Hydrology | Hydraulics | Geomorphology | Design | Field Services

TECHNICAL MEMORANDUM

Date:	December 13, 2013
To:	Irina Kogan, San Mateo County Resource Conservation District
From:	cbec eco engineering - Stillwater Sciences Team
Project:	Develop Solutions to Flooding on Pescadero Road - Project # 13-1032
Subject:	Technical Memorandum #1 - Review of Existing Information, Revised Final Draft

An abundance of information have been developed documenting the historic and present day condition and function of the lower reaches of Butano and Pescadero Creeks and the Marsh. The information pertains to ecologic condition and utilization by various species, as well as the physical conditions which led to the formation of the historic marsh as well as its current form. In this technical memorandum we summarize the existing information we have reviewed as it pertains to developing solutions to flooding on Pescadero Creek Road. We limit our review to the information immediately relevant to the present project, and do not attempt to summarize all that has ever been done. Far more studies were obtained and reviewed than are referenced in the following discussion.

A brief summary of documents which provide background information on the natural and human induced evolution of the marsh and creek channels is followed by discussions regarding physical components of the system (i.e. hydrology, topography, sediment, and past hydraulic modeling). Information regarding past and current use of the project area by focus species: California red-legged frog (*Rana draytonii*), San Francisco garter snake (*Thamnophis sirtalis tetrataenia*), tidewater goby (*Eucyclogobius newberryi*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) is provided. Lastly a brief description of the permitting requirements to undertake a project is given.

Throughout the memorandum, reference to specific geographic areas within the project area follow the established names as shown in Figure 1. For the biological and permitting sections, the project area is defined as extending from at least 200 feet upstream of the Pescadero Creek Road crossing on Butano Creek to the mouth of Butano Creek, and all of the North, Middle, and East Butano marshes, as well as the Delta and East Delta Marshes. For physical components of this review, a larger geographic area has been considered including the lower reaches of Pescadero Creek, and extending farther upstream on Butano Creek. This expanded area is driven by the need to develop a hydraulic and sediment transport model for an area extending beyond the project area where management actions are considered.

2544 Industrial Blvd, West Sacramento, CA 95691 USA
T/F 916.231.6052
www.cbecoeng.com

1 Background

The geologic and climactic conditions which led to the development of a lagoon and estuary at the mouth of Pescadero Creek have been described by many efforts (e.g. Viollis 1979, Curry et al. 1985, PWA 1990, Cook 2002, ESA et al. 2004, Frucht 2013). A recent history of the watershed focusing on human interaction with the environment was developed by ESA et al. (2004), elements of which have also been summarized by others (e.g. Curry et al. 1985, Cook 2002, ESA 2008, Frucht 2013). A hydrologic enhancement plan for the Marsh and lower reaches of the creeks was developed by PWA (1990) with additional information provided in a subsequent document by California Department of Parks and Recreation (1992). A review of the implementation of the hydrologic enhancement plan is provided by ESA (2008), and a discussion of hydrologic issues related to the implementation of various components of the plan was developed by Swanson (2001a). Recommendations on how to proceed with the future modifications to the system following the 1993 and 1997 enhancement efforts have also been made in several separate efforts (e.g. Swanson 2001a, Cook 2002, ESA 2008, CEMAR 2010).

2 Information Regarding Physical Components of the System

In this section we review information regarding physical components of the system that pertain to evaluating the effects of future modification of the system to reduce flooding at Pescadero Road. Specifically the information required for the development, evaluation and application of a hydraulic and sediment transport model is prioritized.

2.1 Hydrology

Flow data are an important input to hydraulic and sediment transport modeling efforts. A number of gaging records are available including: USGS Gage 11162500 - Pescadero Creek near Pescadero, USGS Gage 11162540 - Butano Creek near Pescadero, Balance Hydrologics records at the former Butano Creek Gage location, and CEMAR flow records conducted on Pescadero (three locations) and Honsinger Creeks.

The USGS Pescadero Creek near Pescadero gage (#11162500) is located 5.3 mi upstream from the mouth and reflects surface runoff from the 45.9 mi^2 drainage area above the gage. Data have been collected since April, 1951, and according to the USGS, the records are of "fair" quality except for flows below 20 cfs (USGS 2012). Curry et al. (1985) notes that the station historically had a "less-than-adequate quality of gaging record," due to scour and fill and plugged conditions that persisted for months at the site. Various authors have synthesized daily or peak flow records to improve the quality or lengthen the period of record for the Pescadero Creek gage (Curry et al. 1985, ESA 2008).

The USGS Butano Creek near Pescadero gage (#11162540) was located ~2.2 mi upstream of Pescadero Road and reflects surface runoff from the 18.9 mi^2 drainage area above the gage. Data were collected between July 1, 1962 and October 7, 1974. Curry et al. (1985) notes that the station historically had a "less-than-adequate quality of gaging record," due to scour and fill and plugged conditions that persisted for months at the site.

Flow data for Butano Creek have been collected by Balance Hydrologics at the former Butano Creek USGS Gage location. Data have been collected since 2006, and include high flows. The monitoring is paid for by a local farmer to support a water rights proceeding. We have submitted a request to Balance who have in turn put in a request with their client. We believe these data will be of value to this project. However these data alone will not provide all that is needed. In order to simulate a large flood event (e.g. February 1998), flow data for Butano Creek will need to be synthesized. The flows recorded in the Balance Hydrologics monitoring record correspond to events which occur more frequently than every 4 years when evaluated by the peaks which occurred on Pescadero Creek. Data synthesis could be accomplished through the correlation between the overlapping daily average data at the two USGS gages, as there appears to be a high correlation between the data sets with a (R^2) of 0.90 (Figure 2). However when the instantaneous peaks are compared, the coefficient of determination is less strong.

Four gaging stations maintained by the Center for Ecosystem Management and Restoration have been in operation since the winter/spring of 2012. The rating curves that have been developed do not include high flows. If high flow data were available for the Lower Pescadero Creek and the Honsinger Creek gages, it could be used to further inform sub-watershed contributions to the system downstream of the USGS gages. In the absence of flood flow data for these locations, we do not plan to utilize these data in this project.

To better understand the geomorphic evolution of the marsh, Curry et al. (1985) synthesized peak daily flow records for 1937-1951 using a correlation with recorded flows on the San Lorenzo River and those recorded on Saratoga Creek (located on the northeastern side of the Santa Cruz Mountains). ESA et al. (2004) synthesized an annual flow peak data set for 1937-1951 also using a correlation with the San Lorenzo River at Big Trees (USGS #11160500) records. Several studies have developed flow frequency analyses of the Pescadero Creek gage (e.g. Curry et al. 1985, USACE 1989, Swanson and MBK 1999, ESA et al. 2004). Using annual maximum instantaneous flood peaks for 1952-2001, ESA et al. (2004) found $Q_{1.5}$ (the 1.5-yr return interval flood magnitude) to be 1,230 cfs, Q_2 - 2,080 cfs, Q_5 4,860 cfs, Q_{10} - 6,980 cfs, Q_{25} - 9,710 cfs and Q_{100} - 13,600 cfs. These values reflect flood peaks at the gage, not as Pescadero Creek enters the marsh, nor do they reflect the frequency of floods produced by the Butano watershed. Flood frequency estimates for Butano Creek were developed by Swanson and MBK (1999) using the 13 years of available peak data from the Butano Creek gage record. Flood Frequency estimates were also developed by USACE (1989) for the Pescadero Creek Road bridge (not the gage site) and are greater than those produced from the gage record.

Curry et al. (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 two sub-basins combined as they flow into the marsh (marsh inflow peak = 1.54 x gage peak). They also found that runoff (not the maximum flow observed) into the marsh is 1.7 times the value observed at the gage. The difference in these two multipliers is due to differences in the time of concentration of peak runoff from the two sub-basins, as Butano Creek peaks ahead of Pescadero Creek.

We believe there are enough flow data available to undertake this effort. Flows for Butano Creek may need to be synthesized or scaled to provide a hydrograph for a larger magnitude, less frequently occurring events.

2.2 Topography and Bathymetry

Topography and bathymetry are crucial inputs to hydrodynamic and sediment transport models. A number of data sets are available to reflect the ground surface elevation of the creek channels, and surrounding areas (i.e. marsh, floodplain, etc.). Data sets include cross sections that were physically surveyed, and well as surface models or digital elevation models (DEMs) derived from remotely sensed data (e.g. using LiDAR or aerial photogrammetric methods).

Cross section data have been collected by various efforts in various areas throughout the years (Figure 3). We limit our discussion (in most cases) to cross section surveys that were collected recently, and are likely to represent close to the existing conditions. The most recent data are the cross sections surveyed by WEST Consultants in Fall 2012 (WEST 2013). WEST collected 17 cross sections along Butano Creek starting roughly 150 feet upstream of Pescadero Creek Road and extending roughly 4,000 feet. In the report documenting the survey effort WEST compare their data to the 2009-2011 CA Coastal Conservancy Coastal LiDAR Project: Hydro Flattened Bare Earth DEM. The graphical comparisons indicates that the LiDAR data are often 1-3 ft higher than the actual ground surface as surveyed. Specifically channels (low points) are not represented well. These data are the best available information for the area immediately downstream of Pescadero Creek Road.

ESA PWA (2011) re-surveyed a number of cross sections (29 in total) that had been surveyed previously in 1987 (PWA 1987) and/or in 2001-2002 (ESA 2002, ESA 2003). These cross sections are located in the lower portion of the Butano and Pescadero Creeks, as well as some sections in the East Butano Marsh, the North Pond and the North Marsh. These data are the best available information for the lower reaches of Pescadero and Butano Creeks.

Swanson and MBK (1999) surveyed seven cross sections in the vicinity of the Pescadero Creek Road bridge. Three cross sections are located above the bridge and four are located below the bridge. While two of the cross sections extend farther upstream than any other recent data set, they are 14 years old and unlikely to accurately reflect current conditions. In a subsequent effort, Swanson and WRC (2002) surveyed changes to the road and potential locations of culverts, but did not collect additional cross section data of the creek.

In addition, cross sections have been compiled and/or surveyed at the Pescadero Creek Road bridge over Butano Creek by William Cook (2002), and compared to surveys conducted earlier by others. While these cross sections are useful in documenting the amount of deposition and reduction of cross sectional area that has occurred in the area, they will not be used in the model development. Historic and recent cross sections were also compared for Cloverdale Road bridge over Butano Creek and for several bridges along Pescadero Creek (ESA et al. 2004). The comparison of data at Cloverdale Road indicate the channel has incised by up to 4.7 feet since 1962. Similar comparisons at the Stage Road and Pescadero Cutoff Bridges over Pescadero Creek show both scour and deposition, with incision of the thalweg of 0.2 feet since 1961 and 0.9 feet since 1957, respectively.

Recent cross section data for Pescadero Creek, aside from those provided for the lower reaches by the ESA PWA 2011 survey, have not been located. Cross Section data are available for Pescadero Creek, collected in 1979, used in the HEC-2 hydraulic model developed for the FEMA Flood Insurance Study (FEMA 1982).

Beyond cross section datasets, which are limited to elevations along one particular alignment, several surface models or DEMs are available for the project area. The most recent is the California Coastal Conservancy Coastal LiDAR Project: Hydro Flattened Bare Earth DEM, which was developed using LiDAR data (NOAA 2009-2011). LiDAR technology are limited by standing water (the laser returns the water surface rather than the ground surface), and heavy vegetation (dense vegetation is often perceived as the ground surface). Figure 4 shows the DEM as well as indicates the areas where the surface represents ponded water or dense vegetation conditions. Note that the East Butano Marsh and the Butano Creek riparian corridor are not represented well with this dataset. A DEM derived from LiDAR data collected in 2005 was also obtained through San Mateo County. This DEM appears to resolve the ground surface better than the NOAA DEM. This DEM is also poor in the Butano Creek riparian corridor and the East Butano Marsh, although it appears to resolve the Pescadero Creek channel better than the NOAA 2009-2011 DEM. A one foot contour map of the area was developed by Towill Inc. using aerial photos collected in July 1987. While this data set is older than the other DEMs described above it may be useful towards understanding the topographic changes to the system which have occurred in the last 26 years. Hard copies of these maps were provided by State Parks staff. We are not aware if digital copies of these maps are available.

Recent topographic data (e.g. WEST 2013) indicate the historic Butano Creek channel downstream of the Pescadero Road bridge has aggraded (i.e. filled with sediment) to such a degree that a channel is no longer present. Field reconnaissance conducted by members of the cbec-Stillwater team verified that downstream of the bridge, the Butano Creek channel becomes topographically indistinguishable from the adjacent marsh and floodplain areas. Under the conditions observed (during August and October, 2013 field visits) flow from Butano Creek exited the channel and flowed overland (i.e. not through a defined channel) to the west into the Butano Marsh. These conditions are likely causing fish passage problems, which are discussed further below.

Based upon our review of the existing topographic information, we believe additional cross section data need to be collected for Butano Creek and the adjacent floodplain areas upstream of Pescadero Road bridge. We also suspect that certain important hydraulic features (e.g. breaches in levees in the Butano Marsh) should be surveyed to capture their current condition.

2.3 Existing Hydraulic Models

Several hydraulic models have been developed for portions of the project area. The FEMA (1982) developed a HEC-2 model of Pescadero and lower Butano Creek and the marsh to support their Flood Insurance Study. The model was designed to evaluate water surface elevations which would occur under large magnitude, low frequency flood events (e.g. 100-yr). As noted above, the cross sections were collected in 1979. Swanson and MBK (1999) developed a HEC-RAS model for the area immediately above and below the Pescadero Road bridge. They used this model to simulate existing conditions and the effects of various road raising scenarios. The model utilized cross section data collected in 1999. In a subsequent effort Swanson and WRC (2002) refined the previous hydraulic model slightly to investigate measures such as culverts under the roadway that could offset the increased water surface elevations resulting from proposed road raising scenarios. In a separate study, Swanson (2001b) developed a HEC-RAS model for Pescadero Creek in the vicinity of the 90 degree bend to investigate the effects of levee removal on hydraulic conditions. This study utilized the one foot contour map produced in 1987 by Towill, Inc. We have obtained and reviewed each of these existing models.

Other hydraulic studies have been undertaken by various parties (e.g. Curry et al. 1985, USACE 1989, ESA et al. 2004). The models, or datasets used to develop these studies are not readily available or are of limited use to this effort due to the nature of the study, age of the data, or geographic focus area. In addition, KHE (2006) provide an overview of modeling needs and a review of existing data as they pertain to the development of a hydrodynamic and water quality model of the lagoon/marsh to investigate causes and potential solutions to the ongoing fish-kills following breaching of the sand bar.

After reviewing these existing models and studies, we intend to develop a new hydraulic model for this effort, and implement its development such that it best meets the specific needs of this project. While we intend to use any data that can be utilized from the previous modeling efforts (e.g. Pescadero Road Bridge geometry), if will be more efficient and cost effective to develop a new model rather than to try to expand or update an existing model that was built for a slightly different purpose (i.e. not sediment transport modeling).

2.4 Sediment Data

2.4.1 Sediment Yield

Several studies have estimated the total annual yield from the watersheds. Curry et al. (1985) estimated an annual yield of ~ 800 $yd^3/mi^2/yr$ from the watershed, with an additional 2.7 million yd^3 produced from incision of the Butano Creek and 800,000 yd^3 produced from the incision of lower Pescadero between 1955 and 1984. Curry et al. (1985) concluded that for the period of 1955-1985, the average sediment yield per square mile of watershed area from Butano watershed is ~4 times the yield from the Pescadero Creek watershed.

More recently ESA et al. (2004) developed sediment yield estimates for three separate time periods (each roughly 20 years), with the 1937-2002 average of 2,000 $yd^3/mi^2/yr$, and with 1,700 $yd^3/mi^2/yr$ of this total being delivered to the stream channels. This value reflects the average sediment yield of the entire Pescadero watershed. Calculations for the geologic conditions present in the lower parts of the Butano Creek watershed (the area west of the San Gregorio Fault, HGU 7 in the ESA study) are much higher (i.e., 2-15 times) than other areas comprised of different geologic units or rock types. This is the area supplying sediment to the lower reaches of Butano Creek.

Data from the ongoing TMDL process (Frucht 2013) are not yet available for review. It is our understanding that they should be available by the end of October 2013. Through communication with Setenay Frucht at the Region Water Quality Control Board, we have learned that total annual yield for various historic periods will be provided, and that the yield from the current period is roughly twice the pre-1830 value.

2.4.2 Particle Size Distribution

In addition to the amount and rate of sediment production, the size of the sediment delivered to the streams is important to the current project. Sediment transport models utilize particle size distributions (the amount of material in various sizes classes) to determine when and how much sediment move. The mixture is not treated as a whole, rather individual size classes are treated (transported or deposited) differently. For instance, a given flow may be able to transport sand, but not able to transport gravel or cobble sizes. Not only are particle size distributions needed at the boundaries of a model, they are also needed throughout the model domain. Fortunately WEST (2013) collected and analyzed 17 sediment samples distributed from the Pescadero Road bridge to the mouth.

ESA et al. (2004) characterized bed material at various locations within the watershed, with one sample occurring at or near Pescadero Road, and another at the Giannini Bridge upstream. As would be expected the sediment at the upstream location was considerably coarser (D50 = 20 mm as opposed to <4mm) than that observed at Pescadero Road. Samples collected along Pescadero Creek were also coarser.

We will need to collect additional sediment samples in the alder thicket upstream of Pescadero Road, and may also need to collect some sediment samples on Pescadero Creek upstream of the confluence.

2.4.3 Sediment Transport Measurements

A typical input to sediment transport models is a time series of sediment delivery to the boundary of the model. This is also often specified through a sediment rating curve, where the mass of sediment transported is specified as a function of the flow rate. The development of a sediment rating curve requires a thorough field effort to collect sediment loads (suspended and bedload) across a wide range of flows. The USGS collected suspended sediment at the Pescadero Creek gage from 1970 to 2010. There are enough data to develop a reasonable suspended sediment rating curve from these data. Curry et al. (1985) collected some bedload data, however it was only for very low flows (36 cfs on Butano Creek and ~72 cfs on Pescadero Creek). As part of the development of the Hydrologic Enhancement

Plan, PWA (1990) collected some field measurements in order to calculate sediment transport in Butano Creek.

In the absence of a robust bedload dataset, we plan to employ a transport limited boundary condition in our modeling effort. This essentially means that the model will simulate the transport of as much sediment as the water could potentially carry. This is in contrast to a sediment limited condition where the transport capacity exceeds the material available to transport. Given the magnitude of sedimentation occurring in Butano Creek, this is a reasonable assumption. Curry et al. (1985) also made this assumption in their analysis.

3 Biological Information - Species Synthesis

This section synthesizes available information on California red-legged frog (*Rana draytonii*), San Francisco garter snake (*Thamnophis sirtalis tetrataenia*), tidewater goby (*Eucyclogobius newberryi*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use and habitat conditions in the Develop Solutions to Flooding on Pescadero Road project area. The goal of this synthesis is to establish a baseline from which to assess the potential effects of flood control alternatives on these sensitive species, and to identify the potential for habitat enhancements. The influence of the potential project is considered to extend from at least 200 feet upstream of the Pescadero Creek Road crossing on Butano Creek to the mouth of Butano Creek, and all of the North, Middle, and East Butano marshes, as well as the Delta and East Delta Marshes (Figure 1, referred to as the "project area").

3.1 California red-legged frog

California red-legged frog is listed as threatened under the federal Endangered Species Act (ESA) and is a California Department of Fish and Wildlife (CDFW) species of special concern. Associated with permanent or ephemeral water sources, California red-legged frog is largely restricted to coastal drainages on the central coast, including Pescadero Marsh. Breeding habitats are generally characterized by still or slow-moving water with deep pools and emergent and overhanging vegetation (Jennings and Hayes 1994). Breeding occurs between late November and late April (Jennings and Hayes 1994). Eggs hatch within 6–14 days and larvae (tadpoles) require approximately 11–20 weeks to metamorphose, generally from May to September, though overwintering by California red-legged frog larvae has been documented (Fellers et al. 2001, USFWS 2002).

Pescadero Marsh is considered to support one of the largest remaining populations of California red-legged frog (USFWS 2002). In the project area, California red-legged frogs have been documented to use areas of Butano Creek, East Butano Marsh, Middle Butano Marsh, and East Delta Marsh (Jennings and Hayes 1990, Smith and Reis 1997, Reis 1999). Habitat conditions have changed in the project area over the last 20 years from restoration actions, changes in in management, and natural processes. Surveys for California red-legged frog conducted more recently continue to document presence in the project area.

In Butano Creek, California red-legged frog sightings have primarily been within the section approximately 1,000 feet downstream of Pescadero Creek Road, and have not included egg masses or larvae. While Jennings and Hayes (1990) found no California red-legged frogs in Butano Creek in March 1989, over 80 frogs were observed the following August. Similarly, Smith and Reis (1997) found no larvae in this section of Butano Creek, but young-of-the-year and adults were common to abundant there in fall. Jennings (1992) reported common sightings of adults and juvenile California red-legged frog along the willow (*Salix* spp.)-lined main stream channel of Butano Creek. A few adults have been documented in Butano Creek downstream of this area, which has seasonally high salinities (Smith and Reis 1997).

California red-legged frog breeding has been documented in East Butano Marsh (Jennings and Hayes 1990, Smith and Reis 1997). Jennings and Hayes (1990) documented egg masses here, and observed and heard adults calling along the edges of open, deep water among the matrix of dense emergent vegetation. While abundant larvae were found in East Butano Marsh during surveys in 1996, there only a few individual young-of-the-year were observed, presumably due to summer drying and high salinity (Smith and Reis 1997).

In Middle Butano Marsh, Jennings and Hayes (1990) observed and heard adults calling along the edges of open, deep water among the matrix of dense emergent vegetation, though no egg masses or larvae were observed. After opening levees between the three segments of Butano Marsh in 1993 to improve water circulation, only a few adults were documented in Middle Butano Marsh, where salinities were seasonally high (Smith and Reis 1997).

No California red-legged frogs were observed in North Butano Marsh, which was presumed to be too saline, during 1989 surveys; a few adults (but no larvae) were documented there in 1996 (Jennings and Hayes 1990, Smith and Reis 1997).

In East Delta Marsh, California red-legged frog adults were found using the deep water channel along the west margin during periods of decreased flow (Jennings and Hayes 1990). Smith and Reis (1997) found abundant larvae in the East Delta Marsh, but far fewer young-of-the-year compared to larval abundance, likely because of summer drying and high salinity. The northern part of the East Delta Marsh also had adult California red-legged frogs (Smith and Reis 1997).

No California red-legged frogs were found in Delta Marsh during surveys, likely because of water depths that were too shallow (Jennings and Hayes 1990, Smith and Reis 1997).

Bullfrogs (*Rana catesbeiana*) prey on California red-legged frog and compete with them for habitat and food resources. Adult bullfrogs have also been found to prey on smaller San Francisco garter snakes, and may be a contributing factor in their decline as well (USFWS 2007). Bullfrog adults were observed in the project area in Butano Creek, East Butano Marsh, Delta Marsh, and Delta Marsh (Smith and Reis 1997). Bullfrog larvae and juveniles were documented in Butano Creek near Pescadero Creek Road, but these may have been washed downstream from suitable breeding areas upstream on Butano Creek in farm ponds, rather than having reproduced in this portion of Butano Creek (Jennings and Hayes 1990, Reis

1999). Conditions in the project area are generally marginal for bullfrog reproduction, since water temperatures do not usually reach the level bullfrogs need to reproduce (Jennings and Hayes 1990). There has been no confirmed breeding of bullfrogs in Pescadero Marsh.

Based on available information, California red-legged frogs have high potential to occur in nearly all portions of the project area throughout the year. Breeding within the project area is likely limited to East Butano, Middle Butano, and East Delta Marsh (as evidenced by the presence of larvae and/or egg masses during past surveys), depending on current site conditions (e.g., water depth and salinity levels). Egg masses, which are more sensitive to disturbance due to their lack of mobility, would be expected in the project area between approximately late November and April; larvae would be expected to occur until as late as September. As a result of the restoration and other activities that have occurred within the last 20 years, site conditions (e.g., increase in amount and changes in type of emergent and overhanging vegetation; changes in water quality such as salinity, temperature and dissolved oxygen; and changes in water depth and extent) have been changing since focused surveys for California red-legged frog were last conducted. Therefore, a reconnaissance-level survey will be conducted to evaluate the current project area conditions for California red-legged frog habitat suitability.

3.2 San Francisco garter snake

San Francisco garter snake is known to occur in and near Pescadero Marsh (Jennings 1992, Barry 1994, USFWS 2006). San Francisco garter snake is listed as endangered under the federal and California ESAs, and is fully protected under the California Fish and Game Code. Essential habitat for a breeding population of San Francisco garter snakes includes ponds, lakes, shallow marshlands, or slow-moving creeks with emergent vegetation for cover, an adequate prey base, and exposed uplands for basking, movement, and aestivation (USFWS 1985, McGinnis 1987, USFWS 2006). Upland areas with an abundance of small mammal burrows are important as winter hibernation sites, though snakes may be active year-round (Larsen 1994). San Francisco garter snakes mate during the spring (March–April) and fall (September–November), producing live young as early as July and as late as early September (Larsen 1994).

A sizeable population of San Francisco garter snake is expected in Pescadero Marsh (Jennings 1992). Jennings (1992) found five San Francisco garter snakes in Pescadero Marsh during focused surveys in 1991, and there were a few confirmed sightings of San Francisco garter snake during California red-legged frog surveys by Smith and Reis in 1996. San Francisco garter snake sightings were primarily in areas with an abundance of adult and larval frogs, their primary prey. Jennings (1992) found that San Francisco garter snakes were associated with bulrush (*Scheonoplectus* sp.) and cattail (*Typha* spp.) in aquatic areas, and with blackberry (*Rubus ursinus*) and coyote brush (*Baccharis pilularis*) scrub in upland areas. Jennings did not observe San Francisco garter snake in dense eucalyptus groves or eucalyptus/poison oak (*Toxicodendron diversilobum*)-covered hillsides, which lacked suitable prey and open areas for basking.

San Francisco garter snakes have historically used levees in Butano Marsh (Jennings 1992, Smith and Reis 1997). These levees were only partially removed during restoration in the mid-1990's to retain some basking habitat for the snake (ESA 2008). In 2002–2003, these remaining levees had a dense vegetative overstory, which may reduce their value for basking (ESA 2008). Based on Jennings (1992) observations in Pescadero Marsh, preferred upland sites had south facing slopes adjacent to marsh habitats with patches of dense vegetative cover. Such areas had open areas for basking, dense patches of vegetation and rodent burrows for refuge and escape from predators, and nearby aquatic habitats with abundant prey.

While information regarding specific use of the project area by San Francisco garter snake is limited and verified detections seem to be uncommon, this species is expected to primarily use inland and upland areas of the project area and surrounding region. Due to the considerable prey base (e.g., California red-legged frog and Pacific treefrog), San Francisco garter snakes presumably forage in Butano Creek, East Butano Marsh, Middle Butano Marsh, and East Delta Marsh, particularly where there are adjacent upland areas suitable for basking and refuge. San Francisco garter snakes may use these areas year-round, but are expected to be most active between March and November. The winter months are a period of reduced activity, when the snake is usually hibernating in small mammal borrows or other refugia; ground disturbance during this time is a greater potential hazard due to the reduced mobility of the species.

3.3 Tidewater goby

Tidewater goby occur within the project area (Smith and Reis 1997, Rischbieter 2013). It is an endangered species under the federal ESA (USFWS 2005) and a California species of special concern. The fish are an estuarine species that disperse infrequently through the ocean, but have no dependency on marine habitat for its life cycle (Swift et al. 1989, Lafferty et al. 1999). Tidewater goby prefer low-velocity habitat with sandy substrate. Tidewater gobies have been documented in water with temperatures ranging from 8–25°C (46–77°F) and salinities that range from 0–41 ppt (Swift et al. 1989, Moyle 2002, Chamberlain 2006). Tidewater gobies have been observed spawning regularly in water temperatures of 17–22°C (62–71°F) and salinities of 8–15 ppt (USFWS 2005). Tidewater gobies have also been found over a broad range of DO levels (4–19 mg/l) (Irwin and Soltz 1984 as cited in Chamberlain 2006).

Salinity, temperature and DO conditions are generally suitable for tidewater goby within a broad range of the Pescadero-Butano Lagoon, whereas water velocity often limits distribution (Smith Reis 1997). Tidewater goby sampling was conducted in the late 1990's by Smith and Reis (1997), and is currently being conducted as part of ongoing monitoring efforts by California State Parks (Rischbieter 2013). When the lagoon sandbar is closed (the timing of bar closure varies, but opening typically occurs during the fall), lower Butano Creek and adjacent marsh habitat is inundated with calm, low-water-velocity habitat. Tidewater goby have been regularly observed under these conditions in spring in within the project area in Butano and East Delta marshes (Smith and Reis 1997), and by Rischbieter (2013) in summer within similar areas (Figure 1). When lower riverine reaches of Pescadero Creek become backwatered many tidewater goby have been observed (Rischbieter 2013), including throughout deep pools and main channel sites. The only constraint on tidewater goby distribution within the project area appears to moderate to high water velocity, such as the non-marshy portions of the lagoon, in channels, in open water with substantial tidal movement, or in lower riverine portions of Butano Creek (Smith 1990, Smith and Reis 1997).

In general, the project area includes a large amount of suitable habitat for tidewater goby when water velocity is low and tidal movement is minimal. When the sandbar is not closed and marsh habitat is not inundated (e.g., in the winter), suitable habitat for tidewater goby is reduced, and tidewater goby are likely present but less common in the project area.

3.4 Coho salmon

Coho salmon previously found in the Pescadero Creek watershed belong to the Central California Coast evolutionarily significant unit (ESU) (NMFS 2012), which is listed as endangered under both the federal and California ESAs (NMFS 2005). In a status review of the ESU based on all available biological information Spence and Williams (2011) concluded that the Pescadero coho salmon population is currently at extreme risk of extirpation, and presently the watershed is not believed to support a viable self-sustained population of coho salmon (Anderson 1995). However, coho salmon could potentially re-establish a population in the watershed.

Fine sediment accumulations within the riverine habitat of lower Butano Creek preclude coho salmon spawning (ESA et al. 2004). However, suitable spawning habitat in upper Butano Creek does occur (ESA et al. 2004). Therefore adult coho salmon could be expected to migrate upstream through the project area to access spawning habitat. Based on observations in Waddell Creek, adult upstream migration would be expected mostly November through February (Shapovalov and Taft 1954). Sediment that has deposited in the lower Butano Creek channel downstream of the Pescadero Road crossing results in the lack of a defined stream channel and may impair upstream fish migration through lower Butano Creek (Butler 2013, Nelson 2012).

Early fry and juvenile rearing of coho salmon is typically observed in the vicinity of spawning habitat, and ESA et al. (2004) observed little suitable summer rearing habitat for coho salmon in lower Butano Creek (which is downstream of most spawning habitat). Although water temperatures are likely suitable for coho salmon during summer (SFBRWQCB 2007), ESA (2008) concluded that habitat in lower Butano Creek in the project area currently contains overall marginal habitat for salmonid rearing, with generally shallow pool depths, limited amounts and frequency of large woody debris, and relatively high levels of fine sediments.

During winter (November through March), juvenile coho salmon are typically associated with low-velocity habitats. Suitable winter habitat (e.g., inundated off-channel floodplain habitat) is common in the project area, and thus if coho salmon occurred in the watershed, rearing during winter would be likely.

Juvenile smolts produced in upstream habitat would migrate downstream through the project area while migrating to the ocean. Coho salmon smolt outmigration generally occurs in the spring in association with precipitation events from March through June (Shapovalov and Taft 1954).

In general, if coho salmon were to occur in the Butano Watershed, the project area would be a migratory corridor for adult coho salmon during fall and winter and for smolts during spring. In addition, suitable rearing habitat for juvenile coho salmon is available during winter.

3.5 Steelhead

Steelhead belonging to the Central California Coast Distinct Population Segment (DPS) are currently found in the Pescadero Creek watershed (NMFS 2006). This DPS is listed as threatened under the federal ESA (NMFS 2006). Steelhead have been found in fish surveys throughout the watershed, including within Butano Creek upstream of the project area (CDFG 1996).

Although fine sediment deposition precludes spawning in the project area (ESA et al. 2004), adult steelhead migrate upstream through the project area to reach suitable spawning habitat in upper Butano Creek and its tributaries. Winter-run steelhead generally enter spawning streams from late fall through spring, contingent upon adequate flow conditions for continuous passage from the ocean to upstream spawning grounds (Shapovalov and Taft 1954). As described for coho salmon, sediment that has deposited in the lower Butano Creek channel downstream of the Pescadero Road crossing results in the lack of a defined stream channel. NMFS has stated that based on their observations they "expect steelhead passage is severely restricted, if not blocked"(Butler 2013).

Juvenile downstream migration in the region typically occurs from March through July, with peaks in late April and early May, contingent upon adequate flow conditions (Shapovalov and Taft 1954). Depending partly on growing conditions in their rearing habitat, steelhead may migrate downstream to estuaries as age 0+ or age 1+ juveniles or may rear in streams for up to four years (most frequently two years) before outmigrating to the lagoon and ocean (Shapovalov and Taft 1954). Nelson (2012) has also stated that because of sediment deposition in the channel it appears that passage for downstream migrating juveniles and smolts is, “problematic,” in Butano Creek downstream of the Pescadero Road crossing.

Inundated marsh and lagoon habitat in the project area is used extensively by rearing steelhead juveniles (Smith 1987). Sampling in Pescadero marsh and lagoon habitat has documented extensive rearing of age 1+ and 2+ steelhead during spring, summer, and fall with bar in either open or closed conditions. During monthly sampling, Huber and Carlson (unpubl. data) found that juvenile steelhead are common in the lagoon during much of the year, only absent from the catches (or nearly so) during the winter (~December–February). (note that anglers regularly catch adult steelhead in the lagoon during winter). Smith (1990) observed juvenile steelhead entering the lagoon from riverine reaches as early as April, with rearing occurring there through summer regardless of sandbar condition. Smith (1990) observed large schools of juvenile steelhead in the project area entering the deeper channels of Butano Marsh to feed. Smith (1987) reports that steelhead used almost all habitats of Pescadero Marsh, including Butano Creek in the project area.

Sloan (2006) and ESA (2008) documented the presence of hydrogen sulfide and anoxia in the channels of the Butano marshes, suggesting that the Butano marshes in the project area may be a major source of hydrogen sulfide and/or anoxic water circulating in the marsh at the breaching of the sandbar.

Passage of adult and smolt steelhead though lower Butano Creek to habitat in upper Butano Creek is likely currently restricted. However, steelhead currently occur throughout the project area downstream of this restriction during most of the year, and if passage were improved adults, smolts, and juveniles would be expected to occur within and upstream of the entire project area.

4 Permitting Issues

The project area supports Federal and State listed species and/or their habitat. As in-channel work is expected to be a component of the proposed solution, the following permits and actions are likely to be required:

- Clean Water Act (CWA) Section 404 Permit from the U.S. Army Corps of Engineers (USACE) for dredge or fill activities below the ordinary high water mark (OHWM) of Butano Creek channel and in adjacent wetlands. Based on this permit, USACE is likely to be the federal lead agency of the proposed project.
- A Coastal Development Permit (CDP) from San Mateo County for work proposed above the Mean High Tide (MHT) line and a CDP from the California Coastal Commission for work proposed below the MHT line or on historic tidelands due to the project's location in the Coastal Zone.
- A delineation of the Butano Creek OHWM and adjacent wetland boundaries to inform the Section 404 Permit and the CDP applications.
- CWA Section 401 water quality certification from the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) to ensure the activities permitted under Section 404 also meet relevant federal and State water quality standards. Depending on the level of concern over hydrogen sulfide levels in Butano Creek and Butano Marsh sediment, the SFBRWQCB could require sediment testing or other studies to inform the 401 certification process.
- A Biological Opinion (BO) from the National Marine Fisheries Service (NOAA Fisheries) and U.S. Fish and Wildlife Service (USFWS) to ensure the activities permitted under Section 404 by USACE comply with Section 7 of the federal Endangered Species Act (ESA).
- A Biological Assessment of the proposed project's potential effects on species listed and critical habitat designated under the federal ESA to inform the BO and an analysis of the proposed project's impact to environmentally sensitive habitat areas to inform the CDP application.

- Depending upon the specific Section 404 permit applied for, a National Environmental Policy Act (NEPA)-compliance document may need to be prepared to ensure the activities permitted by USACE comply with NEPA. Depending on the project(s) proposed, an Environmental Assessment (EA) or Environmental Impact Statement (EIS) may be required.
- Database queries and focused surveys for cultural resources may be necessary for completion of the Section 404 Permit and CDP applications, as well as the NEPA document, if required.
- California Fish and Game Code Section 1600 Permit/Streambed Alteration Agreement from the California Department of Fish and Wildlife (CDFW) for activities that may alter the bed or bank of Butano Creek.
- An Encroachment Permit, Grading/Land Clearing Permit, and Street Closure Permit from San Mateo County.
- Right-of-Entry Permits from California State Parks and/or Peninsula Open Space Trust may be necessary if project actions occur outside of San Mateo County's right-of-way along Pescadero Creek Road.
- A California Environmental Quality Act (CEQA)-compliance document to ensure the activities permitted by CDFW and/or San Mateo County comply with CEQA. Depending upon the activities and timing of the proposed project, a Mitigated Negative Declaration or Environmental Impact Report (EIR) may be required. Depending on what is proposed, San Mateo County, the RCD, CDFW, State Parks of another entity could be the State lead agency for the proposed project.
- Based on the information provide in the preceding sections on special-status species, it seems unlikely that protocol-level or presence/absence surveys for these species will be necessary, as their presence during certain times of the year can be assumed.
- San Francisco garter snake is a Fully Protected species and, as such, no potential take of the species is permitted by CDFW. Since there are no seasonal restrictions for when this species might occur in the project area, pre-construction surveys and daily biological monitoring will be required to ensure that all San Francisco garter snakes in or that travel through the project area are fully avoided and no incidental or accidental take occurs.

5 Next Steps and Conclusion

As our team moves forward in developing solutions to flooding on Pescadero Road, the next step is to refine our scope of work to address some of the data gaps we identified in this review of the existing information. There is a fundamental need to collect additional cross section data in various areas of the proposed model domain. Cross sections need to be collected for Butano Creek upstream of Pescadero Road. In addition select surveys in the Butano Marshes will improve our ability to characterize the hydraulics of the area. Of specific interest are the breaches in the various levees/dikes, as these control flow through this region. We may also opt to collect some cross section data for Pescadero Creek, but need to undertake a more thorough review of the existing DEMs to inform this decision. The focus of this project is the reduction of high frequency flooding resulting from low magnitude runoff events from Butano Creek, so we may be able to utilize the existing topographic information for Pescadero Creek, particularly since recent cross sections of the downstream reach are available. In addition to cross section data, we also need to collect and analyze sediment samples for Butano Creek upstream of Pescadero Road. We may also opt to collect a small number of samples for Pescadero Creek, but again since the focus of this effort is on sedimentation issues on Butano Creek, we will need to further evaluate this need as we refine our scope of work and the available budget. Lastly, we recommend a reconnaissance-level survey be conducted to evaluate the current project area conditions for California red-legged frog habitat suitability.

6 References

Anderson, K. R. 1995. A status review of the coho salmon (*Oncorhynchus kisutch*) in California sought of San Francisco Bay. Prepared for California Department of Fish and Game, Monterey.

Barry, S. J. 1994. The distribution, habitat, and evolution of the San Francisco garter snake, *Thamnophis sirtalis tetrataenia*. University of California, Davis.

BGC (Berlogar Geotechnical Consultants). 1988. Geotechnical report Pescadero Marsh: Pescadero State Beach, Pescadero, California. Prepared for Office of the State Architect.

Butler, D. 2013. Re: Fish passage in Butano Creek. Letter from D. Butler, North Central Coast Office Supervisor, Protected Resources Division, National Marine Fisheries Service, Santa Rosa, California to T. Frahm, California Central Coast Steelhead Coordinator, Trout Unlimited, San Juan Bautista, California. Dated March 19, 2013.

California Department of Parks and Recreation. 1992. Pescadero Marsh Natural Preserve Hydrologic Enhancement Plan.

CDFG (California Department of Fish and Game). 1996. Stream Inventory Reports for Butano Creek, Central Coast Region, Monterey, CA. 1995.

CEMAR (Center for Ecosystem Management and Restoration). 2010. Considerations for Restoration of the Pescadero Marsh. Prepared for the Pescadero Marsh Working Group.

Chamberlain, C. D. 2006. Environmental variables of northern California lagoons and estuaries and the distribution of tidewater goby (Eucyclogobius newberryi). Arcata Fisheries Technical Report TR 2006-04. U.S. Fish and Wildlife Service, Arcata, California.

Cook, W. 2002. The Restoration of Butano Creek, its Lower Channel and Floodplains & The Flooding of Pescadero Road. November, 2002 Edition.

Curry, R., R. Houghton, T. Kidwell, and P. Tang. 1985. Pescadero Marsh Management: A plan for persistence and productivity. for California State Parks by University of Santa Cruz. Draft Report.

ESA (Environmental Science Associates). 2002. Butano Creek Cross-sections Survey Report. California Department of Parks and Recreation, Bay Area District, San Francisco, CA. 13 pp.

ESA. 2003. Re-Survey of the 1987 Pescadero Marsh Cross-sections on Pescadero Creek. Department of Parks and Recreation, Bay Area District, San Francisco, CA. 14 pp.

ESA. 2008. Pescadero Marsh restoration assessment and recommendations for ecosystem management. Final Report. Prepared for California Department of Parks and Recreation, Half Moon Bay, California.

ESA (Environmental Science Associates), Pacific Watershed Associates, O'Connor Environmental, Albion Environmental, and D. Jackson. 2004. Pescadero-Butano Watershed Assessment. Final Report. Prepared for Monterey Bay National Marine Sanctuary Foundation, Monterey, California.

ESA PWA. 2011. Geomorphic Evolution of Pescadero Marsh: 1987-2011 - Results of Field Monitoring and Data Collection. Prepared for San Mateo County Resource Conservation District and California Department of Parks and Recreation.

FEMA (Federal Emergency Management Agency). 1982. Flood Insurance Study, San Mateo County, California, Unincorporated Areas. Community Number 060311, 480 map panels, text and profiles.

Fellers, G. M., A. Launer, G. Rathbun, S. Bobzien, J. Alvarez, D. Sterner, R. B. Seymour, and M. Westphal. 2001. Overwintering Tadpoles in the California Red-Legged Frog (*Rana aurora draytonii*). Herpetological Review 32(3):156−157.

Frucht, S. B. 2013. Pescadero-Butano Watershed Sediment TMDL Project Definition and Project Plan. San Francisco Bay Regional Water Quality Control Board. Available at: http://www.waterboards.ca.gov/ sanfranciscobay/water_issues/programs/TMDLs/pescadero/PBW_Project_Plan_Website.pdf

Huber, E., C. Post, S. Kayed. 2011. Relationship between juvenile steelhead survival and winter habitat availability. Hydrology, Water Resources Collections and Archives, University of California Water Resources Center, UC Berkeley.

Jennings, M.R. 1992. Final report of preliminary studies on habitat requirements of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) at Pescadero Marsh and Theodore J. Hoover Natural Preserves.

Jennings, M.R., and M.P. Hayes. 1990. Status of the California red-legged frog (*Rana aurora draytonii*) in the Pescadero Marsh Natural Preserve. Prepared for the California Department of Parks and Recreation under contract no. 4-823-9081 with the California Academy of Sciences.

Jennings, M.R., and M.P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final Report. Prepared for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, CA.

KHE (Kamman Hydrology and Engineering Inc.). 2006. Data Synthesis and Hydrodynamic model development feasibility report Pescadero Lagoon, San Mateo County, California. Prepared for the California Coastal Conservancy.

Lafferty, K. D., C. C. Swift, and R. F. Ambrose. 1999. Extirpation and decolonization in a metapopulation of an endangered fish, the tidewater goby. Conservation Biology 13: 1447–1453.

Larsen, S. 1994. Life history aspects of the San Francisco garter snake at the Millbrae habitat site. Unpublished Master's Thesis. California State University, Hayward.

McGinnis, S. M. 1987. The distribution and feeding habitat requirements of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Final Report. Prepared for California Department of Fish and Game Interagency agreements C-673 and C-1376.

Moyle, P. B. 2002. Inland fishes of California. Revised edition. University of California Press, Berkeley, California.

Nelson, J. 2012. Butano Creek barrier assessment. Internal memorandum to G. Neillands, Senior Environmental Scientist, California Department of Fish and Game.

NMFS (National Marine Fisheries Service). 1997. Endangered and threatened species: Listing of several evolutionarily significant units (ESUs) of west coast steelhead. Federal Register 62: 43937-43954.

NMFS. 2005. Endangered and threatened species: final listing determinations for 16 ESUs of West Coast Salmon, and final 4(d) protective regulations for threatened salmonid ESUs. Federal Register 70: 37160-37204.

NMFS. 2006. Endangered and threatened species: final listing determinations for 10 Distinct Population Segments of west coast steelhead. Federal Register 71: 834–862

NMFS. 2012. Final recovery plan for the Central California Coast Coho Salmon Evolutionarily Significant Unit. NMFS, Southwest Region, Santa Rosa, California.

NOAA (National Oceanographic and Atmospheric Administration). *2009 -2011 California Coastal Conservancy Coastal LiDAR Project: Hyrdo Flattened Bare Earth DEM*, accessed September 5, 2012, from<http://www.csc.noaa.gov/dataviewer/>

PWA (Philip Williams & Associates, Ltd.). 1987. Pescadero Marsh Natural Preserve Survey Report. California Department of Parks and Recreation, Natural Heritage Section, CA 35 pp.

PWA. 1990. Pescadero Marsh hydrological enhancement plan. Prepared for California Department of Parks and Recreation.

Reis, D.K. 1999. Habitat characteristics of California red-legged frogs (*Rana aurora draytonii*): Ecological differences between eggs, tadpoles, and adults in a coastal brackish and freshwater system. M.S. Thesis. San Jose State University.

Rischbieter, D. 2013. SFWO—2012 Summary Annual Report Elements, Recovery Permit #TE101154-1 (Tidewater Goby).

SFBRWQCB (San Francisco Bay Regional Water Quality Control Board). 2007. Water quality monitoring and bioassessment in nine San FranciscoBay Region watersheds: Walker Creek, Lagunitas Creek, San Leandro Creek, Wildcat Creek/San Pablo Creek, Suisun Creek, Arroyo Las Positas, Pescadero Creek/Butano Creek, San Gregorio Creek, and Stevens Creek/Permanente Creek. Oakland, CA: Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin 98. California Department of Fish and Game.

Sloan, R. 2006. Ecological investigations of a fish kill in Pescadero Lagoon, CA. M.S. Thesis San Jose State University

Smith, J. J. 1987. Aquatic habitat and fish utilization of Pescadero, San Gregorio, Waddell, and Pomponio Creek estuary/lagoon systems. Report prepared under Interagency Agreement 4-823-6004, between Trustees for California State University and the California Department of Parks and Recreation.

Smith, J. and D. Reis. 1997. Pescadero Marsh Natural Preserve salinity, tidewater goby and red-legged frog monitoring for 1995-1996.

Smith, J. J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio Creek Estuary/Lagoon systems, 1985-1989. Prepared by Department of Biological Sciences, San Jose State University, California.

Spence, B., and T. H. Williams. 2011. Status Review Update For Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Central California Coast Coho Salmon ESU. NOAA-TM-NMFS-SWFSC-475. NOAA's National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA.

Swanson (Swanson Hydrology & Geomorphology). 2001a. Hydrologic Issues regarding Management of Pescadero Marsh in light of Enhancement Projects completed in 1993 and 1997. Prepared for California Department of Parks and Recreation.

Swanson (Swanson Hydrology & Geomorphology). 2001b. Letter Report from Hydraulic Study of Lower Pescadero Creek. Prepared for California Department of Parks and Recreation.

Swanson (Swanson Hydrology & Geomorphology) and MBK (Murray, Burns, Kienlen). 1999. Pescadero Creek Road Hydraulic Study. Prepared for the County of San Mateo Public Works Department, Redwood City, California.

Swanson (Swanson Hydrology & Geomorphology) and WRC (WRC - Nevada). 2002. Memorandum - Preliminary Modeling Results - Pescadero Creek Road Raising Hydraulic Study. Prepared for the County of San Mateo Public Works Department, Redwood City California.

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, *Eucyclogobius newberryi* (Pisces: Gobiidae) of California. Contribution Science. Natural History Museum of Los Angeles County, Los Angeles, California 404: 19.

USACE (U.S. Army Corps of Engineers). 1989. Section 205 Reconnaissance Report Flood Control Improvements, Pescadero and Butano Creeks, San Mateo County, California.

USFWS (U.S. Fish and Wildlife Service). 1985. Recovery plan for the San Francisco garter snake, *Thamnophis sirtalis tetrataenia*. Final Report. USFWS, Portland, Oregon.

USFWS. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS. 2005. Recovery plan for the tidewater goby (*Eucylcogobius newberryi*). U.S. Fish and Wildlife Services, Portland, Oregon.

USFWS. 2006. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) 5-year review: summary and evaluation. USFWS, Sacramento, California.

USGS (U. S. Geological Survey). 2012. Water Data Report 2012 - 11162500 Pescadero Creek near Pescadero, CA.

WEST (WEST Consultants, Inc.). 2013. Field Data Collection and LiDAR Assessment for Butano Creek. Prepared for NOAA's National Marine Fisheries Service Southwest Region.

Viollis, F. S. 1979. The evolution of Pescadero Marsh. San Francisco State University. Masters of Science.

Coastal Overview

Watershed boundary

Rivers & streams

N

0 0.25 0.5 1 Kilometers

0 0.25 0.5 Miles

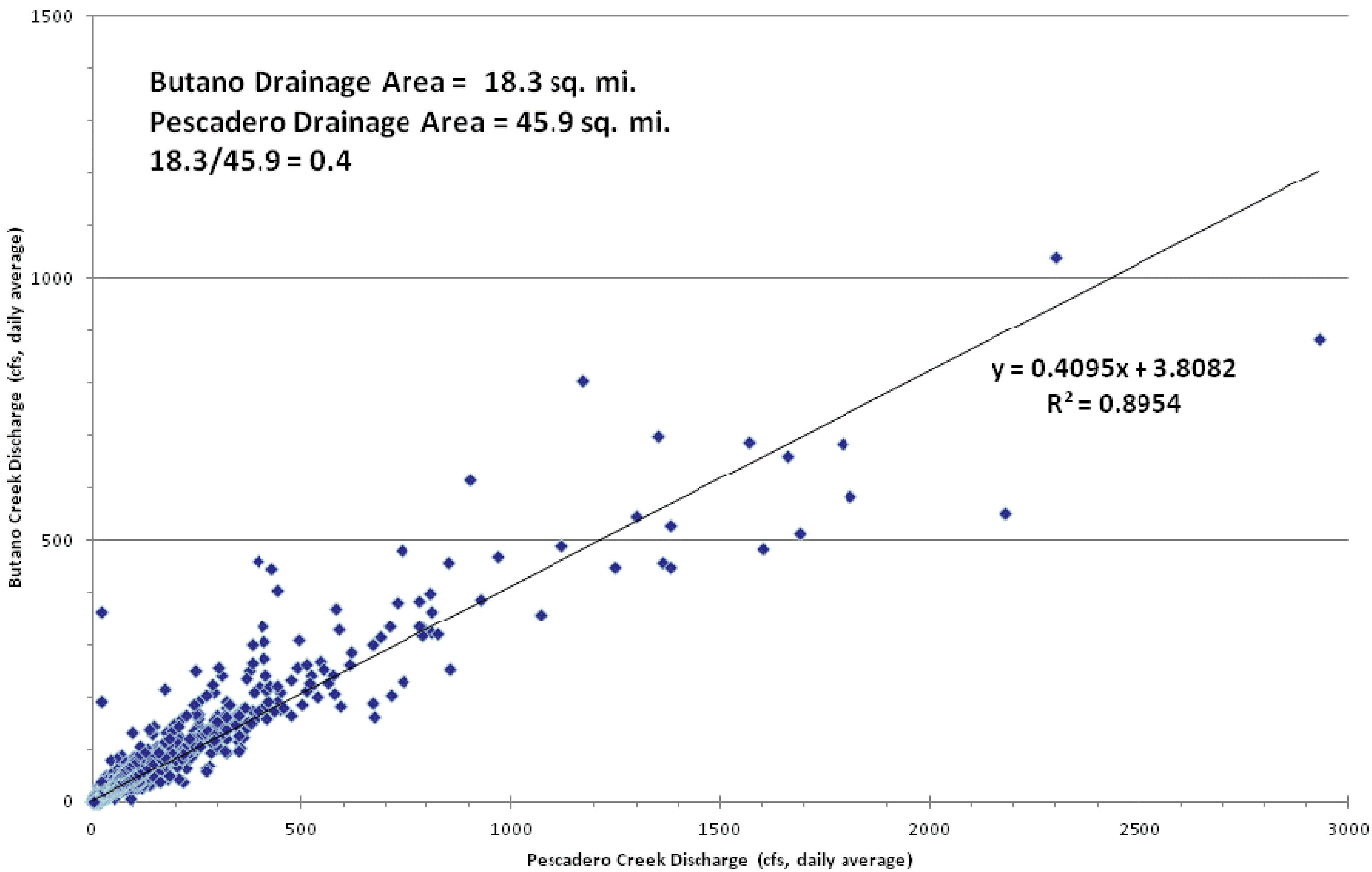
Map Sources:
Imagery (NAIP 2009); Watershed boundary (SWS); Cities, Roads, Streams (ESRI 2012)

Stillwater Sciences
www.stillwatersci.com

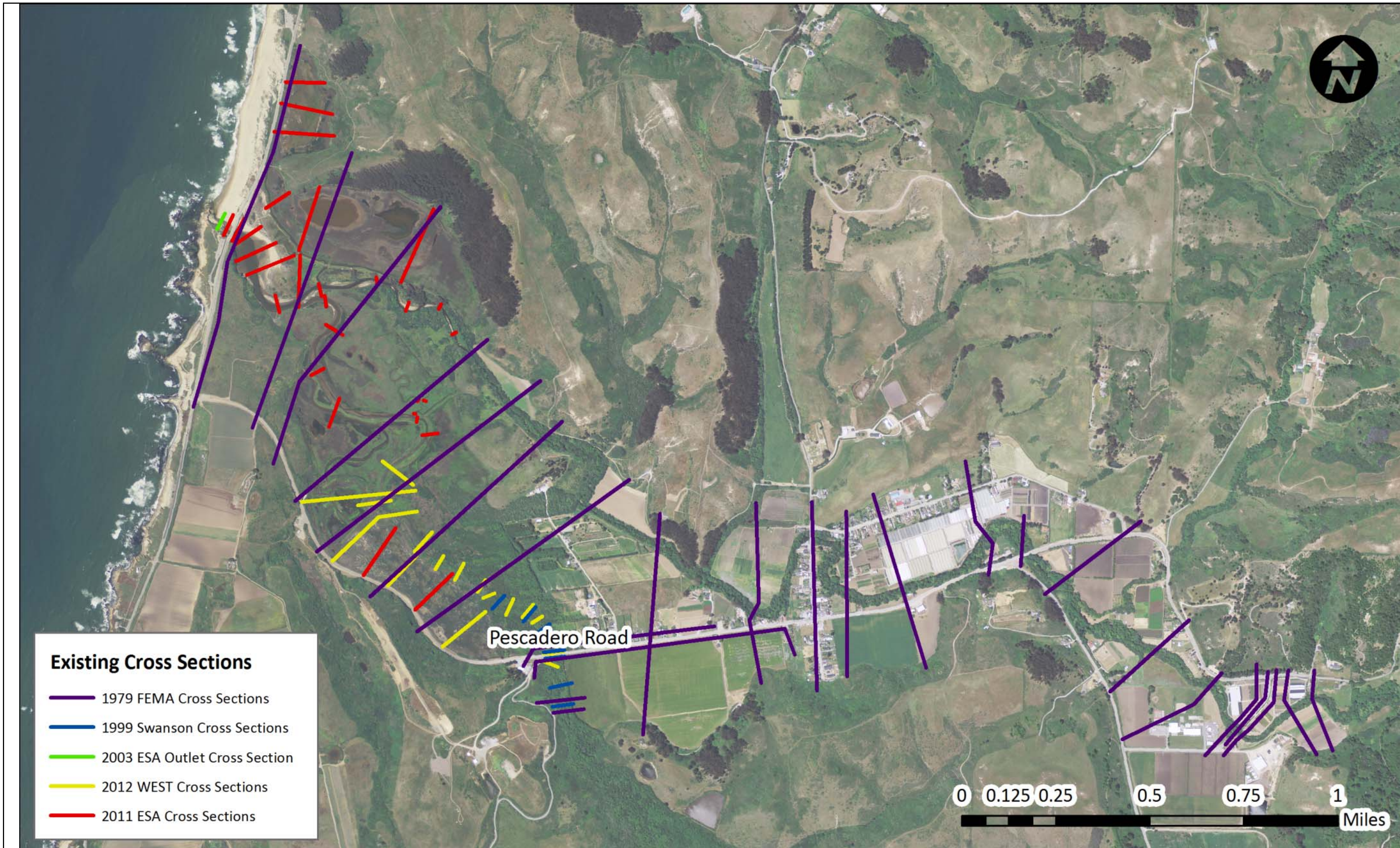
Map Location

Notes:	cbec eco engineering	*Develop Solutions to Flooding on Pescadero Creek Road* **Study Area**		
		Project No. 13-1032	Created By: Stillwater	**Figure 1**

C:\Work\Projects\13-1032_Pescadero_Rd\Task 1\Figures\Fig_1_Study_Area.docx
12/13/2013



Notes: Data for USGS Pescadero Creek near Pescadero gage (#11162500) and USGS Butano Creek near Pescadero gage (#11162540)	cbec eco engineering	*Develop Solutions to Flooding on Pescadero Creek Road* **Correlation of Flow Data from Pescadero and Butano Creek USGS Gages**		
		Project No. 13-1032	Created By: CTH	**Figure 2**



Notes:
Background image NAIP 2012. Dates reflect year of data collection, not the year the reports were published. Cross section database source documents: FEMA 1982, Swanson 1999, ESA 2004, ESA PWA 2012, WEST 2013.

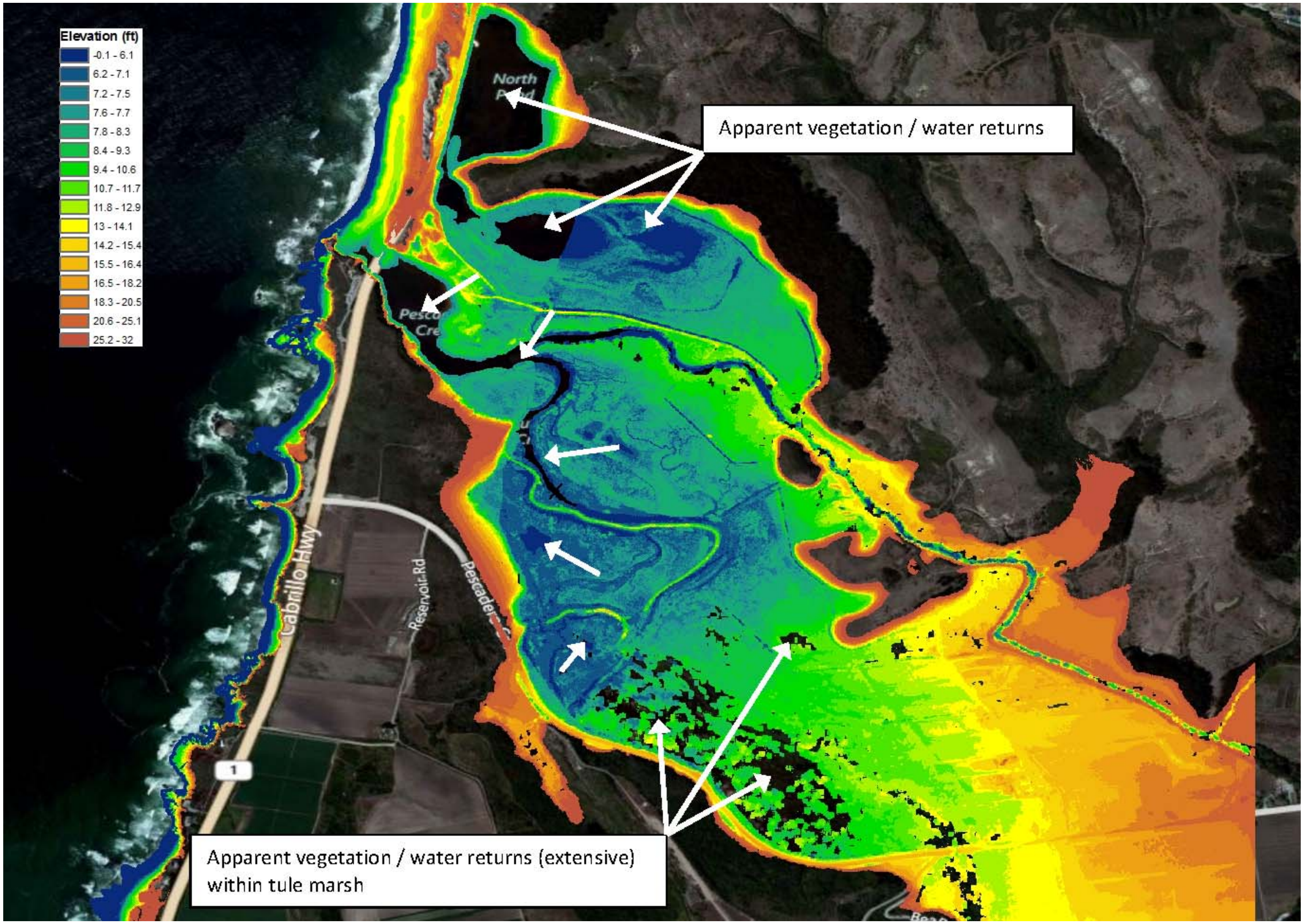
cbec eco engineering

Develop Solutions to Flooding on Pescadero Creek Road

Existing Cross Sections

Project No. 13-1032	Created By: DT	**Figure 3**

C:\Work\Projects\13-1032_Pescadero_Rd\Task 1\Figures\Fig_3_XS.docx
12/13/2013



Notes: NOAA 2009-2011	cbec eco engineering	*Develop Solutions to Flooding on Pescadero Creek Road* **CCC Coastal LiDAR Project: Hydro Flattened DEM**		
		Project No. 13-1032	Created By: JS	**Figure 4**