 3. Taylor Shingle Mill; Pharis, 1873-1884. 4. Hamilton & McCormick Mill; 1890s-1905


SEPTEMBER 19, 1903.

REDWOODS OF THE PESCADERO VALLEY TO FALL UNDER THE WOODMAN'S AX

California Timber Company Purchases Holdings in San Mateo County, Installs a Large Plant on Waterman Creek and Begins to Clear the Forest

Figure 18. Excerpt from San Francisco Call of September 19, 1903 and Photograph of the Hopkins Mill.

The first timber mill was built in upper Waterman Creek around 1870. The mill was abandoned in the beginning of the century after intense logging. The Hopkins family who started a new timber company, California Timber Company, built the modern mill in the place of the old mill to process the remaining large redwoods in the Watermen Creek. The article states "The days of the redwood trees which have made famous the valley through which Pescadero Creek runs are numbered. The principal owner of the timberlands in the valley is Timothy Hopkins, who purchased them twenty years ago at an average price of about $12.50 per acre. He and his associates own the larger portion of a thickly timbered region more than eight miles long…[]….A dam has been placed across Waterman Creek and a good sized mill pond created. The mill is located on the sidehill above this pond. No longer are the logs hauled to the mill by teams of gigantic oxen. A good sized donkey engine at the end of a skidway Is equipped with two immense cylinders, upon which wire cables are coiled. The light cable is intended for hauling the heavy cable out to the end of the skidway, which may be a mile away up some gulch. The heavy cable is then made fast to a row of immense logs fastened end to end by iron chains. A signal is given by the man In charge of the log train, which at once begins its journey to the mill. At a certain point the logs are uncoupled and rolled into the millpond. A steam elevator quickly raises the logs to the mill, in which they are rapidly cut into board measure. The mill has a capacity of 60,000 feet per day….[]There are two other mills operating upon the slopes of Upper Pescadero Creek. One is known as the Ryder mill and the other the Carmichael. It is evident that within a few years the redwoods in this section will be nearly all destroyed." https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SFC19030919.2.44

Figure 19. Photographs Showing 19th Century Logging Practices

The demand for timber for a growing San Francisco encouraged loggers to find ways of removing felled trees more rapidly. Logging operations descended into coastal canyons from the easily accessed ridge tops where timber availability had declined by 1880. Skid roads enabled workers to transport felled trees longer distances without having to move the mill. Workers cleared a path from the cutting site to the mill. Over this path, they positioned small logs less than a meter apart on the ground. Grease spread over the logs decreased friction while oxen pulled the felled logs over the road to the small mill. During the late 1880s, sawmills shifted to the steam-powered circular saw, enabling operators to cut more logs and meet the growing demand. By 1895, timber operations began using a combination of cable, steam energy, and animals to cut, load, and transport lumber. Companies cut trees of all sizes and types. Controlled fires removed unwanted sapwood, brush, and forest floor debris, leaving only the desired trees. This process of removal denuded the hillsides of vegetation and led to mass landsliding. Logs pulled through vegetation by the donkey engine and cable system also destroyed the topsoil and increased erosion. The degradation of the land was likely a major reason land was sold cheaply after logging operations moved on to the other areas.

Figure 20. Photographs of 20th Century Logging Practices Santa Cruz Lumber Company Practices (1930s and 1940s)

The second phase of timber development began in the 1930s and incorporated heavy machinery. In order to meet the demand for finished timber products timberlands were cleared at a rapid pace. After the clear cutting of the forest, everything remaining was burned. The slash-and-burn method made it easy for the big machines to haul the logs away. Without vegetation, massive landslides and slope failures were common after heavy rains.

Figure 21. Upper Butano Creek, 1915

Butano channel was much less incised than today and was connected to its floodplain. The left bank appears to be 10 to 15 feet high at the time. The channel banks range from 25 to 30 feet today.

In summary, not only has overall sediment input to the channels more than doubled compared to natural background rates but sediment storage along the alluvial channels and the valley has been eliminated and converted to sediment sources through channel erosion. The channels have become disconnected from their floodplains. The zone of sediment storage shifted from alluvial channels and the valley downstream to the lagoon and marsh (Figure 22). The lagoon, which is one of the most sensitive habitats for listed species, now receives more sediment. Bradley Creek, which currently drains directly into the marsh and is no longer storing any sediment due to incision, is producing significant amounts of sediment due to intense ongoing and legacy grazing, cultivation, and channel modifications. There is more sediment input to the channels, no storage on the floodplains, and an efficient drainage system that transports all delivered sediment downstream into the estuary where most of it deposits (Figure 23). If no action is taken, channel and bank erosion, as well as hillslope erosion, will continue and high rates of sedimentation in the lagoon and marsh will persist.

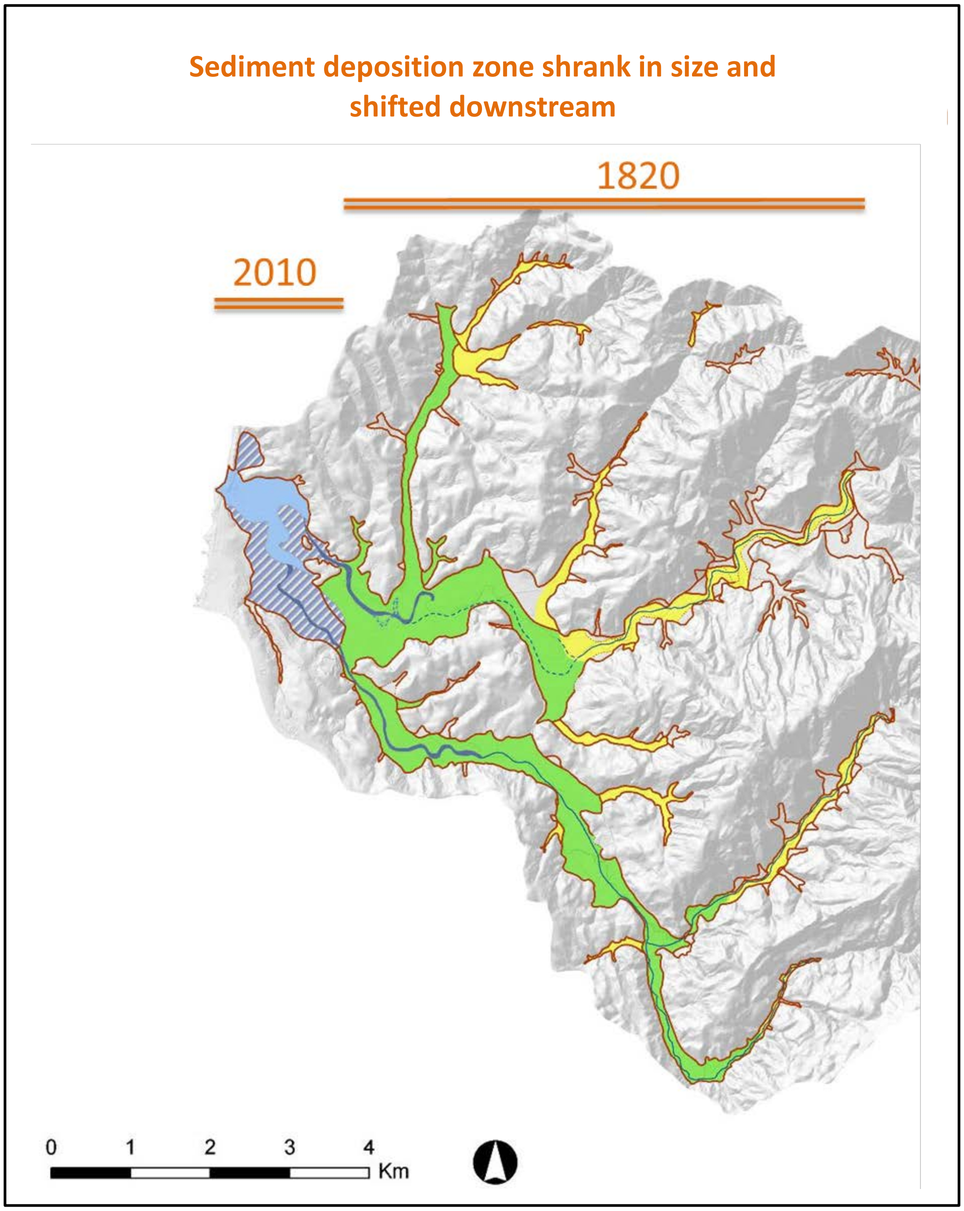

Figure 22. Historic and Current Zone of Sediment Deposition in the Pescadero-Butano Watershed

Watershed land use has changed dramatically in the last two centuries. In addition to grazing, logging, agriculture, and roads released large amounts of sediment to the channels, wet meadows and valley surfaces were ditched and drained and stream channels in the watershed were progressively placed with straighter channels to make alluvial fans more habitable, more productive for farming, and better suited for efficient flood conveyance. These land use and channel modifications resulted in channel incision, which in turn converted channels from storage reservoirs to sediment sources through bed and bank erosion. Resultant disconnection of floodplains and elimination of overbank flows, coupled with connecting of tributary channels to main stem Pescadero Creek, eliminated sediment deposition in the valley. Sediment deposition zone shifted from the entire lower valley to the lagoon.

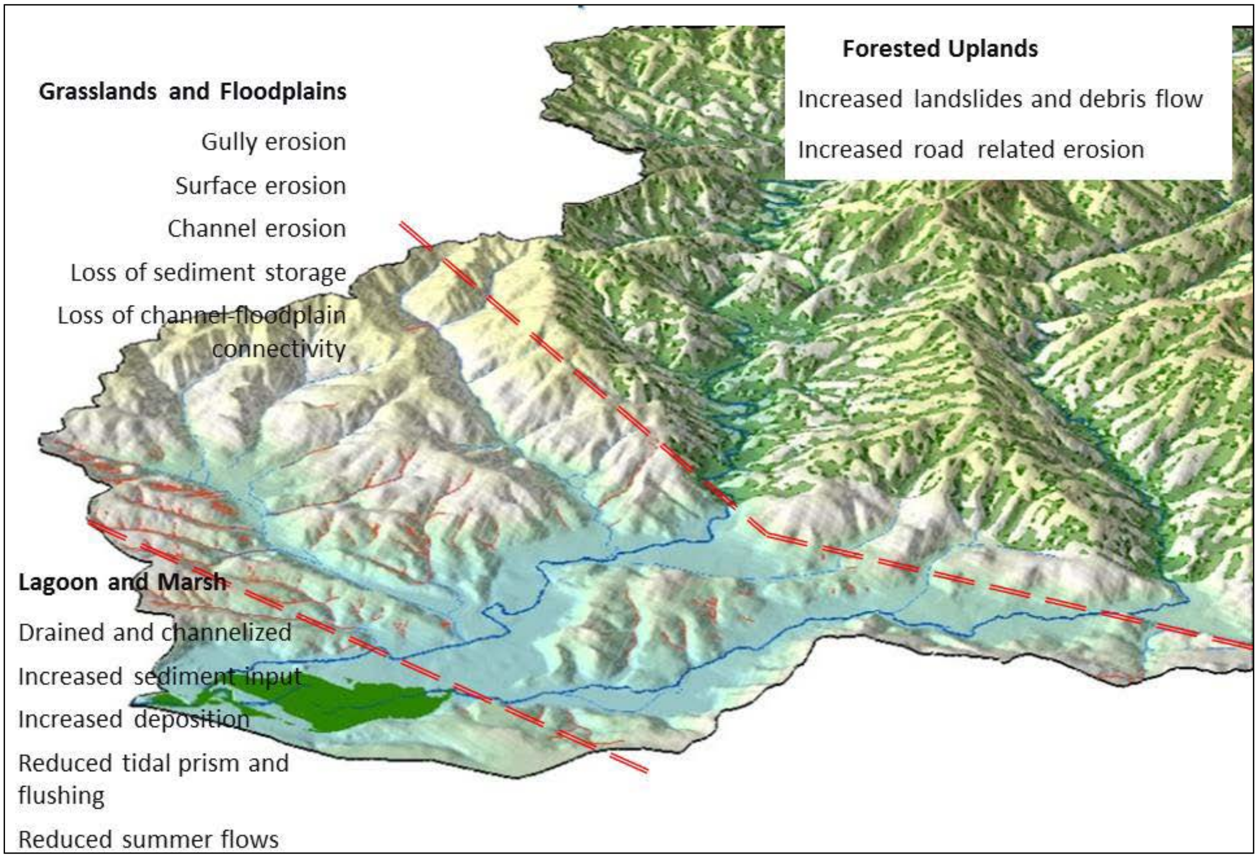

Figure 23. Summary of Geomorphic Changes in the Last Two Centuries in the Pescadero-Butano Watershed

Basic Tenets of Watershed and Channel Change

- Channels are sensitive to external disturbance.
- Rivers adjust to changes in their load of water, sediment, and wood; the resulting changes in habitat can dramatically alter the health and abundance of species that live in them.
- Channel form components such as depth, width, slope, sediment size, are interrelated: the modification of one component initiates response within others.
- Watershed and channel components are linked along a continuum: hillslopes and channels, fluvial and marine environments have important linkages. Change at one place triggers change at another with an appropriate time-lag.

CHAPTER 5

SEDIMENT SOURCE ANALYSIS

Key Points

- Sediment delivery to fish bearing channels has increased by more than a factor of two in the last one hundred and fifty years as compared to natural background due to historic and/or current land use activities including logging, grazing, roads, agriculture, and removal of wood from creeks. Currently, more than 250,000 tons per year of sediment is delivered to channels annuals.
- Sediment delivered to channels comes from roads, channel incision, gullies, landslides, and surface erosion.
- Roads are the most significant source, closely followed by channel incision.
- More than 30,000 tons of sediment that historically deposited on floodplains and alluvial valley is now transported downstream to the estuary.
- More than half of the sediment is generated in and delivered from the grasslands and alluvial valley, occupying the western quarter of the watershed. This contribution in the lowlands is significant due to close proximity to the lagoon and marsh, where most sediment eventually ends up.
- There has been more than an order of magnitude of increase in marsh and lagoon sedimentation: from 2,000 tons/year to 30,000 tons/year.
- Elevated sediment loads and lagoon sedimentation are expected to continue without intervention.

5.1. Introduction

A sediment TMDL must identify sediment source categories and estimate loads associated with each source. To establish the sediment TMDL, we used a "rapid sediment budget approach" to identify significant processes that deliver sediment to Pescadero and Butano watersheds, and to estimate rates of sediment input to channels since the 1970s.[20] Reid and Dunne (1996) define a sediment budget as follows:

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[20] A rapid sediment budget is a measurement technique that can be performed over a short period of time to provide approximate estimates of rates and sizes of sediment input to channels. Estimated rates are expected to be within a factor of two of actual values (Reid and Dunne, 1996, pp.136-137).

> "A sediment budget is an accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin."

To understand how anthropogenic disturbances have altered channel sediment supply and transport processes, we contracted with Balance Geo to develop a rapid sediment budget that quantitatively characterizes natural background, historical, and current and rates of sediment delivery to channels, and also changes in channel sediment storage and lagoon sedimentation rates within the Pescadero-Butano watershed. We rely on field surveys, computer modeling, and a review of available information and historic maps to develop the sediment budget for natural background and current conditions. The natural background conditions are represented by conditions that existed in the late Holocene prior to Mexican and European settlement within the watershed (pre-1820's conditions). This period incorporates minimal land use practices of Native Americans where sediment was primarily generated through natural landscape denudation. It provides an estimate of natural background sediment input levels and therefore provides reference conditions. Current conditions are represented by conditions during the period from 1970 to 2010. This period reflects on-going land use practices, as well as legacy impacts of prior land use practices that still impact channels and sediment delivery and storage. To understand how anthropogenic disturbances may have altered sediment and ultimately what actions are needed to rehabilitate habitats, we compared the sediment budget for current conditions to reference or natural background conditions.

5.2. Natural Background Sediment Budget

Located in a tectonically active region with steep slopes, underlain by weak, erodible rocks, and subject to a Mediterranean climate, the Pescadero-Butano watershed has a naturally high sediment load. However, under natural conditions a large portion of the sand and all the coarser sediment delivered from the hills deposited in alluvial fans or on the floodplains. Some of the larger tributaries to the lower valley e.g., Bradley Creek were naturally disconnected, ending in alluvial fans without reaching the main channel and storing much of the sediment before it reached the main channel or the lagoon. Incised channels, as ubiquitous as they may be in the present state, were uncommon and channels were well connected to adjacent floodplains. Large woody debris in the channels was likely one of the primary agents that stored sediment, shaped the channels and created complex habitats: they would block channels, facilitating rapid upstream deposition, overtopping of channel banks, and redirection of flow to form a new channel. In the valley, sediment either accumulated within the channel in channel storage elements (e.g., riffles and bars) or deposited behind large woody debris jams; or it accumulated on the floodplains when transported from the main channels via overbank flows. Finer sediments that didn't deposit in the valley were delivered to the marsh and lagoon complex. Deep and wide tidal channels that almost reached upstream to the current location of the town along Pescadero Creek or to the Pescadero Creek Road along Butano Creek were able to transport a significant portion of the sand out to the ocean.

Natural Background Erosion

Under natural conditions, landslides constituted the main source of sediment. Although both deep-seated landslides and shallow landslides were common in the watershed, deep-seated landslides generated the majority of the sediment delivered to the channels. Brabb et al. (2000) digitized deep-seated landslides for the Pescadero-Butano watershed (Figure 2) from the inventory prepared by Brabb and Pampeyan (1972) showing large landslide scarps and deposits and illustrating how wide-spread deep-seated landslides are in the watershed. Deep-seated landslides are large slope failures involving soil, weathered rock and/or bedrock in which the sliding surface is deeply located. On the most basic level, weak rocks and steep slopes are more likely to generate deep-seated landslides. Such slope failures move slowly and infrequently, often following prolonged rainfall or earthquakes, and leave head scarps and deposits that persist for many years and can be recognized on air photos. Shallow landslides are debris slides or debris flows in which the sliding surface is located within the soil mantle. Presence of historic slides is important since future movement on the slopes is most likely to occur within and around places where they have previously occurred.

Accurate estimates of long-term, natural erosion rates are rare. Traditionally, basin-wide erosion rates relied on measuring the current sediment load in streams or the volume of soil that has accumulated in deposits of known age. Both of these methods have uncertainties and inherent inaccuracies and such measurements are typically not available to provide an adequately long record that includes rare flood events that transport the majority of sediment. A relatively new method, cosmogenic nuclides, has emerged since the 1990s to infer long-term erosion rates (Nishiizumi et al., 1986; Granger et al., 1996; Gosse and Phillips, 2001). Cosmogenic nuclides are produced in minerals near the earth's surface by cosmic radiation and their concentration in a mineral grain records the speed with which that grain has been unearthed and exposed to rays[21]. When measured in sediments in a channel, cosmogenic nuclide concentrations correspond to erosion rates of the parent rock and can be applied to the whole watershed to estimate long-term erosion rates. Because cosmogenic nuclide concentrations are insensitive to recent changes in erosion rates, they are particularly useful for estimating long-term background rates of erosion, which then can be used as a benchmark for evaluating the erosional effects of land use.

BalanceGeo (2015) reviewed data collected by Gudmundsdottir et al. (2013), who inferred denudation rates based on cosmogenic analysis of sands deposited in stream channels within the Santa Cruz Mountains (in channel reaches where there is little long-term upstream sediment storage) to approximate the natural average annual erosion rate over the last few thousand years within the Pescadero-Butano watershed. BalanceGeo considered denudation rates that Gudmundsdottir et al. documented along Butano Ridge, as well as nearby watersheds (Gudmundsdottir, 2013b, Supplement 6), and estimated an average value based on area-weighted representation of characteristic geologic units (Figure 24). The erosion rates that were included in the estimates are: 1) Butano Creek rate of 0.24 mm/year representing Butano Sandstone (35 percent of the watershed); 2) Peters Creek rate of 0.33

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[21] Glacial geology professor Edward Evenson explains cosmogenic nuclide dating analysis by likening it to measuring the degree of redness on a person's skin to estimate the duration of exposure to sunlight.

mm/year representing mixed geologic units in upstream Pescadero sub-watershed (40 percent of the watershed); and 3) Pomponio Creek rate of 0.15 mm/year representing Purisima Formation in the Pescadero sub-watershed (25 percent of the watershed).

Using these erosion rates and areas they represent, an average erosion rate of **0.25 mm/year** for the whole watershed was estimated. This erosion rate was applied to the whole watershed with an area of 81 mi^2 (or 210 km^2). Therefore, the average annual background erosion rate was estimated as 52,500 m^3. Applying an average bulk density value for sedimentary bedrock units of 2.6 tons/m^3 (Wells, 2004, p. E55. Table 1), an average erosion rate of 650 tons/km^2-year was calculated.

A small part of the total denudation is due to chemical weathering whereby rocks are decomposed, dissolved, or loosened by chemical processes. Phillips and Rojstaczer (2001) reported a Pescadero-Butano watershed average chemical denudation rate of 0.03 mm/year. Assuming a bulk sediment density of 2.6 tons/m^3 the chemical denudation rate was estimated as 80 tons/km^2.

Subtracting the chemical denudation rate of 80 tons/km^2 from the total landscape denudation rate of 650 tons/km^2-year results in an average long-term sediment production rate of **570 tons/km^2-year** or **1,475 tons/mi^2-year** for the Pescadero-Butano watershed. Applying this rate to the watershed area, we estimate that on an annual basis approximately **120,000 tons** of sediment is produced in the watershed under natural background conditions.

The background erosion rate of 0.25 mm/year inferred from cosmogenic analysis is in line with the estimated erosion rate for Pescadero Creek of 0.22 mm/year, developed by Anderson (1990). The estimated background erosion rate also matches bedrock weathering rates for sites along the central California coastline of 0.2 to 0.3 mm/year, reported by Rosenbloom and Anderson (1994). The cosmogenic estimate is also similar to the inferred range for uplift rates in the region. In active plate margins such as the California Coast where an extended period of continuous deformation has taken place, rates of denudation and uplift could be similar (Burbank and Beck, 1991; Willett and Brandon, 2002)[22]. The following studies in this area reported uplift rates ranging from 0.15 to 0.45 mm/year:

- Weber and Allwardt (2001) reported an uplift rate of 0.31 mm/year for the Pigeon Point Quaternary marine terrace (close to the Pescadero Butano watershed);
- Hanks et al. (1984) and Lajoie et al. (1991) reported Quaternary marine terrace uplift rates of 0.2 to 0.45 mm/year in this region; and
- Valensise and Ward (1991), Montgomery (1993), Rosenbloom and Anderson (1994), Burgmann et al. (1994), Weber et al. (1995), Hitchcock and Kelson (1999), and Ducea et al. (2003) reported tectonic surface-uplift rates ranging 0.15 to 0.45 mm/year in this region.

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[22] This is primarily due to the competing sources of uplift and erosion naturally tending toward attainment of a balance. As initially low-relief landscapes are uplifted, erosion rates steadily increase over time in response to steepening of river profiles and adjacent hillslopes, which then is enhanced by increased orographic precipitation. Eventually erosion rates increase sufficiently to counterbalance the rock uplift rate, and a steady-state landscape is achieved.

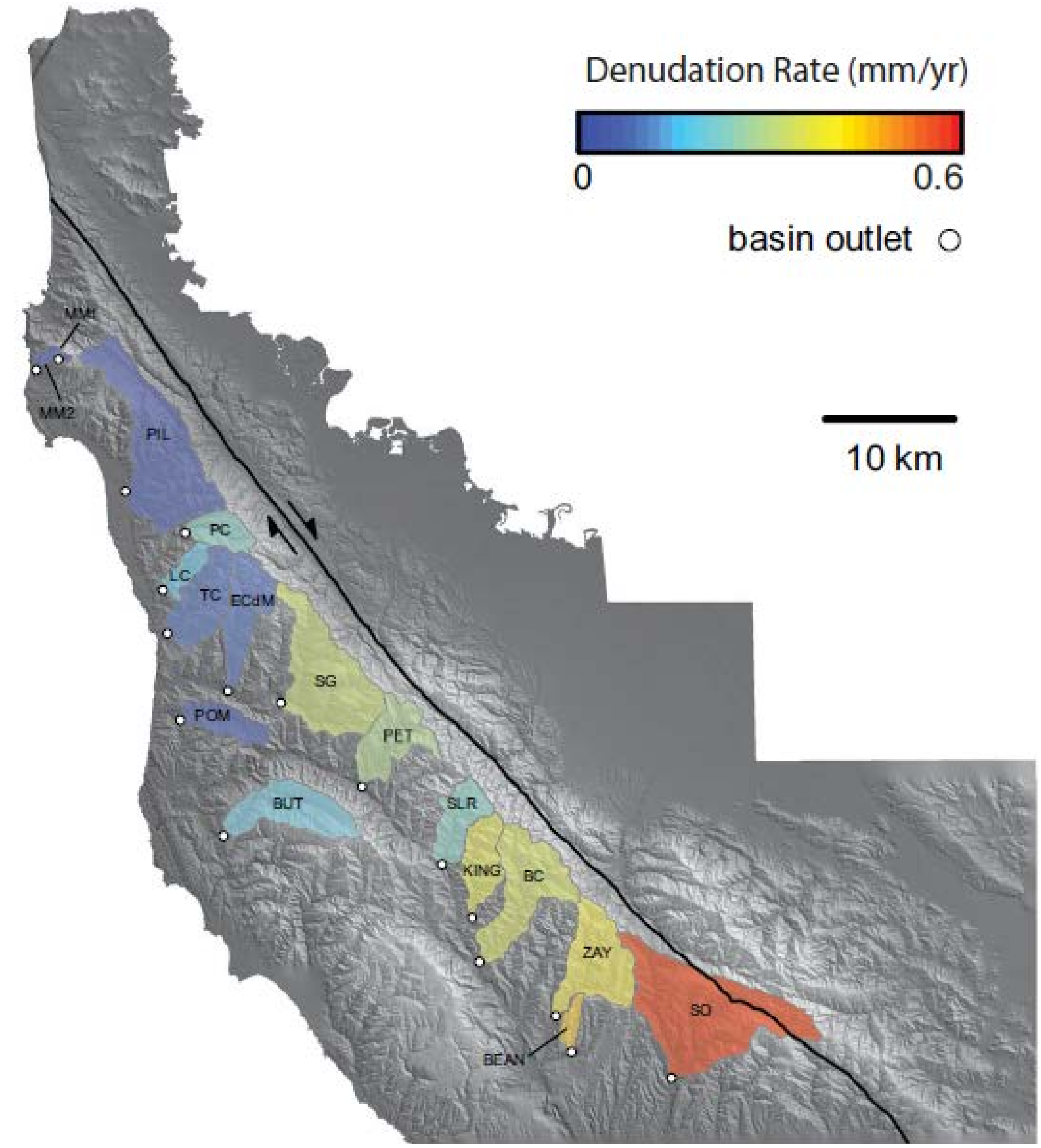

Figure 24. Cosmogenically-derived Denudation Rates in Santa Cruz Mountains.

Source is Gudmundsdottir et al. (2013b, GSA Data Repository, 2013236, Supplement 6). BUT (Butano Creek watershed) and PET (Peters Creek watershed) are both tributaries to Pescadero Creek. POM (Pomponio Creek watershed), SG (San Gregorio), and SLR (San Lorenzo River) are directly adjacent to the Pescadero-Butano watershed.

Natural Background Sediment Storage

Part of the sediment generated in the upper Pescadero-Butano watershed either temporarily or permanently deposited in different storage units throughout the watershed including the channels, alluvial fans, floodplains, or at the marshand lagoon complex downstream. In-channel deposition took place in the form of channel bars. Alluvial fans were formed by ephemeral or perennial streams emerging from steep terrain on to lowlands where either an abrupt reduction in slope or a sudden change from confined to unconfined status occurs. Fans were common in the Pescadero-Butano valley where tributary channels joined the larger streams or on the toe of hillslopes. Floodplains were the most ubiquitous depositional feature and are formed largely from a combination of within channel and overbank deposits (fine-grained material deposited from the suspended sediment in overbank floodwaters). At the most downstream end, Pescadero lagoon and marsh also stored sediment.

15,000 years ago (post ice age) sea level was approximately 330 feet lower than today and the ocean was 15 miles west of present-day shoreline (Viollis, 1979) (Figure 25). At the time Pescadero and Butano creeks likely originated at around the same area as today and flowed through their valleys out to sea. As sea level rose with melting glaciers the advancing sea invaded the mouth of Pescadero Creek approximately 6,500 years ago (Viollis, 1979) and spread inland. As the ocean flooded the valleys stream energy decreased and sediments carried downstream in the creeks deposited where flow velocities slackened, either on alluvial fans and floodplains upstream, or in the estuary. Therefore, extensive areas of the Pescadero-Butano watershed are underlain by thick deposits of sediment, derived from erosion of uplands in the last 6,500 years.

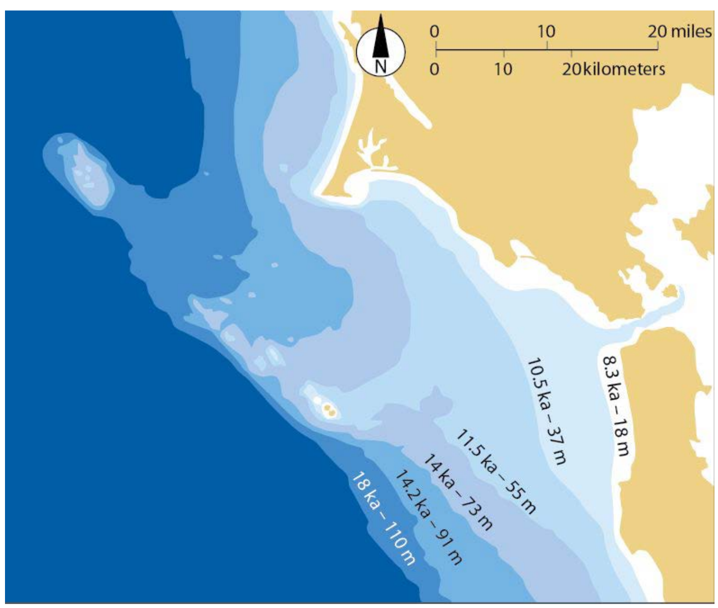

Figure 25. Rising Sea Level as Glaciers Melted After the Last Ice Age. Time in thousands of year ago (ka); depth in meters (from Sloan, 2006)

The extent and depth of sediment deposition in the valley were estimated by reviewing published geologic maps, historic maps, soil maps, current LiDAR map, and conducting extensive fieldwork within channels and adjacent areas. The boundary between the valley wall and alluvial sediment was delineated as the location where the steep, natural-sloping, soil-mantled, vegetated hills are met by the relatively flat, sparsely vegetated, coarse alluvial floodplain surface. Our review indicates that sediment deposited over an area of approximately 3,250 acres and depth of sediment ranged from 15 feet to 30 feet in the Pescadero-Butano valley (Figure 26).

BalanceGeo characterized Pescadero and Butano valley fill in two different reaches: the wet meadow reach and the alluvial fan reach. Figure 4 illustrates where sediment is stored in the lower watershed and delineates the extent of these two landforms.

The alluvial fan reach of Pescadero Creek extends from 5,000 feet upstream of USGS station 11162500 (near Pescadero Creek Road at White Russian Way) downstream to the vicinity of Butano Cutoff Road. The alluvial fan reach includes the valley fill (the amount of sediment deposited in the mainstem valley) and alluvial fans. The wet meadow reach of Pescadero Creek extends from Butano Cutoff Road downstream to the marsh. Along Butano Creek, the alluvial fan reach extends from Butano Falls downstream to the Cloverdale Road Bridge, approximately. The wet meadow reach extends from the Cloverdale Road Bridge downstream to the Pescadero Creek Road Bridge. In addition to mainstem channels, Bradley Creek, Honsinger Creek, and Little Butano Creek valleys are also mapped and characterized primarily as wet meadows.

Table 6. Estimated Volume of Lowland Valleys, Alluvial Fans, and Wet Meadows

Landform	Average Depth m(ft)	Area m^2 (ac)
Pescadero Creek Valley Fill	7 m (~25)	1.6 million (400)
Pescadero Creek Alluvial Fan	10 m (~30)	4.6 million (1,150)
Pescadero Creek Wet Meadow	5 m (~15)	3.0 million (750)
Butano Creek Valley Fill	7 m(~25)	0.4 million (100)
Butano Creek Alluvial Fan	10 m (~30)	0.2 million (60)
Butano Creek Wet Meadow	10 m (~30)	3.3 million (800)

Based on field work and the mapping analysis we estimate that the total volume of sediment stored in the valley in the last 6,500 years is **110 million m^3** (**90 million acre-feet)** or **176 million tons** (assuming a bulk density of 1.6 tons/m^3). Of the total storage, approximately 65 percent is in the Pescadero sub-watershed (71.5 million m^3 or 114.4 million tons) and 35 percent are within the Butano Creek sub-watershed (38.5 million m^3 or 61.6 million tons). We estimate that approximately 40 percent of the total storage is within the wet meadow valley fill and 60 percent is stored in floodplains and alluvial fans.

We estimated that the 110 million m^3 of sediment deposited in the valleys in the last 6,500 years starting at the time when advancing sea invaded the mouth of Pescadero Creek. If we apply the denudation rate of 0.25 mm/year in the same time frame, we estimate that approximately 340 million m^3 (275,000 acre-feet or 880 million tons) of sediment was delivered to the channels. Therefore, we conclude that approximately one-third of the sediment delivered to the channels was trapped and two-thirds (230 million m^3 or 600 million tons) of the incoming sediment washed out to the sea.

On an average annual basis (ignoring different landscape level changes under different climates), we estimate that over the last 6,500 years 120,000 tons of sediment have been delivered to the channels every year. Of this, **40,000 tons/year** historically deposited in the valleys and 80,000 tons/year washed out to the ocean.

Berlogar (1988) undertook a geotechnical investigation of the Pescadero Marsh to provide geologic conditions, to estimate depth to bedrock and to delineate stratigraphy. The study obtained a series of radiocarbon (C^{14}) dates to assess the age of the marsh and to estimate paleosedimentation rates. Based on the radiocarbon dating investigation, Berlogar reported that the Pescadero Marsh formed at an average vertical accretion rate of **0.6 mm/year** in the last 3000 years[23] over an area of 340 acres. This amounts to sediment storage of 2,475,000 m^3 (2,000 acre-feet) or 3,974,400 tons in approximately the last 3,000 years. On an annual basis, the average sedimentation rate would be 1,325 tons/year.

Clarke et al (2014) analyzed a sediment core taken from an undisturbed back-barrier area of Pescadero marsh and analyzed particle size distribution of 2-mm sections. They also used chronological markers e.g., ^{137}Cs, ^{210}Pb, ^{14}C, and geochemical trends implying sub-soil erosion (Clarke, 2011, Table 7.1) to date European impact on the site. They suggested a pre-Euro-American impact sedimentation rate of **0.5 to 1** mm/year. This would translate to 1,650 tons to 3,300 tons annually.

Similarly, Mudie and Byrne (1980) determined that pre-European settlement sedimentation rates in coastal marshes from central California were approximately 0.5 mm/year.

[23] Berlogar (1988) reported an accretion rate of 6.0 ft - 6.5 ft in the last 3,200±140 years over an area of 340 acres. The study also reported that over the Holocene (10,000 years) an estimated 65 ft (20 m) of continental sediments deposited in the Marsh, corresponding to a Holocene average rate of sedimentation of approximately **2 mm/year**. The rate of sediment accumulation was much slower in late Holocene at 0.6 mm/year.

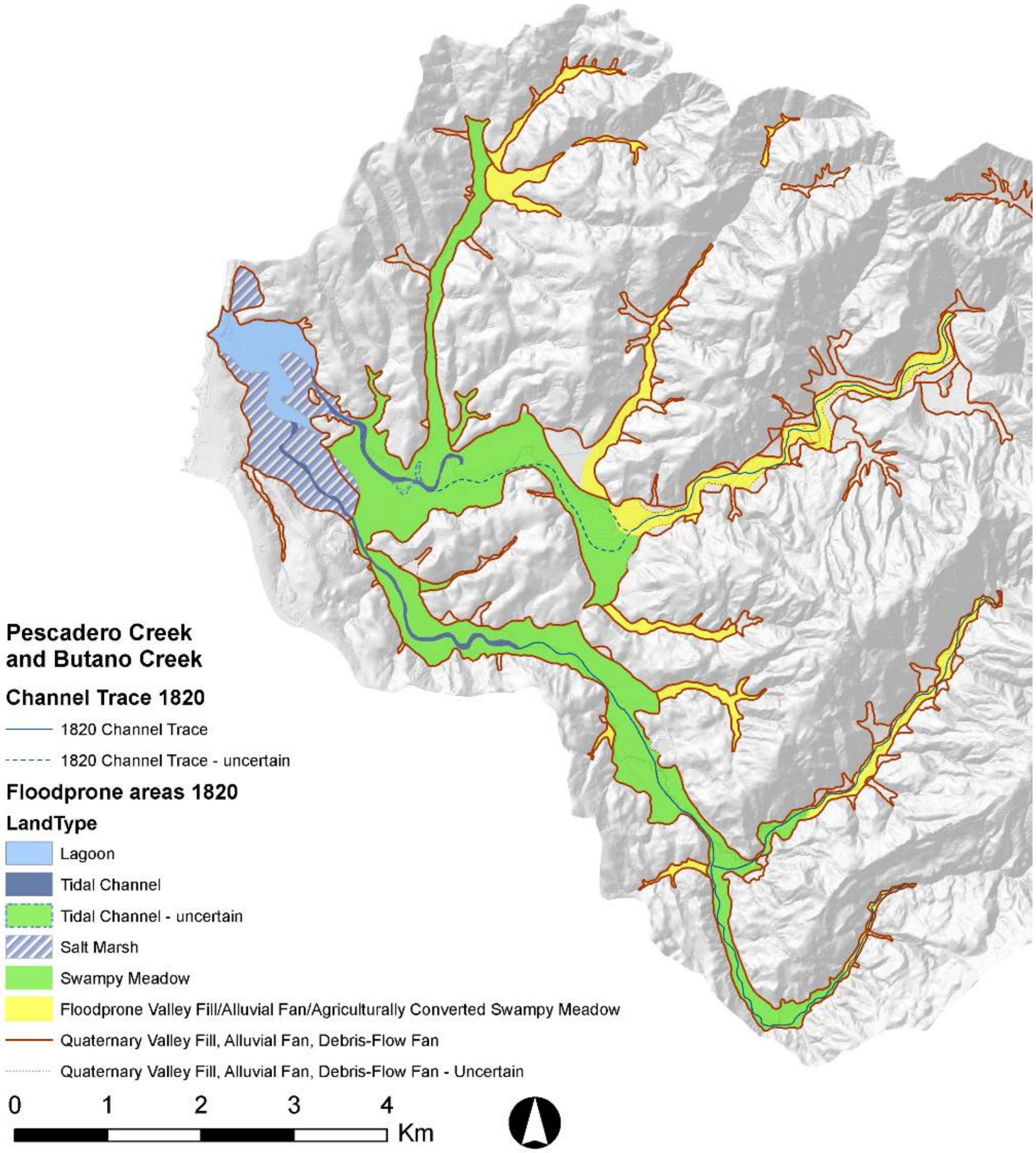

Figure 26. Alluvial Fan and Wet Meadow Reaches of Pescadero and Butano Creeks

Therefore, we estimate the average annual sedimentation rate in the Pescadero marsh before European settlement to range between 0.5 to 1 mm/year. The area of the Pescadero marsh and estuary was approximately 500 acres pre-European settlement. Therefore, annual sedimentation rate in the marsh and the lagoon ranged between 1,650 tons and 3,300 tons. Considering these three studies, we estimate that **2,000 tons/year** is an adequate estimate to represent the long-term average sedimentation in the marsh.

5.3. A Sediment Budget for Current Conditions (1970-2010)

Current conditions are represented by conditions during the period from 1970 to 2010. This period adequately represents recent and on-going land use practices and their impacts on sediment delivery. In this period, especially in the latter half, intensive logging practices and irrigation crop agriculture have decreased; however, legacy impacts of past land management practices still generate significant amounts of sediment and grazing, ranching, streamside agriculture, and selective logging are on-going.

As described in Table 7 below, active sediment sources in the Pescadero-Butano watershed were determined through a variety of approaches including synthesis of existing documents, modeling, and extensive field work. Background information and existing studies were collected and reviewed. Historic aerial photographs, historic maps, old paintings and photographs, and current LiDAR topography were analyzed in detail to document watershed and channel changes. Empirical and computer models were used to estimate sediment generation from surface erosion and road-related erosion, respectively. Lastly, extensive field work was conducted to understand, document, and survey sediment processes on the ground. The location of field surveys was not random and was constrained primarily by our ability to obtain permission for access to privately owned land, and by our available budget and schedule. Sequential air photographs of the marsh lagoon-complex from 1928, 1943, 1960, 2000, and 2014 were analyzed to delineate changes in the last century. We have also compiled and analyzed the following historic maps and paintings to document channel and watershed changes and estimate sediment inputs:

- Early sketches and property diseno maps (1833-1861)
- Plat of the Rancho Butano finally confirmed to Manuel Rodriguez, 1862, U.S. Surveyor General, 1862, 40 ch. To 1 inch
- A Topographical Map of the Country known as the Rancho Pescadero in Santa Cruz Co., Surveyed March 1861, by Chas.T.Healy and S.Worsley Smith, 40 chs.the inch
- United States Coast Survey T-sheet (T-682), 1854, Punta Del Bolsa Northward to Tunitas Creek, California, W.M.Johnson, 1:10,000
- Paintings, 1855 by an unknown artist and 1884 by E.A. Rockwell
- Lithograph by Grafton Tyler Brown, 1874
- Historic photographs of the town from 1867, 1890, and 1930 and of Pescadero and Butano Creeks from early 1900s and 1940s

The following categories of active and significant processes deliver sediment to channels in the Pescadero-Butano watershed:

- Road-related erosion processes
- Channel incision
- Gully erosion
- Shallow landslides
- Surface erosion

Gully erosion and surface erosion processes are active and significant processes that deliver sediment to channels in the grasslands located in the western quarter of the watershed where land uses such as livestock grazing and croplands disturb soil and vegetation cover. These processes are especially significant in the Bradley Creek watershed, which drains directly into the Pescadero marsh and delivers massive amounts of fine sediment. In addition, due to channel modifications and incision of its bed, Bradley Creek no longer stores sediment in its floodplain. Further, due to land reclamation and the need to efficiently drain agricultural fields, extensive ditches at the bottom of hillslopes efficiently deliver all water and eroded sediment downstream to the marsh.

Channel incision and accompanying bank erosion (which has become more significant in the last decade but was not estimated) occur in the alluvial valley and fan deposits. Road crossing erosion, and gullies and landslides caused by road-related changes in hillslope runoff and/or distribution of mass, are also significant active processes that deliver sediment to channels. Road-related erosion processes occur everywhere in the watershed.

Table 7 below lists all the sediment sources that were considered in the sediment budget and includes information on whether the source is natural or management-related and if the latter, its management association and methods for evaluation.

Table 7. Sediment sources in the Pescadero-Butano watershed

Sediment Source	Source Type*	Management Association	Methods for Evaluation
Landslides			
natural	d		journal publications, field survey, air photos
management-related	d	roads and logging	ESA (2004)
Gullies			
management-related	d	roads, grazing, agriculture	field survey, air photos
Channel incision			
management-related	c	channelization, flood management, logging, agriculture,	field survey, air photos, LiDAR analysis, historic maps/photos
Surface erosion			
management-related	c	roads, grazing, agriculture	USLE
Road surface erosion			
management-related	c	roads	SEDMODL2 ESA (2004)
Soil creep			
natural	c		SEDMODL2
management-related	c	roads	SEDMODL2

*c = chronic source, d = discrete source

1. Road-Related Erosion

Paved and unpaved roads, driveways, trails, and footpaths collect and channel surface runoff, resulting in erosion and possible slope instability. Roads are a major source of erosion and sedimentation in the following ways (Weaver et al., 2014):

- Compacted road surfaces substantially increase the rate, volume, and locations of runoff;
- Road cuts and fills alter drainage pathways and the distribution of mass on the hillslope, often contributing to greater rates of landslide activity;
- Roads often can intercept and bring groundwater to the surface increasing the volume of runoff and erosion;
- Ditches concentrate storm runoff and can transport sediment to nearby channels; and
- Road crossings over channels may be undersized for the conveyance of peak runoff rates and/or may be easily plugged by large debris during storms causing overtopping and/or diversion of channel flows, with resulting channel crossing erosion, and/or gully erosion through diversion of channel flows to another channel or hillslope location; and
- Lack of inspection and maintenance of drainage structures and unstable road fills along old, abandoned roads can also result in soil movement and sediment delivery to streams.

Balance Geo (2015) reviewed and interpreted road-related sediment delivery estimates by Pacific Watershed Associates (PWA, 2003) as reported in (ESA, 2004). PWA conducted an extensive field inventory and aerial photographic analysis of sediment sources in the Pescadero-Butano watershed. They estimated the magnitude of past erosion and sediment delivery and determined what proportion has some association with existing land management practices, including roads. To estimate sediment delivery volumes from chronic surface erosion of roads, ditches, and cutbanks PWA relied on an inventory of road-related sediment delivery for the three San Mateo County Parks in the watershed (PWA, 2003). BalanceGeo provide another estimate of road surface erosion and delivery using SEDMODL2, a GIS-based model that identifies road segments that deliver sediment to streams from road treads and road cuts.

The entire Old Haul Road[24] through the County park complex (5.7 miles) was assessed separately (PWA, 2003) and is discussed below in detail.

[24] The Old Haul Road was built in the 1930s as a major railroad alignment used to transport saw logs to a mill located at Waterman Gap. Martin Trso surveyed the OHR and inspected each road-watercourse crossing. He observed that almost all stream crossings have diversion problems and most were incised significantly.

We did not have access to PWA (2003) or ESA (2004) GIS layers for the road network. BalanceGeo developed a composite road network map using existing road maps and coverages including San Mateo County road map and MidPeninsula Regional Open Space District road map. In some places, BalanceGeo revised the County road coverage to align with the LiDAR topography. The map of channel crossings was developed by overlaying the road coverage with a channel network coverage derived from the 2005 1.5-meter resolution LiDAR topography (Figure 37). BalanceGeo mapped a total of 293 miles of roads in the Pescadero-Butano watershed: 237 miles in the Pescadero Creek sub-watershed and 56 miles in the Butano Creek sub-watershed. 213 miles of these roads are unpaved (174 miles in the Pescadero subwatershed and 39 miles in the Butano subwatershed) and 80 miles are paved (63 miles in the Pescadero subwatershed and 17 miles in the Butano subwatershed). Balance Geo mapped 1,380 road crossings in the Pescadero-Butano watershed (Figure 37). While 1,100 of them (80 percent) are in the Pescadero sub-watershed, 280 (20 percent) are in the Butano sub-watershed. PWA also derived total road lengths for the watershed from an unspecified GIS road layer (ESA, 2004) and mapped 325 miles of unpaved roads and 70 miles of paved roads. As we did not have access to PWA's road layer we cannot confidently state why their road length estimates are significantly higher than that of Balance Geo; however, we hypothesize that this is primarily due to their use of a more detailed map of roads in the three San Mateo County Parks, as well as in other open space lands and parks in the watershed.

Road-Stream Crossing Failures

Erosion due to road-stream crossings and road-related landslides contribute significant amounts of sediment to the channels in the Pescadero-Butano watershed (ESA, 2004). We reviewed and interpreted PWA's road sediment delivery assessment as reported in ESA (2004) and estimated sediment delivery at road-watercourse crossings due to: 1) failed or washed-out stream crossing erosion; 2) gullies along the road and/or ditch; 3) hillslope gullies associated with stream diversions; and 4) road, skid trail, or landing cut or fill failures.

PWA used sequential aerial photographs and conducted field surveys to map erosion features and assigned a land use associated to each feature (ESA, 2004). Methods used by PWA are as follows:

1. Deep-seated and shallow landslides and gullies were mapped and quantitatively assessed on time sequential aerial photographs (1956, 1982, and 2000). Information mapped on aerial photographs was digitized in GIS.
2. A total of forty field plots of 40 acres each were systematically surveyed for erosional features that delivered sediment to a stream channel. Erosional features were transferred to GIS.
3. All erosional features mapped on the aerial photographs or field sample plots were assigned a primary land use association based on evidence that a particular land use activity contributed to the initiation of a feature. Total road-related sediment delivery estimate (whether logging, ranch, driveway, county roads or state highways) included failed or washed-out stream diversions, and road/skid trail/landing cur or fill failures.
4. During field sampling, efforts were made to field verify and measure 5 percent of the air photo-identified features for verification of dimensions, volumes, and attributes. Air photo-identified features encountered within field sample plots were not counted.

PWA study estimated the total amount of road-related sediment delivery from both paved and unpaved roads to channels as 61,500 tons/year (50,379 cubic yards [CY]/year) for the period from 1983 to 2002[25]. Of this amount, 27,500 tons/year (22,500 CY/year) are due to surface lowering. Therefore, the remaining amount is attributed to gullies and landslides at road-stream crossings, which results in an average annual rate of **35,000 tons/year (28,500 CY/year)**. Given that there are 1,380 road crossings in the watershed the annual sediment delivery rate for each crossing is estimated as 25 tons. This rate corresponds to a watershed average road crossing rate of 165 tons/km^2-year. This rate is derived by applying the estimate of sediment delivery to channels from road crossing-related erosion by the watershed area that the roads drain into. This estimate is comparable to Balance Geo estimates at other sites e.g., 146 tons/km^2-year at the Gualala River Preservation Ranch property between 1996 and 2006 and 155 tons/km^2-year at South Fork Eel River watershed between 1981 and 1996 (Balance Geo, 2015).

Based on Balance Geo road maps, which showed that 80 percent of the of roads are in the Pescadero sub-watershed and 20 percent are in the Butano sub-watershed, we conclude that 28,000 and 7,000 tons of road-related sediment is delivered to Pescadero and Butano creeks, respectively.

Road Surface Erosion Estimate

We developed an estimate for road surface erosion by averaging two different estimates by PWA (ESA, 2004) and Balance Geo's estimate using SEDMODL2[26] .

PWA's inventory of road surface erosion and sediment delivery along the 40-mile road network (35 miles of unpaved roads and 5 miles of paved roads) in the San Mateo County Parks included: 1) cutbank erosion delivering sediment to the ditch triggered by dry ravel, rainfall, freeze-thaw processes, cutbank landslides and brushing/grading practices; 2) inboard ditch erosion and sediment transport; 3) mechanical pulverizing and wearing down of the road surface; and 4) erosion of the road surface during wet weather periods. PWA mapped 35 miles of gravel or dirt roads and 5 miles of paved roads in the County parks and found that approximately 45 percent of all the roads were "hydrologically connected" and were delivering sediment to nearby stream channels. To estimate persistent surface erosion, PWA assumed: 1) for unpaved roads: a 25 feet road prism contributing area and 0.4 foot of surface lowering over two decades (surface lowering or denudation rate is the average depth of erosion over the feature referenced); and 2) for paved roads: 10 feet cutbank and inboard ditch contributing area and 0.4 foot of surface lowering over two decades. PWA applied these delivery rates to those road segments that are hydrologically connected to the stream system. PWA derived total road lengths for

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[25] See Table 6-13 on page 6-46 and 6-12 on page 6-44 of ESA (2004). PWA did not specify contributions from paved versus unpaved roads. However, considering paved roads (70 miles) constitute approximately 18 percent of the total road length PWA mapped (395 miles), we infer that 18 percent of the 35,000 tons/year or 6,200 tons/year can be attributed to paved roads.

[26] SEDMODL2 is a GIS-based road surface erosion and delivery model (Boise Cascade and National Council on Air Improvement and Stream Improvement). It identifies road segments with a high potential for delivering sediment to streams based on proximity and estimates relative amounts of sediment delivered to watercourses from road treads and cut slopes.

the entire Pescadero-Butano watershed and reported 325 miles of unpaved roads and 70 miles of paved roads and applied the estimated hydrologic connectivity of 45 percent to both unpaved and paved roads. PWA estimated that the delivery rates for unpaved and paved roads are 148 and 34 CY/mi/year, respectively (Table 8 and ESA, 2004, pp.6-42) and the total annual sediment delivery rate is 27,500 tons or (22,500 CY) from road surface erosion during the period from 1983 to 2002.

Table 8. Road erosion estimates in the Pescadero-Butano watershed

Roads	Length of Roads miles (km)	Length of Hydrologically Connected Roads miles (km)	Sediment Delivery Per Length of Road CY/mi/year (tons/km/year)	Total Road Surface Sediment Delivery[27] CY/year (tons/year)
Unpaved roads	325 (520)	145 (232 km)	148 (113)	21,450 (26,250)
Paved roads	70 (112)	31 (48)	34 (26)	1,050 (1,250)
Total	395 (632)	176 (280)	-	**22,500 (27,500)**

Balance Geo estimated road surface erosion rates on both paved and unpaved roads using SEDMODL2, which incorporated delivering road segments in the following land use areas with differing patterns of traffic: a) agricultural/ranching land use - 96 miles (154 km); b) timber harvesting land use - 47 miles (75 km); c) park or open space land use - 100 miles (162 km); and d) residential – 50 miles (81 km). Balance Geo estimated a rate of sediment delivery from road surface erosion of 4,300 CY/year (5,210 tons/year) for the period from 1970 to 2010. Approximately 40 percent of sediment delivery from road surface erosion is in the sand grain size fraction and the remaining 60 percent the silt and clay size fractions.

There is a notable difference between the PWA (2003) and Balance Geo estimates for road surface erosion. As stated, Balance Geo's road map is less extensive compared to that of PWA, likely resulting in a lower total estimate. On the other hand, ESA relied on an average surface lowering rate that is based primarily on PWA's experience in the Pacific Northwest in a wetter climate, and that was applied everywhere in the watershed (0.4 ft of lowering over two decades). This approach likely overestimated sediment delivery from road surface erosion. We did not have access to the primary source files that these analyses were based on. Therefore, we do not have the necessary information to make a determination on which analysis more accurately represents road surface erosion rates in the watershed and we are not able to provide a range of values that would accurately reflect the margin of error involved in the analyses[28]. A road surface erosion simulation study in the Jackson Demonstration State

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[27] To estimate the total annual road surface erosion based on the values provided in Table 8, we performed the following calculation: [145*148] = 21,460 and [31*34] = 1,054 CY. Total road surface sediment delivery estimates were rounded to the nearest tenth.

[28] ESA (2004) stated that the source analysis provides gross estimates of sediment production at order-of-magnitude accuracy.

Forest in the Caspar Creek Watershed estimated a road surface erosion rate of 27 CY/mi/year and stated that this is within the predicted range of 19 to 94 CY/mi/year as estimated for the same road segment (Ish and Tomberlin, 2007 as quoted in Barrett et al., 2012). Considering the wide range of existing road surface erosion estimates, in general, and the lack of primary source details for the Pescadero-Butano watershed analyses, in particular, we estimated their mean (22,500 CY/year and 4,300 CY/year -rounded to the nearest thousandth) to represent the central tendency. Therefore, an average annual road surface erosion rate of **16,000 tons/year (13,000 CY/year)** was estimated for the period from 1970 to 2010.

Old Haul Road

The Old Haul Road is a timber hauling rail and truck road that was built in the 1930s. Currently, within the San Mateo County Park complex, the Old Haul Road is a major access route providing important recreation, maintenance, and fire access. The road also extends to the timber harvest lands in the southeast of the watershed where it's in frequent use and provides access. The road is approximately 8 miles long, of which 5.7 miles is in the Pescadero Creek County Park. The Old Haul Road runs parallel to Pescadero Creek on the south side and intersects southern tributaries draining the Butano Ridge. It was originally built as a major railroad alignment to transport saw logs to a Santa Cruz Lumber Company mill located at Waterman Gap. In order to keep the railroad alignment on contour and at a relatively even grade, huge log and fill structures were constructed to span major tributaries to Pescadero Creek which cross the alignment. The Old Haul Road blocks 14 major tributaries with cobble-boulder substrate, which is important for aquatic habitat. There are significant amounts of sediment and woody debris upstream of the road. The historic accounts of logging practices upstream of the road revealed that logs were pulled down the creek beds with tractors, and creeks are incised more than 15 feet in places.

The principal concern along the Old Haul Road is the stability of the creek crossings and the risk of failure which would result in enormous amounts of sediment delivered to Pescadero Creek. Both PWA (2003) and Best (2015) assessed the condition of the Old Haul Road along the Pescadero Creek County Park to identify sediment sources, to make recommendations, and to prioritize treatment alternatives.

PWA (2003) inventoried 5.7 miles of the Old Haul Road, identified a total of 45 sites (21 stream crossings, of which 3 are log and fill crossings) with sediment delivery potential, and estimated a potential future sediment delivery of 67,000 tons (55,000 CY) if sites are left untreated. More than 70 percent of this amount is estimated to deliver from two large log and fill crossings (Humboldt crossings) at Dark Gulch and Carriger Creek. PWA estimated that 3.8 miles of the Old Haul Road (67 percent) are hydrologically connected and deliver sediment and runoff to channels. Surface erosion along Old Haul Road was estimated as 13,000 tons (10,500 CY). PWA (2003) also reported that the 1998 El Nino storms caused approximately 21,200 tons (17,350 CY) of erosion and sediment delivery to Pescadero Creek and its tributaries from four sites along the Old Haul Road.

Best (2015) evaluated the erosion potential along 4.2 miles of Old Haul Road and stated that the most significant features along the road are 8 large stream crossings that incorporate crib logs that are in varying states of decay and at risk for failure. These structures can be quite large; the volume of crossing fill at Dark Gulch is measured at over 36,500 tons (30,000 CY) with fill exceeding 65 feet in depth. Best (2015) estimated that the total fill volume at these 8 crossings amounted to 85,000 tons (69,000 CY), with Dark Gulch and Carriger Creek comprising more than 70 percent. Best (2015) estimated an average annual sediment delivery rate of 18,000 tons (15,000 CY) over the next two decades.

2. Channel Incision

We use the term channel incision to refer to the progressive lowering of the streambed over multiple decades-or-longer. often accompanied by rapid rates of bank erosion. Mean annual volume of sediment input to channels from channel incision was calculated as follows:

Average annual volumetric rate of channel incision (since start of incision) =
(Width of incision) * (depth of incision) * (incised channel length) ÷ (years since start of incision)

Balance Geo analyzed documented land use changes, historic ground photographs and paintings and combined these with field evidence to reveal that channel incision was triggered around 1860 on Pescadero Creek and around 1920 on Butano Creek. ESA's (2004) detailed land use history also confirms this timeline. Balance Geo conducted field surveys between the spring and fall of 2010 throughout the mainstem Pescadero and Butano creeks, as well as Pescadero Creek tributaries (

Figure 30). The estimates for channel incision and bank erosion processes are based on field surveys, interpretation of LiDAR topography (yielding volume estimates of "voids" along channels), and all the other historic and existing details about channels.

The extent of incision along Pescadero Creek was identified along three distinct reaches: the wet meadow reach, the alluvial fan reach, and the inner gorge reach (Figure 28). The extent of incision along Butano Creek was identified along two distinct reaches: the wet meadow reach and the alluvial fan reach (Figure 29). The length of each of these reaches was measured from LiDAR created digital elevation models (DEM)[29] (Table 9).

In each of these reaches, there are different primary factors that resulted in incision and habitat simplification. Incision along the canyon reach of Pescadero Creek (which is primarily the evacuation of the Holocene alluvial fill that had accumulated within the channel) has resulted from one or more of the following disturbances: 1) logging of old-growth redwoods (increasing storm runoff); and 2) removal of large woody debris for salvage and to enable transport of logs (lowering local base level and subsequently steepening the slope). In the alluvial fan reaches, channel incision can be attributed to 1) logging; 2) associated agricultural conversion of the valley floor and all the consequent channel modifications; and 3) removal of LWD. In the lower valley along the wet meadow reaches, the following land use practices are the drivers for incision: 1) ditching and draining of the valley floor by connecting naturally disconnected tributaries; 2) relocation of the channels; 3) channel straightening and ditching to reclaim the valley floors for agriculture from 1860s to 1970s; 4) salvage/snagging of LWD in the channels for flood control earlier and fish passage in the 1950s and 1960s[30]; and 5) removal of riparian vegetation

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[29] For a shaded relief map derived from LiDAR DEM of different reaches along Pescadero and Butano creeks, please see the figure on page 50 of BalanceGeo (2015).
[30] High levels of slash in channels that were a result of excessive amounts of logging have historically provided the impetus for "stream cleaning" programs by government resource agencies. These stream cleaning programs often also removed naturally occurring debris jams. The overall effect was not only to reduce levels of LWD in streams

for flood control purposes in the 1880s. For instance, removal of woody debris within the Butano Fall residential tract in the 1930s contributed to significant degradation of Butano Creek in the alluvial fan reach. Along Pescadero Creek, channel ditching in areas of shingle mills and splash dams during the period from 1855 to 1920 steepened channel slopes locally and resulted in the evacuation of sediment from the channel bed and associated channel bed lowering (Figure 17 and Figure 27).

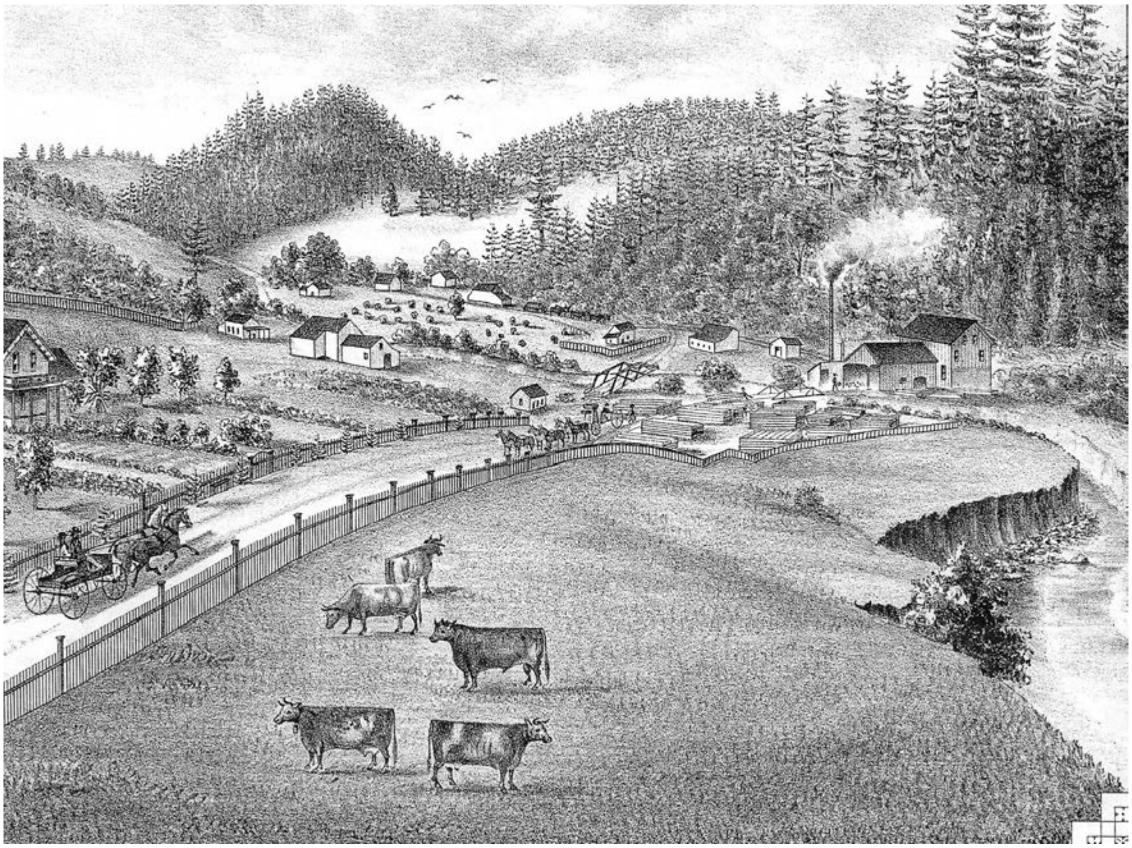


Figure 27. Brown Lithograph (1874) Showing the Hayward Mill Site on Pescadero Creek

An excerpt from the Brown lithograph (1874) showing the Hayward Mill site on Pescadero Creek, at the location of the present-day USGS station. The lithograph reveals a fresh-appearing channel incision downstream of the mill along the alluvial fan reach of Pescadero Creek. The channel appears to have a rectangular shape and dimensions of approximately 10 feet x 10 feet based on dimensions of other features including livestock, fence, bridges, and people. Currently, the channel dimensions are 15 feet x 50 feet suggesting that the channel incised by 5 feet and widened by 40 feet since 1857 when the mill was built.

Width of incision is assumed to equal width of the channel between left and right bank terraces as measured in the channel at the base of the terrace. Channel width was measured in the field by surveying tape or pace along reaches that were accessed. It was also measured in GIS from the 2005-

and to simplify and degrade channels; it also left as a legacy the misperception that debris jams block fish movement. That misperception has recently been challenged and mostly reversed.

2006 high resolution LiDAR generated digital elevation model (DEM).[31] Depth of channel incision was defined based on field observations of differences in height between perched features and current streambed elevation (e.g., perched tributary channels, perched former gravel bars that now terrace benches covered by mature even-age trees, bank stabilization structures and culverts or bridges that have been undercut, etc.). Height differences between the current elevation of the streambed and the perched features was measured with a surveying rod.

No historic trends with incision were noted. Therefore, Balance Geo assumed that average annual volumetric rates of channel incision correspond to that of total volume of sediment evacuated from the channel bed through bed lowering divided by the number of years incision has been active.

Table 9. Estimated width, depth, length, and resulting volume of incision along Pescadero and Butano creeks

Channel Incision along Pescadero Creek over 150 years (1860-2010)					
	Length feet	**Width feet**	**Depth feet**	**Total Incision Volume Ac-ft (Million CY)**	**Annual Incision tons/year[2,3]**
Wet Meadow	13,100	33	16	160 (0.26)	2,100
Alluvial Fan	20,000	50	13	300 (0.48)	3,900
Inner Gorge	26,000	50	10	300 (0.48)	3,900
Sub-Total				745 (1.20)	9,900
Channel Incision along Butano Creek over 90 years (1920-2010)					
Wet Meadow	16,400	65	28	685 (1.11)	15,000
Alluvial Fan	10,000	50	21	241 (0.39)	5,300
Sub-Total				910 (1.50)	20,300
Watershed Total				**1,655**	**30,200**

[1] Values in millions CY rounded to the nearest hundredth
[2] Assuming an average bulk density of 1.22 tons/CY
[3] Values in tons rounded to the nearest hundred

Since 1860, a total of 1.2 million cubic yards of sediment has been eroded from an 11-mile reach along Pescadero Creek channel. This process is still active and corresponds to an annual rate of sediment delivery of 9,900 tons. A total of 1.5 million cubic yards of sediment eroded from a 5-mile reach of Butano Creek, corresponding to an annual rate of sediment delivery of 20,300 tons. Balance Geo did not quantify in-channel gullying or incision along Bradley or Honsinger creeks or along tributaries within the county parks or timberlands. Channel incision has resulted in loss of 1,500 acres of wet meadow valley

[31] 1-meter (3-feet) resolution LiDAR data acquired and processed in 2005 over San Mateo County. Comparisons to on-site check points yielded a vertical accuracy of 0.332 ft RMSE, a 90% confidence interval of 0.651.

floors and abandonment of 500 acres of floodplains due to loss of connectivity between the channels and floodplains during high flows (Figure 4).

Figure 28. Geomorphic Reach Boundaries along Pescadero Creek

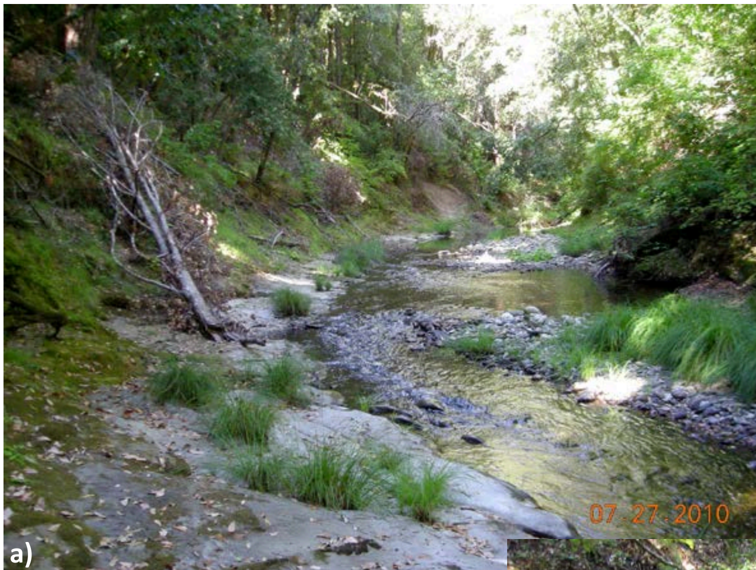
Wet meadow reach extends from approximately Bradley Creek confluence to Butano Cutoff Road. The Alluvial fan reach extends from Butano Cutoff Road to slightly upstream of USGS Station. The inner gorge reach extends from USGS Station to approximately 5 miles upstream.

Figure 29. Geomorphic Reach Boundaries along Butano Creek

Wet meadow reach extends from the upstream end of the willow/alder thicket to Cloverdale Road. Alluvial fan reach extends from Cloverdale Road to Butano Falls.

Figure 30. Documenting Channel Incision along Pescadero and Butano Creeks.

Balance Geo conducted field surveys between the spring and fall of 2010 throughout the mainstem Pescadero and Butano creeks, as well as several of the Pescadero Creek tributaries. Channel features were observed, measured, and interpreted to estimate channel incision depth, width, and age. The field-based estimates for channel incision and bank erosion processes were supplemented with interpretation of LiDAR topography (yielding volume estimates of "voids" along channels), historic maps and existing studies to develop an estimate for the total volume of sediment evacuated from Pescadero Creek since 1860 and from Butano Creek since 1920.



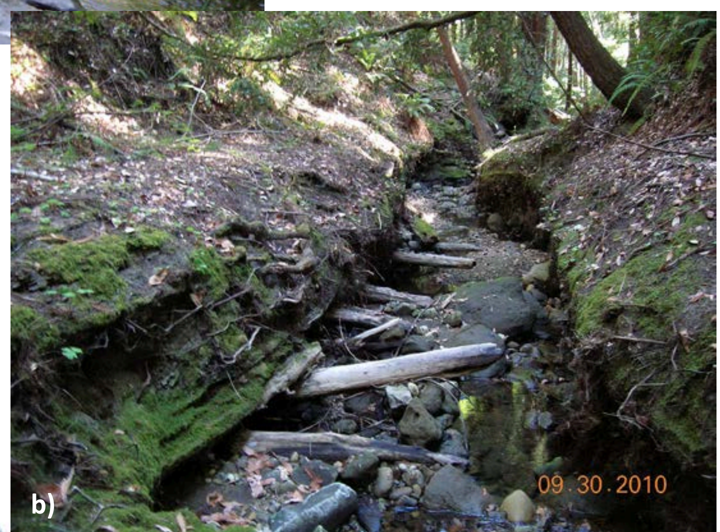


Figure 31. Channel Incision and Bank Erosion along Pescadero and Butano Creeks (photo courtesy of Balance Geo)

a) Channel incision and related active terrace bank instability along the canyon reach of Pescadero Creek; b) Incised tributary channel in the canyon reach of Pescadero Creek; note skid rows in the channel which are a legacy of in-channel log skidding during the timber harvest activities in the late 1800s; and c) channel incision and related active terrace bank instability (and fine sediment supply) in the wet meadow reach of Butano Creek.

3. Gully Erosion

Based on our analysis of aerial photography, high-resolution topography, and field visits, we determine that hillside gullying is one of the most significant processes delivering large amounts of sediment to the channels in the Pescadero-Butano watershed. Recent studies have shown that gully erosion may constitute a large proportion of the total sediment yield. NRCS (1997 as quoted in Poesen et al. 2003) found that ephemeral gully erosion accounted for 35 percent of the total erosion in seventeen states in the USA. Gullies are associated with land management and are typically formed during high intensity storm events at sites where land use activities have intensified peak rates of storm runoff (e.g., grazing, roads, and hillside agriculture). Based on 1800s ground photographs, paintings and sketches, and present-day field evidence, Balance Geo estimated that the process of gullying was triggered around 1860 in the areas that naturally supported scrub/chaparral vegetative cover (Figure 14 and 32).

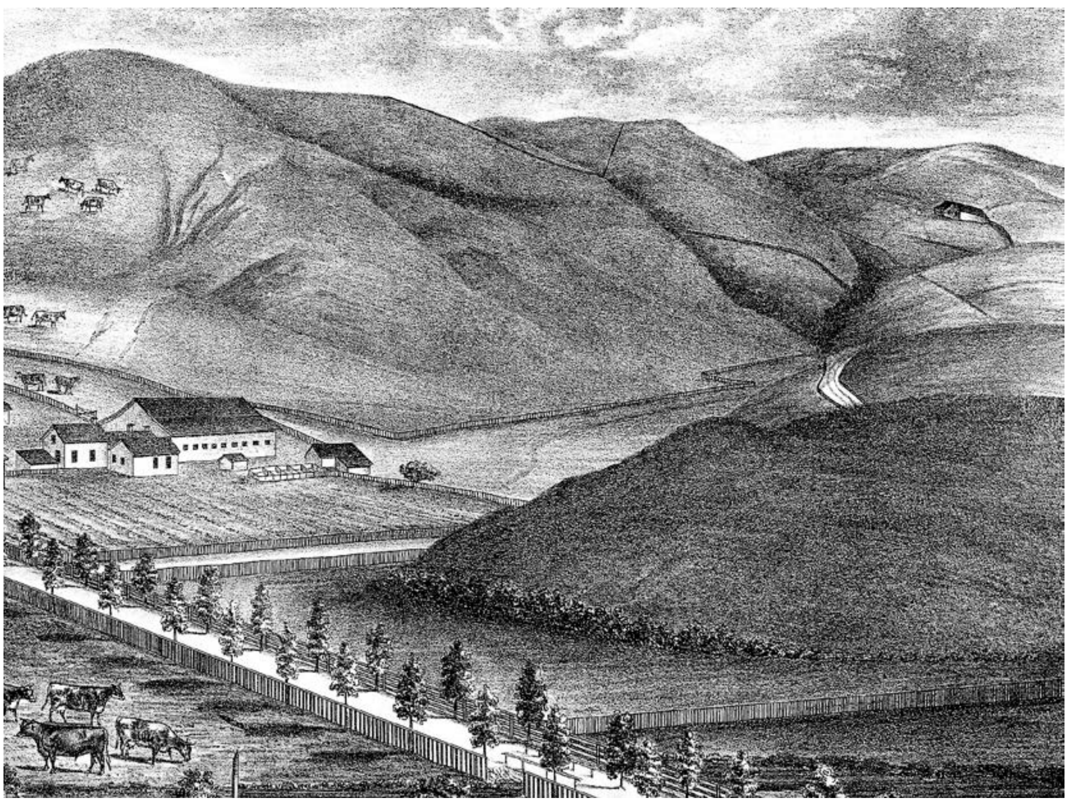


Figure 32. Gullies on the Hills of Bradley Creek Watershed circa 1874.

An excerpt from the Brown Lithograph (1874) of Moore Ranch in Bradley Creek watershed. The lithographs reveal localized and recently-formed gullies where grazing occurs.

Gullies are indicative of accelerated erosion and landscape instability brought about by an increase in the amount of flood runoff. Gully development typically coincides with periods of land clearing, often in combination with intense rains, resulting in a change of watershed hydrology in response to changing environmental conditions (Poesen et al., 2003). Swanson et al. (1989) examined monthly and daily rainfall records for the Pescadero area (1955 to late 1980s) and for the larger San Francisco Bay area (1875 to late 1980s) to inspect for any long-term changes in precipitation that could have influenced gully development in the area and concluded that there were no long-term changes in total precipitation, seasonal distribution, or daily intensity that might explain the proliferation of gullies. Swanson et al. (1989) also found that subsurface erosion was far more significant for the gullies on the San Mateo coast than headcut migration in the initiation and extension of gully channels. Their study concluded that intensity of the gullying strongly correlated with bedrock lithology and associated soils, especially within the Tahana member of the Purisima Formation. Tahana member is a sandstone/ siltstone rich in volcanic lithic fragments that produce soils with relatively permeable A horizons underlain by impermeable B horizons. Large desiccation cracks develop annually. The volcanic lithic fragments found in the Tahana weather to produce expansive smectite clays, which are rendered dispersive in the presence of sodium (Swanson et al., 1989). The ocean provides a ready source of sodium. As a result, soils developed on the Tahana member are highly vulnerable to subsurface erosion by a high concentration of throughflow in the dispersive soils of the A horizon above the impermeable claypan of B horizon. Swanson et al. (1989) stated that the presence of smectite clay soils with high exchangeable sodium, annual soil cracking, sharp contrasts in permeability of soil horizons, and intensive land use, are conditions found to be conducive to soil piping as reported by other authors. Similar to Swason et. al. (1989), Johnson and Finnegan (2015) based on their analysis of the erodibility of Tahana member, suggested that soils derived from the Tahana member –especially when vegetation is present, are more resistant to erosion than the underlying rocks. This again implies that once initiated, gully erosion likely accelerates once it encounters Tahana member bedrock, which is the opposite of the way gullying is conceptualized. Tahana member of the Purisima formation occupies approximately a quarter of the watershed underlying the western rangelands, as well as the north of Pescadero Creek along the County park complex.

Our analysis focused primarily on the gullies on the rangelands and agricultural lands. We assumed that gullies in the forested areas did not contribute significant amounts of sediment based on the ESA (2004) sediment study that conducted field surveys on both rangelands and forested lands and analyzed sequential aerial photographs to conclude that gullies were most heavily concentrated on western rangelands.

Hillside gully erosion rates were estimated by a combination of field surveys and analysis of aerial photographs and LiDAR topography as follows:

1. Location, length, and surface area of gullies were digitally mapped using aerial photographs and LiDAR topography;

2. Where access was granted, field surveys were conducted to confirm mapping analysis findings on the ground and to quantify average gully depths;

3. Average top widths and depths of selected gully cross sections were measured from the LiDAR data and a subset of them confirmed in the field; and

4. Aerial and ground photographs for the period 1860 to 2010 were analyzed in detail to detect trends in gully erosion over time.

We measured the depth and top width of 30 gully cross sections and derived median top width and depth values as 30 feet and 15 feet, respectively. The volume of hillside gully erosion was obtained by multiplying the measured length of gully channels with the median depth and top width estimates.

It is estimated that since 1860, approximately 3 million tons of gully erosion has occurred in the areas subject to agricultural land uses and grazing. The total surface area subject to gully erosion was estimated as 7,400 acres (30 km^2). The total gully erosion estimate is comparable to the results of the PWA (2004) study, which estimated a total gully erosion of 2.8 million tons[32].

Of the 3 million tons of sediment, it is estimated that approximately a quarter or 750,000 tons of sediment have been deposited at fans at the base of the hillside gullies. Accordingly, the remaining three quarters or 2.25 million tons have been delivered to streams and the marsh-lagoon complex. Therefore, the amount of sediment derived from gully erosion and delivered to channels for the last 150 years is approximately 15,000 tons/year or 580 tons/km^2-year. Accordingly, the amount of sediment stored in hillside gully fans is 5,000 tons/year or 190 tons/km^2-year.

This total volume of sediment was generated due to gully erosion that spanned a period of 150 years and so the average annual estimate of 15,000 tons/year assumes that gully erosion rates have stayed constant over time. However, there are several studies that considered the trends in gully erosion over time in this region. For instance, Swanson (1983) studied relative gully erosion rates in different periods in the nearby Aptos Creek watershed. Although sediment rates were not quantified, it was reported that in the period from 1930 to 1980 hillside gully erosion increased significantly by approximately 300 percent. The same finding is also reported in Swanson et al. (1989) for several gullies in the Pescadero and neighboring Pomponio watersheds. Our analysis substantiates this observation. Indeed, a review of ground photographs from 1890, 1940, and 2005, as well as aerial photography from 1943, 1960 and 2000, indicates the following relative gross changes in gully erosion rates as compared to the period 1860 to 1920: 100 percent increase in the period 1920 to 1970 and 200 percent increase in the period 1970 to 2010. Therefore, keeping the period 1860-2010 erosion volumes the same and considering the observed trends in hillside gully erosion as stated above, we derived “trend correction factors” (Table 10). Applying these factors to the average annual rate in the last 150 years, we estimate that average annual sediment delivered to the channels due to gully erosion in the last 40 years is approximately **24,150 tons/year.**

[32] The PWA (2003) study attributed the estimated gully erosion volume to the 1937-2002 period and estimated that, of their total, 1,984,420 tons of sediment were delivered and 781,190 tons deposited on hillside fans, resulting in a 72 percent delivery ratio. See Table 6-11 on page 6-37 for HGU No.7.

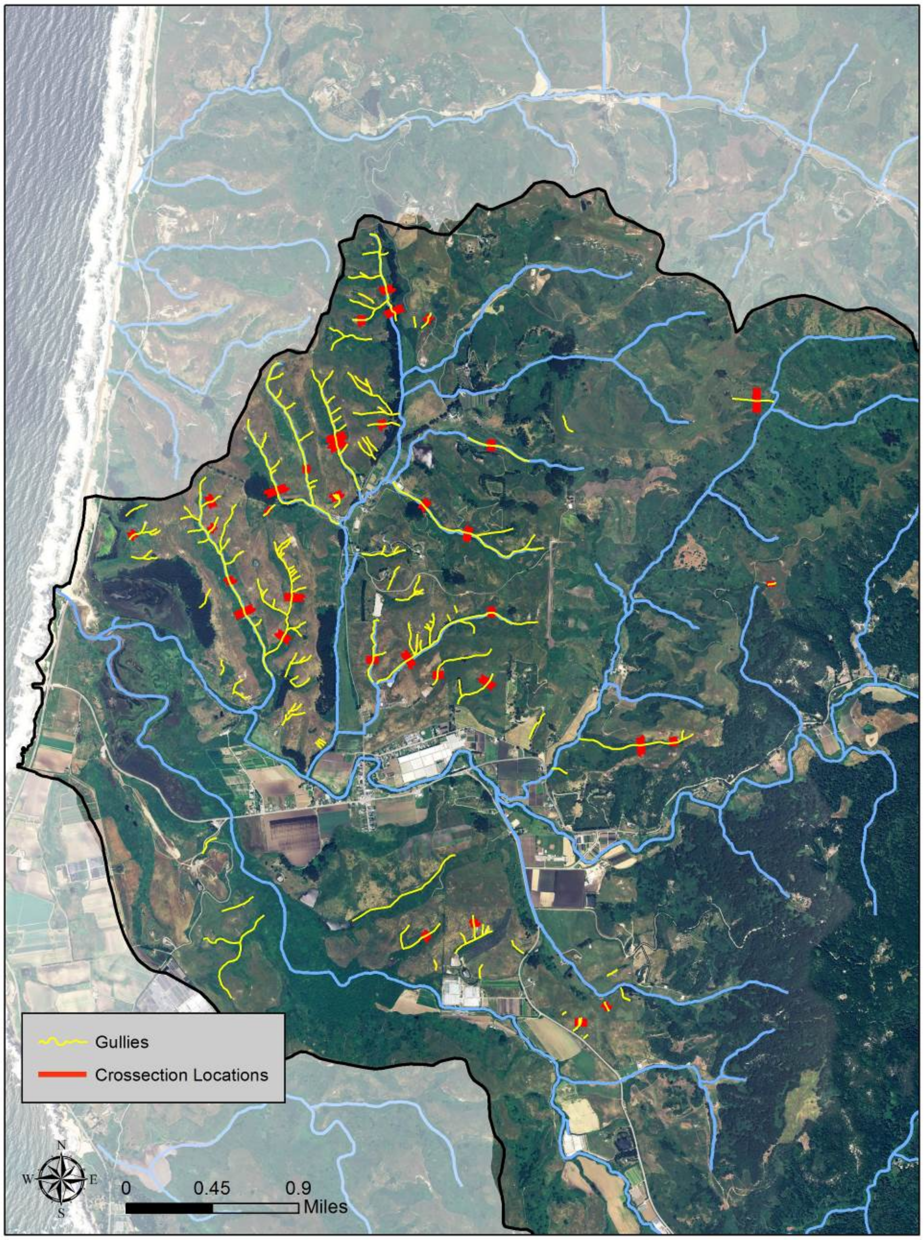


Figure 33. Mapped Gullies in the Lower Pescadero-Butano Watershed.

Mapped gullies that were delineated using LiDAR-derived topography and were cross-checked using recent aerial photographs. Figure 30 also shows the location of cross sections which were randomly selected. Length, width, and depth of these cross sections were derived from the LiDAR topography and were averaged to develop representative dimensions for gullies.

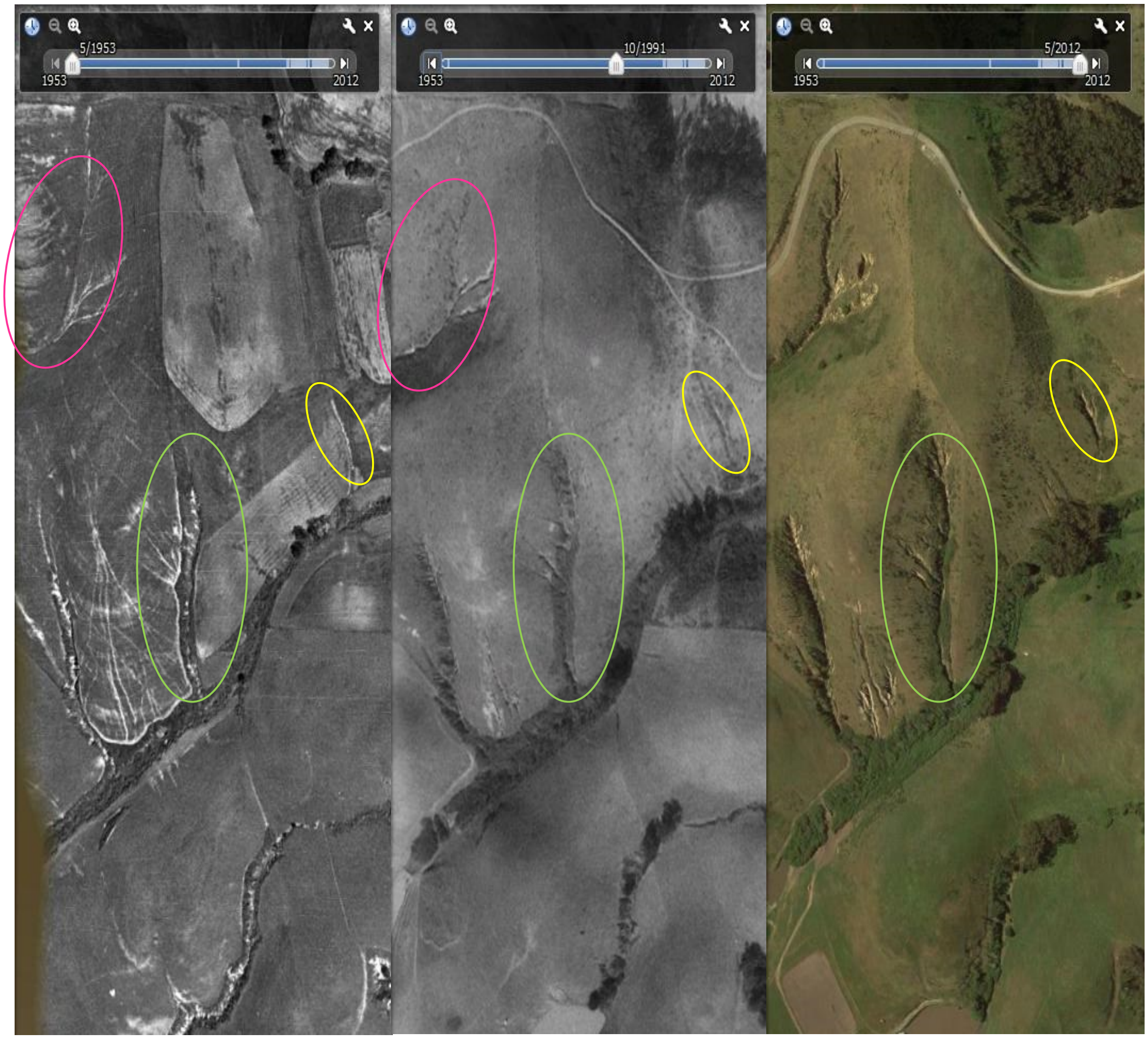


Figure 34. Growth of Gullies in Bradley Creek Watershed Over 60 years (photo courtesy of Google Earth) Aerial photographs of gullies from May 1953, October 1991, and May 2012 in a section of Bradley Creek. May 1953 photograph shows significant surficial activity with shallow gully channels. By October 1991, four decades later, gully channels are more pronounced. Two decades later, in May 2012, both main gully channels and their tributaries are wider and deeper. There has been an increase in gully network and gully drainage density. Gully erosion in this area has accelerated since the 1950s.

The post-1970 rate of sediment delivery from gully erosion corresponds to a unit area rate of 930 tons/km^2-year. This process is active under the present conditions, delivering fine-grained sediment over long distances (hundreds of meters).

Table 10. Gully development over time

Period	Gross Changes in Gully Erosion	Trend Correction Factor	Sediment Delivery (tons/year)
1860-1920	Initial condition of X	0.54	8,100
1920-1970	2X	1.07	16,050
1970-2010	3X	1.61	24,150

To estimate the relative gully erosion amounts in Pescadero and Butano sub-watershed, we applied the ratio derived from the length of gully channels in each sub-watershed. 87 percent of the channels are in the Pescadero sub-watershed and 13 percent are in the Butano sub-watershed. Therefore, the amount of sediment from gully erosion in Pescadero and Butano sub-watersheds were estimated as 21,000 and 3,150 tons/year, respectively.

4. Timber Harvest Related Landslides and Debris Flows

We used ESA (2004) analysis to estimate the volume of sediment delivered to streams from shallow landslides and debris flows associated with timber-harvest activities.

ESA[33] analyzed three sets of aerial photographs for the whole watershed: 1956 (1:24,000), 1982 (1:12,000), and 2000 (1:24,000) and documented large erosion and landslide features. In addition to aerial photography analysis, ESA also surveyed erosional features that delivered sediment to channels on forty randomly-selected field plots then statistically extrapolated field results to the whole watershed. Both of these sediment source components quantified shallow debris slides or landslides, debris torrent tracks, active, deep-seated landslides, and gullies. ESA then assigned a land use association to all the features identified from aerial photography analysis or field surveys. Land use activities they associated with timber harvest include tractor or cable clear-cutting, tractor or cable partial harvest, and skid trails. We derived our estimates of recent sediment delivery due to landslides and debris flows in timber harvest areas based on their estimates of sediment delivery to channels due to timber harvest activities for the period from 1983 to 2002[34], which is 23,000 tons/year (19,000 CY/year) (assuming a bulk density of 1.22 ton/CY). This rate is comparable to their estimate of shallow landslides of 22,500 CY/year between 1957 and 1982, which is also based on aerial photography analysis augmented by random field surveys.

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[33] Refer to ESA (2004) pages 6-14 through 6-19 for a detailed discussion on their aerial photography analysis, assumptions, and limitations; and pages 6-22 through 6-27 for results.

[34] Sediment delivery rates for 1983-2002 is 18,683 CY/year as presented in ESA (2004) Table 6-13 on page 6-46 and assumed a bulk density of 1.22 ton/CY.

Figure 35. Prolific Gullies Formed in Grazing Lands Underlain by the Tahana Member of the Purisima Formation.

Tahana member is a sandstone/siltstone rich in volcanic lithic fragments that produce soils with relatively permeable top soils underlain by impermeable layers. The volcanic lithic fragments found in the Tahana weather to produce expansive smectite clays, which are rendered dispersive in the presence of sodium, which is readily provided by the ocean. Soils developed on the Tahana member are highly vulnerable to subsurface erosion by piping. Tahana member of the Purisima formation occupies approximately a quarter of the watershed underlying the western rangelands, as well as the north of Pescadero Creek along the County park complex.

ESA stated several caveats related to the aerial photography analysis:

- The small scale of the 1956 and 2000 set made it more difficult to identify some erosional features confidently, especially smaller features such as small debris slides and gullies. As a result, the number of erosional features identified on the 1956 and 2000 photos may be underestimated.
- The 1982 aerial photo set was flown during the winter and was underexposed resulting in dark photos with deep shadows. Even though the scale was appropriate for feature identification, the photography was difficult to map upon.
- There was a 26-year time period between the 1956 and 1982 photo sets. Erosional features or road construction could have been obscured by vegetation within the long time period in between the sets.

Therefore, ESA noted that the aerial photography analysis may have slightly underestimated sediment delivery rates. However, ESA also noted that 90 percent of the total sediment delivery that was associated with timber harvesting practices e.g., clearcutting and tractor yarding are no longer in widespread use in the watershed. Therefore, shallow landslides that are directly related to timber harvest practices (and not roads) are likely to decrease in the future. Considering the negating effects of these uncertainties, we believe the ESA's shallow landsliding delivery estimate of **23,000 tons/year (19,000 CY/year)** is accurate.

5. Hillside Surface Erosion

Surface erosion from sheetwash and rilling appears to be an important active process for sediment delivery to channels in the Pescadero-Butano watershed. Intensive grazing has the potential to reduce ground cover vegetation density, change vegetation structure and species assemblage, and compact soils, causing infiltration capacity and permeability to be reduced. These effects of grazing, in turn, may greatly increase overland flow runoff during storms, leading to significant increases in the rates of surface erosion. In addition, certain agricultural practices and the amount of vegetative cover on the croplands may significantly increase the volume of sediment that enters the creeks. Surface erosion from woodland areas was excluded because sheetwash erosion is only possible where overland flow occurs, and it generally does not occur in heavily vegetated and canopied areas.

The estimate of hillside surface erosion within the rangelands and agricultural lands is based on Universal Soil Loss Equation (USLE). The USLE is an empirical model that estimates average annual soil loss caused by sheet and rill erosion from hillslopes. In relatively large watersheds, most sediment gets deposited within the watershed and only a fraction of the soil that is eroded from hillslopes reaches the stream system or watershed outlet. This fraction or portion of sediment that is available for delivery is referred to as the Sediment Delivery Ratio. This ratio can be multiplied by the predicted erosion rate to estimate the percent of eroded material that will reach the watershed outlet.

The equation representing soil loss averaged over time and total area and has the following form (Wischmeier and Smith 1978):

$$E = R * K * L * S * C * P$$

where:

E [ton/(acre.year)] = average annual soil loss

R [MJ.mm/ha.hr.year] = rainfall erosivity factor

K [tons.acre.hr/hundreds.acre.ft.tonsf.in] = soil erosion factor

LS [dimensionless] = topographic (length-slope) factor

C [dimensionless] = cover factor

P [dimensionless] = erosion control practice factor

The rainfall erosivity factor is a measure of how raindrop impact and total storm energy contribute to soil erosion. The value for R was estimated as 150 based on the Isoerodent map of California from Renard et al. (1997) and was confirmed by the NRCS soil scientist for the San Mateo area (K. Oster, pers.comm, May 10, 2013).

Soil erosiveness, K, was estimated as 0.24 based on a weighted average, where typical K values for soils derived from each sediment supply terrain unit are multiplied by percentage of the watershed area in each terrain unit and was confirmed both by the NRCS soil scientist for the San Mateo area (K. Oster, pers.comm, May 10, 2013) and by the state wide RUSLE soil erodibility map values[35]. Per our request, the NRCS office for the San Mateo Area generously offered to run the RUSLE 2 model for Bradley and Honsinger subwatersheds and provided us with the values used, further confirming the choice of the USLE factors in our analysis. All calculated LS values are taken from Table 4.1 (Renard et al., 1997).

For the LS factor, we subdivided all agricultural and rangelands into three slope categories: <5 percent; 5 percent to 30 percent, and >30 percent. For the <5% slope category, we used an average value of 5 percent as the value to input to the model. For the 5 percent to 30 percent category, we used an average slope of 20 percent to input to the model. For the >30 percent category, we used an average slope of 35 percent to input to the model. Based on field observations during watershed reconnaissance and per our discussions with the NRCS soil scientist for the area, we estimated an average slope length of 200 feet for rangelands and agricultural lands.

We analyzed Department of Conservation Farmland Mapping and Monitoring Program (FMMP) farmland and grazing land acreage data for San Mateo County for the year 1984 to represent the sediment budget period. We overlaid, in GIS, all these areas where surface erosion is active with the

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[35] This value was also confirmed by the state-wide K-factor map analysis summarized at: http://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/constpermits/guidance/k_factor_map.pdf

slope map and calculated the total surface area for each slope category (Table 2). The total area where surface erosion is active in the Pescadero-Butano watershed was estimated as 7,610 acres located primarily in the western watershed, with a minor acreage in the northeastern watershed (Figure 5).

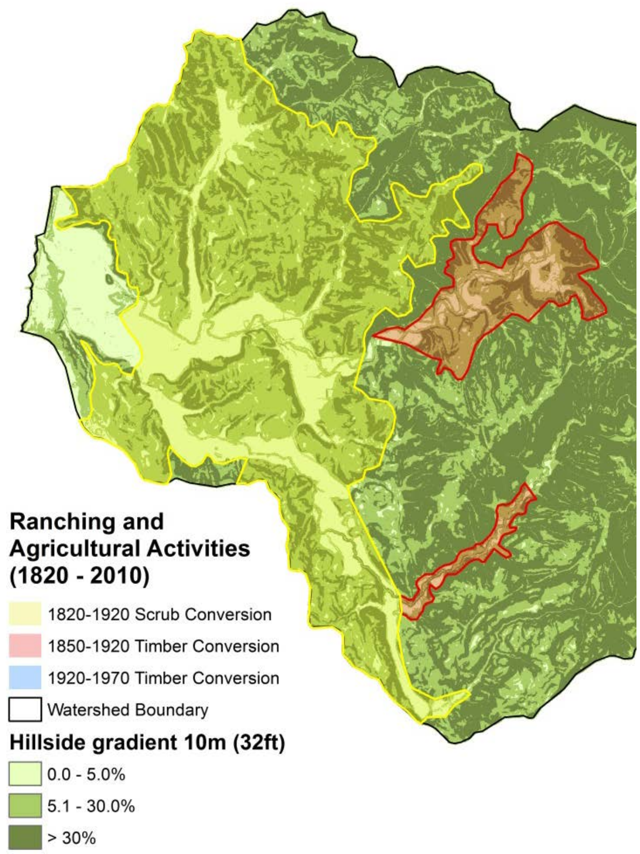

Figure 36. Agricultural Lands and Rangelands where USLE Was Applied

The P-factor is the erosion control or support practice factor. It reflects the effects of practices (e.g., cross-slope cultivation, contour farming and strip cropping) that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. It represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The practice factor P is set equal to 1.0 as a conservative approach.

Table 11. Estimated Area of Surface Erosion where USLE Was Applied

Land Use Classification	Slopes <5%	Slopes 5% - 30%	Slopes >30%	Total USLE-applied Area (ac)
Farmlands	Not included because total farmland acreage is small and sediment delivery from surface erosion is negligible			
Grazing Lands	315	5,149	2,146	7,610
Total	**315**	**5,149**	**2,146**	**7,610**

The C-factor represents the effect of land use on soil erosion and incorporates surface cover and roughness. By definition, C is equal to 1 under standard fallow conditions. As surface cover is added to the soil, the C-factor value approaches zero. Modeled rates of surface erosion are quite sensitive to the values selected for the cover parameter, which accounts for the influence of vegetation cover in resisting erosion. For this analysis, we applied one representative cover factor to all the delineated areas where soil erosion is active. In calculating the C-factor, we initially used the C-factor values developed by Wischmeier and Smith (1978, p.32): we assumed no appreciable canopy, with 80 percent ground cover of grass or grass like plants. This corresponds to a C-factor of 0.013. This value was confirmed by the Natural Resource Conservation Service (NRCS) soil scientist for the San Mateo area (K. Oster, pers.comm, May 10, 2013). In addition, the C-factor values developed for recent research to characterize erosion potential for approximately 14,000 acres of rangelands (that will be submitted soon for publication) for three different grazing scenarios (heavily-, moderately-, and lightly-grazed) corroborate the C-factor of 0.013 used in our analysis (personal communication Lewis, D.J., 2016). This study estimated cover factors to range between 0.006 and 0.013 with an average of 0.009 for moderately-grazed areas. Per our field observations and discussions with the area soil scientist, grazing areas in the Pescadero-Butano watershed can overall be characterized as moderately grazed (although there are parcels that could be characterized as heavily grazed and several that are lightly grazed, rangelands in the watershed are considered moderately-grazed).

This estimate excludes sediment delivery from hillside gullying, which has been taking place in the same geographical areas since about 1860. No hillside surface erosion has been assumed to occur in the forested timbering-activities areas or in agricultural lands on slopes less than 5 percent.

The USLE estimates the total amount of soil erosion. The fraction or portion of sediment that is available for delivery is referred to as the sediment delivery ratio. No characteristic relationship is known to exist between erosion on the hillslopes and sediment delivery to channels. Many factors including the sediment source, proximity to sources, transport system, texture of eroded material, and watershed characteristics, influence the sediment delivery ratio and the relationship between erosion and sediment delivery varies considerably from watershed to watershed. We estimated a sediment delivery ratio of 30 percent based on previous studies in similar drainage areas, texture, and transport systems as reported in USDA (1983, Chapter 6). USDA (1983) reported that data obtained from six different studies all around the country showed that sediment delivery ratios vary inversely as the 0.2 power of the size of the drainage area. A graphic synthesizing previous studies as reported in USDA (1983, Figure

6-2) shows that for drainage areas ranging between 1 and 10 mi^2 the average sediment delivery ratios vary largely between 20 and 40 percent. In addition, USDA (1983) also reported results of a source-texture analysis in a watershed where, similar to Pescadero-Butano watershed, sediment sources are sheet erosion, gullies, roadbanks, ditches, and bank erosion and sediment consists largely of sands, silts, and clays. This analysis resulted in a delivery ratio of 33 percent for sheet erosion (USDA, 1983, Table 6-2). We averaged these two approaches and estimated a sediment delivery ratio of 30 percent for the Pescadero-Butano watershed. The remaining 70 percent is likely stored on hillsides or within the flatter areas.

The USLE derived surface erosion for the period 1970 to 2010 is thus estimated as **4,500 tons/year (3,680 CY/year)**. The area where surface erosion is active is approximately 7,610 acres (31 km^2); therefore, the annual sediment delivery rate from surface erosion is estimated as of 145 tons/km^2 for grazing lands.

Figure 37. Observed Surface Erosion in Rangelands in Pescadero-Butano Watershed.

Excessive grazing removes vegetation and has the potential to compact soil and weaken or destroy aggregates if grazed excessively when soils are wet, all of which increase runoff and erosion. On the other hand, well-managed grazing has the potential to stimulate root growth, which promotes soil organic matter accumulation and resilience to erosion. Rangelands support numerous and diverse plant and animal species, as well as ecosystem services e.g., water capture and storage. In addition, rangeland soils can make a major contribution in the capture and storage of carbon. If residual dry matter (RDM) is properly measured and targets as specified in the UC, 2002, California Guidelines for Residual Dry Matter Management on Coastal and Foothill Annual Rangelands (Rangeland Monitoring Series Publication 8092) are met, a high degree of protection from soil erosion and nutrient losses can be expected. This study showed that maximum productivity within the 15-to-40-inch annual precipitation zone e.g., Pescadero-Butano watershed, occurred with 750 pounds per acre of EDM in the fall.

6. Summary of Sediment Delivery to Pescadero and Butano Channels

As detailed in the preceding sections, Table 12 summarizes our best estimates of sediment loads to Pescadero and Butano creeks.

Table 12. Average annual sediment delivery to channels in the Pescadero-Butano watershed by erosion processes (under natural background and current conditions)

	Pre-1820 (tons/year)*	1970-2010 (tons/year)*	1970-2010 (tons/km^2-year)	% of Total Human-Caused Sediment
Natural Sediment Sources	120,000	120,000	570[1]	N/A
Anthropogenic Sediment Sources				
a. Landslides and gullies at road crossings		35,000	170	26
b. Channel incision		30,000	145	23
c. Gullying on rangelands		24,000	800[2]	18
d. Landslides and debris flows in timber harvest lands		23,000	250[3]	17
e. Road surface erosion		16,000	80	12
f. Surface erosion on rangelands		4,500	145[4]	4
Total Delivery due to Anthropogenic Erosion		133,000	635	100
Total Delivery	**120,000**	**252,500**	**1,200**	

*Above estimates are rounded to the nearest thousandth.

Notes: 1) Pescadero-Butano watershed area is 210 km^2 (81mi^2); 2) Area subject to gullying is 30 km^2 (11.5 mi^2); 3) Shallow landslides in timber harvest lands are primarily legacy sources prior to 1970 and took place in an area of 90 km^2 (35 mi^2); and 4) Surface erosion applies to 24 km^2 of grazing lands, of which 75% is in the Pescadero subwatershed.

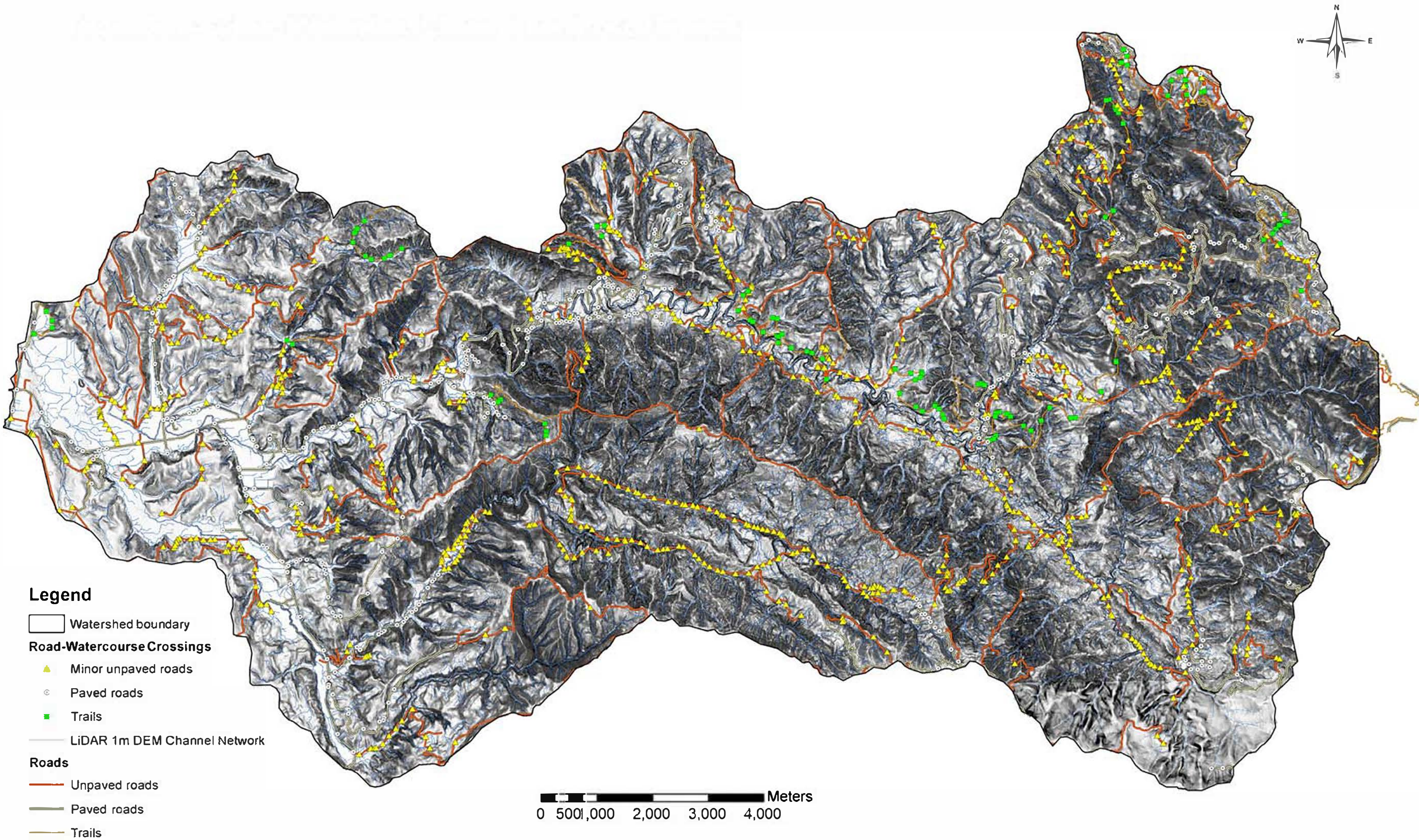

Figure 38 - Pescadero-Butano Watershed Road Network

In the entire Pescadero-Butano watershed a total of 252,500 tons of sediment is delivered to channels on an average annual basis. Approximately 45 percent of this volume is due to natural erosion processes. The remaining 132,500 tons/year is human-caused and due to land use activities. For the entire watershed, this translates into an average annual sediment discharge per unit watershed area of approximately **1,200 tons/km²-year** since 1970 (1.6 ac-ft/mi²-year or 2,550 cy/mi²-year).

Table 13 summarizes sediment input rates to Pescadero and Butano creeks separately.

Table 13. Average Annual Sediment Delivery to Pescadero and Butano Creeks

	Pescadero Subwatershed[1] (tons/year)	**Butano Subwatershed[1] (tons/year)**
Natural Sediment Sources	85,000	35,000
Anthropogenic Sediment Sources		
a. Road crossings[2]	25,000	10,000
b. Channel incision[3]	10,000	20,000
c. Gullying on rangelands[4]	17,000	7,000
d. Landslides and debris flows due to timber harvest[5]	16,000	7,000
e. Road surface erosion[6]	13,000	3,000
f. Surface erosion[7]	3,250	1,250
Total Delivery due to Anthropogenic Erosion	84,250	48,250
Total Delivery	**169,250**	**83,250**

Notes: 1) Pescadero and Butano subwatershed areas are 150 km² (58 mi²) and 60 km² (23 mi²), respectively. Or 70% and 30% of the total area; 2) 35,000 tons/year partitioned proportional to subwatershed areas; 3) As measured in the field along Pescadero and Butano channels; 4)Distributed based on subwatershed area i.e. 70% in Pescadero and 30% in Butano subwatersheds; 5) Area subject to gullying is 21 km² (8 mi²) or 70% of the total in Pescadero and 9 km² (3.5 mi²) in Butano subwatershed; 6) Based on our GIS analysis of roads, 80% of the total road length is in Pescadero and 20% is in Butano subwatershed; and 7) Surface erosion applies to 24 km² of rangelands, of which 75% is in the Pescadero subwatershed.

A strong line of evidence for sediment yield rates can be established where reservoir surveys are available. Pomponio Reservoir, which is immediately north of the watershed was surveyed in 1958 after being built in 1952 (Ferral, 1959). The reservoir is a 260 acre-feet (105 ha) capacity, irrigation water storage reservoir along Pomponio Creek. Despite the short period between surveys, the results, which reflect six seasons of water and sediment collection, are significant because the time period incorporates two large floods: December 1955 and April 1958. The watershed area draining to the reservoir is 362 acres (150 ha). Pomponio Reservoir is large in relation to its watershed (storage capacity 70 percent of watershed area) and has a high trap efficiency. A Google Earth aerial image of the reservoir from 1953 reveals that the watershed was cleared of vegetation, had perennial range grasses and had been grazed. The primary processes delivering sediment appear to be sheet and rill erosion and gullies. Its watershed appears to have been subject to the similar intense land uses as Bradley Creek and other drainages in the coastal grasslands. The survey revealed a sediment accumulation rate of 2.4 ac-ft/mi^2-year, which is equivalent to 1,830 tons/km^2-year (using a bulk density of 1.6 tons/m^3). This is a conservative estimate and provides an upper limit for sediment delivery due to surface and gully erosion as it incorporates the impacts of recent land use practices and two big floods, which have significant impacts on sediment delivery. Our USLE model applied to the coastal grasslands in the Pescadero-Butano watershed estimated a sheet and hill erosion rate of 200 tons/km^2-year assuming 30 percent delivery. Based on the aerial photography of the reservoir in 1953 and the observed denuded conditions of the Pomponio Reservoir watershed we would double the C-factor to estimate surface erosion (Salls, 2016). In addition, in a very small watershed area, e.g., that of the Pomponio Reservoir, with high trap efficiency, the sediment delivery ratio would be closer to 50 percent (USDA, 1983, Figure 6-2). Therefore, our assumptions and approach would result in an estimated delivery of approximately 700 tons/km^2-year for conditions similar to that in the Pomponio Reservoir watershed in 1950s. Our gully erosion estimate for the same area where gullies are prominent is 800 tons/km^2-year. Therefore, our analysis would result in sediment delivery rate from surface erosion and gully erosion of 1,500 tons/km^2-year. We find that our USLE and gully erosion estimate totals are therefore comparable to the measured reservoir sedimentation rate of 1,830 tons/km^2-year.

Figure 39. Pomponio Reservoir and Its Watershed in 1953 (Photo courtesy of Google Earth)

The reservoir capacity is 260 acre-feet and the watershed area draining to the reservoir is 362 acres: Pomponio Reservoir is large in relation to its watershed and has high trap efficiency. The aerial image of the reservoir from 1953 reveals that the watershed was cleared of vegetation, had perennial range grasses and had been grazed. The reservoir was built in 1952 and surveyed in 1958. Despite the short period between surveys, the results are significant because the period incorporates two large floods: December 1955 and April 1958. The reservoir surveys revealed a sediment accumulation rate of 2.4 ac-ft/mi^2-year, which is equivalent to 1,830 tons/km^2-year.

The total sediment delivery rate estimated as 1,200 tons/km^2-year since 1970 (1.6 ac-ft/mi^2-year or 2,550 cy/mi^2-year) is comparable to Curry (1985) study findings: 240,000 tons/year[36], corresponding to 1,125 tons/km^2-year on a unit watershed area basis (1.5 ac-ft/mi^2/year or 2,400 cy/mi^2/year). However, he attributed most of the sediment to channel incision, especially along Butano Creek, and of the total only 80,000 tons/year (380 tons/km^2-year or 0.5 ac-ft/mi^2/year) to long-term average annual yield from upland areas of the watershed. His estimate of sediment delivery due to Butano Creek incision is a total of 3.4 million tons and due to Pescadero Creek is a total of 1.3 million tons. He estimated that 30% of

[36] He estimated that of the total yield 60 percent is generated in Butano subwatershed and 40 percent is generated in Pescadero subwatershed. When unit area delivery is considered, Butano generates four times more sediment than Pescadero subwatershed: 2,400 tons/km^2-year (3.1 ac-ft/mi^2-year) versus 700 tons/km^2-year (0.9 ac-ft/mi^2-year).

the material was silt-clay size and did not deposit in the marsh. He assumed that the incision had happened since 1955 resulting in an annual deposition in the marsh-lagoon complex of 93,500 tons/year and 60,000 tons/year (2.1 ac-ft/mi^2-year and 0.5 ac-ft/mi^2-year) due to Butano and Pescadero incision, respectively. Although, Curry's total sediment delivery estimate is remarkably comparable to our analysis and we support his finding of total volume of sediment, we disagree on his timeline. Based on field work and sequential map analysis, we believe that the incision and erosion processes he accounted for had already started happening in the late 1800s.

The ESA (2004) study estimated a sediment delivery rate of 800 tons/km^2-year (1.1 ac-ft/mi^2/year or 1,700 cy/mi^2/year). This estimate is also comparable to our findings. Although, our study incorporated some ESA methods and estimates including shallow landslide estimate, the majority of our findings are based on fieldwork, modeling, and analysis of LiDAR data and maps and are thus independently developed. Therefore, we consider the ESA (2004) study as another line of evidence supporting our findings.

For comparison purposes, we are also providing sediment yield estimates developed for other TMDLs in the San Francisco Bay Area. Lagunitas Creek sediment TMDL study estimated an average annual sediment discharge rate of 110 tons/km^2-year for 1983 through 2008. Napa River sediment TMDL study estimated an approximate sediment discharge rate of 600 tons/km^2-year.

7. Sediment Storage

Under natural background conditions and prior to channel incision along creeks, more than 40,000 tons/year of sediment or a third of the total sediment delivered to channels was deposited on the floodplains and interconnected alluvial fans. Channel incision dissociated floodplains from their channels eliminating sediment storage in the valley. Channel incision and wood removal also resulted in simplified channels that transport most sediment downstream to the marsh and lagoon complex eliminating channel storage units such as riffles, gravel bars, and deposition zones behind LWD. Therefore, sediment storage in the channels and floodplains is estimated as negligible under current sediment budget.

We would like to note, however, that there is a significant amount of sediment stored along channels upstream of the Old Haul Road. In order to keep the railroad alignment on contour and at a relatively even grade, massive log and fill structures were constructed to span 14 tributaries draining Butano Ridge to Pescadero Creek. Significant amounts of sediment and woody debris deposited along these tributaries upstream of the road. Martin Trso estimates that the amount of sediment deposits upstream of the Old Haul Road could be up to 2 million tons based on an analysis of LiDAR data (personal communication, Martin Trso, email 6/3/2014). This estimate is not a part of our sediment budget as these deposits are currently in storage. However, it is important to note that failure of these crossings would be catastrophic and would result in massive delivery of sediment to Pescadero Creek.

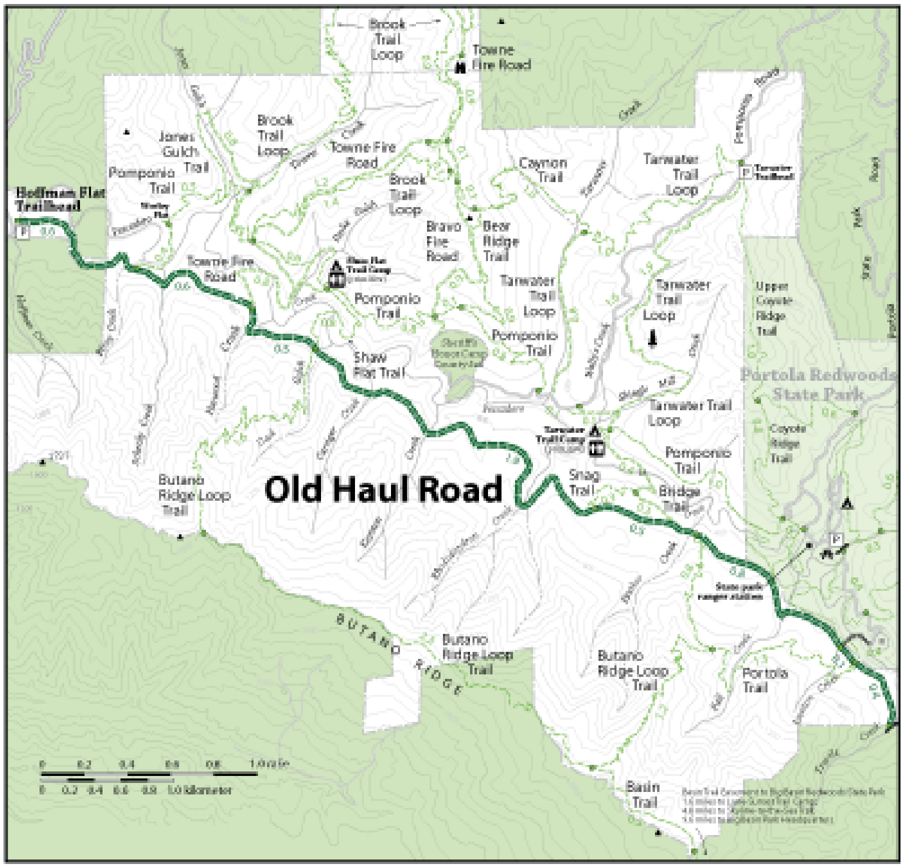

Figure 40. Old Haul Road

The Old Haul Road is an 8-mile long timber hauling rail and truck road that was built in the 1930s. It was originally built as a major railroad alignment to transport saw logs to a Santa Cruz Lumber Company mill located at Waterman Gap. In order to keep the railroad alignment on contour and at a relatively even grade, huge log and fill structures were constructed to span 14 major tributaries draining the Butano Ridge. Several of these tributaries have cobble-boulder substrate, which is important for aquatic habitat and which is currently blocked upstream of the road. There are also significant amounts of sediment and woody debris upstream of the road. The principal concern along the Old Haul Road is the stability of the creek crossings and the risk of failure which would result in enormous amounts of sediment delivered to Pescadero Creek.

The principal concern along the Old Haul Road (Figure 40) is the stability of the creek crossings and the risk of failure which would result in enormous amounts of sediment delivered to Pescadero Creek.

5.4. Marsh and Lagoon Sedimentation

The recent rate of sedimentation within the Marsh-Lagoon Complex has been interpreted using the results of the ESA PWA field monitoring study (2011), Clarke et al (2014) coring study, Curry (1985) analysis, and qualitative estimates from historic maps and anecdotal information.

ESA PWA re-occupied the same transects that they had surveyed in 1987 across various locations in the marsh and the lagoon (Attachment B). These transects covered approximately 50 percent of the marsh/lagoon area. Their study revealed that within the present-day lagoon, which approximately covers an area of 27 acres, average deposition between 1987 and 2010 along the thalweg ranged between 0.5 ft and 3.5 ft. We analyzed cross sectional changes as captured by the 1987 and 2011 surveys and estimated the net change in capacity at each cross section. We then estimated the volumetric change by multiplying the distance between cross sections with the average of the capacity values at two bounding cross sections. This analysis revealed that there has been a volumetric reduction of approximately (865,000 ft^3) 24,500 m^3. This corresponds to a sediment deposition of approximately 39,185 tons in 24 years. Therefore, we can estimate an average lagoon sedimentation rate of 1,630 tons/year. The deposition in the tidal channels and the lagoon can also be approximated by estimating the loss of tidal prism. The effective tidal prism in 1854 was estimated as 225 ac-ft (PWA, 1990). The ESA PWA (2011) study estimated the current effective tidal prism as 60 ac-ft. Therefore, we can infer that there has been at least a loss of 165 ac-ft of volume in the lagoon and channels. Assuming a bulk density of 1.6 tons/m^3, a minimum of 325,000 tons of sediment deposited in the lagoon and tidal channels since 1854. Notwithstanding the episodic nature of sediment delivery and deposition, this equates to an average sediment deposition rate of 2,080 tons/year in the lagoon. Considering both of these approaches, we approximated an average lagoon sedimentation rate of 2,000 tons/year.

In addition to the lagoon, ESA PWA (2011) re-surveyed cross sections in different parts of the marsh. Their surveys indicated that the East Butano Marsh, the North Pond, and the North Marsh aggraded by 0.1 m to 0.4 m (0.3 to 1.3 ft) amounting to an average deposition of 10,970 tons/year on the marsh plains. Therefore, the average annual sedimentation rate within the marsh-lagoon complex would be estimated approximately as 13,000 tons/year.

Clarke et al (2014) analyzed a sediment core taken from an undisturbed back-barrier area of lower Pescadero marsh and analyzed particle size distribution of 2-mm sections. They also used chronological markers e.g., 137Cs, 210Pb, 14C, and geochemical trends implying sub-soil erosion (Clarke, 2011) to date European impact on the site. Their analysis dated the core section at a depth of 75 cm to approximately 1850 suggesting a post-European sedimentation rate of approximately 5 mm/year. This would translate to an average annual deposition rate of 13,000 tons/year[37] at the back-barrier area of the lower marsh. This estimate is comparable to that obtained from comparing historic and current cross sections in the most downstream part of the marsh.

Curry (1985) estimated a deposition rate for the period between 1955 and 1985 for: i) the upstream part of the marsh lagoon complex; and ii) the willow/alder thicket upstream of the Pescadero Creek Road. His analysis included core sampling in the marsh, the lagoon, and the channels (to roughly estimate the thickness of deposited sediments following major flood events) and field observations to project lines of equal thickness of sediment units in less-disturbed areas.

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[37] Assuming an average surface area for the marsh-lagoon complex of 160 hectares (400 ac) in the last 150 years, an average deposition rate of 5 mm, and a bulk density of 1.6 tons/m3, the estimate is found as follows: (5/1000)m*(1.6 million m^2)*1.6 tons/m^3

Figure 41. Pescadero Lagoon in 1915 and 2010

Photographs taken approximately at the same location illustrate the loss of open water and the substantial sediment infill (front and right of the photo). The lagoon was an open-water estuary prior to accelerated sediment delivery due to land use in the watershed; currently the system is more like a shallow-creek delta. Between approximately 1900 and 1960, over one-half of the open water volume within the marsh and lagoon was lost to sedimentation (Viollis, 1979). The tidal prism is one quarter of what it was in 1854 (PWA, 1990). There has been an average shallowing of the lagoon by about 1.3 feet since 1990 (Largier et al., 2015).

i) Considering topographic gradients Curry estimated that Butano sediments dominated approximately 95 ha (235 ac) and Pescadero dominated 75 ha (189 ac). He hypothesized that sedimentation due to Butano Creek sources was on the order of 70 cm to 1 m (2 to 3 ft) post 1955 flood; however, he questioned the timing. He stated that sedimentation due to Pescadero sources was discontinuous and varied from less than 30 cm (1 ft) near the beach to 70 cm (2 ft) near the eastern edge of the marsh. Using these approximate surface areas and deposition rates (and assuming a bulk density of 1.6 ton/m^3), he inferred that between 1.3 million and 2.1 million tons of sediment deposited in the marsh between 1955 and 1985 that was primarily transported due to the 1955 flood. On an average annual basis, this would correspond to 55,000 tons/year. This provides an upper bound for the deposition rates.

ii) Curry observed 2 m (6 ft) of sediment in the alder-thicket area that had accumulated during and since the 1955 flood. He estimated the area of the thicket as 20 ha (50 ac). This would amount to a total deposition of 600,000 tons. He assumed that most of this sediment was associated with the 1955 flood and the period after that. Therefore, an annual deposition rate of approximately **20,000 tons/yr** in the willow/alder thicket area was inferred.

Considering these three estimates, ranging from 13,000 tons/year to 55,000 tons/year, at different parts of the marsh-lagoon complex, we approximate that 30,000 tons/year of sediment has been accumulating in the marsh-lagoon complex in the last four decades (Table 14).

Table 14. Sediment Storage in the Pescadero-Butano Watershed (under Natural Background and Current Conditions)

	Pre-1820 (tons/year)*	**1970-2010 (tons/year)***
Natural Sediment Sources	120,000	120,000
Anthropogenic Sediment Sources		133,000
Total Delivery to the Watershed	**120,000**	**253,000**
Sediment Storage		
1a. Wet meadow/alluvial valley storage	38,000	Unknown
b. Marsh and lagoon sedimentation	2,000	30,000
c. Sedimentation in willow/alder thicket	No information	20,000
Total Storage in the Watershed	**40,000+**	**50,000**

5.5. Sediment Supply from Urban Stormwater Runoff

Urban stormwater runoff is a minor point source[38] in the Pescadero-Butano watershed. In estimating sediment supply from urban stormwater runoff, we considered inputs from construction activities and road maintenance activities. In estimating sediment supply from construction activities, we have assumed a typical sediment delivery ratio of 50 percent (half of the eroded sediment is actually delivered to a stream channel). Using best professional judgment, we assume ground disturbance associated with construction is ≤30 acres per year and average soil erosion rate is 10 tons per acre with Best Management Practices in place. Using these values, we calculate that average annual sediment supply to Pescadero and Butano Creeks from construction activities is approximately 150 tons/year. Sediment supply from the remaining urban stormwater runoff discharges is estimated as 300 tons/year and is based on applicable factors such as rainfall, runoff coefficients, suspended sediment concentrations, and the acreage in different land uses (i.e. commercial, residential, and roadways). Sediment supply from roads managed by California Department of Transportation (CalTrans) is estimated as less than 50 tons/year. Table 15 below presents the estimated sediment supply form urban stormwater sources, and provides the basis for the estimates.

Table 15. Urban Stormwater Sediment Load to Pescadero-Butano Watershed

Point Source Category	Assumptions/Data	Estimated Mean Annual Delivery (tons/year)
Municipal Stormwater	Acreage of urban land use: 3,900[a] Runoff coefficient: 0.35[b] Average rainfall: 40 inches/year TSS concentration: 100 mg/L[c] Sediment delivery rate: 50%[d]	300[e]
Construction Stormwater	Ground disturbance ≤ 30 acres Sediment delivery rate: 50% Average soil erosion rate: 10 tons/ac	150
Caltrans	Acreage of Caltrans roads: 45 acres[f] TSS concentration: 100 mg/L[g] Runoff coefficient: 1 Average rainfall: 40 inches/year	<50[h]

[a] Source: San Mateo County land cover data
[b] Typical urban coefficient is 0.35 (BASMAA, 1996).
[c] WEF Manual of Practice No. 23/ASCE Manual No.87, assumes median urban site (WEF and ASCE, 1998)
[d] Assumes half of sediment is retained on land or removed via culverts, detention basins, etc.
[e] Rounded to the nearest hundred.
[f] Source: GIS Data for roads from San Mateo County
[g] Approximation based on Storm Water Monitoring & Data Management Discharge Characterization Study Report (California Department of Transportation, 2003)
[h] Estimated as 18.5 tons/year and rounded up.

[38] Point sources typically are discharges of pollutants from a discrete conveyance (or pipe). Nonpoint sources are everything else that has not been defined as a point source (e.g., agricultural lands, rangelands, roads, etc.).

5.6. Sediment Storage along Lower Butano

Lower Butano Creek, which has a very low gradient and has functioned as a flow capacitor and sediment storage area, has been receiving dramatically increased amounts of sediment due to legacy and current land use practices. Increased sedimentation and flooding in the lower valley can best be observed at Pescadero Creek Road bridge, which is located at the base of the Butano Creek. Sedimentation in the last fifty years has been documented through cross section surveys (Figure 42). At this location, nearly 7 feet of sediment has accumulated since the bridge was constructed in 1961 (more in reality, as the channel has been dredged multiple times during this period and sediment has been removed).

Approximately five hundred feet downstream of the Pescadero Creek Road bridge, Butano channel is completely filled with sediment and disappears into the marsh. There is no defined Butano channel for more than half a mile (Figure 43).

Curry (1985) estimated the amount of sediment deposited in the marsh, as well as upstream of the Pescadero Creek Road bridge and the willow thicket. His analysis included core sampling in the marsh, the lagoon, and the channels (to roughly estimate the thickness of deposited sediments following major flood events) and field observations to project lines of equal thickness of sediment units in less-disturbed areas. He observed 6 feet of sediment in the willow thicket area that had accumulated primarily since the 1955 flood event. He estimated the area of the thicket as 50 acres. This would amount to a total deposition of 300 ac-ft or 600,000 tons in thirty years. Based on his observations and report, we infer an annual deposition rate of approximately 20,000 tons/year in the willow thicket area.

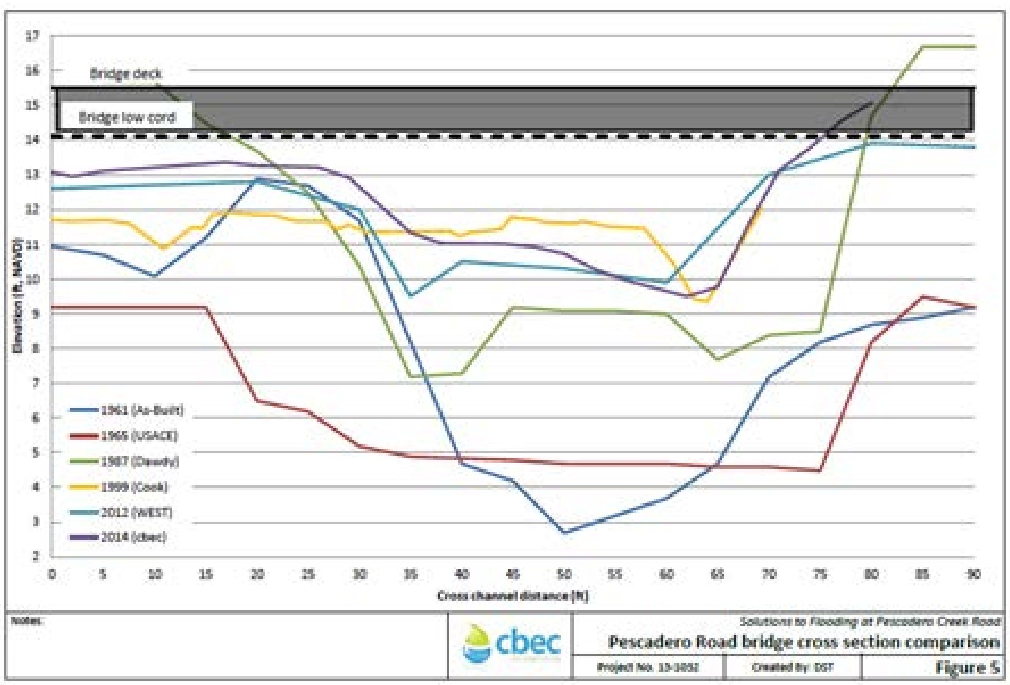

Figure 42. Butano Creek at Pescadero Creek Road Bridge

The bridge was constructed in 1961. Cross sections taken at the bridge in 1961, 1965, 1987, 1999, 2012, and 2014 show that there has been more than 7 feet of accumulation since 1961. This is a significant underestimate as the channel in the vicinity of the bridge has been dredged several times since 1961.

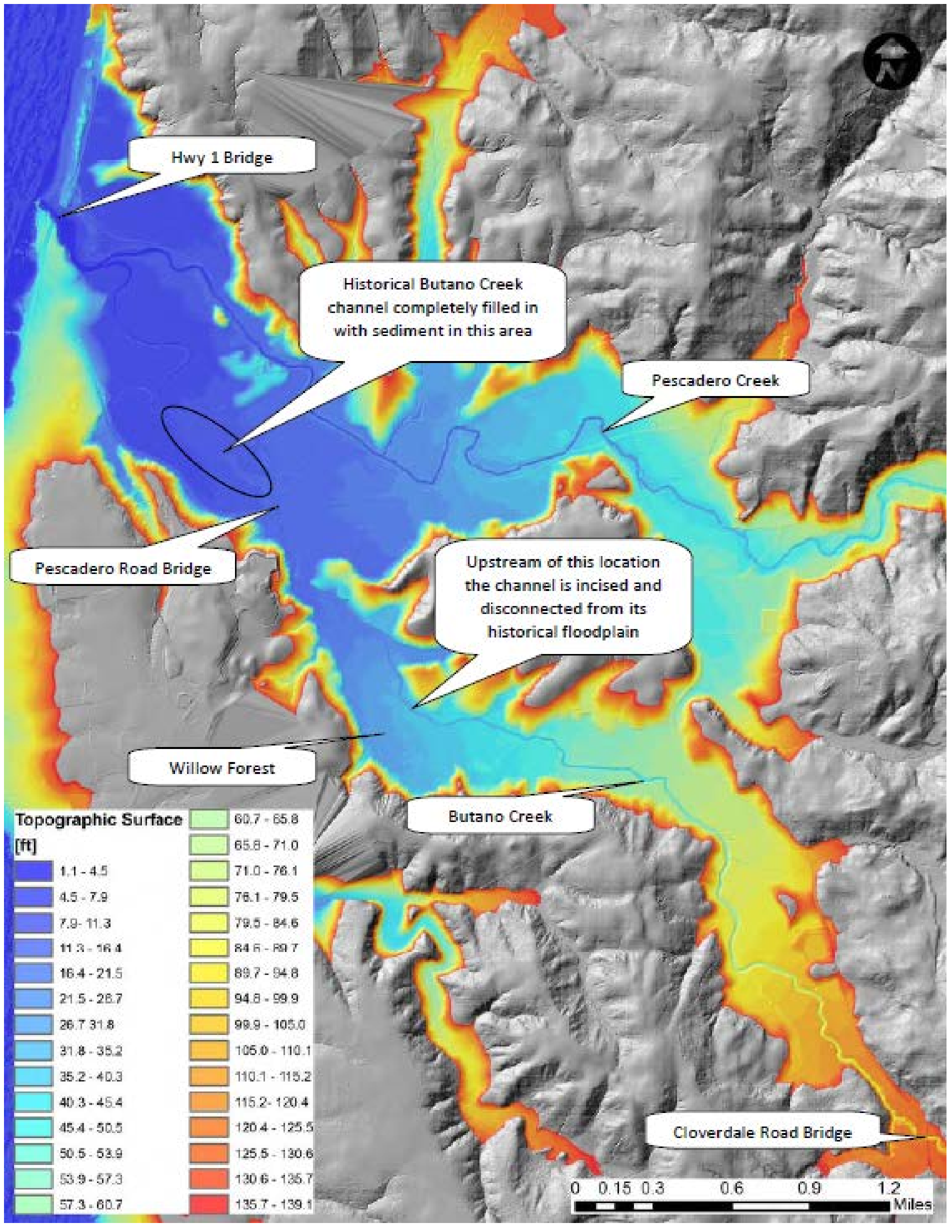

Figure 43. Topography of the Pescadero Lagoon and Marsh (from CBEC, 2014)

Butano channel disappears approximately 500 feet downstream of Pescadero Road Bridge due to accumulated sediment (shown as the black circled area). East Butano Marsh located west of the Butano Creek is lower than the delta of sediment that has deposited within and adjacent to the alignment of the historical channel. The figure also shows the incised reach that begins upstream of the Willow Forest.

5.7. Sediment Source Analysis Conclusions

Based on the results of the sediment budget, we conclude the following:

1. Sediment delivery to channels in the Pescadero-Butano Creek watershed has more than doubled since the European settlement of the watershed in 1820. Approximately 253,000 tons/year of sediment is delivered to the channels which is approximately 210 percent of natural background conditions.
2. Land use practices since the 1820s increased sediment delivery by 133,000 tons/year.
3. In addition to increased erosion and sediment delivery, Pescadero-Butano watershed has undergone a significant loss of sediment storage function compared to natural conditions.
4. Five significant categories of human-caused sediment sources are: 1) road-related erosion everywhere in the watershed; 2) channel incision and bank erosion; 3) gullies on rangelands; 4) landslides and debris flows in timber harvest lands; and 5) surface erosion on rangelands.
5. Road-related erosion contributes 51,000 tons/year and is the largest sediment delivery mechanism triggered due to land use practices.
6. Prior to Euro-American settlement, most channels were not incised. Nearly all channels were well connected to adjacent floodplains that were covered by extensive wet meadows. Channels are incised as a result of management actions that increased shear stress on the bed due to LWD removal, ditching and draining adjacent lands, and channel modifications.
7. Approximately half of the human-caused sediment, 59,000 tons/year, is generated in the western quarter of the watershed by channel incision in the valley and by gullying and surface erosion on rangelands.
8. Channel incision contributes approximately 30,000 tons/year to both Pescadero and Butano Creeks. The impact of channel incision on the sediment budget is amplified due to the dual impact of loss of sediment storage and increased erosion. Prior to the European settlement of the watershed, most channels were not incised and nearly all channels were well connected to adjacent floodplains. These lowland valleys and floodplains, which are now the largest sediment source, used to function as sediment storage areas metering sediment to the marsh and lagoon complex. We roughly estimated that on average 38,000 tons of sediment deposited on the floodplains during Holocene. This average amount coupled with the 30,000 tons that is generated due to incision is now transported downstream to the marsh. Therefore, the cumulative impact of this source on the marsh is more than twice as much as the source itself.
9. In the forested lands, roads[39] and shallow landslides contribute approximately 61,000 tons/year.
10. Sediment processes active in the lowlands and the western watershed are significant due to their close proximity to the lagoon. Fine sediment from surface erosion and both fine and coarse

[39] Roads in the forested lands would contribute approximately 38,250 tons/year, assuming that the roads in the forested lands constitute approximately three-quarters of the total mileage of roads -similar to the same proportion of forested land area to the total watershed area.

sediment from gullying in the lower tributary watersheds (e.g., Bradley Creek) are directly input to the channels and the lagoon. The ditching and draining of the lowlands downstream of rangelands cause all the sediment that is generated from the hills to be delivered to the main channels without any prospects of temporary or permanent storage.

11. In addition to reducing sediment delivery to the marsh-lagoon complex and improving its ability to flush out the sediment, the problem of channel incision in the watershed needs to be addressed. Moreover, substantial reductions in sediment input from land uses in upland areas, including roads and grazing practices, will be needed to improve the quality of spawning and rearing habitat for salmon in the channels and the lagoon.

12. Not only did sediment delivery to the marsh increase more than two-fold, the marsh itself has undergone land use changes including channelization, diking, modified Highway 1 Bridge, and restoration efforts that reduce its capability to flush sediment out to the ocean. Sedimentation in the lagoon increased more than an order of magnitude and is estimated to be approximately 30,000 tons/year. The lagoon provides critically significant rearing habitat for steelhead and its rehabilitation will therefore be a significant focus of the Pescadero-Butano sediment TMDL.

13. Elevated sediment loads due to land use are expected to continue into the future. Channel incision is the largest sediment source and once triggered is a self-perpetuating process of positive feedback, with ever-deepening channels containing larger flood flows with higher erosive force and deepening the channel. As incision progresses, the height of the banks increases and banks become unstable (higher than critical height that the bank material can maintain). Therefore, incision is typically followed by systemic bank erosion[40]. Similarly, gully erosion is also expected to continue delivering large amounts of sediment. Gully erosion rates in the last forty years have tripled compared to late 1800s and have doubled compared to the period from 1920 to 1970 (Swanson, 1983; Swanson et al., 1989).

14. Determining the relative contributions of littoral and alluvial sediment to sedimentation is difficult. However, by estimating the long-term rate of watershed delivery under natural conditions and by comparing it to long-term deposition amounts in the marsh and the lagoon, we can assess the order of magnitude of each source. Based on cosmogenic isotope analysis, the long-term sediment delivery to the marsh was estimated to be about 50,000 tons year (40,000 CY/year) using a 0.25 mm/year of an average denudation rate, one third of which deposited in the valley. Based on cores collected in several places in the marsh, the long-term deposition rate has been between 0.5 and 1 mm or approximately 3,000 tons/year (2,500 CY/year). The

[40] In addition to the self-perpetuating nature of bank erosion processes once channels have incised, we note that the characteristics of the rock underlying Pescadero Creek indicates that the bank erosion along the creek is expected to be significant. While the majority of Pescadero Creek is underlain by the Tahana Member of the Purisima Formation, Butano Creek is primarily underlain by the Butano sandstone. A study comparing the erosive behavior of the Tahana Member showed that while the Butano sandstone and Purisima Formation have comparable tensile strengths, after one wet and dry cycle, the Butano sandstone maintains its original tensile strength, whereas the Tahana member loses so much strength that it disintegrates under its own submerged weight (Johnson and Finnegan, 2015). This very low slake durability of the Purisima Formation results in a very high susceptibility to erosion by clear water flows and implies a high bank erosion potential along Pescadero Creek.

implication of this comparison is that, prior to European settlement of the watershed, sediment delivery to the marsh and lagoon is more than an order of magnitude larger than the deposition at the marsh and lagoon. Given the low tidal velocities and low littoral sediment contribution, a significant majority of sediment deposition in the marsh and lagoon is hypothesized to be due to alluvial sources.

CHAPTER 6

NUMERIC TARGETS

Key Points

- Water quality objectives for sediment, settleable material (sedimentation), and population and community ecology (habitat complexity and connectivity) are not being met.
- TMDLs require a quantitative numeric target to implement existing water quality objectives. To evaluate attainment of water quality objective for population and community ecology, we define measurable targets for sediment and large woody debris (LWD) loading.
- Sediment supply is too high. Channels are incised, simplified, and disconnected from floodplains. There is not enough sediment storage.
- To protect coho salmon and steelhead, as well as other native species, rates of sediment supply and channel incision must be reduced in a manner than enhances aquatic habitat conditions.
- To evaluate attainment of the water quality objective for settleable material, we define measurable targets for residual pool volume (V*) and percent fines in the substrate.
- To evaluate attainment of water quality objective for population and community ecology, we define measurable targets for large woody debris and floodplain area and propose technical studies to guide future actions to reestablish channel-floodplain connection and enhance natural sediment storage in the valley.
- Although LWD and floodplains are not indicators of substrate quality, in addition to reductions in sediment discharge, both of these features need to be restored in order to attain the numeric targets for settleable material.
- The proposed targets are consistent with water quality objective and anti-degradation policies.

The Basin Plan establishes water quality objectives, which are necessary for the reasonable protection of the beneficial uses and for the prevention of nuisance (see Table 1 for applicable narrative water quality objectives). TMDLs require one or more numeric targets to demonstrate attainment of these narrative objectives. The numeric targets proposed herein for the Pescadero-Butano watershed focus on the elimination of sediment as a pollutant of concern and provide instream water quality goals for restoring the cold-water fishery habitat.

To evaluate attainment of the applicable narrative water quality objectives (sediment, settleable material and population and community ecology), we translate these objectives into measureable criteria, or numeric targets for sediment and habitat conditions. Also, as described in Chapter 2

(Problem Statement), beneficial uses that are threatened by sediment impairment include cold freshwater habitat, preservation of rare and endangered species, and fish spawning. Therefore, we developed targets to link sediment to properly functioning habitat conditions for listed populations of coho salmon and steelhead, and for the entire native fish and wildlife assemblage. We defined target values for three parameters that are responsive to and/or influence sediment supply and transport, and also are related to the ecological requirements of coho salmon, steelhead, and other native species. These parameters are: 1) residual pool volume; 2) substrate composition – percent fines; and 3) large woody debris (LWD) loading. These targets are described in detail in the sections that follow.

6.2. Residual Pool Volume (V*) as a Measure of Fine Sediment Loading

V* is a unitless measure of the fraction of a pool's volume that is filled by fine sediment and is representative of the in-channel supply of mobile bedload sediment. It provides a direct measurement of the impact of sediment on pool volume. The hypothetical mechanism behind this response is as follows: as more sediment is added to a stream, the bed becomes more mobile at a given discharge. At high flow, sand and small pebbles become abundant over most of the surface of the bed, and bedload transport rates of all grain sizes are greater than they would be if the supply of sediment were smaller. As flow wanes and transport rates decrease after a flood, this finer sediment is winnowed from areas of the bed where boundary shear stress is high, such as riffles, and deposited in areas of low shear stress, such as pools. Thus, riffles and much of the rest of the bed become armored while pools are blanketed with a layer of fine sediment. In channels with a low sediment load and a less mobile bed, less fine sediment is available for winnowing from riffles--thus deposits of fines in pools are smaller. Therefore, the fraction of pool volume filled with fine sediment, V*, is directly related to the supply of sediment and the mobility of the channel as a whole.

Overwintering habitat requirements for salmonids include deeper pools, undercut banks, side channels, and especially large, unembedded rocks that provide shelter for fish against the high flows of winter. By contrast, pool habitat is the primary habitat for steelhead in summer. The deeper pools provide greater habitat value. Fish biologists working in coastal streams in Santa Cruz County found that densities of yearling steelhead are usually regulated by water depth and the amount of escape cover that exists during low-flow periods of the year (July-October). In most small coastal streams, availability of this habitat characterized by depth and cover appears to determine the number of smolts produced by the smaller streams (Alley, 2011).

Based on studies of tributaries to the Trinity River, V* is a good indicator of sediment supply, especially fines (Lisle and Hilton, 1992). This selected parameter is appropriate because of its strong correlation with upslope disturbances: Knopp (1993) showed significantly lower values of V* in channels draining basins either pristine or logged in the 19th century than in channels draining recently logged basins. Lisle and Hilton (1999) demonstrated the usefulness of the parameter by comparing annual sediment yields of select streams with their average V* values and concluded that V* was well correlated to annual sediment yield and that V* values can quickly respond to changes in sediment supply. Lisle and Hilton (1999) provided more evidence that V* responds to variations in sediment supply, but only where the supply includes abundant sandy material. V*minimizes bias to the maximum extent practicable as its variance in a reach of stream has been shown to be low enough to provide precise estimates of mean values with a reasonable amount of effort (Hilton and Lisle, 1993).

Excessive fine sediment has been documented throughout the watershed to embed spawning gravels and fill pools (e.g., CDFG 1994b, 1996a–c, and 1997; ESA, 2004), and high turbidity has been observed during recent storm events. High turbidity, poor gravel quality, and a lack of pools—all related at least in part to excessive fine sediment—were identified by NMFS (2012) in their coho recovery plan as constraints to coho salmon adult, egg, summer and winter rearing juvenile, and smolt life-stages. Similarly, shallow pool depths and relatively high levels of fine sediment were identified by ESA et al. (2004) as two of the primary factors limiting salmonid habitat in the watershed. Aggradation of sediment in Pescadero Marsh has been, and continues to be, responsible for the loss of important estuary rearing habitat.

Adequate data on V* are not available for the Pescadero-Butano watershed. Based on V* data collected in 60 streams on California's north coast, Knopp (1993) found that in reference streams (those having no human disturbance for the past 40 years or more) the region-wide mean V* value was 0.21 or less and the maximum V* value was 0.45 or less in reaches with slopes between 1 and 4 percent. V* values measured in other relatively undisturbed streams in northern California corroborate this finding (Lisle and Hilton, 1999). We therefore propose numeric targets of 0.21 as the mean value and 0.45 as the maximum value applicable in channel reaches with slopes ≤5 percent.

We recognize that conditions in the Pescadero-Butano watershed do not completely overlap with those in the North Coast and we may modify these values as watershed-specific V* data become available. Because the Pescadero-Butano watershed has a Mediterranean climate and active tectonic setting, natural sediment loads are highly variable and native biota are adapted to large infrequent sediment inputs associated with natural disturbances (e.g., large storm events, wildfires, and major earthquakes). Native biota are not adapted however to chronic increases in fine sediment load caused by land-use activities that disturb vegetation cover and/or infiltration capacity of soil (e.g., road-related erosion, agriculture, construction, timber harvest, livestock grazing, etc.). Under the natural sediment input regime, fine sediment input would be very low in most years, and the amount of fine sediment stored in the channel would be reduced rapidly following a large natural disturbance event, back to levels favorable for fish spawning and rearing. By this same rationale, significant reductions in the amount of chronic fine sediment input from landuse activities will facilitate a significant reduction in mean values of pool filling. Such reductions will not be achieved in the short-term: Knopp found that V* results may take upwards of 40 years before mitigation of current disturbance is positively reflected (Garcia River Sediment TMDL, USEPA, 1998, p20).

These targets are also likely to address other fish-related beneficial uses such as migration. This is because V* reflects sediment aggradation of pools, and we expect that as sediments are reduced in the pools (resulting in clear streamflows and deeper pools to provide more protection from predators), migration areas within the stream channel will improve.

6.3. Substrate Composition – Percent Fines

We propose two targets for percent fines in the substrate: 1) percent fines less than 0.85 mm in diameter is less than or equal to 14% of the total bulk core sample (i.e., ≤14% fines < 0.85 mm) and 2) percent fines less than 6.40 mm in diameter is less than or equal to 30% of the total bulk core sample (i.e., ≤ 30% fines < 6.40 mm). These targets are applicable to potential spawning sites for anadromous salmonids in wadeable[41] streams and rivers with a gradient less than 3 percent. Potential spawning sites for anadromous salmonids can be identified based on the following characteristics: 1) dominant substrate size in the streambed surface layer is between 8 and 128 mm; 2) surface area of the gravel deposit is ≥1.0 m^2 within the mainstem channels and is ≥0.2 m^2 in tributaries; and 3) location at a riffle head, pool tail, pool margin, and/or it is a gravel deposit associated with a flow obstruction (e.g., woody debris, boulders, banks).

The composition of substrate is a common measure of salmonid spawning habitat quality because fine sediment grains, called fines, have the potential to fill the interstitial spaces of gravels and thus to impact embryo development and block passage of fry (Phillips et al., 1975; Chevalier et al., 1984; Kondolf, 2000).

Fine sediment that impacts embryo development has been defined as particles that pass through a 0.85 mm sieve (NWRQCB, 2006)[42]. Fines fill the interstitial spaces of gravels used by salmonids to hold and incubate eggs (a redd). Once salmonid eggs are laid and fertilized, the spawning fish cover the redds with substrate material from just upstream of the redd. Interstitial spaces between substrate particles allow for water to flow into the interior cavity of the redd where dissolved oxygen, a necessity to growing embryos, is replenished. The interstitial spaces also allow water to flow out of the interior cavity carrying away metabolic wastes. Fine sediment particles can intrude into these interstitial spaces, reducing gravel permeability, which results in reduced rates of oxygen delivery and the removal of metabolic wastes. Ultimately, reduced permeability results in reduced embryo survival and deleterious effects on the cold water fishery beneficial uses.

Particles ranging from 1 mm to 10 mm in size have the potential to cover the redd and can block fry emergence while still allowing enough water flow through the redds to support embryo development (Kondolf, 2000; NCRWCB, 2006). A high percentage of sand or fine gravel in the streambed can adversely affect the frequency of streambed scour, biomass of vulnerable prey species in the streambed, and/or suitability in general of summer and winter rearing habitat for salmonids.

Much research has been conducted to relate salmonid survival to emergence with the size of the substrate. Based on extensive literature review, the North Coast Regional Water Board determined that

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[41] A wadeable stream is one which an average human can safely cross on foot during the summer, low flow season while wearing chest waders.

[42] The specific reference sizes, 0.85 and 6.4 mm (as opposed to 1 and 6 mm), result from the fact that the earliest researchers used US Standard Sieve mesh sizes (e.g., the sieves are machined in English units). They subsequently reported their research results in scientific journals, which use metric units. For comparison purposes, most subsequent researchers have used these same reference sizes.

the salmonid freshwater habitat desired conditions for substrate composition are: a) percent of fine sediment less than 0.85 mm in diameter is less than or equal to 14% of the total bulk core sample, and b) percent of fine sediment less than 6.40 mm in diameter is less than or equal to 30% of the total bulk core sample (NCRWCB, 2006). As detailed in the North Coast Water Board's Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices (NCRWCB, 2006), these targets correspond to a survival-to-emergence rate of 50 percent.

Percent fines targets are empirically correlated with emergence success and significant amounts of data are already available. Some of the studies evaluated for the desired condition were conducted in salmonid streams, while others were conducted in an experimental setting where the substrate was manipulated to study the effect of substrate size on survival-to-emergence. These targets are easily repeatable indicators of target conditions and they complement the proposed residual pool volume targets: when considered all together they provide a good indicator of sediment supply and directly descriptive measures of spawning gravel and rearing habitat quality.

6.4. Large Woody Debris Habitat Targets

Large Woody Debris Loading in Redwood Channel Reaches

One of the numeric targets for LWD is based on loading estimates to managed redwood channels. The watershed-wide average value for LWD loading in redwood channels shall be ≥300 m^3/ha. The timeframe for achievement of this target is 10 years from adoption of the TMDL. Redwood channels are defined as those where the adjacent valley floor and/or hillslopes are vegetated primarily by coast redwood forest. The target applies only in channel reaches located in public property, open space land, or timber harvest lands and where projects and actions would not threaten public safety or damage property.

LWD in channels provides multiple functions, which are critical for maintenance of the health of stream habitat and the moderation of sedimentation in the streams. LWD includes both logs and root wads that at least partially extend into the bankfull channel of a water body. LWD plays an important role in channel morphology by forming habitat such as pools and by increasing hydraulic complexity. LWD provides an effective mechanism in metering and sorting of instream sediment. It also provides cover to salmonids and contributes to the production of benthic macroinvertebrates. Key pieces of LWD, those large enough to resist transport even during large floods, are the primary agent structuring complex and interconnected channel and floodplain habitats in forested watersheds in the Pacific Coastal Ecoregion[43] (Collins et al., 2012). In addition, when land-use activities reduce the size of the largest trees recruited to channels and/or the rate of input of key pieces in general, this causes the physical habitat structure in channels to become greatly simplified (Collins et al., 2012).

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[43] Pescadero-Butano Watershed is within the Pacific Coastal Ecoregion, which extends along the west coast of North America from southeast Alaska through the California Coast Range, south into the Santa Cruz Mountains (Naiman and Bilby, 1998).

Anadromous salmonids in the Pacific Coastal Ecoregion, as well as all other native aquatic and riparian species, have evolved to exploit the complex and interconnected habitat structure created by large wood. Coho salmon, for example prefer deep pools with good cover alternating with gravel riffles, and well shaded channel reaches that are connected to adjacent floodplains by debris jams that cause floodplain patches, alcoves, and side channels to form (NMFS, 2012: Ch.3). All of these habitats are formed and maintained by key pieces of LWD.

There is a factor of twenty in the natural range of variability in LWD loading in channels draining old-growth redwood forests, from approximately 250-to-4,500 m^3/ha with a median value of 300 m^3/ha (Knopp, 1993). This large range of natural variability highlights a primary challenge in trying to develop a defensible target value (Keller and Tally, 1979 as reported in Lisle, 2002; Lisle, 2002). Current values for LWD loading in redwood channels in the Pescadero-Butano Creek watershed, sampled over less than 10 percent of the length of Pescadero and Butano channels, are categorized as wood-poor and are significantly lower than natural range (ESA, 2004; NOAA, 2012; NOAA, 2015).

Considering all of the above, and the critical importance of LWD in shaping suitable habitat for coho salmon, we establish the LWD loading target at 300 m^3/ha, which is the median value for LWD loading in managed redwood channels (Knopp, 1993 as reported in Lisle, 2002) and is approximately equal to the 25 percent[44] value for old-growth redwood channels (Keller and Tally, 1979 as reported in Lisle, 2002). This target applies to public lands, open spaces, and timber harvest lands. Approximately 16 miles of Pescadero Creek continuously flows through timberlands and park lands. In Butano sub-watershed, 9 miles of North and South Fork Butano Creek channels are in timberlands. In addition, approximately 10 miles of tributary channels in the Pescadero watershed are located in open space lands or timberlands. Therefore, the LWD loading target for redwood channels applies to approximately 35 miles of channels that would provide habitat to salmonids in the upper Pescadero and Butano subwatersheds.

Large Woody Debris Loading for Hardwood Channel Reaches

A second numeric target for LWD loading is proposed for managing hardwood channel reaches. The watershed-wide average value for LWD loading in hardwood channels shall be ≥ 100 m^3/ha. The timeframe for achievement of this target is 10 years from adoption of the TMDL. Hardwood channels are defined as channels where the adjacent valley flat is vegetated by a hardwood forest (typically some combination of willow species, cottonwoods, alders, bays etc.). The target applies only to channel reaches that provide actual or potential spawning or rearing habitat for anadromous salmonids along 4 miles each of Pescadero and Butano creeks upstream of the Pescadero Creek Road. Potential spawning sites for anadromous salmonids can be identified based on the following characteristics: 1) dominant substrate size in the streambed surface layer is between 8 and 128 mm; 2) surface area of the gravel deposit is ≥1.0 m^2 within the mainstem channels and is ≥0.2 m^2 in tributaries; and 3) location at a riffle head, pool tail, pool margin, and/or it is a gravel deposit associated with a flow obstruction (e.g., woody debris, boulders, banks).

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[44] 75 percent of old-growth channels have more wood (Figure 2 in Lisle, 2002).

This target corresponds to the median value for LWD loading in hardwood channels located on public or private lands.[45] Actions and projects to achieve this target will be implemented in such a way to not damage property and threaten public safety.

6.5. Floodplain Restoration

As articulated in Chapter 4, under natural reference conditions most of the reaches along Pescadero and Butano creeks were well connected to their adjacent floodplains. Historical and/or ongoing land use activities in the last 150 years have caused channels to become deeply incised, such that historical floodplains have been isolated and converted to terraces that are infrequently or very rarely inundated even during extreme high flows.

Floodplains provide essential winter rearing and refuge habitats for coho salmon including alcoves and side channels (Bustard and Narver, 1975; Nickelson et al., 1992a and b; Tschaplinski and Hartman, 1983). Floodplain loss is thought be a primary factor in the decline of coho salmon populations throughout the Pacific Coastal Ecoregion (Nickelson et al., 1992a; Beechie et al., 2001; Giannico and Hinch, 2003), and locally in the Pescadero-Butano watershed (Stillwater Sciences, in prep.) where the coho salmon population is at risk of extinction. Floodplains also provide winter rearing and refuge habitat for juvenile steelhead (Swales and Levings, 1989; Solazzi et al., 2000; Stillwater Sciences, in prep.), and essential habitat for many other native fish and wildlife species within the wet season and/or throughout the year.

For salmonids, in addition to the primary impact of the loss of access to floodplain habitats, conversion of floodplains into terraces also adversely affects substrate conditions in channels. A significant fraction of the sand and finer sediment being carried by a river during high flow may be deposited on a floodplain when it is inundated going into long-term storage, and therefore, is not a source of fine sediment deposition in the streambed.[46] Because terraces are only rarely inundated, they do not provide significant sediment storage and metering. In addition, banks along terraces become higher and steeper due to incision and are therefore more prone to erosion. Therefore, terrace bank erosion is a significant human-caused source of sand and finer sediment delivery to channels.

Another impact of conversion of floodplain to terraces on channel substrate conditions is that high flows are contained in the channel even during extreme events (recurrence interval ≥ 50 years). Therefore, the shear stress exerted on the streambed is significantly amplified, greatly increasing bed mobility and scour for all flows above the former bankfull reference value (recurrence interval = 1.5-to-2.5 years).

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[45] We note that all of the hardwood channels surveyed by Opperman (2005), including those on public lands, likely have experienced historical land-use activities that reduced large woody debris loading below natural reference values, complicating establishment of a protective target.

[46] The sediment budget for the Pescadero-Butano Creek watershed demonstrates that prior to European settlement, approximately 30 percent of the total channel sediment input went into long-term storage in floodplains. Similarly, in Redwood Creek, which drains Muir Woods in Marin County, approximately 70 percent of the total sediment supply to the channel upstream of Big Lagoon, prior to historical incision of the channel, went into long-term storage in the floodplain (Stillwater Sciences, 2004).

Biological consequences of high bed mobility may include higher rates of direct mortality to salmonids during incubation (Montgomery et al., 1996), and indirect influences on growth and survival of juvenile salmonids as a result of lower biomass of benthic macro-invertebrates (Matthai and Townsend, 2000).

Restoring floodplain-channel connection in reaches of Pescadero and Butano creeks along the lowland valley and downstream of the canyons would greatly enhance the quality and quantity of potential habitat for salmonids. Floodplain restoration would involve actions to increase the elevation of the streambed and/or to decrease the elevation of the adjacent valley flat, in order to increase the frequency, area, and duration of inundation of the adjacent valley flat. As a result, stream and riparian habitat connectivity and complexity is enhanced by: a) formation of side channels and alcoves (that provide essential habitat for coho salmon and other native species); b) establishment of diverse vegetation and substrate patch types; c) enhanced recruitment and loading of LWD; d) a substantial increase in fine sediment storage on floodplains; and e) a reduction in shear stress (elevated rates of streambed mobility) in the channel during large storms (because a greater proportion of discharge is conveyed on the floodplain).

The TMDL implementation plan calls for detailed technical studies to characterize reach-specific opportunities and priorities for floodplain restoration. Potential opportunities and constraints influencing floodplain restoration potential are a function of not only physical attributes of the channels (e.g., sediment supply, flow regime, riparian forest type, valley and channel size and geometry, historical disturbances and changes over time) but also development, present-day land uses, and infrastructure. There are reaches with great potential with regard to enhancement of sediment storage and ecological function along Pescadero and Butano creeks where land adjacent to channels is publicly owned or along privately owned reaches where existing infrastructure may not be threatened by floodplain restoration. There are also reaches where opportunities are limited as a result of the close proximity of many buildings to the channel.

Currently we do not have a complete understanding of accurate estimates of the area of floodplain, evaluation of the potential benefits of incremental increase in floodplain area, and analysis of what is feasible and where to achieve optimal ecological and water quality benefits. Therefore, although we are not currently proposing a floodplain area target we recommend that detailed technical studies be conducted first to develop a more complete understanding of the opportunities, constraints, and potential benefits of floodplain reconnection.

CHAPTER 7

TMDL, LINKAGE ANALYSIS AND ALLOCATIONS

Key Points

- The Pescadero-Butano Watershed sediment TMDL is 125 percent of natural background. This implies that management-related allowable loading is 25 percent above natural background sediment loading.
- Attainment of the TMDL will require sediment inputs to be reduced by approximately 78 percent.

The TMDL is the total sediment load that can be discharged into Pescadero and Butano Creeks and their tributaries to attain water quality standards. When the TMDL is achieved, the impairment due to sediment will be eliminated. In this chapter, we evaluate linkages between sediment inputs and the selected water quality targets and we present our rationale for how we combine them to develop estimates of sediment assimilative capacity. We also establish sediment load allocations that each source category must meet in order to achieve the TMDL.

7.1 Approach to Development of Linkage Analysis

The best available science does not yet provide for a quantitative mathematical linkage between sediment inputs and instream water quality, however, there is a clear qualitative basis to establish a linkage based on a a weight-of-evidence approach. In addition, several studies have linked instream indicators to sediment loadings through the use of statistical regression analysis. For this linkage analysis we are only focusing on the TMDL targets for sediment and not the LWD loading habitat target.

Knopp's (1993) study of northern California coastal streams demonstrated that sediment generated from upslope disturbances had a measurable effect on the structure of the aquatic environment (p.40). Knopp identified a statistical link between watershed disturbance and residual pool volume (V*). This linkage is the basis for selecting the target value for V*.

Extensive research has occurred looking at salmonid survival or emergence and linkage to the substrate size. The selected substrate composition targets (percent fines <0.85 mm and 6.40 mm) are empirically correlated with emergence success and significant amounts of data are already available from other

California, Oregon and Washington watersheds (as summarized in NBRWQCB, 2006, p11; NMFS, 1996[47]). These studies establish the linkage between the numeric targets and instream conditions.

7.2 Establishing the TMDL

Linking channel conditions to sediment supply is challenging because channel form and sediment deposits reflect the temporal and spatial integration of sediment inputs to and transport through stream channels. In addition to sediment supply, channel transport capacity and storage are influenced by: a) magnitude, duration, and frequency of high flows; b) channel slope and depth; and c) channel roughness, or elements that concentrate or disperse flow energy. For these reasons, time lags between sediment input and discharge may be several years to decades or more, and specific channel responses to changes in sediment supply may vary substantially. These challenges acknowledged, we relied on two existing TMDLs for similar natural stream channels in the north coast that were based on a comparison to either a reference watershed or reference time period where beneficial uses and water quality objectives were attained.[48] These north coast TMDLs were expressed as a percentage of natural background load under which a desired level of water quality would be achieved. The two sediment TMDLs we identified that relied on a reference approach are:

1. Redwood Creek in Humboldt County, where the TMDL was established by comparison to reference sub-watersheds; and
2. Noyo River on the Mendocino Coast where the load was established by comparison to a reference time-period.

In both cases, a reference state was identified where salmonid populations are/were robust, and inferentially, where water quality objectives for sediment-related parameters are/were attained. For Redwood Creek, the sediment load corresponding to robust steelhead and salmon populations equals 117 percent of natural background. For Noyo River, the sediment TMDL equals 125 percent of natural background. Similar to the Pescadero-Butano Sediment TMDL, the primary goal of these TMDLs is the recovery of native salmonid populations.

Expressing the TMDL as a percentage of the natural background rate of sediment input to channels is appropriate for the Pescadero-Butano watershed because:

a. Pescadero-Butano watershed has a Mediterranean climate and an active tectonic setting, therefore, natural sediment input rates are highly variable, and native stream species are adapted to large infrequent sediment pulses associated with natural disturbances e.g., large storm event, wildfires, and major earthquakes; however,
b. Native fish and aquatic wildlife species are not adapted to chronic delivery of sand and finer sediment, and/or to substantial alteration of natural channel transport and storage processes.

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[47] NOAA Fisheries developed a Matrix of Pathways and Indicators that was designed to summarize important parameters and corresponding levels of condition. This matrix can be found in the Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (NMFS 1996).
[48] Where water quality standards are attained including water quality objectives for sediment, and where salmonid populations are robust.

> Under the natural sediment regime, fish-bearing channels were buffered from the full impact of large infrequent sediment pulses by the sediment storage, metering, and sorting functions provided by debris jams and floodplains, and by the fact that many tributaries were naturally disconnected.

Therefore, to emulate natural sediment dynamics and adaptations of native biota to infrequent pulse disturbances (but not to chronic press disturbances), expressing the TMDL as a percentage of natural sediment loading to channels mimics the pattern and magnitude of natural sediment inputs under current conditions where management actions may dominate sediment regime.

Of the two watersheds, Noyo shares more common attributes with Pescadero and Butano creeks, including a similar uplift rate, similar average annual rainfall, weak sedimentary rocks, and predominance of channel incision and gullies as significant human-caused sediment sources. Therefore, Noyo River under historical conditions –circa 1940s- when there was a modest increase in sediment load (e.g., 125 percent of natural background) and robust steelhead and salmon runs were observed, appears to be a suitable reference watershed for evaluating the assimilative capacity of Pescadero and Butano creeks for sediment.

Therefore, we find that a sediment load of 125 percent of natural background to Pescadero-Butano watershed, together with restoration of desired habitat conditions, will support a healthy steelhead population and result in attainment of water quality objectives for sediment and settleable material.

7.3 Load Allocations

Consistent with the approach used in other northwestern California streams, as well as three San Francisco Bay region watersheds (Napa River, Sonoma Creek, and Lagunitas Creek) where sediment TMDLS have been adopted, the Pescadero-Butano watershed sediment TMDL is established as 150,000[49] tons per year, which is approximately 125 percent of the long-term natural background load. Allocations by sediment source category are specified as a percentage of the natural background. An estimate of the percent reduction from current proportion of the total load is also provided (Table 16).

Overall, discharges from human-caused sediment must be reduced from current levels by approximately 78 percent in order to achieve the TMDL. As shown in Table 16, sediment discharges from point sources are significantly small and negligible compared to natural sources, therefore no reductions are required from the point source discharges.

[49] Sediment TMDL target of 150,000 was estimated by rounding up the 125 percent of the natural background load of 120,000 tons/year to the nearest ten thousand.

Table 16. Load Allocations for Sediment Discharges for Pescadero and Butano Creeks

Source Category	Current Load	Estimated Reductions Needed (percentage)	Load Allocations	
	tons/year		tons/year	Percentage of Natural Background
▪ Natural processes	120,000	0	120,000	100
▪ Human actions:				
o Landslides and gullies at road crossings	35,000	78	8,000	6.5
o Channel incision	30,000	78	6,600	5.5
o Gullies	24,000	78	5,300	4.4
o Landslides and gullies at timber harvest lands	23,000	78	5,100	4.2
o Road surface erosion	16,000	78	3,500	3.0
o Surface erosion on rangelands	4,500	78	1,000	0.8
TOTAL	**252,500**		**149,500**	**124.4**
	Current Load	**Estimated Reductions Needed (percentage)**	**Wasteload Alllocations**	
	tons/year		**tons/year**	**Percentage of Natural Background**
Municipal Stormwater NPDES Permit No.CAS612008	300	0	300	0.3
Construction Stormwater NPDES Permit No.CAS000002	150	0	150	0.3
CalTrans Stormwater NPDES Permit No.CAS000003	<50	0	50	0
TOTAL	**500**		**500**	**0.6**

7.4 Margin of Safety

The Clean Water Act, Section 303(d) and associated regulations at 40 CFR § 130.7 require that a TMDL include a margin of safety that takes into account any lack of knowledge concerning the relationship between the pollutant loads and desired receiving water quality. The margin of safety may be employed implicitly by making conservative assumptions (USEPA, 1991). For the Pescadero-Butano watershed TMDL, we employed conservative assumptions in setting the numeric targets for substrate composition (percent fines), and residual pool volume (V*). Attainment of the numeric targets for substrate composition and LWD will involve sediment source reductions (to enhance quality of spawning and rearing habitat), as well as channel restoration actions to enhance the quantity and connectivity of spawning and rearing habitat in the creeks and their tributaries. This will be accomplished through channel restoration projects that will increase the habitat area in riffles, gravel bars, alcoves, and side channels, and the amount of floodplain habitat that is inundated during frequent floods. As such, proposed targets provide additional benefits to salmonids above those required solely to achieve sediment-related water quality standards.

Similarly, an implicit margin of safety for sediment-related water quality standards is also provided through implementation actions recognized to address other key stressors of salmon and steelhead populations in the Pescadero-Butano watershed including actions to protect and/or enhance baseflow, fish passage, and habitat complexity, as described in the implementation plan (Chapter 8). Coupling of sediment reduction and habitat enhancement actions contributes further to the margin of safety.

7.3 Seasonal Variation and Critical Conditions

The TMDL must describe how seasonal variations were considered. Sediment input to channels in the Pescadero-Butano watershed and its effects on beneficial uses are inherently variable on seasonal, annual, and longer timeframes. The TMDL and allocations are designed to apply to the sources and are expressed as a percentage of the natural load.

In the California Coast Range, almost all sediment delivery to channels occurs during the wet season. Although rainfall patterns vary on seasonal, inter-annual, and longer timeframes, review of long-term precipitation data for sites in the watershed indicates that in most years most precipitation occurs between the months of October and April. Sediment input to channels from natural process sources is positively correlated to precipitation volume and/or intensity. Shallow landslide failures whether caused by natural processes or land use activities, typically occur during high intensity precipitation events occurring when the soil is already saturated by previous storms. Sediment delivery to channels from shallow landslide failures in the Pescadero-Butano watershed is low during most wet seasons, and high during very wet years (winter of 1997-1998) and/or during very high intensity storms (e.g., the 1982 storm). Gullies, all of which are associated with land use activities, are typically formed during high intensity storm events at sites where land use activities have intensified peak rates of storm runoff.

Most channel incision and associated bank erosion along Pescadero and Butano creeks occur during large infrequent runoff events (e.g., recurrence intervals greater than 10 years), or in years of average or above normal runoff that immediately follow such events. Other land-use related sources, such as sheetwash erosion associated with agricultural lands or roads, are chronic, in that they occur during the wet season almost every year, with rates being proportional to precipitation.

Critical conditions with regard to flow are addressed through implementation actions to protect or enhance baseflow as described in Chapter 8. Other critical water quality parameters are also addressed by including the target for residual pool volume and water quality objectives for habitat complexity (e.g., an aspect of population and community ecology). In the summer low flow months, some reaches have little flow and pools are critical rearing habitats for steelhead. Pool filling compromises the quality and quantity of that habitat. The recommended habitat enhancement measures to enhance habitat complexity will address both summer (low flow) and winter (high velocity) conditions.

CHAPTER 8 - IMPLEMENTATION PLAN

Key Points

- The implementation plan describes actions to attain water quality objectives for sediment, settleable material, and for population and community ecology.
- Actions to reduce sediment delivery focus on management of roads, grazing areas, agricultural lands, timberlands, and channel incision.
- Sediment delivery from paved and unpaved roads erosion is a problem common to all watershed land use types (e.g., timber, parklands, county roads, rangelands, and agricultural lands).
    - Necessary reductions in sediment delivery from San Mateo county-maintained rural roads and from County parks are proposed to be achieved through the continued implementation of existing NPDES permits that include requirements to control erosion, sedimentation, and hydromodification. These actions will be complimented, as necessary, by waste discharge requirements (WDRs) or a waiver of WDRs.
    - Necessary reductions in sediment delivery from parks and open space districts will be achieved through the implementation of best management practices for maintenance of unpaved roads, survey of stream crossings, and the development and implementation of a plan for replacement and/or repair of high priority sediment reduction and control projects, and through compliance with applicable WDRs or waivers of WDRs.
    - Reductions in sediment delivery from active road networks on timberlands will be accomplished through Water Board review and comment on active timber harvest plans (THPs); however, areas outside the THPs that contain "secondary" infrequently used and abandoned logging roads and skid trails that should be inventoried and treated, can be guided and directed through Water Board regulatory action, as necessary.
- Reductions in sediment delivery to channels from ranch and farm lands can be achieved through implementation of local ranch management programs (e.g., RCD sponsored ranching program), and as necessary, through the issuance of WDRs or a waiver of WDRs.
- Implementation of WDRs or waivers of WDRs to control sediment discharges alone will not be sufficient to protect, remediate, restore, and enhance the Pescadero-Butano watershed given the cumulative impacts of legacy channel disturbances in the watershed.
- To address legacy sediment sources and the effects of channel incision and habitat simplification, a collaborative restoration approach is needed to increase large woody debris in channels and to reconnect the channels to their floodplain in reaches where this is safe and feasible.

8.1 Overview

A TMDL and its implementation plan provide a framework for assessing the watershed condition, identifying the sources of pollution contributing to the water quality impairment, and developing a water quality restoration plan for the watershed to address the impairment. USEPA has recommended that a TMDL implementation plan, which is basically a water quality attainment strategy, include each of the following elements: (USEPA, 1999):

- List of actions needed to achieve pollutant allocations and numeric targets specified by the TMDL, and a schedule, including interim milestones for implementation of those actions
- Reasonable assurances (provided by the state water quality agency) that implementation actions specified in the plan will occur. These include being able to demonstrate that the specified actions will be effective, and that adequate resources will be available to successfully execute the program.
- A description of the legal authority (of local, state, and/or federal government agencies) under which the necessary actions will or could be required
- Monitoring or modeling plan, including milestones for measuring progress, in achieving water quality standards
- Adaptive management plan that includes a schedule for iterative update(s) of the TMDL in response to monitoring or modeling results, and/or other information that is new and relevant to the determination of whether water quality standards have been achieved.

The ultimate vision for the Pescadero-Butano watershed TMDL is the restoration and protection of beneficial uses of the Pescadero and Butano creeks and their tributaries. Therefore, the overarching goals of the Sediment TMDL and Habitat Enhancement Plan are to:

- Conserve and augment steelhead trout populations;
- Restore an annual spawning run of coho salmon;
- Protect and enhance habitat for native aquatic species; and
- Protect and enhance the aesthetic and recreational values of the creek and its tributaries.

To achieve these goals, specific actions are needed to:

- Reduce sediment loads to Pescadero and Butano creeks and their tributaries;
- Re-establish sediment storage in the valley and upper watershed and decrease sedimentation in the lagoon;
- Attain and maintain suitable gravel substrate quality and adequate pool depth in freshwater reaches of Pescadero and Butano creeks and their tributaries; and
- Enhance stream-riparian habitat complexity and connectivity by restoring floodplains, installing large woody debris jams, and enhancing natural wood loading.

As described in Chapter 5 (Source Analysis), significant human-caused sediment sources to the Pescadero and Butano creeks and their tributaries include road-related erosion, channel incision, and surface erosion and gullies. A majority of these sources are the result of multiple direct and indirect historical and ongoing land disturbances. In addition, to resolve sediment-related threats to steelhead and salmon, progress is also needed toward resolution of all other factors e.g., habitat access and habitat complexity that limit steelhead productivity and survival in the watershed.

8.2 Key Considerations Regarding Implementation

Key considerations that may influence implementation actions to resolve sediment impairment in the Pescadero-Butano watershed include the following:

- Due to anthropogenic impacts, total sediment delivery to channels has increased two-times the natural background rate and the overwhelming majority of sediment is derived from non-point sources.
- Total sediment delivery to channels associated with land use activities needs to be reduced by 78 percent in order to meet the proposed targets and allocations for sediment and achieve the TMDL.
- Sedimentation in the lagoon increased by an order of magnitude in the last two centuries and the tidal prism of the lagoon decreased by three quarters. Ongoing sediment delivery to the lagoon is filling the lagoon, and threatens the viability of the steelhead population and impedes the recovery of beneficial uses. Although this TMDL addresses sediment impairment within the channel network upstream of the lagoon and does not include implementation actions specific to the lagoon itself, achievement of this TMDL is a necessary condition to restore water quality and beneficial uses of the lagoon.
- Channel restoration actions in the low gradient stream reaches (downstream of canyons) of Pescadero and Butano creeks, combined with sediment load reductions from management-related hillslope sediment sources (e.g., roads, gully erosion, surface erosion, etc.), are necessary to restore ecosystem functions, abate nuisance flood conditions, attain ambient water quality objectives, and recover beneficial uses.
- The Nonpoint Source Policy (NPS Policy)[50] requires regulation of nonpoint discharges using the Water Board's administrative authorities, including issuance of Waste Discharge Requirements (WDRs) or waivers of WDRs (conditional waivers), adoption of Basin Plan Discharge Prohibitions, or some combination of these.
- The NPS Policy also provides the Water Board with flexibility and discretion in using their administrative permitting tools and encourages the consideration of innovative and creative NPS management programs that recognize local pollution control efforts.
- We support collaborative stewardship efforts that select and implement the most effective and appropriate best management practices to achieve the TMDL.

[50] The policy can be obtained at https://www.waterboards.ca.gov/water_issues/programs/nps/docs/plans_policies/nps_iepolicy.pdf.

- We anticipate relying on the implementation of existing local regulatory requirements and policies (by San Mateo County, open space districts, etc.), and implementation of the rural public works construction and maintenance requirements within the Municipal Regional Stormwater Permit (Order No. R2-2015-0049), to serve as the basis for the control of sediment discharges from the network of county and open space-controlled unpaved and paved roads.
- We will evaluate the performance of existing regulatory programs to control sediment discharges from the watershed road network and develop permits (WDRs or conditional waivers), as necessary, to require sediment control actions specified in the TMDL that are not already being implemented through the enforcement of an existing local/county program.
- Based on a review of previously approved sediment TMDLs for similar California streams, typical timeframes for the development and submittal of management plans to reduce surface and road-related erosion and/or for documenting effective sediment reduction practices are 3 to 5 years following the adoption of the TMDL.
- Similarly, typical timeframes for achieving TMDL allocations and targets are 10 to 20 years following the generation of erosion control and management plans. We recommend a 20-year timeframe to achieve the Pescadero-Butano Sediment TMDL targets.
- We support exploring opportunities to optimize cost effective sediment source reduction actions through the development of sediment source-control stewardships/collectives (groups) that could be administered by local public agencies or other capable and interested groups. Conceptually, such groups might organize around a source category (roads, ranching/cultivation, etc.) and/or subwatershed (e.g., tributary, mainstem channel reach), allowing members to assess and target priorities and the most cost-effective source control actions, for those priorities. Local public agencies, including those with source control responsibilities (e.g., San Mateo County), and those with expertise and experience in erosion control and landowner assistance (e.g., San Mateo County Resource Conservation District and National Resource Conservation Service), may be able to provide leadership, administrative, and technical support for such ventures, should there be interest. Such partnerships would be in favorable positions to receive grant funding from State and federal agencies to support implementation of sediment control actions and would result in significant cost savings to public and private landowners.
- Our proposed sediment allocations are expressed as a percentage of the natural sediment load. Therefore, TMDL effectiveness monitoring will focus on measuring human and natural sources of sediment delivery to channels, and channel response to management and natural events (e.g., V*, percent fines). With this focus, we will be able to rapidly evaluate effectiveness of a variety of management practices implemented to reduce sediment loads, and progress toward attainment of the TMDL. Furthermore, under this approach, human-caused sediment discharges are evaluated within the context of total supply, which is strongly influenced by hydrologic conditions encountered in the monitoring period.
- We expect individual landowners (or those participating in sediment cooperatives or stewardships/partnerships) to perform monitoring to document that implementation actions have occurred (TMDL implementation monitoring). We do not expect individual landowners

however, to perform effectiveness monitoring (e.g., post implementation monitoring of human-caused and natural sediment delivery to channels, and/or channel response to management and natural events). Ideally, such effectiveness monitoring should be coordinated and conducted by an agency or organization with appropriate scientific expertise and demonstrated capability to work effectively with property owners and other interested parties to gain permissions for access, as needed to collect the monitoring data.

- We recommend the TMDL monitoring program include census of steelhead and salmon populations, focused studies to improve understanding of limiting factors, and other relevant biological information. With such information in hand, it may be possible to further prioritize management and restoration actions based on estimated costs and environmental benefits, and/or to adaptively update sediment allocations, numeric targets, and/or schedule for sediment implementation actions.
- We believe there is substantial value in supporting and expanding voluntary participation in reach-based stewardships for tributary streams (for instance Bradley Creek), as well as mainstem creeks, that will work with public agencies to implement projects to achieve significant large-scale enhancements of stream and riparian conditions in the Pescadero-Butano watershed.
- We note that restoration/habitat enhancement project proponents must seek permits from resource agencies in order to work in areas of special status species habitat, which can be a lengthy process. Water Board staff is committed to facilitating restoration projects in the watershed and will work with other permitting entities to help coordinate the permitting process where possible.

8.3 Legal Authorities and Requirements

The Water Board's legal authorities to require water pollution control actions are derived from the State's Porter-Cologne Water Quality Control Act (Porter-Cologne Act or the Water Code) and federal Clean Water Act. The Porter-Cologne Act establishes a comprehensive program to protect water quality and beneficial uses of waters of the State. It gives Water Board the authority to issue waste discharge prohibitions, WDRs and/or waivers of WDRs, to control discharge of pollutants from point-and-nonpoint sources into the waters of the state (Water Code 13000 et seq.).

In 2004, the State adopted the NPS Policy, a policy for implementation and enforcement of its nonpoint source pollution control program, which requires regulation of all nonpoint pollution sources that could affect water quality with WDRs, waivers of WDRs, and/or waste discharge prohibitions (Water Code Section 13369). Given the extent and diversity of nonpoint source discharges, the NPS Policy provides guidelines for the development of third-party nonpoint source control programs. A primary advantage of these locally administered water quality protection programs is their ability to reach multiple numbers of dischargers who individually may be unknown to the Water Board. Furthermore, third-party programs may facilitate eligibility for waivers and grants, and hence, provide a more attractive venue for achieving compliance with the TMDL and the State's NPS program.

8.4. Approaches to Achieve Allocations

The sediment TMDL implementation plan described below is developed around each major source category including agriculture, ranching, paved and unpaved road networks, timber harvesting, and channel incision. Actions required to minimize and control unpaved road erosion are common to all land use types in the watershed. Other aspects of the required sediment reductions are somewhat unique to the specific land uses in the watershed. The proposed approach towards achieving the sediment allocations relies on the continued implementation, and in some instances, expansion of local and county regulatory policies and plans and efforts, augmented, as needed, with the development of regulatory discharge programs administered by the State.

Agriculture

Based on acreages presented in the Department of Conservation Farmland Mapping and Monitoring Program (FMMP) for San Mateo County for 2016, there are 1,006 acres of farmland in the watershed, compromising approximately 2 percent of the land use. It is not a dominant land use type. Approximately 55 percent of agricultural land use takes place on the valley floor on slopes with less than 5 percent grade, while there is some limited farming on slopes steeper than 30 percent grade. Most notable examples of steeper farming can be found at or near the top of Bradley Creek watershed and towards the northeast quadrant of the watershed where some vineyards have been developed.

Farmlands of 5 acres or greater will be required to plan, prioritize, and implement sediment management actions. Farmlands of less than 5 acres are not required to take action under the TMDL.

Sediment delivery to the channels due to surface erosion in farmlands is small: much less than 500 tons/year. Therefore, farmlands are not required to implement sediment management actions to reduce **surface erosion**. There may be exceptions where such lands are delivering a significant amount of surface sediment discharges to the channels (e.g., due to poor agricultural practices on steep lands). Farmlands of five acres or greater are required to meet performance standards for other sediment sources (e.g., road-related erosion, gully erosion).

Through the implementation of a local regulatory program; voluntary watershed efforts (e.g., stewardship program, third party advisory program); Water Board issuance of sediment control requirements to be contained in future permits (WDRs/conditional waivers); or some combination of these efforts (Table 17), we expect owners and/or operators of farmlands of 5 acres or greater to:

1. Inventory and assess the natural resources and agricultural practices through a planning and prioritization process that documents all sediment discharge sources and evaluates stream and river riparian corridor and receiving water body condition within three years of the Basin Plan Amendment's effective date;
2. Inventory and evaluate the performance of all best management practices (BMPs) being implemented to control sediment discharges from the planted area;
3. Inspect the points of surface water discharge from the farm for signs of erosion of the bed and bank of the receiving channel;

4. Identify where changes to management practices, and/or, additional BMPs are needed to control surface erosion from the farm and at points of surface water discharge that exhibit signs of receiving water erosion;
5. Complete an assessment of unpaved road condition on the property and evaluate current management and maintenance methods to control excessive road-related erosion;
6. Develop an implementation schedule for actions and improvements identified during the farm planning (site inventory) and roads assessment; and
7. Implement the identified management practices or repairs per the schedule developed by the planning process.

The level of detail involved in implementation actions will be commensurate with the farm's size, crop, and accounting for its erosion potential and complexity (steepness, soil type, etc.).

Ideally, landowners will work with the local resource conservation district to develop and implement a program of sediment reduction control actions that achieves the sediment delivery reduction requirements by meeting performance measures. Sediment delivery reductions from farms can generally be achieved through maintaining a stream and riparian setback and buffer, similar to the voluntary water quality protection requirements proposed by the Coalition of Central Coast County Farm Bureaus, requirements imposed by Peninsula Open Space Trust (POST) on lands leased back to farmers, and, in some instances, managing farming practices on steeper slopes through implementation of wet season, no-till, or crop planting practices.

Such programs could be incentive-based and/or voluntary, and would ensure compliance with State and federal water quality laws, federal Endangered Species Act, pesticide regulations, and local regulations. We propose the development of third-party certifications that address water quality and habitat protection that contain the key elements of the NPS Enforcement Policy. Owners and operators of agricultural lands who are already implementing sediment control BMPs that protect creeks and riparian areas would continue their good stewardship and document these efforts to demonstrate compliance. Those who currently do not have sediment control BMPs in place, or need to enhance current control and management measures, will be required to develop a plan and schedule to implement adequate BMPs within the TMDL's implementation timeframe.

If existing policies and local efforts are not sufficient to address farm-related erosion, control of discharges may be addressed through a waiver of WDRs or WDRs, for discharges from agricultural lands (Agricultural Discharge Permit). Permit details, including the compliance schedule and appropriate management practices, would be determined during the permit development process, which would include stakeholder participation. The goal of the Agricultural Discharge Permit would be to build off existing local efforts to control sediment delivery from the farmed area and supporting unpaved road network. Criteria for applicability may include the size of the farmed area, slope, farm practices, and/or proximity and connectivity of the farm operation to stream channels, or other measures relevant to the discharge of sediment, including the early implementation of water quality protective practices (e.g., vegetated buffer strip, no till, wet season erosion control strategies, etc.). Information collected as part of this TMDL (see the Sediment Source Analysis) may be helpful in determining such criteria or in prioritization efforts.

Livestock Grazing

Based on acreages presented in the Department of Conservation Farmland Mapping and Monitoring Program for San Mateo County for 2016, 7,960 acres are in grazing land use in the watershed. Poorly managed livestock grazing, on even a small operation, can accelerate sediment loss and delivery from rangelands to receiving waters. Concentrated in a small area, livestock can completely denude the soil surface, exposing it to sheet and rill erosion processes, which can move a significant volume of soil downslope. The weight of the animals can compact the soil, which in turn increases the speed of runoff and can activate and accelerate gully and streambank erosion. In addition to sediment, discharges from grazing lands are also sources of nutrients and pathogens to receiving waters.

For grazing lands[51], we define a minimum threshold of 50 acres that triggers the requirement to plan, prioritize, and implement sediment management actions. Grazing lands of less than 50 acres are not required to take action under the TMDL.

Effective means of reducing sheetwash and gully erosion on ranch lands could involve adopting livestock and/or range management practices that result in sufficient plant material being left on the ground to effectively resist sheetwash erosion. One such approach that has been successfully applied to control soil erosion and nutrient losses at many rangeland sites in California is to manage grazing so as to maintain adequate residual dry matter on pasture lands. Residual dry matter (RDM) is defined as “the old plant material left standing or on the ground at the beginning of a new growing season” (University of California, 2002). Other effective sediment erosion control measures that could also accelerate natural recovery of gullies and landslides include the installation of temporary or permanent exclusion fencing to keep livestock out of creeks and away from creek banks, planting of native woody vegetation, diversion or dispersion of concentrated runoff originating from roads, modification of grazing strategies, densities, and locations, and the construction of alternative water supplies for livestock. The Natural Resource Conservation Service Field Office Technical Guide provides guidance on selection and implementation of these management practices.

The Water Board anticipates developing WDRs or waivers of WDRs for discharges from grazing lands that are 50 acres or greater, which would require the control of sediment discharges (Grazing Permit) (Table 18). Within the Pescadero-Butano watershed, there are approximately 7,960 acres of grazing lands. The details of a Grazing Permit, including the compliance schedule and appropriate management practices, would be determined during permit development, which would include participation and input from local stakeholders. Achievement of sediment reductions for farm and grazing land can be met through maintaining stream and riparian setbacks, maintaining appropriate levels of residual forage and crop residue to reduce surface soil erosion, and to minimize gully erosion, both cultivation and grazing should be kept at relatively low intensities on steeper slopes. Criteria for permit applicability, such as qualifying parcel and herd sizes, parcel slope, etc., would be determined during permit development and would consider the information contained in the sediment budget (Chapter 5).

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[51] Grazing lands are defined as all lands grazed by livestock, including ranchlands, riparian areas, and pasturelands.

Since 2008, the Water Board has implemented a rangeland program for the control of discharges from grazing lands in the Tomales Bay, Napa River, and Sonoma Creek watersheds, as part of implementing sediment, pathogen, and mercury TMDLs completed for these watersheds (North Bay Grazing Waivers). Therefore, regulatory options for grazing management in the Pescadero-Butano watershed include extending the geographic scope of the existing grazing programs to include the Pescadero-Butano watershed, or developing a new program specific to the Pescadero-Butano watershed.

Based on available information and experience gained from implementing the North Bay Grazing Waivers and in keeping with NPS Policy and the Water Code, the Pescadero-Butano Grazing Permit may require owners or operators of grazing lands to:

1. Complete a comprehensive inventory and assessment of natural resources, rangelands, and management practices through a ranch plan assessment process. This includes documenting all sediment sources and evaluating stream and river riparian corridors and water bodies.
2. Inventory and assess all BMPs being implemented to control erosion including: animal fencing, providing off-stream water sources, maintaining adequate amounts of residual dry matter (RDM), winterization practices (such as densely seeding field roads), and practices/management measures in place to reduce gully erosion through animal fencing and/or adjusting animal stocking densities on steeper slopes prone to gully erosion.
3. Identify where changes to management practices are necessary to control erosion, or where new or additional BMPs are needed.
4. Complete an assessment of unpaved road condition on the property and evaluate current management and maintenance methods to control excessive road-related erosion.
5. Develop an implementation schedule for actions identified during the farm planning (site inventory) and roads assessment.

Ranch owners or operators could work with local conservation agency staff to develop and implement a program that achieves the sediment control actions, or requirements, described immediately above. As noted above, the Water Board supports the development of locally administered third-party certifications that address water quality and habitat protection and recognizing such efforts in the management of discharges from grazing lands. Owners and operators of agricultural lands who are already implementing sediment control BMPs that protect creeks and riparian areas would continue their good stewardship and document these efforts.

If locally administered grazing-related programs are not adequate to address the sediment impairment, WDRs or waivers of WDRs may be developed. If WDRs or waivers of WDRs are developed, those ranchers who have already completed a ranch inventory planning process would not be required to duplicate efforts, but would amend or supplement their existing ranch plan, if needed to comply with permit conditions. Those ranches without sediment control BMPs, or those who need to enhance current control and management measures, would be required to develop a plan and schedule to implement adequate BMPs within the specified implementation timeframe. TomKat Ranch, in Pescadero, is an example of a working livestock farm that incorporates into their operation the preparation of an annual grazing plan designed to achieve the conservation goals of the Ranch. Goals include avoiding the creation of bare ground, increasing cover of native perennial grass, and protecting habitat for grassland nesting birds, or other species and sensitive habitats.

Even if WDRs or waivers of WDRs are developed, locally administered water quality protection programs may facilitate eligibility for landowners to qualify for waivers, and hence a more attractive venue for achieving compliance with the TMDL and the State's NPS Policy. Water Board staff would continue to collaborate with staff of the University of California Cooperative Extension (UCCE), NRCS, and/or RCD during permit development and implementation. Water Board staff is also interested in partnering with one or more of these organizations and/or a rancher member organization to pursue grants to offset costs for the development and implementation of ranch plans and funding to address legacy sediment sources, gullies and landslides caused by intensive historical grazing and/or active or abandoned roads and/or other human structures such as channel incision and/or gullies downstream of stock ponds, etc.

Roads

Roads are a major source of erosion and sedimentation on most managed forest and ranch lands (Weaver et al., 2014). Compacted road surfaces can increase the rate of runoff, and road cuts can intercept and bring groundwater to the surface, affecting drainage and road stability. Ditches concentrate storm runoff, can transport sediment to nearby stream channels, and cause and contribute to significant gully erosion. Culverted stream crossings can plug, causing erosion where the diverted streamflow runs down nearby roads and hillslopes. Roads built on steep or unstable slopes can trigger landslides, which deposits sediment in stream channels. Lack of inspection and maintenance of drainage structures and unstable road fills along old or abandoned roads, such as those found within the timberland areas and parks (San Mateo County, State, and Open Space Districts) within the watershed, can also result in soil movement and sediment delivery to stream channels.

Roads and their associated drainage systems are typically interconnected with natural streams and drainages. The degree of connectivity between roads and stream channels is a significant consideration to understand sediment contribution from road erosion. This degree of connectivity is typically characterized as the length or percent of the road that drains to streams during a runoff event. These roads and segments are termed "hydrologically connected roads". Weaver et al. (2014) noted that using simple road drainage techniques, connectivity can usually be reduced to 10-15 percent. The implementation plan limits the length of roads that are hydrologically connected to 25 percent of total road length for all roads in the watershed.

There are approximately 395 miles of roads in the Pescadero-Butano watershed, of which 325 miles are unpaved and 70 miles are paved (ESA, 2004). The hydrologic connectivity of roads in the watershed was estimated as 45 percent (ESA [2004], using PWA [2003] assessment of roads in the San Mateo County Parks). There are approximately 1,400 crossings. Not including trails and driveways, the density of roads in the Pescadero-Butano watershed is approximately 4.9 mi/mi^2.

The total amount of road-related erosion in the Pescadero-Butano watershed is **51,000 tons/year (41,800 CY/year)** and constitutes 35 percent of human-caused sediment delivery. The TMDL proposes 78 percent reductions in road-related erosion and allocates approximately 11,500 tons/year (9,400 CY/year). Over the 20-year timeline and applied to the approximate total of 395 miles in the watershed, this translates into a maximum total of 500 CY/mi, which the Water Board set as a performance standard for the unpaved roads in all land uses.

Many aspects of road erosion-control projects can make them attractive to public agencies that award grants for water quality and/or habitat enhancement. In comparison to other significant human-caused sediment sources, erosion control and prevention actions for earth surfaced roads may be one of the most cost effective sediment sources to control within the Pescadero-Butano watershed. In addition, strategic investments to control future road erosion pay significant dividends to property owners in terms of large reductions in maintenance and/or repair costs.

Because a large proportion of the total length of roads in the watershed is privately owned and earth surfaced, there may be several advantages to local governmental agencies and private landowners exploring the possibility of entering into sediment control cooperatives to reduce road-related erosion in a way that also substantially reduces costs and burdens to both agencies and landowners. By working together within a larger group, landowner costs for road erosion inventories and execution of control actions could be substantially reduced because of the economies of scale. By comparison, individual private landowners would be less likely to obtain grants, and potential problems associated with run-on from adjacent properties (that are causing road-erosion) will be difficult to resolve without cooperation across property boundaries. A cooperative could also benefit from the involvement of the RCD and/or NRCS to provide professional expertise in erosion control and landowner assistance. To this end, we strongly support providing several potential incentives to road sediment control cooperative partnerships including prioritization of such efforts for grant funding.

Old Haul Road

The Old Haul Road is a significant concern for road-related sediment delivery. It is an 8-mile-long road on the south side of Pescadero Creek through the Pescadero Creek County Park (5.7 miles) and RedTree Partners (2.3 miles) (historically Santa Cruz Lumber Co.). It was built in the late 1920s through 1930s as a timber hauling rail and truck road to transport saw logs to a Santa Cruz Lumber Company mill located at Waterman Gap. Currently the Old Haul Road is a major access route within the County Park providing important recreation, maintenance, and fire access (Figure 40. Old Haul Road).

The Old Haul Road was constructed in a way to keep the railroad alignment on contour and at a relatively even grade. Massive log and fill structures (Humboldt crossings) were built where the road crosses tributaries to Pescadero Creek draining Butano Ridge. There are significant amounts of sediment and woody debris deposited along tributaries upstream of the road. The principle concern along the Old Haul Road is the stability of the creek crossings. Failure of a creek crossing due to fluvial erosion would result in enormous amounts of sediment delivered to Pescadero Creek. In addition, a significant portion of the road, approximately two thirds (3.8 miles), is hydrologically connected and is actively delivering runoff and sediment directly to channels. The Old Haul Road blocks fourteen major Pescadero Creek tributaries that deliver cobble-boulder substrate, which is important for aquatic habitat.

PWA (2003) and Best (2015) assessed the condition of the Old Haul Road along the Pescadero Creek County Park to identify sediment sources, to make recommendations, and to prioritize treatment alternatives[52]. The estimated potential future erosion and sediment delivery range between 70,000 and 85,000 tons (57,000 and 70,000 CY) from unstable sites at stream crossings if erosion prevention measures are not undertaken. Both assessments emphasize the importance of addressing a few very large log and fill crossings that incorporate crib logs that are in varying states of decay and at risk for failure (e.g. Dark Gulch and Carriger Creek). The fill (and therefore, the potential future sediment delivery) at these two sites were estimated to range between 50,000 and 60,000 tons (~40,000 and 50,000 CY) comprising three quarters of the total potential future sediment delivery from the Old Haul Road. PWA (2003) also estimated the average rate of surface lowering on cutbanks and along 3.8 miles of connected road segments, which currently drain directly to stream channels. This chronic surface erosion rate was estimated as 13,000 tons (10,400 CY) or 3,345 tons/mile (2,735 CY/mile). This rate is more than an order of magnitude larger than other unpaved roads in the watershed. Best (2015) estimated an average annual sediment delivery rate of 18,000 tons (15,000 CY) along the Old Haul Road by integrating a chronic road drainage-related erosion estimate and a risk-based approach for how fast crib log crossings will degrade in the next twenty years.

Based on these studies and their estimates for both chronic surface erosion and potential future sediment delivery at crossings, Water Board staff concludes that the risk of failure of crossings along the Old Haul Road is very high and resulting sediment delivery amounts would be substantial and potentially damage fish habitat. The implementation plan highlights the Old Haul Road specifically to identify stream crossing improvements and storm-proofing along the road as a high priority for the responsible parties to address.

San Mateo County Roads

We acknowledge San Mateo County's inspections and maintenance of roads within its jurisdiction. In addition, San Mateo County has directed road erosion inventories (PWA, 2003; Best, 2015), and fish passage assessments of its road crossings (Ross Taylor & Associates, 2004).

Currently, construction and maintenance of San Mateo County rural roads and public works projects within the watershed are subject to provision C.2.e (Public Works Construction and Maintenance) of NPDES No. CAS612008 (also referred to as the Municipal Regional Stormwater Permit (Order No. R2-2015-0049)). The permit requires San Mateo County to adopt and implement road maintenance guidelines to protect aquatic habitat, water quality, and salmonids fisheries; conduct an annual training program for road maintenance staff, and report annually on the implementation of and compliance with

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[52] PWA (2003) inventoried 5.7 miles of the Old Haul Road, identified a total of 45 sites (21 stream crossings, of which 3 are log and fill crossings) with sediment delivery potential, and estimated a potential future sediment delivery of 67,000 tons (55,000 CY) if sites are left untreated. PWA also reported that the 1998 El Nino storms caused approximately 21,200 tons (17,350 CY) of erosion and sediment delivery to Pescadero Creek and its tributaries from four sites along the Old Haul Road.

Best (2015) evaluated the erosion potential along 4.2 miles of Old Haul Road and stated that the most significant features along the road are eight large crib log crossings that are in varying states of decay and at risk for failure. The volume of crossing fill at Dark Gulch is measured at over 36,500 tons (30,000 CY) with fill exceeding 65 feet in depth. Best (2015) estimated that the fill volume Dark Gulch and Carriger Creek comprises more than 70 percent of the total potential future sediment delivery.

BMPs for rural roads construction and maintenance, including reporting on increased maintenance in priority areas. The permit requires its permittees, including San Mateo County, to minimize impacts on streams and wetlands in the course of rural road and public works maintenance and construction activities:

1. Road design, construction, and maintenance, and repairs in rural areas that prevent and control road-related erosion and sediment transport;
2. Identification and prioritization of rural road maintenance on the basis of soil erosion potential, slope steepness, and stream habitat resources;
3. Construction of roads and culverts that do not impact creek functions.
4. Implementation of an inspection program to maintain rural roads' structural integrity and prevent impacts to surface water;
5. Maintenance of rural roads adjacent to streams and riparian habitat to reduce erosion, replace damaging shot-gun culverts, and address excessive erosion;
6. Re-grading of unpaved rural roads to slope outward where consistent with safety standards, and installation of water bars, where appropriate; and
7. Replacement of existing culverts or design of new culverts or bridge crossings to reduce erosion, provide fish passage, and to maintain natural stream geomorphology in a stable manner.

While the NPDES permit applies to rural public works construction and maintenance activities, it may not address excessive sediment delivery from the entire County-controlled paved and unpaved rural road network. If warranted, the control of excessive sediment discharges from existing County roads will be compelled by the Water Board through a regulatory action, either through the issuance of WDRs or waivers of WDRs, to implement the road performance standards for County-controlled paved and unpaved roads (see Table 19).

The regulatory action would require the County to complete a roads assessment, including a survey of stream crossings associated with paved public roads, and to develop a prioritized implementation plan for the repair or replacement of high priority crossings/culverts to reduce road related erosion. For unpaved roads, the assessment would evaluate the degree of hydrologic connection between the road and receiving waters, surface erosion from the road surface, and stormwater drainage features such as inboard ditches, and it would include an assessment of culverts and crossings. The regulatory action would require a schedule to implement any identified sediment control measures and may include requirements to "storm-proof" roads. Storm-proofing can significantly reduce sediment delivery from roads by addressing: 1) road surface drainage (e.g., roads are hydrologically disconnected from stream channels); 2) stream crossings; and 3) unstable fill slopes (i.e., unstable fills slopes are treated to minimize sediment delivery and flow is directed away from unstable slopes).

State Highways Stormwater Program

California Department of Transportation (Caltrans) is responsible for runoff from State highways and associated construction activities. Discharges from State highways are regulated via a Statewide stormwater permit issued to Caltrans. Caltrans' responsibility under this TMDL is limited to the section of State Highway 35 and State Highway 9 draining to and/or forming the eastern watershed boundary.

Parks and Open Space Roads

For open space districts and State Park roads, Water Board staff will consider a regulatory action, such as the issuance of WDRs or a waiver of WDRs, to implement the road-related performance standard to control sediment discharges from paved and unpaved roads (see Table 20). The regulatory action is similar to what is proposed above for San Mateo County roads and would rely on a road inventory, conditions assessment, prioritization to retrofit or replace, and time schedule to implement identified sediment control measures.

CHARACTERISTICS OF STORM-PROOFED ROADS

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year flood flow (including woody debris and sediment).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Culvert inlets have low plug potential (trash barriers or deflectors are installed where needed).
- Culverts are installed at the base of the fill and in line with the natural channel.
- Any existing culverts or new emergency overflow culverts that emerge higher in the fill have full round, anchored downspouts that extend to the natural channel.
- Stream crossing culvert outlets are protected from erosion (extend culverts at least 6 feet beyond the base of the fill and use energy dissipation, where needed).
- Culvert inlet, outlet and bottom are open and in sound condition.
- Deep fills (deeper than a backhoe can reach from the roadbed) with undersized culverts or culverts with high plugging potential are fitted with an emergency overflow culvert.
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Stream crossing fills are stable (unstable fills are removed or stabilized).
- Approaching road surfaces and ditches are "disconnected" from streams and stream crossing culverts to the maximum extent feasible using road shaping and road drainage structures.
- Class I (fish-bearing) crossings meet State Fish and Wildlife and National Marine Fisheries Service fish passage criteria.
- Decommissioned stream crossings are excavated to exhume the original, stable, stream bed and channel sideslopes, and then stabilized with mulch and vegetation.

Storm-proofed road and landing fills

- Unstable and potentially unstable road and landing fills that could deliver sediment to a stream are excavated (removed) or structurally stabilized.
- Excavated spoil is placed in locations where eroded material will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Storm-proofed road surface drainage

- Road surfaces and ditches are hydrologically "disconnected" from streams and stream crossing culverts. Road surface runoff is dispersed, rather than collected and concentrated.
- Ditches are drained frequently by functional ditch relief culverts, rolling dips or cross road drains.
- Outflow from ditch relief culverts does not discharge to streams.
- Ditch relief culverts with gullies that deliver to a stream are removed or dewatered.
- Ditch and road surface drainage does not discharge (through culverts, rolling dips or other cross drains) onto active or potential landslides.
- Decommissioned roads have permanent drainage and do not rely on ditches.
- Fine sediment contributions from roads, cutbanks and ditches are minimized by utilizing seasonal closures and installing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping or crowning), rolling dips, ditch relief culverts, waterbars and other measures to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

Gullies and Surface Erosion

Gullies and surface erosion account for over 20 percent of the human-caused sediment delivery to channels and are the result of:

1. Natural processes;
2. Legacy land use disturbances (e.g., intensive historical grazing, agriculture, and logging); and
3. Active/ongoing land uses, including poorly-designed roads that concentrate storm runoff and continued active grazing in and around active or dormant gullies and landslides.

The regulatory actions proposed for farm and ranch lands and unpaved roads will be effective in achieving the TMDL load allocations for gullies and surface erosion.

On properties of 50 acres or greater where livestock grazing is active, reductions in sediment delivery from actively eroding gullies and landslides can be accomplished through the application of best management practices (

Table **18**) to: a) achieve targets for residual dry matter; b) restrict animal grazing from active or potentially active landslides and gullies; c) redirect culverts and managed drainages away from gullies or gully-prone areas; and d) stabilize actively eroding gullies and/or shallow landslides through implementation of best management practices, and/or, reshaping and resurfacing.

Timber Harvest Lands

NOAA has stated that timber harvest remains a threat to steelhead habitat in the Pescadero-Butano watershed (to a lesser degree when compared to historical practices) (NMFS, 2015). Timber harvest is identified as a threat for the winter rearing requirements for coho salmon due to potential increases in turbidity during the wet weather period and the potential for lost trees that could be recruited into the channel if they were not harvested.

Timber harvest activities occur on private lands in the Pescadero-Butano watershed over approximately 20 percent of the watershed area (~ 11,000 acres). Timber harvesting activities with the greatest potential to impact waters of the State include: felling, yarding, and hauling of trees; road construction and reconstruction; and watercourse crossing construction, reconstruction, or removal. Excessive alteration of vegetation, soil erosion, and sediment delivery associated with these activities can impact the beneficial uses of water by: 1) causing sedimentation in fish spawning habitats; 2) filling in pools, creating shallower, wider, and warmer streams, and increasing downstream flooding; 3) creating unstable channels; 4) losing riparian habitat and function; and 5) clogging water intakes. Timber harvesting in the riparian zone can also adversely affect stream temperatures by removing stream shading, which is especially important for maintaining cold water beneficial uses.

Timber harvesting on private lands in California is regulated under the California Forest Practice Rules by the lead agency, Department of Forestry and Fire Protection (CalFire).[53] In watersheds with listed

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[53] The Board of Forestry is mandated by Public Resources Code (PRC) 4562.7 to "Adopt rules for control of timber operations which will result or threaten to result in unreasonable effects on the beneficial uses of the waters of

anadromous species, such as Pescadero-Butano, Anadromous Salmonid Protection rules[54] apply. In addition, revised Road Rules (CDF, 2013), adopted in 2014 by the Board of Forestry and Fire Protection, improve upon existing protections of water courses from the potentially adverse impacts of timber harvesting, associated roads, landings, and watercourse crossings. The State Water Board, State Board of Forestry, and CalFire entered into a Management Agency Agreement (MAA) in 1988 for overseeing water quality protection on Timber Harvest Plan (THP). Under the MAA, the Water Board is a responsible agency and plays an advisory role.

The Water Board maintains two active roles in the review of THPs, Non-industrial Timber Management Plans (NTMPs), and other commercial timber harvest projects on private lands as follows:

1. The Water Board may issue WDRs and waivers of WDRs, which establish conditions or requirements to control discharges of waste to waters of the State. Discharges associated with timber harvesting activities typically include sediment from erosion and/or increased water temperature from loss of riparian canopy.
2. As a member of the CalFire Review Team, the Water Board also participates in pre-harvest inspections and submits comments and recommendations to CalFire to protect water quality and to avoid violations of the Basin Plan and Porter-Cologne through the CalFire THP review process.

The Forest Practice Rules require the submission and approval of a THP prior to starting most timber operations. Once a THP is submitted to CalFire, Water Board staff review the plan as a "Review Team" member, along with the California Department of Fish and Wildlife, California Geological Survey, and CalFire. Consensus on site-specific water quality measures are developed through the THP multi-agency review team process, which allows each agency stakeholder to evaluate proposed THPs on a site-by-site basis to protect salmonid habitat from excessive sedimentation and to minimize changes to riparian ecosystems from road-related mass wasting.

Existing regulations in the Forest Practice Anadromous Salmonid Protection rules include specific BMPs for timber harvest sites for implementation of management measures for the control of sediment, canopy, and large wood recruitment impacts. The management measures outlined in these regulations address:

- Identification and treatment of existing sediment discharge sources;
- Measures designed to prevent new discharge sources;
- Long-term uneven age management of timber;
- The establishment of adequate riparian protection zones; and

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the state." (http://www.bof.fire.ca.gov/about_the_board/board_mandate/). The counties of San Mateo, Santa Cruz, and Santa Clara petitioned the Board of Forestry to make changes to Forest Practice Rules, which resulted in the formation of "County Rules" in the Southern Sub-District of the Coast District.

[54] In 2010, the Board of Forestry passed a comprehensive set of rule changes concerning stream protection measures in the Coastal Anadromy Zone. The 2010 set of rules changes, commonly referred to as the Anadromous Salmonid Protection rules (ASP), resulted in further delineation of stream protection zones and more adaptive practices aimed at improving conditions along salmonid-bearing streams.

- Adequate retention of riparian canopy;

Water Board staff may recommend additional site-specific protection measures such as riparian buffer zones prior to approval of NTMPs or THPs by CalFire to address potential impacts to the beneficial uses of water. For THPs, the Water Board will likely increase staff presence at Pre-Harvest Inspections where Class I and Class II watercourses are affected by road crossings, or by significant harvest operations. The Water Board may also conduct post-harvest inspections three to five years after harvest on these same watercourses, as necessary.

While the Water Board reviews active THPs, discharges of sediment to channels from paved or unpaved roads, and abandoned skid trails that fall outside the active THP remain a concern. To ensure that effective sediment source controls are implemented on all roads, Water Board staff recommends that WDRs or waivers of WDRs be developed to achieve the road sediment delivery performance standards (Table 21). Timberlands of 100 acres or greater would be required to plan, prioritize, and implement sediment management actions. Timberlands of less than 100 acres are not required to take action under the TMDL. As described for the road source category above, permit actions would require owners and operators of roads to conduct an inventory of their unpaved road network to identify poorly functioning roads (i.e., sediment delivery sites), and produce a schedule for treatment to reduce erosion, as needed to achieve the sediment delivery performance standard within the timeframe identified in the TMDL.

Channel Incision and Bank Erosion

Channel incision and associated bank erosion has been a large human-caused sediment source in the Pescadero-Butano watershed in the last forty years. Water Board staff estimated an average sediment supply rate due to channel incision of approximately 30,000 tons/year, which contributes approximately one fifth of the total sediment supply to channels. However, the overall impact of channel incision to the sediment budget is considerably larger due to the loss of sediment storage function along channelized and incised reaches. Under natural conditions, more than 30,000 tons/year of sediment, or approximately 30 percent of the total sediment is delivered to channels, deposited on the floodplains and interconnected alluvial fans. This storage function has been lost, therefore, channel incision contributes a total of 60,000 tons/year of sediment to downstream reaches and to the Pescadero lagoon and marsh.

Channel incision greatly increases sediment transport rates, degrades channel habitat complexity, and disconnects the channel from the floodplain. Field reconnaissance indicates that channel incision rates along Pescadero and Butano creeks appear to have slowed down in the last decade; however, the tributaries in the upper watersheds may still be incising to adjust to the base level change. In alluvial systems, bed degradation is typically followed by widening and then filling: once channels incise and the banks become unstable, bank erosion follows. Therefore, it is expected that in the future channel erosion will continue to deliver significant amounts of sediment to the channels in the watershed.

With incision and less LWD in the channels, pool habitat has been degraded (i.e., pool frequency, depth, and cover have been significantly reduced), and sub-reaches with uniform beds and no complexity to provide spawning or rearing habitat are now more common. Also, as incision has progressed, channels have become much narrower, inhibiting deposition/formation of gravel bars and inset floodplains. Therefore, bank erosion and resultant channel widening (in narrow incised reaches) is a necessary ingredient to support recovery/restoration of complex channel habitat and the formation of an inset floodplain. For these reasons, bank erosion should not automatically be considered a threat to buildings or other critical infrastructure in most locations (where buildings and roads are located far enough away, such that future predicted widening would not be a threat) and should be allowed to evolve without intervention, where possible, to widen the channels toward more complex processes and habitat.

This Implementation Plan does not require channel and/or floodplain restoration to resolve adverse ecological and water quality impacts of channel incision for the following reasons:

- Channel incision problems along Pescadero and Butano creeks and their lower tributary reaches reflect and integrate multiple historic and ongoing disturbances, some of which are local and/or direct and others that are indirect and distal. In this sense, with the exception of an individual who owns property on both sides of the river over a very long distance, it is not possible for an individual to effectively control or be responsible for the channel incision that may be taking place on his or her property.
- An effective program to control channel incision in a way that enhances habitat for fish and aquatic species will require cooperative and coordinated actions by multiple landowners over significant distances across the watershed.

However, we also would like to emphasize that sediment impairment will likely not be eliminated and an appreciable improvement in habitat conditions will not be realized until the majority of impacts of channel incision are addressed. The following sections (Floodplain Restoration and Wood in Channels) further detail opportunities to restore habitat complexity and connectivity and to reverse incision trends in the watershed.

Floodplain Restoration

Floodplains, including alcoves and side channels, provide essential winter rearing and refuge habitats for coho salmon (Bustard and Narver, 1975; Nickelson et al., 1992a and b; Tschaplinski and Hartman, 1983). Floodplain loss is thought to be a primary factor in the decline of coho salmon populations throughout the Pacific Coastal Ecoregion (Nickelson et al., 1992a; Beechie et al., 2001; Giannico and Hinch, 2003) and locally in the Pescadero-Butano watershed (NMFS, 2012) where the coho salmon population is extirpated. Floodplains also provide winter rearing and refuge habitat for juvenile steelhead (Swales and Levings, 1989; Solazzi et al., 2000) and essential habitat for many other native fish and wildlife species within the wet season and throughout the year.

Within the watershed, a suite of historical and/or ongoing land use activities have caused channels to become deeply incised, such that historical floodplains have been isolated and cut off from the channels and are rarely inundated, even during extreme high flows. Butano Creek channel, for instance, is so incised that the 100-year flow is contained within the existing channel along the reach from Cloverdale Road to three mile downstream (CBEC, 2014).

Floodplain restoration opportunities within the Pescadero-Butano watershed are geographically limited to the alluvial fan and wet meadow reaches (Figure 28 and 29) with slopes that are less than 3 percent and which are located downstream of the USGS gauging station on Pescadero Creek and downstream of Cloverdale Road along Butano Creek.

Once channels have incised, there are essentially four approaches that can be employed to re-establish connection to floodplains:

1. Grade control and natural sediment deposition to aggrade the channel;
2. Grade control and earth moving to aggrade the channel;
3. Passive restoration of an inset floodplain via bank erosion and channel widening; and
4. Active restoration of an inset floodplain via earthmoving and biotechnical engineering.

Approaches 1 and 2 reconnect the channel to its historical/former floodplain by re-establishing its former bed elevation. Approaches 3 and 4 create a new floodplain at a lower elevation, and the width of the inset floodplain is typically much narrower than the former/historical floodplain because the inset floodplain is nested within and confined by the higher and wider historical floodplain.

Approaches 1 and 3 typically require several decades or more to re-establish the connection between the channel and floodplain (Beechie et al., 2008). Also, Approach 1 is premised on sufficiency of sediment supply, which is the case in Pescadero-Butano watershed.

Approaches 2 and 4 are much more expensive because they involve significant earth moving and import and/or export of fill. These approaches have the advantage, however, of immediately reconnecting the channel to its floodplain and of being feasible in many locations throughout the channel network.

Grade control, associated with Approaches 1 and 2, can be accomplished using engineered log jams (typically steps or valley jams, see Abbe et al., 2003) and/or by construction of biotechnical (boulder steps) or traditional engineering structures.

In addition to substantial enhancement of habitat complexity and connectivity for coho salmon, steelhead, and other native fishes, floodplain restoration also would increase sediment storage and substantially reduce shear stress on the channel bed during large floods. The sediment storage benefits associated with floodplain restoration would not be limited just to water quality restoration, but also could be significant with regard to carbon sequestration. Under natural conditions, floodplains likely stored one-third-or-more of the sediment supplied to fish-bearing channels (Sections 4 and 5). In addition, the floodplains provide sites for growth of massive long-lived coast redwood and Douglas fir, and then contribute large fallen trees that trap much of the coarse and fine woody material that is transported in the channels. As such, it is possible there might be additional interest and potential funding for floodplain restoration with regard to potentially significant carbon sequestration benefits. Upon adoption of the TMDL, the Water Board would identify floodplain restoration projects within the watershed as having a priority for funding under the Clean Water Act Section 319(h) grant program.

An impressively large floodplain restoration project was constructed in the Fall of 2016 to reconnect Butano Creek to approximately 100 acres of its historical floodplain. The project was developed by the San Mateo County Resource Conservation District (RCD) and Peninsula Open Space Trust (POST) as the landowner. The purpose of the project is to restore channel-floodplain connectivity and enhance or improve natural creek function along the creek to allow for more frequent inundation of the floodplain, to reestablish sediment deposition and storage on the floodplain while reducing the amount of sediment delivered to downstream reaches, and to provide high flow refugia for juvenile salmonids.

Restoration actions included the construction of engineered log jams (Figure 44), a rock ramp, floodplain connector channels, and recruitment of living bank side alder trees. The project addresses water quality impairment for sediment and will improve habitat conditions for several rare and endangered species including coho salmon, steelhead trout, red-legged frog, and San Francisco garter snake. The project was funded by grant money awarded in 2015 by the California Department of Water Resources (DWR) through the Urban Streams Restoration Program, as well as design funds provided by the State Coastal Conservancy (SCC), U.S. Fish and Wildlife Service (USFWS), and POST.

The Water Board was a part of the Technical Advisory Group that provided input to the design and will continue to support and promote floodplain restoration project opportunities in the Pescadero-Butano watershed. We view this project as a wonderful start to restoring sediment dynamics and function to Butano Creek and its floodplain. Additional projects along both Pescadero and Butano creeks are needed to restore full function to the watershed, to eliminate water quality impairment, and to reverse sediment deposition trends in the lower watershed and the lagoon.

Figure 44. A large wood structure constructed for the Butano Farms floodplain restoration project

The Basin Plan amendment calls for detailed technical studies to characterize reach-specific opportunities and priorities for floodplain restoration. Potential opportunities and constraints influencing floodplain restoration potential are a function of not only physical attributes of the channels (e.g., sediment supply, flow regime, riparian forest type, valley and channel size and geometry, historical disturbances and changes over time), but also development, present-day land uses, and infrastructure.

There are reaches with great potential with regard to enhancement of sediment storage and ecological function along Pescadero and Butano creeks or their tributaries (e.g., Bradley Creek), where lands adjacent to channels are publicly owned, and along privately owned reaches where existing infrastructure may not be threatened by floodplain restoration or existing land uses are compatible with occasional flooding. There are also reaches where opportunities are limited as a result of the close proximity of many buildings to the channel. Currently we do not have a solid understanding of accurate estimates of the current area of floodplain, evaluation of the potential benefits of incremental increase in floodplain area, and analysis of what is feasible and where to achieve optimal ecological and water quality benefits. Therefore, we are not currently proposing a floodplain area target and recommending that detailed technical studies be conducted first to develop a solid understanding of the opportunities, constraints, and potential benefits of floodplain reconnection. We recommend giving these studies and subsequent implementation projects top priority for TMDL contract and Water Board grant programs, and working in partnership with other stakeholders as needed to achieve significant ecological and water quality benefits.

Wood in Channels

The role of LWD is implicitly linked to channel processes that benefit salmonids. LWD plays an important role in controlling channel morphology, the storage and routing of sediment and organic matter, and the creation of fish habitat. The geomorphic potential of the channel to process wood into features that benefit salmonids is often limited by the quantity and size of wood (Abbe and Montgomery, 1996).

During the historical period in the Pescadero-Butano watershed, there has been a significant reduction in the number and size of large fallen trees in channels. This change has been a key factor in channel incision, simplification of channel habitats, disconnection of the channel from its floodplain, elevated rates of streambed mobility, and increases in fine sediment deposition. Much more wood is needed in channels in order to achieve the TMDL and related targets for sedimentation and habitat complexity and connectivity.

Anadromous salmonids in the Pacific Coastal Ecoregion, as well as all other native stream and riparian species, have evolved to exploit complex and interconnected habitat created by large wood. Coho salmon, for example, prefer deep pools with good cover alternating with gravel riffles, and well shaded channel reaches that are connected to adjacent floodplains, alcoves, and side channels. All of these habitats are formed and maintained by key pieces of LWD. Drawing on an extensive body of research, Collins et al. (2012) postulate that key pieces of LWD - those large enough to resist transport even during large floods[55] - are the primary agent structuring complex and interconnected channel and floodplain habitats in forested watersheds in the Pacific Coastal Ecoregion. Also, as a corollary hypothesis, they propose that when land-use activities reduce the size of the largest trees recruited to

[55] In general, key pieces of debris (e.g., large fallen trees) have a diameter ≥ one-half bankfull depth and length ≥ one-half bankfull width with an intact root-wad.

channels and/or the rate of input of key pieces in general, this causes the physical habitat structure in channels to become greatly simplified.

Research examining natural process-form relationships governing debris jams in the Nisqually and Queets rivers, large rivers in the Pacific Northwest that have experienced minimal disturbance, may provide insight about the types of debris jams that were likely present in Pescadero and Butano Creeks prior to disturbance (Collins and Montgomery, 2002; Abbe and Montgomery, 2003).

Analysis of relationships governing debris jam formation in reference channels like the Queets and Nisqually rivers, together with careful examination of naturally formed debris jams found (albeit rarely) in Pescadero or Butano Creeks today, can help create a template for the placement of key pieces and/or design of engineered log jams, that could help address the near-term wood deficit in the watershed. The approach of using natural process-form relationships to guide design and construction of engineered log jams has been successfully implemented in many other streams and rivers in northwestern California (Fiori Geosciences, 2012) and Washington State (Pess et al., 2001; Abbe et al., 2003a).

Another approach that would be favorable in the parks or timberlands, where potential risks to public safety and property are low, is to topple large whole-trees intact (e.g., trees large enough to form stable jams), and then to let the channel design the jams itself. This approach can be implemented at a fraction of the cost of a traditional hard engineered log jam. Toppling trees and letting the channel form its own jams might work well along public lands, open space preserves, and timberlands where wood loading and channel complexity is low, and large redwood trees are growing adjacent to the channel. Coordinating instream large wood placement with future timber harvest activities in the watershed could result in substantial cost savings and serve as an opportunity for effective timber harvest plan mitigation.

In summary, increasing LWD loading (the number of large fallen trees in the channel) will greatly enhance the structural complexity of channel habitat and its connection to the floodplain. Many plane-bed reaches will be converted to pool-riffle reaches, average pool depth and cover will be enhanced, the size and frequency of riffles and gravel bars will increase, and the total length of side channels and percent of channel length connected to the floodplain will be increased. As a result, we predict there will be a significant increase in winter and summer carrying capacity for juvenile coho salmon and steelhead trout. Upon adoption of the TMDL, the Water Board may identify large woody debris enhancement projects within the Pescadero-Butano watershed as having a priority for funding under the Clean Water Act Section 319(h) grant program.

8.5. Pescadero-Butano Watershed Sediment and Habitat Enhancement Plan

The primary objectives of the Pescadero Butano sediment and habitat enhancement plan are to:

a) Attain and maintain suitable gravel quality and diverse streambed topography and mosaic of habitat patches in freshwater reaches of Pescadero Creek and its tributaries; and

b) Reconnect the channel to its floodplain where technically feasible and compatible with adjacent land-uses.

To these ends, the plan calls for actions to:

a) Substantially decrease the rate of sediment delivery to channels that is primarily the result of legacy land-uses (and to a lesser extent sediment delivery to channels from road-related erosion); and

b) Substantially increase the amount and caliber of LWD in channels, including facilitation of local channel aggradation and reconnection to the floodplain, and/or to enhance physical habitat complexity within the channel, in channel reaches where such actions and/or projects would not pose a significant threat.

These actions are intended to restore properly functioning conditions with regard to sediment delivery to channels; improve sediment transport and storage in freshwater channel reaches; and are needed to conserve and restore ecological functions of the Pescadero Lagoon and Marsh.

The Water Board expresses its strong commitment to work with all interested parties to develop and implement a broad program of restoration actions in the watershed that is premised on a sound understanding of the system, so that it will be effective in conserving steelhead and other native fish and aquatic wildlife species. We look forward to the opportunity to contribute to this very important work.

8.6. Evaluation and Monitoring

Four types of monitoring are recommended to assess baseline conditions and progress toward achievement of numeric targets and load allocations for sediment:

1) Baseline monitoring to characterize existing conditions and provide a basis for future comparison;

2) Implementation monitoring to document actions taken to reduce sediment discharge and enhance habitat complexity and connectivity;

3) Upslope effectiveness monitoring to evaluate effectiveness of sediment control actions in reducing rates of sediment delivery to channels; and

4) In-channel effectiveness monitoring (e.g., pool filling and substrate composition) to evaluate channel response to management actions and natural processes.

Adequate baseline data for V* (residual pool volume), substrate composition, or LWD loading do not exist for the Pescadero-Butano watershed. Water Board staff is planning to conduct baseline monitoring of V* and substrate composition along Pescadero and Butano channels in the summer/fall of 2018.

Implementation monitoring would be conducted by landowners or designated agents. The purpose of this type of monitoring is to document that sediment control actions, i.e., best management practices, specified herein occur.

Water Board staff anticipates working in partnership with other government agencies to conduct upslope effectiveness monitoring, to update all or a portion of the watershed sediment budget, and to re-evaluate rates of sediment delivered to channels from land use activities and natural processes ten years subsequent to Basin Plan amendment adoption.

In-channel effectiveness monitoring should be conducted by local government agencies with scientific expertise and demonstrated capability in working effectively with private property owners (to gain permissions for access), as needed to develop a representative sample of stream habitat conditions, in relation to sediment supply and transport within the watershed. In-channel effectiveness monitoring will be conducted to evaluate: a) progress toward achieving water quality targets, and b) channel response to management measures and natural processes. The main parameter that will be monitored to assess progress toward achieving water quality targets is pool filling.

Pool filling (residual pool volume) and substrate composition should be monitored every two to three years to provide for an assessment of trend analysis.

LWD loading in channels also needs to be surveyed and assessed to evaluate attainment of the numeric targets for LWD loading, and to guide development of reach-specific prescriptions for installation of engineered log jams and riparian management actions to maintain or exceed the target values in future years through natural recruitment. Lawrence et al. (2012) and Schuett-Hames et al. (1999) provide guidance regarding methods for surveys to estimate LWD loading. Desired level of statistical confidence is 90% and desired level of power is 80% for estimate values of wood loading in redwood and hardwood channel reaches. Desired measurement frequency for LWD is also once every three years. At a minimum, repeat surveys should be conducted every five years.

We recommend that habitat complexity-related water quality indicators should also be monitored to assess progress towards functional Pescadero and Butano channels to attain the following conditions:

a) An increasing trend in bankfull channel width-to-depth ratio - ideally toward 12:1;
b) A decreasing trend in the average spacing between alluvial and/or forced gravel bars within the active channel – ideally ≤7 times the width of the bankfull channel; and
c) An increasing trend through time in the mean area and frequency of riffles and gravel bars within the mainstem channel.

These indicators provide a clear linkage between sediment loads and the complexity and interconnectivity of channel habitat beneficial for fish and wildlife species that have evolved in these streams.

8.7. Adaptive Implementation

In concert with the monitoring programs described above, the Pescadero-Butano Watershed TMDL and Sediment Reduction and Habitat Enhancement Plan will be updated as necessary. We will consider the results of validation monitoring or anticipated studies that enhance understanding of the population status of steelhead trout and coho salmon and of the effects of actions to enhance LWD loading and floodplain area on population dynamics of these fish. Therefore, Water Board recommends salmonid population monitoring programs including juvenile population estimates, adult spawner surveys, and smolt outmigration surveys be performed to evaluate the status and trends of these populations and also related analyses of smolt population dynamics in response to changes in the quantity and quality of freshwater habitat and will consider results of these studies.

The Water Board may propose alternative water quality parameters and/or numeric target values at a future date as part of the adaptive implementation process, when/if information becomes available to conclude with a high degree of confidence that one or more alternative parameters or target values provide a superior basis for determining attainment of water quality objectives for sediment and the protection of fisheries-related beneficial uses.

Table 17. Required TMDL Implementation Measures for Sediment Discharges Associated with Non-Grazing Agricultural Lands of 5 Acres or Greater

Land Use	Performance Standards	Actions	Implementing Parties	Completion Dates
NON-GRAZING AGRICULTURAL LANDS	**Roads**: Design, construct, and maintain roads to i) reduce road-related sediment delivery to channels to ≤ 500 cubic yards per mile per 20-year period; **and** ii) limit the length of roads that are hydrologically connected to 25 percent of total road length; **and** iii) culvert inlets have low plug potential; **and** iv) critical dips installed at culverted crossings that have a diversion potential; **and** **Stream corridors:** Protect streambanks, wetlands, and riparian areas from degradation through vegetated buffers; **and** **Gullies and/or shallow landslides:** Manage non-grazing agricultural practices to allow for natural recovery of gullies and/or landslides, prevent human-caused increases in sediment delivery from unstable areas, and decrease connectivity of gullies to stream channels; **and** **Effectively attenuate significant increases in storm runoff**, so that the runoff from non-grazing agricultural lands shall not cause or contribute to downstream increases in rates of bank or bed erosion.	**PLANNING AND PRIORITIZING** Inventory and assess natural resources, agricultural lands, and management practices that may deliver sediment to streams. Evaluate stream and riparian corridors for opportunities for improving habitat. Develop and submit a report acceptable to the Executive Officer that includes a prioritized list of actions for farm owner(s). **EITHER** Submit a Report of Waste Discharge (ROWD) to the Water Board that provides, at a minimum, the following: a description of the land; identification of site-specific erosion control measures needed to achieve performance standard(s) specified in this table; and a schedule for implementation of identified erosion control measures. **OR** Comply with applicable Waste Discharge Requirements (WDRs) or waiver of WDRs. Develop and begin implementing an erosion control plan that would be approved as part of WDRs or waiver of WDRs.	Non-grazing agricultural land owner and/or operator of properties ≥5 acres	3 years from effective date of this Basin Plan amendment 5 years from effective date of this Basin Plan amendment As specified in applicable WDRs or waiver of WDRs

Table 18. Required TMDL Implementation Measures for Sediment Discharges Associated with Grazing Lands of 50 Acres or Greater

Land Use	Performance Standards	Actions	Implementing Parties	Completion Dates
GRAZING LANDS	**Surface erosion associated with livestock grazing**: Attain or exceed minimal residual dry matter (RDM) values consistent with University of California Division of Agriculture and Natural Resources Guidelines[1]; **and** **Stream corridors:** Protect streambanks, wetlands, and riparian areas from degradation through grazing management, livestock access controls, and vegetated buffers; **and** **Roads**: Design, construct, and maintain roads to i) reduce road-related sediment delivery to channels to ≤ 500 cubic yards per mile per 20-year period; **and** ii) limit the length of roads that are hydrologically connected to 25 percent of total road length; **and** iii) culvert inlets have low plug potential; **and** iv) critical dips installed at culverted crossings that have a diversion potential; **and** **Gullies and/or shallow landslides:** Manage grazing practices to allow for natural recovery of gullies and/or landslides, prevent human-caused increases in sediment delivery from unstable areas, and decrease connectivity of gullies to stream channels.	**PLANNING AND PRIORITIZING** Inventory and assess natural resources, agricultural practices, and management practices that may deliver sediment to streams. Evaluate stream and riparian corridors and water bodies for opportunities for improving habitat. Develop and submit a report acceptable to the Executive Officer that includes a prioritized list of actions for farm owner(s). **EITHER** Submit a ROWD to the Water Board that provides, at a minimum, the following: description of the property/ranch and road network; identification of site-specific erosion control measures to achieve performance standard(s) specified in this table; and a schedule for implementation of identified erosion control measures. **OR** Comply with applicable Waste Discharge Requirements (WDRs) or waiver of WDRs. Develop and begin implementing Grazing Management plan that would be approved as part of WDRs or waiver of WDRs.	Landowner and/or ranch operator of properties ≥50 acres	3 years from effective date of this Basin Plan amendment 5 years from effective date of this Basin Plan amendment As specified in applicable WDRs or waiver of WDRs

[1] University of California 2002, California guidelines for residual dry matter (RDM) management on coastal and foothill annual rangelands. Rangeland Monitoring Series Publication 8092.

Table 19. Required TMDL Implementation Measures for Sediment Discharges associated with the San Mateo County

Landowner Type	Performance Standards	Actions	Implementing Parties	Completion Dates
SAN MATEO COUNTY	**Roads:** Design, construct, and maintain roads to i) reduce road-related sediment delivery to channels to ≤ 500 cubic yards per mile per 20-year period; **and** ii) limit the length of roads that are hydrologically connected to 25 percent of total road length; **and** iii) culvert inlets have low plug potential; **and** iv) critical dips installed at culverted crossings that have a diversion potential; **and** **Gullies and/or shallow landslides:** Promote natural recovery and minimize human-caused increases in sediment delivery from unstable areas. Manage existing roads and other infrastructure to prevent additional erosion of legacy sediment delivery sites and/or delivery from potentially unstable areas.	**PLANNING AND PRIORITIZING** Comply with the NPDES Permit No. CAS612008 (also referred to as the Municipal Regional Stormwater Permit). **AND** Create an inventory of roads that may contribute to sediment delivery to streams and develop a prioritized list and schedule of actions. Where performance standards are not achieved or where road-related sediment sources are not covered by the permit CAS612008, do one of the following: **EITHER** Submit a Report of Waste Discharge to Water Board that provides, at a minimum, the following: description of the road network and/or segments; identification of erosion and sediment control measures to achieve performance standard(s) specified in this table; and a schedule for implementation of identified control measures. For paved roads, erosion and sediment control actions could primarily focus on road crossings to meet the performance standard. **OR** Comply with applicable Waste Discharge Requirements (WDRs) or waiver of WDRs.	San Mateo County	3 years from effective date of this Basin Plan amendment 5 years from effective date of this Basin Plan amendment As specified in in applicable WDRs or waiver of WDRs

Table 20. Required TMDL Implementation Measures for Sediment Discharges associated with Parks and Open Space Lands

Landowner Type	Performance Standards	Actions	Implementing Parties	Completion Dates
PARKS/OPEN SPACE LANDS	**Roads:** Design, construct, and maintain roads to i) reduce road-related sediment delivery to channels to ≤ 500 cubic yards per mile per 20-year period; **and** ii) limit the length of roads that are hydrologically connected to 25 percent of total road length; **and** iii) culvert inlets have low plug potential; **and** iv) critical dips installed at culverted crossings that have a diversion potential; **and** **Gullies and/or shallow landslides:** Promote natural recovery and minimize human-caused increases in sediment delivery from unstable areas. Manage existing roads and other infrastructure to prevent additional erosion of legacy sediment delivery sites and/or delivery from potentially unstable areas.	**PLANNING AND PRIORITIZING** Adopt and implement best management practices for maintenance of unpaved (dirt/gravel) roads, and conduct a survey of stream-crossings associated with unpaved public roadways, and develop a prioritized implementation plan and schedule for repair and/or replacement of high priority crossings/culverts to reduce road-related erosion and protect stream-riparian habitat conditions. **EITHER** Submit a Report of Waste Discharge to Water Board that provides, at a minimum, the following: description of the road network and/or segments; identification of erosion and sediment control measures to achieve performance standard(s) specified in this table; and a schedule for implementation of identified control measures. For paved roads, erosion and sediment control actions could primarily focus on road crossings to meet the performance standard. **OR** Comply with applicable Waste Discharge Requirements (WDRs) or waiver of WDRs.	State of California, Department of Parks and Recreation MidPeninsula Open Space District Peninsula Open Space Trust	3 years from effective date of this Basin Plan amendment 5 years from effective date of this Basin Plan amendment As specified in in applicable WDRs or waiver of WDRs

Table 21. Required TMDL Implementation Measures for Sediment Discharges Associated with Timberlands of 100 acres or Greater

Land Use	Performance Standards	Actions	Implementing Parties	Completion Dates
TIMBERLANDS	**Roads**: Design, construct, and maintain roads to i) reduce road-related sediment delivery to channels to ≤ 500 cubic yards per mile per 20-year period; **and** ii) limit the length of roads that are hydrologically connected to 25 percent of total road length; **and** iii) culvert inlets have low plug potential; **and** iv) critical dips installed at culverted crossings that have a diversion potential; **and** **Gullies, shallow landslides, and/or unstable areas:** Manage operations (e.g., tree removal (felling), hauling of trees, road construction, heavy equipment use, etc.) to prevent additional erosion of legacy sediment delivery sites, and/or delivery from other potentially unstable areas, and to decrease connectivity of gullies to stream channels.	**PLANNING AND PRIORITIZING** Comply with California Forest Practice Rules, Anadromous Salmonid Protection Rules, and Road Rules or other requirements to control sediment sources from timber harvest operations that are provided by the Water Board. Inventory and assess natural resources and management practices that may contribute to sediment delivery to streams. Evaluate stream and riparian corridors and water bodies for opportunities for improving habitat. Develop and submit a report acceptable to the Executive Officer that includes a prioritized list of actions for timberland owner(s). **EITHER** Submit a Report of Waste Discharge to the Water Board that provides, at a minimum, the following: description of the property road network; identification of site-specific erosion control measures to achieve performance standard(s) specified in this table; and a schedule for implementation of identified erosion control measures. **OR** Comply with other applicable Waste Discharge Requirements (WDRs) or waiver of WDRs.	Landowner and/or timberlands operator of properties ≥100 acres	Ongoing 3 years from effective date of this Basin Plan amendment 5 years from effective date of this Basin Plan amendment As specified in in applicable WDRs or waiver of WDRs

Table 22. Recommended Actions to Reduce Sediment Load and Enhance Habitat Complexity in Pescadero and Butano Creeks and Their Tributaries

Stressor	Management Objective(s)	Actions	Implementing Parties	Completion Dates
Habitat degradation as a result of incision along Pescadero and Butano creeks.	Reduce rates of sediment delivery (associated with incision) to channels, by 78 percent. Increase sediment storage in the channels and on the floodplains. Enhance channel habitat complexity and connectivity as needed to support self-sustaining run of steelhead and coho salmon and enhance the overall health of the native fish community.	Develop detailed technical studies to characterize reach-specific opportunities and priorities for floodplain restoration. Develop and implement plans to enhance stream-riparian habitat conditions and channel complexity. Comply with conditions of Clean Water Act Section 401 certifications in the implementation of projects to increase channel-floodplain connectivity.	State and local government agencies, landowners and/or designated agents, and reach-based stewardships	Technical studies to characterize reach specific opportunities and priorities for floodplain restoration will be completed within 5 years of Basin Plan amendment.
Habitat degradation as a result of reduction in large woody debris in stream channels.	Enhance quality of rearing habitat for juvenile salmonids.	Develop and implement plans to enhance large woody debris loading and restore natural rates of recruitment to channels, as needed to achieve numeric targets for large woody debris loading. This plan will include a survey to quantify baseline values for large woody debris loading. Comply with conditions of Clean Water Act Section 401 certifications in the implementation of projects for large woody debris loading and recruitment.	State and local government agencies, landowners and/or designated agents, and reach-based stewardships	Targets for large woody debris loading will be achieved within 10 years of Basin Plan amendment adoption.

CHAPTER 9 – REGULATORY ANALYSIS

This section of the Staff Report presents the results of an environmental impact analysis required under the California Environmental Quality Act (CEQA) and a discussion of economic considerations in compliance with Public Resources Code section 21159, subdivision (a). The Water Board is the lead agency for evaluating the potential environmental impacts of the proposed Basin Plan amendment that establishes both a TMDL for sediment in the Pescadero-Butano watershed and an implementation plan. Regional basin planning is a certified regulatory program for which a substitute environmental document (SED) may be prepared in lieu of an Environmental Impact Report (EIR) or negative declaration under CEQA (Pub. Res. Code § 21080.5; Cal. Code Regs., tit. 14, §§ 15251 (g), 15252(a)). This Staff Report, including the CEQA checklist and the analyses that follow, constitutes the SED, which provides public information about the project and reviews the impacts, mitigation, and alternatives to the TMDL as proposed.

This section is organized into three main parts: 1) the Environmental Analysis and Checklist; 2) Alternatives Analysis; and 3) Economic Considerations. The Environmental Analysis considers impacts of the proposed Basin Plan amendment and reasonably foreseeable environmental impacts of reasonably foreseeable activities that will implement the TMDL. An Environmental Checklist is used as the framework for the analysis and includes a discussion of the potential environmental impacts as well as probable mitigation measures that could be used to eliminate or reduce the environmental impacts. Because the Water Board cannot mandate adoption of any specific implementation methods or projects, the analysis of the potential environmental impacts of the TMDL provided here is at a general level of detail and contemplates foreseeable activities, but not site-specific details. Specific projects that may be proposed to implement the sediment TMDL may be subject to review under CEQA, as well as relevant permitting procedures by local, State, and federal agencies as site-specific details of proposed actions are developed. Our analysis is a general review of likely impacts and mitigation measures based on our best knowledge of the required TMDL actions and our analysis of reasonable foreseeable compliance measures.

The Alternatives Analysis presents several alternatives to the proposed Basin Plan amendment. The evaluation of alternatives is required under the Water Board's Basin Planning Certified Regulatory Project under CEQA Guideline 15252, subdivision (a)(2)(A) to avoid or reduce any significant or potentially significant effects on the environment.

The Economic Considerations section provides a discussion of economic costs associated with various measures described by the TMDL's Implementation Plan. Again, it should be noted that the TMDL is not prescriptive; no specific actions to achieve the numeric targets are required; rather dischargers must determine and implement, based on specific site conditions, those best management practices to meet the performance standards identified in Tables 17-22. As a result, the discussion of costs is limited to those actions that are currently technically feasible and those that dischargers are most likely to adopt.

9.1 Environmental Checklist and Analysis

Under the Water Board's certified regulatory program for basin planning, the Water Board must satisfy the requirements of California Code of Regulations, title 23, section 3777, subdivision(a), which requires a written report that includes a description of the proposed activity, an alternatives analysis, and an identification of mitigation measures to minimize any significant adverse impacts. Section 3777(a) also requires the Water Board to complete an environmental checklist as part of its substitute environmental documents. Additionally, the Water Board must comply with Public Resource Code section 21159 when adopting performance standards such as those in the proposed Basin Plan amendment. Section 21159 requires the environmental analysis to include: (1) the reasonably foreseeable environmental impacts of the method of compliance; (2) the reasonably foreseeable mitigation measures; and (3) the reasonably foreseeable alternative means of compliance with a rule or regulation. The analysis must take into account a reasonable range of environmental, economic, and technical factors, population and geographic areas, and specific sites. Section 21159 further states that Board is not required to engage in speculation or conjecture or to conduct a project-level environmental analysis.

This section contains the environmental checklist and analysis for the proposed Basin Plan amendment, and includes the required analyses mentioned above. The explanations integrated into respective sections of the checklist provide details concerning the environmental impact assessment. Based on this analysis, Water Board staff concludes that adoption of the proposed Basin Plan amendment may cause significant adverse environmental impacts, but mitigation for each of those impacts reduces all foreseeable impacts to less than significant.

Project Description

The proposed project is a Basin Plan amendment that would establish a TMDL for sediment in stream channels in the Pescadero-Butano watershed and an implementation plan to achieve the TMDL and related goals for stream-riparian habitat enhancement.

The project area includes the entire land area and all channels draining into and including Pescadero and Butano Creeks west of the eastern watershed boundary along State Highway 35 and Highway 9, downstream to the Pescadero marsh and lagoon complex (see Figure 1). The project area excludes the Pescadero marsh and lagoon.

The project includes:

- Performance standards for runoff and sediment control;
- Numeric targets for residual pool volume, substrate composition, and the amount of large woody debris in channels; and
- Processes by which the best management practices are proposed and implemented.

The sediment TMDL is established at ≤125 percent of natural background. Sediment sources and land use categories identified in the TMDL include livestock grazed agricultural lands; non-grazed agricultural lands; parks, open space, and public works; and timberlands. To achieve the Pescadero-Butano Watershed Sediment TMDL and the habitat enhancement goals for the land types, land uses, or roadways listed in Tables 6 through 10 of the Basin Plan amendment, the entire Pescadero-Butano watershed, except the marsh and lagoon complex, should be included in the proposed sediment control programs. The minimum parcel size and/or pollutant discharge thresholds that would trigger the requirement to obtain a permit or waiver will be determined as part of a subsequent project. For purposes of this analysis of potential impacts, we have evaluated all parcels, regardless of parcel size or potential pollutant discharge threshold.

The goal of the Basin Plan amendment is to improve environmental conditions by addressing excessive sediment discharges, enhancing stream-riparian habitat complexity and connectivity, and improving salmonid and steelhead habitat. The Basin Plan amendment would include targets for fine sediment (primarily sand) concentrations in the bed of Pescadero and Butano creeks and/or in their tributaries that are expressed as numeric criteria for residual pool volume and substrate composition, and establish sediment allocations necessary to achieve the targets. The Basin Plan amendment implementation plan would require actions to achieve the targets and allocations for sediment, and numerous actions to enhance other habitat attributes needed to conserve and enhance steelhead and salmon populations.

The Basin Plan amendment contains sediment allocations for dischargers and discharge categories. Consistent with the Water Code, the Basin Plan amendment does not prescribe specific projects through which discharge categories will meet the sediment allocations.

The implementation plan would require actions by landowners to reduce sediment discharges associated with key sources: roads, grazing lands, agricultural lands, timberlands, and parks and open space. Required actions by landowners include 1) submittal of reports of waste discharge; 2) compliance with WDRs or conditional waivers; and 3) implementation of best management practices to control erosion and sediment delivery to Pescadero and Butano creeks.

The proposed Basin Plan amendment also recommends actions that will enhance other habitat attributes necessary for the conservation and growth of native fishes and to support recovery of listed populations of steelhead and coho salmon by increasing channel floodplain connectivity and channel-riparian habitat complexity.

Reasonably Foreseeable Methods of Compliance

While the Water Board would not directly undertake any actions that could physically change the environment, adoption of the proposed Basin Plan amendment would result in future actions by landowners, municipalities and other agencies to comply with the requirements of the Basin Plan amendment and these actions may results in a physical change to the environment. The environmental impacts of such physical changes are evaluated below, to the extent that they are reasonably foreseeable. Changes that are speculative in nature do not require environmental review.

Table 23. Reasonably Foreseeable Compliance Projects

TMDL Actions	Environmental Changes Subject to Review
Road erosion control and prevention projects	Actions to reduce road surface erosion and to improve road drainage. Environmental changes may include: a) installation, repair, or replacement of road crossings (i.e., culvert, bridges, and fords) over channels; b) installation and maintenance of trash racks at road crossings; c) installation of ditch relief culverts and cross-drains along inboard ditches on roads; d) soil excavation at road-related landslides; e) construction of rolling dips or out-sloped road segments on dirt roads; f) sediment and/or vegetation removal to maintain conveyance capacity along inboard ditches and/or at stream crossings; and/or g) removal of road berms (as needed).
Surface erosion control in grazing lands	Site-specific grazing management measures to protect soil from erosion, to promote infiltration, and to reduce sediment runoff. Possible environmental changes may include a) construction and installation of water wells and associated water routing piping and storage; b) minor soil disturbance related to construction of trenches associated with pipes connecting to off-stream watering facilities; c) property fencing (post holes for new livestock exclusion fencing); d) rehabilitation of cattle crossings; e) installation of grassed filter strips or riparian buffers; f) grazing management to maintain adequate residual dry matter, and g) repairing and installing small drainage facilities such as drop inlets, trash racks or energy dissipation structures.
Surface erosion control on non-grazing agricultural lands	Site-specific management measures to protect soil from erosion, to promote infiltration, and to reduce sediment runoff. Possible environmental changes may include a) limiting tillage and planting cover crops, b) installing vegetated buffers and stream setbacks; and c) repairing and installing small drainage facilities such as drop inlets, trash racks or energy dissipation structures.
Stream and floodplain habitat enhancement actions	Actions to increase channel and floodplain connectivity, reduce channel incision, and to enhance riparian habitat. Environmental changes may include: a) minor earth moving and vegetation removal; b) earth moving (excavation and grading) to install log jams (comprised of several large trunks with intact rood-wads) or to construct floodplains; c) water diversion and dewatering of the construction area; d) soil bioengineering to minimize post-construction erosion where streambanks are set back to facilitate jam installation and/or to construct an inset floodplain; e) stockpiling of excavated material in adjacent uplands; and f) planting of native riparian tree and ground-cover species.
Gully and landslide erosion control and prevention	Actions to stabilize and repair gullies and landslides. Environmental changes may include: a) re-contouring slopes to remove debris and/or stabilize slopes or gullies; and b) reinforcing and revegetating unstable areas through bio-technical methods such as large woody debris, boulders, and planting appropriate vegetation.
Stormwater runoff	Best management practices to manage runoff and prevent erosion. Environmental changes may include: a) installing energy dissipater facilities, spreaders, and benches; b) installing sedimentation/detention basins and associated minor construction; and c) reducing impervious surfaces; and d) installing stream buffers and grassy swales.

Until the parties that must comply with requirements derived from the Basin Plan amendment propose specific projects, many site-specific physical changes to the environment cannot be anticipated. That said, it is reasonable foreseeable that the following activities may take place to comply with the Basin Plan amendment: 1) minor construction, 2) earthmoving operations, 3) enhancement of vegetation and woody debris in riparian corridors and stream channels, and 4) installation of stream habitat enhancement structures. Although these activities are reasonably foreseeable methods of compliance, the implementation plan does not specify the locations of these actions. Therefore, we consider these activities in general terms. To illustrate the possible nature of these activities, some examples are described below:

- ***Minor construction***. Basin Plan amendment-related construction projects would generally be small. Examples may include: a) installation/replacement and/or retrofit of road crossings (e.g., replacement of culverts and/or bridges, retrofits of culvert to include downspouts, etc.), b) installation or repair of trash racks upstream of road crossing to avoid blockage or crossings; c) installation or repair of ditch relief culverts or cross-drains to reduce concentrated runoff from roads; and d) stream and floodplain habitat enhancement actions through the installation of engineered log jams ; e) construction of temporary dams/diversions in stream channels to divert streamflow and dewater the construction area at sites where large woody debris jams are installed; f) construction of detention basins to capture sediment and/or reduce surface runoff during storms; g) construction of bio-swales or vegetated buffers to deposit sediment; h) installation of minor fencing adjacent to some stream reaches or actively eroding gullies in rangelands to accelerate re-establishment of native scrub and tree cover.
- ***Earthmovings***. Adoption of the Basin Plan amendment would result in earthmoving to reduce sediment supply to Pescadero and Butano Creeks and their tributaries. For instance, to reduce road-related erosion, dischargers may recontour the surface of some unpaved roads to disperse concentrated runoff (e.g., outsloping of road segments, construction of rolling dips, installation of water bars), remove road berms, excavate soil at road-related landslides, and bioengineer soil to reshape and stabilize road-related gullies. Earthmoving also includes excavating and beneficially reusing sediment for habitat restoration and erosion control. Earthmoving may also be employed to reduce erosion rates and enhance stream habitat complexity by re-establishing channel geometry to reduce the height and steepness of channel banks and to widen channel width. Earthmoving to increase large woody debris in channels may include excavation/fill of stream banks and/or in the streambed to buttress key pieces of wood into the channel. Minor excavation and/or fill may be necessary to provide temporary access for heavy equipment or hand crews to the construction sites. Some actions undertaken to stabilize gullies or landslides and to enhance stream and floodplain habitat may involve earthmoving.
- ***Enhancement of Vegetation and Woody Debris in Riparian Corridors and Stream Channels***. To attain the proposed numeric target for the amount of large woody debris (large fallen trees), there would be a two-to-six fold increase in large woody debris in channels, and a consequent enhancement of the diversity of riparian habitat patch types and total area of riparian habitat adjacent to the creeks. This would be accomplished in part by construction and installation of dozens of engineered and/or anchored log jams, enhanced natural recruitment through

targeted planting and management of riparian habitat, and the protection of ecologically significant large woody debris in stream channels.

- ***Installation of Stream Habitat Structures***. Adoption of the Basin Plan amendment could lead to an increase in the number of stream and floodplain habitat structures installed in Pescadero and Butano Creeks and lower reaches of their tributaries. Habitat enhancement structures could include logjams, step-pools, willow waddles, log crib walls, and rockwork. Habitat structures would be installed to enhance bank stability in channel reaches where disturbances have accelerated erosion rates, and/or to enhance hydraulic and topographic complexity within the channel.

These examples are not exhaustive or exclusive, but other conceivable actions that could be taken as a result of the Basin Plan amendment would require speculation, and therefore, need not be evaluated.

Environmental Analysis

The proposed Basin Plan amendment does not define the site-specific actions that responsible parties would take to comply with requirements derived from the Basin Plan amendment. As discussed above, physical changes resulting from the Basin Plan amendment are foreseeable, but the attributes of specific implementation actions (e.g., location, extent, etc.) are unknown, pending responsible parties proposing actions to comply with Basin Plan amendment requirements. Therefore, this analysis considers the above-mentioned reasonably foreseeable methods of compliance with the Basin Plan amendment in general terms. In most cases, we have concluded that there will be no impact or a less than significant impact with mitigation incorporated.

Specific compliance projects, when they are developed, will be subject to review and/or approval by the Water Board, which will, as part of administering its program responsibilities, likely either disapprove projects with significant and unacceptable environmental impacts (e.g., instream work with too many impacts) or require implementation of routine mitigation measures (e.g., best construction management practices) to ensure that environmental impacts remain at or are reduced to less-than-significant levels. Additionally, there are existing local and state agency performance standards (e.g., air standards and noise ordinances) and performance standards specified in the Basin Plan amendment with which compliance projects must comply to keep impacts at less-than-significant levels. An explanation for each box checked on the environmental checklist is provided under the corresponding section of the checklist.

ENVIRONMENTAL CHECKLIST AND IMPACTS

1. Project Title:	Pescadero-Butano Watershed Sediment Total Maximum Daily Load (TMDL) and Habitat Enhancement Basin Plan Amendment
2. Lead Agency Name and Address:	California Regional Water Quality Control Board San Francisco Bay Region 1515 Clay Street, Suite 1400 Oakland, California 94612
3. Contact Person and Phone:	Setenay Bozkurt Frucht (510) 622-2388
4. Project Locations:	Pescadero-Butano Watershed San Mateo County, California
5. Project Sponsor's Name & Address:	California Regional Water Quality Control Board San Francisco Bay Region (Water Board) 1515 Clay Street, Suite 1400 Oakland, California 94612
6. General Plan Designation:	Not Applicable
7. Zoning:	Not Applicable

8. Description of Project:

The project is a proposed Basin Plan amendment to the water quality control plan (Basin Plan) to establish a total maximum daily load (TMDL) for sediment in stream channels in the Pescadero-Butano watershed, and an implementation plan to achieve the TMDL and related goals for stream-riparian habitat enhancement. The project would involve numerous management actions and erosion control projects to reduce fine sediment delivery (e.g., sand, silt, and clay) to Pescadero and Butano creeks and their tributaries, and management actions to 1) enhance channel and floodplain connectivity; 2) enhance stream-riparian habitat complexity; and 3) increase the amount of large woody debris in channels including through construction/installation of engineered log jams primarily in public parklands and timberlands. The TMDL is established at ≤125 percent of natural background, along with numeric performance standards for sediment delivery from roads and residual dry matter in grazing areas. It also establishes numeric targets for residual pool volume, substrate composition, and the amount of large woody debris in channels to define attainment of water quality objectives for sediment and settleable material, as well as for habitat complexity. The project area includes the entire land area and all channels draining into and including Pescadero and Butano creeks lying west of the eastern watershed boundary along State Highway 35 and Highway 9, downstream to the Pescadero marsh and lagoon complex. The project area excludes the Pescadero marsh and lagoon.

9. Surrounding Land Uses and Setting:

The Pescadero and Butano Creeks drain approximately 81 square miles (mi^2) of the Santa Cruz Mountains in western San Mateo County (with a very small portion of it in Santa Cruz County) and enter the Pacific Ocean near the town of Pescadero. The watershed contains steep forested slopes, deep canyons with steep inner gorges, a coastal valley, and rolling hills and grasslands near the coast. The region is geologically active and is bordered by the east by the San Andreas Fault. While the Pescadero sub-watershed is 58 mi^2, the Butano sub-watershed is 23 mi^2. Land uses in the watershed are dominated by ranching, farming, timberlands, and parks and open space. Residents of the town of Pescadero number less than 700. The watersheds provide habitat for a diverse array of aquatic life. In addition to steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*), which were historically supported by both Pescadero and Butano creeks and some of their tributaries, the watershed also hosts other species of concern including tidewater goby (Eucyclogobius newberryi), red-legged frog (Rana aurora draytonii), and San Francisco garter snake (Thamnophis sirtalis tetrataenia).

10. Other public agencies whose approval is required:

The State Water Board, the California Office of Administrative Law, and the U.S. EPA must approve the Basin Plan amendment following adoption by the Water Board. In addition, actions taken to achieve the Basin Plan amendment including installation of engineered log jams in stream channels and/or replacement or retrofit of road-crossings over stream channels (to reduce sediment delivery), would require permits from the US Army Corps of Engineers (Clean Water Act Section 404 permit); the US Fish and Wildlife Service (Endangered Species Act Section 7 Consultation); the California Department of Fish and Wildlife (Streambed Alteration Agreement); the Water Board (Clean Water Act Section 401 permit); and the County of San Mateo. Other road-erosion control projects implemented to achieve performance standards for sediment delivery from roads will involve substantial earth moving, and therefore would require discretionary permits from the County of San Mateo.

I. AESTHETICS

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☐	X
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	X

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	X
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☐	X

a-d) Any physical changes to the aesthetic environment as a result of the Basin Plan amendment would be small, local, and short-term. No actions or projects that could result from the Basin Plan amendment would result in tall or massive structures that could obstruct views from or of scenic vistas, or degrade the existing visual character or quality of any site or its surroundings. It would not create any new source of light or glare. The Basin Plan amendment would not result in adverse aesthetic impacts.

II. AGRICULTURE AND FORESTRY RESOURCES

In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment Project; and the forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board.

Would the project:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?	☐	☐	X	☐
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	X

c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)), timberland (as defined by Public Resources Coe section 4526), or timberland zoned Timberland Production (as defined by Government Code section 51104(g))?	☐	☐	☐	X
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	X
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use?	☐	☐	X	☐

a) Adoption of the Basin Plan amendment could increase the level of landowner participation in cooperative efforts to enhance channel stability and stream-riparian habitat conditions in Pescadero and Butano creeks and their tributaries (e.g., Butano Farms restoration project), which could in turn result in a reduction in the amount of land cultivated near channels (e.g., voluntary increases in setbacks of agriculture from channels) or establishment of vegetated filter strips). However, these actions would not substantially reduce the fertility of soils in areas designated as Prime, Unique, or Farmland of Statewide Importance.

The Basin Plan amendment includes best management practices (BMPs) to control sediment discharges from surface erosion, gullies, and/or shallow landslides. Because the BMPs and the performance standards are not prescriptive, they can be selected within the context of site-specific constraints. The Basin Plan amendment also includes performance standards for sediment discharges from roads. Road BMPs would be constructed and maintained within the footprint of existing roads, or within the footprint of new roads where they are constructed, and therefore, would not have any direct effect on agricultural production or present any direct potential for conversion of farmlands to other uses.

b) The Basin Plan amendment would not affect existing agricultural zoning or any aspects of Williamson Act contract and would not have any adverse impact in this regard.

c) The Basin Plan amendment would not conflict with existing zoning for, or cause rezoning of, forest land, timberland, or timberland zoned Timberland Production and would not have any adverse impact in this regard.

d) The Basin Plan amendment would not result in the loss of forest land or conversion of forest land to non-forest use. It, therefore, would not have any adverse impact in this regard.

e) Adoption of the Basin Plan amendment could increase the level of landowner participation in cooperative efforts to enhance channel stability and stream-riparian habitat conditions and to minimize soil disturbance in sensitive areas (on steep slopes and adjacent stream channels), which could result in a localized, minor reductions in the amount of land cultivated, particularly adjacent to stream channels (e.g., voluntary increases in setbacks of agriculture from channels). Adoption of the Basin Plan amendment, through installation of vegetated buffer strips up to 35 feet wide or setback areas that would be fallow, could also result in a localized, minor reductions on the amount of land cultivated adjacent to stream channels. These buffer or setback areas would comprise a small amount of land area. Therefore, overall, less-than-significant impacts could result.

III. AIR QUALITY

Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations.

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	X
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	X	☐	☐
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	X	☐
d) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	X	☐
e) Create objectionable odors affecting a substantial number of people?	☐	☐	X	☐

a) Because the Basin Plan amendment would not cause any significant changes in population or employment, it would not generate ongoing traffic-related emissions. It would also not involve the construction of any permanent emissions sources. For these reasons, no permanent change in air emissions would occur, and the Basin Plan amendment would not conflict with applicable air quality plans.

b) The Basin Plan amendment would not "violate any air quality standard or contribute substantially to an existing or project air quality standard." Nor would it involve the construction of any permanent emissions sources or generate ongoing traffic-related emissions. Construction that would occur as a result of Basin Plan amendment implementation such as earthmoving operations to reduce sediment discharges from eroding areas like roads or sediment management BMPs would be of short-term duration and would likely involve discrete, small-scale projects as opposed to massive earthmoving activities.

   Fine particulate matter less than 10 micrometer (PM_{10}) is the pollutant of greatest concern with respect to construction. PM_{10} emissions can result from a variety of construction activities, including excavation, grading, demolition, vehicle travel on paved and unpaved surfaces, and vehicle and equipment exhaust. Given the limited duration and scale of reasonably foreseeable construction activities to comply with the Basin Plan amendment, PM_{10} standards, however, would not be "substantially" violated, if at all. Additionally, if specific construction projects were proposed to comply with requirements derived from the proposed Basin Plan amendment, such projects would have to comply with the Bay Area Air Quality Management District's (BAAQMD) requirements with respect to the operation of portable equipment. Moreover, BAAQMD has identified readily available measures to control construction-related air quality emissions (BAAQMD 1999) that are routinely employed at most construction sites. These measures include watering active construction areas; covering trucks hauling soil; and applying water or applying soil stabilizers on unpaved areas. Therefore, in consideration of all of the foregoing, the Basin Plan amendment would not violate any air quality standard or contribute substantially to any air quality violation, and its temporary and localized construction-related air quality impacts would be less-than-significant.

c) In accordance with BAAQMD CEQA Guidelines, for any project that does not individually have significant operational air quality impacts, the determination of significant cumulative impact should be based on an evaluation of the consistency of the project with the local general plan and of the general plan with the regional air quality plan. The Basin Plan amendment will not result in, nor authorize, new land uses, housing, or other uses that would generate sustained air emissions. The Basin Plan amendment projects would be consistent with the 2001 Bay Area Ozone Attainment Plan and the 2000 Bay Area Clean Air Plan. Therefore, the Project would not result in a cumulatively considerable net increase in any criteria pollutant. This would be a less than significant impact.

d) Because the Basin Plan amendment would not involve the construction of any permanent emissions sources but rather involves short-term and discrete construction activities, it would not expose sensitive receptors to substantial pollutant concentrations. The Project area is primarily rural and agricultural, and residential uses are low density. Minor construction and/or earth moving undertaken to comply with the Basin Plan amendment during site preparation and road modification/construction could result in particulates in the air in the immediate area of grading and construction but would not expose sensitive receptor, likely to be located substantial distances, to substantial pollutant concentrations.

e) Because the Basin Plan amendment would not involve the construction of any permanent emissions sources but rather involves short-term and discrete construction activities, it would not create objectionable odors affecting a substantial number of people. Diesel engines may be used for some construction equipment during site preparation and construction activities to modify existing roads and road crossings. Odors generated by construction equipment would be variable, depending on the location and duration of use. Diesel odors may be noticeable to some individuals at certain times, but would not affect a substantial number of people given that agriculturally zoned districts contain a low population density. Therefore, the impact of the Basin Plan amendment with regard to odors is considered to be less than significant.

IV. BIOLOGICAL RESOURCES

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	X	☐	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	X	☐	☐
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☐	X	☐	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☐	X	☐	☐

e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	X	☐
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	X	☐

The Basin Plan amendment was developed specifically to enhance, restore, and protect water quality and beneficial uses, including fish, wildlife, and rare and endangered species. Nonetheless it is possible that in order to comply with the proposed Basin Plan amendment, specific projects involving construction and earthmoving activities could be proposed that could potentially affect candidate, sensitive or special status species (collectively, special-status species), either directly or through habitat modifications. While the minor construction and earthmoving operations would occur in already disturbed areas and might involve reconstruction, reshaping and blading for proper drainage, or replacement of existing roads and structures, it is possible (although not likely) that these and other activities to reduce erosion and enhance stream habitat could occur in and impact areas where there are special-status species and habitats.

a) Table 22 provides a summary of the types of reasonably foreseeable compliance actions. In general, there are six types of reasonably foreseeable compliance actions: 1) projects to reduce sediment delivery from road-related erosion; 2) projects to increase LWD loading in channels (including construction/installation of log jams); 3) projects to enhance stream and floodplain habitat; 4) projects to reduce sediment delivery from surface erosion; 5) projects to reduce sediment delivery from gullies and landslide erosion; and 6) projects to manage stormwater runoff to reduce sediment delivery.

   Reasonably foreseeable projects that may adversely affect special-status species would be subject to review and approval by the Water Board and/or other resource agencies. For instance, all of the log jam or inset floodplain construction projects and projects to enhance stream habitat would occur in stream channels that provide potential habitat for steelhead and/or coho salmon, and therefore, permits to protect special status species would be required from:

   - Regional Water Quality Control Board, which reviews and conditions projects to ensure that water quality is protected;
   - US Army Corps of Engineers, which regulates placement of all materials in waters of the US;
   - NOAA Fisheries, which conditions US Army Corps permits to protect commercially important species, including steelhead and coho salmon, that are listed under the federal Endangered Species Act;
   - US Fish and Wildlife Service, which conditions US Army Corps permits to protect all non-commercial species listed under the federal Endangered Species Act, including California red-legged frog, San Francisco garter snake, and marbled murrelet;
   - California Department of Fish and Wildlife, which reviews and conditions projects to protect all state-listed candidate, sensitive, threatened, and/or endangered species;

- California Coastal Commission, which regulates development within the coastal zone and delegates permit authority to San Mateo County and its certified Local Coastal Program [LCP]; and
- County of San Mateo, which would require a CEQA determination and a Biological Site Assessment to ensure that all species listed as rare, threatened, endangered, or of special concern under state or federal law are protected.

Where construction for projects overlaps with and/or disturbs a stream channel, riparian area, and/or other wetlands or waters of the United States, the Water Board would require the project proponent to apply for a Clean Water Act Section 401 permit authorization and waste discharge requirements, and also to comply with the requirements thereof. Standard conditions of the Water Board CWA Section 401 permit and waste discharge requirements include the requirements to comply with the terms and conditions of the CDFW Streambed Alteration Agreement and the Section 7 consultations, which would reduce impacts to all special-status species to a less than significant level.

The Water Board, in the course of carrying out its statutory duties to protect water quality and beneficial uses (including preservation of rare and endangered species and wildlife habitat as set forth in the Basin Plan), will either not approve compliance projects with significant adverse impacts on special-status species and habitats or require avoidance or mitigation measures to reduce impacts to less-than-significant levels. The Basin Plan amendment includes project components to avoid or mitigate impacts to special status species including but not limited to: a) pre-construction surveys; b) construction buffers and setbacks; c) relocation and restoration of sensitive habitats were permissible and avoidance is impossible; d) limiting the timing of construction activities to avoid site-specific impacts to fisheries and other aquatic wildlife to the period between June 1 and October 1, unless CDFW, USFW, and/or NOAA Fisheries define an alternative work window to avoid site specific impacts on special-status species; e) limiting all construction to daylight hours to protect California red-legged frog; and f) where noise from heavy equipment e.g. during culvert removal, placement of large woody debris, has the potential to cause nesting marbled murrelets to abandon nests, limiting such work to the fall and winter months, and excluding use of heavy equipment within ¼ mile of occupied or un-surveyed suitable marbled murrelet habitat (CDFW could modify the work window at individual sites if protocol surveys determine that habitat quality is low and occupancy is very unlikely).

Long-term impacts of actions taken to comply with the Basin Plan amendment would be beneficial for all special-status species. Considering the above mitigation measures, short-term construction-related impacts of Basin Plan actions would be reduced to a less than significant level.

The other type of reasonably foreseeable actions to comply with the Basin Plan amendment, would relate to road-erosion control on the County, State, or open space lands. For any road-erosion control project involving a stream crossing, and/or other jurisdictional wetlands, the same logic as presented above would apply, and that impacts to special status species would be less than significant. For the remainder of road-erosion control actions/project types (e.g., cross drains and ditch relief culverts, excavation of road-related landslides, construction of rolling dips, out-sloping of road segments, installation of water bars, management of sediment and vegetation in inboard ditches, and removal of road berms), where roads are located on public land, impacts to upland animal and plant species would be less than significant because: i) vegetation surveys and rare plant inventories have been completed for the parks and open space lands in the watershed; and ii) the County of San Mateo would require a Biological Site Assessment and CEQA determination for the road erosion control projects. For the privately-owned roads, almost all construction activity would be confined to the footprint of the existing roads, and for projects involving grading of 250 cubic yards or more, the County of San Mateo would require permits and an environmental review and compliance with CEQA. Therefore, we conclude that impacts would be less than significant.

b) As indicated in section IV-a) above, the Basin Plan amendment is designed to benefit biological resources, including riparian habitat and other sensitive natural communities. The Water Board, in the course of discharging its statutory duties to protect water quality and their beneficial uses, will either not approve compliance projects with significant adverse impacts on riparian habitats and other sensitive natural communities, or would require mitigation measures to reduce impacts to less-than-significant levels. Where avoidance of impacts is not possible, the Water Board requires mitigation measures for work it approves that may impact riparian habitats or other sensitive natural communities. Such requirements include but are not limited to pre-construction surveys; construction buffers and setbacks; restrictions on construction during sensitive periods of time; employment of on-site biologists to oversee work; avoidance of construction in known sensitive habitat areas; and relocation and restoration of sensitive habitats where permissible and avoidance is impossible. For instance, although reasonably foreseeable compliance actions e.g., construction of engineered log jams to increase LWD loading in channels and channel restoration projects could result in minor and short term disruption to riparian habitat, such projects would result in an overall enhancement of riparian habitat conditions. This finding is based on the reasoning that, as the number and frequency of key pieces of large woody debris in channel reaches is greatly increased, the complexity of channel habitat and connectivity to the floodplain would also be greatly enhanced with resultant enhancement of the extent and diversity of riparian habitats (Collins et al., 2012, also see Chapter 7 of this report for additional details).

Reasonably foreseeable projects to comply with the Basin Plan amendment in the upland areas e.g., road, surface, or gully erosion control projects are subject to review and approval by the Water Board and other resource and public agencies. For any upland road-erosion control projects on the County, State, or open space lands involving a stream crossing and/or riparian habitat the same logic as presented above would apply, and that impacts to special status species would be less than significant. For the remainder of upland road-erosion control actions/project types (e.g., cross drains and ditch relief culverts, excavation of road-related landslides, construction of rolling dips, out-sloping of road segments, installation of water bars, management of sediment and vegetation in inboard ditches, and removal of road berms), where roads are located on public land, impacts to upland sensitive communities would be less than significant because: i) vegetation surveys and rare plant inventories have been completed for the parks and open space lands in the watershed; and ii) the County of San Mateo would require a Biological Site Assessment and CEQA determination for the road erosion control projects. For the privately-owned roads, almost all construction activity would be confined to the footprint of the existing roads, and for projects involving grading of 250 cubic yards or more, the County of San Mateo would require permits and an environmental review and compliance with CEQA. Therefore, we conclude that impacts would be less than significant.

c) Basin plan amendment-related implementation actions will involve channel habitat enhancement and/or erosion control projects, a fraction of which would occur within and/or overlap with wetlands. The adverse impacts on wetlands would not be substantial, however because under the Nationwide or individual permit programs administered by the US Army Corps of Engineers, there are general conditions that require that for projects that may adversely affect all wetlands, as defined under Section 404 of the Clean Water Act, responsible parties must demonstrate that avoidance, minimization, and mitigation has occurred to the maximum extent practicable to ensure that adverse impacts to the aquatic environment are minimal. Furthermore, for all potential projects where wetland losses would exceed 0.1 acres, applicants are required to provide compensatory mitigation at a ratio that is greater than or equal to 1:1. For projects where wetland losses are less than 0.1 acre, on a case by case basis, the District Engineer may require compensatory mitigation. If TMDL implementation projects are proposed that could have the potential to disturb wetlands, they also would be subject to the Water Board's review and approval under Section 401 of the Clean Water Act and the Porter-Cologne Water Quality Control Act, and the Water Board must, consistent with its Basin Plan, require mitigation measures to avoid, minimize, and mitigate impacts to less-than-significant levels. As specified in the Basin Plan, the Water Board uses the USEPA Section 404(b)(1) Guidelines for dredge and fill material in determining the circumstances under which the filling of wetlands may be permitted. This policy requires that avoidance and minimization be emphasized and demonstrated prior to consideration of mitigation. Moreover, the California Wetland Protection Policy also is incorporated into the Basin Plan. The goals of this policy include ensuring that "no overall net loss" and "long-term net gains in the quantity, quality, and permanence of wetland acreage and values…" (Governor's Executive Order W-59-93). Wetlands not subject to protection under Sections 404 and 401 of the Clean Water Act are still subject to regulation and protection under the California Water Code. Please also see discussion in part b) above relating to sensitive natural communities, some of which are wetland types.

d) The Basin Plan amendment would not substantially interfere with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites. The main goal of the Basin Plan amendment is to improve and enhance fish passage. Thus compliance projects would entail improving migratory fish corridors, not adversely affecting them. It is possible, however, that projects could be proposed to comply with the Basin Plan amendment that involve construction or earthmoving activities that could interfere with wildlife movement, migratory corridors, or nurseries (e.g., channel habitat enhancement projects, fish passage enhancement projects, road or surface erosion control projects). If that occurs, the projects would be subject to and have the same process and impacts described in responses a, and b, above. Furthermore, none of the reasonably foreseeable compliance actions (Table 22) has the potential to substantially interfere with wildlife movement, therefore we conclude that the impacts is less than significant with mitigation incorporated.

e) The Basin Plan amendment itself does not conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance. There is no evidence to suggest that projects proposed to comply with Basin Plan amendment requirements would conflict with these plans. In all cases, these projects would be subject to discretionary permits from the County of San Mateo (as applicable) that would be conditioned to avoid potential conflicts with local policies and/or ordinances that protect biological resources. Potential impacts will be less than significant.

f) The Basin Plan amendment itself does not conflict with any adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan. There is no evidence to suggest that projects proposed to comply with Basin Plan amendment requirements would conflict with these plans. Potential impacts will be less than significant.

V. CULTURAL RESOURCES

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in § 15064.5?	☐	☐	X	☐
b) Cause a substantial adverse change in the significance of a unique archaeological resource pursuant to § 15064.5?	☐	X	☐	☐
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	X	☐	☐
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	X	☐	☐

a) Projects involving earthmoving or construction to comply with requirements of the proposed Basin Plan amendment are reasonably foreseeable. The proposed Basin Plan amendment and its reasonably foreseeable compliance projects (e.g., small-scale earthmoving and construction) would not cause a substantial adverse change in the significance of a historical resource as defined by CEQA Guidelines section 15064.5.

There are no reasonably foreseeable actions that would affect buildings that meet the definition of historical resources. Other types of historical resources that we have identified could be affected by reasonably foreseeable actions to comply with the Basin Plan amendment include the following:

- Civilian Conservation Corps erosion control structures (e.g., stream bank or bed stabilization structures, check-dams, detention basins, etc.), water supply dams, and/or road or trail structures (e.g., embankments, stream crossings, rock surfaces, and/or rock-lined ditches or cross-drains, etc.)
- Archeological sites that meet the definition of historical resources under the California Public Resource Code.

Civilian Conservation Corps (CCC) work projects occur within public parklands. In the project area, there are two state parks: Portola State Park and Butano State Park. The California Department of Parks and Recreation prepared an index that includes all major existing buildings and structures constructed by the CCC in the California State Parks[56]. For state parks in the Pescadero-Butano watershed, no CCC projects are documented. Although it is possible that other "minor features and infrastructure elements" were constructed by the CCC, and may be present in state parks in the Pescadero-Butano watershed, the Public Resources Code (section 5024) requires that all state agencies consult with the Office of Historic Preservation when any proposed project may adversely affect any historical resources on state-owned property.

The Office of Historic Preservation (OHP) is an arm of the State Parks Agency, and its purpose is to insure that federal and state agencies comply with state and federal laws to avoid and/or minimize adverse impacts to historical resources.[57] Furthermore, sections 5024 and 5024.5 of the Public Resource Code require that each state agency shall formulate policies to preserve and maintain, when prudent and feasible, all historical resources within their jurisdiction or potentially eligible for inclusion in the National Register of Historic Places or registered as a landmark. Therefore, we conclude that reasonable foreseeable actions to comply with the Basin Plan amendment would have a less than significant impact on CCC projects and/or other historical resources located on public lands because there are no historical resources identified in the project area where implementation actions would occur.

b) With regard to projects involving earth moving or construction to comply with the Basin Plan amendment, earth moving and construction would generally be small in scale and would occur in already disturbed areas, within the footprint and/or right-of-way of existing roads. No roads would need to be relocated in order to comply with the Basin Plan amendment. Therefore, we conclude that potential impacts of road-erosion control projects implemented to comply with the Basin Plan amendment are less than significant.

With regard to log jams construction projects implemented to comply with the Basin Plan amendment, earthmoving and vegetation disturbance to provide construction site access, and/or to install key large woody debris pieces into the streambed and/or banks would be minor. No log jams will be constructed where they might adversely impact archeological resources. In order to obtain a Clean Water Act section 401 permit, prior to starting construction of any log jam project, the Water

[56] https://www.parks.ca.gov/?page_id=24878
[57] http://ohp.parks.ca.gov/pages/1072/files/sanmateo.pdf

Board also would require a copy of the CEQA determination for the project including documentation of the analyses performed to determine whether the project site overlaps with known or potential archeological sites (as determined through review of the County's Archeological Sensitivity Map). To avoid impacts to archeological resources, for sites that may overlap with archeological resources, prior to constructing any engineered log jam project that would involve earth moving, the Water Board would require as mitigation measures that: 1) a field survey be performed by a qualified archeologist, who would provide recommendations and/or procedures to further investigate and/or mitigate adverse impacts; and 2) if cultural resources are discovered during field survey or subsequent construction activities, all earth moving would cease until a qualified archeologist assesses the potential resources and their significance, and then develops recommendations or procedures to mitigate any impacts.

c) With regard to projects involving earth moving or construction to comply with requirements of the proposed Basin Plan amendment, earth moving and construction would occur in already disturbed areas, within the footprint and/or right-of-way of existing roads. No roads would need to be relocated in order to comply with the Basin Plan amendment. Therefore, we conclude that potential impacts on paleontological resources of road-erosion control projects implemented to comply with the Basin Plan amendment are less than significant.

   With regard to log jams construction projects implemented to comply with the Basin Plan amendment, earthmoving and vegetation disturbance to provide construction site access, and/or to install key large woody debris pieces into the streambed and/or banks would be minor. No log jams will be constructed where they might adversely impact paleontological resources. In order to obtain a Clean Water Act section 401 permit, prior to starting construction of any log jam project, the Water Board also would require a copy of the CEQA determination for the project including documentation of the analyses performed to determine whether the project site overlaps with known or potential paleontological sites. To avoid impacts to paleontological resources, for sites that may overlap with such resources, prior to constructing any engineered log jam project that would involve earth moving, the Water Board would require as mitigation measures that: 1) a field survey be performed by a qualified paleontological resources specialist, who would provide recommendations and/or procedures to further investigate and/or mitigate adverse impacts; and 2) if cultural resources are discovered during field survey or subsequent construction activities, all earth moving would cease until a qualified paleontologist assesses the potential resources and their significance, and then develops recommendations or procedures to mitigate any impacts.

d) With regard to projects involving earth moving or construction to comply with requirements of the proposed Basin Plan amendment, earth moving and construction would generally be small in scale and would generally occur in areas already disturbed by recent human activity and not occur in areas of known human remains (the only known cemetery in the Pescadero-Butano watershed is the Mount Hope Cemetery), whether historic or prehistoric, as defined by section 15064.5 of the CEQA Guidelines. State law requires that any human remains are encountered during site disturbance, all ground-disturbing work shall cease immediately and the County coroner shall be notified immediately. If the coroner determines the remains to be Native American, the Native American Heritage Commission shall be contacted within 24 hours. The Native Heritage Commission would then identify the person(s) it believes to be the most likely descendants, and they would be responsible for making recommendations for the disposition and treatment of the remains. Therefore, we conclude that any potential impacts would be less than significant with mitigation incorporation.

VI. GEOLOGY AND SOILS

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i) Rupture of a known earthquake fault, as delineated on the most recent applicable Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist, or based on other substantial evidence of a known fault? (California Geological Survey, Special Publication 42: Fault-Rupture Hazard Zones in California).	☐	☐	☐	X
ii) Strong seismic ground shaking?	☐	☐	☐	X
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	X
iv) Landslides?	☐	☐	☐	X
b) Result in substantial soil erosion or the loss of topsoil?	☐	X	☐	☐
c) Be located on geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	X
d) Be located on expansive soil, as defined in Title 24, section 1803.5.3 of the California Code of Regulations, creating substantial risks to life or property?	☐	☐	☐	X
e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater				

disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	X

a) The Basin Plan amendment would not involve the construction of habitable structures; therefore, it would not involve any human safety risks related to fault rupture, seismic ground-shaking, ground failure or landslides.

b) Specific projects involving earthmoving or construction activities to comply with requirements derived from the proposed Basin Plan amendment are reasonably foreseeable. Such activities would not result in substantial soil erosion or the loss of topsoil. The purpose of the Basin Plan amendment is to reduce erosion, not increase it. To meet the Basin Plan amendment targets, construction would be designed to reduce overall soil erosion associated with erosion. However, temporary earthmoving operations could result in short-term, limited erosion. These specific compliance projects would be subject to the review and approval of the Water Board, which requires implementation of routine and standard erosion control best management practices and proper construction site management. In addition, construction projects over one acre in size would require a general construction National Pollutant Discharge Elimination System permit and implementation of a stormwater pollution prevention plan to control pollutant runoff such as sediment. Therefore, the Basin Plan amendment would not result in substantial soil erosion, and its impacts would be less-than-significant.

c) The Basin Plan amendment could result in projects involving roads, creek crossings, and other projects located on steep slopes or unstable terrain. These projects would be designed to stabilize existing sources of sediment, such as roads or eroding gullies and landslides, and/or to reduce erosion and sedimentation. In addition, all Basin Plan amendment construction activities would be designed and conducted under the supervision of a certified Professional Geologist licensed in California. Construction activities would be designed to minimize any potential for landslides, lateral spreading, subsidence, liquefaction or property risks due to unstable soils.

d) The Basin Plan amendment would not involve construction of buildings or any habitable structures (as defined in Uniform Building Code). Local agencies proposing construction to comply with requirements derived from the Basin Plan amendment would be required to obtain building permits to ensure that they do not locate structures on expansive soils. Minor grading and construction could occur in areas with expansive soils but this activity would not create a substantial risk to life or property. Therefore, the Basin Plan amendment would not result in impacts related to expansive soils.

e) The Basin Plan amendment would not require wastewater disposal systems; therefore, affected soils need not be capable of supporting the use of septic tanks or alternative wastewater disposal systems.

VII. GREENHOUSE GAS EMISSIONS

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☐	☐	X	☐
b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	X

The Natural Resources Agency adopted the CEQA Guidelines Amendments to analyze the environmental impact of greenhouse gas emissions (GHGs) in December 2009. San Mateo County adopted the San Mateo Energy Efficiency Climate Action Plan in 2013.

a) Specific projects involving earthmoving or construction activities to comply with requirements derived from the proposed Basin Plan amendment are reasonably foreseeable. Short-term construction-related impacts and mitigation measures are divided into BMPs that would result in the construction of linear features and those that would result in the non-linear features. The BMPs that would result in construction of linear futures include road-related construction e.g., water bars, ditch relief culverts, road crossings, road storm-proofing, and road reshaping and other BMPs e.g., vegetated buffer strips. The BMPs that would result in construction of non-linear futures include cover crops, conservation tillage, and soil bioengineering techniques for channel stabilization projects.

   Implementation of BMPs that would result in the construction of both linear and non-linear features may generate short-term GHG emissions. The magnitude of construction activities would vary widely between types of BMPs and, for each type of BMP, would vary widely between individual sites. Construction activities would include site preparation, materials transport, grading, trenching, and placement of landscaping and erosion control features. Any short-term increases in GHG emissions would be offset by the longer-term carbon sequestration benefits of engineered log jams and floodplain restoration, riparian enhancements, and increases in the total area of riparian habitat. Impacts are therefore considered less than significant.

b) The Basin Plan amendment would not conflict with any plan, policy, or regulation adopted for the purpose of reducing GHGs.

VIII. HAZARDS AND HAZARDOUS MATERIALS

Would the project:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	X	☐
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	X	☐
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	X
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code, section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	X
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	X
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	X
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	X
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	X

a-d) It is highly unlikely that hazardous materials or substances be discovered during project activities associated with erosion control and/or habitat enhancement. If discovered, required remediation actions would include the proper disposal and transport of contaminated soils, but such waste is expected to be of small volume. Proper handling in accordance with relevant laws and regulations would minimize hazards to the public or the environment, and the potential for accidents or upsets. Construction associated with implementing the Basin Plan amendment erosion control measures would not involve the use or transport of hazardous materials, aside from those fuels (e.g., gasoline, diesel) and lubricants typically used for heavy construction equipment. Fuels and lubricant quantities would be small and their application would be limited to the operation of construction-related equipment and vehicles. Compliance with the Basin Plan amendment would not affect the transportation of potential release of hazardous materials, nor create a significant public safety or environmental hazard beyond any hazards currently in existence.

Therefore, hazardous waste transport and disposal would not create a significant public or environmental hazard, and would be a less-than-significant impacts.

e-f) The project would not require actions in the vicinity of airports or airstrips.

g) Actions to implement the Basin Plan amendment would not interfere with any emergency response plans or emergency evacuation plans.

h) The Basin Plan amendment would not affect the potential for wild-land fires.

XI. HYDROLOGY AND WATER QUALITY

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☐	X
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	X
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion of siltation on- or off-site?	☐	X	☐	☐

d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	X	☐	☐
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	X
f) Otherwise substantially degrade water quality?	☐	☐	☐	X
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	X
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	X	☐	☐
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	X	☐
j) Inundation of seiche, tsunami, or mudflow?	☐	☐	☐	X

a) The project would amend the Basin Plan, which articulates applicable water quality standards, to attain and maintain water quality standards in the Pescadero-Butano watershed. Therefore, it would not violate standards or waste discharge requirements and the effect of the Basin Plan amendment on attainment of water quality objectives will be beneficial.

b) The Basin Plan Amendment would not decrease groundwater supplies or interfere with groundwater recharge. LWD construction projects to reduce sediment delivery and/or other channel habitat enhancement projects e.g., those to increase channel-floodplain connectivity could promote increases in groundwater recharge.

c) Specific projects involving earthmoving or construction activities to comply with requirements derived from the proposed Basin Plan amendment are reasonably foreseeable. Such projects could affect drainage patterns. However, to meet proposed Basin Plan amendment allocations, they would be designed to reduce overall soil erosion, not increase it. Moreover, included in the Basin Plan amendment is a performance standard requiring that non-grazing agricultural lands effectively attenuate significant increases in storm runoff such that runoff from non-grazing agricultural lands shall not cause or contribute to downstream increases in rates of bank or bed erosion. This performance standard ensures that erosion control measures (implemented to comply with the Basin Plan amendment) will not result in increased storm runoff and related stream bed or bank erosion. Additionally, projects components include: a) the requirement to prepare hydrologic and geomorphic analyses to support design and construction of engineered log jams or erosion-control features, as needed to avoid erosion and flooding impacts; and b) limiting the project construction period to the dry season and requiring that all Basin Plan amendment construction projects include preparation of a stormwater pollution prevention plan to control erosion and protect water quality. Nevertheless, temporary earth moving operations could result in short-term, limited erosion. These specific compliance projects also would be subject to the review and approval of the Water Board, which requires implementation of routine and standard erosion control best management practices and proper construction site management. Mitigation measures to control construction-related impacts include control of or restricting the timing of construction, requiring construction site management, control of erosion during and following construction, limiting where and when heavy equipment can be used, limiting earth moving, limiting vegetation disturbance, and requiring replanting of native vegetation. In addition, construction projects over one acre in size would require a general construction National Pollutant Discharge Elimination System permit and implementation of a storm water pollution prevention plan. Therefore, the Basin Plan amendment would not result in substantial erosion and its impacts would be less-than-significant with mitigation incorporated. The overall effect of the project on erosion and sedimentation would be a beneficial reduction in erosion and siltation.

d) Reasonably foreseeable actions to comply with the Basin Plan amendment will involve earthmoving that could affect existing drainage patterns, and construction of engineered log jams that will contribute to increases in the amount of riparian vegetation and/or LWD in stream channels. Road-erosion control projects will reduce storm runoff from roads, and engineered log jams will provide additional floodplain water storage in public park reaches, where additional inundation would not threaten structure or human safety. Also, the project includes as a mitigation measure, the requirement to prepare hydrologic and geomorphic analyses to avoid significant increases in erosion and/or flooding. These required studies will be prepared by a Certified Professional Geologist and/or a Registered Civil Engineer that is licensed to practice in the State of California, who has expertise in fluvial geomorphology, hydrology, and river restoration. All construction projects will require use permits from the County of San Mateo, and be subject to review under the CEQA. Therefore, we conclude that the impact of the Basin Plan amendment on increases in runoff and/or flooding is less than significant with mitigation incorporated.

e) Basin Plan amendment-related activities are, by design, intended to decrease peak runoff rates from roads, as needed to reduce sediment delivery to channels and channel erosion. Therefore, the Basin Plan amendment would not increase the rate or amount of runoff, exceed the capacity of storm water drainage systems, or degrade water quality, and there is no impact.

f) The purpose of the Basin Plan amendment is to attain and maintain all water quality objectives. Reasonably foreseeable compliance actions would not otherwise adversely affect water quality.

g) Basin Plan amendment will not result in construction of housing. Therefor no housing would be placed within the 100-year flood hazard zone as a result of the proposed action. No flood hazard impacts would occur.

h) The Basin Plan amendment-related construction, with the mitigation measures incorporated, as described above in d) that will govern design and construction of engineered log jams within channels, will result in impacts that are less than significant with mitigation incorporated. For Basin Plan amendment actions to address road-related erosion, there are two types of BMPs that may be employed that involve placement of fill in channels: a) storm-proofing road crossing over channels; and b) soil bioengineering and/or biotechnical stabilization techniques to control erosion in unstable upland areas (e.g., gullies and landslides). Storm-proofing includes upgrading the road crossing to typically convey the 100-year peak flow as well as the inferred sediment and large woody debris loads. Therefore, where such undersized or failing culverts are located in flood hazard areas, the effect of actions taken to comply with the Basin Plan amendment would be beneficial (to reduce flooding) in the long-term and the impacts would be less than significant with mitigation incorporated. Soil bioengineering and/or biotechnical techniques would only be installed or constructed in channels or gullies located in upland areas to minimize erosion and sediment delivery, none of which overlap with defined flood hazard areas. Therefore, the impacts would be less than significant with mitigation incorporated.

i) The Basin Plan amendment will not result in construction or modification of dams or levees or activities that would expose people to significant damage from dam or levee failure and no adverse impacts would occur.

j) Basin Plan amendment-related construction would not be subject to substantial risks due to inundation by seiche, tsunami, or mudflow.

X. LAND USE AND PLANNING

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Physically divide an established community?	☐	☐	☐	X
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	X

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	X

a) Basin Plan amendment-related construction would be too small in scale to divide any established community.

b) Reasonably foreseeable actions to comply with the Basin Plan amendment would not conflict with the policies and implementing programs of the San Mateo County General Plan, and/or plan and policies of other state and federal agencies responsible for management of public lands and/or any state or federal agencies with regulatory authority over compliance actions.

c) Reasonably foreseeable actions to comply with the Basin Plan amendment would not conflict with any habitat conservation plan or natural community conservation plan. Projects proposed to comply with Basin Plan amendment requirements would be subject to local agency review and would not conflict with habitat conservation plans or natural community conservation plans.

XI. MINERAL RESOURCES

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	X
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	X

a-b) Basin Plan amendment-related TMDL-related excavation and construction would be small in scale and would not result in loss of availability of any known mineral resources.

XII. NOISE

Would the project:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	X	☐	☐
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	X	☐
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	X
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	X	☐	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	X
f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	X

a) Earthmoving and construction activities to comply with the requirements derived from the Basin Plan amendment could temporarily generate noise. Most reasonably foreseeable compliance actions would be located in very rural portions of the watershed, which is dominated by open space. These reasonably foreseeable compliance actions would be required to be consistent with the local agencies' own standards. Chapter 4.88 of the San Mateo County Code of Ordinances regulates noise in the County and exempts construction from the ordinance provided activities do not take place between the hours of 6:00 p.m. and 7:00 a.m. weekdays, 5:00 p.m. and 9:00 a.m. on Saturdays or at any time on Sunday, Thanksgiving and Christmas.

b) The Basin Plan amendment would not exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels. Any increases in groundborne vibration would temporary and short-term in nature.

c) The Basin Plan amendment would not cause any permanent increase in ambient noise levels. Any noise would be short-term in nature.

d) To comply with requirements derived from the Basin Plan amendment, specific projects involving earth moving or construction, which could result in temporary noise impacts, are reasonably foreseeable. Noise-generating operation would, however, have to comply with local noise ordinances to keep levels to less-than-significant levels. Therefore, the Basin Plan amendment would not result in substantial noise impacts, and its impacts would be less-than-significant.

e-f) The Basin Plan amendment would not cause any permanent increase in ambient noise levels, including aircraft noise. Therefore, it would not expose people living within an area subject to an airport land use plan or in the vicinity of a private airstrip to excessive noise.

XIII. POPULATION AND HOUSING

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	X
b) Displace substantial existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	X
c) Displace substantial numbers of people necessitating the construction of replacement housing elsewhere?	☐	☐	☐	X

a-c) The Basin Plan amendment would not affect the population of the Bay Area or San Mate County. It would not induce growth through such means as constructing new housing or businesses, or by extending roads or infrastructure. The Basin Plan amendment would also not displace any existing housing or any people that would need replacement housing.

XIV. PUBLIC SERVICES

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the Project:				
a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times, or other performance objectives for any of the public services:				
Fire protection?	☐	☐	☐	X
Police protection?	☐	☐	☐	X
Schools?	☐	☐	☐	X
Parks?	☐	☐	☐	X
Other public facilities?	☐	☐	☐	X

a) The Basin Plan amendment would not affect population growth or involve construction of substantial new government facilities. The Basin Plan amendment would not affect service ratios, response times, or other performance objectives for any public services, including fire protection, police protection, schools, or parks.

XV. RECREATION

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the Project:				
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	X	☐

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?	☐	☐	☐	X

a-b) Although the Basin Plan amendment would not affect population levels, potential enhancement of fisheries habitat and stream aesthetics has the potential to contribute to an increase in river-focused recreational activities (e.g., kayaking, rafting, fishing, swimming, wading, birding, etc.). Increases in these activities are expected to cause less than significant impacts on the environment. No recreational facilities would need to be constructed or expanded.

XVI. TRANSPORTATION / TRAFFIC

Would the project:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
a) Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume-to-capacity ratio on roads, or congestion at intersections)?	☐	☐	☐	X
b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?	☐	☐	☐	X
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	X
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	X
e) Result in inadequate emergency access?	☐	☐	☐	X
f) Result in inadequate parking capacity?	☐	☐	☐	X
g) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	X

a) Basin Plan amendment actions could result in minor construction that would require the use of heavy equipment and trucks to move soil, longs, or other materials needed for road, hillslope, and/or stream channel enhancement projects. Any earthmoving or construction activities would be temporary, and related traffic would be of short-term duration. Therefore, the Basin Plan amendment would not substantially increase traffic in relation to existing conditions. Levels of service would be unchanged.

b) Because the Basin Plan amendment would not increase population or provide employment, it would not generate any ongoing motor vehicle trips and would not affect level of service standards established by the county. Therefore, the Basin Plan amendment would not result in permanent, substantial increases in traffic above existing conditions.

c) The Basin Plan amendment would not affect air traffic. It is intended to reduce sediment delivery from unpaved roads and grazed and farmed lands to the Pescadero-Butano creek watershed and to enhance and restore channel habitat conditions.

d) Reductions in road-related erosion called for by the Basin Plan amendment would not require implementation of hazardous design features or incompatible uses in order to meet the TMDL.

e) Minor construction and earthmoving operations to reduce road-related erosion that would occur as a result of adoption of the Basin Plan amendment is not expected to restrict emergency access. Local agencies would confirm that specific proposal would not restrict emergency access through their environmental reviews.

f) Because the Basin Plan amendment would not increase population or provide employment, it would not affect parking demand or supply.

g) Because the Basin Plan amendment would not generate ongoing motor vehicle trips, it would not conflict with adopted policies, plans, or programs supporting alternative transportation.

XVII. UTILITIES AND SERVICE SYSTEMS

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	X
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	X
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	X

	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	X
e) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	X
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	X
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	X

a) The project would amend the Basin Plan, which is the basis for wastewater treatment requirements to improve water quality and the environment in the Bay Area; therefore, the Basin Plan amendment would be consistent with such requirements.

b) The Basin Plan amendment does not include changes to wastewater treatment facilities and no impacts would occur.

c) New or expanded stormwater drainage facilities are not called for under the proposed Basin Plan amendment.

d-e) Because the Basin Plan amendment would not increase population or provide employment, it would not require an ongoing water supply. It would also not require ongoing wastewater treatment services.

f-g) Basin Plan amendment implementation would not substantially affect municipal solid waste generation or landfill capacities.

XVIII. MANDATORY FINDINGS OF SIGNIFICANCE

	Potentially Significant Impact	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	X	☐	☐

b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past, current, and probable future projects)?	☐	X	☐	☐
c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	X	☐

a) When taken as a whole, the proposed Basin Plan amendment would not substantially degrade the quality of the environment. Reasonably foreseeable actions to comply with the Basin Plan amendment will benefit native fish and wildlife species including rare and endangered species by decreasing sediment supply and enhancing stream-riparian habitat conditions in Pescadero and Butano Creeks and their tributaries such that fish and wildlife species and their populations in and near waters of the state thrive. Reasonably foreseeable compliance actions in all cases would be permitted by the Water Board, the California Department of Fish and Wildlife, the US Fish and Wildlife Service, NOAA Fisheries, and the County of San Mateo (which would require a CEQA determination, and as applicable, a biological assessment). As described earlier in the Biological Resources section, we conclude that compliance actions would not threaten any plant or animal community, and/or reduce the number or restrict the range of a rare or endangered plant or animal species. Also, as described in the explanation for the checklist response for Cultural Resources, there are no significant impacts to Cultural Resources.

b) *Discussion of Cumulatively Considerable Impacts*. Project-specific impacts in all resource categories are less than significant, in some instances because of mitigation, and therefore, taken together, the impacts are less than significant with mitigation. The project incorporates design and construction requirements to avoid potential impacts of erosion and sediment delivery reduction projects and LWD jam projects on salmonids and all special status bird species; and to avoid potentially significant impacts to cultural resources and to flooding and erosion. As specific implementation proposals are developed and proposed, they would likely be subject to review and/or approval by the Water Board, the California Department of Fish and Wildlife, the US Fish and Wildlife Service, NOAA Fisheries, and/or the County of San Mateo, which would either disapprove projects with significant and unacceptable impacts or require mitigation measures.

Adoption of the Basin Plan amendment is intended to facilitate implementation of the TMDL. However, the requirements identified in the TMDL implementation plan are generally implemented through waste discharge requirements, waivers of waste discharge requirements, or other regulatory tools. The Basin Plan amendment would be cumulatively beneficial to the environment in terms of some resource areas, particularly water quality and biological resources. We are not aware of any planned projects where there may be a direct overlap with or where impacts to resources may be additive when considered with any reasonably foreseeable project per the Basin Plan amendment. Potential impacts from any such future project will be reviewed and mitigated as necessary through required permit conditions by resource agencies.

c) The Basin Plan amendment would not cause any substantial adverse effects to human beings, either directly or indirectly. The Basin Plan amendment is intended to benefit human beings through implementation of actions predicted to enhance fish populations, aesthetic attributes, recreational opportunities, and contribute to a reduction in property damage in and/or nearby stream channels in the Pescadero-Butano watershed.

9.2 Alternatives Analysis

In defining and presenting reasonable alternatives to the proposed Basin Plan amendment, we discuss how each alternative could affect foreseeable environmental outcomes, and the extent to which each alternative would achieve the goals and objectives of the proposed amendment.

The objectives of the Pescadero-Butano Watershed Sediment Reduction and Habitat Enhancement Plan (Project) are to:

- Substantially reduce sediment supply to channels, to enhance channel substrate quality and complexity, and
- Enhance floodplain-channel connections in the mainstem creeks and their tributaries, as needed, to support conservation and to facilitate recovery of watershed populations of steelhead and coho salmon.

Considering the nature of the proposed amendment –a total maximum daily load (TMDL) for sediment and a related habitat enhancement plan- this alternatives analysis examines the effects of different choices for key elements of the TMDL and habitat enhancement plan including: a) the timeframe for achieving water quality objectives for sediment and for population and community ecology; b) sediment allocations; and/or c) schedule, spatial extent, and types of actions required to achieve allocations, targets, and habitat enhancement goals. Our analysis includes the following alternatives:

1. **No Action/No Basin Plan amendment** – No sediment TMDL or habitat enhancement plan would be adopted by the Water Board.
2. **Proposed Basin Plan amendment** – Involves actions to reduce sediment supply to 125 percent of natural background supply, and actions to enhance habitat conditions in stream channels and riparian corridors. Sediment reduction and habitat enhancement objectives are achieved by 2038.
3. **Implementation actions to reduce sediment supply only** – identical to proposed Basin Plan amendment, omitting the Habitat Enhancement Plan.
4. **Proposed Basin Plan Amendment with Restoration of Historic Floodplain Habitats** - identical to the proposed Basin Plan amendment except it also includes a water quality target of restoring all of the historic floodplains (approximately 500 acres) and all of the historic wet meadows (approximately 1,350 acres), or approximately a total of 1,850 acres of historic floodplain and lowland habitats.

Alternative 1: No Action/No Basin Plan Amendment

If the Water Board does not adopt the proposed Basin Plan amendment, the U.S. Environmental Agency (USEPA) will be required to do so, pursuant to the Clean Water Act Section 303(d) sediment listing for Pescadero and Butano creeks. USEPA would most likely rely, at least in part, on the scientific analyses completed to date. Within legal constraints, the agency would be free to develop a TMDL in any manner it deems appropriate. The environmental impacts of that yet-to-be-developed TMDL are unknown. Subsequently, the Water Board would be required to prepare a plan specifying actions to resolve the impairment (e.g. an implementation plan), as needed to attain and maintain the numeric targets and sediment allocations established by USEPA. Absent USEPA completion of an alternative TMDL, it would be speculative to evaluate whether or not reasonably foreseeable actions needed to achieve the alternative TMDL would reduce or increase environmental impacts (as compared to the proposed Basin Plan amendment).

Alternative 2: Proposed Basin Plan Amendment

The proposed Basin Plan amendment is based on the technical analyses presented in Chapters 2 through 8 of this Staff Report. The amendment includes: a) numeric targets for residual pool volume, substrate composition, and LWD; b) a TMDL for sediment in the Pescadero-Butano watershed; c) allocations for sediment inputs to channels, by source category; and d) an implementation plan specifying actions to reduce fine sediment supply associated with land use activities, and complementary actions to enhance habitat complexity. Adoption of the Basin Plan amendment sets the sediment TMDL at 125 percent of natural background load.

Implementation actions to reduce sediment supply associated with land use activities would focus on road-related erosion for all land uses, surface and gully erosion in grazing and agricultural lands, channel incision, gully and landslide erosion in parks and open space lands and in timberlands, and stormwater runoff management. Reasonably foreseeable actions to comply with the Basin Plan amendment include retrofits and/or maintenance actions to control erosion, best management practices to manage runoff and prevent stormwater erosion, and habitat enhancement through the installation of LWD in channels and grading and re-vegetation projects along channels. Adoption of the proposed Basin Plan amendment would result in attainment of numeric targets and allocations for sediment and habitat enhancement objectives by early 2038.

Based on the environmental analysis, presented earlier in this chapter, we conclude that, subject to implementation of mitigation, there are no potentially significant impacts resulting from reasonably foreseeable actions to comply with the proposed Basin Plan amendment.

Alternative 3: Implementation Actions to Address Sediment Only

This alternative is identical to the proposed Basin Plan amendment except implementation would focus solely on action to reduce sediment input to channels from land use activities. Under this alternative, the Water Board would not set targets and goals or recommend actions to enhance stream or riparian habitat.

This alternative would satisfy legal requirements associated with the Clean Water Act and would resolve sediment-related threats to coho salmon and steelhead populations. However, actions to control sediment discharges alone will are not sufficient to protect, remediate, restore, and enhance the Pescadero and Butano creeks because the decline in salmonid populations is linked not only to elevated sediment input to channels but also to loss of habitat due to habitat simplification and floodplain disconnection. For instance, of all the sediment categories, channel incision has a very high priority for source reduction and control because sediment input from channel incision is produced locally, and therefore may have a greater effect on fine sediment deposition at spawning and rearing sites than more remote sources of sediment delivery. Also, of greater importance than its role as a sediment source, as the channels incise in the Pescadero-Butano watershed, they obliterate the basic physical habitat structure of the creeks, expressed by a substantial reduction in quantity of gravel bars, riffle margins, side channels, sloughs, and disconnection of the channels from their floodplains. In addition, streamside land uses, public works infrastructure, and utilities are threatened by high rates of bank erosion associated with channel incision processes. Therefore, stream and riparian habitat enhancement projects called for in the Basin Plan amendment and large-scale grading and revegetation projects along the mainstem channel are necessary both to achieve the sediment TMDL, and to enhance habitat conditions. Therefore, potentially significant impacts associated with this alternative are less than those identified for the proposed Basin Plan amendment, but this alternative is not preferred because it does not achieve one of the primary objectives.

Alternative 4: Proposed Basin Plan Amendment plus Restoring Historic Floodplain Habitats

This alternative is identical to the proposed Basin Plan amendment except it also includes a target to restore all of the historic floodplain and lowland habitats, which covered an area of approximately 1,850 acres. This would entail more than an order of magnitude increase in the existing floodplain habitats. For the floodplain, we use the definition of Dunne and Leopold (1978):

> "The floodplain is the flat area adjoining a river channel constructed by the river in the present climate and overflowed at times of high discharge. It is inundated on the average once every one or two years (p.600)."

Historically, there were approximately 1,350 acres of wet meadows and 500 acres of floodplains along the Pescadero and Butano creeks, as well as Bradley Creek. The broad and frequently inundated floodplains of Pescadero and Butano valleys and the wet meadows provided a tremendous amount of high quality winter rearing habitat for coho salmon in alcoves and side channels; winter rearing and refuge habitat for juvenile steelhead; essential habitat for many other native fish and wildlife species within the wet season and/or throughout the year; and supported a more extensive riparian forest (see Chapter 4.2). Due to 1) channel incision and subsequent loss of connectivity between channels and floodplains; and 2) land use changes along the riparian zone, only a minor portion of historic floodplains currently function as floodplain. There are up to 200 acres[58] of existing floodplain and wet meadow habitat, approximately half of which is the Butano Farms floodplain restoration project area that was completed in 2016. Therefore, this alternative includes a goal of restoring an additional 1,650 acres in the Pescadero and Butano valleys. As a result, in addition to the engineered log jams that are part of the proposed Basin Plan amendment (some of which will increase floodplain area locally in backwaters of jams), this alternative would involve large-scale floodplain restoration projects (e.g., 1,500 feet-or-greater in length) constructed adjacent to channels located in public parklands, timberlands, and private lands where feasible. Floodplain restoration involves actions to increase the elevation of the streambed and/or to decrease the elevation of the adjacent valley flat, in order to increase the frequency, area, and/or duration of inundation on the valley flat.

This alternative incorporates the following assumptions:

1. The amount and quality of different types of habitat are reasonable predictors of juvenile salmonid abundance and production (Beechie et al., 1994);
2. Large amounts of habitat need to be restored within a watershed to have a measurable effect at a population or watershed scale (Roni et al., 2010);
3. Floodplain restoration efforts would include conservation easements and acquisitions, construction and reconnection of floodplain habitats, restoration of channel alcoves, side sloughs and channels, and riparian habitat restoration; and
4. The TMDL timeline would be extended to at least 30 years, considering the time it would take to secure conservation easements and acquisitions and for stream habitat and fish response.

The geomorphic and biological objectives associated with the floodplain area target include increasing the side channel, alcove, and wetted area (during winter baseflow and higher flows) by more than an order of magnitude, storing a substantial fraction of the fine sediment supply on the floodplain, and restoring natural rates of recruitment of LWD from riparian area of channels located on timberlands or public lands. As compared to the Basin Plan amendment, this alternative would involve a much greater amount of earth moving and construction in/around stream channels, and potentially significant short-term impacts to biological resources (with significant positive medium- and long-term benefits), and

[58] This is an estimate of the current area of floodplain and wet meadows within a factor-of-two. An accurate estimate of the present-day area is not available and developing this information is challenging due to access and/or availability of high-resolution topographic information. The Water Board does not have resources available to support preparation of a complete and accurate map of present-day floodplain area. Even where access is granted or high quality topographic data is available, there is considerable variation in channel cross-section area, streambed slope, roughness, and variability in the amount of large woody debris and vegetation in the main channel and on the floodplain, it is challenging to develop this information.

potentially significant impacts to hydrology and water quality. In addition, depending upon the specific attributes of a given incised channel reach, where little or none of the adjacent valley flat is a floodplain at present, different techniques and/or approaches for reconnecting the floodplain would be called for. These techniques likely vary considerably with regard to amount of potential short-term disturbance to existing biological resources. Therefore, we conclude that a more detailed understanding of the opportunities and constraints and of the potential benefits of floodplain reconnection is warranted before implementing large-scale floodplain project, in order to optimize potential environmental benefits. This alternative is not preferred.

Analysis of the Preferred Alternative

The *No Action* alternative is not preferred. Although there is a legal requirement under the Clean Water Act to develop a TMDL, the concurrent development of an implementation plan to achieve the TMDL is not a CWA requirement. Therefore, the State would be required to develop the implementation plan. Because two agencies would be involved in the process, there is a higher potential for disconnects between the TMDL and its implementation plan. In addition, this two-step process would further delay establishment, and subsequent implementation, of the TMDL. Further delay would not be the best use of public funds, as significant public dollars already have been spent to develop the proposed Basin Plan amendment. Lastly, delaying TMDL implementation would only lengthen the duration of the sediment impairment.

The *implementation actions to address the sediment only alternative* would resolve sediment-related threats to salmonids, and related beneficial uses. However, actions to enhance habitat complexity and stream and floodplain connectivity are necessary to rebuild and sustain viable populations of steelhead and coho salmon in the Pescadero-Butano watershed, and these objectives of the proposed Basin Plan amendment would not be met. The timeframe for rebuilding and sustaining viable populations of steelhead and salmon also would be increased. In addition, as described above, the sediment only alternative does not result in avoidance of any potentially significant impacts associated with the proposed Basin Plan amendment alternative and would not achieve one of the primary objectives, which is supporting conservation and facilitating recovery of stheelhead and coho salmon populations. Therefore, the *sediment only alternative* is not preferred.

The *Proposed Basin Plan amendment plus restoring historic floodplain habitats* is not preferred because available information is not sufficient to accurately evaluate potential impacts and/or to optimize benefits. However, this alternative would involve a much greater amount of earth moving (>1,000 acres) and construction in/around stream channels, and potentially significant short-term impacts to biological resources (with significant positive medium- and long-term benefits), and potentially significant impacts to hydrology and water quality. In addition, because of the massive amounts of earthmoving and/or land acquisition that the cost of this alternative would be much greater compared to the proposed project.

The *Proposed Basin Plan amendment* alternative is preferred because it meets the primary objectives, has no significant impacts (with mitigation), provides the means for attaining water quality standards and addressing the sediment impairment listing, and reasonably foreseeable compliance actions would result in similar or fewer long-term adverse environmental impacts as compared to the project alternatives

Benefits of Project

In order to approve the proposed Project, it is up to the Water Board to find, that based on specific economic, social, and other considerations, the benefits of the proposed Project outweigh its unavoidable adverse environmental impacts.

Some of the specific environmental benefits of the project include substantial enhancement of: a) substrate quality; b) stream and riparian habitat complexity, connectivity, and function; c) sediment storage; d) fish passage; and e) baseflow persistence. An additional environmental benefit of the project is reduced sediment loading to Pescadero marsh and lagoon, which are impaired by excessive sedimentation.

Economic benefits of the project include:

a) Lowering the predicted costs for road maintenance and repair because roads that erode less will function better and be less costly to maintain over the long run;
b) Reduced costs associated with damaged infrastructure and/or property that is located within, or adjacent to, actively eroding and incising stream channels by reducing the rates of erosion in these critical areas through re-establishing a balance between stream power, sediment supply, and storage; and
c) Reducing the frequency and related costs of dredging at Pescadero Creek Road Bridge located at the downstream boundary of the Project area by reducing upper watershed sediment loading and by trapping more sediment on floodplains.

Social benefits of the proposed Basin Plan amendment include: a) enhanced recreational, aesthetic, and cultural experiences that are associated with healthy fisheries, the overall enhancement of stream and riparian habitats and their functions, and supporting conservation of salmonid populations within the watershed for the benefit of current and future generations.

9.3 Government Code Section 57004: Peer Review

Independent peer review of the Basin Plan amendment and the staff report was provided by two scientists: 1) Dr. Noah Finnegan, a fluvial and tectonic geomorphologist at the Department of Earth and Planetary Sciences at UC Santa Cruz, who is conducting research on landscape evolution and specializes in channel incision and bedrock rivers; and 2) Dr. Darren Ward, an applied freshwater ecologist at the Department of Fisheries Biology at Humboldt University, whose research focuses on Pacific salmon conservation.

The peer reviewers' responses confirmed that the scientific portion of the proposed TMDL and implementation plan are based on sound scientific knowledge, methods, and practices, thus satisfying Government Code section 57004. Actions to implement the habitat enhancement plan are recommended, not required, and therefore not part of the rule making process subject to scientific peer review requirements. A summary of the peer review comments and our responses is provided below.

Dr. Finnegan's review focused on the watershed and channel change analysis (Chapter 4) and sediment source analysis (Chapter 5). On watershed and channel change analysis, Dr. Finnegan stated that:

> I found the analysis of the historical changes that have occurred in Pescadero Creek watershed very compelling. To accomplish this requires an impressive mix of history and geomorphology. To me, this section effectively demonstrated the degradation in habitat that has occurred in Pescadero Creek as well as the physical changes that have occurred due to land-use practices in the watershed.

On the source analysis, Dr. Finnegan suggested that we incorporate a recent study on the erosive behavior of the Tehana member of the Purisima Formation that have implications for the mechanisms of gully erosion and incision on this geologic unit. He also suggested that we revise the natural background long-term erosion rate to incorporate channel areas as well as hillslopes. Dr. Finnegan recommended presenting a range of values or incorporating estimates for uncertainties into road surface erosion and timber harvest related landslide erosion. In response, we either revised the Staff Report to incorporate the suggestions or provided clarification or additional information.

In his introductory remarks, Dr. Ward wrote:

> As is to be expected for most watersheds, site-specific historical data is not available for all metrics, bringing some uncertainty into the analysis. However, reference to analogous sites within the region and non-quantitative historical accounts provide sufficient background to reasonably approximate extent of habitat alternation and effects of land use change and compare current anthropogenic and background sedimentation rates.

While supporting the basis for the proposed TMDL for sediment, Dr. Ward also commented that there are some issues that are not addressed adequately in the document, including oversimplification and lack of clarity in explanation related to the numeric targets. Specifically, he raised concerns on the limited focus of the numeric targets, how the temporal and spatial variations of numeric targets were addressed, and how they were linked to the demonstrated habitat alterations. He also highlighted some inconsistencies in the text and missing citations. In response to Dr. Ward's comments, we revised the Staff Report to address the inconsistencies and included additional information on the numeric targets.

All peer review comments and our specific responses are contained in a document entitled "Pescadero-Butano Watershed Sediment TMDL: Responses to Peer Review Comments."

9.4 Economic Considerations

CEQA requires that whenever the Water Board adopts a rule that requires the installation of pollution control equipment or establishes a performance standard or treatment requirement, it must conduct an environmental analysis for reasonably foreseeable methods of compliance (Pub. Res. Code § 2759, subd. (a)(3)(c)). This analysis must take into account a reasonable range of factors, including economics. Furthermore, if the rule includes an agricultural control plan, then the total cost of the program must be estimated and potential sources of funding must be identified (Wat. Code § 13141).

The proposed Pescadero-Butano Watershed Sediment TMDL and Habitat Enhancement Plan and the Basin Plan amendment includes performance standards (i.e., targets and allocations), and therefore requires the consideration of economic factors. The Total Maximum Daily Load (TMDL) implementation plan also proposes activities for agriculture, and therefore, the total cost of the implementation effort is estimated.

In amending the Basin Plan, the Water Board must analyze the reasonably foreseeable methods of compliance with proposed performance standards and treatment requirements (Pub. Res. Code § 21000 et seq.). This analysis must include economic factors, but does not require a cost-benefit analysis.

Additionally, in accordance with the Water Code, it is the policy of the State to protect the quality of all waters of the State. Waters of the State include “any surface water or groundwater, including saline waters, within the boundaries of the state” (Water Code § 13050). When adopting the Water Code, the Legislature declared that all values of the water should be considered, but then went on to provide only broad, non-specific direction for considering economics in the regulation of water quality.

> The Legislature further finds and declares that activities and factors which may affect the quality of the waters of the State shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible (Water Code § 13000).

The Water Code directs regulatory agencies to pursue the highest water quality that is reasonable, and *one* of the factors used to determine what is reasonable is economics. It is clear, though, that economic factors cannot be used to justify a result that would be inconsistent with the federal Clean Water Act or the Water Act. The Water Board is obligated to restore and protect water quality and beneficial uses.

Cost Estimates

We present cost estimates for sediment control actions by source category (e.g., actions to control road-related erosion, floodplain connection, gullying and landslides, etc.). These cost estimates include all costs for control of sediment discharges. We then estimate the proportion of total costs associated with agricultural sources (e.g., Agricultural Water Quality Control Program Costs).

Wood and Floodplain Restoration Costs

Channel incision is one of the largest sediment sources associated with land use activities and is the primary agent for simplification of stream and riparian habitat in the Pescadero-Butano Creek watershed.

As described in Chapter 8 (Implementation Plan), we will rely upon collaborative participation by landowners in reach-based stewardships that will work with public agencies to implement projects that jointly reduce sediment discharges and enhance spawning and juvenile rearing habitat for salmonids and other native aquatic species. Such partnerships would be in favorable positions to receive grant funding from State and federal agencies to support implementation of sediment control actions and would result in significant cost savings to public and private landowners.

To address legacy sediment sources and the effects of channel incision and habitat simplification, a collaborative restoration approach is needed to increase large woody debris (LWD) in channels, and to reconnect the channels to their floodplains in reaches where this both is safe and feasible. In estimating costs associated with reducing sediment discharges from channel incision and associated bank erosion, we assumed that stream reaches on Butano and Pescadero Creeks, downstream of Cloverdale Road and the USGS Gauge Station, respectively, would be treated with floodplain restoration projects. This cost estimate assumes that treating these approximately 9.5 miles of streams will reduce sediment loading by 23,400 tons per year, in order to achieve the load allocation.

In developing cost estimates, we relied on unit costs for a floodplain restoration project constructed in 2016 on Butano Creek (Irina Kogan, personal communication). Costs for floodplain restoration projects that reduce sediment discharges from channel incision and related bank erosion are estimated at $5.9 to $11.9 million. Table 24 presents the costs and assumptions.

In estimating costs to rehabilitate channel habitat complexity through implementation of LWD installation projects, we rely on data compiled by Thompson and Pinkerton (2008) and/or by Evergreen (2003). This project would require permission and support of property owners on both sides of the creeks. We think it may be safe and feasible to install LWD and/or engineered log jams (excluding the town of Pescadero and where it will not threaten or damage infrastructure or property) over 35 miles of creeks in the watershed: along 16 miles of Pescadero Creek (between Loma Mar and Waterman Creeks), 10 miles of tributaries to Pescadero Creek (including Oil, Slate, Tarwater, and Peters), and 9 miles of Butano Creek. A conservative estimate of the total cost for projects to enhance LWD in the 35 miles of Pescadero and Butano creeks is estimated at $0.8 million to $3.5 million and provided in Table 25.

Table 24. Cost Estimates to Enhance Floodplain Connectivity

Actions	Implementing Parties	Item	Low Cost ($millions)	High Cost ($millions)
Develop and implement plan to enhance floodplain connectivity and reduce sediment supply on 5 miles of Pescadero Creek below Loma Mar and 4.5 miles of Butano Creek below Cloverdale Road	Landowners in partnership with government agencies	• Design and environmental review • Construction • Maintenance and monitoring	0.5 4.9 0.5	1.0 9.9 1.0
Total			**5.9**	**11.9**

Key assumptions and information:

1. Butano Creek (4.5 miles) and Pescadero Creek (5 miles) are treated with floodplain restoration improvements to reduce sediment supply by 23,400 tons peryear.
2. Cost for floodplain restoration is based on the 2016 Butano Creek Floodplain Restoration Project (San Mateo RCD, 2016) and assumes that 4 additional, equivalent projects will be required to achieve the load allocation.
3. Floodplain restoration project costs include costs for large woody debris placement and/or engineered log jams.
4. Low cost assumes a passive design for floodplain restoration, which relies on natural sediment deposition to produce floodplain connectivity over several decades.
5. High cost assumes an active approach for floodplain restoration that relies on significant earth moving and import/export of fill to immediately reconnect the channel to its floodplain. This approach is assumed to cost twice as much as the low cost approach.
6. Design and environmental review costs, and monitoring and maintenance costs are assumed to each equal about 10 percent of constructioncosts.
7. Costs are presented rounded to the nearest $0.1 million; individual costs were summed prior to rounding, adjusted based on a 2.8% annual rate of inflation since 2016, and the total was then rounded to the nearest $0.1 million.

Table 25. Cost Estimates to Enhance Habitat Complexity

Actions	Implementing Parties	Item	Low Cost ($millions)	High Cost ($millions)
Develop and implement LWD projects in the Pescadero-Butano Creek Watershed	Landowners in partnership with government agencies	• Design and environmental review • Construction • Maintenance and monitoring	0.07 0.7 0.07	0.3 2.9 0.3
Total			**0.8**	**3.5**

Key assumptions and information:

1. Pescadero Creek and its tributaries (26 miles) and Butano Creek (9 miles) are treated with LWD projects.
2. We assume a construction cost per stream mile of $20,000 to $80,000 for large woody debris projects (Thompson and Pinkerton 2008; Evergreen 2003).
3. Floodplain restoration project costs include costs for large woody debris placement and/or engineered log jams.
4. Low cost estimate assumes small to medium size engineered log jams, or toppling whole-trees intact where feasible.
5. High cost estimate assumes complex projects that require large engineered log jams, significant excavation and grading, rock work, or gravel augmentation required for project implementation.
6. Design and environmental review costs, and monitoring and maintenance costs are assumed to each equal about 10 percent of construction costs.
7. Costs are presented rounded to the nearest $0.1 million; individual costs were summed prior to rounding, and the total was then rounded to the nearest $0.1 million and adjusted based on a 2.8% annual rate of inflation since 2016.

Grazing Land Surface Erosion

Based on acreages presented in the Department of Conservation Farmland Mapping and Monitoring Program (FMMP) for San Mateo County for 2016, 8,966 acres are in agricultural and grazing land use in the Project area. This indicates that up to 20 percent of the total area of the watershed is in agricultural and rangeland use.[59]

[59] The land use distribution in the Pescadero-Butano watershed are: 26% public lands; 23% timberlands, 11% open space 17% agricultural lands and rangelands, and 23% in other private lands. The acreages may be adjusted in the future if FMMP data are found to incorrectly map the acreages of agricultural and grazing practices. (FMMP data can be found at http://www.conservation.ca.gov/dlrp/fmmp).

For grazing lands, we define a minimum threshold of 50 acres that would trigger the requirement plan, prioritize, and implement sediment management actions. In other words, we do not expect or intend to implement sediment management regulations or permit requirements on farmlands that are less than 5 acres, or on grazing lands that are less than 50 acres.

The proposed Basin Plan amendment anticipates that agricultural land owners of properties 5 acres or greater and grazing land owners/operators of properties 50 acres or greater will need to perform an inventory and assessment of sediment and erosion control practices, and develop a plan and schedule to implement best management practices (BMPs) needed (if any), to control identified sediment sources. We anticipate that landowners will work with the local resource conservation district to develop and implement voluntary programs that achieve the sediment reduction control actions or requirements. In cases where existing policies and actions are not sufficient to control sediment discharges and erosion, control of such discharges will be addressed through permits issued by the Water Board such as a waiver of waste discharge requirements (WDRs) or WDRs. While the future permit conditions have not yet been determined, we do expect that the inventory and assessment of sediment sources will require ranchers and farmers to develop, or amend, water quality protection plans that are specific to their operations. Both grazing and agricultural operations will be required to meet minimum standards related to minimizing sediment loads to surface water, develop an implementation plan and schedule to meet the minimum standards, and conduct compliance monitoring and reporting.

Available information regarding costs indicate a wide range of unit costs, depending on the type of BMPs implemented, such as fencing, developing off-stream water sources, installing hardened cattle crossings, etc. For example, livestock exclusion to protect riparian areas is generally more expensive than the installation of cover crops to control surface erosion. The exact combination of BMPs that will be used at a site will depend on site-specific conditions and would be selected by the grazing or agricultural land operator/owner. To develop a range of costs, we assumed costs of combinations of similar practices (i.e., streambank stabilization practices (high-end cost) and permanent vegetative cover on critical areas (low-end cost), as defined by the Agricultural Stabilization and Conservation Service). Total costs of actions to reduce sediment from rangeland surface erosion/livestock grazing, information sources, and key assumptions are presented in Table 26. Our cost estimate is based on unit costs reported by U.S. EPA (1993). Land surface erosion control costs, information sources, and key assumptions are presented in Table 26. We estimate costs to reduce sediment discharge from grazing and agricultural land surface erosion necessary to achieve the allocation to be $0.5 million to $1.7 million over the 20-year implementation period.

Note that other rangeland and agricultural water quality enhancement measures will be needed to control sediment discharges from road-related erosion and/or unstable areas, and these are not estimated in this section. For example, a portion of the total cost of road-erosion control on private lands (see Road-Related Erosion below) are for unpaved roads located on grazing and agricultural lands.

Table 26. Cost Estimates to Reduce Sediment from Grazing Land Surface Erosion

Actions	Implementing Parties	Item	Low Cost ($)	High Cost ($)
Implement management measures to reduce sediment from grazing lands	Agricultural and Rangeland owners and/or operators	Assessment and inventory, Implementation of erosion and sediment control measures, and monitoring via a farm plan or ranch water quality plan	475,200	1,730,500
Attain residual dry matter standards in pastures (e.g. ground cover in fall)	Ranch owners and/or operators	Ranch water quality plan		
Total			**475,200**	**1,730,500**

Key Assumptions and Information:

1. Based on Farmland Mapping and Monitoring Program (FMMP) for San Mateo County for 2016, there are approximately 8,966 acres used for grazing and non-grazing agricultural activities in the watershed.
2. Costs for rangeland erosion control range from $53 per acre to $193 per acre, including assessment, BMP implementation, and monitoring.
3. Low Cost assumes rangeland needing treatment will have permanent vegetative cover on critical areas (ASCS practice code SL11), practices such as cover and green manure crop, critical area planting, fencing, field borders, filter strips, forest land erosion control system, mulching, streambank protection and tree planting. Average cost per acre for Pacific Region assumes $21 per acre, adjusted from $10 per acre values in 1993 (U.S. EPA, 1993) based on a 2% annual rate of inflation.
4. High Cost assumes rangeland needing treatment will have Streambank Stabilization (ASCS practice code SP10), practices such as critical area planting, livestock exclusion, mulching, streambank protection, and tree planting. Average cost per acre for Pacific Region assumes $161 per acre, adjusted from $100 per acre values in 1993 (U.S. EPA, 1993) based on a 71% cumulative rate of inflation.
5. Assessment and monitoring will each cost $16 per acre, which is 10 percent of high cost BMP implementation.
6. Implementation period is 20 years.
7. Costs are rounded to the nearest hundredth.

Road-Related Erosion

There are approximately 395 miles of roads within the Pescadero-Butano watershed, 325 miles of which are unpaved and 70 miles of which are paved (ESA, 2004). The Basin Plan amendment establishes sediment-discharge performance standards for roads, including the following:

1. Predicted future sediment discharge is ≤500 cubic yards per mile per 20-year period;
2. ≤ 25 percent of the total length of unpaved roads are hydrologically connected;
3. All culvert inlets have a low plug potential; and
4. Critical dips, or other technically effective and feasible drainage structures, shall be installed at culverted crossings that have a diversion potential.

Costs for Unpaved Roads

To estimate erosion-control costs for unpaved roads in the Pescadero-Butano watershed, the Water Board relied on cost and sediment savings data developed for projects completed in the Napa River watershed during the last five years, which involved regrading more than 20 miles of unpaved roads on private property (Bill Burmingham, personal communication, 2016).

In this approach, the costs considered include: a) outsloping hydrologically connected road reaches (to reduce overall percent connectivity to ≤ 25 percent); b) construction of critical dips at culverted crossings that have diversion potential; c) installation of single post trash racks at culverted crossings that have plug potential; and d) costs associated with administering these projects. The average cost for these projects in the Napa River watershed was approximately $20,000 per mile. POST recently estimated that road work treatments such as road shaping can cost $35,000 per mile.

This average cost was applicable to roads, where the baseline (pre-project) value for hydrologic connectivity was 40-to-50 percent, and where the predicted future sediment discharge following project completion is ≤ 500 cubic yards per mile per 20-year period.

Considering the above, the total estimated costs for erosion control efforts on unpaved roads throughout the watershed, excluding the Old Haul Road, which is estimated separately below, are as follows:

- An average cost of $35,000 per mile to regrade a typical unpaved road (to meet Basin Plan amendment performance standards) X a factor of 1.2 (e.g., the estimated overhead rate to cover the costs of permitting) X 325 miles of roads = $13,650,000.

Costs for the Old Haul Road

The Water Board relied on the report prepared by Timothy Best, Engineering Geology and Hydrology (2015), which estimated the cost for recommended erosion control treatments on the Old Haul Road at approximately $1,040,000. Assuming permit costs could be up to an additional 20 percent, and accounting for 4.1 percent inflation form 2015-present, the total cost is estimated to be $1,300,000.

Costs for Paved Roads

Comparing typical cost data prepared by Pacific Watershed Associates for road erosion control projects completed on unpaved and paved roads (PWA, 2003), it is estimated that the average cost per unit of sediment savings (sediment discharge reduction) on a paved public road is about three-times as much as for an unpaved private road. The higher unit costs for paved roads are due to the excavation and restoration of the pavement at sites where drainage structures are installed/retrofitted, additional costs associated with management of roadway traffic during construction, and costs incurred to meet engineering design standards. Therefore, the Water Board estimates that average construction cost per mile to retrofit a paved road in the Pescadero-Butano watershed is approximately $60,000 per mile.

Considering the above, the total cost of erosion control efforts on paved roads throughout the watershed is estimated as follows:

- An average cost of $60,000 per mile to regrade a typical paved road (to meet Basin Plan amendment performance standards) X a factor of 1.2 (e.g., the estimated overhead rate to cover the costs of permitting) X 2.8 percent inflation (between 2016 and present) X 325 miles of roads = $5,200,000.

Unstable Areas

Historical grazing, agriculture, logging and other historical or current land use activities combined with weak and easily disintegrating rocks have caused or contributed to the erosion of gullies and/or shallow landslides, many of which may continue to erode for several years into the future and deliver significant volumes of sediment to stream channels in the Pescadero-Butano Creek watershed.

To address gullying and shallow landslides, landowners will conduct sediment source inventories and implement control measures to accelerate natural recovery and avoid future human caused increases in sediment delivery from unstable areas. Future sediment delivery from gullying and landslides needs to be reduced by 18,720 tons and 17,940 tons per year, respectively. Gully and landslide erosion control costs, information sources, and key assumptions are presented in Table 27. Total cost for actions to accelerate natural recovery and avoid future sediment delivery from unstable areas is $253,000 to $1.01 million over the 20-year period for implementation actions to achieve the TMDL (Table 27).

Table 27. Cost Estimates for Implementation Measures to Reduce Sediment from Gullying and Landslides

Actions	Implementing Parties	Item	Low Cost ($)	High Cost ($)
Accelerate natural recovery and avoid future human-caused increase in sediment delivery from unstable areas	Agricultural, rangeland, and timberland owners, other rural private property owners, and public agencies	Assessment and inventory	21,000	84,000
		Implementation of erosion and sediment control measures	211,000	843,000
		Maintenance and Monitoring	21,000	84,000
Total			**253,000**	**1,011,000**

Key Assumption and Information:

1. Future sediment delivery from gullying and landslides needs to be reduced by 18,720 and 17,940 tons/year, respectively.
2. Assumes 20-year implementation period
3. High value for average cost per ton of sediment prevented from entering a channel (from gully and/or landslide erosion) = $25 per ton, adjusted from $20 per ton values by S. Chatham (personal communication, 2005) based on a 2.2% annual rate of inflation.
4. Low cost per ton of erosion prevented from entering a channel is estimated to equal 25 percent of high value, assuming an approach the would emphasize addressing present-day management influences on gully or landslide erosion at half or more of all sites (e.g. dispersion and/or diverting concentrated runoff to stable areas, planting of native wood, etc.).
5. Assessment and inventory costs, and maintenance and monitoring costs are assumed to each equal about 10 percent of construction costs.
6. Costs are rounded to the nearest thousand.

Agricultural Water Quality Program Costs

Implementation measures located on grazing and agricultural land constitute an agricultural water quality control program and therefore, consistent with Water Code requirements (Section 13141), the cost of this program is estimated herein. This cost estimate includes the cost of implementing all road-related and surface erosion related sediment control measures specified in the implementation plan, and is based on costs associated with technical assistance, project design, and implementation of actions needed to achieve the TMDL.

There are no other costs to farmers or ranchers associated with actions to enhance channel habitat complexity and floodplain connection, because participation by private landowners is voluntary, and almost all of the cost of these projects is expected to be paid for from grants by public agencies and/or non-profits. In estimating costs, the Water Board estimates that owners of grazing and non-grazing agricultural businesses own up to 20 percent of total land area. The Water Board estimates that total cost to agricultural businesses associated with efforts to reduce sediment supply to Pescadero and Butano creeks watershed is $200,000-to-300,000 per year. A summary of cost estimates for agricultural sources are rounded up to be conservative as presented in Table 28.

Table 28. Agricultural Water Quality Control Programs Costs

Item(s)	**Responsible Parties**	**Agricultural Sources (percent cost)**	**Low Cost to Agriculture ($millions)**	**High Cost to Agriculture ($millions)**
Reduce road-related erosion on grazing and non-grazing agricultural lands	Owners of roads on agricultural lands ≥5 acres and grazing lands ≥50 acres	20	2.7	2.7
Control land surface erosion on grazing ~~and non-grazing~~ agricultural lands	Owners and/or operators of grazing lands ≥50 acres	100	0.5	1.7
Accelerate natural recovery and avoid future human caused increases in sediment from unstable areas[60]	Ranchers, farmers, landowners, public agencies	20	0.1	0.2
All measures to reduce sediment discharge to Pescadero and Butano creeks	Same as above	…	3.3	4.6
Average annual cost over 20-year implementation period			0.17	0.23

[60] Other than conducting sediment source inventories and staying away from unstable areas (e.g., gullies) to reduce potential future erosion, participation in accelerating natural recovery of gullies and shallow landslides are voluntary. Therefore, the estimated costs of addressing sediment sources from unstable areas were not included in the total cost estimate.

Sources of Funding

Potential sources of funding include monies from private and public sources. Public financing includes but is not limited to grants, as described below; single-purpose appropriations from federal, state, and/or local legislative bodies; and bond indebtedness and loans from governmental institutions.

There are several potential sources of public financing through grant and funding programs administered by the Water Board, the State Water Board, the California Department of Fish and Wildlife, and the Wildlife Conservation Board. These programs vary over time depending upon federal and state budgets and ballot propositions approved by voters. Public grant and funding programs that are pertinent to the proposed Pescadero-Butano Creek Watershed Sediment Reduction and Habitat Enhancement Basin Plan amendment, and are currently available at the time of this writing or will be available in the near future are summarized and described below.

Nonpoint Source (NPS) Grant Program

The federal Clean Water Act Section 319(h) grant program is administered in California by the State Water Board. This program is an annual federally funded nonpoint source pollution control program that is focused on controlling activities that impair beneficial uses and on limiting pollutant effects caused by those activities. Grant applicants compete in a statewide grant selection process in which potential grants are reviewed by a panel of SWRCB, RWQCB and EPA staff. Project proposals that address TMDL implementation and those that address problems in impaired waters receive priority in the selection process. The minimum funding request is $250,000 and maximum $800,000 with a 25 percent match requirement.

In addition, the NPS Grant Program funds projects that implement forest management measures on forest lands to improve water quality via funds it receives from the Timber Regulation and Forest Restoration Fund.

Fisheries Restoration Grants Program (FRGP)

FRGP is administered by the CDFW and is a competitive funding program for projects that restore, enhance, or protect anadromous salmonid habitat in anadromous watersheds of California or projects that lead to restoration, enhancement, or protection of anadromous salmonid habitat, as well as contribute to the objectives of the California Water Action Plan, State Wildlife Action Plan, and the fulfillment of CDFW's mission. Project types that can be funded under this program include instream habitat restoration, riparian restoration, instream bank stabilization, and watershed restoration.

Proposition 1 Grants

The Wildlife Conservation Board (WCB) provides funding through the Proposition 1 California Streamflow Enhancement Program (CSFEP). Funded by the Water Quality, Supply and Infrastructure Improvement Act of 2014, the specific purpose of CSFEP is to address environmental challenges as they relate to streamflow. While improving streamflow most immediately benefits aquatic and riparian species, the environmental changes ultimately enrich peripheral plants and animals as well.

California Coastal Conservancy Proposition 1 grants fund multi-benefit ecosystem and watershed protection and restoration projects. Priority project types include water sustainability improvements, anadromous fish habitat enhancement, wetland restoration and urban greening.

CHAPTER 10 – REFERENCES

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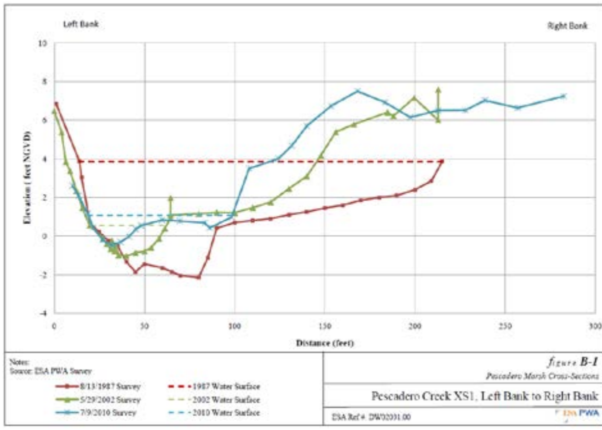
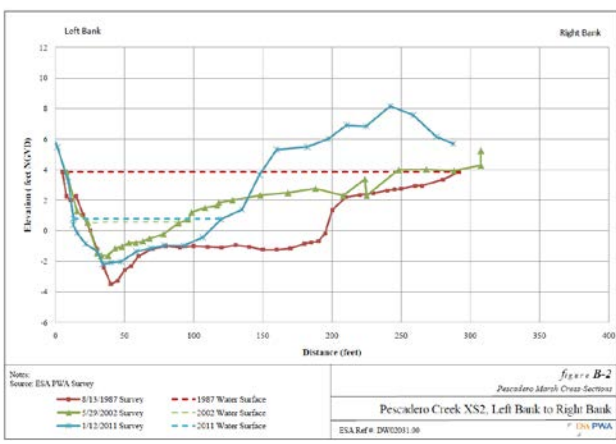
ATTACHMENT A

PESCADERO LAGOON AND MARSH
CROSS SECTION ANALYSIS

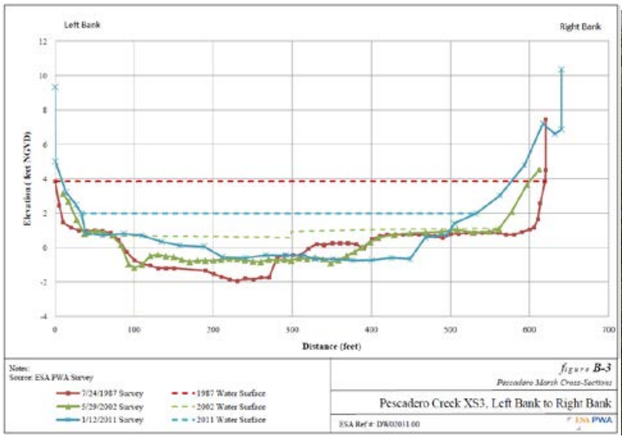
We estimated the volume of sediment deposited in the marsh and the lagoon by comparing two different sets of cross sections, one set from 1987 and another from 2011, collected by PWA and ESAPWA, respectively. We first estimated the change in cross sectional area for each cross section. We then used the "average end area method" and estimated the average volume between two cross sections by taking the average of two areas and multiplying that by the distance between the cross sections. The location of cross sections, the thalweg profiles, and cross section survey plots are presented below.



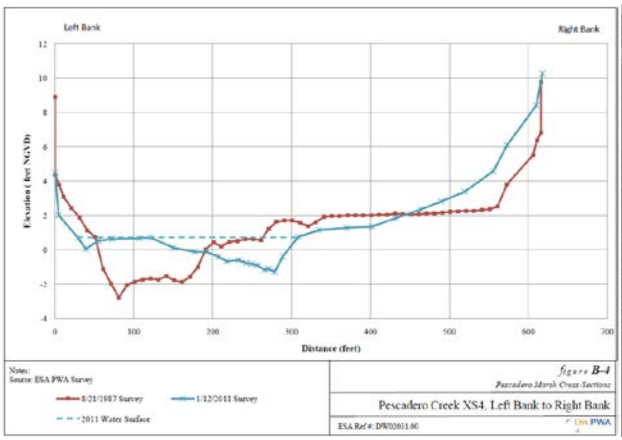
The XS1 traverses Pescadero Creek just downstream of Highway 1 Bridge. The actual location of the original cross section is likely directly under the current bridge which was reconstructed around 1997. The endpoints of XS1 were not recovered during the resurvey; however, since XS1 is known to have been located under the old Highway 1 Bridge, the resurvey location is adequate for comparison. The resurvey shows that the channel thalweg has aggraded by 1.6 ft since 1987. The channel dimensions in the intertidal zone are significantly diminished (ESAPWA, 2011). The high intertidal zone and supratidal zone has aggraded significantly up to 5 ft. We estimate that the channel capacity at XS1 has decreased by approximately 600 ft.



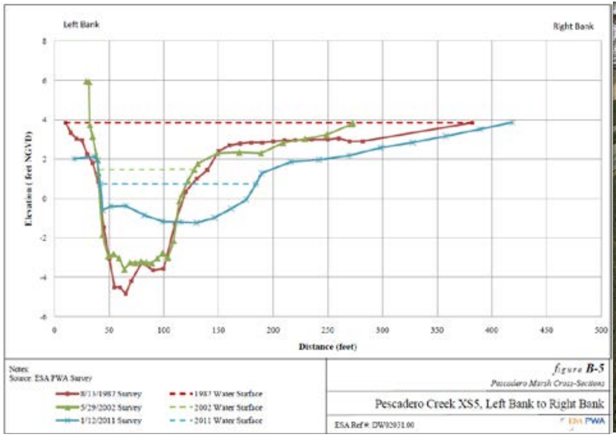
The endpoints of XS2 were not recovered during the resurvey; however, since XS2 is located just upstream of the Highway 1 Bridge the overall location is well approximated. The thalweg has aggraded by approximately 1.2 ft. More significantly the right bank has aggraded by 4 to6 ft over a distance of 200 ft. We estimate an overall channel capacity change of approximately 780 ft^2.



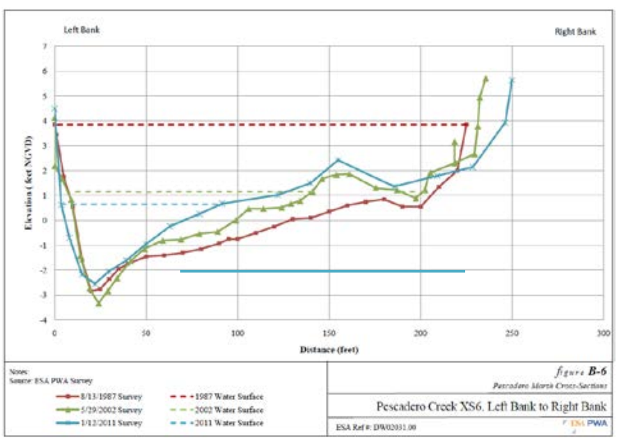
The endpoints of XS3 were not recovered during the resurvey; however, the endpoints were established using GPS coordinates from earlier surveys and therefore the location of XS3 approximates previously surveyed location. The channel thalweg has aggraded 1.25 ft and broadened by about 350 ft. We estimate an overall deposition of 550 ft^2 at XS3.



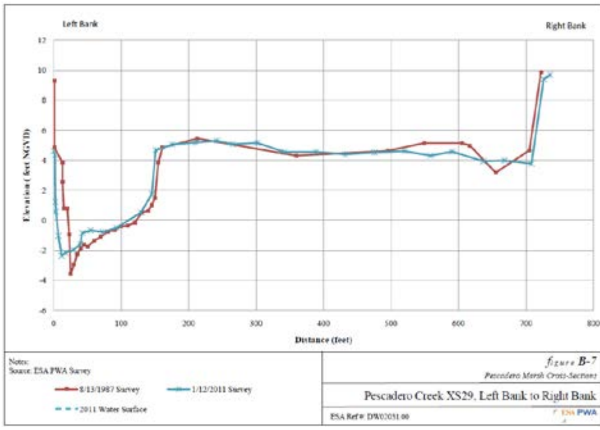
The resurvey of XS 4 did not recover the endpoints of the 1987 survey so some of the cross sectional changes may be due to differences in survey line alignments. The resurvey shows that the channel migrated approximately 200 ft from left bank to right bank. The thalweg aggraded overall by 1.5 ft. We estimate a cross sectional capacity change of approximately 375 ft^2.



The resurvey of XS5 shows that this section became shallower and wider since 1987. The thalweg of XS5 aggraded considerably, by about 3.5 ft but the channel has widened by 75 ft towards the right bank, resulting in a negligible net change in channel capacity. The deposition on the thalweg would suggest a decrease in energy gradient through this reach and therefore a reduced ability to flush. No endpoint was recovered along this cross section.



The right bank of XS6 is shown on the spreadsheet and Google Earth image with an orange line. The survey shows on average 1.5 ft of deposition over a distance of 150 ft (1,500 ft^2). Only one endpoint was recovered so the alignment of the 1987 and 2011 cross sections may not overlap perfectly. However, the 2011 survey shows that the right bank surface aggraded uniformly and the Google Earth photograph clearly indicates the depositional surface.



The resurvey of XS 29, which is approximately 150 ft downstream of the confluence of Pescadero and Butano Creeks, shows no change. The endpoints of this cross section were recovered in 2011.

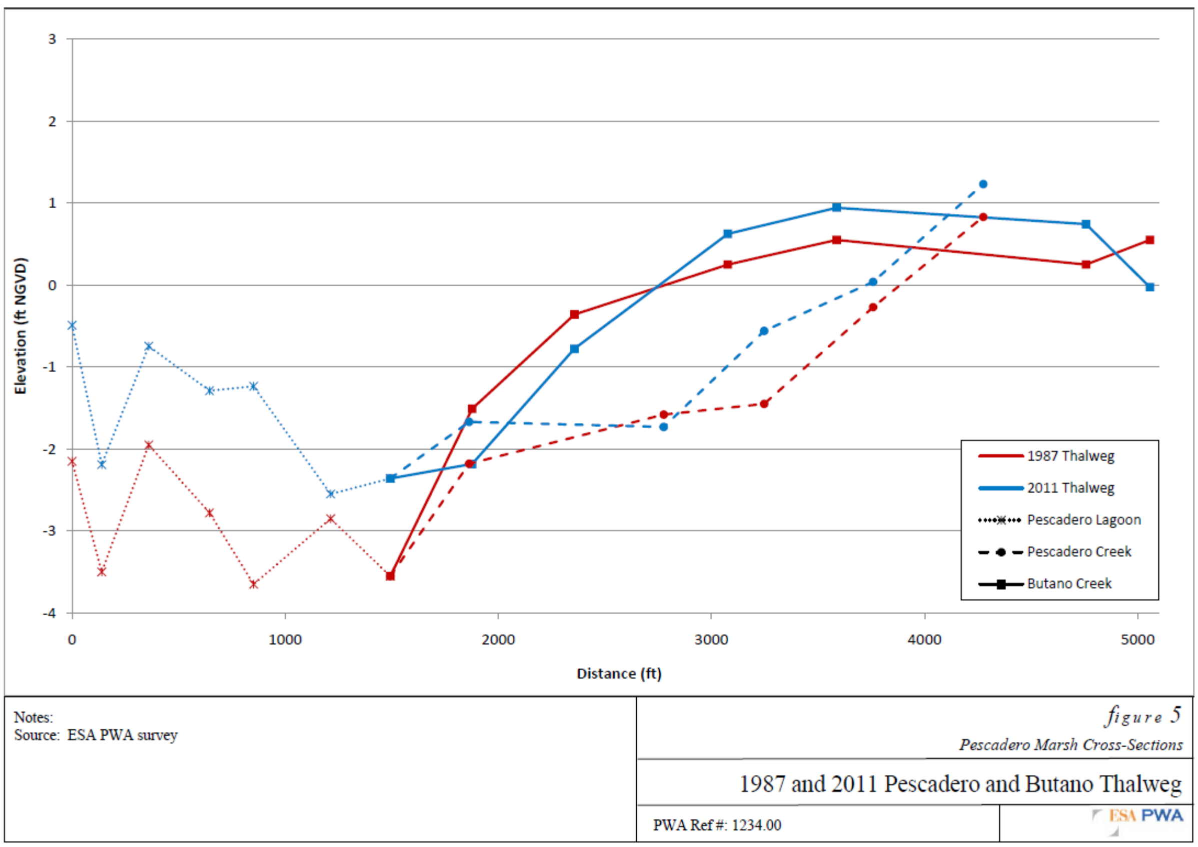
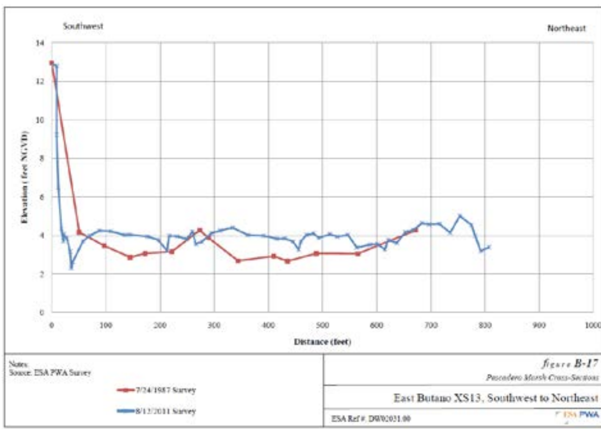


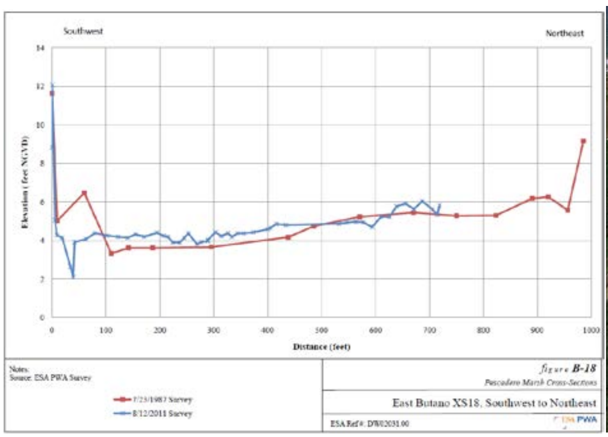
Figure 5 of ESAPWA (2011) study, as shown above, indicates that Pescadero lagoon thalweg accreted by 1.2 to 3.5 feet along a distance of 1,500 ft.

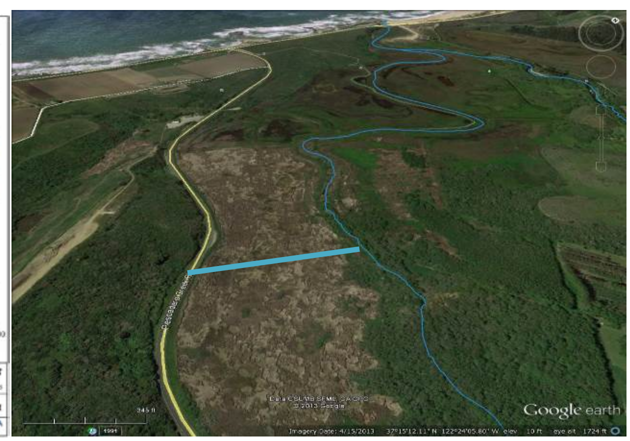
Using the cross sectional changes that were outlined above and using the average distances between cross sections, we estimated an overall capacity change in the lagoon. We applied half of the distance between each cross section to estimate the volumetric change. Our analysis suggests an overall deposition volume of more than 850,000 ft^3 (24,500 m^3) or 39,000 tons over 24 years. This would suggest an average deposition of **1,625 tons/yr** in the Pescadero lagoon.

ESAPWA (2011) study also includes comparisons of cross sections of different parts of the Pescadero-Butano marsh (see Figure below for names of different parts of the marsh).

The **East Butano Marsh** cross sections show aggradation across their width of more than 600 ft. We noted that 1 to 1.3 ft of sediment deposited across the marsh plain. Estimating the area of the marsh as 54 acres, we can estimate a total deposition of 106,575 tons to 138,550[i] tons in the period from 1987 to 2011 (assuming a bulk density of 1.6 ton/m^3). This suggests an annual deposition rate **of 4,440 to 5,773 tons/yr** or an average of **5,106 tons/yr**. In the figures below, note the recently scoured channel immediately adjacent to the left bank by the Pescadero Creek Road.

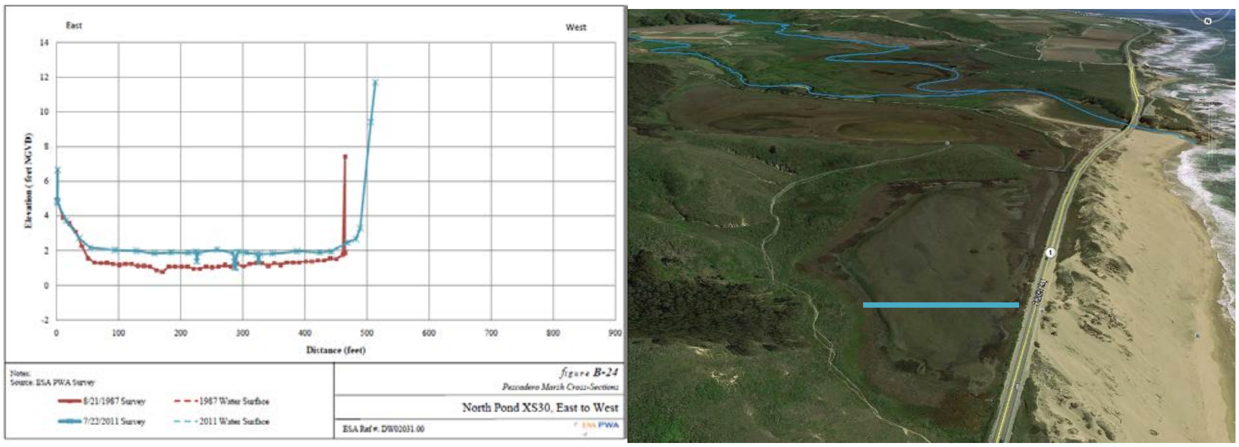


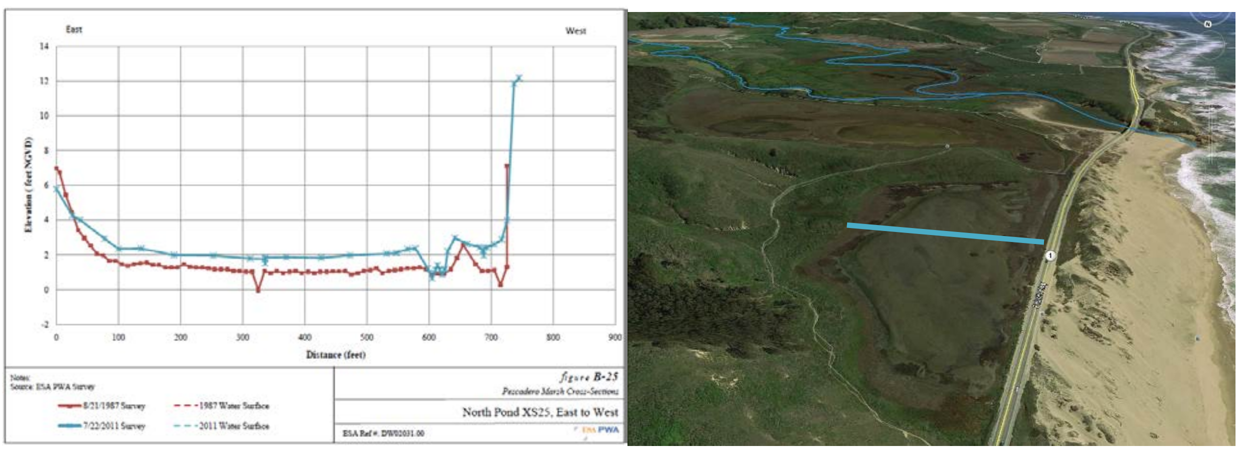


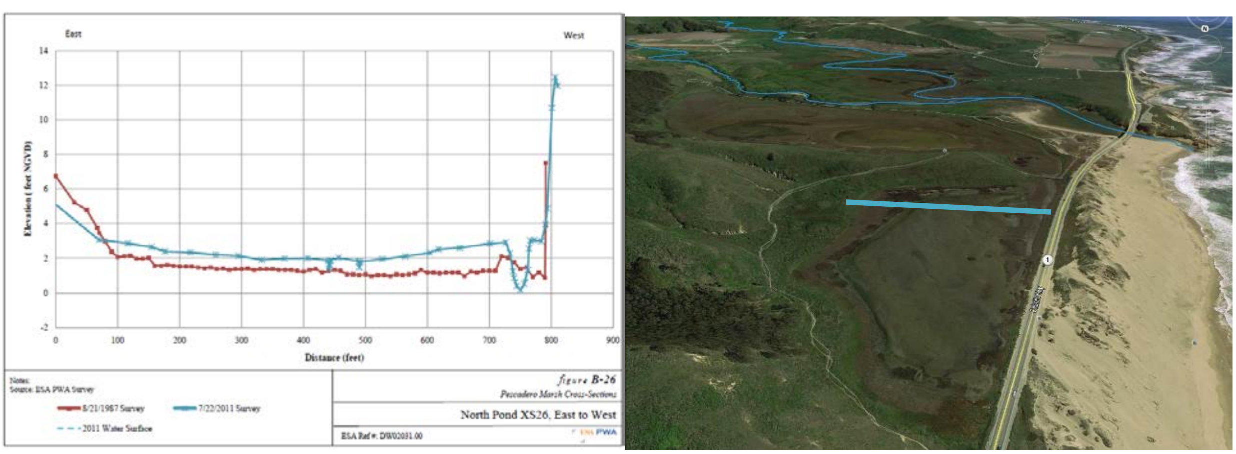


[1] 1.3 ft x (0.305 m/1ft) x 54 ac x (4,047 m^2/ac) x 1.6 $tons/m^3$

The **North Pond** shows clear aggradational trends. This part of the marsh has aggraded on average 1 ft between 1987 and 2011. In addition, a well-defined channel has developed near the western side of the North Pond (right bank) by Highway 1. The surface area of the North Pond is approximately 20 ac. Therefore, we estimate the volume of deposited sediment as 39,473 tons during a period of 24 years from 1987 to 2011. That corresponds to an average annual sedimentation rate of **1,645 tons/yr.**







Two of the three repeat cross sections surveyed in **North Marsh** were not aligned properly (no end points were recovered for neither of 3 cross sections). Only cross section 28 appears to be adequate for comparison based on the alignment of the channels on the left and right banks. The cross sections comparison suggests an average aggradation of 0.3 feet. The surface area of the North Pond is approximately 54 ac. Therefore, we estimate the volume of deposited sediment as 101,255 tons during a period of 24 years from 1987 to 2011. That corresponds to an average annual sedimentation rate of **4,220 tons/yr.**