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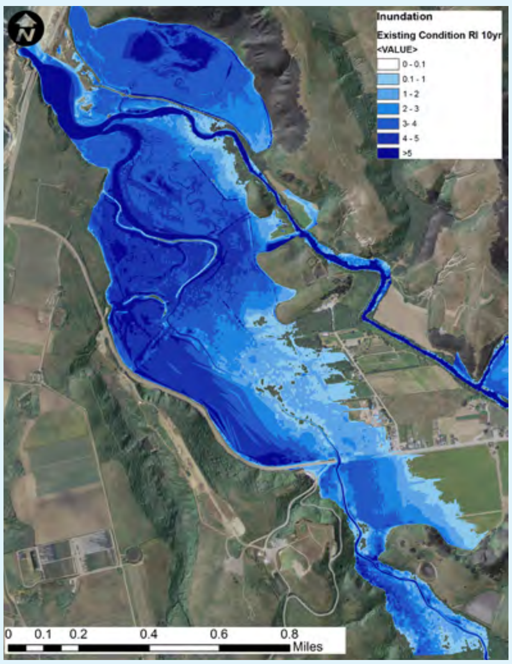

Photo courtesy Half Moon Bay Review

Solutions to Flooding on Pescadero Creek Road

San Mateo County Resource Conservation District

Prepared for:
San Mateo County Resource Conservation District

Prepared by:
cbec, inc. eco engineering
with assistance from Stillwater Sciences

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Project # 13-1032

SOLUTIONS TO FLOODING
AT PESCADERO CREEK ROAD

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GLOSSARY OF ACRONYMS

Acronym	Meaning
BA	Biological Assessment
BO	Biological Opinion
CDFW	California Department of Fish and Wildlife
CDP	Coastal Development Permit
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CNDDB	California Natural Diversity Database
CWA	Clean Water Act
DO	Dissolved Oxygen
DPS	Distinct Population Segment
EA	Environmental Assessment
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ELJ	Engineered Log Jam
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
IS/MND	Initial Study/Mitigated Negative Declaration
IS/ND	Initial Study/Negative Declaration
ITP	Incidental Take Permit
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
POST	Peninsula Open Space Trust
RCD	San Mateo County Resource Conservation District
ROW	County Right-of-Way
SAA	Streambed Alteration Agreement
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

In its current condition, Butano Creek frequently exceeds its channel capacity and subsequently flows across its floodplain to the east and then overtops Pescadero Creek Road during low magnitude, frequently occurring flood events. This frequent flooding has impacted access to the unincorporated community of Pescadero for several decades, and poses a safety hazard to both residents and visitors to this coastal community. In addition to the well-documented flooding issues along lower Butano Creek, downstream of Pescadero Creek Road, the creek drains into Pescadero Marsh, which is considered a critical ecological system that is home to a variety of federally and state listed fish and wildlife species. The current condition of the crossing and the sediment impacted reach directly downstream has resulted in a significant passage impediment to salmonids attempting to migrate upstream into Butano Creek. The goals of this project are to identify feasible long-term solutions to the flooding of the road, while maximizing opportunities to enhance or restore wetland and floodplain habitats, fish passage, as well as create more natural sediment dynamics upstream, downstream and near the road to restore the creek system and reduce the frequency and extent of future management interventions.

The cause of the frequent flooding is a result of Pescadero Creek Road's position in the watershed, its elevation above the floodplain, as well as the amount of sediment delivered to the area, which has increased dramatically in comparison to historical conditions. Human modification of the watershed has dramatically accelerated the amount of sediment delivered to the creek channels beyond natural levels, as well as the erosion, transport and storage of sediment in the valley bottom. Not only has the channel become disconnected from its floodplain, which has transformed areas that once provided sediment storage into areas where sediment is produced (due to channel incision and widening), but the amount of sediment being generated from the uplands has increased substantially as well. Historical changes to the Butano Creek watershed and channels included: clear cutting upland forests; increased farming and ranching of both lowlands and hillslopes; diking and draining Pescadero Marsh; building or improving roads; channel management; and the development of rural residential communities.

During the initial phases of this project, several potential components of a solution to reduce flooding of the road were suggested by the RCD, members of the RCD's project advisory group, and members of the community. Each of these potential components was preliminarily evaluated to assess its potential to reduce the frequent flooding of the road. In the process of this preliminary evaluation, over 13 potential components were assessed, and most components required the simulation and evaluation of multiple configurations or iterations. The components can be grouped by the general location of the solution: upstream of the road, near the road and downstream of the road. They can also be distinguished by whether the component will directly reduce flood levels at the road or if the component is intended to indirectly reduce the frequency of flooding through reduction of sediment being delivered to the lower reaches of Butano Creek where the road is located.

Following the preliminary evaluation, a subset of management actions were selected and investigated more thoroughly. These actions include: floodplain restoration upstream of the road to reduce sediment loads; construction of a causeway across the flood-prone creek corridor; and various configurations of channel dredging at the road crossing and downstream. Each action or component of

a solution to flooding at the road was assessed with hydrodynamic and sediment transport models to simulate the amount of flood benefit for the road immediately after construction, as well as in the future. Construction methods and costs were also explored, as were potential benefits or impacts to sensitive species. Lastly, the potential complexity of permitting for each action was evaluated.

A complete solution that reduces the frequent road flooding over the long-term and improves habitat for sensitive species will require multiple, linked actions at various scales and locations. These actions include:

- Implementation of upland sediment control activities to reduce the amount of sediment delivered to the project area;
- Reconnection or restoration of floodplains to absorb sediment and flood water energy, thereby reducing transport of sediment to downstream reaches;
- Creation of additional flow capacity at the road either through construction of a causeway, and/or channel dredging; and
- Restoration or creation of a stable and open channel to provide habitat connectivity for salmonids and other aquatic species from Butano Creek upstream of the road downstream into the lagoon.

Sediment control in the watershed is a vital component to address flood reduction and habitat enhancement in Butano Creek, its floodplain, the marsh and the lagoon. Fortunately several preliminary efforts are underway aimed at reducing the sediment generated by the hillslopes of the watershed. These efforts can provide the foundation for the additional management actions within and along the creek to reduce the frequency of flooding of the road. These efforts must be commensurate with the rates and volumes of sediment being delivered to the system in order to have the desired impact to current conditions.

The restoration of the creek's ability to store sediment on its floodplain is another crucial component of a sustainable solution to flooding of the road and aquatic habitat enhancement. One example of a floodplain restoration project is provided as a starting point for the larger-scale effort that is ultimately required. The sediment benefits of the proposed floodplain reconnection project are twofold. First, the floodplain reconnection will allow sediment that is being transported by the creek to access the floodplain, where some portion of this sediment will be deposited, thereby reducing the amount carried downstream. Second, the construction of grade control structures will reduce the amount of channel incision, which will reduce the amount of sediment that is contributed to the stream by both the bed and banks.

Beyond the sediment benefits, floodplain reconnection could dramatically improve much needed winter rearing habitat for coho salmon and steelhead. However, for these habitat improvements to benefit anadromous fish, they must be able to make it upstream to this part of the creek, and currently passage is severely limited. Beyond habitat benefits in the floodplain reconnection area, the reduction of sediment supplied downstream will improve channel conditions in downstream reaches, including increasing the longevity and success of any measures to remove sediment to restore habitat connectivity in lower Butano Creek.

While floodplain reconnection was only explored in depth for one area, additional floodplain restoration opportunities must be pursued as well. In addition, in areas where the floodplain is not restored and tall, steep and unstable banks remain, efforts to restore and or stabilize these banks must also be pursued. These site specific projects will reduce the sediment load, and depending on how they are implemented can be designed to directly improve aquatic habitat. Successfully reducing the sediment load in Butano Creek can only be achieved through a collection of projects ranging from small to large in scale and relative contribution. Actions to control sediment, either at the watershed scale or along the creek, will take time for improvements to be observed at the bridge. There is a considerable amount of sediment stored upstream of the bridge and some amount of this legacy sediment will need to move down the system before the benefits are fully felt.

In the vicinity of the bridge, many potential project components provided a reduction in water surface elevations and thereby the amount of frequent flooding. Dredging alone reduced water levels, but not enough to prevent flooding of the road in a 2-year flood event. Dredging would temporarily reduce the amount of the frequently occurring flooding until the channel at the road fills in again. Sediment transport simulations suggest that the capacity at the bridge will diminish after one or more significant flood events, which means that for a dredging component to be a long-term solution on its own without additional flood reduction measures, it (and its associated permitting) would need to be repeated indefinitely into the future. This could be annually, and there could be wet periods during which dredging at multiple points in the year would be desirable.

The construction of a new, higher and wider causeway over Butano Creek and its floodplain was the only component considered that provided road access during larger floods (e.g., a 10-year flood event) immediately after construction, as well as in the future. While it comes at a substantial capital investment, the benefits are vastly superior to other solutions with regards to flood reduction at the road. However, it alone provides no immediate direct substantial benefit to the sensitive species. That said, it is likely that a wider causeway will restore more natural geomorphic processes that could allow the channel to move laterally and/or create new channel alignments and habitats that could benefit sensitive species in the future. While channel dredging comes at a lower cost initially, these repeat costs will accumulate through time, making the causeway a far better investment for providing safe access to Pescadero into the future. In addition, while not quantified in this effort, a causeway also provides the best defense against sea level rise that will eventually add to the sediment deposition and subsequent flooding at the road.

The most significant way that a project action aimed at providing a solution to flooding could benefit any of the sensitive salmonid species is by restoring habitat connectivity from the lagoon to the watershed upstream of the bridge. This would require dredging a channel or parts of a channel either along the historical alignment or along an alternate alignment through the marsh. Not only would this substantially increase the amount of habitat available, but it would also provide fish migratory connectivity that could allow fish to escape poor water quality conditions in the Butano Marsh and lagoon that sometimes accompany the breaching of the barrier bar. A defined and restored channel could also help address water quality concerns in the marsh by enhancing circulation.

Two downstream alignments were considered: the most recent historical alignment and an alternate alignment through the Butano Marsh. The historical alignment is appealing as this would be a restoration of a former channel, however access to dredge this alignment could result in a slower and more costly construction process. The marsh alignment could be constructed more rapidly, and at a lower cost, however the water quality conditions that currently develop in Butano Marsh provide greater uncertainty in the beneficial outcome of this alignment. Particularly the soils in the vicinity of the proposed channel should be tested to identify if their exposure would contribute to poor water quality conditions. It is possible that the construction activity associated with this alignment could be expanded to address adjacent man-made depressions (e.g., historical ditches and borrow pits), which could act to improve water quality conditions within the Butano Marsh. Dredging a restored connection to the lagoon is the only project component that would ensure that other restoration activities for salmonids in the Butano Creek watershed are effective.

Sediment will accumulate in the upper portion of the dredged channel in either alignment until the time that sediment supplied from upstream has been dramatically reduced. As such, to maintain fish passage into the future, significant floodplain restoration that increases upstream sediment storage, along with reduction in sediment supplied from the watershed to the project area, must be carried out. Repeated dredging at the bridge should be considered and planned for the interim. The extent and frequency of this repeated dredging is inversely proportional to the increased sediment storage/floodplain restoration and sediment load reduction accomplished upstream. Dredging near the bridge could be viewed as maintaining a sediment basin that would extend the longevity of downstream dredging.

If building a new causeway gains momentum and the appropriate level of funding is obtained, the placement of the causeway should be considered further. If the fire station has been relocated and Bean Hollow Road can be realigned, the alignment of the causeway could be shifted to the west, which would provide more direct access to the low elevation areas in the upper portions of the East Butano Marsh. This project would require additional funding (realigning Bean Hollow Road and grading the area currently occupied by the fire station), and it would provide additional flood reduction to the residential area downstream of the road by directing floodwaters to the East Butano Marsh.

Multiple related but separate projects will be required to address each of the required actions to provide a complete solution. A solution that takes a holistic approach, addressing sediment, capacity at the bridge and habitat improvements will achieve greater success in procuring the necessary funding and permits. A phased approach could be taken to allow actions in the short-term while preparing for the longer-term actions. For example, Phase 1 could include the establishment of in-channel sediment basin at the bridge that could dredged annually (if needed) during the summer to provide short-term temporary relief to frequent road flooding. Phase 2 could include design and implementation of upland sediment reduction, and floodplain restoration projects as well as the design of a causeway and downstream channel dredging and restoration. Phase 3 could then include construction of the causeway and downstream channel dredging and restoration.

1 INTRODUCTION

In the current condition, Butano Creek exceeds its channel capacity, subsequently flows across floodplain areas, and then overtops Pescadero Creek Road (Pescadero Road) during low magnitude, frequently occurring flow events. This frequent flooding has impacted access to the unincorporated community of Pescadero for several decades, and poses a safety hazard to both residents and visitors to this coastal community. Flooding causes hardship and disruption to the community including blocking services for emergency response, schools, local agriculture and businesses. Finding solutions to reduce the flooding at Pescadero Road has been identified by Pescadero residents and officials as a resource management priority. In response to the need to address this resource management priority, the San Mateo County Resource Conservation District (RCD) initiated a project to develop and analyze potential solutions to reduce the flooding of Pescadero Road caused by Butano Creek. This project is funded through the County of San Mateo (County), the Bay Area Integrated Regional Water Management Plan program under Proposition 84, and U.S. Fish and Wildlife Service (USFWS) Coastal Program.

The goals of this project are to identify feasible long-term solutions to reduce the flooding of the road, while maximizing opportunities to enhance or restore wetland and floodplain habitats, fish passage, as well as create more natural sediment dynamics upstream, downstream and near the road to reduce the frequency and extent of future management interventions. Water quality conditions and resulting fish kills within the Pescadero lagoon are an important resource management priority for this area as well; however, developing solutions for the fish kill is not a specific objective of this effort. Ultimately, this report was created to provide the community, San Mateo County and various regulatory agencies the knowledge and tools necessary to take actions towards eliminating the frequent flooding of Pescadero Road.

2 BACKGROUND

2.1 PROJECT AREA

Pescadero is an unincorporated farming and ranching community located along the Pacific Coast of San Mateo County. Butano Creek is the largest tributary to Pescadero Creek draining from the Santa Cruz Mountains through forested and agricultural land, crossing under Pescadero Road and into the Pescadero Marsh before joining Pescadero Creek, and then exiting to the Pacific Ocean. The Pescadero Road bridge is located near the base of the Butano Creek watershed at the upstream extent of the Pescadero Marsh Natural Preserve. The area potentially influenced by the various flood solutions, or components thereof, included in this project was considered to extend from the Cloverdale Road bridge over Butano Creek, which is approximately 4 miles upstream of the Pescadero Road bridge, down 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").

2.2 BRIEF HISTORY OF THE CHRONIC FLOODING

Pescadero Road in the area of the bridge is located on the floodplain of Butano Creek. In some areas the elevation of the road is essentially the same as the elevation of the floodplain upstream of the road.

Prior to any human modification to the watershed or the creek, this area would have flooded frequently, perhaps as often as every year, and maybe multiple times in wetter years with many larger flood events. Human modification of the watershed (e.g., logging, grazing, agriculture, road construction, etc.) changed the amount of sediment that is making its way to the creek channels. Channel management activities (e.g., removal of large wood, realignment, vegetation removal, road crossings, etc.) have changed the way sediment is eroded and deposited along the length of the creek (SFBRWQCB In prep.).

These changes, in addition to others, have led to a dramatic increase in the amount of sediment being delivered to the lower watershed and marsh, so much that it has overwhelmed the system. The accumulation of sediment in the channels has made any area that already naturally flooded frequently into an area that floods anytime it rains more than a couple of inches. The frequency of the recurrent flooding has grown worse through time. In general, Pescadero residents recall flooding along Pescadero Road had become a chronic problem by the 1980s (Cook 2002). The onset of the chronic flooding likely corresponds to the large floods that occurred in 1982 and 1983, which are the 2nd and 5th largest flood events recorded in the 62-year record of flows observed at the U.S. Geological Survey (USGS) gage on Pescadero Creek (Figure 2). For reference, the 1998 storm, which many residents can still recall, was an approximate 32-year flood event, meaning a flood of that size or larger would be expected once in 32 years; a 32-year storm has a 3% probability of occurring in any given year.

3 ASSESSMENT APPROACH

Prior to assessing any potential solutions to flooding of Pescadero Road, relevant studies, reports and datasets were acquired and reviewed. This information pertained to both physical aspects of the system as well as biological components. The information that was deemed relevant to this project, was summarized in Technical Memorandum #1 - Review of Existing Information. This technical memorandum is provided in Appendix A.

During the initial phases of the effort, several potential components of a solution to reduce flooding of Pescadero Road were suggested by the RCD, the members of the RCD's project advisory group[1] and members of the community. Each of these potential components was preliminarily evaluated to assess its potential to reduce the frequent flooding of Pescadero Road as well as impacts and/or benefits to wildlife and wetland habitats (Section 6). In the process of the preliminary evaluation, over 13 potential components were assessed, and most components required the simulation and evaluation of multiple configurations or iterations.

Following the preliminary evaluations, a subset of the solutions, or components of a solution, that were most likely to provide a sustainable long-term reduction of chronic flooding of the road were selected. The subset of solutions or components of a solution were then more completely analyzed in a feasibility assessment (Section 7). The feasibility assessment includes:

[1] Membership of the project advisory group and information regarding the meetings held by the group are provided in Appendix D.

- An analysis of flood reduction immediately after construction as well as in the future after additional sediment has been transported and deposited within the project area;
- A review of how various components could be constructed and an estimate of probable construction costs;
- A discussion of potential benefits or impacts to native Trust Species (i.e., state or federally listed species) that are found in the project area; and
- A discussion of the potential permitting process.

The primary tools used in the potential flood reduction analysis were one dimensional hydrodynamic and sediment transport models developed for the project area. This modeling approach was selected based upon the available data, the large number of potential solution components to be evaluated and the budget available. A detailed discussion of the development of the models including the data used, assumptions made and potential limitations of the modeling approach is provided in Appendix B.

The hydrodynamic model was used to predict water surface elevations in the project area in the existing condition and as well as after the implementation or construction of a solution to the flooding. The sediment transport model was used to estimate the distribution and movement (i.e., erosion, transport and deposition) of sediment throughout the project area for a 10-year period that includes the large flood event that occurred in 1998, as well as several other smaller but significant flood events. The model results should be evaluated in a comparative manner, indicating trends and general magnitude of change that differs between various proposed solutions. The results of the sediment transport model should be interpreted with less certainty than the hydrodynamic model and they should not be interpreted as absolute predictions of future conditions.

To compare the relative flood reduction performance of potential solutions, water levels throughout the project area were simulated for two flood events: a 2-year return interval flood and a 10-year return interval flood. The size of these 2-year and 10-year floods was determined through a statistical analysis of 61 years of annual flood peak data recorded on Pescadero Creek, as a sufficiently long data set was not available for annual peak flow rates on Butano Creek (Figure 2). Peak flow rates for Butano Creek were estimated using the ratio of watershed areas. The watershed area scaling factor (0.4) was very similar to the correlation between daily average flow rates recorded on Butano and Pescadero Creeks while flow gages were active on both creeks.

A 2-year return interval flood event has a 50% probability of being equaled or exceeded in any given year. In other words, over the long-term, one would expect to see at least one flood event that was this size, or bigger in half of the years. It does not mean that this size flood will happen consistently every other year. On Pescadero Creek the peak flow rate of the 2-year flood was calculated to be 2,175 cubic feet per second (cfs) and for Butano Creek the peak flow rate was estimated to be 870 cfs. The most recent flood event that was similar in size to a 2-year event occurred on February 15, 2009, where peak flow recorded at the Pescadero Creek gage was 2,710 cfs. That historical flood event was slightly larger than the 2-year flood, with an approximate return interval of 2.4 years (i.e., 42% probability of occurring in any given year).

A 10-year return interval flood has a 10% probability of being equaled or exceeded in any given year. On Pescadero Creek the peak flow rate of the 10-year flood was calculated to be 6,900 cfs and for Butano Creek the peak flow rate was estimated to be 2,760 cfs. The most recent flood event that was similar in size to a 10-year event occurred on December 31, 2005, where peak flow recorded at the Pescadero Creek gage was 5,980 cfs. That actual flood event was smaller than the 10-year flood, with an approximate return interval of 8.5 years (i.e., 12% probability of occurring in any given year).

These two flood events were simulated with the hydrodynamic model and the results were used to:

- Evaluate the accuracy of the flood inundation predictions in the absence of other data (e.g., surveyed water surface elevations or flood inundation extents during flood events with a known flow rate) to formally calibrate and validate the models;
- Understand how the system is currently functioning with respect to flooding and sediment deposition; and
- Compare the potential short-term and long-term flood reduction benefits achieved by various solutions to flooding of the road.

Construction cost estimates were developed for the six solutions or components of a solution that were analyzed in-depth. The cost estimates focus on the construction aspects of each component, and it is important to note that budget amounts have not been estimated for additional planning, design, permitting, mitigation and future maintenance that will be required to implement various components of a project. These cost categories are highly dependent upon specific details of each project as well as which components or how many components are included in the integrated project to address both flood reduction and habitat enhancement. The costs for these additional categories will add substantially to the total project costs. The cost estimates provided assume that dredge spoils will be transported to a disposal site that is located in close proximity to the dredged area. If a suitable location cannot be identified, additional costs will be incurred in the disposal of dredged material.

4 SUMMARY OF EXISTING CONDITIONS

4.1 PHYSICAL CONDITIONS

4.1.1 SEDIMENT DELIVERY, TRANSPORT AND STORAGE

Pescadero Road bridge is located at the base of the Butano Creek watershed, which is 20.3 mi^2 (upstream of Pescadero Road) and consists of highly erodible geologic formations (e.g., primarily sandstone, siltstone and mudstone). The bridge is situated in an area that was naturally prone to flooding and sediment deposition prior to any human modification of the marsh or in the watershed upstream. However, human modification of the watershed has dramatically changed the amount of sediment delivered to the creek channels, as well as the erosion, transport and storage of sediment in the valley bottom. Historical changes to the watershed and creeks included: clear cutting upland forests; increased farming and ranching of both lowlands and hillslopes; diking, draining, and restoration of Pescadero Marsh; building or improving Highway 1 and other major roads; channel management; and the development of rural residential communities. Human modifications to the watershed have had significant effects upon the condition and function of the stream channels, the adjacent floodplains and the rest of the watershed with respect to sediment delivery and storage, and subsequently aquatic habitat. Several studies (e.g., Curry et al. 1985, ESA 2004, ESA 2008, SFBRWQCB In prep.) have documented accelerated erosion and increased sediment loads due to human influences throughout the watershed. Environmental Science Associates (ESA 2004) estimated that 90% of all sediment entering stream channels is due to erosional features associated with human land use and infrastructure.

The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) is in the process of developing a Total Maximum Daily Load (TMDL) for sediment in the Pescadero and Butano Creek watersheds. One aspect of this study was the development of an updated sediment budget for the watersheds. At the time of writing this report, the results of the sediment budget have not been finalized; however, SFBRWQCB staff shared preliminary results with us. When comparing estimates for the pre-1820's period to the current condition (as quantified by the 1970-2010 period), the results are alarming. A summary of some aspects of the soon to be published sediment budget results for the Butano Creek Watershed is provided below (SFBRWQCB In prep.).

- Sediment delivery to the stream channels increased by a factor of 2.5.
    - Historically this was 32,000 tons/year on average
    - Currently it is 80,000 tons/year on average
- Channel incision (mostly in the lower parts of the watershed) and road-channel crossings (e.g., gullies/landslides at road-stream junctions, mostly in the upper parts of the watershed) are the greatest sources of increased sediment. Channel incision started around the 1920s. In the canyon reach, incision began in full force after the 1940s when the removal of large wood in the stream channels began in earnest.
- Other sources of sediment include: landslides/debris flows, gullying on ranchlands, surface erosion on ranchlands, and road surface erosion; however, in the Butano Creek watershed these provide much smaller contributions than channel incision and road-channel crossings.
- Historical floodplain areas that used to store sediment are now disconnected from the stream channels by incision, and now provide a source (rather than a storage area) for sediment due to incision and bank erosion.
    - Historically, of the 32,000 tons/year of sediment were delivered to the channels, approximately 10,000 tons/year were deposited on the floodplains.
    - Currently, of the 80,000 tons/year of sediment that is delivered to the channels, virtually none of it is deposited on the floodplains, instead it is transported to the marsh.
- Butano Creek appears to be the major contributor of sediment to the marsh, and the very low channel slope in the lower 3 miles prevents it from transporting the incoming sediment to the sea. Instead it is deposited in the lower portions of the willow forest and the marsh, the only areas where the creek can access the floodplain.
- In contrast, Pescadero Creek has sufficient channel slope that provides adequate capacity that allows the creek to carry its sediment load to the beach and sand dunes.
- Elevated sediment loads are expected to continue.

It is particularly useful to understand how the function of floodplain areas between Pescadero Road and Cloverdale Road have changed. In the past, the channel in this area was well connected to the adjacent floodplain areas. When floods occurred, water and sediment would flow out of the channel and across the floodplains. As it flowed across the floodplains, some of the sediment would have been deposited before the water receded back into the channel or infiltrated into the ground. Historically these areas stored considerably more sediment than they generated. Now the reverse is true. Depositional areas (areas where sediment is still actively being stored on floodplains) are limited to the lower portion of the willow forest, and the marsh, which is 10-20% of the historical floodplain area.

Human modification of the watershed and channels resulted in incision (i.e., downcutting) of the creek channel such that a much larger flood event is now required for floodwaters to exit the channel and inundate the adjacent floodplain. Evidence for the incision can be seen at the Cloverdale Road bridge over Butano Creek, where cross section surveys show that the channel at this location incised more than 4 ft between the as-built channel in 1961 and a survey conducted in 2003 by ESA (Figure 3). Data collected more recently show that incision may still be occurring[2].

As noted above, the incision has led to a disconnection of the creek from the adjacent floodplains. Hydrodynamic modeling performed for this effort (discussed in Section 4.1.2) shows that even a 10-year flood event does not spill out of the channel at locations more than one mile upstream of Pescadero Road. Figure 4 shows areas that were "flood-prone" historically as well as those in the current condition. Historically the flood-prone areas extended up into the Butano Canyon area; however, in the current condition, the flood-prone zone begins within the downstream end of the Willow Forest, not far upstream of Pescadero Road. These historically flood-prone areas would have stored sediment; however, in the current condition they no longer store sediment because incision prevents the creek waters from accessing them except during very large flood events. Thus, not only do they not store sediment, but they are now a contributing sediment source as the tall, steep, unstable banks erode as the channel widens. These floodplain areas are much smaller than they were historically, and do not function to store sediment as they did historically, instead contributing to the sediment load, and are not as flood-prone as they historically were.

To summarize, sediment delivery to the Butano Creek channel has increased substantially compared to historical levels. Not only has the channel in the Butano Valley upstream of the road become disconnected from its floodplain, which has transformed areas that once provided sediment storage into areas where sediment is produced (due to channel incision and widening), but the amount of sediment being generated from the uplands has increased substantially.

In contrast to the incision occurring upstream, significant sedimentation has been documented through cross section surveys at the Pescadero Road bridge (Figure 5). At this location, the channel has aggraded (i.e., accumulated sediment) nearly 7 ft since the bridge was constructed in 1961. Much of this accumulation occurred more than a decade ago, as repeat surveys show that the elevation of the

[2] It should be noted that the 2014 cbec cross section survey was collected at the downstream face of the bridge (as opposed to the upstream face for the earlier surveys shown), so it may be documenting slightly different conditions than the earlier surveys.

channel bed at the bridge has remained fairly similar since the turn of the century. Approximately 1,000 ft downstream of the Pescadero Road bridge the channel has accumulated so much sediment that the former channel location has completely filled in to the elevation of adjacent marsh and floodplain.

The topography of the project area is shown in Figure 6. The incised reach, that begins in the Willow Forest and extends upstream is shown, as is the reach where the Butano Creek channel no longer exists downstream of Pescadero Road. The topography also shows that the East Butano Marsh located west of the Butano Creek channel is lower than the delta of sediment that has deposited within and adjacent to the alignment of the historical channel.

4.1.2 HYDRODYNAMIC MODEL RESULTS FOR THE CURRENT CONDITION

The hydrodynamic model was used to estimate maximum water surface elevations that would occur during 2-year and 10-year flood events. Figure 7 shows a profile of the bed elevation[3] and the maximum simulated water surface elevations for the 2-year and 10-year flood events. The profile shown extends from the Pacific Ocean at the downstream end (main channel distance on Figure 7 is 0 ft) through the lagoon and up the historical alignment of Butano Creek to a location approximately half of a mile upstream of Pescadero Road (main channel distance on Figure 7 is 14,000 ft). The elevation of the bridge deck and the top of the sandbags which line the south side of Pescadero Road are shown, as is the elevation of the East Butano Marsh to the west of the historical alignment of Butano Creek. The bed elevation profile shows the area downstream of the road (distance 8,000-11,000 ft) where so much sediment has accumulated that the channel is no longer apparent. The vertical exaggeration shown on the figure can be misleading, and makes it seem like there is more slope to the channel than there actually is. From the Pescadero Road bridge to the Highway 1 bridge, there is approximately 9 ft of vertical drop that occurs over a length of approximately 2 miles. In other words, the channel has a very low slope in this reach.

The water surface elevation profiles[4] for the 2-year and 10-year events show the amount of backwater that occurs in the marsh because the marsh and lagoon fill with water faster than they can drain out to the ocean, creating a deep, ponded low velocity area, referred to as a backwater. During a 2-year flood event, the backwater extends to within 3,000 ft of the bridge. During a 10-year flood event, the backwater extends to within 1,500 ft of the bridge. The upstream extent of the backwater corresponds with the area where sediment has accumulated in the channel, because when flowing water meets deeper slower water (as is present with backwater conditions) the larger sediment drops out of the low velocity water column and is deposited immediately. At the bridge, the 2-year water surface elevation is approximately 0.7 ft higher than the lowest point of the sandbags and 2.1 ft higher than the elevation of the road. The 10-year water surface elevation is above the elevation of the bridge deck. Upstream of the road, both profiles are fairly flat for some distance upstream (indicating a backwater), where a flowing stream would have a steeper profile. These flat profiles show the damming effect that the bridge, sandbags and road have on flood waters passing through this area.

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[3] The thalweg - the deepest point of the channel - is shown, as opposed to an average bed elevation across the channel.

[4] A profile depicts the change in elevation along the length of the channel. In a backwater the slope of the water surface profile is very flat.

Figure 8 provides a cross section view of the creek, road, sandbags[5] and bridge as viewed from a vantage point upstream of the road looking downstream. The cross section shown extends 2,000 ft in total, from west of the fire station to east of Water Lane. The ground elevation just upstream of the bridge is shown, as is the road elevation, and the top of the sandbags located along the upstream edge of the road between the creek and Water Lane. The figure also shows the size and shape of the current bridge opening, as well as the simulated 2-year and 10-year flood water surface elevations. Once the sandbags are overtopped, water flows across the road to the north. During the 10-year event, water levels are higher than the elevation of the road over the bridge.

Figure 9 and Figure 10 show the predicted maximum depth of inundation in the lower portion of the project area for the 2-year and 10-year flood events, respectively. Darker blue areas indicate greater inundation depths (i.e., deeper water). Upstream of the road the inundation in the lower portions of the willow forest is shown, as is the substantial amount of flooding that occurs to the east of the channel, on the Level Lea Farm fields. On both figures, the road is overtopped, and water is shown inundating the residential area between Water Lane and Butano Creek. Greater inundation depths are shown in the East Butano Marsh, west of the channel. The lack of a defined channel is apparent downstream of the bridge, as floodwaters are shown to the east and west of the historical creek alignment, with the channel area virtually dry.

Figure 10 shows many of the same things that are apparent during the smaller magnitude 2-year event. The flood depths are greater and the area inundated is larger, particularly to the east of the creek channel. Although data were not available to formally calibrate and validate the hydrodynamic model, the pattern of flooding predicted is in general agreement with what has been observed in recent flood events. Results of the long-term sediment transport simulation (reported in Section 7) suggest that sediment will continue to accumulate upstream of the road resulting in elevated water levels that will continue to flood the road unless some management action is taken.

To summarize, increased sediment loads, changes in sediment storage and delivery, and the location of the road within the greater context of watershed (i.e., in an area that is expected to have high amounts of sediment deposition) are the major contributors to the channel conditions that result in the frequent flooding of the road. These conditions, and the resultant flooding of the road, will persist unless something is done.

4.2 TRUST SPECIES

Several threatened or endangered species (i.e., Trust Species) have been documented to occur in the project area. These include 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*). Figure 11 shows the documented distribution of these species within the project area, based on the California Natural Diversity Database

[5] The hydrodynamic and sediment transport modeling included the current condition of the sandbags, thus the results provided reflect backwater conditions partially due to their presence.

(CNDDB) and other available information. The development of a final project will consider the potential influence to enhance or restore the habitat used by each of these species (in addition to other species of special concern), as well as potential for construction related impacts.

California red-legged frogs are listed as threatened under the federal Endangered Species Act (ESA) and are a California Department of Fish and Wildlife (CDFW) species of special concern. As described in detail in Appendix A, 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), including in Butano Creek at the Pescadero Road bridge (C. Foster, County of San Mateo, Pers. Comm., 2014). Based on their high abundance throughout the project area, California red-legged frogs are also anticipated to occur within the willow forest of Butano Creek upstream of the Pescadero Road crossing, although results of surveys have not been reported for that location.

In general, California red-legged frog breeding habitats are generally characterized by still or slow-moving water with deep pools and emergent and overhanging vegetation (Jennings and Hayes 1994). Based on available information, California red-legged frogs have high potential to occur in nearly all portions of the project area throughout the year. During the typical in-water work period of late summer, adults and tadpoles are likely to occur. Measures that are typically taken by projects to avoid or minimize effects on California red-legged frogs include: avoiding in-water work during the egg-laying and incubation period; conducting pre-construction surveys for the species and moving individuals outside of work areas; fencing work areas to prevent frogs from moving into the area and impacts to their habitat; continuous biological monitoring when work occurs in suitable habitat areas to identify and prevent injury to frogs in the work area; and controlling fine sediment releases and erosion from work areas to avoid impacting water quality.

San Francisco garter snake is listed as endangered under the federal ESA and California Endangered Species Act (CESA), and is Fully Protected under the California Fish and Game Code. As described in detail in Appendix A, 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. 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). Due to the considerable prey base (e.g., California red-legged frog and Pacific tree frog), San Francisco garter snakes presumably forage in Butano Creek, East Butano Marsh, Middle Butano Marsh, East Delta Marsh, and the willow forest, particularly where there are adjacent upland areas suitable for basking and refuge.

Based on available information, San Francisco garter snake have potential to occur in nearly all portions of the project area, mostly between March and November, with a potential to occur year-round. During the typical in-water work period of late summer, adult and juvenile San Francisco garter snakes may occur in the project area. As a Fully Protected species, “take” of San Francisco garter snake would have to be completely avoided by proposed projects[6]. This is typically accomplished by conducting pre-construction surveys for the species, fencing work areas to prevent snakes from moving into the area and impacts to their habitat, continuous biological monitoring when work occurs in suitable habitat areas to identify and prevent injury to snakes in the work area, and mitigating for impacts to their habitat. The implications of these avoidance activities on the permitting effort are discussed in Section 5.

Tidewater goby is listed as an endangered species under the federal ESA (USFWS 2005) and a California species of special concern. As described in detail in Appendix A, tidewater goby have been documented to occur in aquatic habitat in Pescadero and Butano Marshes. Tidewater goby prefer low-velocity habitat with sandy substrate, and have noted preferences for water temperature, salinity (generally prefer brackish conditions), and dissolved oxygen (DO). When the sandbar is closed, marsh habitats are inundated, and there is abundant suitable habitat for tidewater goby in Pescadero and Butano Marshes within the project area. When the sandbar is not closed and marsh habitat is not inundated (e.g., in the winter), suitable habitat for tidewater goby is reduced.

Under current conditions, sediment that has deposited and vegetation that has established in the lower Butano Creek channel downstream of the Pescadero Road crossing (the area is identified in Figure 6 and Figure 7) restricts aquatic habitat connectivity between much of the marsh habitat within the lower project area that is suitable for tidewater goby and riverine portions of Butano Creek in the vicinity of the Pescadero Road bridge. If aquatic habitat connectivity were restored, adult and juvenile tidewater goby could occur further upstream in riverine portions of Butano Creek within the project area during the typical late summer in-water work period. Measures that are typically taken by projects to avoid or minimize effects on tidewater goby include: conducting pre-construction surveys for the species and moving individuals outside of work areas; dewatering or otherwise excluding goby from accessing in-water work areas; and controlling fine sediment releases and erosion from work areas to avoid impacting water quality.

Coho salmon previously found in the Butano 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). As described in detail in Appendix A, 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). In general, if coho salmon were to occur in the Butano Creek watershed again, 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, including within floodplain habitats, particularly within the inundated habitat of the willow forest. However, under existing conditions excess

[6] The definition of "take" can vary somewhat, but typically refers to the pursuit, injury, killing, or harassment of a wild animal, and can include modification and destruction of the species' habitat. When a species is Fully Protected, take cannot be authorized by CDFW (unless the take results from activities intended to help recovery of the species populations). In contrast to Fully Protected status, both the federal and California ESAs include mechanisms for authorizing limited take of a listed species that is incidental to otherwise lawful activities, so long as the species population is not jeopardized.

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 likely impairs habitat connectivity through lower Butano Creek from the lagoon to upstream habitat (NMFS 2013, Nelson 2012). This restricts the upstream migration for adult coho salmon, as well as juvenile and smolt migration between the lagoon and riverine habitat.

Steelhead found in the Butano Creek watershed belong to the Central California Coast Distinct Population Segment (DPS) and are currently listed as threatened under the federal ESA (NMFS 2006). As described in detail in Appendix A, steelhead have been found in fish surveys throughout the watershed year-round, including within Butano Creek downstream and upstream of the project area (CDFG 1996). While in the riverine environment, rearing steelhead prefer deep pools, access to food, and cover in the form of vegetation, cobble, boulders, or woody debris. Inundated marsh and lagoon habitat in the project area is used extensively by rearing steelhead juveniles year-round (Smith 1987). During the typical in-water work period of late summer, juveniles are likely to occur throughout the project area. However, as described for coho salmon, excess 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 likely impairs habitat connectivity through lower Butano Creek from the lagoon to upstream habitat, restricting upstream migration for adults and downstream migration for juveniles and smolts. In addition, 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. The presence of hydrogen sulfide has been associated with fish kills, including documented mortality of steelhead.

Measures that are typically taken by projects to avoid or minimize effects on coho salmon and steelhead include: conducting pre-construction surveys for the species and moving individuals outside of work areas; dewatering or otherwise excluding the fish from accessing in-water work areas; and controlling fine sediment releases and controlling erosion from work areas to avoid impacting water quality.

4.3 OTHER SPECIES

In addition to the Trust Species discussed previously, there are numerous other native species, some of which are considered rare, that may occur in the project area. These include:

- The plant species coastal marsh milk-vetch (*Astragalus pycnostachyus* var. *pycnostachyus*), perennial goldfields (*Lasthenia californica* ssp. *macrantha*), marsh microseris (*Microseris paludosa*), and Choris' popcornflower (*Plagiobothrys chorisianus* var. *chorisianus*)
- The California brackish water snail, or mimic tryonia (*Tryonia imitator*)
- Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*)
- Pacific tree frog (*Pseudacris regilla*)
- Pacific pond turtle (*Actinemys marmorata)*
- Snowy plover (*Charadrius nivosus)*
- The fish species Pacific lamprey (*Entosphenus tridentatus*), coastal threespine stickleback (*Gasterosteus aculeatus aculeatus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), and staghorn sculpin (*Leptocottus armatus*)

- The bird species bank swallow (*Riparia riparia*), San Francisco common yellowthroat (*Geothlypis trichas sinuosa*), and nesting migratory birds
- Pallid bat (*Antrozous pallidus*)

The development of a final project would need to consider the potential effects on these species and their habitat, including potential construction impacts. In most cases, project elements designed to protect Trust Species will protect these species as well. Additional blooming period surveys for sensitive plant species and nesting season surveys for migratory birds may be required.

5 PERMITTING

Permitting refers to the processes and authorizations necessary for a proposed project to comply with relevant Federal, State, and County laws or regulations. These regulations give authority to particular agencies to implement the regulation and are intended to ensure that a proposed project's potential impacts on the environment are avoided, minimized, and/or mitigated. There are many regulations that would apply to, and many regulatory agencies that would be involved in, the permitting of any component of a flooding solution due to the facts that the project area includes a creek and adjacent wetland areas, is located in the California coastal zone, and is known to support Trust Species and their habitat. In addition, components would involve actions, such as altering the bed and/or banks of a creek, which would trigger the need to comply with numerous environmental regulations.

Table 1 lists the regulations that are likely to be relevant to the components of a solution, the agency with authority for the regulation, the way(s) in which a regulation is likely to be triggered by the components discussed in this report, and the documentation necessary to produce to be issued a permit or demonstrate compliance with the regulation. These regulations would need to be complied with regardless of which entity undertakes a component, and whether or not the component would improve habitat for Trust Species or other species. The regulations in Table 1 that are likely to be required of all solution components and/or that typically drive the complexity of the permitting process are discussed further in Section 5.2.

5.1 INFLUENCES ON PERMITTING LEVEL-OF-EFFORT

Despite the long, and perhaps daunting, list of regulations and permitting requirements that would apply (Table 1), the proposed project components discussed in Section 7 could all be permitted, if planned and executed to sufficiently reduce impacts on environmental resources[7]. Given the number of permits and regulatory agencies likely to be involved (see Table 1) and the efforts that could be necessary to avoid, minimize, and potentially mitigate for impacts to environmental resources, permitting of any of the components would likely be considerably complex, costly, and time-consuming; some more so than others.

[7] In accordance with Fish and Game Code Section 5050, the Fully Protected status of San Francisco garter snake could preclude CDFW from issuing permits under their authority if there is the potential for take of this or other Fully Protected species. This is discussed in greater detail in Section 5.2 below.

Table 1. Regulations, agency with authority for the regulation, and the documents required.

REGULATION/PERMIT	AGENCY OR ENTITY[1]	LIKELY TRIGGERS FOR REGULATION	PRIMARY DOCUMENTS LIKELY REQUIRED TO BE PREPARED[2]
Clean Water Act Section 404/ Individual Permit	USACE	Working below the ordinary high water mark of creek and/or within adjacent wetlands	Individual Permit application; Delineation of jurisdictional waters and wetlands; Preliminary Jurisdictional Determination
Clean Water Act Section 401/ 401 Certification	SFBRWQCB	Need for a 404 permit from USACE	401 Certification application
Endangered Species Act/Biological Opinion	USFWS and/or NMFS	Potential to affect a federally listed species or its habitat	Biological Assessment
National Historic Preservation Act Section 106	State Historic Preservation Office	Potential to affect historic and culturally significant resources	Cultural resources report
National Environmental Policy Act (NEPA) [3]	USACE, USFWS, or NMFS	Potential for a federal action, permit, or funding to result in significant impacts to environmental resources	Environmental Assessment **or** Environmental Impact Statement
California Fish and Game Code Section 1602/ Streambed Alteration Agreement	CDFW	Altering the bed or banks of Butano Creek or adjacent wetlands	Streambed Alteration Agreement application
California Fish and Game Code Section 5050	CDFW	Potential for impacts to Fully Protected species	No permit available or associated documentation required, unless for recovery and research actions
Clean Water Act Section 402 and California Water Code/ Waste Discharge Requirements	SFBRWQCB	Potential to affect surface water quality	Stormwater Pollution Prevention Plan
California Coastal Act/ Coastal Development Permit	San Mateo County (Planning and Building Dept) / Coastal Commission	Grading, construction, dredging, or alteration of any structure in the coastal zone	Coastal Development Permit application
California Environmental Quality Act (CEQA) [3]	CDFW, SFBRWQCB, RCD, State Parks, or San Mateo County	Potential for a State action, permit, or funding to result in significant impacts to environmental resources	Initial Study/Negative Dec. **or** Initial Study/Mitigated Negative Dec. **or** Environmental Impact Report
California Endangered Species Act/Incidental Take Permit or Consistency Determination	CDFW	Potential to affect a State listed species or its habitat	Incidental Take Permit application or Consistency Determination letter
Right of Entry Permits	San Mateo County, State Parks, POST	Accessing non-privately owned property	Permit applications
Non-Discretionary Permits[4]	San Mateo County	Meeting criteria for grading, street encroachment, drilling, and/or similar County permits	Permit applications
* Notes are found on the following page			

Table 1 Notes:
[1]CDFW-California Department of Fish and Wildlife, NMFS-National Marine Fisheries Service, SFBRWQCB-San Francisco Bay Regional Water Quality Control Board, State Parks-California Department of Parks and Recreation, USACE-United States Army Corps of Engineers, USFWS-United States Fish and Wildlife Service, POST-Peninsula Open Space Trust. Agency name and other acronyms are also provided in the acronym glossary at the beginning of this report.
[2]The documents listed here would require a fairly detailed project description, with work windows and areas, equipment to be used, protection measures to be implemented, and more. In addition, many of these documents may already require the preparation of supplemental materials such as mitigation plans, mitigation monitoring and reporting plans, and more.
[3]NEPA and CEQA compliance is undertaken by a “lead agency”, which depends upon the actions or decisions triggering the need for NEPA and CEQA compliance. The agencies identified here are the potential lead agencies.
[4]Non-discretionary permits, which are also referred to as ministerial permits, are those that do not require a decision to be made by the authorized agency (e.g., whether to deny or grant the permit based on project merits or impacts), but are granted based on adherence to pre-established standards.

The level of effort, amount of time, and cost it would take to acquire the permits or comply with the regulations necessary for each component is referred to in this report as permitting level-of-effort. There are many conditions that will influence the permitting level-of-effort of solution components. Those most germane to the solution components, as they are described in Section 7 (i.e., without detailed project designs) include, but are certainly not limited to, the following.

- As Table 1 illustrates, some regulations have different required documentation, which typically depend upon the project’s actions or anticipated level of impact on the environment. Some documentation requires greater levels of analysis and public review periods, and this is one of the factors that influence the permitting level-of-effort. Differences in required documentation between the solution components are summarized in Section 5.2.
- The conditions included in the required document or permit is another factor that greatly influences the effort of permitting. Examples of permit conditions—this is by no means an exhaustive list—that could be relevant to solution components are: pre-construction surveys for Trust Species and cultural resources; fencing of Trust Species habitat and other sensitive habitat types; actions to prevent or limit impacts to farmland; construction monitoring for Trust Species; sediment testing and monitoring during construction; implementation of erosion control measures during and after construction; and mitigation implementation and monitoring. Some of these conditions are further described in Section 5.2 below.
- Mitigation, which typically involves planting the same types of native plants as those impacted, may be required to compensate for construction-related impacts under one or several of the regulations listed in Table 1. For example, mitigation could be required for impacts to waters and wetlands under Clean Water Act (CWA) Section 404, to riparian vegetation under a Streambed Alteration Agreement (SAA), and/or to Trust Species habitat under ESA and CESA. Mitigation can be required at ratios ranging from 1:1 to 10:1 (one to 10 acres of planting for every acre of habitat impacted) or greater, depending upon the resource affected and degree of impact. Mitigation plantings usually have to be monitored for at least five years.

- Temporal and physical elements of the implemented project have important roles in determining the documentation and conditions required for regulatory compliance, and influence permitting complexity. Such elements include: the ability to control construction timing (to avoid disturbance to Trust Species and minimize erosion and water quality impacts); the frequency of maintenance and repeated associated disturbances; the volume of material moved or stored; and the amount and type of habitat disturbed. These project elements and their influence on permitting requirements and conditions are discussed more specifically for each component in Section 7.
- Degree to which the component(s) has long-term benefits, such as habitat enhancement or restoration, that adequately compensate for short-term impacts and are co-equal goals with flood reduction. Projects that contain elements that enhance or restore wetlands, waters, and/or habitat for Trust Species may prove easier to permit, and present opportunities for cost sharing, due to regulatory programs and agreements that can streamline permitting for actions that result in long-term benefits to these habitats, as well as reduced mitigation requirements (these opportunities are discussed further in the sections below and in Section 7).
- Early consultation with resource agency staff on project design, project components, and opportunities to both maximize benefits to public trust resources and minimize impacts, can help provide a clear path and process for permitting early-on. Early consultation allows for potential project modifications to reduce impacts and facilitate permitting, increases coordination and consistency between various permitting efforts, provides early indications of permit conditions and mitigation that can then be planned for accordingly, and helps establish an anticipated schedule.

5.2 SUMMARY OF PRIMARY PERMITS

The permits from Table 1 that are likely to drive permitting effort are summarized below. Not all of the permits from Table 1 are described in more detail, and the permits discussed below should not be misinterpreted as the only permits that may be required for solution components. More specific permitting requirements, or exceptions or alternatives to the discussions provided below, for individual solution components are described in Section 7, as relevant. The descriptions of potential permits and documentation are provided for general reference only and should not be interpreted as the final word in what may be required for permitting and compliance. The specific activities and areas included in each component, as well as the entity undertaking the work, any program under which the work would be conducted, and the opinions of the regulating agencies, will influence the ultimate suite or types of permits that would be necessary. The development of such details was not a component of this preliminary planning project and report, but would be a necessary part of the next stages of planning and implementation of a selected solution.

5.2.1 CWA SECTION 404, SECTION 401, AND NEPA

The objective of the CWA is to restore and maintain the integrity of the nation's waters, including wetlands. Section 404 of the CWA requires that project proponents receive a permit from the USACE to discharge otherwise forbidden dredged or fill materials into jurisdictional waters of the U.S., including wetlands. Butano Creek, much of its floodplain, and the surrounding marshes in the project area are all considered jurisdictional waters. Permits can also be required for the operation of heavy machinery in jurisdictional waters and wetlands. Due to the volume of material that would be moved under any of the solution components, it is likely that an Individual Permit would be required from USACE for Section 404 compliance. Individual Permits typically require the preparation of a jurisdictional water and wetland delineation and preliminary jurisdictional determination from USACE, NEPA compliance document (see below), a more detailed analysis of alternatives referred to as 404(b)(1) guidelines, a mitigation and monitoring plan, a public review period, and Section 401 Certification. While Individual Permits typically require that any permanent impacts to waters and wetlands be mitigated for, projects with long-term habitat benefits may not require mitigation.

Nationwide Permits are a more streamlined option for Section 404 compliance than an Individual Permit (i.e., much less analysis and no public review period). However, only a few solution components may qualify for Nationwide Permits: the Nationwide Permit #3 (for Maintenance) threshold for volume of material moved would be surpassed by all of the solution components discussed in Section 7; and Nationwide Permit #27 (for Aquatic Habitat Enhancement), which has no volume thresholds, would only be applicable if the primary purpose of a solution component were to enhance aquatic habitat conditions. The conditions of Nationwide Permits are such that significant impacts on the environment would be avoided or mitigated and, as a result, preparation of a NEPA compliance document would not likely be necessary.

Since a Section 404 permit would be required and there is potential to affect surface water quality through the suspension of fine sediment and other activities, 401 Certification for CWA Section 401 compliance would be necessary for all solution components. Section 401 of the CWA requires project proponents to “certify” that any discharge subject to Section 404 will comply with relevant water quality standards. In the project area, certification occurs with the SFBRWQCB. 401 Certifications can also require mitigation and, in Butano Creek, would likely require sediment testing and/or monitoring during and after construction.

NEPA establishes policy and goals for the protection, maintenance, and enhancement of the environment. Under NEPA, federal agencies, such as USACE, USFWS, and NMFS, are required to analyze the potential effects of their actions, including permitting and funding, on the environment. This analysis is done via an Environmental Assessment (EA), if significant effects are not anticipated, or an Environmental Impact Statement (EIS). An EIS typically includes a much more detailed analysis and has a longer public review period than an EA. In many cases, project proponents prepare EAs and EISs on behalf of the federal lead agency for NEPA, which for solution components is likely to be USACE (since they would be issuing a Section 404 permit), but could also be USFWS or NMFS.

5.2.2 ENDANGERED SPECIES ACT (ESA)

The objective of the ESA is to protect critically imperiled species from extinction. Section 7 of the ESA requires federal agencies to consult with the USFWS and/or NMFS if any project that they are authorizing, funding, or carrying out occurs in the habitat of a species listed under the ESA. Due to the documented occurrences of federally listed species in and around the project area, consultation with USFWS and/or NMFS would be necessary for all solution components and a Biological Assessment (BA) would likely be prepared to inform the USACE’s (who would be issuing a Section 404 permit) Section 7 consultation process. Based on this consultation, USFWS and/or NMFS would issue a Biological Opinion (BO) for the project that would, if necessary, authorize some level of incidental[8] take of listed species or their critical habitat. The definition of take can vary somewhat, but typically refers to the pursuit, injury, killing, or harassment of a wild animal, and can include modification and destruction of the species' habitat. Solution components with the primary purpose of long-term habitat enhancement may qualify for coverage under a programmatic BO for restoration actions.

BOs for solution components would likely include numerous conditions to limit the take of listed species, such as pre-construction surveys, construction monitoring, and potentially mitigation for permanent impacts to listed species habitat, if the solution component does not include long-term benefits, such as habitat enhancement or restoration, that adequately compensate for short-term impacts.

5.2.3 CALIFORNIA FISH AND GAME CODE SECTION 1602/SAA AND CEQA

California Fish and Game Code Section 1602 requires project proponents to notify CDFW of any proposed activity that may substantially modify a river, stream, or lake. If CDFW determines that the activity may adversely affect fish and wildlife resources, a SAA is prepared with conditions that must be implemented to protect those resources. Since all solution components would likely require dewatering of the channel and alteration of the bed and banks of Butano Creek, they would all require an SAA from CDFW. SAAs for solution components would likely include similar conditions as to those in BOs, including mitigation if the solution component does not include long-term benefits that adequately compensate for short-term impacts, as well as the actions necessary to avoid the take of San Francisco garter snake (see discussion below).

Similar to federal agencies and NEPA, CDFW would need to ensure that the issuing of a SAA complies with CEQA. CEQA establishes a policy for environmental protection in California, and requires state and local agencies to analyze and publicly disclose the environmental impacts of proposed projects and to adopt all feasible measures to mitigate those impacts. This analysis and disclosure is done via an Initial Study. If significant effects are not anticipated, then an IS/Negative Declaration (IS/ND) or IS/Mitigated Negative Declaration (IS/MND) or an Environmental Impact Report (EIR) may be prepared. An EIR typically includes a much more detailed analysis and has a longer public review period than IS/NDs or IS/MNDs. In many cases, project proponents prepare IS/NDs, IS/MNDs, and EIRs on behalf of the state lead agency for CEQA. Although this discussion assumes that CDFW would be the lead agency for CEQA, since they would be issuing a SAA, the County, State Parks, or the RCD could all be lead agencies for CEQA depending upon who undertakes, funds, or needs to authorize the work.

5.2.4 CALIFORNIA FISH AND GAME CODE SECTION 5050/FULLY PROTECTED SPECIES

Fish and Game Code Section 5050 prohibits the take and possession of species that are classified as Fully Protected by CDFW, with the objective of conserving wildlife species at risk for extinction in California. Unlike the ESA and CESA (described below), there are no permit provisions to authorize the take of Fully Protected species that might be incidental to otherwise lawful actions/projects. Take, which is generally limited to the handling of the species, may only be authorized via a Memorandum of Understanding

[8] Incidental to an otherwise lawful activity.

(MOU) from CDFW for research activities or actions undertaken to recover the population of a Fully Protected species.

As a Fully Protected species, the take of San Francisco garter snake would need to be completely avoided during construction of solution components. This will be extremely challenging, since the project area includes San Francisco garter snake habitat and the species is known to occur in the area. Based on other projects implemented in San Francisco garter snake habitat, the following measures would likely be required by all solution components when working in suitable habitat to sufficiently avoid take:

- pre-construction surveys for the species each day prior to the beginning of construction;
- fencing work areas and installing aquatic barriers from dewatered areas to prevent snakes from moving into the area and impacts to their habitat;
- multiple on-site qualified biological monitors who are working under an MOU that authorizes them to handle and move any San Francisco garter snakes they may encounter;
- equipment will need to move very slowly and excavator/dredger buckets must be checked for San Francisco garter snake after each scoop; and
- mitigation for permanent impacts to their habitat.

These efforts, which would be required year-round (since San Francisco garter snake may be active in the area year-round), will undoubtedly contribute greatly to the permitting complexity of solution components and to the cost of implementation.

Solution components that include restoration activities to improve habitat for San Francisco garter snake and their primary prey, California red-legged frogs, and would contribute to their population recovery, could be eligible for their own MOU authorizing limited take by CDFW. This would require the preparation of a Recovery Action Plan or a BO from USFWS, upon which CDFW can base the MOU. Such an MOU would likely authorize take primarily as a result of trapping, handling, and relocating San Francisco garter snakes, and many of the take-avoidance measures listed above would likely still apply during construction.

5.2.5 CALIFORNIA COASTAL ACT/COASTAL DEVELOPMENT PERMIT

The objective of the California Coastal Act is to promote the effective management, beneficial use, protection and development of the coastal zone. Although the California Coastal Commission has implementing authority of the Coastal Act, this authority is transferred to California counties with approved Local Coastal Plans, of which San Mateo County is one. The project area is within the coastal zone and, as such, a Coastal Development Permit (CDP) from the County Planning and Building Department would be necessary for all solution components. While some solution components' Coastal Development Permits may be approved entirely by the County, most are likely to require review during a Coastal Commission hearing, given the potential for impacts to Trust Species.

CDPs may also require mitigation plantings, maintenance, and monitoring to compensate for impacts to riparian vegetation and Trust Species habitat. Solution components that are undertaken by or with funding from a federal agency may qualify for a CDP consistency determination or consistency certification.

5.2.6 CALIFORNIA ENDANGERED SPECIES ACT (CESA)

The objective of CESA is to protect and preserve native species that are threatened with extinction or that are experiencing a decline that may lead to a threatened or endangered designation. Like the ESA, CESA allows for the incidental take of CESA-listed species, subject to an Incidental Take Permit (ITP) or a Consistency Determination, if a BO for the same species has been issued by USFWS and/or NMFS, from CDFW. Coho salmon, which is listed under CESA, have been nearly extirpated from the watershed and are not able to access the project area due to the downstream sediment barrier. As such, it seems unlikely that an ITP for CESA compliance would be necessary for most solution components. San Francisco garter snake, which is listed under CESA, is also Fully Protected and, as such, an ITP or Consistency Determination cannot be issued since take of the species may not be authorized, except for some recovery and research actions (see discussion above). Therefore, for solution components, CDFW is likely to include measures in the SAA and associated CEQA document to adequately avoid CESA-listed species. Solution components may require an ITP if there are CESA-listed plants in the project area that cannot be avoided (it is unknown if any such plants occur in the project area).

6 PRELIMINARY EVALUATION OF POTENTIAL COMPONENTS OF A SOLUTION TO FLOODING OF PESCADERO ROAD

During the initial phases of the effort, several potential components of a solution to reduce flooding of Pescadero Road were suggested by the RCD, members of the RCD's project advisory group[9] and members of the community. Each of these potential components was preliminarily evaluated to assess their potential to reduce the frequent flooding of Pescadero Road. Following a preliminary review of various factors including: potential flood reduction, impact or benefit to Trust Species and the effort of permitting, some components were advanced for further in-depth assessment as described in Section 7. In the process of this preliminary evaluation, over 13 potential components were simulated, and most components required the simulation and evaluation of multiple configurations or iterations. Each component considered is summarized below, and information is provided with regards to why it was selected for in-depth consideration or not further developed.

Flood reduction benefits for each component are provided in Table 2, which reports water surface elevations for a location just upstream of the road. When considering the predicted water surface elevations it is useful to note that the elevation of the bridge deck is 15.4 ft, the lowest point of the sandbags is 14.2 ft, and the low point of the road is 12.8 ft. Creek water will flow over the bridge deck if the water surface elevation is greater than 15.4 ft, and will overtop the sandbags if the upstream water surface elevation is greater than 14.2 ft. Although water may not flow over the sandbags, the downstream water surface elevation may still be high enough to inundate the road from downstream. Lower water surface elevations indicate a greater flood reduction benefit. Relative reduction values (i.e., the difference between the existing condition and each scenario) are provided in the sections below.

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[9] Membership of the project advisory group and information regarding the meetings held by the group are provided in Appendix D.

Table 2. Simulated water surface elevations immediately after construction.

Scenario	Simulated Maximum Upstream Water Surface Elevation[1] (ft, NAVD88)	
	2-Year Event	10-Year Event
Existing condition	14.9	16.0
Dredge within ROW[2]	13.6	14.4
Dredge ROW and along historical channel[2]	13.5	14.4
Dredge ROW and along historical channel per Sigma Prime	13.5	14.4
Dredge ROW and parallel to historical channel	13.5	14.4
Dredge ROW and parallel to road and through marsh[2]	13.4	14.2
Dredge ROW and ~800 ft parallel to road into marsh[2]	13.4	14.2
Excavate detention basin within Butano Marsh	14.9	16.0
Vegetation management within the channel	14.6	15.9
Reduce sediment supplied from within the project area[2]	14.9	15.9
Raise roadway	15.0	16.9
Construct elevated causeway[2]	13.4	14.3
Create bypass channel through fire station	13.6	14.8

NOTES:

1 - Results reported for a location immediately upstream of the road. Model results have been rounded to the nearest tenth of a foot, although the precision of the model is greater than this reporting level. As the model was not formally calibrated, these levels are useful in a comparative sense, but should not be judged as absolute predictions of potential future conditions.

2 - These components were advanced to the in-depth assessment provided in Section 7.

The components of a solution can be grouped by the general location of the action: upstream of the road, near the road and downstream of the road. They can also be distinguished by whether the component will directly reduce flood levels at the road immediately or if the component is intended to reduce the amount of sediment being delivered to the lower reaches of Butano Creek where the road is located, and therefore reduce flooding in the future due to reduced sedimentation in the channel.

6.1 DREDGE WITHIN COUNTY RIGHT-OF-WAY AT THE BRIDGE

At the Pescadero Road bridge over Butano Creek, the County right of way (ROW) is approximately 100 ft wide. When crossing Butano Creek, the alignment of the ROW shifts northward, such that to the west of Butano Creek, the alignment is approximately 30 ft farther north. On the east side of Butano Creek, the ROW extends 30 ft from the centerline of the road to the north (downstream), and 70 ft to the south. On the west side of Butano Creek, the ROW extends approximately 59 ft from the centerline of the road to the north (downstream) and approximately 41 ft to the south.

The dredge within the ROW component was modeled to include a 100 ft length of dredging (50 ft upstream and downstream of the road centerline) with a channel cross sectional area of 500 ft^2, which is approximately the 1961 as-built channel capacity (Figure 5). Immediately after construction, this amount of dredging would reduce the 2-year maximum water surface elevation upstream of the road by 1.3 ft.

While the road would still flood in a 2-year event, the duration and frequency of smaller magnitude chronic flooding would be reduced by this action.

This proposed project component is appealing due to its relatively small footprint, ease of construction and the limited number of landowners involved. Although fish passage would temporarily be improved at the road[10], this component does not address the channel conditions downstream which at present appear to be the primary limitation to fish passage. This component was carried forward for additional analysis, with additional evaluation provided in Section 7.1.

6.2 DREDGE ROW AND DOWNSTREAM ALONG HISTORICAL CHANNEL

Dredging within the ROW and downstream along the historical alignment of Butano Creek was evaluated. Multiple configurations with variations in the channel depth, width, slope and downstream extent were iteratively evaluated leading to a configuration with a consistent bed slope of 0.001, a 500 ft^2 channel cross sectional area within the ROW and approximately 200 ft^2 of channel cross-sectional area extending 6,500 linear ft downstream through the marsh along the alignment of the historical channel. Similar to dredging just within the ROW, immediately after construction, this amount of dredging would reduce the 2-year maximum water surface elevation upstream of the road by 1.4 ft. While the road would still flood in a 2-year event, the duration and frequency of smaller magnitude chronic flooding would be reduced by this action. In addition to reducing the frequency of chronic road flooding, this component is appealing due to the potential to improve aquatic habitat and fish passage potential through the reach downstream of the bridge, although it should be noted that without other upstream sediment reduction actions the improved fish passage benefits would be temporary. This component was carried forward for additional analysis, with additional evaluation provided in Section 7.2.

6.3 DREDGE ROW AND DOWNSTREAM ALONG HISTORICAL CHANNEL AS PROPOSED BY SIGMA PRIME GEOSCIENCES

A dredging proposal was previously developed by Sigma Prime Geosciences. This dredging proposal was developed with the objective of improving fish passage, not flood reduction. This proposed dredging a semi-circular channel with a 20 ft top width and a depth of 10 ft, resulting in a channel cross sectional area of 157 ft^2 that extended 6,700 linear ft down the historical channel alignment. In addition the proposal called for repairs to some sections of levees or berms that line the channel, as well as removal of sections of levees or berms in other areas. Similar to the component described in Section 6.2, immediately after construction, this amount of dredging would reduce the 2-year maximum water surface elevation upstream of the road by 1.4 ft. While the road would still flood in a 2-year event, the duration and frequency of smaller magnitude chronic flooding would be reduced by this action. In addition to reducing the frequency of chronic road flooding, this component is appealing due to the potential to improve fish passage potential through the reach downstream of the bridge at least temporarily until additional sediment accumulates again.

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[10] As described in detail in Section 7.1 this amount of dredging would fill-in after the first significant flood event.

The dredging to achieve a 10 ft depth along the entire length would create an extensive deep area, with some areas extending below sea level. This depth of dredging was considered to be too deep, as it could result in the development of anoxic water quality conditions, which have been hypothesized to contribute to the fish kills in the lagoon. This specific configuration for dredging downstream of the road was not carried forward for additional analysis, although a very similar component (as described in the previous section) was.

6.4 DREDGE ROW AND DOWNSTREAM ALONG AN ALIGNMENT PARALLEL TO THE HISTORICAL CHANNEL

Dredging a new channel parallel to the historical channel in Butano Marsh was considered and modeled with a similar footprint and channel capacity as the component described in Section 6.2. This proposed component resulted in nearly identical flood reduction benefits as dredging the historical alignment. It is likely that this scenario would be more difficult to permit due to potential impacts to Trust Species because of impacts to upland areas (berms or dikes that parallel the channel) and woody riparian vegetation present along the historical banks. As there were no clear advantages for this scenario as compared to simply dredging the historical alignment (as described in Section 6.2), it was not carried forward for additional evaluation.

6.5 DREDGE ROW AND DOWNSTREAM ALONG AN ALIGMENT ALONG PESCADERO ROAD THROUGH BUTANO MARSH

This component includes creating a new channel through the Butano Marsh along Pescadero Road. A historical ditch is present in this location, and the alignment of this ditch could possibly be used for some portions of the new channel. In other areas a new channel would need to be excavated completely. At the downstream extent, this new channel would connect to existing channels in the Middle and North Butano Marshes, to provide a complete channel connection from the lagoon to Butano Creek upstream of the Pescadero Road bridge.

This component was modeled with a constant slope, a channel cross sectional area of 200 ft^2 downstream and a cross sectional area of 500 ft^2 in the ROW (consistent with the other components considered). Immediately after construction, this amount of dredging would reduce the 2-year maximum water surface elevation upstream of the road by 1.5 ft, the greatest flood reduction benefits of any of the channel dredging components evaluated. While the road would still flood in a 2-year event, the duration and frequency of smaller magnitude chronic flooding would be reduced by this action. This project component is appealing because it not only reduces flooding of the road but provides fish passage (at least temporarily until excess sediment re-accumulates) while taking advantage of the existing lower elevations in the marsh when creating a new channel. Moreover, the alignment of this channel is more similar to what might be expected to occur naturally in the future as sediment continues to accumulate within the historical channel alignment[11] and the channel position shifts to

[11] In deltas and alluvial fans, channels are often abandoned as sediment accumulates in the previous channel alignment, and the channel avulses (i.e., abandons the former alignment and takes a new path) along a path with greater slope.

occupy the low point in the valley, which is present in the Butano Marsh, not along the historical channel alignment (Figure 6).

The alignment of this proposed channel parallels Pescadero Road and could potentially be easier to construct and possibly maintain due to its proximity to the existing road. However there is considerable uncertainty regarding the potential water quality benefits or impacts of dredging through the marsh, where the source of the majority of the anoxic waters associated with the fish kills have been identified. This component was carried forward for additional analysis, with additional evaluation provided in Section 7.3.

6.6 DREDGE ROW AND ~800 FT DOWNSTREAM ALONG AN ALIGNMENT PARALLEL TO PESCADERO ROAD

This solution component builds upon the dredge within the ROW scenario described in Section 6.1, but also includes the excavation of a channel for approximately 800 ft in length, parallel to Pescadero Road into the marsh, similar to the component described in Section 6.5. This new section of channel would allow water to more easily access the lowest point of the valley which is present along the western portion of the Butano Marsh. In order to stay within the county ROW, which extends approximately 40 ft from the edge of pavement, this would require the creek to take an abrupt 90 degree turn immediately after exiting the bridge. The new channel could also take an alignment beyond the ROW on lands owned by the State.

This component was modeled with an area of 500 ft^2 in the ROW (consistent with the other components considered),and a channel cross sectional area of 200 ft^2 which grew smaller farther away from the main channel as the adjacent floodplain/marsh surface elevations grew lower. This alternative performed similarly to the other components that dredged beyond the ROW; however, it would not provide improvements to fish passage, just flood reduction. There is some uncertainty as to whether sediment would be deposited at the mouth of the channel just downstream of the bridge. Unfortunately the one-dimensional sediment transport model used in this analysis is not able to simulate this type of deposition. This component was carried forward for additional analysis, with additional evaluation provided in Section 7.4.

6.7 EXCAVATION OF A DETENTION BASIN WITHIN BUTANO MARSH

A detention basin within the East Butano Marsh was considered. The basin was modeled as an approximately 40 acre area, with the ground elevations lowered by 3 ft. Without additional dredging, this topographic modification did not significantly reduce flooding of the road during the events simulated. Furthermore this amount of disturbance to the marsh could potentially have significant adverse impacts for Trust Species, which accompanied with negligible flood benefits make this component not feasible. This component was not carried forward for further analyses.

6.8 VEGETATION MANAGEMENT WITHIN THE CHANNEL

Removal of vegetation was modeled for approximately 7,700 linear ft of channel, extending upstream a short distance upstream and then downstream to where a defined channel is again present. This scenario was modeled by reducing the channel roughness values in these areas. The results of the modeling indicate minimal changes in water surface elevations (e.g., 0.3 ft reduction during a 2-year event) due to just the removal or management of vegetation. Removal of vegetation to form a shallow channel could be considered to establish fish passage without extensive dredging; however, this would only last until excess sediment re-accumulated, and would not achieve the objective of reducing flooding at Pescadero Road. Vegetation management could also be considered as an ongoing management element following the implementation of any solution that includes dredging of a channel downstream of the bridge beyond the ROW. This component on its own was not carried forward for further analyses.

6.9 REDUCE SEDIMENT SUPPLIED FROM OUTSIDE THE PROJECT AREA

As discussed in Section 4.1, sediment delivery to the Butano Creek channel has increased substantially compared to historical levels. Not only has the channel become disconnected from its floodplain, which has transformed areas that once provided sediment storage into areas where sediment is produced (due to channel incision and widening), but the amount of sediment being generated from the uplands has increased substantially. Projects to reduce the amount of sediment being generated by the uplands are beyond the scope of this effort, but must be considered as part of a long-term solution to flooding at the road. Examples of efforts to reduce the amount of sediment generated by the uplands include[12]:

- improvement of road crossings at streams;
- improved management of forested areas and unpaved roads (e.g., decommissioning of logging roads and spur trails), and
- management of existing gullies and prevention of the initiation of new gullies through soil enrichment or improving drainage[13].

Several projects are currently in planning phases or have already begun early phases of implementation to address many of these sediment source areas in the watershed. The RCD Rural Roads Program, Gullies Project, Good Earth soil health improvement project, stream bank stabilization projects, and technical assistance to farmers and ranchers in partnership with the National Resource Conservation Service are examples of erosion control efforts focused on reducing excess sediment input into the Pescadero Creek and Butano Creek Watersheds. The importance of these projects to a long-term solution to the flooding of the road should be considered and it is essential to understand that these efforts must be commensurate with the rates and volumes of sediment being delivered to the system in order to have the desired impact upon current conditions. These types of projects are not explored further in Section 7; however, they are included in the discussion of potential solutions to flooding of Pescadero Road, provided in Section 8.

6.10 REDUCE SEDIMENT SUPPLIED FROM WITHIN THE PROJECT AREA AND RESTORE THE CREEK'S ABILITY TO STORE SEDIMENT ON FLOODPLAINS

As discussed in Section 4.1, many areas along Butano Creek upstream of the road have transformed from areas where sediment was once deposited and stored on the floodplains, to areas where sediment

[12] Channel incision and bank erosion in areas beyond the project area should also be addressed.

[13] A majority of the existing gullies are within the Pescadero Creek watershed (e.g., Bradley Creek). Treating these gullies will reduce the amount of sediment delivered to the marsh, but these efforts will not likely affect the amount of flooding at the road

is contributed to the creek due to channel incision and bank erosion. A variety of strategies could be used to alter sediment production and storage in the creek and adjacent areas including:

- bank treatment to stabilize and/or restore eroding banks;
- installation of grade control structures (engineered large wood structures, check dams, etc.) to reduce the amount of future incision;
- lowering the elevation of floodplain areas through excavation of material so that they are more frequently inundated and subject to sediment deposition, and therefore able to again store sediment; and
- raising the elevation of the channel bed, reducing the capacity of the creek channel so that historical floodplain areas are reconnected to the creek and therefore inundated more frequently and again able to store sediment.

Examples of many of these types of projects were simulated with the hydrodynamic and sediment transport models[14]. Each of the projects simulated reduced the amount of sediment supplied to the downstream reaches, but did not reduce the amount of flooding of the road without another concurrent action (i.e., dredging or construction of a causeway), nonetheless these sediment reduction actions are considered to be a vital component of a successful long-term solution to the flooding of the road. The goal of the floodplain reconnection projects (excavated floodplains and/or raised channel bed elevation) is to reduce the difference in elevation between the channel bottom and the floodplain, such that water is able to exit the creek channel at a lower flow rate. Both floodplain excavation and projects that propose to raise the elevation of the channel are able to achieve this goal, albeit through different approaches.

Two examples of excavated floodplains were simulated, where the elevation of the floodplain was lowered so that the creek would inundate it more frequently. One consisted of a 25 acre area of floodplain lowered by approximately 4 ft (generating 160,000 yd^3 of excavated sediment). The other consisted of a 30 acre area lowered by approximately 15 ft (generating 726,000 yd^3 of excavated sediment) in an area located farther upstream, where the creek is disconnected from the floodplain to a much greater degree. Each of these excavated floodplains resulted in increased storage of sediment and reduced the amount of sediment delivered to downstream reaches, as well as increased inundated area that would provide off channel habitat that could be used by salmonids[15] as well as other Trust Species, including California red-legged frogs. While these projects reduced sediment and provided additional habitat, they would result in a high project cost due to the large volume of sediment generated as well as significant impact to the proposed project areas.

A third floodplain reconnection project was simulated that resulted in more frequent inundation of the floodplain as a result of reducing the channel capacity by raising the channel bed as opposed to lowering of the adjacent floodplain areas. Raising the channel bed would be accomplished through the installation of a series of engineered large wood structures that would increase the water surface

[14] Bank treatment/stabilization is a management action that could not be simulated with the one dimensional models used in this feasibility assessment.

[15] The term salmonids refers to fish belonging to the salmon family. In Butano Creek this refers to coho salmon, steelhead and resident (i.e., non-anadromous) trout.

elevation by approximately 1 ft each. These structures would also raise channel bed elevations upstream via sediment deposition. These grade control and habitat structures were conceptualized to allow the passage of anadromous salmonids moving upstream to spawn. This concept resulted in the greatest amount of floodplain inundation and sediment storage of the various floodplain reconnection concepts simulated. In addition to reducing the amount of sediment delivered to downstream reaches, the increased floodplain inundation could also restore valuable off-channel habitat that juvenile salmonids could use as both high-growth rearing habitat and refuge habitat during high flows. This floodplain reconnection concept/component of a solution to flooding was advanced for further assessment and is described further in Section 7.6.

6.11 RAISE EASTERN ROADWAY

Raising the eastern portion of the road was considered without dredging or any modification of the existing bridge. Approximately 400 ft east of the creek centerline, the lowest point of the road is present at an elevation of 12.8 ft. On the upstream side of the road, sandbags raise the low point to 14.2 ft. Water level upstream of the road must rise to this elevation to overtop the sandbags and begin flowing over the road. To reduce the frequency of road flooding, the road could be raised to the same elevation as the bridge deck (15.4 ft). This would require raising an approximately 770 ft portion of the road by 0 to 2.6 ft. This alternative was simulated, and did not prevent the road from being overtopped by a 2-year flood event. It is possible that this additional pressure (resulting from deeper water upstream) on the bridge opening would result in less sediment being deposited at the bridge. The elevated road, in combination with the elevated roadway to the west and the bridge deck elevation would in essence create a valley wide dam, which would still be overtopped in even frequently occurring events. It is possible that this valley wide dam could result in the roadway being compromised (i.e., washed out) during larger magnitude flood events. Due to a lack of immediate flood reduction benefit and the potential to compromise the road in the future, this component was not carried forward for further analyses.

6.12 CONSTRUCT ELEVATED CAUSEWAY

Several variations of a new larger bridge or an elevated causeway were simulated. Configurations ranged from the current width (approximately 78 ft) with higher elevations to much wider elevated spans. The configuration selected for discussion included a 500 ft span (starting at the current western bridge abutment and extending eastward beyond the lowest point in the upstream floodplain), with the bridge deck at 17.4 ft, which is 2 ft higher than the current bridge deck. In addition, adjacent portions of the road to the east and west, were raised to an elevation of 16 ft[16]. Immediately after construction, this causeway performed the best of any component considered by providing the capacity for both the 2-year and 10-year flood events to pass without the road flooding. While flooding of the road would be substantially reduced, this action would not provide significant flood reduction benefits for adjacent properties (i.e., the floodplain areas would still flood). This type of project component is appealing because it increases the flood capacity of the road by elevating the infrastructure. In addition, it would result in a comparatively low amount of impact to Trust Species. However, it does not significantly

[16] The elevated roadway would require topographic modification of the driveways of properties along the road west of Water Lane, as well as Bean Hollow Road and the fire station.

address fish passage as it does nothing for the filled channel reach downstream of the road, nor does it deal with sediment delivery, lack of storage, and floodplain disconnection that are major causes of the passage problem created by the filled channel. This component was carried forward for additional analysis, with additional evaluation provided in Section 7.5.

6.13 CREATE A BYPASS CHANNEL THROUGH THE FIRE STATION

A bypass channel through the area currently occupied by the fire station was modeled with a new channel with a cross sectional area of 330 ft^2. This amount of cross sectional area was selected to maintain consistency with the other dredging components considered. The other dredging components had 500 ft^2 in the main channel, while this component provided 330 ft^2 for the bypass channel in addition to the ~170 ft^2 present in the existing channel without any dredging. This bypass channel would require one or two new bridges to be constructed to accommodate the new bypass channel. If Bean Hollow Road remained in the present alignment, two bridges would be required (one for Bean Hollow Road and another for Pescadero Road), but if the alignment of Bean Hollow Road was changed, only one new bridge would be needed. In addition, the fire station would need to be relocated, and substantial grading performed to lower the ground elevations in the area.

With no dredging in the main channel, and the creation of 330 ft^2 of area through the bypass channel, this potential component would reduce the 2-year maximum water surface elevation upstream of the road by 1.3 ft. While the road would still flood in a 2-year event, the duration and frequency of smaller magnitude chronic flooding would be reduced by this action. In the configuration simulated, the 2-year flood event still resulted in flooding of the road, however different configurations including a larger causeway and raising portions of the eastern road would result in similar or better flood reduction benefits than those described for the elevated causeway described in the previous section. If the fire station is relocated, and if funds become available to construct a new bridge or causeway, this potential solution should be considered further. The flood reduction benefits achieved by the elevated causeway (described in Section 6.12) would also apply to this alternative if the location of the causeway were shifted to the west to include both the existing channel and the proposed bypass channel. While this component was not carried forward for in depth analysis in Section 7, the discussions regarding the construction of an elevated causeway and the creation of new channel segments provide context for the cost, constructability and other factors related to the feasibility of this component.

6.14 OTHER POTENTIAL COMPONENTS

Other potential components were also considered in this initial effort. A series of check dams in the channel to catch and store sediment was suggested. This is similar to the floodplain reconnection described in Section 6.10 and was not documented beyond what is covered for that component. A detention basin at the Girl Scout camp in Butano Canyon upstream of Cloverdale Road was considered, but not evaluated with the model because it was beyond the domain of the model. While it would capture sediment and therefore reduce the sediment load downstream, it may not be feasible due to its potential to reduce fish passage. Dredging upstream of the road was considered. In this area, sediment deposition is at its highest due to the expansion of the valley width and the reduction in channel slope. Dredging at this location would disconnect the floodplain from the channel and result in the delivery of even more sediment to the road crossing and the marsh downstream, which would exacerbate flooding of the road. This upstream dredging would also fill in very rapidly. Based on our understanding of sediment deposition, it is preferable to allow this area to continue to accumulate sediment rather than encourage transport farther downstream, as it is essentially the last area where the floodplain is able to store sediment brought downstream by the creek.

Modification of the Highway 1 bridge was also suggested. A different alignment could allow the channel to erode a larger cross section during floods than it currently does. This would reduce water levels in the marsh, which would allow more sediment to be transported a greater distance into the marsh. A larger channel opening would also allow a greater volume of water to enter and exit the marsh during a typical tidal cycle (i.e., tidal prism). An increased tidal prism would allow more sediment to be transported out of the marsh during open mouth conditions. Over the long-term, this would create a larger lagoon, and the influence could reach as far as the Pescadero Road bridge. However without a reduction of sediment to the area upstream of the road, the creek channel would still accumulate sediment because this area has such a low channel slope. As such, the road would still flood frequently.

7 IN DEPTH DISCUSSION OF POTENTIAL COMPONENTS OF A SOLUTION TO FLOODING AT PESCADERO ROAD

Six potential components of a solution to flooding at Pescadero Road were advanced to an in-depth feasibility evaluation. Each component was evaluated with respect to:

- initial and future flood reduction benefits,
- construction methods and preliminary estimate of construction costs,
- benefits and impacts to Trust species, and
- potential differences in permit requirements.

In this section, each of the six components was analyzed on its own, in the absence of other potential project components. In Section 8, components are combined into a feasible long-term solutions to the flooding of the road, that also maximizes opportunities to enhance or restore fish passage, wetland and floodplain habitats, as well as create more natural sediment dynamics upstream, downstream and near the road to restore the creek system and reduce the frequency and extent of future management interventions. When combined, it is likely that the various components act in concert providing greater benefits than if just one component is applied on its own.

As described in Section 3, the hydrodynamic model was used to predict water surface elevations in the project area in the existing condition and as well as after the implementation of each potential project component. The sediment transport model was used to estimate the distribution and movement (i.e., erosion, transport and deposition) of sediment throughout the project area for a 10-year period. Then the hydrodynamic model was again used to assess maximum water surface elevation in the future condition. The model results should be evaluated in a comparative manner, indicating trends and general magnitude of change that differs between various proposed solutions.

Flood reduction benefits are provided in Table 3. Results are provided for both 2-year and 10-year flood events, for both the immediate post-construction condition, as well as with future topographic conditions as predicted with the sediment transport model. When considering the predicted water surface elevations it is useful to note that the elevation of the bridge deck is 15.4 ft, the lowest point of the sandbags is 14.2 ft, and the low point of the road is 12.8 ft. Creek water will flow over the bridge deck if the water surface elevation is greater than 15.4 ft, and will overtop the sandbags if the upstream water surface elevation is greater than 14.2 ft. Lower water surface elevations indicate a greater flood reduction benefit. For the elevated causeway scenario, the lowest road elevation was simulated as 16.0 ft. Therefore in this configuration the model results suggest the road would not flood during a 10-year in the immediate post-construction condition, nor would it flood in the future condition.

Table 3. Simulated water surface elevations for potential components of a solution immediately after construction and in the future.

Scenario	Simulated Maximum Upstream Water Surface Elevation[1] (ft, NAVD88)			
	Immediate Condition		Future Condition[2]	
	2-Year Event	10-Year Event	2-Year Event	10-Year Event
Existing condition	14.9	16.0	15.3	16.0
Dredge within ROW	13.6	14.4	15.1	16.0
Dredge ROW & along historical channel	13.5	14.4	14.4	15.9
Dredge ROW & parallel to road and through marsh	13.4	14.2	14.5	16.0
Dredge ROW & ~800 ft parallel to road into marsh	13.4	14.2	14.7	15.5
Reconnect floodplain	14.9	15.9	15.2	16.0
Construct elevated causeway	13.4	14.3	14.4	15.9

NOTES:

1 - Results reported for a location immediately upstream of the road. Model results have been rounded to the nearest tenth of a foot, although the precision of the model is greater than this reporting level. As the model was not formally calibrated, these levels are useful in a comparative sense, but should not be judged as absolute predictions.

2 - The future condition reflects topographic conditions after the sediment transport model was used to estimate the distribution and movement (i.e., erosion, transport and deposition) of sediment throughout the project area for a 10-year period.

A summary of additional evaluation parameters is provided in Table 4 for each of the components. Specific results for each component are discussed in the following sections.

Table 4. Summary of all evaluation parameters for each component considered.

Scenario	Flood Reduction	Construction Methods	Estimated Cost[1]	Habitat Improvement
Dredge within ROW	Reduces frequent flooding but will need to occur repeatedly	Standard methods from the bridge and banks near the road, or with specialty suction dredging equipment	$168,500 per dredging	Minimal improvement at the bridge, no restoration of fish passage
Dredge ROW & along Historical Channel	Reduces frequent flooding but dredging at the road will need to occur repeatedly	Standard methods with some pieces of specialty equipment. Access along creek channel to limit disturbance to sensitive areas.	$2,237,280	Significant improvement due to restoration of fish passage in downstream reach, although improvements will be temporary until excess sediment accumulates[2]
Dredge ROW & Parallel to Road and through Marsh	Reduces frequent flooding but dredging at the road will need to occur repeatedly	Standard methods from the road, although segment within Middle Butano Marsh will likely require specialty equipment	$1,409,850	Significant improvement due to restoration of fish passage in downstream reach, although improvements will be temporary until excess sediment accumulates[2]
Dredge ROW & ~800 ft Parallel to Road into Marsh	Reduces frequent flooding but dredging at the road will need to occur repeatedly	Standard methods from the road and possibly with specialty suction dredge equipment in the channel	$295,000	Minimal improvement at the bridge, no restoration of fish passage
Elevated Causeway	Road does not flood during large magnitude events after construction or in the future	Standard methods	$10,060,000	No improvement, no restoration of fish passage
Floodplain Reconnection (Example Project)	No immediate flood reduction benefit, but reduces amount of sediment delivered to the area above the bridge	Standard methods, but potentially challenging due to access limitations and need to limit disturbance to sensitive areas	$688,000	Significant improvement due to floodplain restoration, but benefits are limited if downstream fish passage is not also addressed

NOTES:

1 - Details of the preliminary cost estimate are provided in Appendix C.

2 - Downstream dredging will be more sustainable if upstream sediment reduction actions are also implemented.

7.1 DREDGE WITHIN COUNTY ROW AT THE BRIDGE

Dredging within the County ROW would involve excavating 100 linear ft of channel 10 ft deep and 50 ft wide on average (the top would be wider and the bottom narrower), generating approximately 3,000 yd^3 of sediment (Figure 12). The excavation footprint would cover approximately 0.2 ac, and would include the removal of woody vegetation (e.g., alder trees) that has become established on sediment that has accumulated in the channel, as well as on the banks to provide access, if required. In addition to the excavation footprint, additional area would may be disturbed to gain access to the creek in order to remove as much sediment as possible from beneath the roadway; however, this disturbance could possibly be reduced by using specialty suction dredge equipment.

7.1.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

Immediately after construction, this proposed dredge component would reduce water levels during a 2-year flood event (Table 3); however, the road would still flood during this size of event (Figure 13). The frequency and duration of chronic flooding would be reduced, at least initially until sediment fills in the dredged area. While the frequent flooding of the road would be reduced, adjacent floodplain areas to the north and south of the road would still flood, although to a lesser extent. During a 10-year flood event, flooding of the road would still occur as the flow rate occurring during the peak of the flood would exceed the amount that could be conveyed through the dredged bridge opening (Figure 14).

The volume of sediment removed to create this capacity is small relative to the average amount of sediment currently being transported to the marsh each year[17], as such it should not be expected to persist for long periods. It should be noted that sediment delivery occurs in combination with runoff events, such that the amount of sediment delivered would be much less during dry years and much greater during wet years with many larger storm events.

Long-Term Results

Results of the sediment transport simulation covering 10 years of historical flow indicate that after the first significant flood event (e.g., a 2-year or larger event), the channel at the bridge will have filled in to almost the pre-dredged capacity. Figure 15 provides a comparison of the cross section located upstream of the bridge opening at various points during the sediment transport simulation. The various lines plotted are for various points during the simulation (100% indicates the end of the 10 years of simulation). It shows that at the 11% complete simulation time step, the channel has filled in to nearly the pre-dredged area. Following the infilling that is predicted to occur during the first significant event (which occurs before the 11% complete time step), the model suggests that the channel will continue to accumulate sediment, albeit at a much slower rate through the rest of the simulation period.

[17] 3,000 yd^3 is approximately 4,500 tons, although it could range from 3,000 to 5,000 tons depending on the grain sizes present. SFBRWQCB (In prep.) estimate 80,000 tons/yr of sediment is delivered to the creek channels and subsequently the marsh; however, some fraction of this total would be washload and would not be expected to deposit.

Figure 16 and Figure 17 provide long profiles for the thalweg (i.e., the deepest point of the channel), and water surface for the immediate post-construction condition as well as after the 10 year sediment transport simulation. The water surface profile for the existing condition is also provided for reference. The model results suggest that substantial accumulation of sediment will occur in the channel upstream of the bridge. This accumulation will result in increased water surface elevation profiles both above and below the bridge, although the increases are greater upstream of the bridge. Although the model is showing that downstream of the bridge a channel will be eroded slightly, it should be noted that the model predicted large amounts of sediment will accumulate on the floodplain and marsh areas adjacent to the main channel. This accumulation beyond the main channel is not shown in either figure. Both the 2-year and 10-year future condition simulations indicate lower water levels in the lagoon. The lower water levels are a result of significant scouring of the channel which occurs in the vicinity of Highway 1 during the large 1998 flood event which is near the end of the 10 year sediment transport simulation. Lower water levels in this area are predicted for all scenarios considered, including the existing condition.

This component alone provides relief from the frequent chronic flooding immediately after construction. However, the road will likely flood again after sediment is deposited in the dredged area following the first significant storm event (i.e., a 2-year event or larger). With this in mind, for this action to be a component of a long-term solution to flooding at the road, the dredging would have to be repeated as needed, annually, if not even more frequently. It is possible that dredging would not be required after a dry year without any significant floods (e.g., as occurred in the 2014 water year); however, it should be expected that in some wetter years dredging could be required following each significant storm event in order to provide adequate capacity for subsequent events. In other words, in some years dredging could be needed multiple times to reduce the potential for frequent flooding of the road.

7.1.2 CONSTRUCTION METHODS AND POTENTIALCONSTRUCTION COSTS

This component involves removal of sediment from the channel upstream and downstream of the bridge within the ROW as well as beneath the bridge. Most of the sediment under the bridge can be effectively removed by excavation, using a telescoping arm excavator (e.g., a Gradall, one of which is owned by the County). The channel would be dewatered, and a small piece of equipment (e.g., a bobcat) could be lowered into the channel to allow excavation beneath the bridge deck. Dredge material would be dewatered in a separation unit and disposed of off-site. The quarry located off of Bean Hollow Road has been previously proposed as a disposal area of the dredge spoils. This location was used in the development of the construction cost estimate, although it is possible that another location like a nearby field could also be used or that the spoils would need to be hauled to Ox Mountain Landfill in Half Moon Bay. Using an excavator, this alternative should be relatively simple to implement, as it involves common construction equipment. A preliminary estimate for the construction cost (assuming local disposal in Pescadero) of dredging the ROW one time is $168,500[18].

[18] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. Details of this estimate are provided in Appendix C.

Alternatively suction dredging equipment could be used to remove sediment from the channel within the ROW. This would require contracting with a specialized dredging contractor, likely at a similar implementation cost. It is possible that using a suction dredge could result in less environmental impact and therefore require less mitigation. Suction dredging requires a large volume of water, which could potentially limit the efficacy of this type of approach without leading to dewatering of sections of the creek beyond the ROW. In addition, the dredged slurry would contain significantly greater amounts of water and require more elaborate sediment dewatering techniques (e.g., a settling basin or series of tanks), which could result in a greater footprint for the project, although these tanks could be place on the road to limit disturbance to sensitive areas. If dredging within the right of way is pursued, dredging contractors should be consulted to gain more information on the feasibility of using this approach.

7.1.3 TRUST SPECIES IMPLICATIONS

Dredging within the ROW during the in-water work period would affect the channel and banks of Butano Creek, which could impact California red-legged frog adults and tadpoles, San Francisco garter snake adults and juveniles, and steelhead juveniles. Tidewater goby are not likely to occur within the ROW, due to reduced habitat connectivity to the lagoon habitat, and coho salmon are also not likely to occur, due to their near extirpation in the watershed. These species that could occur would need to be surveyed for and excluded or moved from the project work area prior to construction. Due to the relatively small footprint of the dredging, few individuals are likely to be present. If frequent re-occurring dredging is required, impacts and avoidance/minimizations measures would need to be implemented prior to each event.

Dredging within the ROW is not likely to substantially affect Trust Species or their habitat in the long-term. Dredging would remove material and temporarily create a large pool at the bridge, which may provide suitable rearing habitat for red-legged frogs and juvenile steelhead. However, dredging is not likely to create complex pool habitat preferred by rearing juveniles, and the relatively small footprint of the construction is not anticipated to affect the population. In addition, habitat connectivity with the lagoon will not be addressed by dredging at this location, and therefore this component would not improve fish passage restrictions.

7.1.4 PERMITTING IMPLICATIONS

Dredging within the ROW could have the following permitting implications, in addition to those described in Section 5.2[19]:

- Waste Discharge Requirements would likely be necessary for California Water Code compliance, due to the fact that dredging would be repeatedly needed to maintain adequate clearance under the bridge, and could be considered a point discharge. Waste Discharge Requirements would likely require frequent sediment testing and/or monitoring, among other requirements.
  If dredging was required to occur during the winter or spring, and an exception to the summer in-water work period granted, the work could potentially affect California red-legged frog eggs (which are more difficult to avoid than mobile tadpoles and adult frogs), as well as steelhead

[19] This section, and those for other solution components, are not intended as stand-alone discussions, but rather additions to those in Section 5.2.

and potentially coho salmon migration. Such effects would necessitate greater analysis and additional conditions and mitigation as a part of a BO from USFWS and NMFS for compliance with ESA Section 7.

- Section 10 of the ESA provides for a similar incidental take authorization as Section 7, but for projects that are not authorized, funded, or carried out by a federal agency. Section 10 requires the preparation of a Habitat Conservation Plan, rather than a BA, which is much more arduous and time consuming to prepare. BOs based on a Habitat Conservation Plan can, however, cover much longer time frames than Section 7 BOs, which typically cover the same 5-year period as the Section 404 permit. Because a Section 404 permit would be required for all solution components, the need for ESA compliance via Section 10 should be unnecessary. However, if repeated dredging within the ROW is undertaken as the long-term solution to flooding, or as a component of additional regional flood management maintenance activities, then the longer-term take coverage provided via Section 10 may be preferable. Because dredging within the ROW would not enhance habitat in the long-term and would impact jurisdictional waters, riparian vegetation, and potentially Trust Species habitat, mitigation plantings and associated maintenance and monitoring would likely be required under a variety of regulatory mechanisms (see Section 5.2) to compensate for such impacts.
- Due to the location of the work in the County ROW, no other landowners would be significantly involved and therefore right-of-entry permits would not likely be necessary, except potentially for staging areas.
- If this component ends up being part of the long-term solution to flooding, then permitting would have to be repeated or renewed every five years or so, since that is generally the timeframe covered by the permits discussed above.

7.2 DREDGE ROW AND DOWNSTREAM ALONG HISTORICAL CHANNEL

Dredging downstream of the county ROW would involve excavating 6,500 linear ft of the historical channel generating approximately 48,000 yd^3 of sediment (Figure 18). The channel dimensions would match those of the previous component within the ROW. Beyond the ROW, a channel with an approximate channel cross sectional area of 200 ft^2 would be excavated with a slope of 0.001. The excavation footprint would cover approximately 4.5 ac, and would include the removal of both woody vegetation (e.g., alder and willow trees) and herbaceous emergent marsh vegetation. In addition to the excavation footprint, additional areas may need to be disturbed to gain access to the creek alignment. This temporary access could be gained from Water Lane to the east through both private and state property, or the dredging area could be accessed from Pescadero Road near the bridge. In addition to the area disturbed by dredging and by gaining access, an additional area would be needed to act as a staging area for the wet sediment to be stockpiled to allow it to drain or partially dry prior to offsite disposal. It would be preferable for this staging area to be located outside of the marsh in an area currently used for agriculture or grazing. Approximately 0.5-1 ac would be impacted by the temporary access and sediment staging areas.

Dredging downstream of the county ROW would provide fish passage at least temporarily until excess sediment re-accumulates. In addition to dredging the channel, it would be advantageous to include several large wood habitat structures along the banks of the dredged channel to provide channel complexity and cover for aquatic species. These are not required to reduce flooding at the road, but would enhance habitat for sensitive species within the project area, which could result in both funding and permitting opportunities.

7.2.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

Immediately after construction, this proposed dredge component would reduce water levels during a 2-year flood event (Table 3), however the road would still flood during this size of event (Figure 19). The frequency and duration of chronic flooding would be reduced at least initially. While the frequent flooding of the road would be reduced, adjacent floodplain areas to the north and south of the road would still flood, although to a lesser extent. During a 10-year flood event, flooding of the road would still occur as the flow rate occurring during the peak of the flood would exceed the amount that could be conveyed through the dredged bridge opening (Figure 20).

Long-Term Results

The volume of sediment removed to dredge a portion of the historical channel is more than three times the amount of sediment deposited in the marsh each year[20]. Results of the sediment transport simulation covering 10 years of flow indicate that at the bridge, the dredged channel would continue to accumulate sediment, albeit at a slower rate than just dredging within the ROW. After the first significant flood event, the channel at the bridge will have filled in some amount, but not to the same extent as with just dredging within the ROW. Figure 21 provides a comparison of the cross section located upstream of the bridge opening at various points during the sediment transport simulation. As compared to dredging only within the ROW, the bed elevation after the first significant flood event (shown by the 11% complete time step) is approximately 1.5 ft lower, thus providing a great capacity. The capacity declines through the simulation, such that at the end of the simulation, the road would flood with a similar frequency to the existing condition. Thus, the flood reduction benefits are temporary and do not last.

Figure 22 and Figure 23 provide long profiles for the thalweg (i.e., the deepest point of the channel), and water surface for the immediate post-construction condition as well as after the 10 year sediment transport simulation. The water surface profile for the existing condition is also provided for reference. The model results suggest that substantial accumulation of sediment will occur in the channel upstream of the bridge, although less than is predicted by only dredging the ROW. This accumulation will result in increased water surface elevation profiles both above and below the bridge, although the increases are greater upstream of the bridge. The simulated flood elevation for the 2-year event just above the bridge is lower than for the existing condition or dredge ROW simulations in the future condition; however the future 10-year water surface elevations are fairly similar. Although the model is showing that downstream of the bridge a channel will be eroded slightly, it should be noted that the model predicted

[20] SFBRWQCB (In prep.) estimate a rate of 20,000 tons/yr of sediment deposits in the marsh and lagoon, delivered by both Pescadero and Butano Creeks, although Butano Creek appears to be the major contributor. 48,000 yd^3 is approximately is 60,000 to 80,000 tons of sediment.

large amounts of sediment will accumulate on the floodplain and marsh areas adjacent to the main channel. This accumulation beyond the main channel is not shown in either figure.

Although this component provides relief from the frequent flooding and provides fish passage immediately after construction and for a longer duration than just dredging the ROW, the flood reduction benefits do not persist for a long time. The road will likely flood again after sediment is deposited in the dredged area near the bridge following a series of storm events. With this in mind, for this action to be a component of a long-term solution to flooding at the road, the dredging at the road would have to be repeated as needed, perhaps every 3-4 years, or potentially more frequently. Regular dredging at the bridge would slow the rate that the downstream portions of the channel would fill in. For this element to be a viable component of a project to reduce chronic flooding and restore habitat for Trust Species that is not temporary it must be combined with upstream sediment reduction efforts, as discussed in later sections.

7.2.2 CONSTRUCTION METHODS AND POTENTIALCONSTRUCTION COSTS

This component involves extensive dredging of Butano Creek, downstream of the bridge. Dredging would be performed with low-pressure terrestrial equipment, that would use the creek channel as the primarily access and haul route. Dredge material would be dewatered in a stockpile located nearby prior to offsite disposal. The dewatering stockpile area could be located in an adjacent area that would minimize environmental impact (e.g., a nearby field). The volume of material generated could be more than the quarry could handle, therefore other options for local disposal (e.g., in nearby fields) should be investigated. If a local disposal option cannot be identified, disposal at the Ox Mountain Landfill in Half Moon Bay would add substantially to the project cost. Vegetation removal will be required, with the heaviest amount of woody vegetation found in the first 2,200 ft downstream of the bridge. If water levels in the lagoon and creek are high enough to affect construction access, it may be advantageous, or necessary to breach the sandbar to lower the water level of the lagoon.

This project represents the most invasive of the alternatives, as stream bed alteration and vegetation removal will be the most extensive. The project will also be difficult to construct, due to difficult creek access, and wet working conditions within the creek that may present challenges to earth-moving activities. A preliminary estimate for the cost of dredging the ROW and the historical channel (assuming local disposal in Pescadero) is $2,237,280[21].

7.2.3 TRUST SPECIES IMPLICATIONS

Dredging downstream of the ROW along the historical channel alignment during the in-water work period would affect the channel and banks of Butano Creek, which could impact California red-legged frog adults and tadpoles, San Francisco garter snake adults and juveniles, tidewater goby adults and juveniles, and steelhead juveniles (coho salmon are not likely to occur, due to their near extirpation in the watershed). These species would need to be surveyed for and excluded or moved from the project

[21] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. Details of this estimate are provided in Appendix C.

work area prior to construction, and because of the relatively large footprint of the dredging, many individuals are likely to be present. In addition, dredging would cause increased turbidity in and downstream of the work area, which could also impact Trust Species that occur downstream. Silt curtains or similar would need to be used to control fine sediments suspended by the dredging. If frequent dredging is required within the ROW, impacts and measures to avoid them would likely occur for each event. If this component were modified to include re-establishing the historical channel through vegetation management and minor sediment removal rather than an intensive dredging effort (described in Section 6.8), the footprint and potential impact of the project could be considerably less, with consequently fewer effects on Trust Species. However, less intensive dredging would also be even less likely to persist for a long duration before excess sediment would again accumulate.

In the long-term, dredging downstream of the ROW along the historical channel alignment is likely to substantially affect Trust Species and their habitat, but the benefits are temporary without repeat dredging or substantial upstream sediment reduction projects. Dredging in conjunction with channel restoration to increase pool formation and habitat complexity by adding large wood structures would improve the quality of riverine rearing conditions for red-legged frogs and rearing steelhead and coho salmon, and is not likely to adversely affect San Francisco garter snake. The reduction in shallow, inundated, marsh habitat will reduce rearing habitat for tidewater goby, although this habitat overall is not limited in the lagoon or marsh. If this component were modified to consist of re-establishing the historical channel through vegetation management and minor sediment removal, the potential for enhancement of riverine habitat conditions is considerably less than if more extensive dredging and sediment removal were to occur. However, less extensive dredging would result in fewer long-term impacts to tidewater goby habitat.

Dredging along the historical channel or re-establishing the historical channel through vegetation management and minor sediment removal would remove the habitat connectivity restriction between the lagoon and Butano Creek for some period of time before additional sediment accumulated. This would allow adult steelhead and coho salmon unobstructed access to Butano Creek, as well as smolt downstream migration to the lagoon. In addition, improved habitat connectivity would allow fish (including tidewater goby) rearing in the lagoon improved opportunity to migrate upstream into riverine habitat when poor water quality limits the suitability of lagoon habitat. Based on available information, it seems unlikely that dredging within the historical channel would increase the presence of hydrogen sulfide in the lagoon, and may actually improve water quality by allowing water to flow directly down a defined channel, rather than over and through the marsh. It is anticipated that avoiding the formation of deep pools within a dredged channel may also help avoid stratification and the conditions that are contributing to the poor water quality in the lagoon.

7.2.4 PERMITTING IMPLICATIONS

Dredging in the ROW and downstream along the historical Butano Creek channel could have the following permitting implications, in addition to those described in Section 5.2:

- Because this component would restore aquatic habitat connectivity between the lagoon and the Butano Creek watershed, and could include habitat enhancements, which would notably benefit tidewater goby, steelhead, and coho salmon (if present), it may qualify for a Nationwide Permit

#27 for Aquatic Habitat Enhancement for Section 404 compliance, and coverage under NMFS Restoration Center's Programmatic BO for Restoration Actions and related authorizations. To qualify, habitat enhancement would need to be the primary purpose of the component. This could be the case, since the additional dredging under this component (as compared to dredging within the ROW) would provide greater benefits for habitat than it would for flood reduction.

- Although a relatively large amount of riparian vegetation would be impacted under this component, the long-term benefits to fish migration and habitat would likely result in decreased mitigation requirements, as compared to flood control components with no long-term habitat benefits.
- If dredging is required to be repeated as additional sediment accumulates in the channel, Waste Discharge Requirements from SFBRWQCB may be necessary for California Water Code compliance.
- Due to the large area of temporary impact to potential San Francisco garter snake habitat, the types of equipment and methods that would be used, and the fact that the snakes may occur in the work area at any time during the year, it would be extremely challenging to completely avoid take of San Francisco garter snake during construction. If habitat enhancements under this component were designed to also benefit San Francisco garter snake, it may qualify for a MOU for take authorization.
- This component would need a right-of-entry permit from California State Parks and access to the channel could involve private property.

7.3 DREDGE ROW AND DOWNSTREAM ALONG AN ALIGNMENT ALONG PESCADERO ROAD THROUGH BUTANO MARSH

Dredging a new channel downstream of the bridge within the marsh would involve excavating a length of 5,000 ft of channel to connect with the existing well established channel in the North Butano Marsh (Figure 24). The farthest downstream portion of this channel, an approximate length of 1,400 ft, could occupy portions of the existing channel network in the Middle Butano Marsh. It is possible that some portions of this new channel in the East Butano Marsh could utilize an existing historical ditch that parallels Pescadero Road. Dredging this new channel would generate approximately 35,000 yd^3 of sediment, but could be less depending on the size of the existing channels and historical ditches in the marsh and to the extent that they are utilized.

Within the ROW above and below the bridge, the channel dimensions would match those previously described. Beyond the ROW a channel with an approximate channel cross sectional area of 200 ft^2 would be excavated from the floodplain and marsh following an alignment roughly parallel to Pescadero Road. The excavation footprint would cover approximately 3.5 ac, and would include the removal of both woody vegetation (e.g., alder and willow trees) in the upper portions (~500 ft), and herbaceous emergent marsh vegetation farther downstream. In addition to the excavation footprint, additional areas would be disturbed to gain access to the creek alignment with the dredging equipment; however, due to the close proximity of channel alignment to Pescadero Road, this would be relatively small. In addition to the area disturbed by dredging and by gaining access, an additional area may be needed to act as a staging area to allow for stockpiling the wet sediment to allow it to drain prior to transport to an offsite disposal area.

In addition to dredging a channel, it would be advantageous to include several large wood habitat structures at various locations along the banks of the created channel to provide channel complexity and cover for aquatic species. These are not required to reduce flooding at the road, but would enhance habitat for Trust Species within the project area, which could result in both funding and permitting opportunities.

7.3.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

Immediately after construction, this dredging component would lower water surface elevations upstream of the road by 1.5 ft during a 2-year event and 1.8 ft during a 10-year event. Despite these significant reductions in water levels upstream of the bridge, the predicted water level during a 2-year event is still higher than the road elevation of 12.8 ft (Figure 25). As would be expected, the road also floods during a 10-year event (Figure 26). So while the dredging would reduce water levels and would reduce the amount of frequent flooding that is currently occurring during small magnitude events, the road would still flood during more significant events. While the frequent flooding of the road would be reduced from the current condition, adjacent floodplain areas to the north and south of the road would still flood although to a reduced extent.

Long-Term Results

The volume of sediment removed to create a new creek channel is more than two times the amount of sediment deposited in the marsh each year[22]. Similar to dredging the historical channel, the channel in the vicinity of the bridge would rapidly accumulate sediment following the dredging. Results of the sediment transport simulation covering 10 years of flow indicate that after the first significant flood event (shown by the 11% complete time step) the channel at the bridge will have filled in a majority of the dredged opening at the bridge (Figure 27); however, the downstream reach will have accumulated much less sediment. While it does fill in slower than just dredging within the ROW (as described in Section 7.1), the channel at the bridge does fill in sufficiently quickly such that frequent floods (those less than a 2-year magnitude) would again flood the road with increasing frequency as the channel at the bridge fills back in.

Figure 28 and Figure 29 provide long profiles for the thalweg (i.e., the deepest point of the channel), the water surface for the immediate post-construction condition as well as after the 10 year sediment transport simulation. The water surface profile for the existing condition is also provided for reference. The model results suggest that substantial accumulation of sediment will occur in the channel upstream of the bridge, but not nearly as much as with just dredging the ROW or dredging the historical channel alignment. This accumulation will result in increased water surface elevation profiles primarily above the bridge. The model is showing that downstream of the bridge, a channel will also accumulate

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[22] SFBRWQCB (In prep.) estimate a rate of 20,000 tons/yr of sediment deposits in the marsh and lagoon, delivered by both Pescadero and Butano Creeks, although Butano Creek appears to be the major contributor of sediment to the marsh. 35,000 yd^3 is approximately is 50,000 to 60,000 tons of sediment.

sediment and that large amounts of sediment will be deposited on the floodplain and marsh areas adjacent to the main channel. This accumulation beyond the main channel is not shown in either figure.

This component provides relief from the frequent flooding and provides opportunity for fish passage immediately after construction; however, the benefits do not persist through the entire sediment transport simulation period. The road will likely flood frequently again after sediment is deposited in the upstream portion of the dredged area following several significant storm events. With this in mind, for this action to be a component of a long-term solution to habitat enhancement and provide relief for frequent flooding at the road, the dredging within the ROW would have to be repeated as needed. This could be as much as annually or following larger storm events. It is possible that, in some wet years with multiple large flood events, dredging could be needed multiple times to reduce the opportunity for frequent flooding of the road.

7.3.2 CONSTRUCTION METHODS AND POTENTIALCONSTRUCTION COSTS

This component involves excavation of a new creek channel, which for the most part coincides with an existing historical ditch that runs alongside Pescadero Road. The majority of the excavation would be land-based using standard equipment (e.g., dragline and excavators), and easily accessed from the road. Excavation of the ROW would be achieved as described in Section 7.1. The downstream portion of the channel excavation will require access along the bed as the alignment of the historical ditch departs from the road, and will likely require low-pressure construction equipment and material dewatering. This alternative will incur vegetation removal along its length, with the largest woody vegetation occurring mainly in the first 500 ft downstream of the bridge. If water levels in the lagoon and creek are high enough to affect construction access, it may be advantageous, or necessary to breach the sandbar to lower the lagoon water level.

Dredge material would be dewatered in a stockpile located nearby prior to offsite disposal. The dewatering stockpile area could be located in an adjacent area that would minimize environmental impact (e.g., a nearby field). The volume of material generated could be more than the quarry could handle, therefore other options for local disposal (e.g., in nearby fields) should be investigated. If a local disposal option cannot be identified, disposal at the Ox Mountain Landfill in Half Moon Bay would add substantially to the project cost.

Implementation of this alternative involves mainly routine, land based operations, which should proceed at a relatively fast pace. A preliminary estimate for the cost of dredging the ROW and a channel through the Butano Marsh (assuming local disposal in Pescadero) is $1,409,850[23].

7.3.3 TRUST SPECIES IMPLICATIONS

Construction activities associated with implementation of dredging along the historical ditch may potentially affect Trust Species and their habitat. It may be possible to minimize in-water work, but in

[23] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. Details of this estimate are provided in Appendix C.

locations where the dredging connects with existing channels, and where it connects with the lagoon, will require in-water work. Therefore Trust Species including red-legged frogs, San Francisco garter snake, tidewater goby, and steelhead would be potentially affected. These species would need to be moved prior to construction. Because of the relatively large footprint of the associated dredging, many individuals are likely to be present, and would need to be rescued and moved. If frequent dredging is required, impacts would likely occur for each event.

In the long-term, dredging along the historical ditch is likely to substantially affect Trust Species and their habitat. Dredging in conjunction with channel restoration to increase habitat complexity would improve the quality of riverine rearing conditions for red-legged frogs and rearing steelhead and coho salmon by increasing depth of pools, and is not likely to adversely affect San Francisco garter snake or tidewater goby. However, dredging a new channel for the creek where none currently or historically occurred has a lot of uncertainty in terms of the quality and sustainability of aquatic habitat that will be created.

Similar to dredging along the historical channel, dredging along the historical ditch would create habitat connectivity between the lagoon and Butano Creek for some period of time before additional sediment accumulated. This would allow adult steelhead and coho salmon unobstructed access to Butano Creek, as well as smolt downstream migration to the lagoon. In addition, improved habitat connectivity would allow fish (including tidewater goby) rearing in the lagoon improved opportunity to migrate upstream into riverine habitat when poor water quality limits the suitability of lagoon habitat. Based on available information, it seems unlikely that dredging along the historical ditch and through the marsh would increase the presence of hydrogen sulfide in the lagoon, and may actually improve water quality by allowing water to flow directly down a defined channel, rather than over and through the marsh. It is anticipated that avoiding the formation of deep pools within a dredged channel may also help avoid stratification and the conditions that are contributing to the poor water quality in the lagoon.

7.3.4 PERMITTING IMPLICATIONS

Dredging in the ROW and downstream through Butano Marsh, would likely have similar permitting and permit compliance requirements as dredging downstream of the ROW along the historical channel.

- Although impacts to riparian vegetation would be less, impacts to marsh vegetation would increase.
- Uncertainty in the quality and sustainability of aquatic habitat that would be created under this component where no such habitat currently occurs (i.e., in a new channel through the marsh) could result in additional permit conditions and/or mitigation relative to dredging downstream of the ROW along the historical channel.

7.4 DREDGE ROW AND 800 FT DOWNSTREAM ALONG AN ALIGNMENT PARALLEL TO THE ROAD

Dredging a short connector channel downstream of the ROW into the marsh, would involve excavating 100 ft of channel within the ROW (as described previously) and 800 additional linear ft of channel to connect to the lowest elevation portions of the East Butano Marsh (Figure 30). The alignment of this connector channel would parallel Pescadero Road and could possibly be contained within the ROW.

This channel would diminish in cross sectional area as it progressed to the west. Dredging this short connector channel and the ROW would generate approximately 6,000 yd^3 of sediment. It is possible that some portion of this new channel could utilize an existing historical ditch that parallels Pescadero Road. The excavation footprint would cover approximately 0.9 ac, and would include the removal of both woody vegetation (e.g., alder and willow trees) in the upper portions (~500 ft), and herbaceous emergent marsh vegetation farther downstream. In addition to the excavation footprint, additional areas would be disturbed to gain access to the creek alignment with the dredging equipment, however due to the close proximity of channel alignment to Pescadero Road, this would be relatively small. In addition to area disturbed by dredging and by gaining access, an additional area may be needed to act as a staging area to stockpile wet sediment to allow it to drain prior to transport to a disposal area.

7.4.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

Immediately after construction, dredging the ROW and an ~800 ft connector channel into the marsh would lower water surface elevations upstream of the road by 1.5 ft during a 2-year event and 1.8 ft during a 10-year event. Initially it provides nearly identical flood relief as the previously described component that dredges a channel farther downstream within the marsh. Despite the significant reductions in water levels upstream of the bridge, the predicted water level during a 2-year event is still higher than the road elevation of 12.8 ft (Figure 31). As would be expected, the road also floods during a 10-year event (Figure 32). So while the dredging would reduce water levels and would reduce the amount of frequent flooding that is currently occurring during small magnitude events, the road would still flood during more significant events. While the frequent flooding of the road would be reduced from the current condition, adjacent floodplain areas to the north and south of the road would still flood although to a reduced extent.

Long-Term Results

The volume of sediment removed to create this capacity is small[24] relative to the average amount of sediment currently being transported to the marsh each year, as such it should not be expected to persist for long periods. Similar to the other dredging components, the channel in the vicinity of the bridge would rapidly accumulate sediment following the dredging. Results of the sediment transport simulation covering 10 years of flow indicate that after two significant flood events (shown by the 31% complete time step) the channel at the bridge will have filled in a majority of the dredged opening at the bridge (Figure 33). In other words the road would again flood with increasing frequency as the channel at the bridge fills back in.

Figure 34 and Figure 35 provide long profiles for the thalweg (i.e., the deepest point of the channel), and water surface for the immediate post-construction condition as well as after the 10 year sediment transport simulation. The water surface profile for the existing condition is also provided for reference. The model results suggest that substantial accumulation of sediment will occur in the channel upstream

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[24] 6,000 yd^3 is approximately 9,000 tons, although it could range from 6,000 to 10,000 tons depending on the grain sizes present.

of the bridge. This accumulation will result in increased water surface elevation profiles primarily above the bridge. The model is showing that downstream of the bridge the connector channel will also accumulate sediment and that large amounts of sediment will be deposited on the floodplain and marsh areas adjacent to the main channel. This accumulation beyond the main channel is not shown in either figure.

This component provides relief from the frequent flooding immediately after construction; however, the flood reduction benefits do not persist through the entire sediment transport simulation period. The road will likely flood frequently again after sediment is deposited in the upstream portion of the dredged area following several significant storm events. With this in mind, for this action to be a component of a long-term solution to frequent flooding at the road, the dredging within the ROW would have to be repeated as needed. This could be as much as annually or following larger storm events at a reduced frequency.

7.4.2 CONSTRUCTION METHODS AND POTENTIAL CONSTRUCTION COSTS

This component includes 100 ft of excavation beneath the bridge as well as 800 ft of new channel into the marsh. It could be excavated using standard construction equipment. Vegetation removal, including large trees, will be required. Access from the road will facilitate construction, but will require minor construction access improvement down the roadway embankment. Dredge material will be dewatered in a separation unit and disposed of off-site as proposed for other components described previously. Construction of this alternative is straightforward and relatively minor in scale when compared to some of the other proposed components. A preliminary estimate for the cost of dredging the ROW and a connector channel into the marsh (assuming local disposal in Pescadero) is $295,000[25].

7.4.3 TRUST SPECIES IMPLICATIONS

Dredging within the ROW and developing a short connector channel during the in-water work period would affect the channel and banks of Butano Creek, as well as marsh habitat, which could impact California red-legged frog adults and tad poles, San Francisco garter snake adults and juveniles, and steelhead juveniles. Tidewater goby are not likely to occur within the ROW, due to reduced habitat connectivity to the lagoon habitat, and coho salmon are also not likely to occur, due to their near extirpation in the watershed. Species that could occur would need to be surveyed for and excluded or moved from the project work area prior to construction, although because of the relatively small footprint of the dredging, few individuals are likely to be present. If frequent dredging is required, impacts and measures to avoid these species would likely occur for each event.

Dredging within the ROW and developing a connector channel component is not likely to substantially affect Trust Species or their habitat in the long-term. Dredging would remove material and create a large pool at the bridge, which may provide suitable rearing habitat for juvenile steelhead. However, dredging is not likely to create complex pool habitat preferred by rearing juveniles, and the relatively small

[25] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. Details of this estimate are provided in Appendix C.

footprint of the construction is not anticipated to affect the population. In addition, habitat connectivity with the lagoon will not be addressed by dredging at this location, and therefore this component would not improve fish passage restrictions.

7.4.4 PERMITTING IMPLICATIONS

Dredging a connector channel through the marsh could have the following permitting implications, in addition to those described in Section 5.2

- Because dredging a connector channel through the marsh would not enhance habitat in the long-term and would impact jurisdictional waters, riparian and wetland vegetation, and Trust Species habitat, mitigation plantings and associated maintenance and monitoring would likely be required under a variety of regulatory mechanisms (see Section 5.2) to compensate for such impacts.
- This component would likely need a right-of-entry permit from California State Parks and access to the channel could involve private property.

7.5 CONSTRUCT NEW CAUSEWAY

A new causeway would create a 500 ft span with a bridge deck elevation of 17.4 ft (Figure 36 and Figure 37). In addition to the causeway, portions of the road would be raised to 16 ft to prevent overtopping in larger flood events (e.g., 10-year events). Raising the road to 16 ft would represent a 0-3.2 ft increase in the road elevation. The connection with Bean Hollow Road, the access to the fire station and the driveways that connect to Pescadero Road to the west of Water Lane would also need to be modified to accommodate the raised road. The footprint for the causeway and the elevated portions of road would cover approximately 1.3 ac and would fit within the existing ROW. Modifications to driveways may extend beyond the ROW.

7.5.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

With regards to reducing flooding of the road, this component provides the greatest benefit of those considered. Immediately after construction the new causeway would be able to pass both the 2- and 10-year flood events (Figure 38 and Figure 39). Initially, a 10-year event would have more than 2 ft of freeboard along the elevated causeway and almost 1 ft of freeboard along the raised eastern span of the Pescadero Road.

Long-Term Results

Figure 40 shows the predicted channel change through the course of the simulation. Changes in the channel are much less dramatic than the dredging components. Figure 41 and Figure 42 provide long profiles for the thalweg (i.e., the deepest point of the channel), and water surface for the immediate post-construction condition as well as after the 10 year sediment transport simulation. The water surface profile for the existing condition is also provided for reference. The model results suggest that substantial accumulation of sediment will occur in the channel upstream of the bridge. This accumulation will result in increased water surface elevation profiles primarily above the bridge. The model is showing that downstream of the bridge, large amounts of sediment will be deposited on the floodplain and marsh areas adjacent to the main channel. This accumulation beyond the main channel is not shown in either figure.

This component provides relief from the frequent road flooding and larger magnitude, less frequent events immediately after construction (e.g., up to a 10-year event). These benefits persist into the future and despite predicted increases in water levels after the sediment transport simulation a 10-year event can still pass without flooding the road in the future.

7.5.2 CONSTRUCTION METHODS AND POTENTIALCONSTRUCTION COSTS

Building a new causeway involves basic roadway and bridge construction methods. The project involves significant construction, but is relatively straightforward. A preliminary estimate for the cost of building a new causeway is $10,060,000[26]. This is an order of magnitude estimate and should be refined if this component is pursued.

7.5.3 TRUST SPECIES IMPLICATIONS

Construction activities associated with a new causeway or a wider bridge span may potentially affect Trust Species and their habitat. In-water work affecting the channel would likely occur, with potential impacts to red-legged frog adults and tad poles, San Francisco garter snake adults and juveniles, and steelhead juveniles. Each of these species would need to be moved prior to construction. The work footprint impacts for terrestrial species would be potentially relatively substantial, and the footprint for aquatic species would be relatively small. Since no maintenance (e.g., repeated dredging) would be required, these impacts would only occur one time. Tidewater goby are not likely to occur within the ROW, due to reduced habitat connectivity to the lagoon habitat, and coho salmon are also not likely to occur, due to their near extirpation in the watershed.

In the long-term, construction of a new causeway or a wider bridge is not likely to substantially affect Trust Species or their habitat. That said, it is likely that a wider causeway will restore more natural geomorphic processes that could allow the channel to move laterally and/or create new channel alignments and habitats that could benefit Trust Species in the future. Habitat connectivity with the lagoon will not be addressed by a new causeway or wider bridge.

7.5.4 PERMITTING IMPLICATIONS

Constructing a new causeway could have the following permitting implications, in addition to those described in Section 5.2:

- It is very likely that the new causeway would need to be designed to pass the 100-year recurrence interval flow. The causeway as currently described does not, but this could be addressed in the design effort. CDFW typically requires this as a part of SAAs, NMFS generally requires this for new bridges over fish bearing streams, and the CDP may also require it. It is likely that the design of the causeway would need to be reviewed to determine the potential for

[26] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined.

this level of flood protection, and the associated additional impacts to environmental resources. It is possible to get a waiver from CDFW, NMFS, and in the CDP based on site conditions and feasibility.

- This component would likely need a right-of-entry permit from State Parks and permission to stage equipment and materials on private property.
- Constructing a new causeway would not directly contribute to any habitat enhancement that might facilitate permitting or reduce mitigation requirements, but it would also be conducive to habitat enhancement activities in the future. If habitat enhancement elements were planned and implemented along with the new causeway than mitigation requirements may be reduced, but the project would still not likely qualify for restoration-related permits.

7.6 REDUCE SEDIMENT SUPPLIED FROM WITHIN THE PROJECT AREA AND RESTORE THE CREEK'S ABILITY TO STORE SEDIMENT ON FLOODPLAINS

As discussed in Section 4.1, many areas along Butano Creek upstream of the road have transformed from areas where sediment was once deposited and stored on the floodplains, to areas where sediment is contributed to the creek due to channel incision and bank erosion. A variety of strategies could be used in combination to alter sediment production and storage in the creek and adjacent areas including:

- bank treatment to stabilize and/or restore eroding banks;
- installation of grade control structures (engineered large wood structures, check dams, etc.) to reduce the amount of future incision;
- lowering the elevation of floodplain areas through excavation of material so that they are more frequently inundated and subject to sediment deposition, and therefore able to again store sediment; and
- raising the elevation of the channel bed, reducing the capacity of the creek channel so that historical floodplain areas are reconnected to the creek and therefore inundated more frequently and again able to store sediment as they did historically.

In the preliminary analysis, several distinct potential projects were simulated. These projects considered both floodplain excavation to increase the connectivity[27] with the creek, as well as a project that reduced the channel capacity for a section of the creek by raising the channel bed to achieve increased connectivity. Each potential floodplain reconnection project that was simulated resulted in increased sediment storage on the restored floodplains. In the sections that follow, one potential project was chosen for discussion.

The restoration of the creek's ability to store sediment on its floodplain is a crucial component of a sustainable solution to flooding of the road and aquatic habitat enhancement. It is important to understand that the project described on its own does not restore enough floodplain area to reduce the amount of sediment delivered to the marsh back to historical sediment delivery levels. It will make a small contribution, but this project on its own will not be enough without other sediment reduction actions within the project area and farther upstream within the watershed. The project described below

[27] In this context, increasing connectivity is used to indicate increasing the amount of water that flows out of the channel onto the floodplain during flood events.

provides a good place to begin these type of actions, and is anticipated to be synergistic with downstream projects and additional potential floodplain and stream bank restoration efforts located farther upstream.

Example Channel-Floodplain Reconnection Project

One kind of channel-floodplain reconnection effort would involve the construction of several channel spanning engineered large wood structures in order to raise the elevation of the channel bed in areas where the creek is no longer well connected to the adjacent floodplain due to incision. These wood structures could be viewed as small check dams that would trap sediment and prevent additional incision. Structures would be engineered to ensure that they do not become fish passage barriers and do not break loose and become obstructions under or at the road crossing downstream.

There are a number of locations where this floodplain reconnection technique could be applied on Butano Creek upstream of Pescadero Road. One potential project to reconnect upstream floodplains to both improve habitat and restore the creek's ability to store sediment could be located in the willow forest upstream of Pescadero Road (Figure 43). This is not the only floodplain reconnection project that could be undertaken, nor is it the only project within the project area that could be implemented to reduce the amount of sediment delivered to the bridge and improve aquatic habitat.

In this area, in order to reconnect the creek channel to its adjacent floodplain, the elevation of the channel bed could be raised over a length of the channel to allow for more frequent inundation of the floodplain. Raising the channel bed would be accomplished through the installation of a series of engineered large wood structures that would increase the water surface elevation upstream of the structure by ~ 1 ft for each structure by increasing the local channel bed elevation. These grade control and habitat structures would be designed to allow the upstream passage of anadromous salmonids (i.e., steelhead and coho salmon) moving upstream to spawn. The channel capacity would be decreased by half by raising the bed elevation by up to 5 ft through approximately 5,500 ft of channel. At this conceptual level, five engineered large wood structures would be place through an approximately 3,000 ft long reach of channel. The footprint of each structure is less than 0.1 ac, but gaining access for heavy equipment will likely require a larger disturbance footprint.

7.6.1 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL RESULTS

Immediate Results

This component differs from the others described above in that it does not immediately reduce flooding of the road. Instead, it restores a key watershed process: the creek's ability to store sediment in a portion of the historical floodplain. Importantly, reduced sediment loads will allow other solutions at the bridge to function for a longer period of time. Immediately after construction, the 2-year water surface elevation upstream of the bridge is virtually identical to the existing condition, as is the 10-year water surface elevation. Thus, this amount of floodplain restoration does not appear to be enough to result in a significant attenuation of flood peaks in this system[28]. By raising the channel bed and reducing the channel capacity, large areas of floodplain are inundated by the 2-year and 10-year events as shown in Figure 44 and Figure 45, respectively. The predicted change in the bed elevation at the Pescadero Road bridge is shown on Figure 46. It should be noted that this is one example of this kind of project, and that more significant benefits can be realized with additional floodplain restoration.

Figure 47 and Figure 48 provide long profiles for the reach upstream of the road, where the floodplain reconnection project is located. On each figure, three bed conditions are shown: the current profile, the raised profile due to the large wood structures and the future bed profile after the 10 year sediment transport simulation. In addition, the water surface profiles for the immediate post-construction condition as well as after the 10 year sediment transport simulation are provided as is the water surface profile for the existing condition. As would be expected, the raised bed elevation raises the water level locally within the creek, however not as much as the bed is raised. This is because the floodwaters spill out onto the adjacent floodplain.

Upstream of the floodplain reconnection area water levels will also increase. While the historical floodplain areas upstream that are currently used for agriculture are also disconnected from the creek (meaning they currently flood infrequently), they will become more connected through this action. For example, areas that historically only flooded during a 20-year event will flood more frequently. Model simulations show that a 10-year event will still be contained within the banks of the creek.

Long-Term Results

Sediment accumulation was simulated in the reach upstream of the large wood structures and this accumulation results in raised water levels for a short distance upstream. In addition, a considerable amount of deposition occurs on the reconnected floodplain. The amount of deposition occurring through the course of the model simulation can be evaluated by comparing the longitudinal cumulative change in the mass of sediment moving through the project area (Figure 49). Starting at the upstream model boundary (Cloverdale Road), this model output sums the mass change in sediment as a result of channel and floodplain erosion or deposition through every cross-section. Reaches where the cumulative change curve is increasing in a downstream direction indicate the deposition of sediment; whereas when the cumulative change curve is decreasing in a downstream load indicate erosion.

On Figure 49, the curve representing the upstream floodplain reconnection simulation is notably different than the other components simulated. It shows the considerable amount of deposition occurring upstream of the bridge through the course of the simulation. While all of the other scenarios indicate deposition begins at an upstream distance of 15,000 (approximately 3,500 ft upstream of the bridge), the floodplain reconnection results show deposition (rather than erosion) occurring well upstream of Giannini Bridge. Differences between the other components can also be observed, for instance the components that include dredging downstream of the ROW show greater amounts of sediment deposition occurring downstream of the road.

[28] It is probable that more extensive floodplain restoration would result in the attenuation of flood peaks that could result in a reduction of the frequency or duration of flooding at the road.

This component provides the creek the opportunity for additional sediment deposition upstream of the road. On its own, this potential component does not immediately reduce water levels at the road, but it does reduce the amount of sediment being transported downstream. Therefore it would add to the longevity of other actions implemented at the road and farther downstream.

It should again be noted that this is one example of a potential floodplain reconnection project, and that additional floodplain area will also need to be restored in order to have a significant reduction of the amount of sediment being delivered to the marsh. The amount of sediment stored on floodplains will increase with the amount of floodplain area that is reconnected to the creek. Likewise, the amount of habitat available to aquatic species will increase with the amount of floodplain area that is reconnected. The example project proposed, would reconnect/restore less than 10% of the historical floodplain area. On its own, it is not enough to address the dramatic increase in sediment that is being supplied to the creek and subsequently to the marsh, but it is a start.

7.6.2 CONSTRUCTION METHODS AND POTENTIALCONSTRUCTION COSTS

The floodplain reconnection component involves the construction of engineered logjams (ELJs) upstream of Pescadero Road bridge. Wood structures will be constructed at 5 separate locations, each requiring improvements for access, including tree removal and grading of the creek bank. Construction materials (logs, upstream fill) will be imported to the site. The large wood structure construction will require excavation of the bank, and the bed, to secure the structures in place. Fine sediment will be placed upstream of the ELJs, to aid in sealing them to flow through the structure. Construction of this solution component will be complicated by both location and methods. Construction will involve standard equipment, but will require construction methods and techniques that are not typical. Access to the sites themselves may be difficult. A preliminary estimate for the cost of constructing the ELJs to reconnect the floodplain is $688,000[29].

7.6.3 TRUST SPECIES IMPLICATIONS

Construction activities associated with implementation of floodplain reconnection may potentially affect Trust Species and their habitat. It may be possible to minimize in-water work, such that effects to aquatic species including steelhead would be minimal. However, potentially terrestrial occurring species could still be impacted by construction, including red-legged frogs and San Francisco garter snake (although this is upstream of their more preferred habitat). These species would need to be moved prior to construction. Because of the relatively large footprint of potential floodplain project, many individuals are likely to be present (with the exception of San Francisco garter snakes), and would need to be rescued and moved. Tidewater goby are not likely to occur within the ROW, due to reduced habitat connectivity to the lagoon habitat, and coho salmon are also not likely to occur, due to their near extirpation in the watershed.

[29] This estimate covers only construction costs. Costs associated with planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. Details of this estimate are provided in Appendix C.

In the long-term, floodplain restoration is likely to substantially benefit Trust Species and their habitat. Improved off-channel rearing habitat would increase available habitat for California red-legged frogs and San Francisco garter snake. Based on the upstream location of the floodplain restoration tidewater goby are not likely to be affected in the long-term. Improved floodplain conditions could dramatically improve winter rearing habitat for coho salmon and steelhead. A lack of suitable low velocity habitat during winter is believed to be one of the factors limiting production of coho salmon in the watershed, as well as a contributor to declines in steelhead abundance (Stillwater Sciences *in review*). Improved floodplain connectivity, and creation of off-channel low-velocity rearing habitat has been demonstrated to increase the survival and production of both species.

Floodplain reconnection would be conducted upstream of Pescadero Road to increase sediment deposition, and thus would not directly affect the restriction in habitat connectivity located downstream of the road. However, in the long-term, reducing sediment delivery to the marsh would reduce the cause of the restriction, and thus increase the sustainability and success of any measures to remove sediment to restore habitat connectivity in lower Butano Creek.

7.6.4 PERMITTING IMPLICATIONS

Because the actions included in this component provide greater benefits to habitat than to flood reduction, it would likely qualify for a number of streamlined permitting processes available for restoration actions. These could include:

- Nationwide Permit #27 (Aquatic Habitat Enhancement) for Section 404 compliance.
- Coverage under NMFS and/or USFWS programmatic BOs for restoration actions, for ESA compliance.
- Expedited SAA processing.
- If covered by the NOAA Restoration Center's Programmatic BO for Restoration Actions, then also streamlined CDP processing (via an existing consistency determination).
- If funded through CDFW's Fisheries Restoration Grant Program, which provides funding for restoration that will enhance habitat for steelhead and coho salmon, then the component would also have access to the permitting processes available through that program.
- Reduced or removed mitigation requirements.

  An Initial Study/Mitigated Negative Declaration would likely suffice for CEQA compliance since the long-term benefits of the component would help mitigate for temporary construction-related impacts. If floodplain reconnection would result in increased flooding of adjacent farmland, this would need to be analyzed in the CEQA document including alterations of lands currently encumbered with Williamson Act Contracts.
- This component would also likely enhance San Francisco garter snake habitat and, therefore, potentially qualify for a MOU for the limited take of the species. That said, many of the measures described in Section 5.2 for San Francisco garter snake avoidance would still be required during construction.
- This component would need a right-of-entry permit from POST and access to the channel would likely involve private property, and potentially a Planned Agricultural District permit.

8 POTENTIAL SOLUTIONS TO REDUCE FLOODING OF THE ROAD

The goals of this project are to identify feasible long-term solutions to the flooding of the road, while maximizing opportunities to enhance or restore wetland and floodplain habitats, fish passage, as well as create more natural sediment dynamics upstream, downstream and near the road to restore the creek system and reduce the frequency and extent of future management interventions. Any feasible long-term solution will likely include multiple components including:

- Implementation of upland sediment control activities to reduce the amount of sediment delivered to the project area;
- Reconnection or restoration of floodplains to absorb sediment and flood water energy, thereby reducing transport of sediment downstream and limiting additional sediment inputs due to incision and bank erosion;
- Creation of additional flow capacity at the road either through construction of a causeway, and/or channel dredging; and
- Restoration or creation of a stable and open channel to provide habitat connectivity for salmonids and other aquatic species from Butano Creek upstream of the road into the lagoon.

While not covered in great detail in this report, sediment control in the watershed is a vital component to address flood reduction and habitat enhancement in Butano Creek, its floodplain, the marsh and the lagoon. There is much to be accomplished on this front. Some efforts are underway (e.g., in planning phases or early implementation) aimed at reducing the sediment generated by the hillslopes of the watershed. These efforts can provide the foundation for the additional management actions within and along the creek to reduce the frequency of flooding of the road. These efforts must be commensurate with the rates and volumes of sediment being delivered to the system in order to have the desired impact to current conditions.

The restoration of the creek's ability to store sediment on its floodplain is the next crucial component of a sustainable solution to flooding of the road and aquatic habitat enhancement. One example of floodplain restoration project was provided as a starting point for the larger-scale effort that will ultimately be required. The sediment benefits of the proposed floodplain reconnection project are twofold. First the floodplain reconnection will allow sediment that is being transported by the creek to access the floodplain. Once on the floodplain, some portion of this sediment will be deposited, thereby reducing the amount carried downstream. Second the construction of wood grade control structures will reduce the amount of incision, which will reduce the amount of sediment that is contributed to the stream by the bed and banks. Although the pilot project described will help, there is a threshold capacity for this type of action, below which little benefit will be realized.

Beyond the sediment benefits, floodplain reconnection could dramatically improve much needed winter rearing habitat for coho salmon and steelhead. However, for these habitat improvements to benefit anadromous fish, the fish must be able to make it upstream to this part of the creek, and currently passage is severely limited. Beyond habitat benefits in the floodplain reconnection area, the reduction of sediment supplied downstream will improve channel conditions in downstream reaches, including increasing the sustainability and success of any measures to remove sediment to restore habitat connectivity in lower Butano Creek.

While floodplain reconnection was only explored in depth for one area, additional floodplain restoration opportunities must be pursued. In areas where the floodplain is not restored and tall, steep and unstable banks remain, efforts to restore and or stabilize these banks that line much of Butano Creek must be pursued as well. These site specific projects will reduce the sediment load, and depending on how they are implemented can be designed to directly improve aquatic habitat. Successfully reducing the sediment load in Butano Creek can only be achieved through a collection of projects ranging from small to large in scale and relative contribution. Actions to control sediment, either at the watershed scale or along the creek, will take time for improvements to be observed at the bridge. There is a considerable amount of sediment stored upstream of the bridge and some amount of this legacy sediment will need to move down the system before the benefits are fully felt.

In the vicinity of the bridge, multiple components explored in Section 7 provided a reduction in water surface elevations. Dredging alone reduced water levels, but not enough to prevent flooding of the road during a 2-year flood event. Dredging would reduce the amount of the frequently occurring flooding which currently plagues the road, for some time until the channel at the road fills in again. However, this benefit is short-lived for many components. Sediment transport simulations suggest that the capacity at the bridge will diminish after one or more significant flood events, which means that for a dredging component to be a long-term solution on its own without additional flood reduction measures, it (and its associated permitting) would need to be repeated indefinitely into the future. The dredging could be required annually, and there could be wet periods during which dredging at multiple points in the year would be desirable (albeit very challenging to permit this type of frequent dredging).

The construction of a new, higher, wider causeway over Butano Creek and its floodplain was the only component considered that provided road access during larger floods (e.g., a 10-year flood event) immediately after construction, as well as in the future. While it comes at a substantial capital investment, the benefits are vastly superior to other solutions with regards to flood reduction at the road. However, it alone provides no immediate direct substantial benefit to the Trust Species. That said, it is likely that a wider causeway will restore more natural geomorphic processes that could allow the channel to move laterally and/or create new channel alignments and habitats that could benefit Trust Species in the future. While dredging comes at a lower cost, these repeat costs will accumulate through time, making the causeway a far better investment for providing safe access to Pescadero into the future. In addition, while not quantified in this effort, a causeway also provides the best defense again sea level rise that will eventually add to the deposition and flooding at the road.

The most significant way that a project action aimed at providing a solution to flooding could benefit any of the sensitive salmonid species is by restoring habitat connectivity from the lagoon to the watershed upstream of the bridge. This would require dredging a portion of the channel either along the historical alignment or through the marsh. Not only would this substantially increase the amount of habitat available, but it could also provide fish migratory connectivity to escape poor water quality conditions in the Butano Marsh and lagoon that sometimes accompany the breaching of the barrier bar. A defined and restored channel could also help address known water quality concerns in the marsh/lagoon by enhancing circulation.

Two downstream channel alignments were considered in depth in Section 7. The historical alignment is appealing as this would be a restoration of the former channel; however, access to dredge this alignment could result in a more complicated, slower and costly construction process. The marsh alignment could be constructed more rapidly, and at a lower cost; however, the water quality conditions that currently develop in Butano Marsh provide greater uncertainty in the beneficial outcome of this alignment. It is possible that the construction activities associated with this alignment could be expanded to address adjacent man-made depressions (e.g., historical ditches and borrow pits) which could act to improve water quality conditions within the Butano Marsh. Dredging a restored connection to the lagoon is the only project component that would ensure that other restoration activities for salmonids in the Butano Creek watershed are effective.

Sediment will accumulate in the upper portion of the dredged channel in either alignment until the time that sediment supplied from upstream has been dramatically reduced. As such, to maintain fish passage into the future, floodplain restoration that increases upstream sediment storage, along with reduction in sediment supplied from the watershed to the project area, must be carried out. Repeated dredging at the bridge should be considered and planned for the interim. The extent and frequency of this repeated dredging is inversely proportional to the increased sediment storage/floodplain restoration and sediment load reduction accomplished upstream. Repeated dredging within the ROW could be viewed as maintaining a sediment basin that would extend the longevity of downstream dredging.

If building a new causeway gains momentum and the appropriate level of funding is obtained, the placement of the causeway should be considered further. If the fire station has been relocated and Bean Hollow Road can be realigned, the alignment of the causeway could be shifted to the west, which would provide more direct access to the low elevation areas in the upper portions of the East Butano Marsh. This project would require additional funding (realigning Bean Hollow Road and grading the area currently occupied by the fire station), but it would provide additional flood reduction to the residential area downstream of Pescadero Road by directing floodwaters to the East Butano Marsh.

9 CONCLUSIONS AND NEXT STEPS

A collection of components to a solution of flooding at the road were assessed and documented. Both long-term and short-term solutions were identified. The construction of a causeway provides the greatest flood benefit, but also comes at the greatest initial capital investment. Many of the other components of the solution also require significant funding.

Rather than one stand-alone project, several of these efforts will need to be advanced simultaneously as a multi-faceted, integrated approach with efforts to control sediment, reduce flooding and improve habitat for Trust Species within the Butano Creek watershed. A solution that takes a holistic approach, addressing sediment, capacity at the bridge and enhancing habitat will achieve greater success in procuring the necessary funding and permits. An integrated approach that includes habitat enhancement along with flood reduction will also reduce the amount of mitigation actions required as compared to a project with solely a flood reduction objective.

A phased approach could be taken to allow actions in the short-term while preparing for the longer-term actions. For example, Phase 1 could include the establishment of in-channel sediment basin at the bridge that could be dredged annually (if needed) during the summer to provide short-term temporary relief to frequent road flooding. Phase 2 could include design and implementation of upland sediment reduction and floodplain restoration projects, as well as the design of a causeway and downstream channel dredging and restoration. Phase 3 could then include construction of the causeway and downstream channel dredging and restoration.

Actions in the marsh downstream of the bridge could improve water quality in the marsh, which could reduce the severity of the frequently occurring fish-kills in the lagoon. While the potential to affect water quality was considered, it did not drive the development of those components of a solution. As such, the components located in the marsh could potentially be expanded beyond what was described in previous sections to better address conditions resulting in poor water quality.

Many yet to be determined factors will affect the ultimate cost of the project. Initial estimates have been provided for the construction phases of potential projects. Costs associated with additional planning, design, permitting, mitigation and future maintenance will be substantial and will need to be estimated once additional details regarding the project specifics have been determined. The disposal of the dredged material could substantially affect project costs. Disposal options located in close proximity to the project area should be sought after as one way to reduce project costs.

Lastly, to reiterate, it is highly likely that a solution that takes a holistic approach addressing sediment, capacity at the bridge and habitat/migration corridor improvements will achieve greater success in procuring the necessary permits and funding.

10 REFERENCES

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

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

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.

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.

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.

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

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.

NMFS. 2013. Letter to Trout Unlimited regarding fish passage in Butano Creek. National Marine Fisheries Service, Santa Rosa, California. March 19, 2013.

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.

SFBRWQCB (San Francisco Bay Regional Water Quality Control Board). In preparation. Pescadero-Butano Watershed Sediment TMDL and Habitat Enhancement Plan. Staff Report.

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.

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.

11 LIST OF PREPARERS

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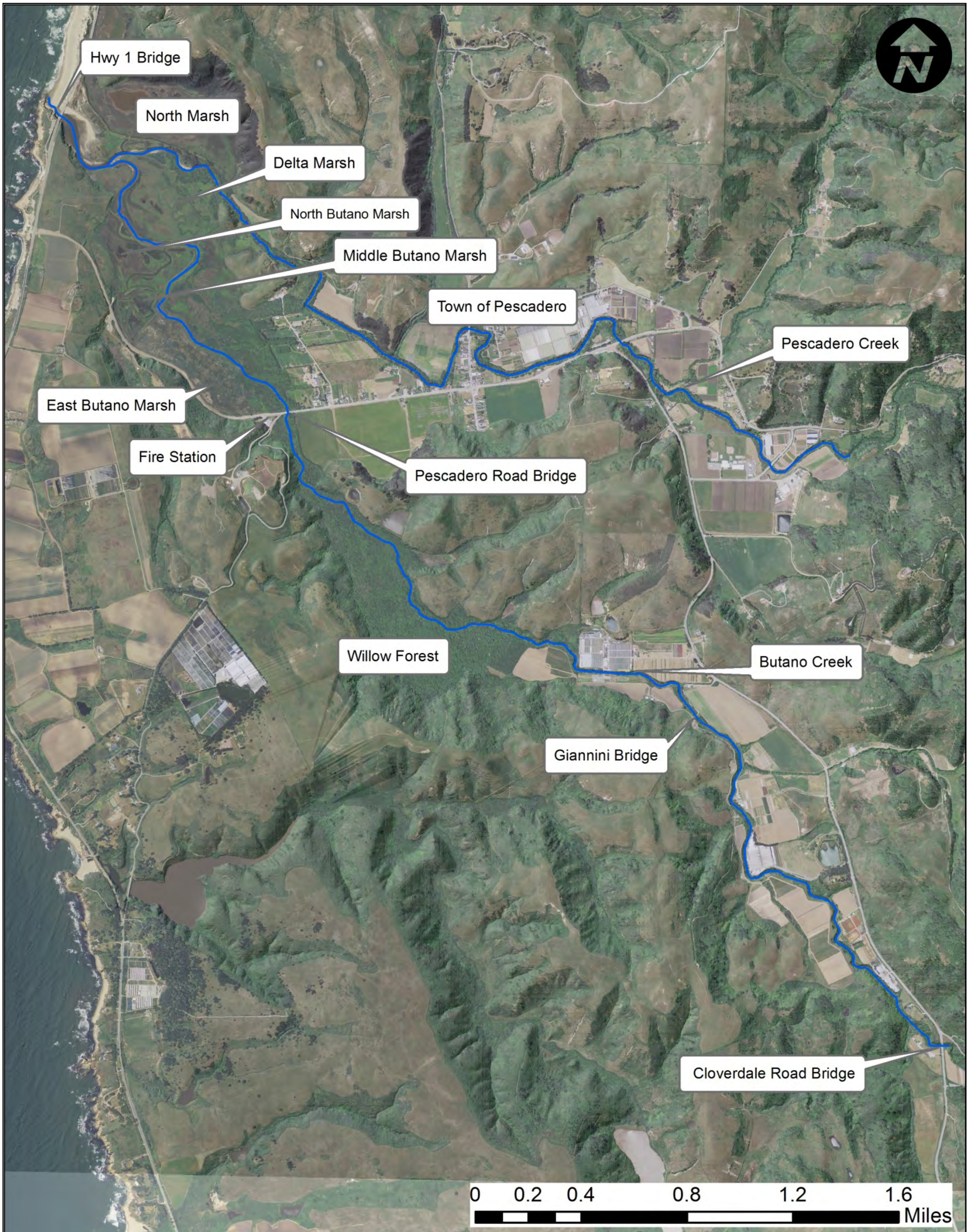
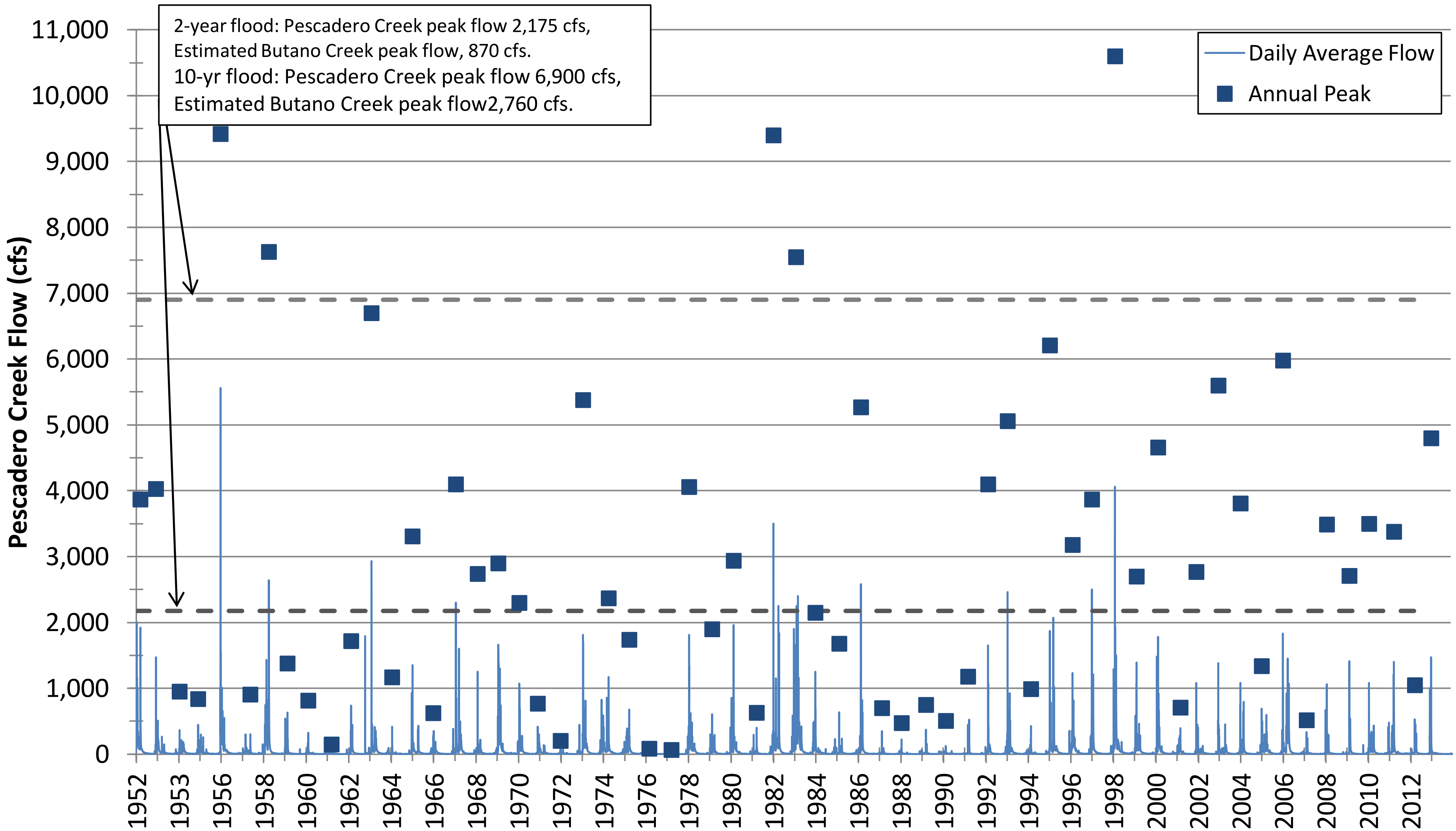


Notes: Background Image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Project area**		
		Project No. 13-1032	Created By: DST	**Figure 1**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Flow data for Pescadero Creek**		
		Project No. 13-1032	Created By: DST	**Figure 2**

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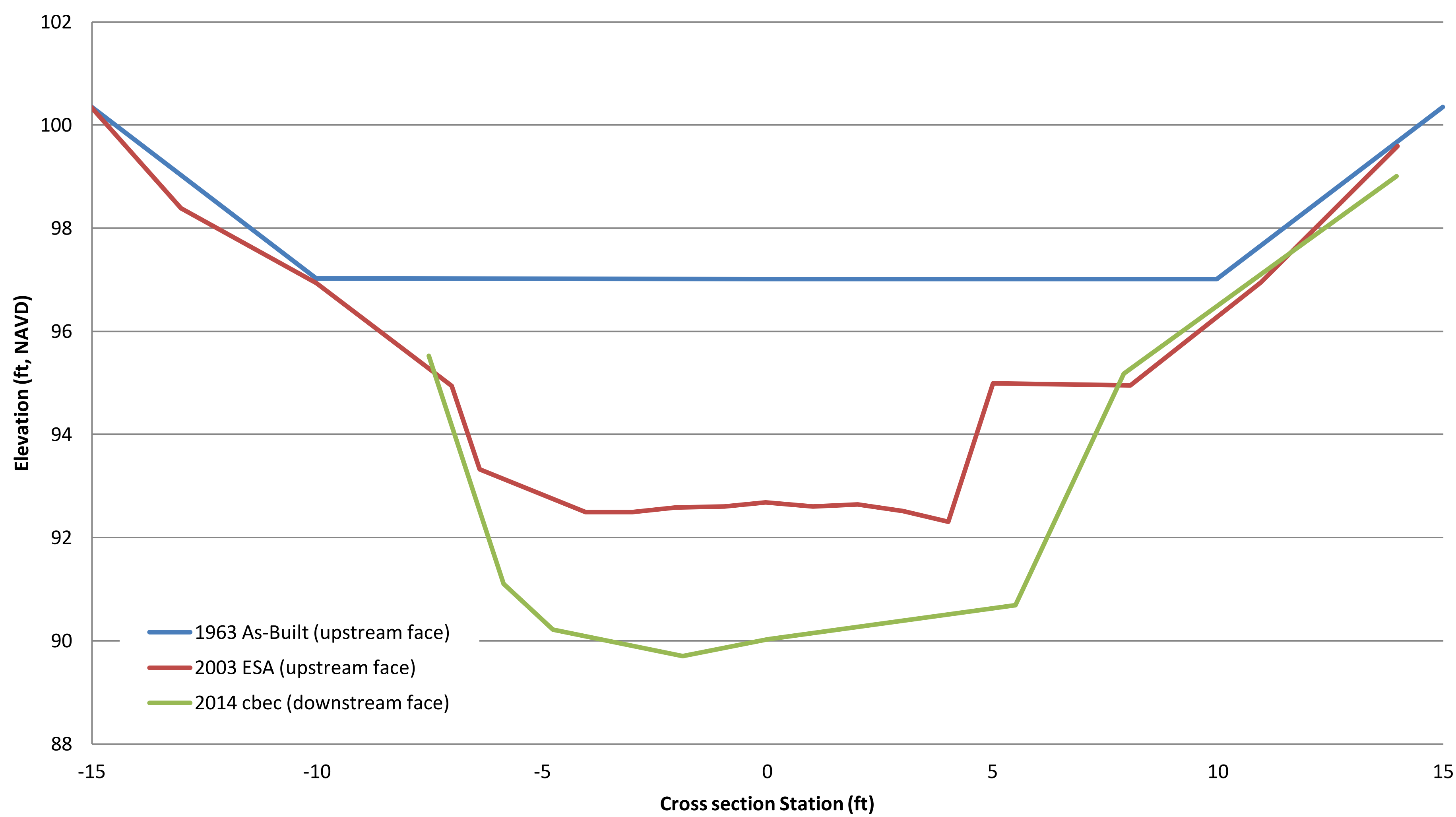
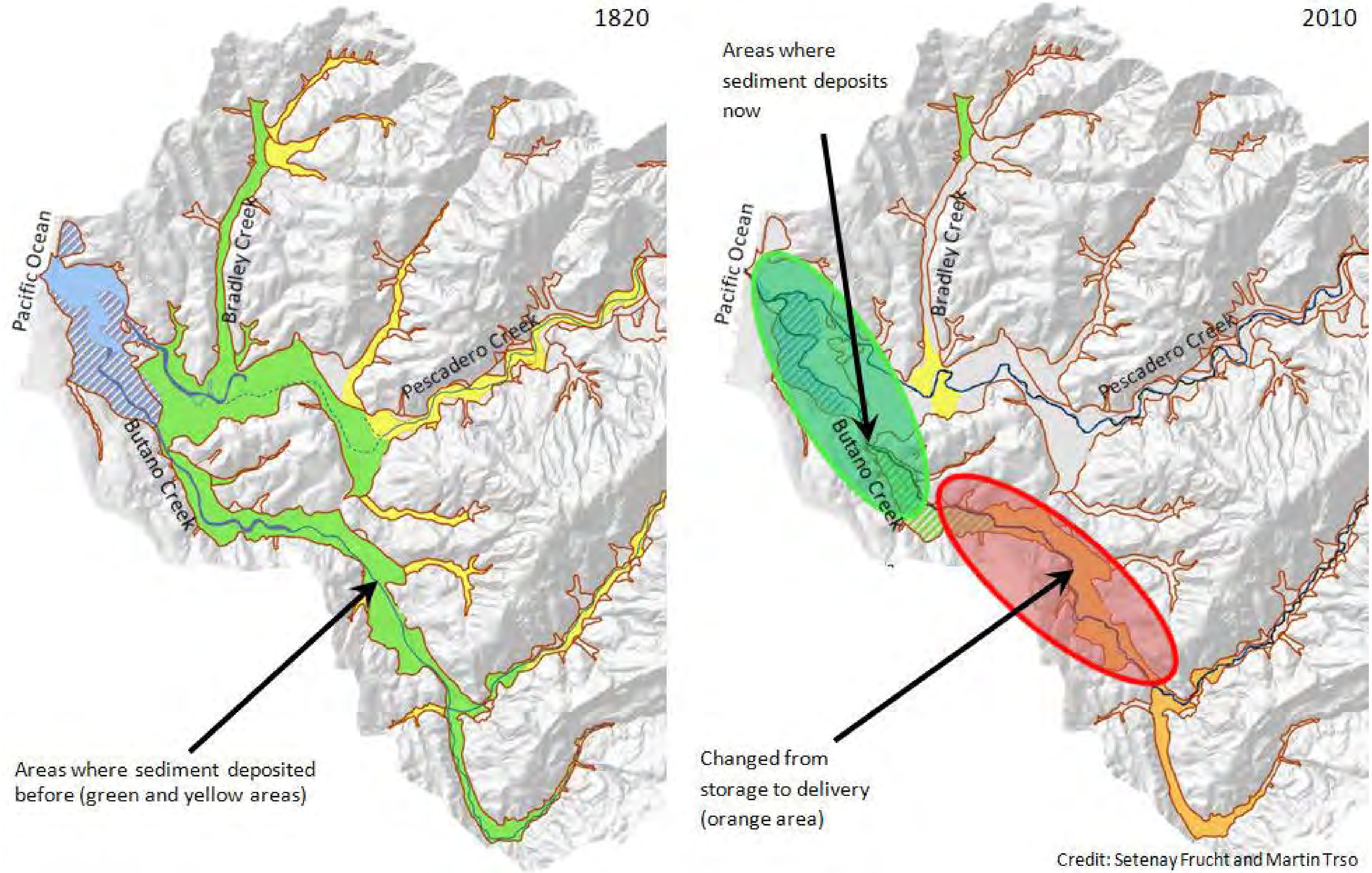


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Cloverdale Road bridge cross section comparison**		
		Project No. 13-1032	Created By: DST	**Figure 3**



Notes: Modified from Frucht, 2013	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Historical and current flood-prone areas**
		Project No. 13-1032 · Created By: DST · **Figure 4**

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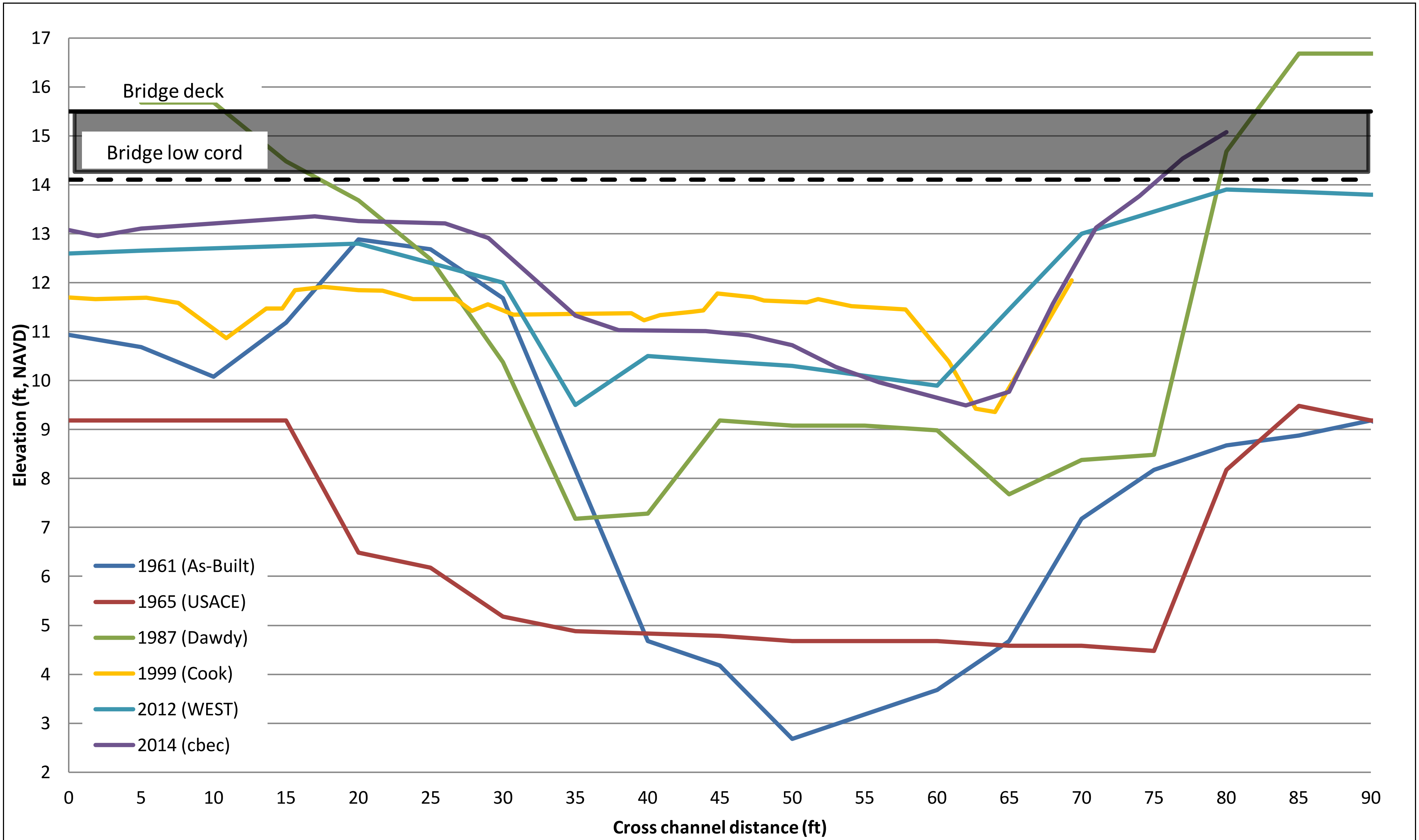
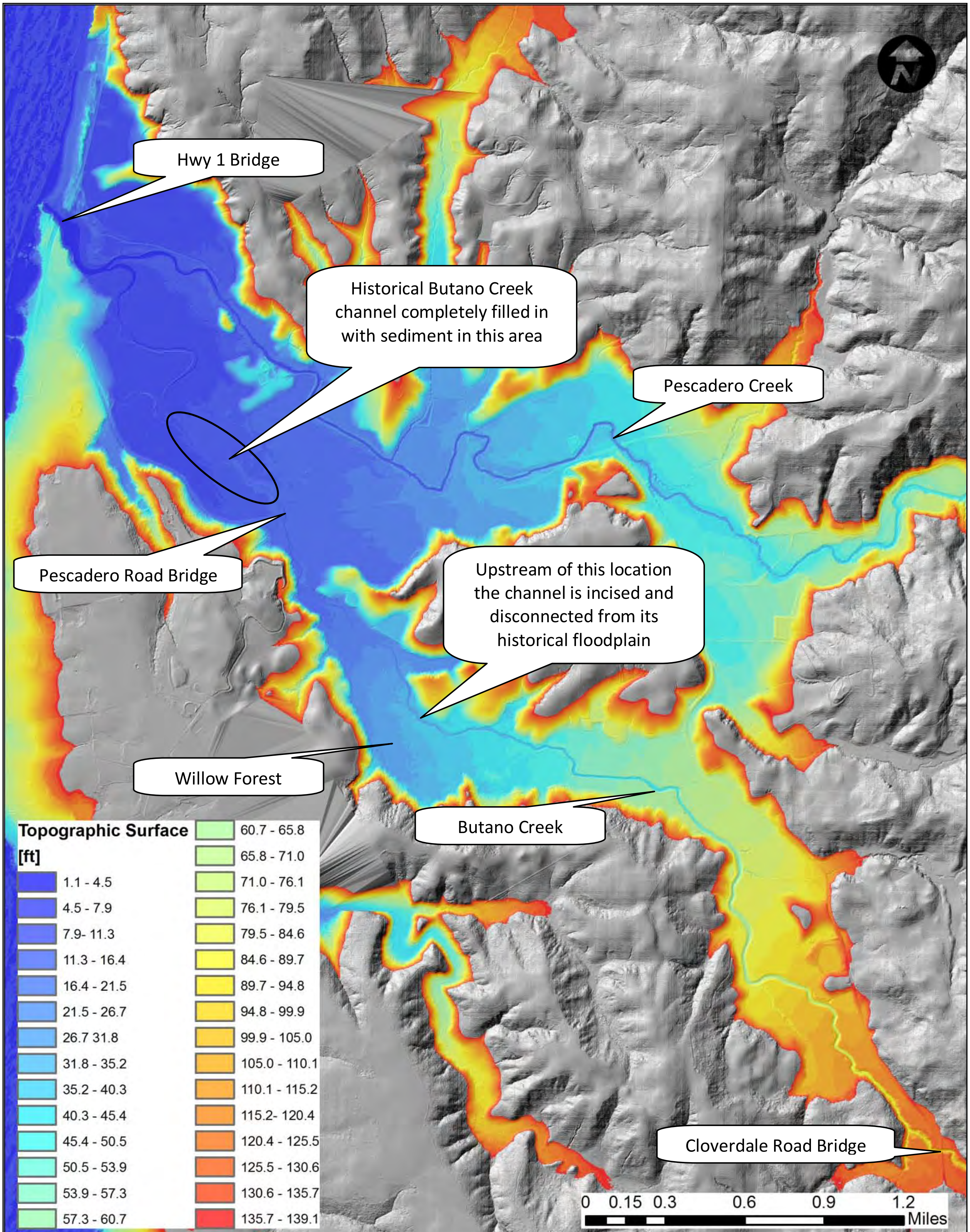


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Pescadero Road bridge cross section comparison**		
		Project No. 13-1032	Created By: DST	**Figure 5**

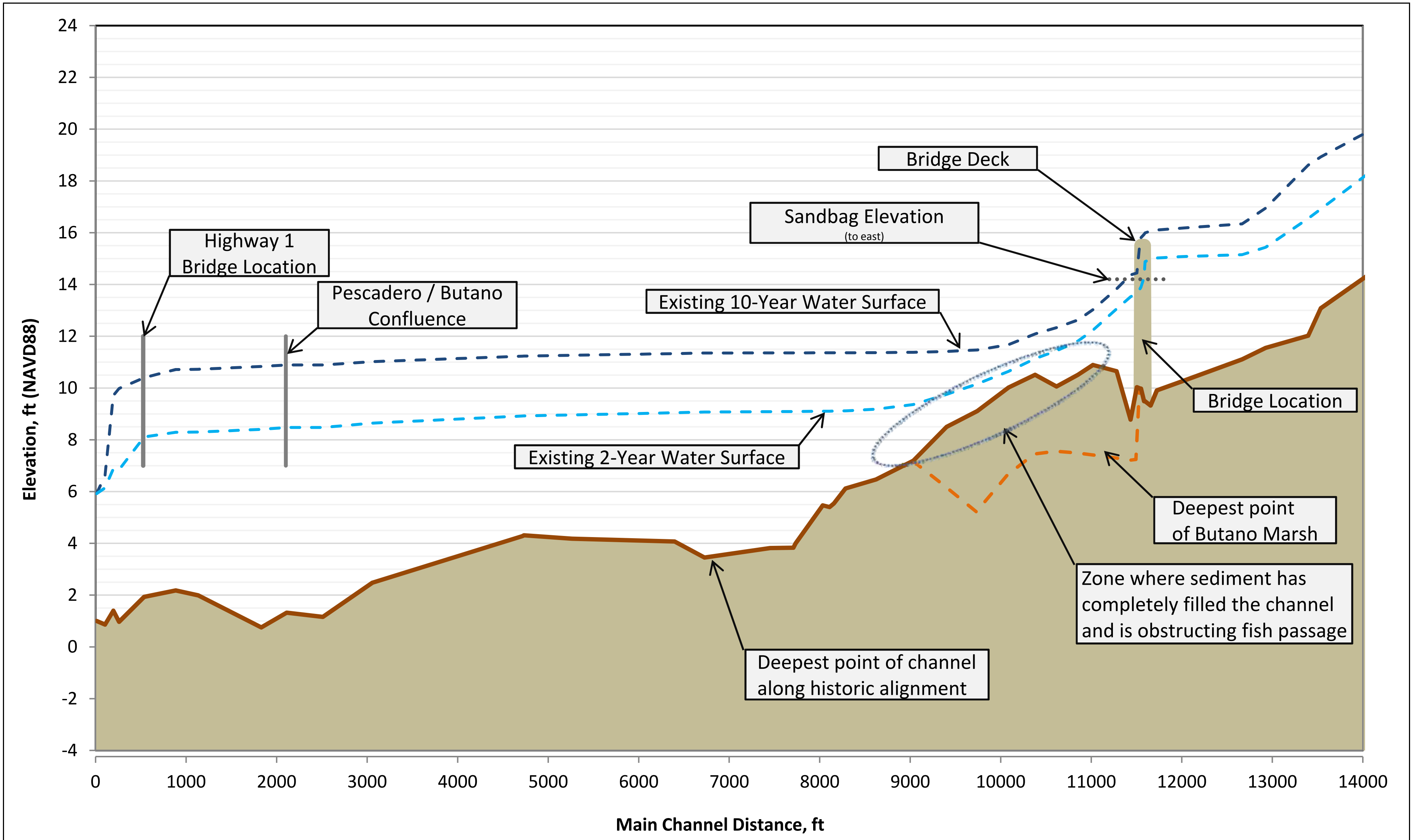


Notes:
Composite topographic surface created using a combination of 2010 LiDAR data and cross section data collected by PWA (2011), WEST (2012), and cbec (2014)

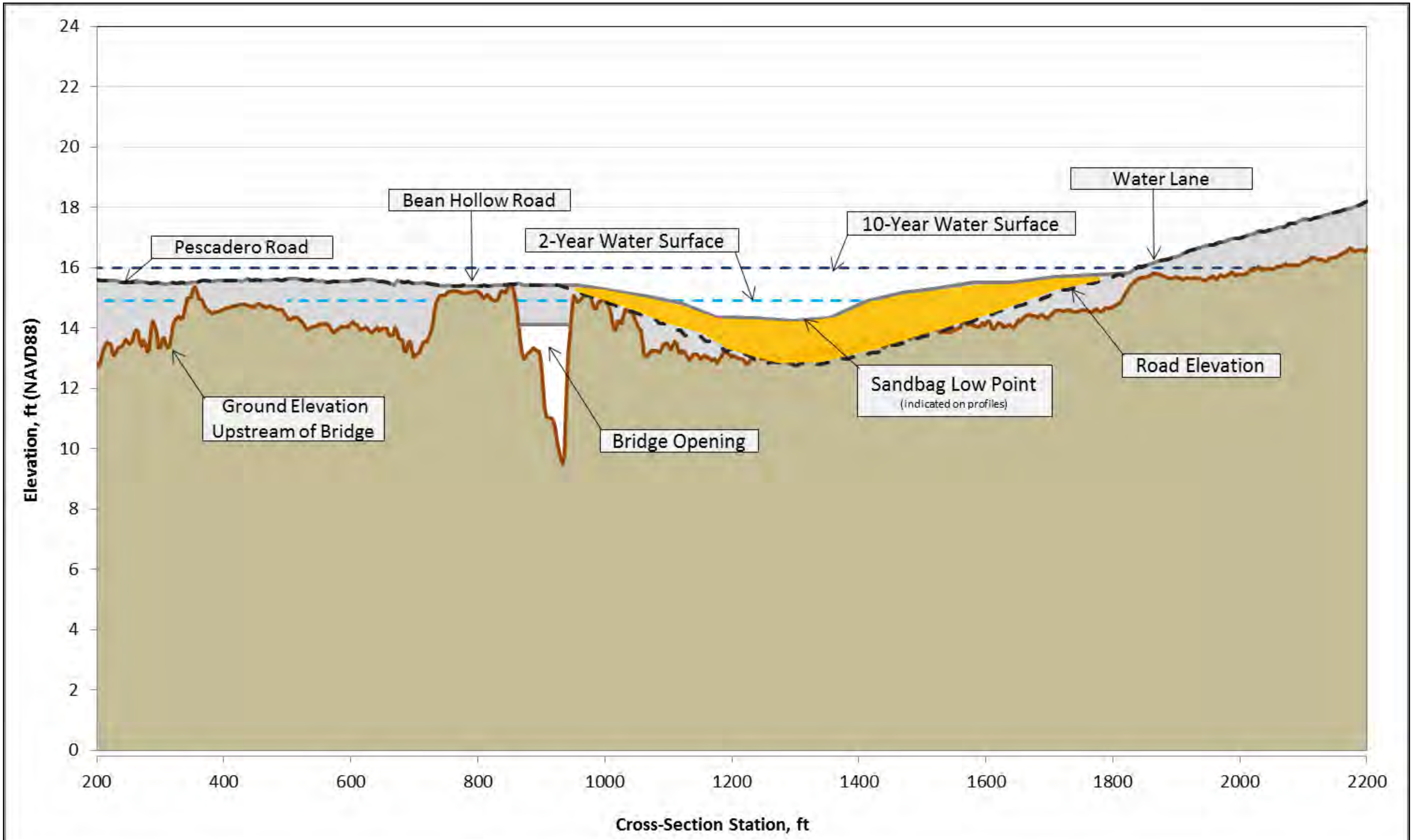
Solutions to Flooding at Pescadero Creek Road

Topography of the project area

Project No. 13-1032 | Created By: DST | **Figure 6**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Existing condition peak water surface profile**		
		Project No. 13-1032	Created By: DM	**Figure 7**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Existing condition cross section of the bridge and adjacent areas**		
		Project No. 13-1032	Created By: DST	**Figure 8**

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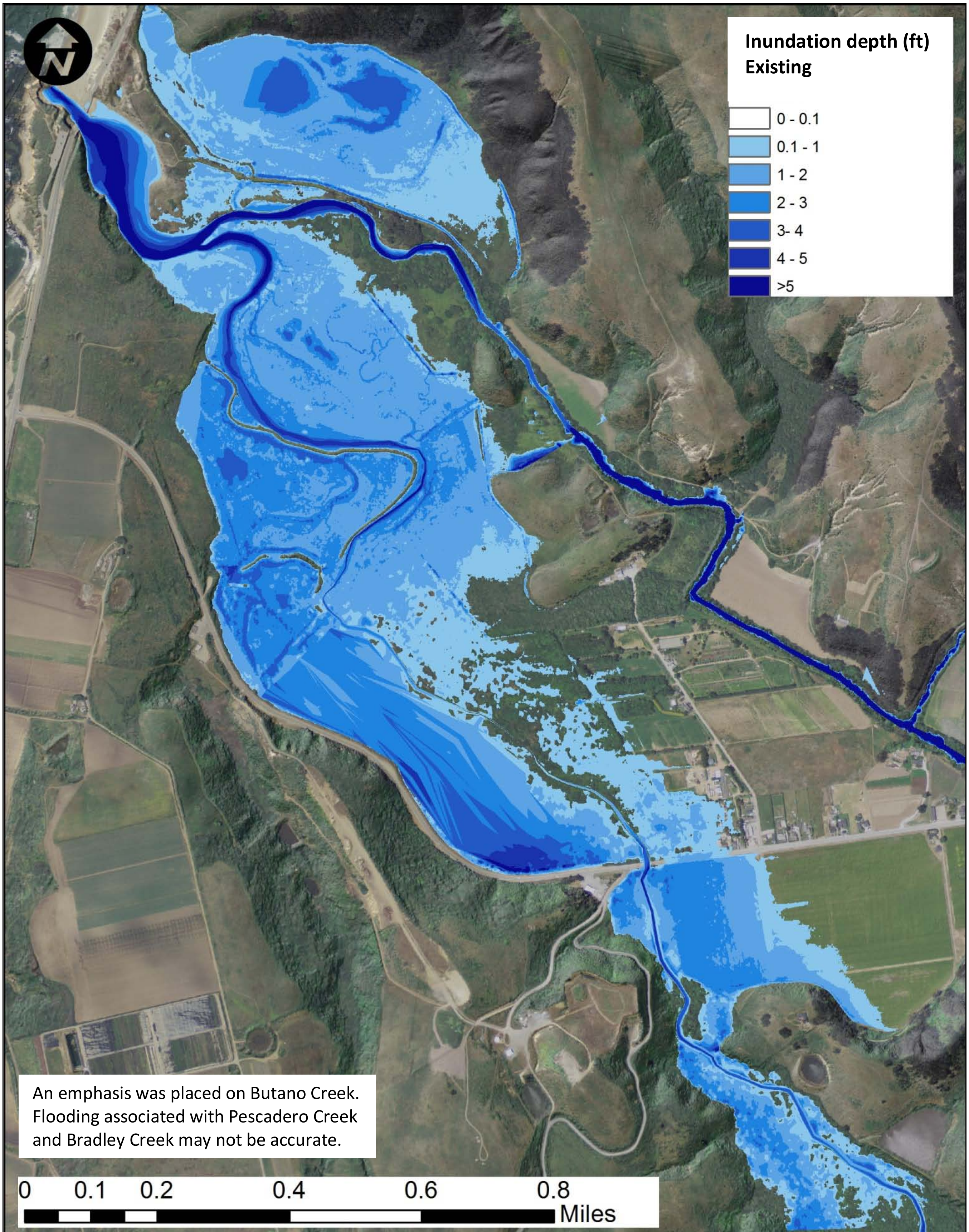
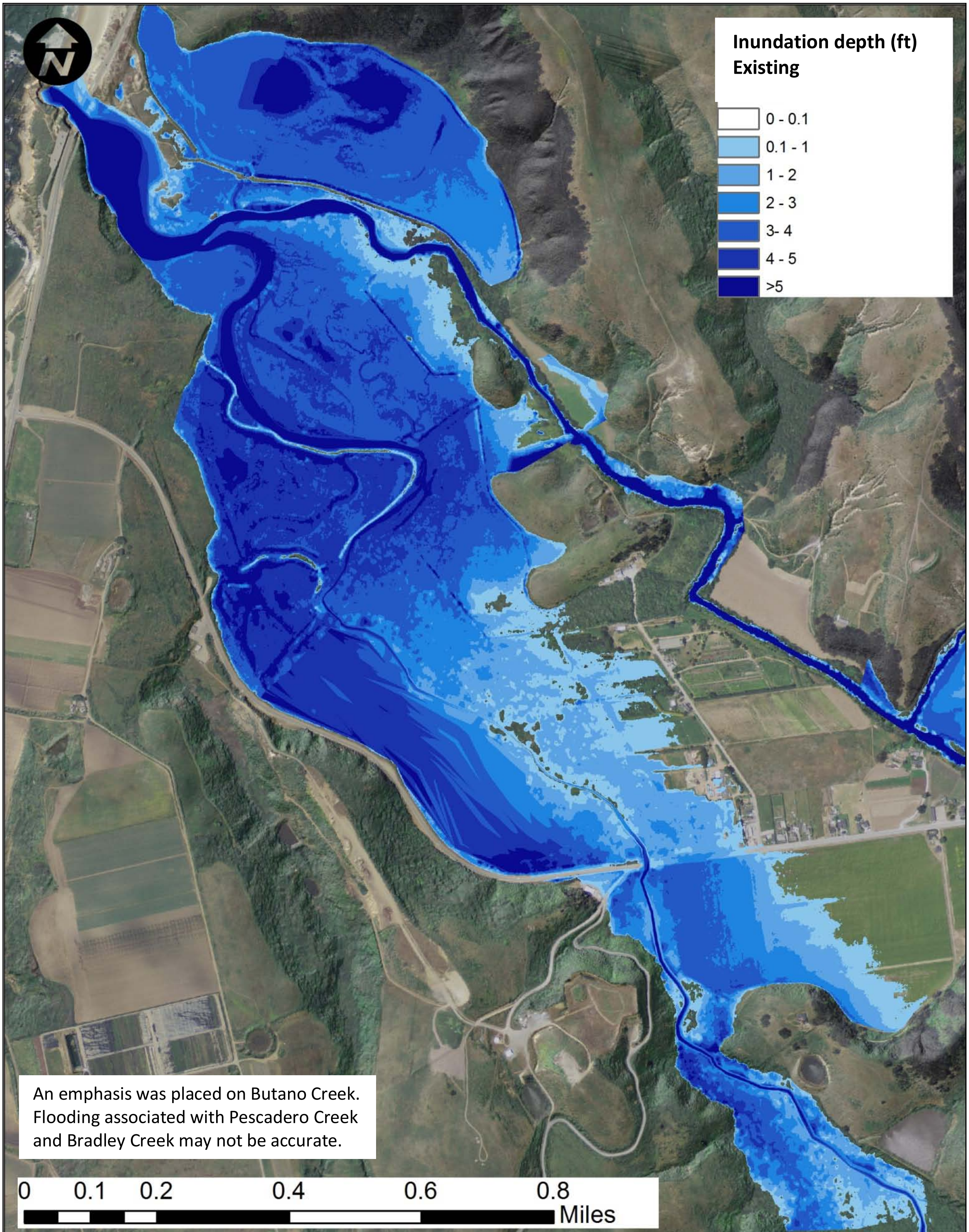
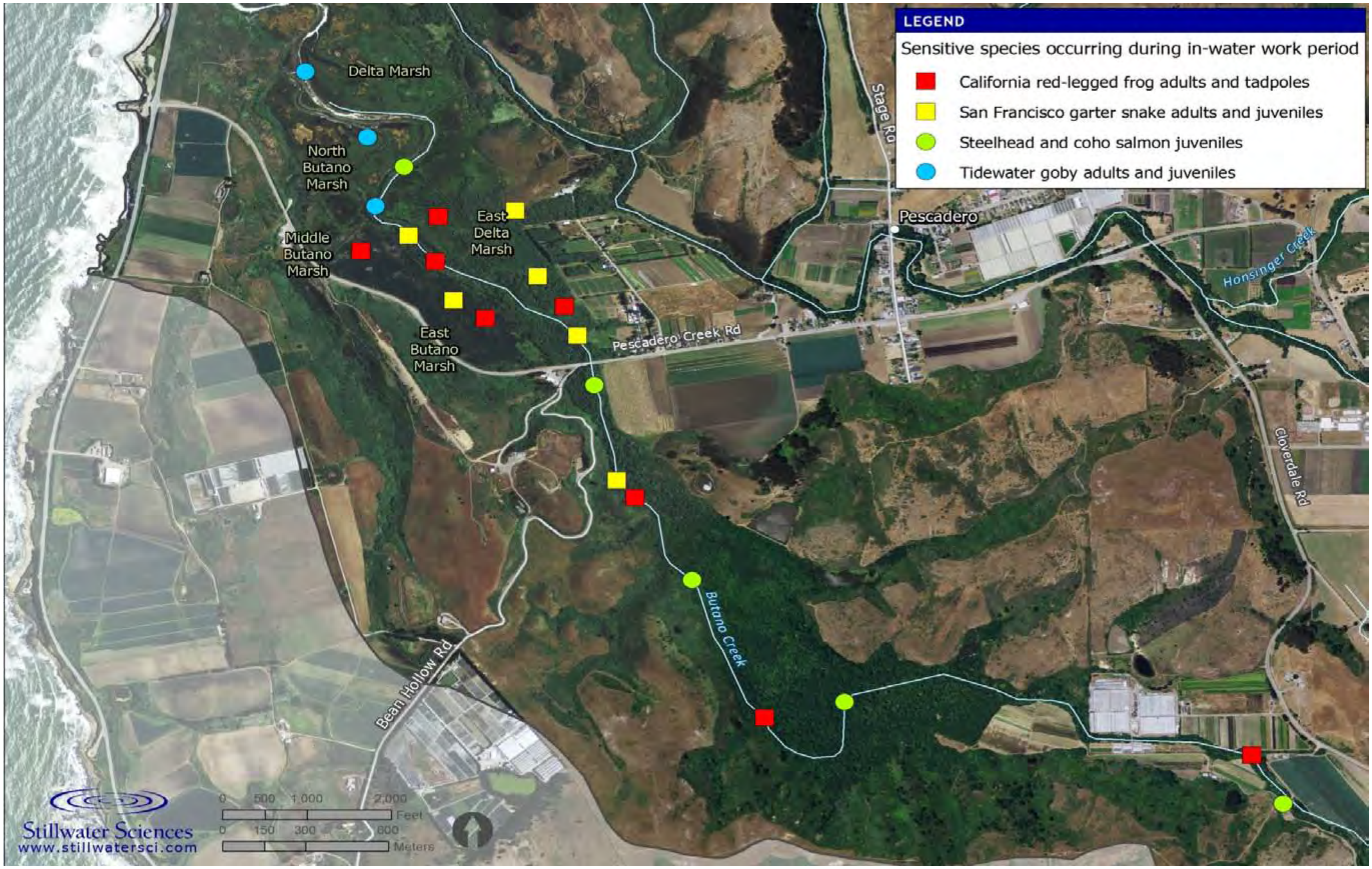


Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Existing condition 2-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 9**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Existing condition 10-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 10**



Notes: Sensitive species occurrence based on the California Natural Diversity Database and other available information	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Distribution of sensitive species in the project area**		
		Project No. 13-1032	Created By: DST	**Figure 11**

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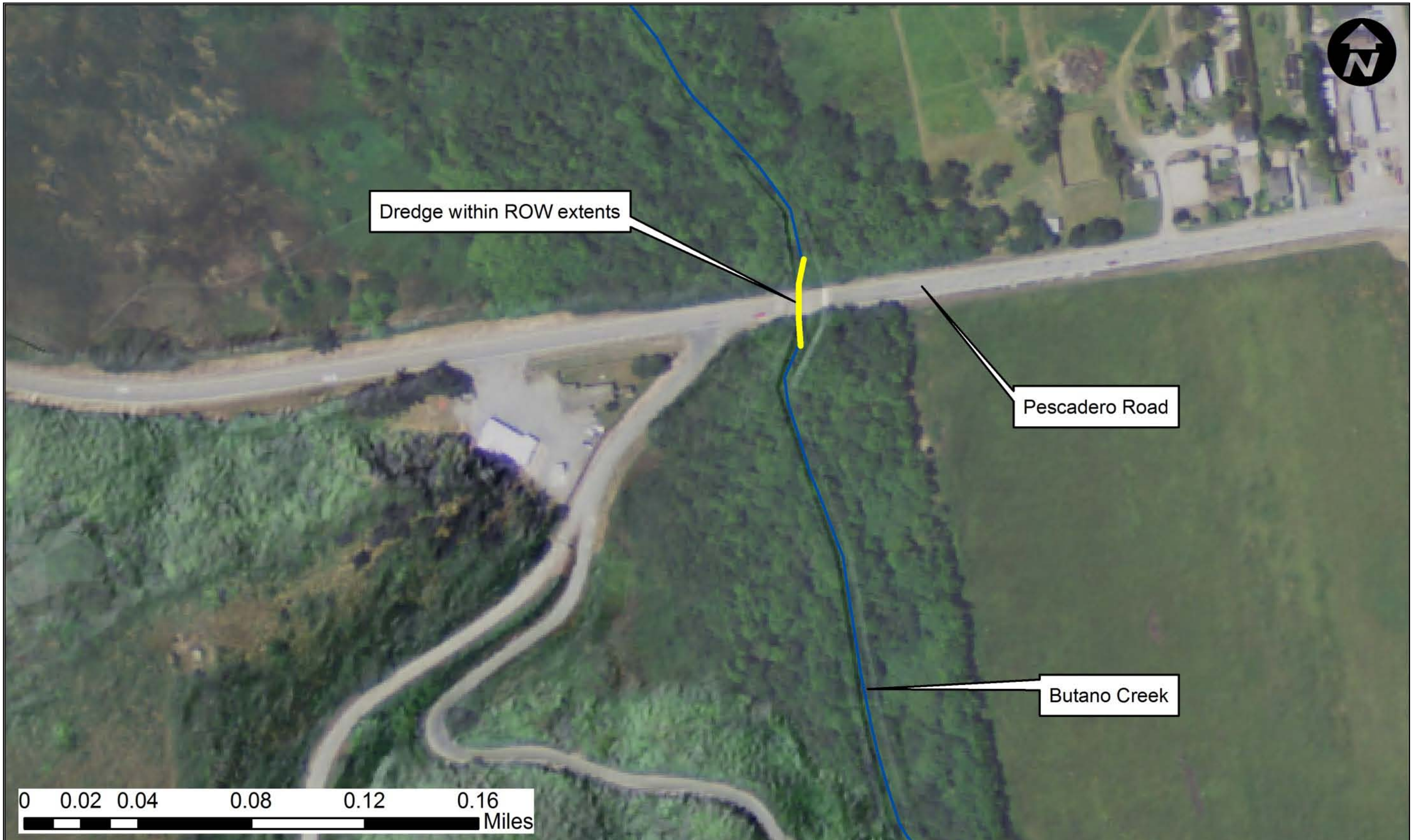
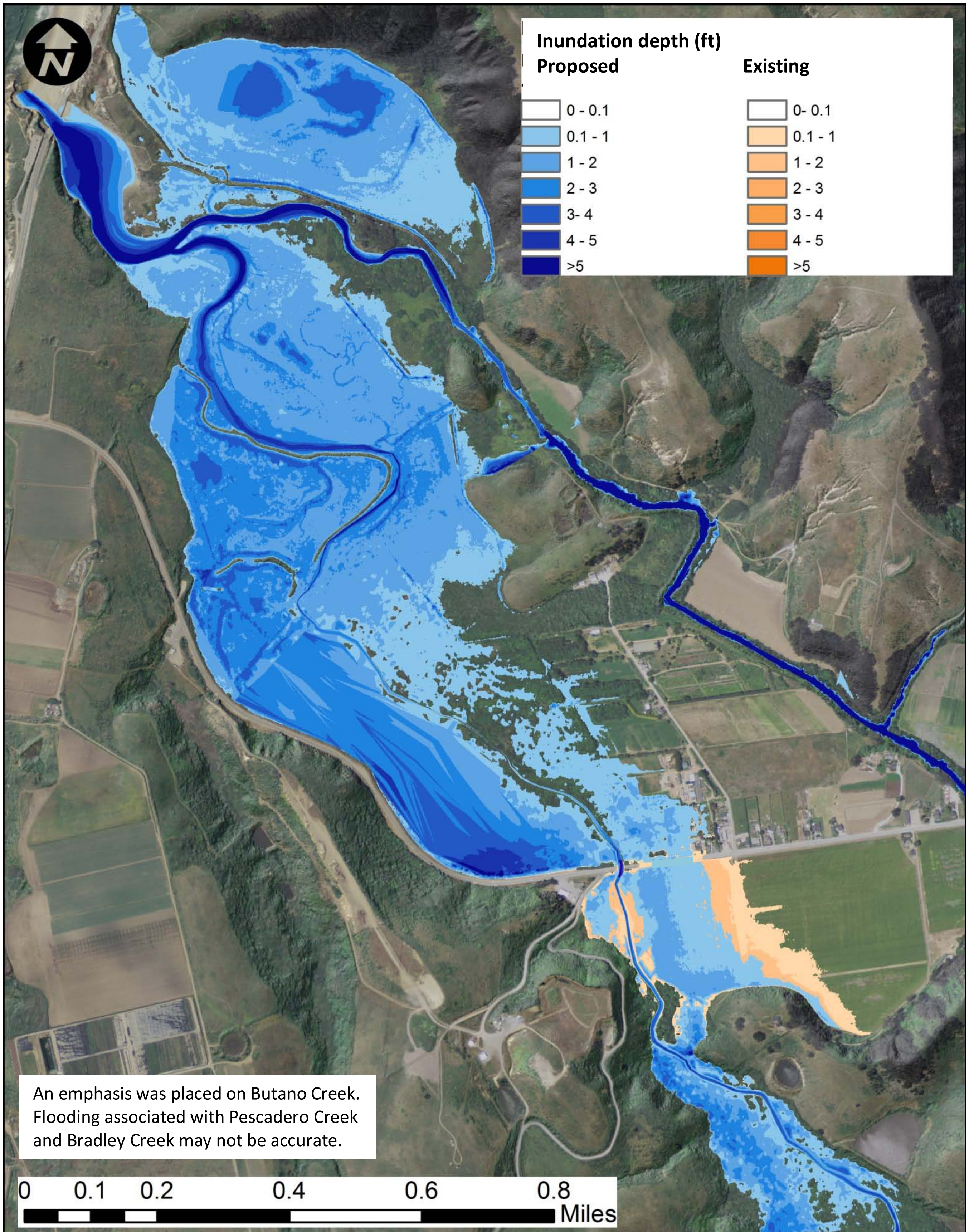


Notes: Background image: NAIP 2012

Solutions to Flooding at Pescadero Creek Road

Dredge within ROW plan view

Project No. 13-1032	Created By: DST	**Figure 12**



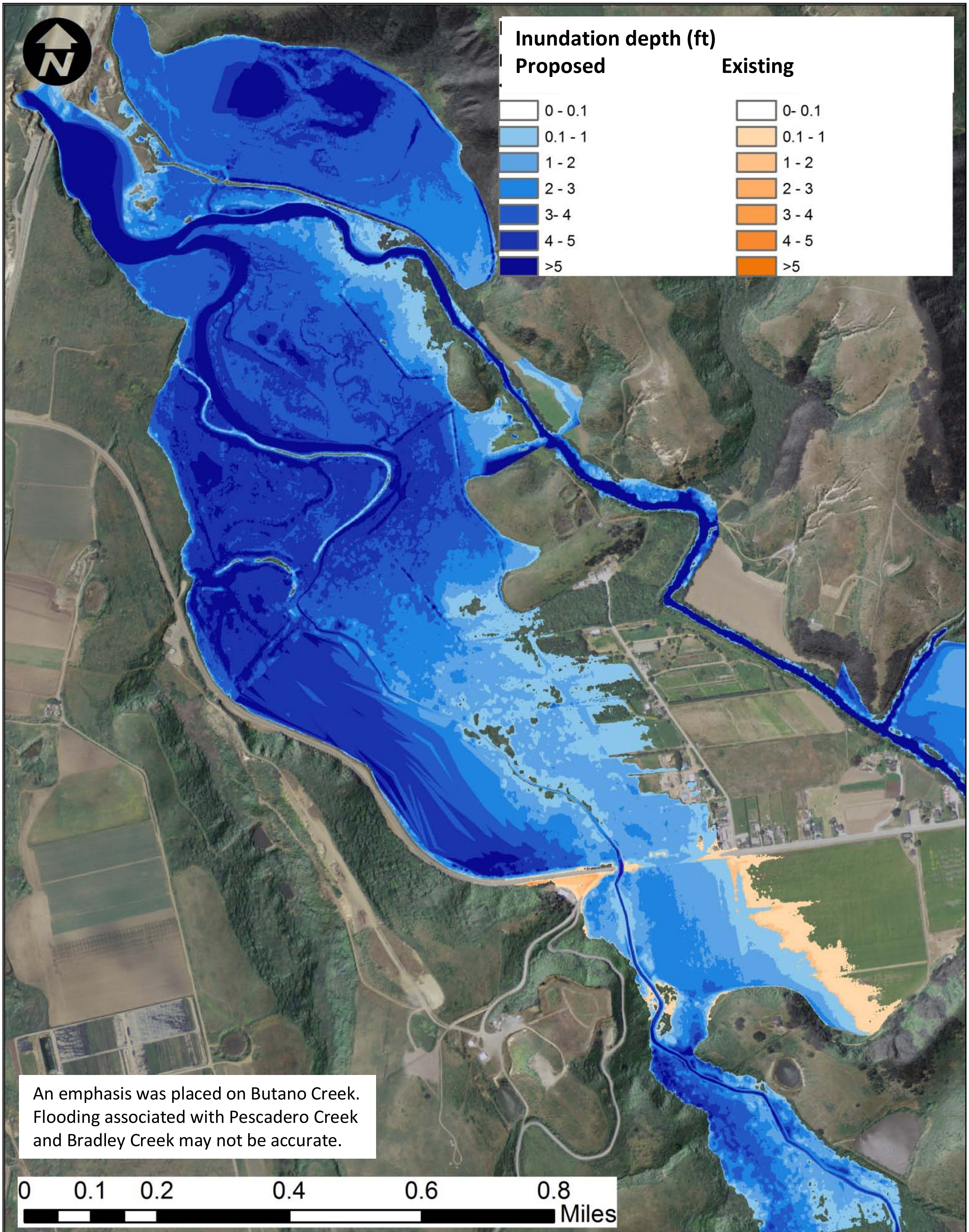
Notes:
Background image source: NAIP 2012

cbec eco engineering

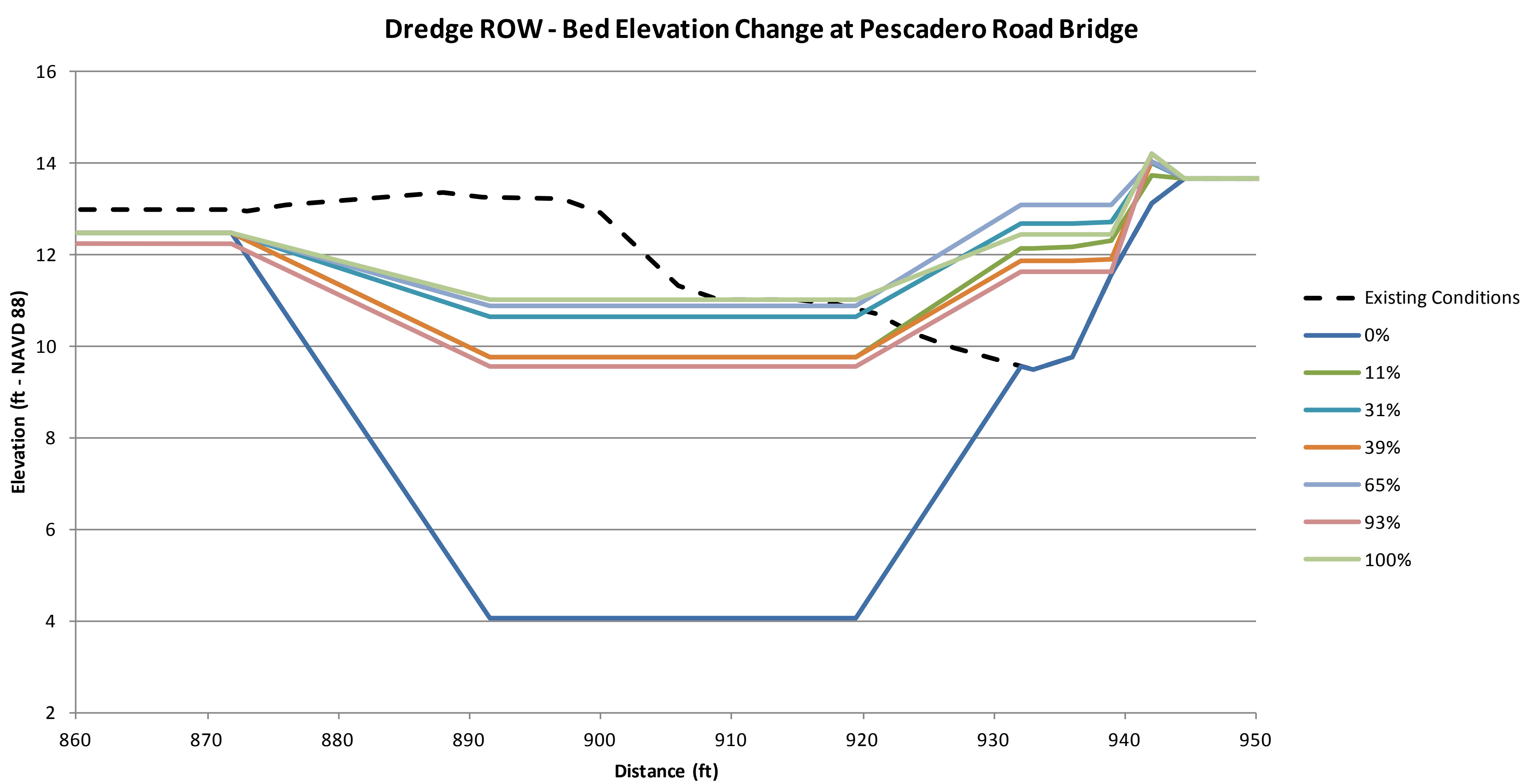
Solutions to Flooding at Pescadero Creek Road

Dredge within ROW 2-yr event inundation

Project No. 13-1032	Created By: DST	**Figure 13**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW 10-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 14**



Notes:		*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW - bridge cross section comparison through sediment transport simulation**		
	cbec eco engineering	Project No. 13-1032	Created By: JS	**Figure 15**

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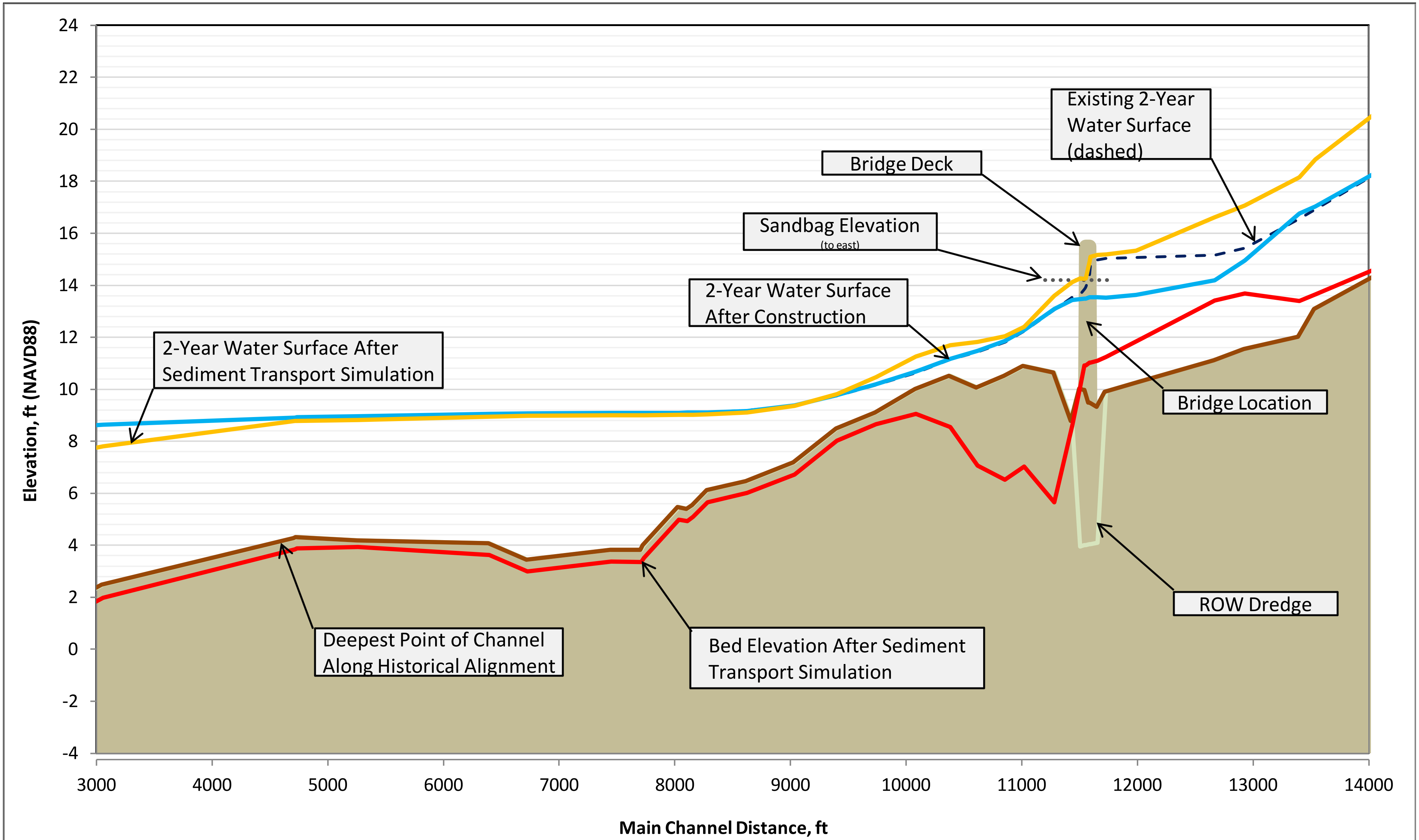
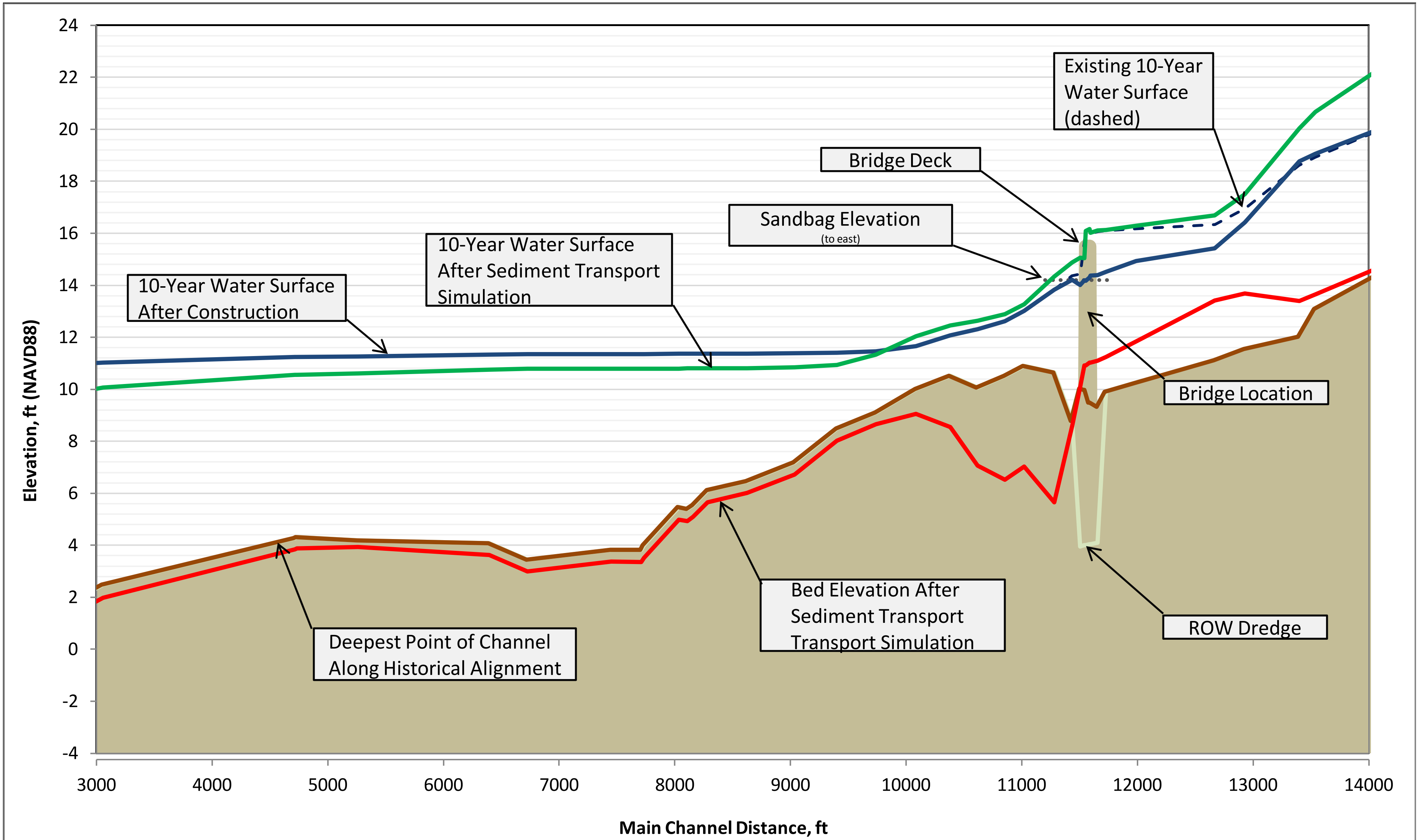


Notes:

Solutions to Flooding at Pescadero Creek Road

Dredge within ROW 2-yr water surface profiles

Project No. 13-1032	Created By: DST	**Figure 16**



Notes:	cbec	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW 10-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 17**

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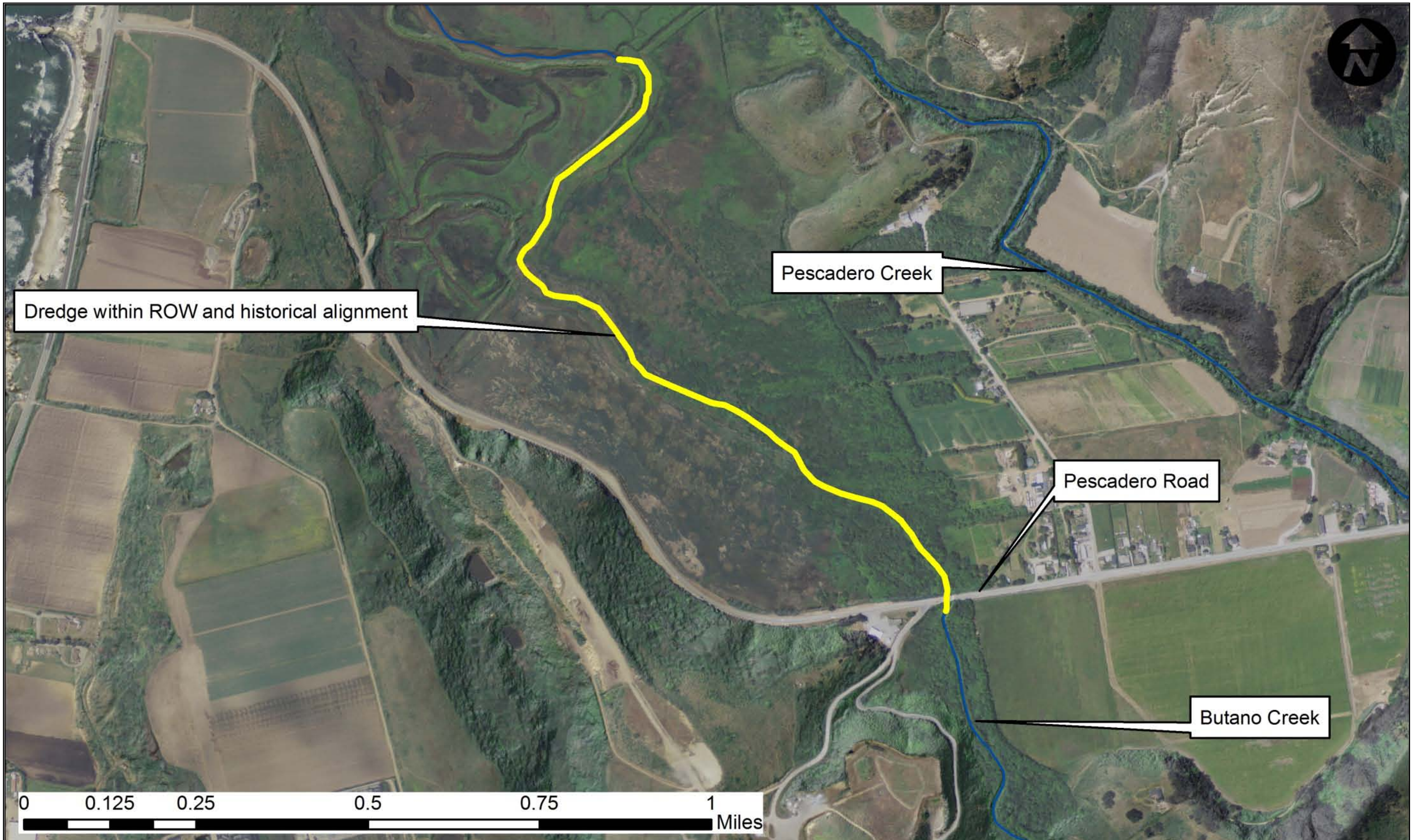
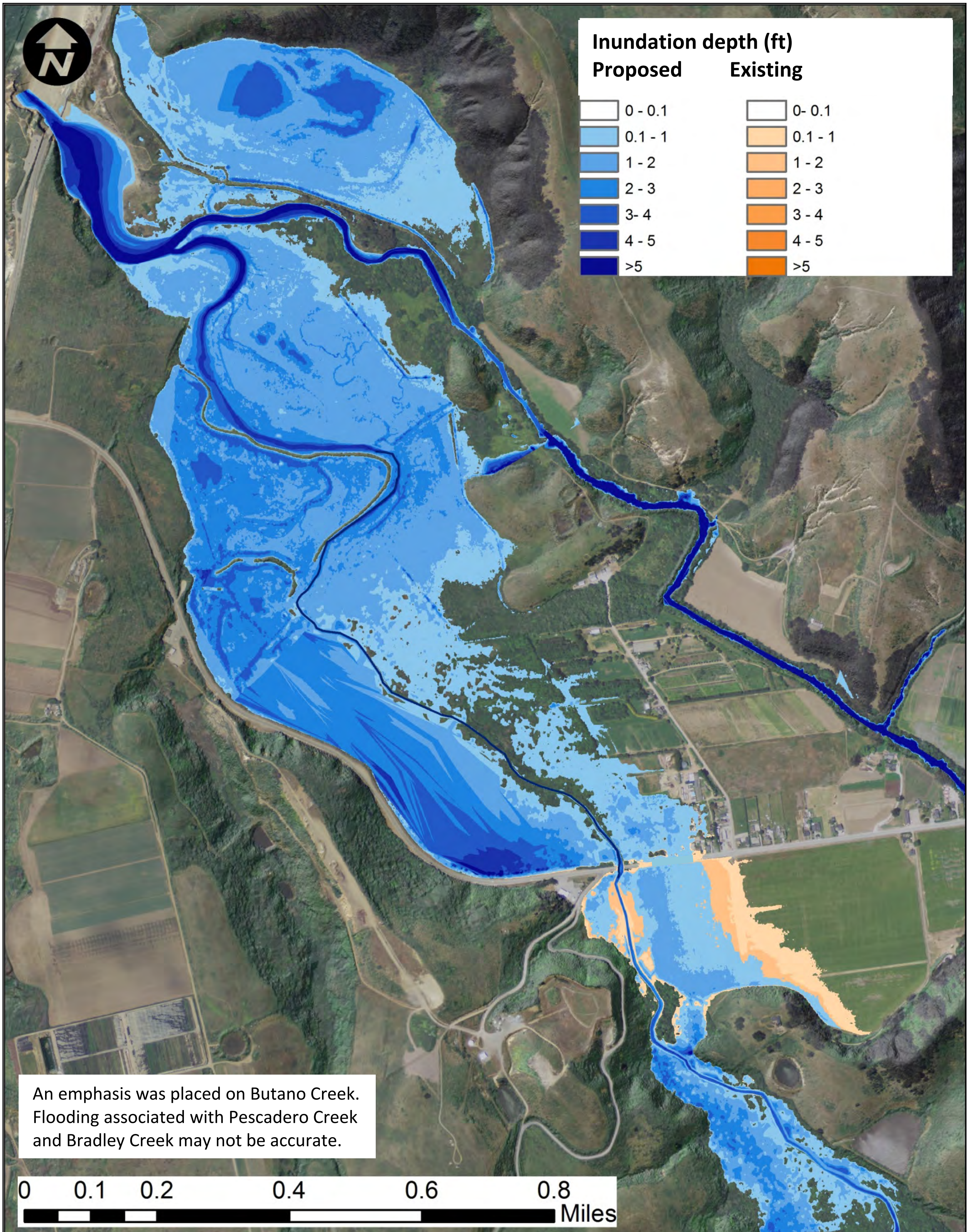


Notes: Background image: NAIP 2012

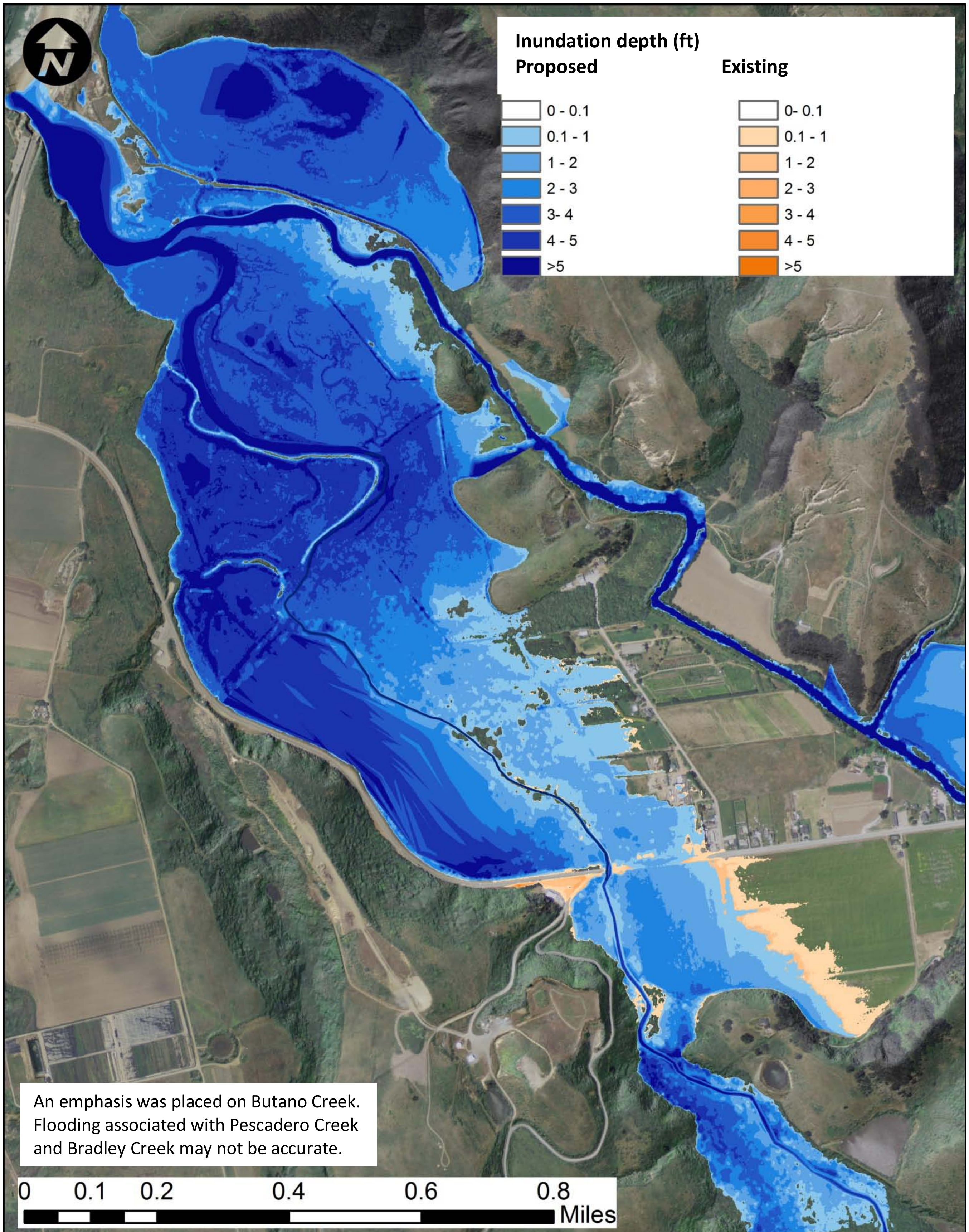
Solutions to Flooding at Pescadero Creek Road

Dredge within ROW and historical alignment plan view

Project No. 13-1032	Created By: DST	**Figure 18**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and historical alignment 2-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 19**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and historical alignment 10-yr event inundation**		
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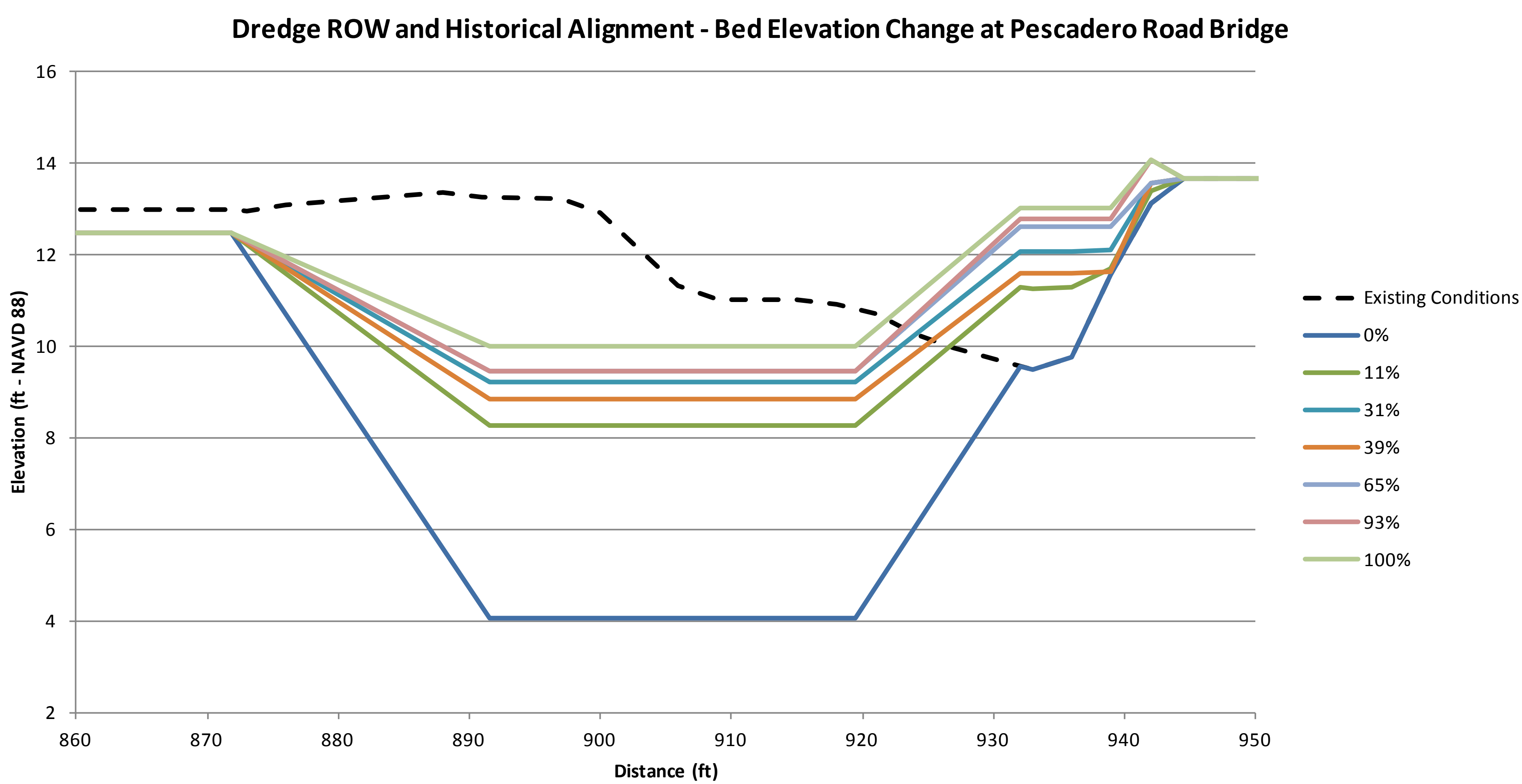

Notes:		*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and historical alignment - bridge cross section comparison through sediment transport simulation**		
		Project No. 13-1032	Created By: JS	**Figure 21**

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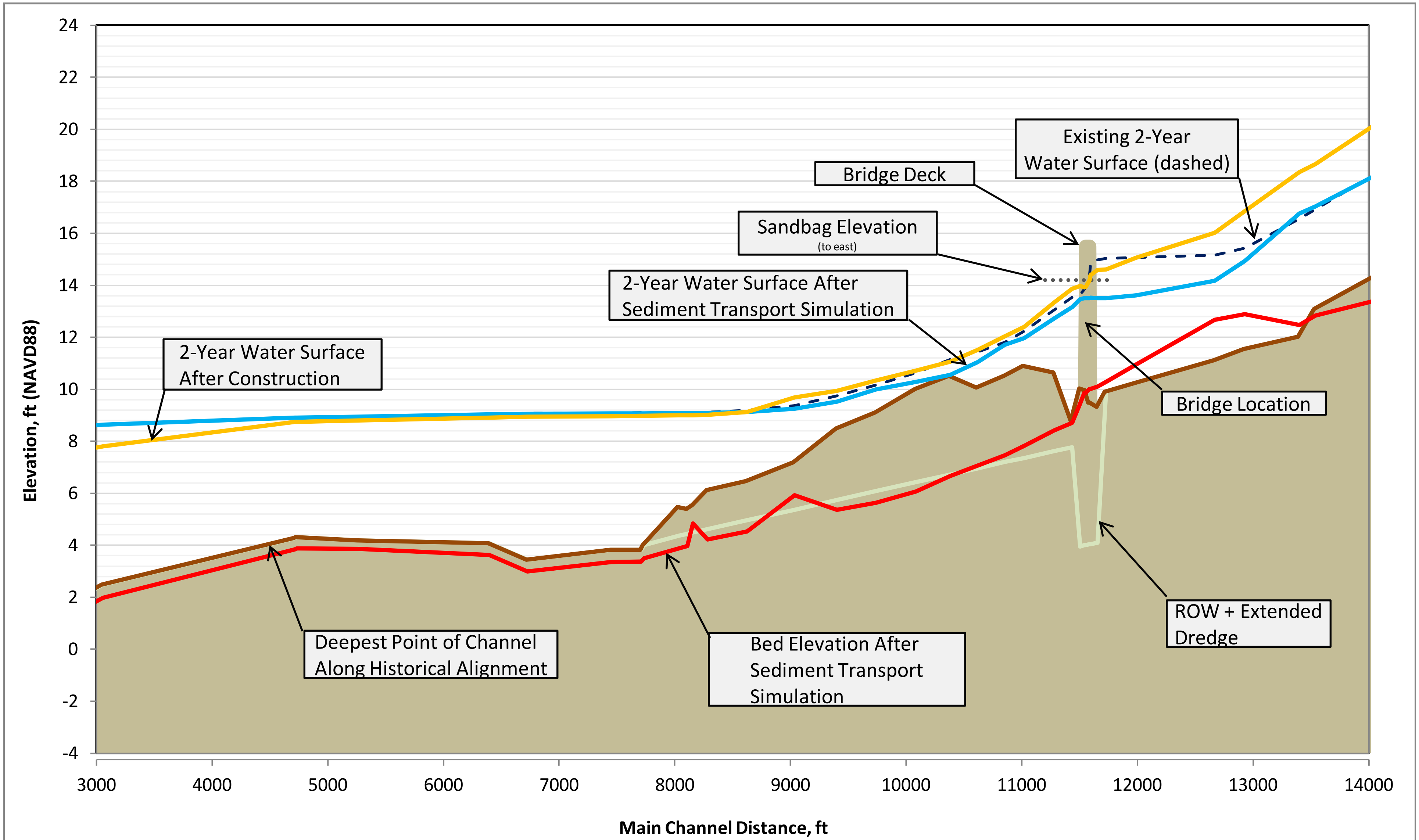
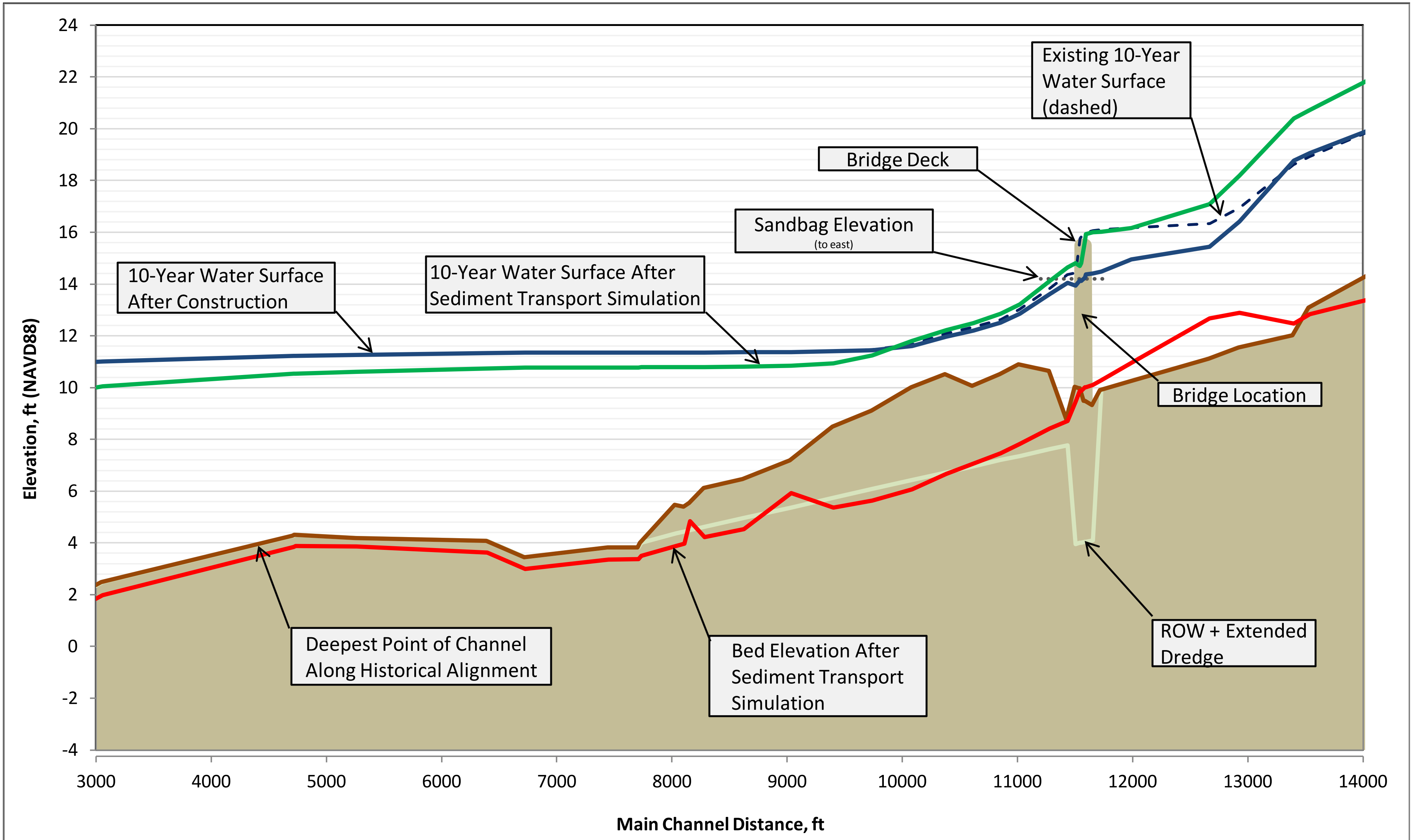


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and historical alignment 2-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 22**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and historical alignment 10-yr water surface profiles**		
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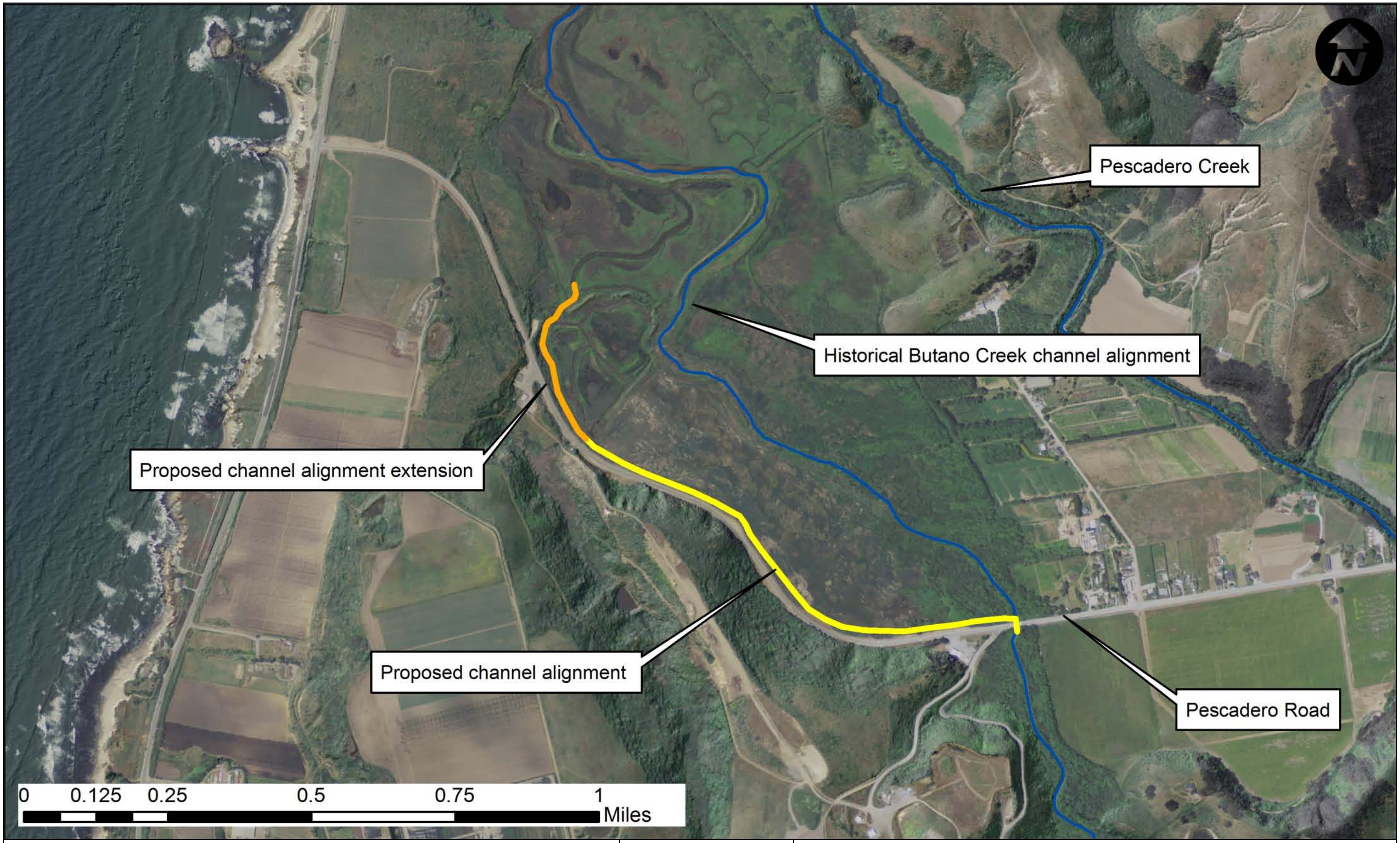
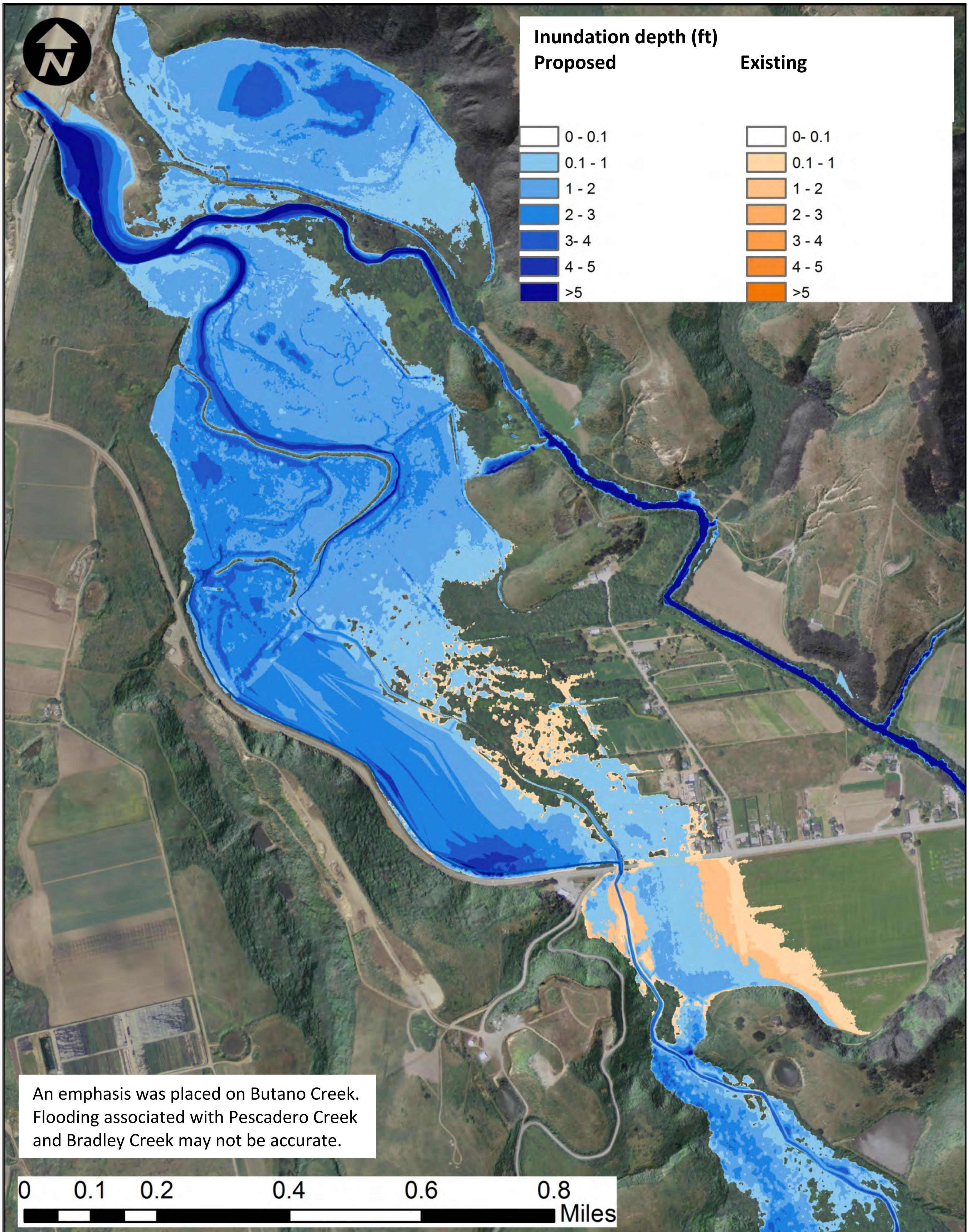


Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and marsh alignment plan view**
		Project No. 13-1032 · Created By: DST · **Figure 24**



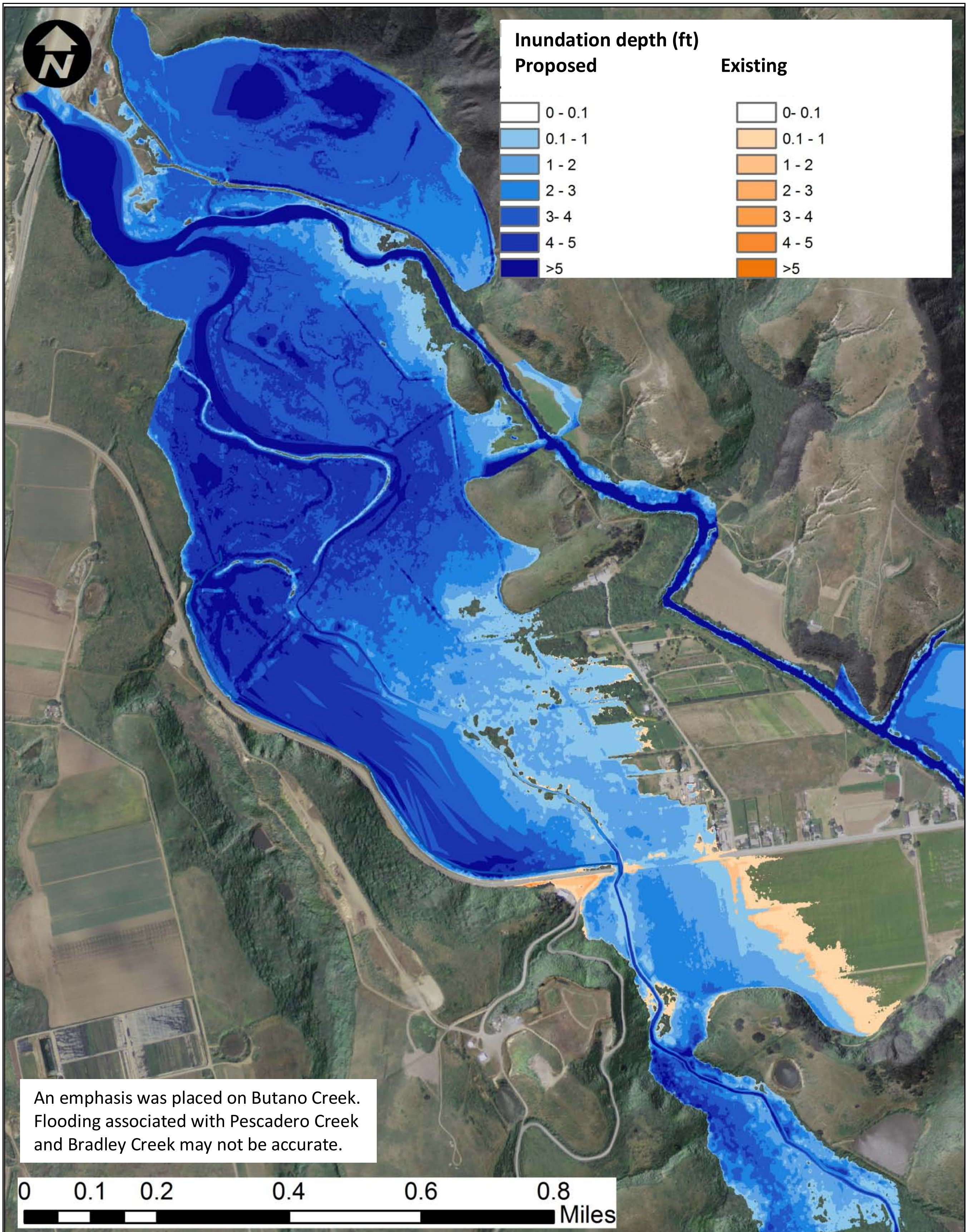
Notes:
Background image source: NAIP 2012

cbec eco engineering

Solutions to Flooding at Pescadero Creek Road

Dredge within ROW and marsh alignment 2-yr event inundation

Project No. 13-1032 | Created By: DST | **Figure 25**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and marsh alignment 10-yr event inundation**		
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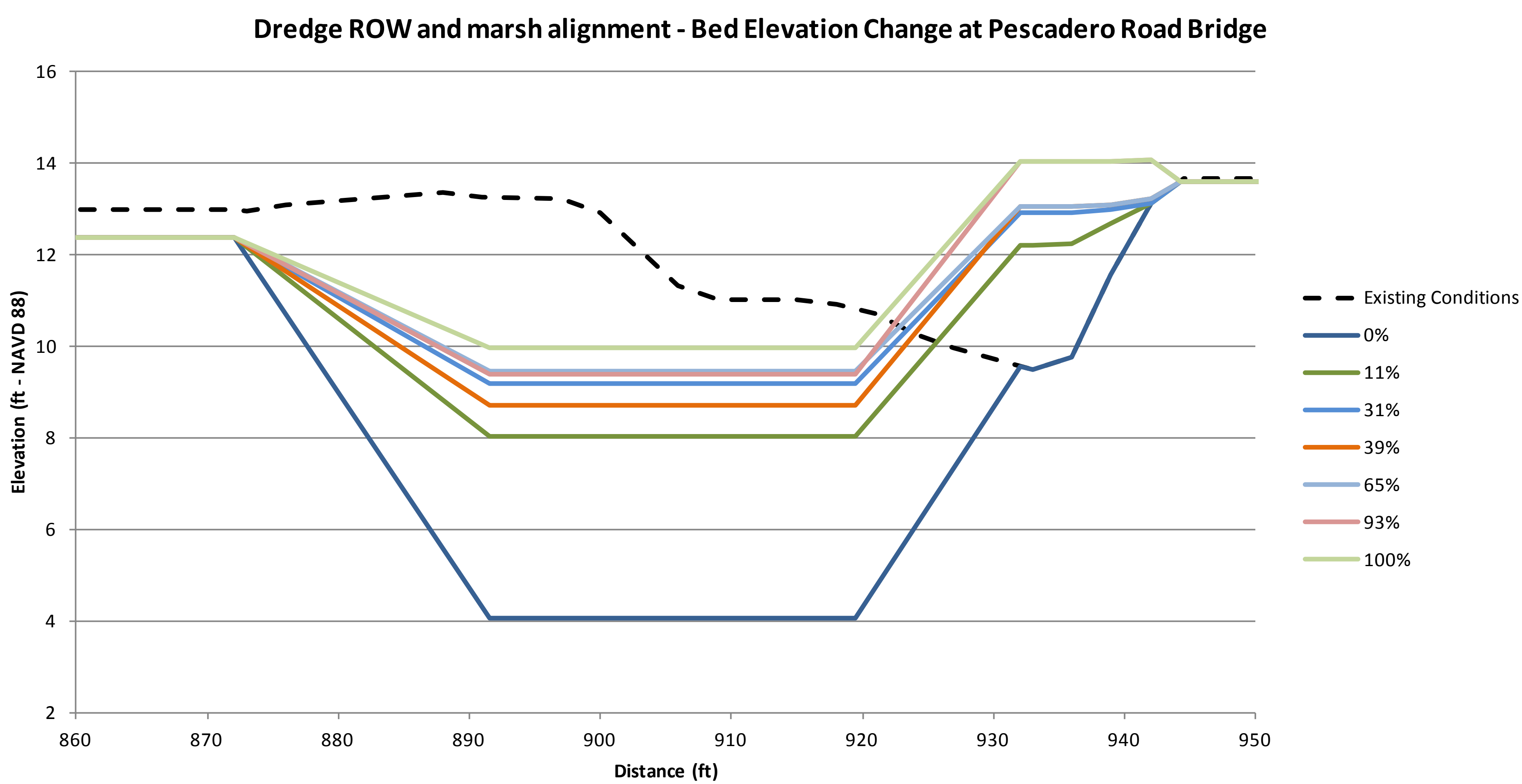

Notes:		*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and marsh alignment - bridge cross section comparison through sediment transport simulation**		
		Project No. 13-1032	Created By: DM	**Figure 27**

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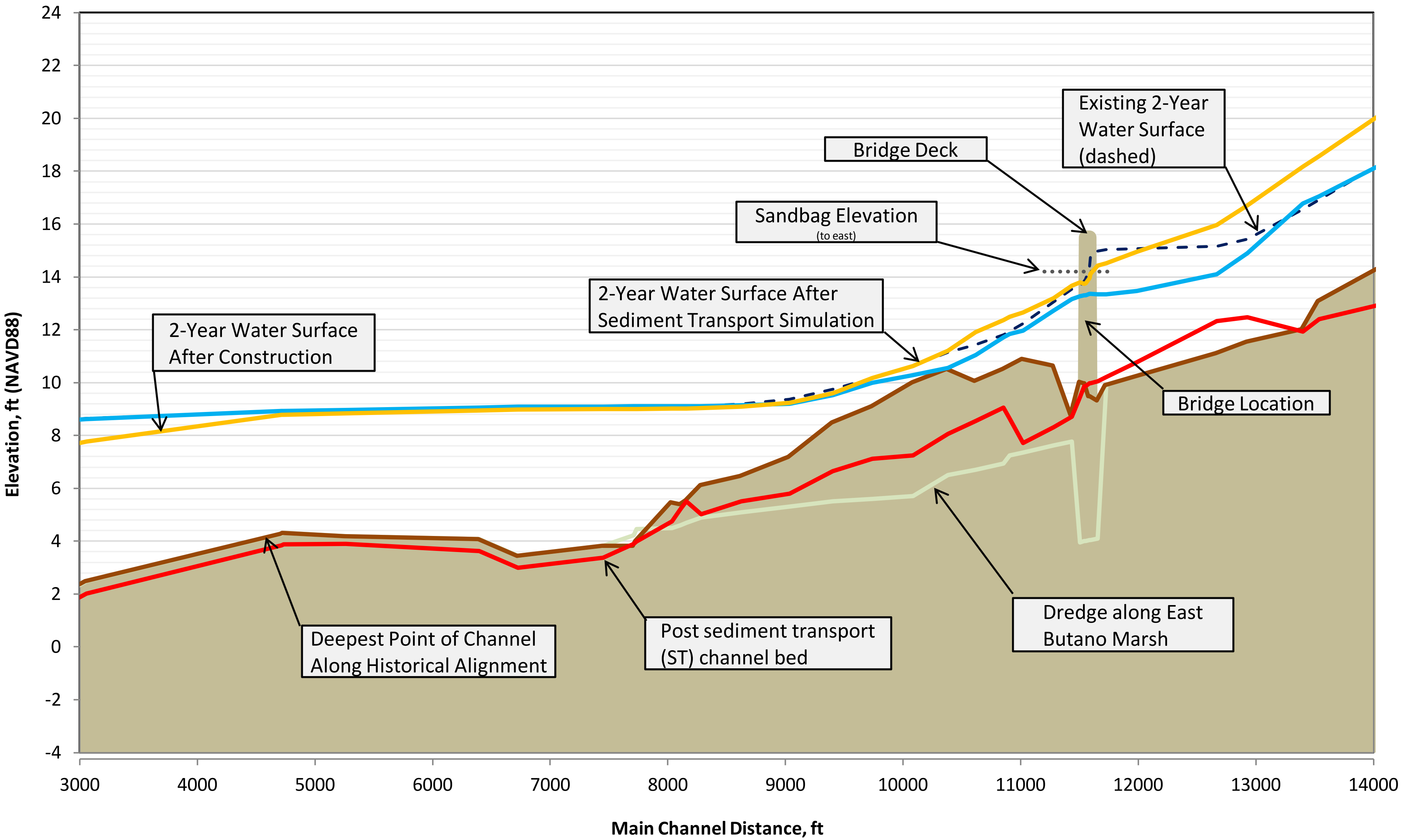
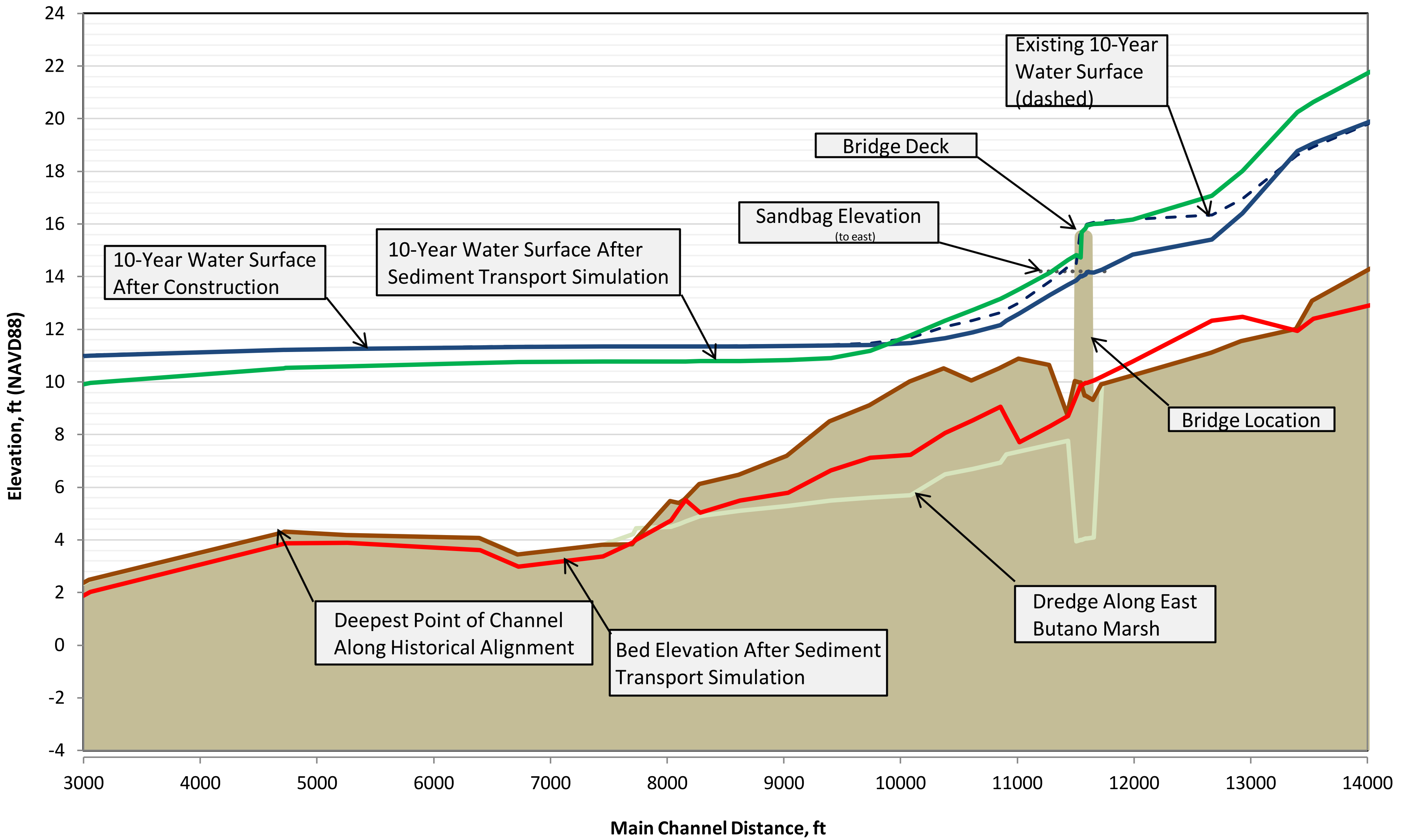
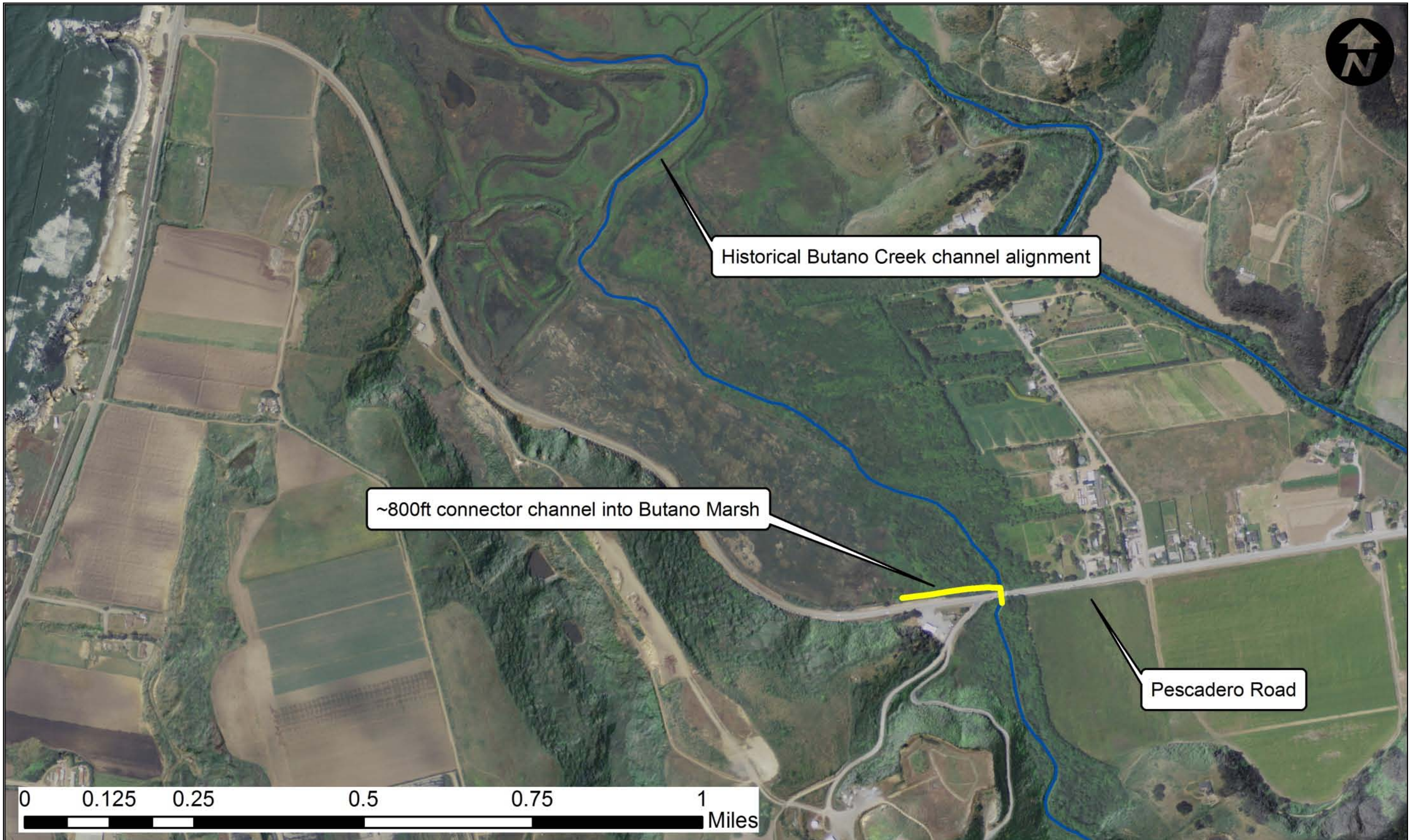


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and marsh alignment 2-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 28**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and marsh alignment 10-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 29**



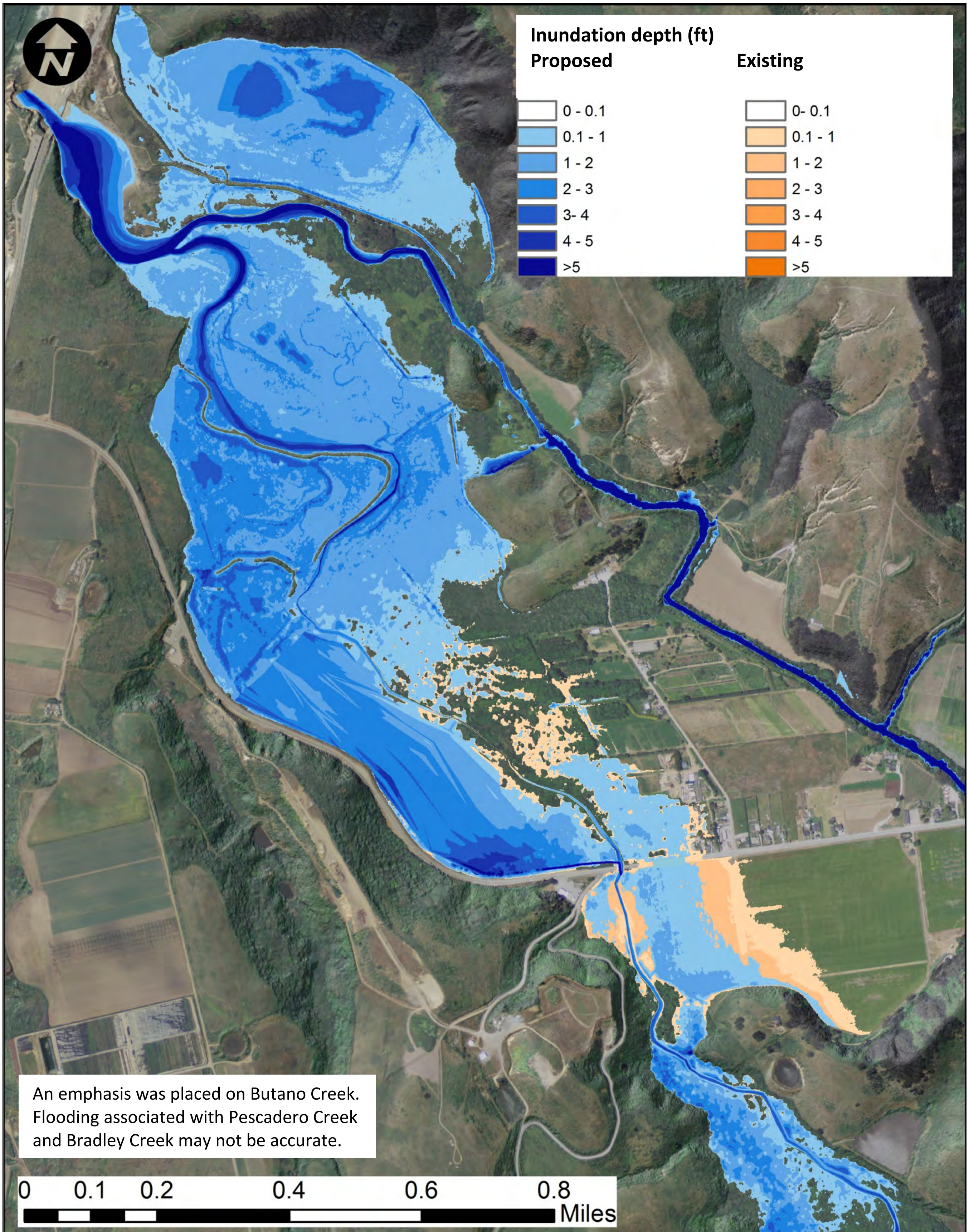
Notes: Background image: NAIP 2012

cbec eco engineering

Solutions to Flooding at Pescadero Creek Road

Dredge within ROW and ~800 ft channel into marsh plan view

Project No. 13-1032	Created By: DST	**Figure 30**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and ~800 ft channel into marsh 2-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 31**

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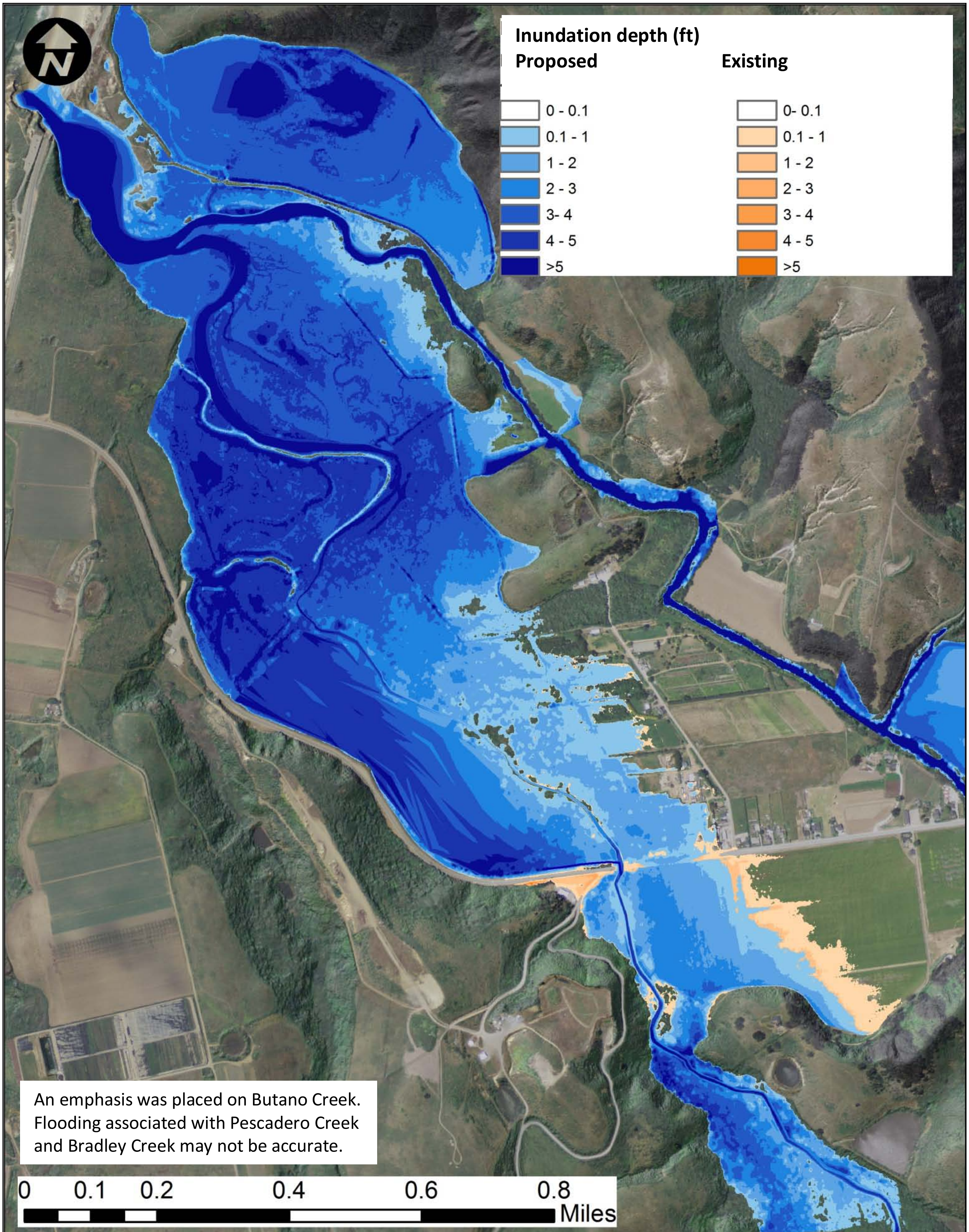

Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and ~800 ft channel into marsh 10-yr event inundation**	
		Project No. 13-1032	Created By: DST
		Figure 32	

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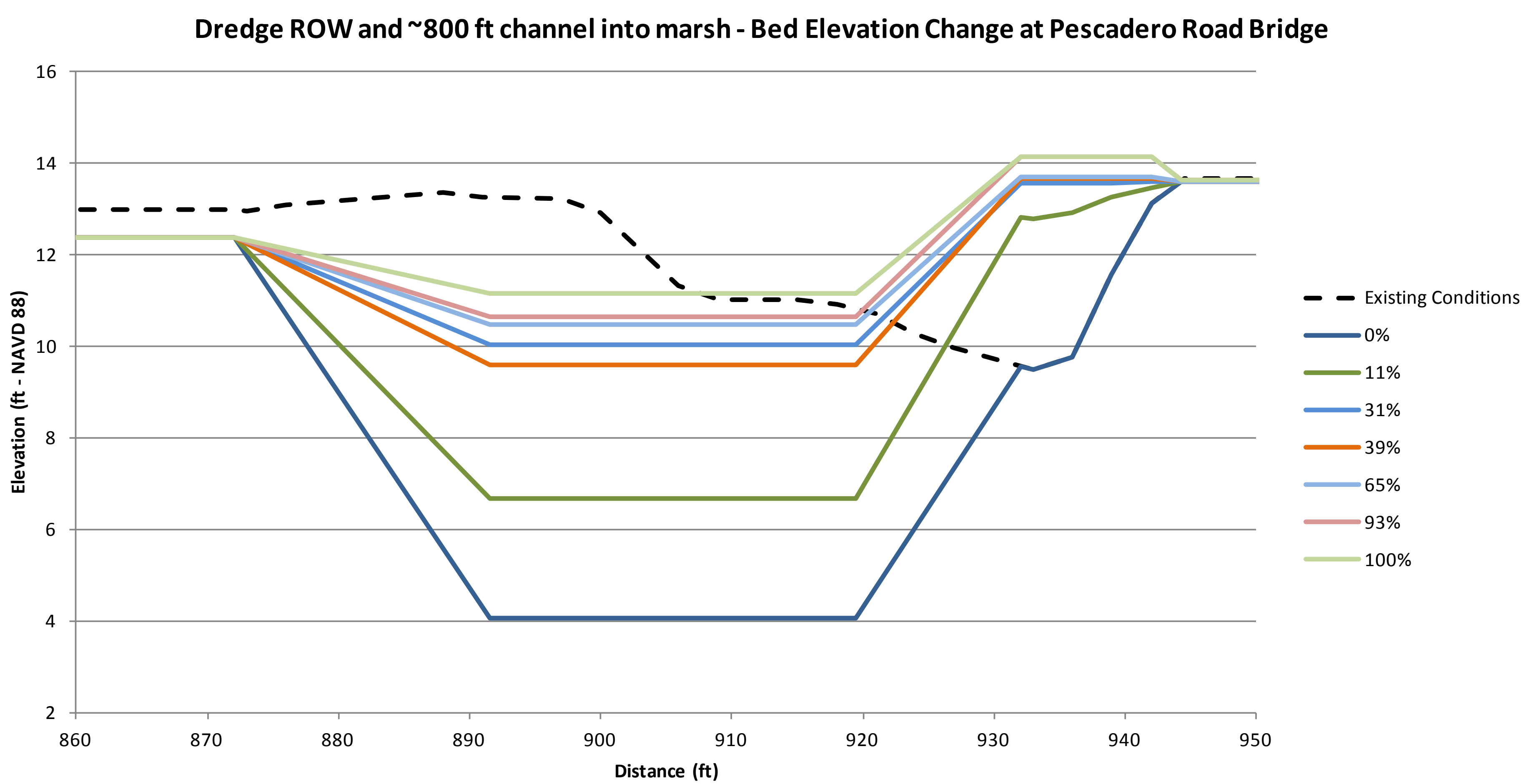

Notes:

Solutions to Flooding at Pescadero Creek Road

Dredge within ROW and ~800 ft channel into marsh - cross section comparison through sediment transport simulation

Project No. 13-1032	Created By: JS	**Figure 33**

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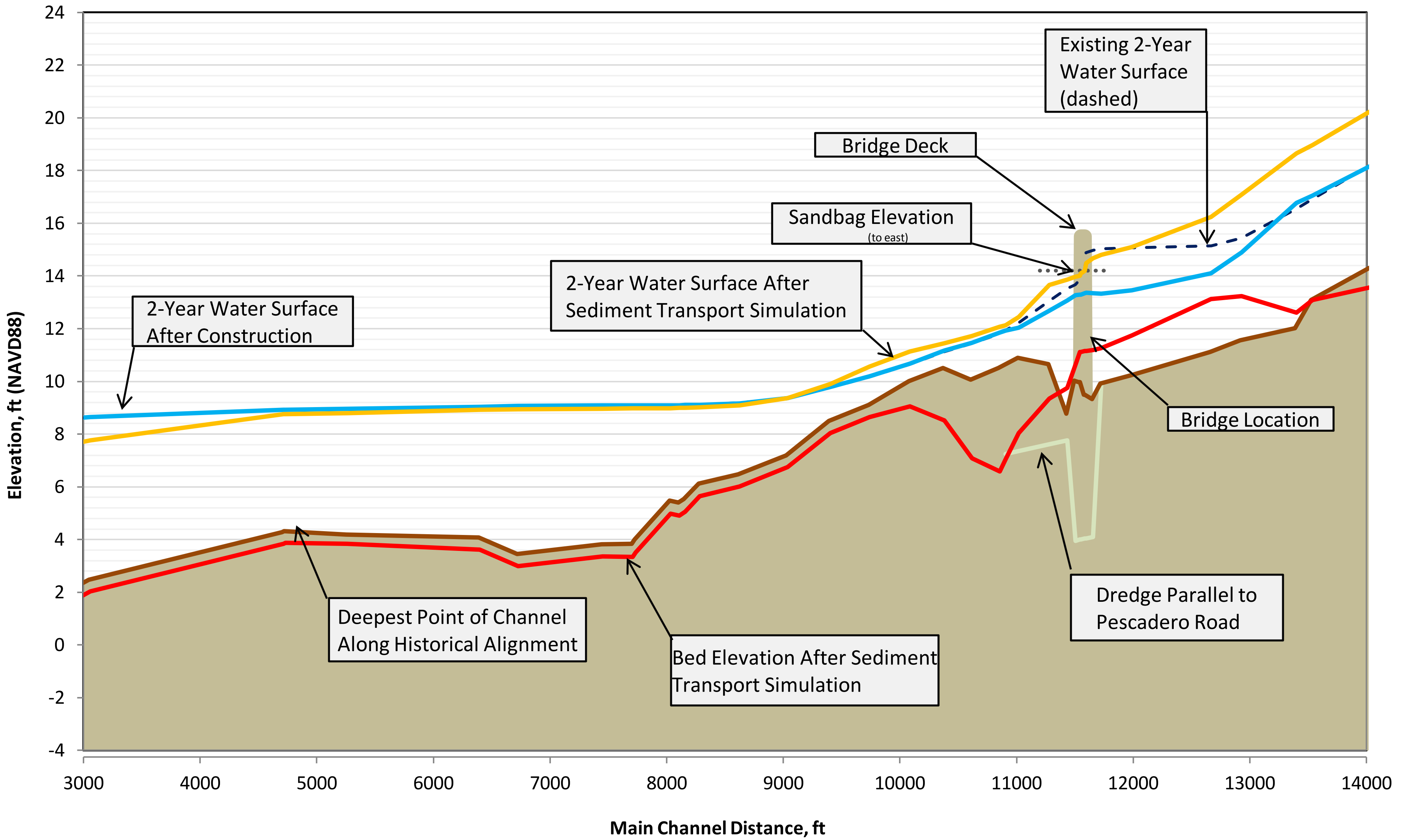
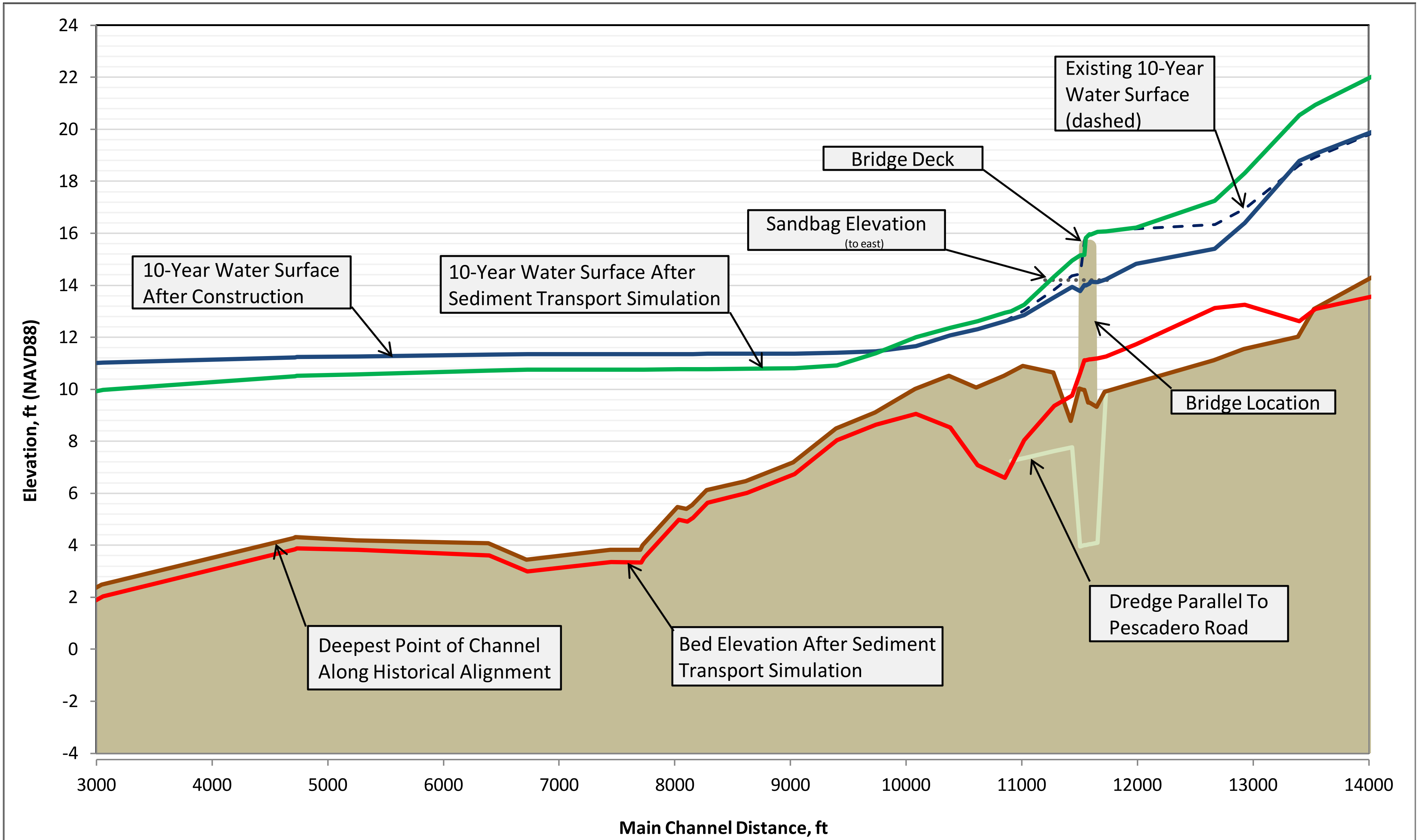
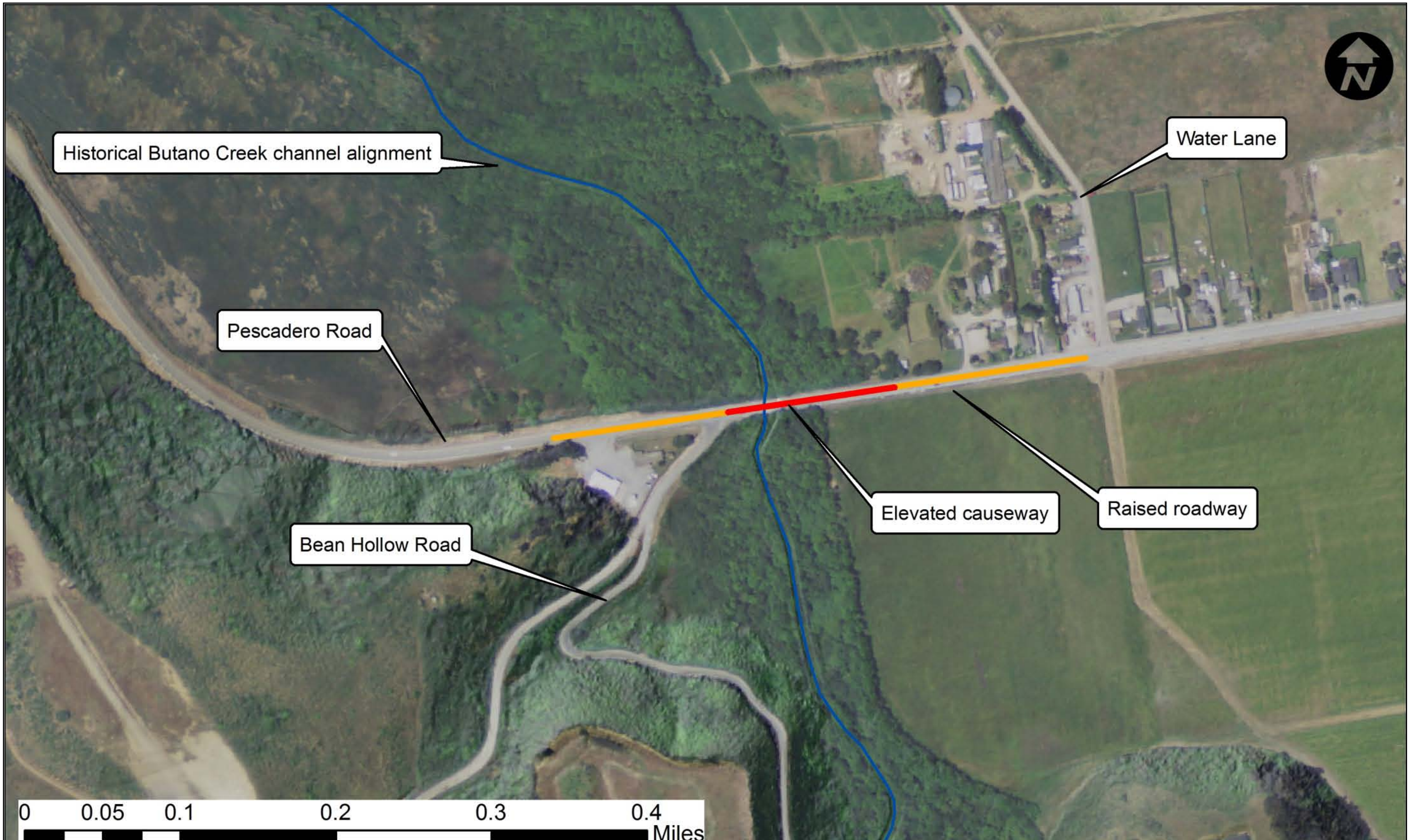


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and ~800 ft channel into marsh 2-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 34**

R:\Projects\13-1032_Pescadero\Reporting\Figures\Fig34_Shortconnector_2yrProfile.docx
10/17/2014



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Dredge within ROW and ~800 ft channel into marsh 10-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 35**



Notes: Background image: NAIP 2012

Solutions to Flooding at Pescadero Creek Road

Causeway plan view

Project No. 13-1032	Created By: DST	**Figure 36**

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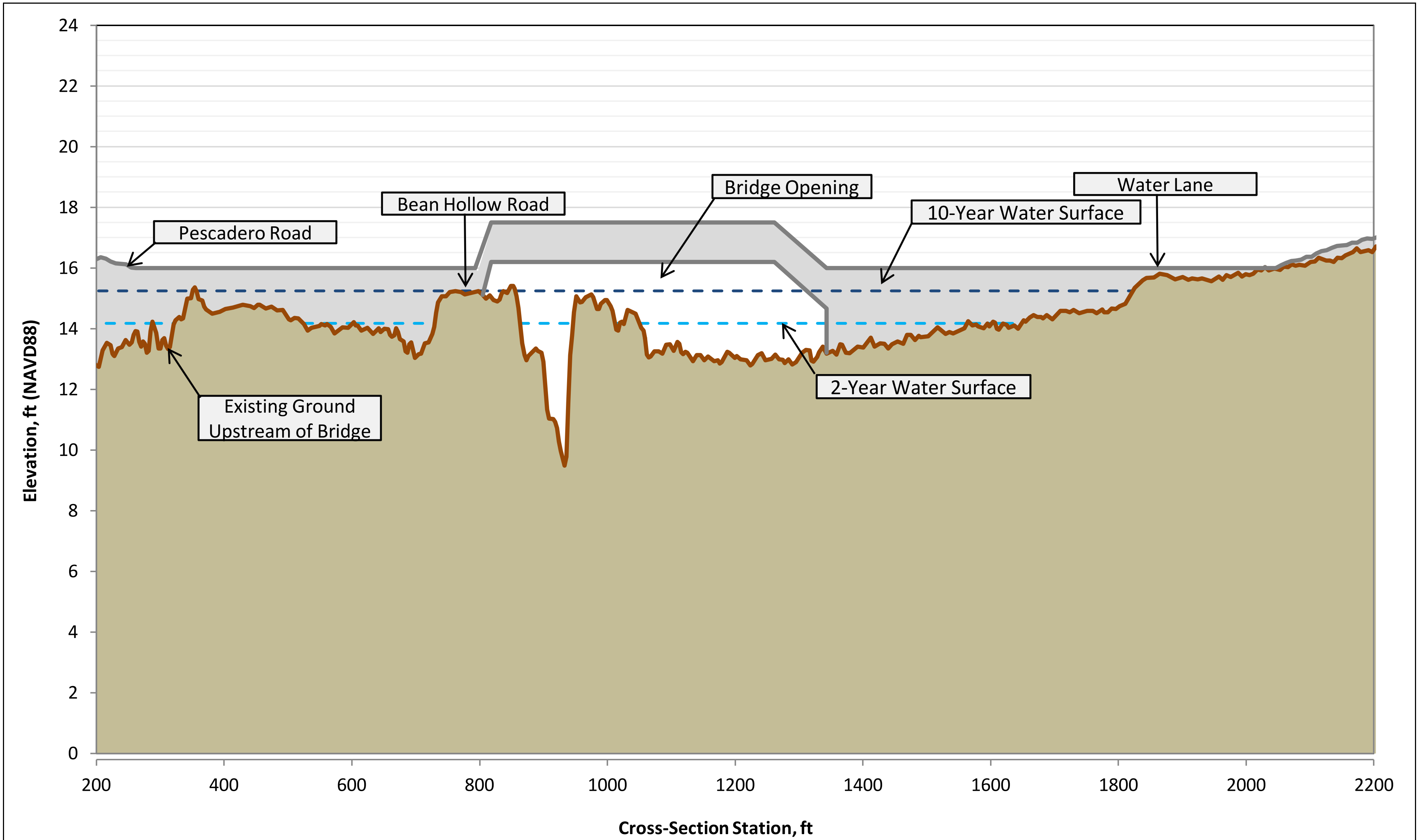
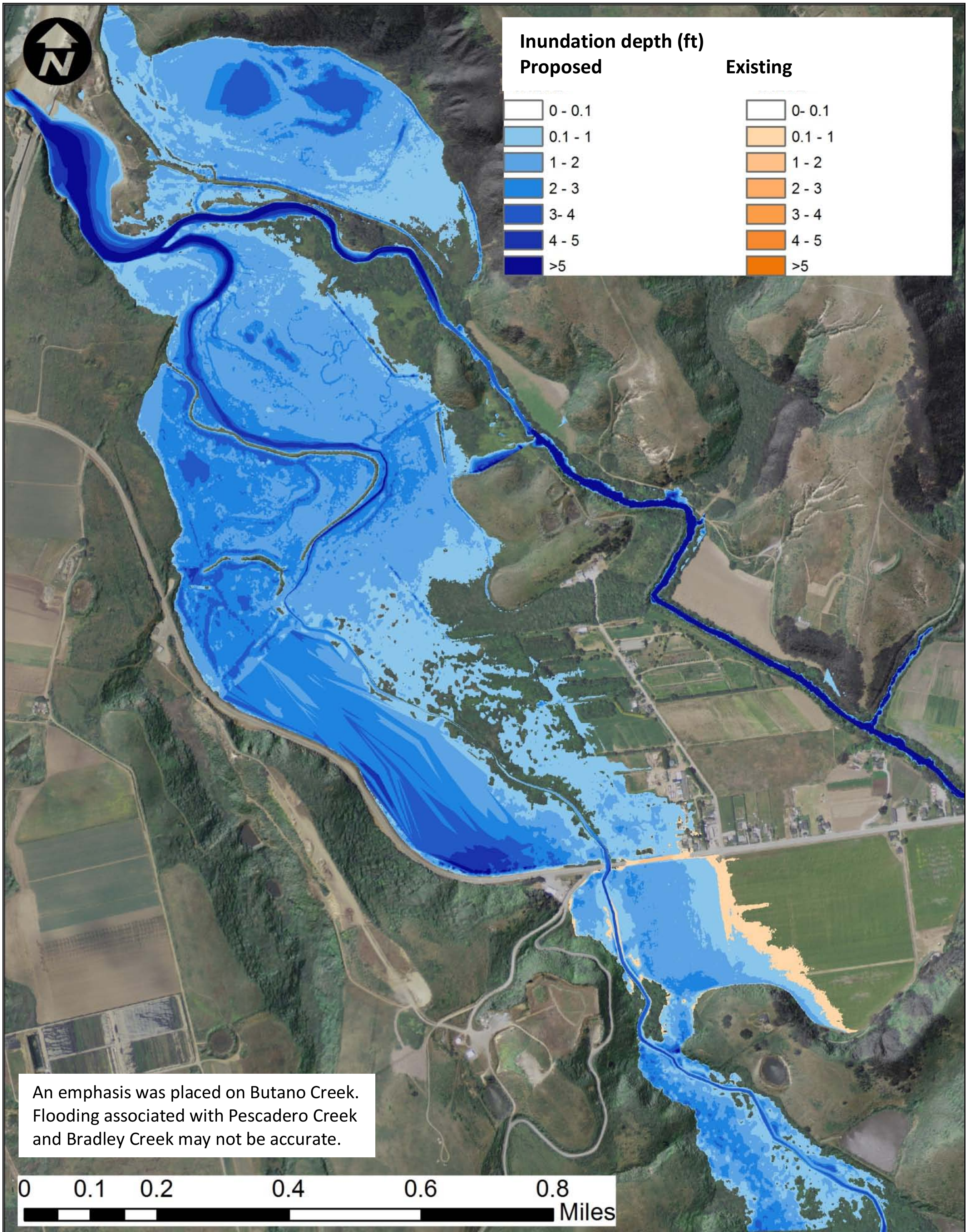
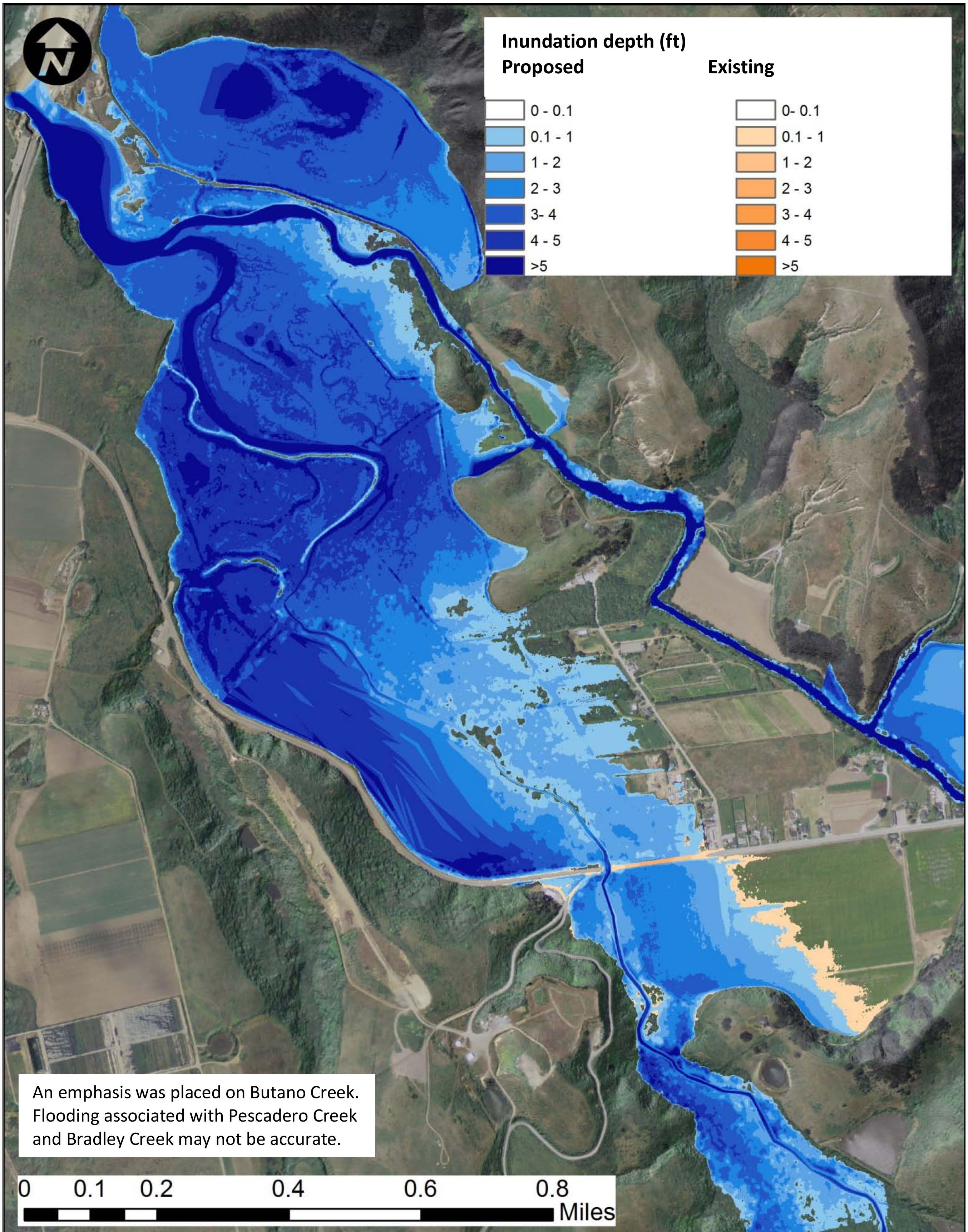
10/17/2014



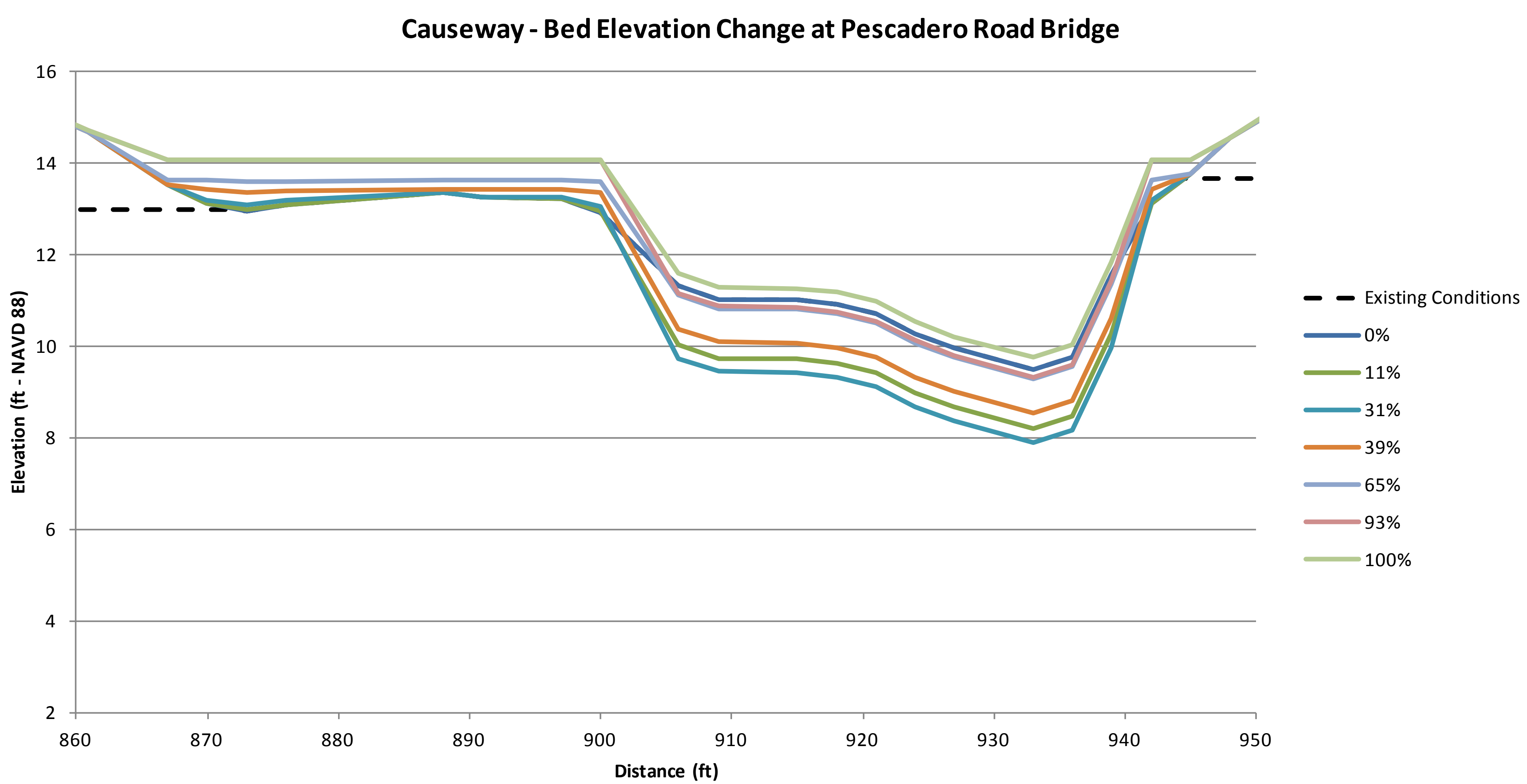
Notes:		*Solutions to Flooding at Pescadero Creek Road* **Causeway section view**		
		Project No. 13-1032	Created By: DST	**Figure 37**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Causeway 2-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 38**

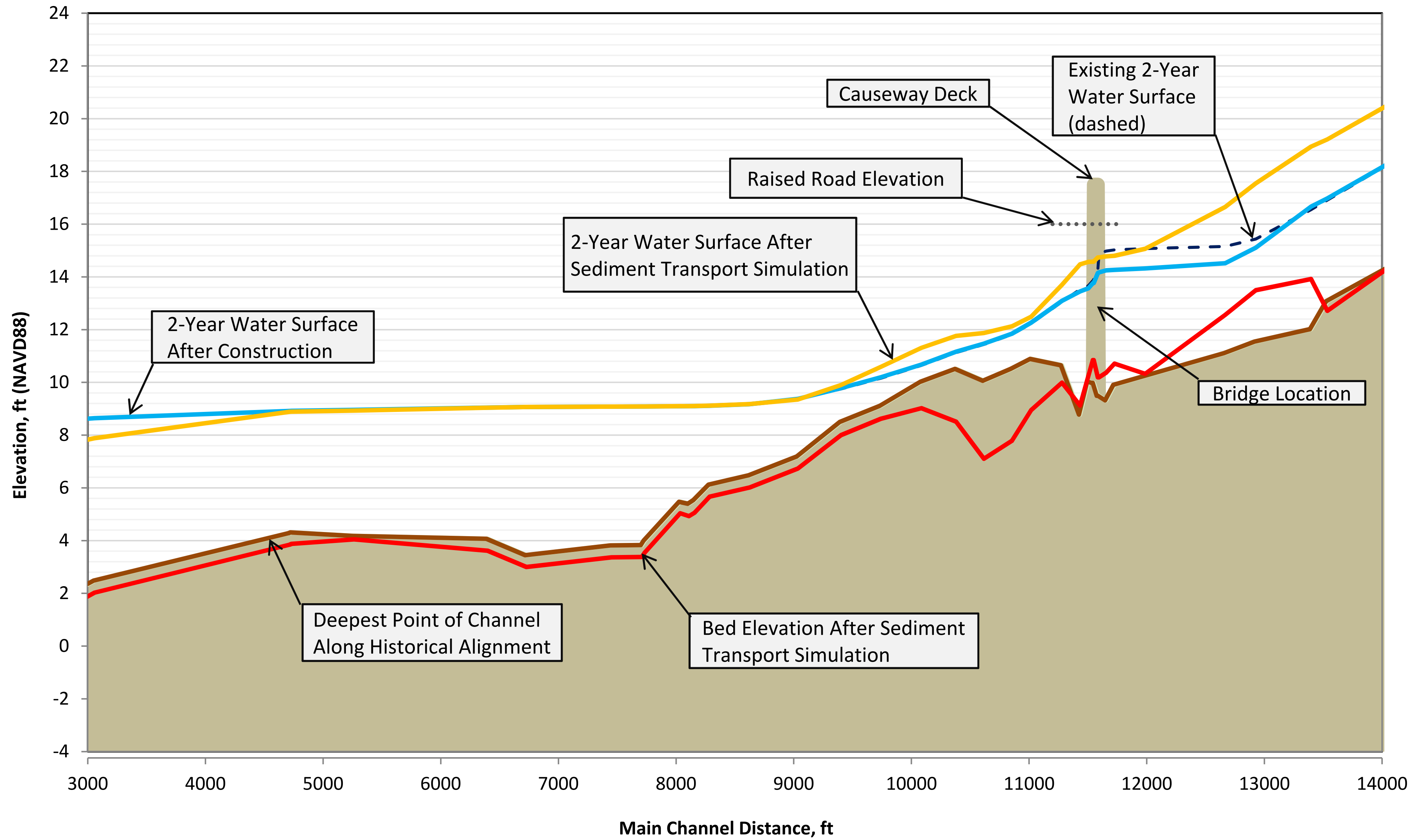


Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Causeway 10-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 39**



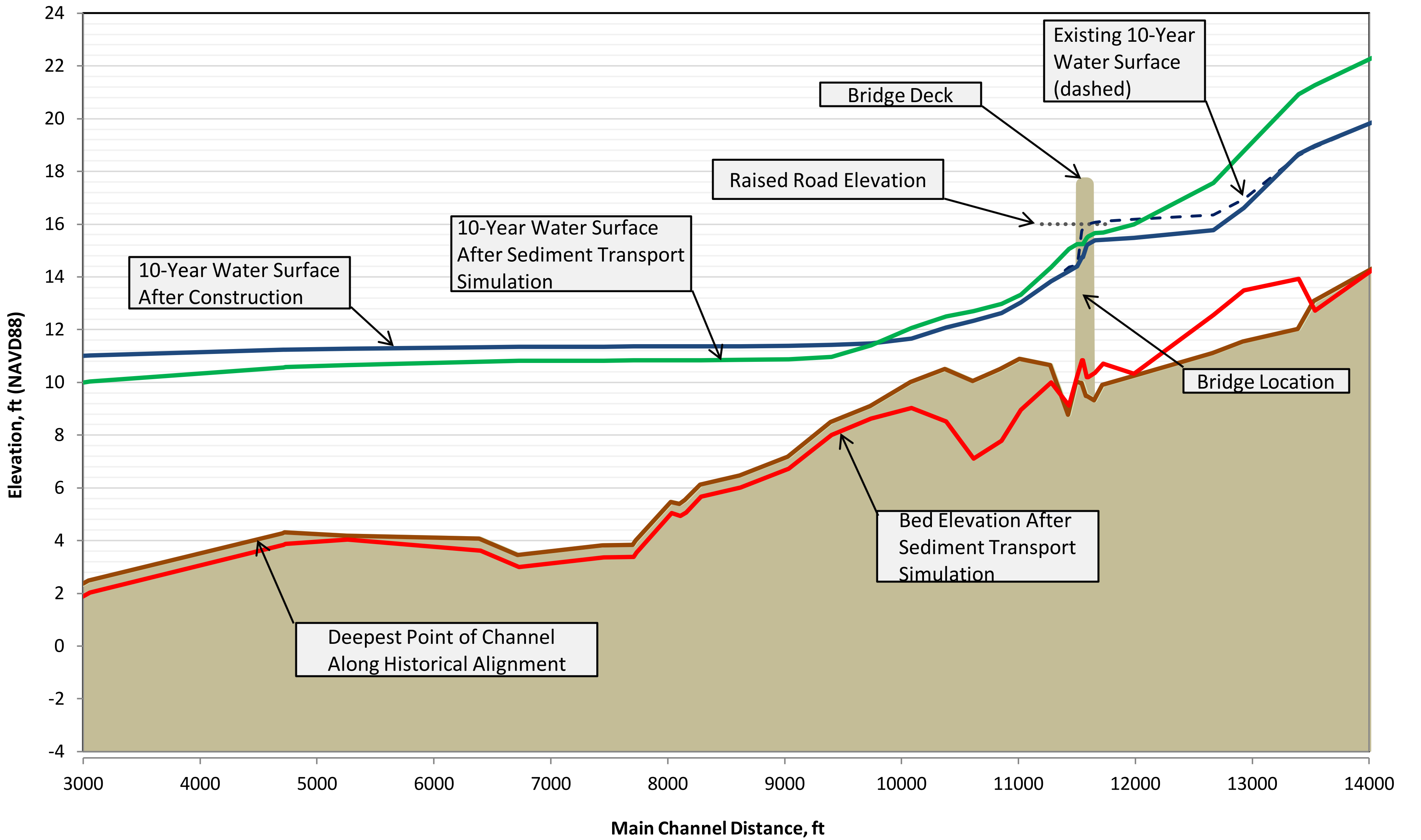
Notes:		*Solutions to Flooding at Pescadero Creek Road* **Causeway - bridge cross section comparison through sediment transport simulation**		
		Project No. 13-1032	Created By: JS	**Figure 40**

R:\Projects\13-1032_Pescadero\Reporting\Figures\Fig40_XS_compare_causeway.docx
10/17/2014

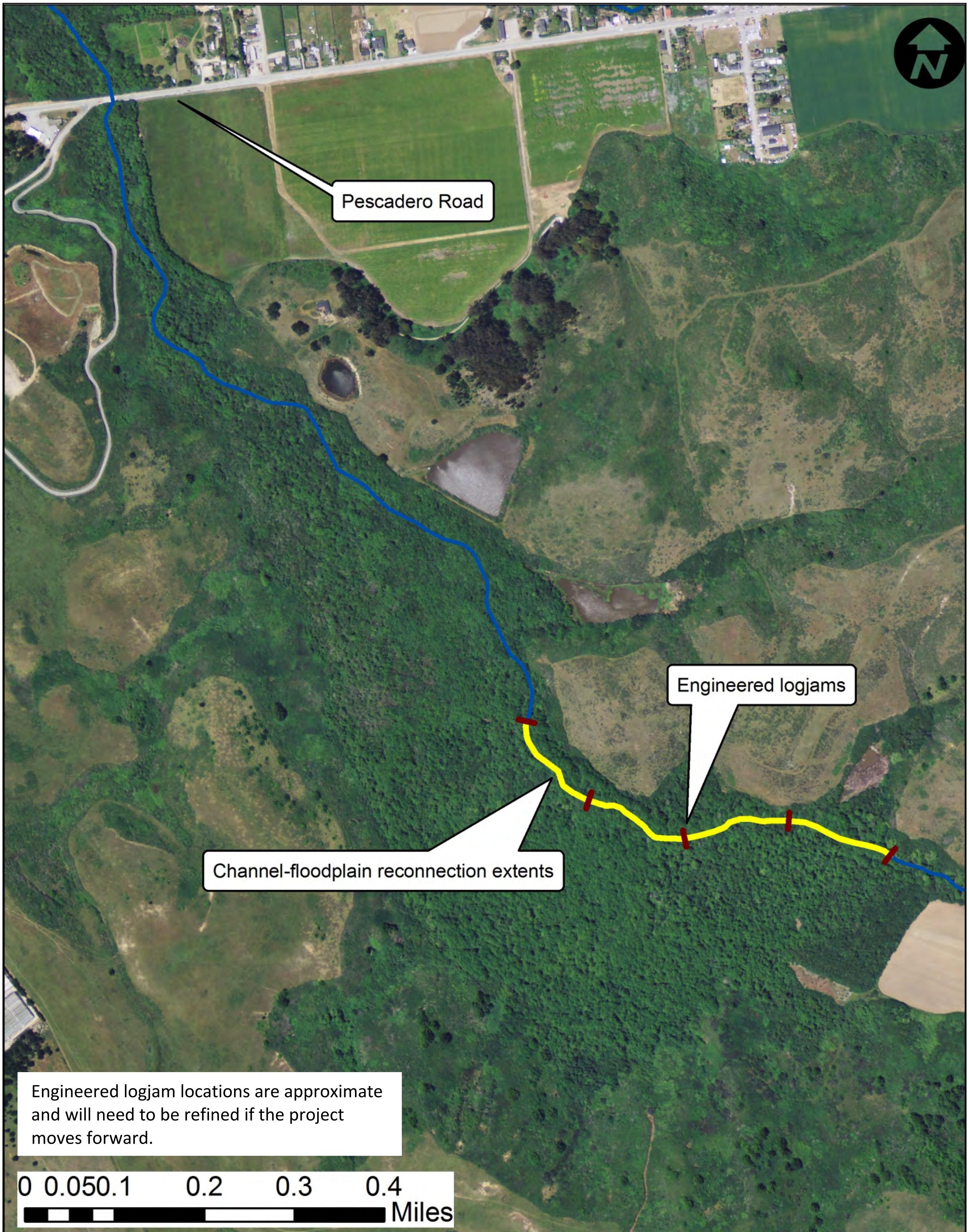


Notes:	cbec	*Solutions to Flooding at Pescadero Creek Road* **Causeway 2-yr event water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 41**

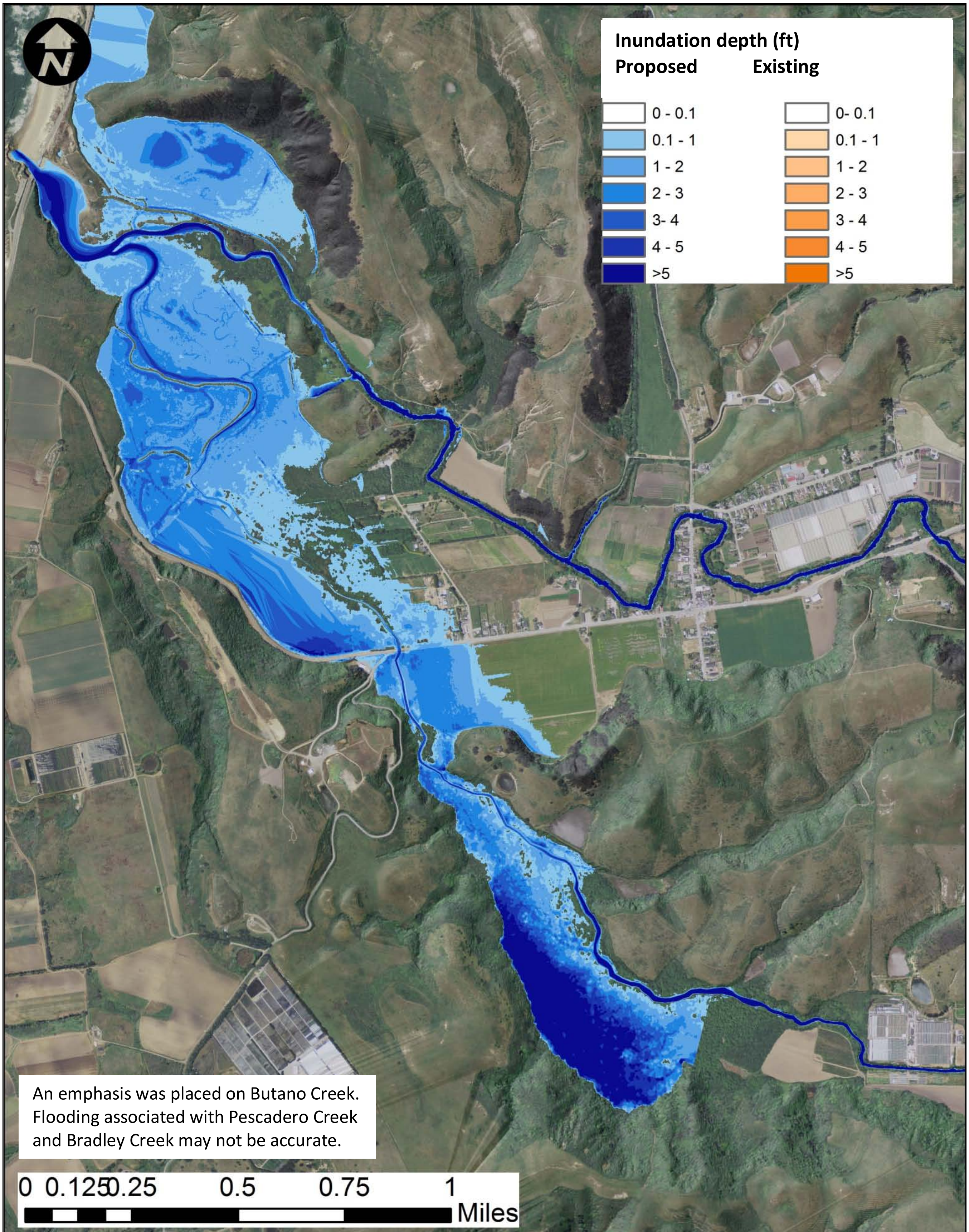
C:\Work\Projects\13-1032_Pescadero_Rd\Reporting\Figures\Fig41_Elevatedcauseway_2yrProfile.docx
10/17/2014



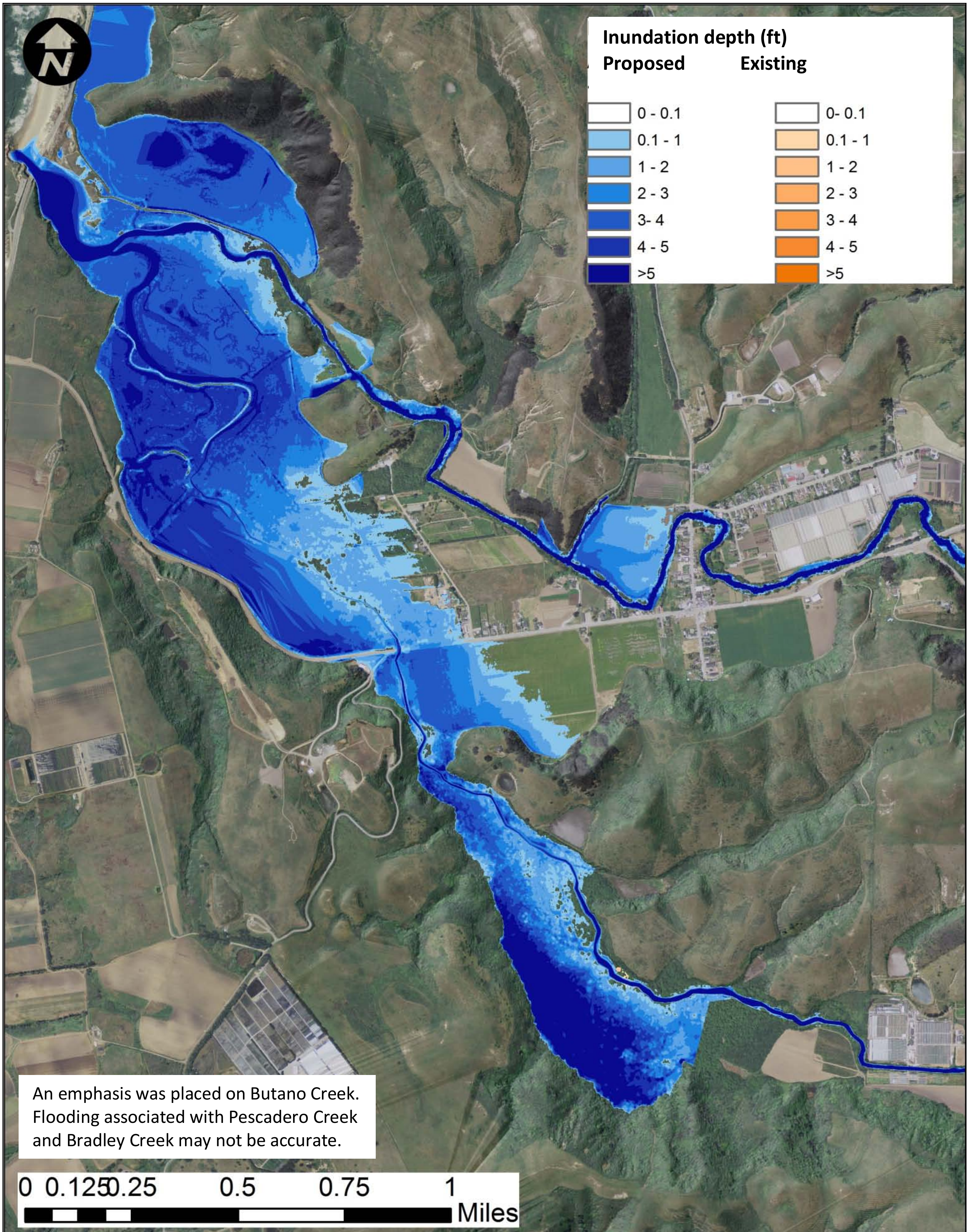
Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Causeway 10-yr event water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 42**



Notes: Background Image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Floodplain reconnection schematic**	
		Project No. 13-1032	Created By: DST	**Figure 43**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Floodplain reconnection 2-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 44**



Notes: Background image source: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Floodplain reconnection 10-yr event inundation**		
		Project No. 13-1032	Created By: DST	**Figure 45**

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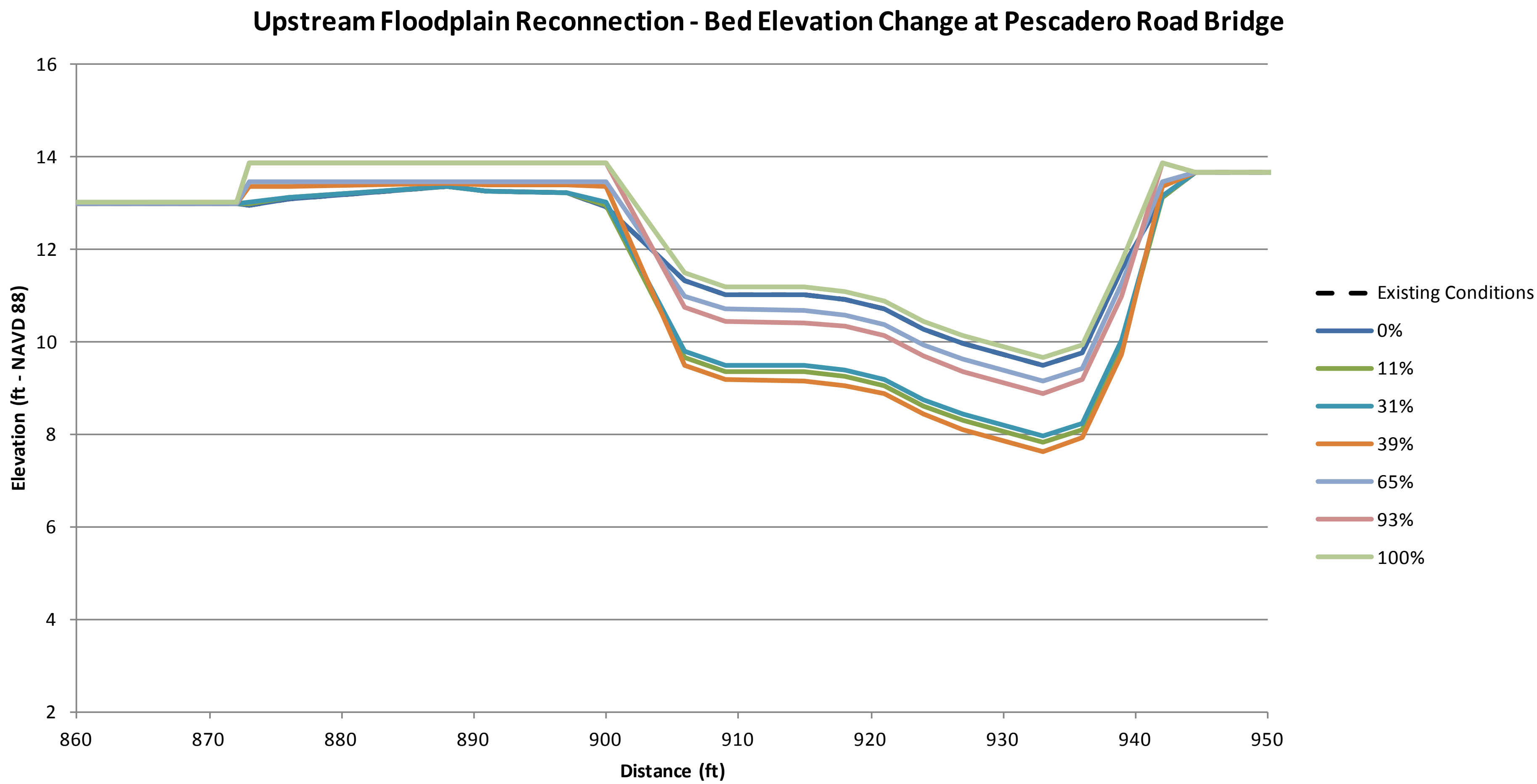
10/17/2014



Notes:

Solutions to Flooding at Pescadero Creek Road

Floodplain reconnection - bridge cross section comparison through sediment transport simulation

Project No. 13-1032	Created By: JS	**Figure 46**

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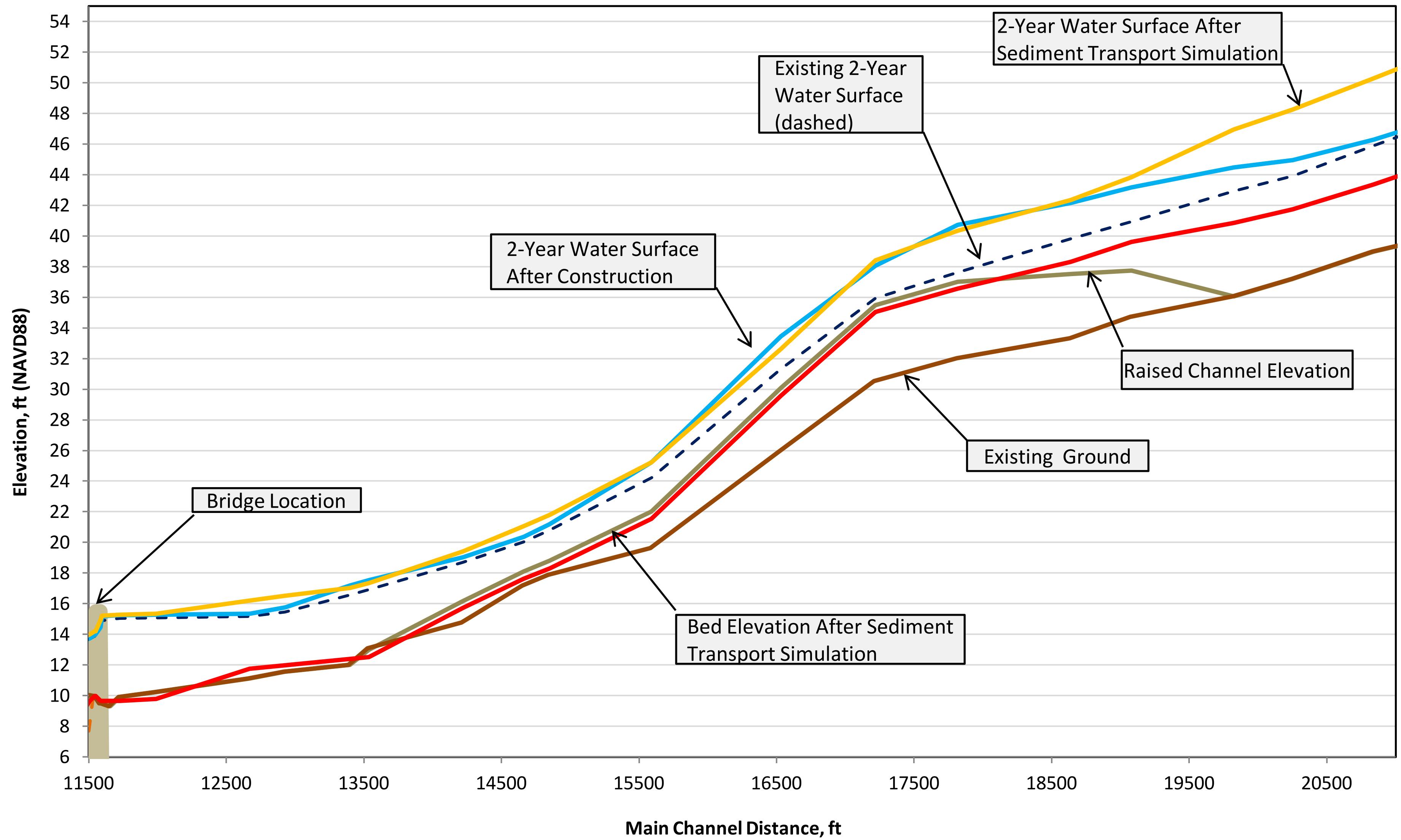
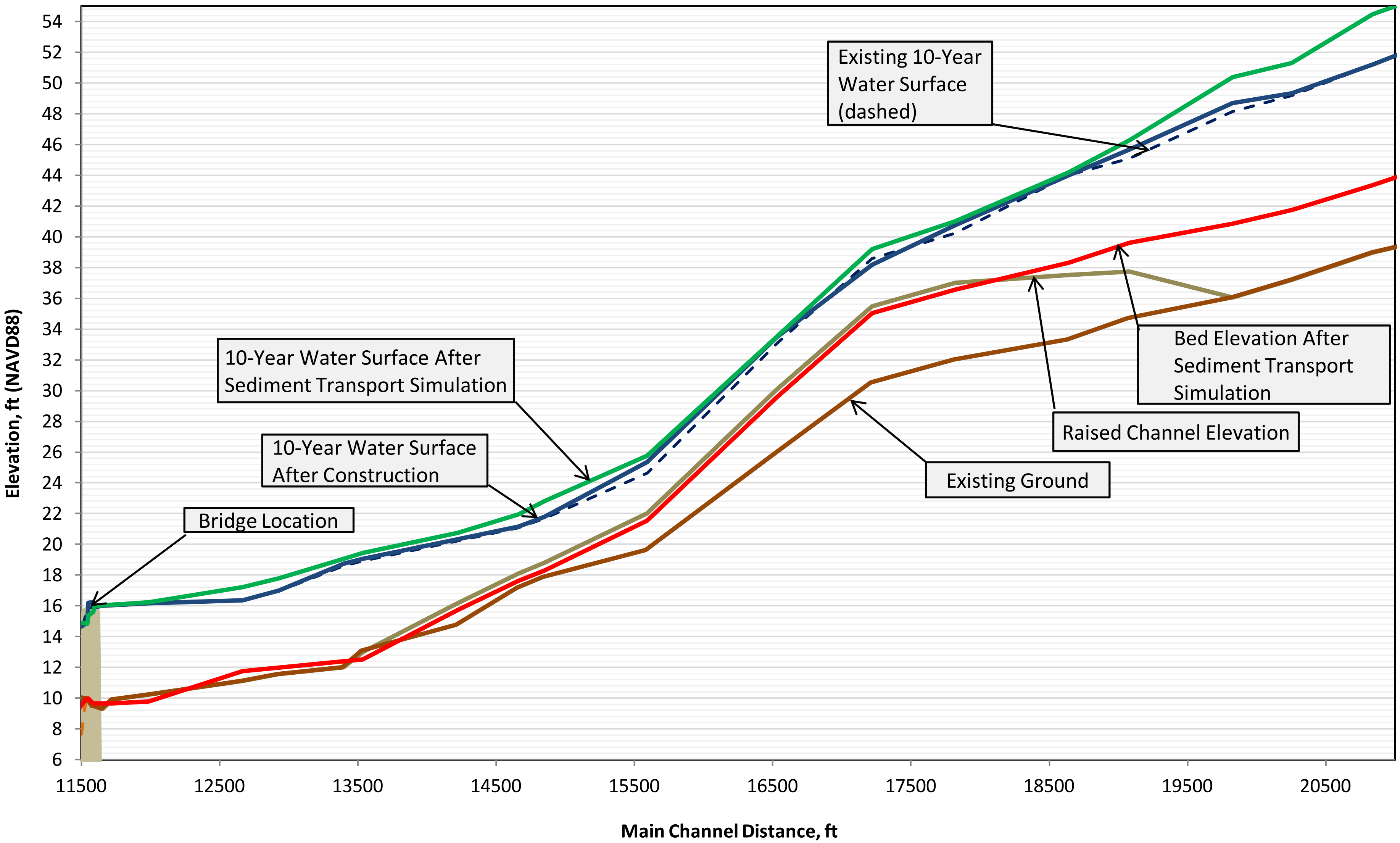
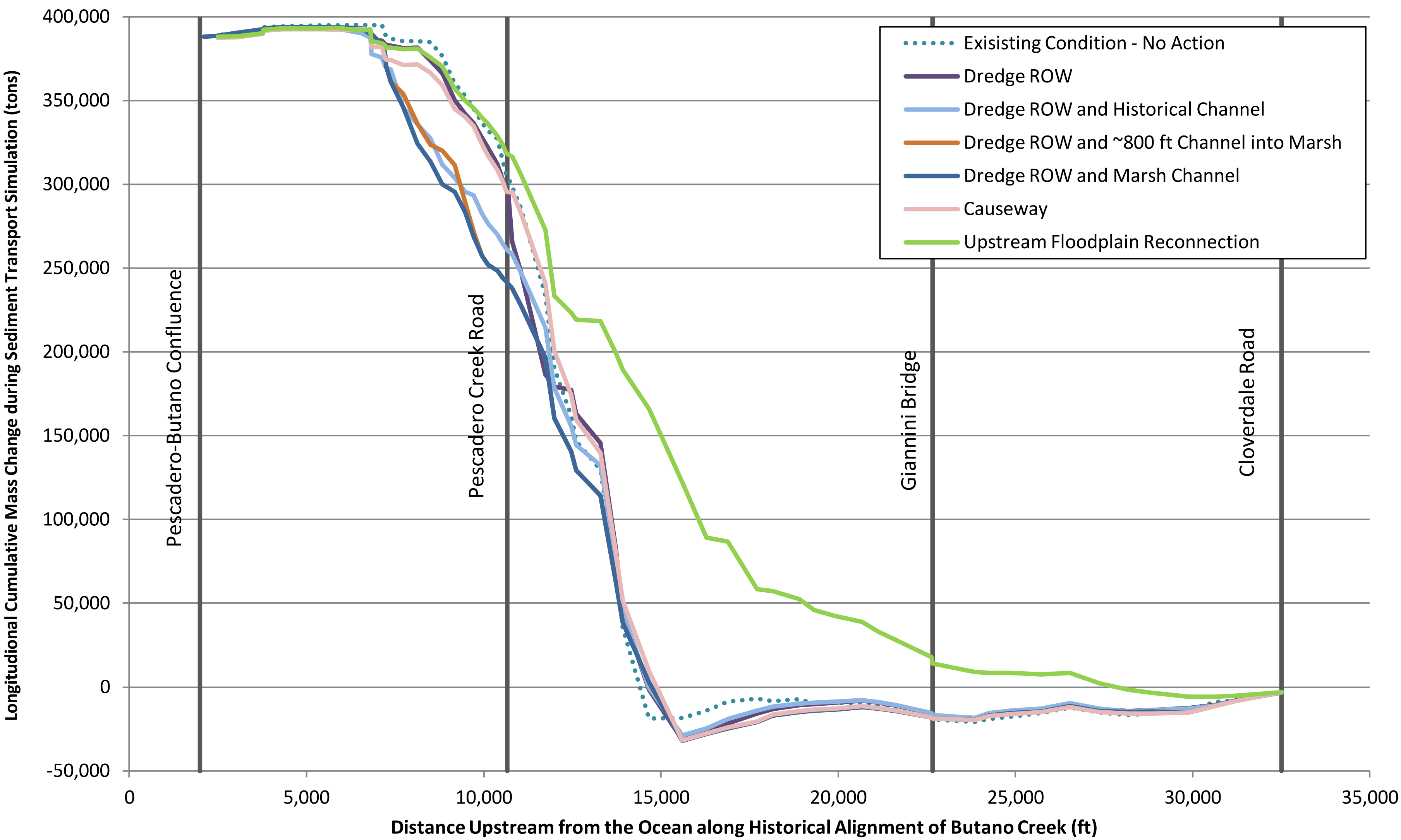


Notes:		*Solutions to Flooding at Pescadero Creek Road*
		Floodplain reconnection 2-yr water surface profiles
	Project No. 13-1032	Created By: DST	**Figure 47**



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Creek Road* **Floodplain reconnection 10-yr water surface profiles**		
		Project No. 13-1032	Created By: DST	**Figure 48**

R:\Projects\13-1032_Pescadero\Reporting\Figures\Fig48_FloodplainRestoration_10yrProfile.docx
10/17/2014



Notes:		*Solutions to Flooding at Pescadero Creek Road* **Cumulative longitudinal sediment accumulation through the project area**		
		Project No. 13-1032	Created By: JS	**Figure 49**

R:\Projects\13-1032_Pescadero\Reporting\Figures\Fig49_CumulativeSediment.docx
10/17/2014

APPENDIX A

Technical Memorandum #1 - Review of Existing Information, Revised Final Draft

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.

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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.

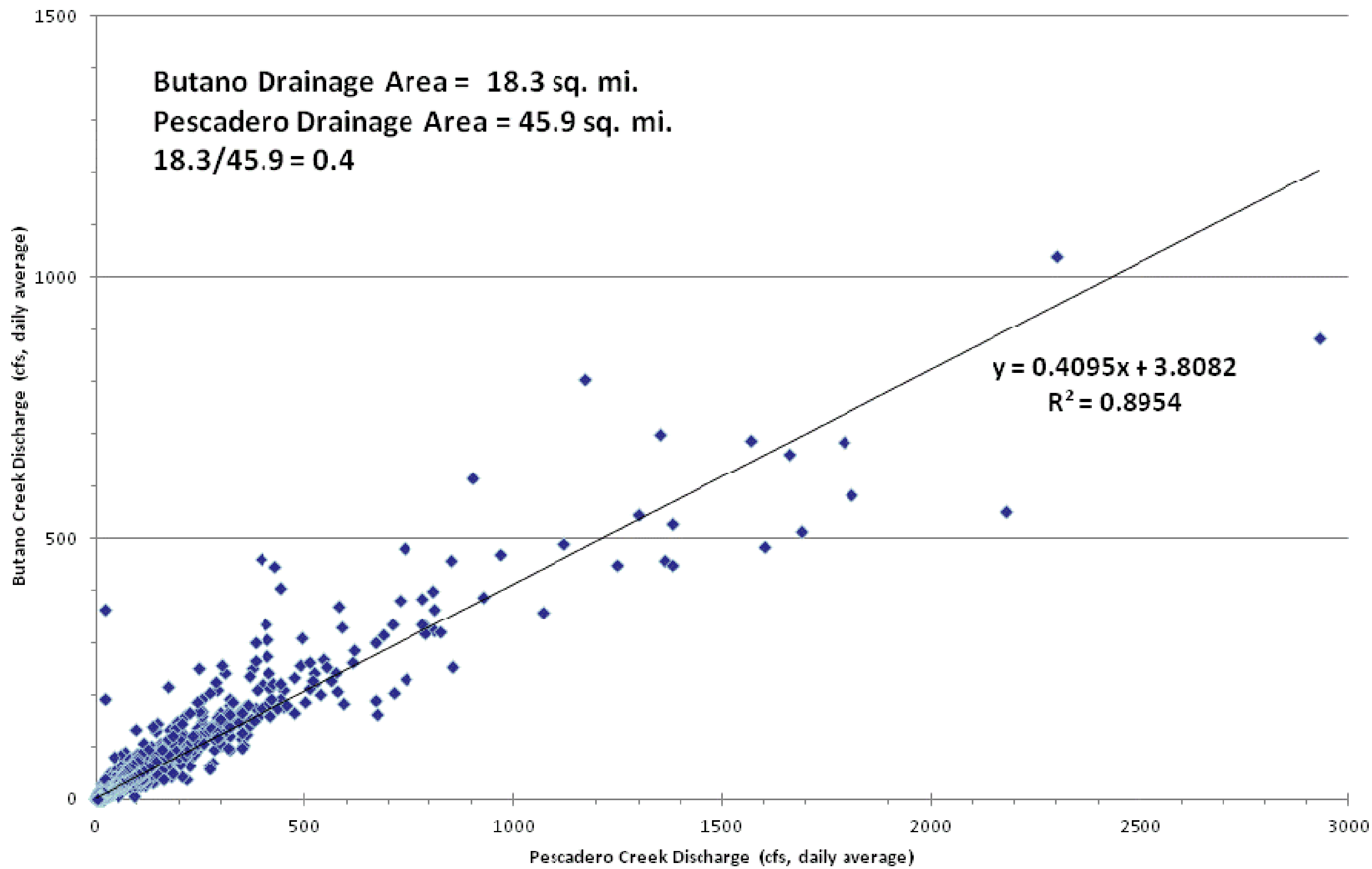
USFWS. 2006. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) 5-year review: summary and evaluation. USFWS, Sacramento, California.

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.

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

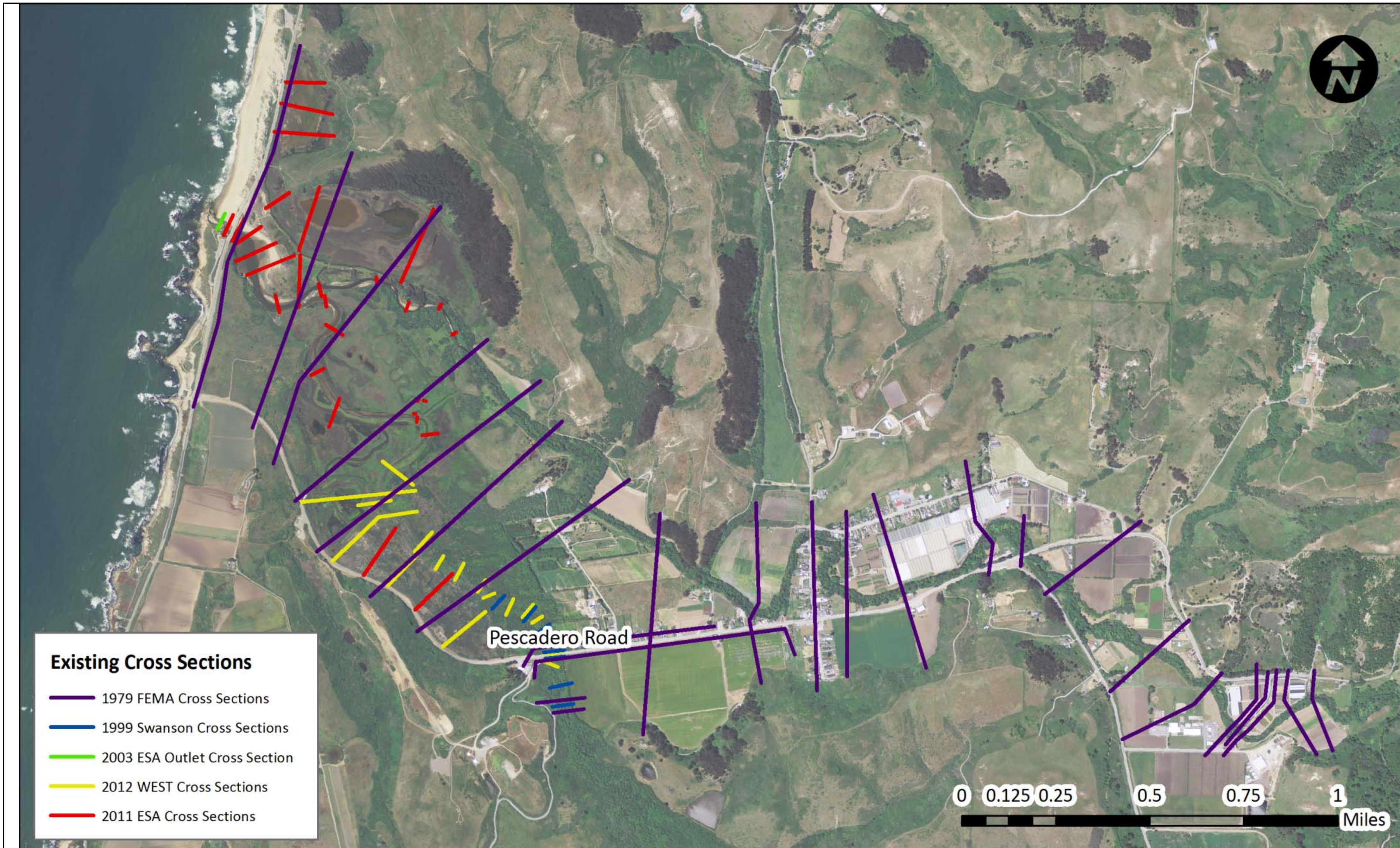


Notes:
Data for USGS Pescadero Creek near Pescadero gage (#11162500) and USGS Butano Creek near Pescadero gage (#11162540)

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**



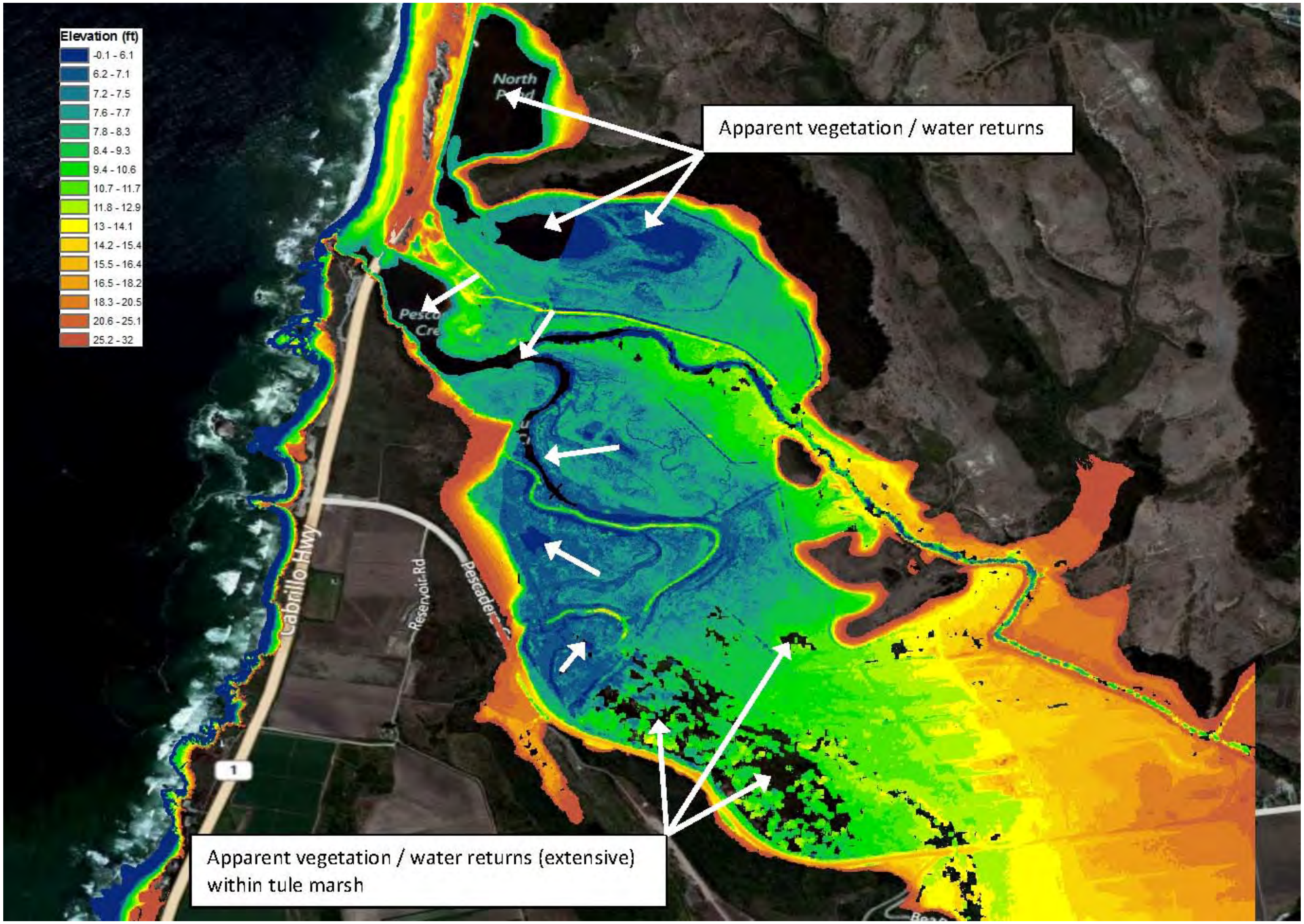
Notes:
Background image NAIP 2012. Dates reflect year of data collection, not the year the reports were published. Cross section database source documents: FEMA 1982, Swanson 1999, ESA 2004, ESA PWA 2012, WEST 2013.

cbec eco engineering

Develop Solutions to Flooding on Pescadero Creek Road

Existing Cross Sections

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



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**

APPENDIX B

Development of the Hydraulic and Sediment Transport Models

APPENDIX B

Date:	10/17/2014
To:	Irina Kogan, San Mateo County Resource Conservation District
From:	cbec eco engineering - Chris Hammersmark, John Stofleth, Denise Tu
Project:	Develop Solutions to Flooding on Pescadero Road - Project # 13-1032
Subject:	Hydrodynamic and Sediment Transport Model Development

1 INTRODUCTION

Butano Creek is the largest tributary to Pescadero Creek located along the Pacific Coast of San Mateo County, California. Butano Creek frequently inundates Pescadero Road during low magnitude flood events. This flooding has impacted access to the town of Pescadero for several decades. Pescadero Road crosses Butano Creek at the upstream extent of the Pescadero Marsh near the downstream end of the Butano watershed (Figure 1). The watershed is comprised of highly erodible material and the Pescadero Road crossing is located in a depositional reach as a result of a rapid transition in channel slope associated with the transition into the Pescadero Marsh. In addition to its geographic setting, a number of anthropogenic impacts to the watershed (e.g., timber harvesting and channel straightening) have had profound effects upon the condition and function of the channel and watershed with respect to sediment delivery, storage, and aquatic habitat. To address the flooding issues at Pescadero Road, a number of project components have been developed and analyzed, which vary from localized dredging near Pescadero Road to watershed-scale solutions involving multiple actions addressing sediment reduction, improvement of infrastructure and aquatic habitat. To aid in the analysis and development of a long-term solution, HEC-RAS hydrodynamic and sediment transport models were developed and applied. This technical memorandum describes the development of both the one-dimensional hydrodynamic and sediment transport HEC-RAS models.

1.1 STUDY OBJECTIVES

The goal of this project is to develop and analyze a long-term, sustainable and cost-effective solution to reduce flooding at Pescadero Road, while minimizing impacts to endangered species (e.g., California red-legged frog (*Rana draytonii*), San Francisco garter snake (*Thamnophis sirtalis tertrataenia*), tidewater goby (*Eucyclogobius newberryi*) , coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*)). Model results and associated analysis are included main body of the report.

2 MODEL DEVELOPMENT

To analyze the potential for the proposed project components to reduce flood risk, sedimentation, and improve habitat quality, a HEC-RAS one-dimensional (1D) hydrodynamic and sediment transport model was developed to analyze several project components for lower Butano Creek. The HEC-RAS model platform was developed by the United States Army Corps of Engineers Hydraulic Engineering Center (HEC) and is widely used for hydraulic and sediment transport analysis in natural and constructed channels (HEC, 2012).

2.1 MODEL DOMAIN

The HEC-RAS 1D model used in this analysis extends along 5.5 miles of Butano Creek from Cloverdale Road at the upstream model boundary to its confluence with Pescadero Creek in the Pescadero Marsh (Figure 1). The model also includes approximately 4 miles of Pescadero Creek extending from upstream of the town of Pescadero to the downstream boundary at the Pacific Ocean.

2.2 BATHYMETRY AND TOPOGRAPHY

Topographic and bathymetric data utilized in this project were derived from the following sources:

- 2010 NOAA LiDAR: California Coastal Conservancy Coastal LiDAR Project
    - Projection / Datum: NAD 1983 UTM Zone 10N FT, NAVD 88 FT (GEOID 09)
- 2005 San Mateo County LiDAR
    - Projection / Datum: NAD 1983 UTM Zone 10N FT, NAVD 88 FT (GEOID 09)
- 2012 West Consultants (WEST) Topographic and Bathymetric Survey
    - Projection / Datum: NAD 1983 CA State Plane Zone 3 FT, NAVD 88 FT (GEOID12A)
    - Coverage: 17 cross sections along lower Butano Creek, water control structures, breached levees within Pescadero Marsh (Figure 2)
- 2011 ESA / PWA Topographic and Bathymetric Survey
    - Projection / Datum: NAD 1983 CA State Plane Zone 3 FT, NGVD 29 FT (GEOID03)
    - Coverage: 30 cross sections characterizing lower Pescadero Creek, North Marsh, Butano Creek and Butano Marsh (Figure 2)
- 2014 cbec Topographic and Bathymetric Survey
    - Projection / Datum: NAD 1983 CA State Plane Zone 3 FT, NGVD 29 FT (GEOID09)
    - Coverage: 36 cross sections within Pescadero Marsh adjacent to Butano Creek and Butano Creek channel and floodplain upstream of Pescadero Road, water control features, bridges, Butano Creek channel and floodplain between Gianni bridge and Cloverdale Road (Figure 2)

2.2.1 FIELD SURVEYS AND DATA COLLECTION

2.2.1.1 Overview

Supplemental Butano Creek channel and Butano Marsh cross sections were surveyed by cbec staff. Multiple survey methods were employed including: foot-based RTK GPS, total station and auto-level surveys. Due to dense vegetation and limited satellite reception, total station and auto-level surveys were necessary to collect data along most sections of Butano Creek. Topographic details collected included high and low points, channel expansions, contractions, changes in grade, surface breaks (i.e., bank toe and top), and channel thalweg.

2.2.1.2 Control Points

cbec staff surveyed two NGS benchmarks in the project area including (1) HT 1504 and (2) HT1506.
HT 1504 is an NGS benchmark located past the junction of Bean Hollow Road on Pescadero Road bridge along the southern bridge guard rail. HT 1504 has a registered elevation of 15.65 ft, NAVD88.
HT1506 is an NGS benchmark located on a concrete head wall along the south east corner of the intersection of Hwy 1 and Pescadero Road. HT 1506 has registered elevation of 50.29 ft, NAVD88.

2.2.1.3 Topographic Surveys

Topographic data were collected during a series of field efforts conducted between January and March, 2014. During the January field survey, 21 cross sections along Butano Creek upstream of Pescadero Road were surveyed using RTK GPS and an auto-level. RTK GPS surveys were vertically adjusted to HT 1504. For each auto-level cross section the two end points and back site location were recorded by GPS and tied back to temporary control points set by RTK GPS. During a February field survey, additional RTK-based surveys were performed to characterize an additional cross section across the Butano Marsh, water control features such as levees, levee breaches, deep channels, and the pedestrian bridge at the downstream end of Butano Marsh. During field surveys collected in March, 15 additional cross sections were obtained. Three cross sections were taken at the river mouth after the sand bar breached on March 3, 2014 and 12 cross sections were surveyed between Giannini bridge and Cloverdale Road using a total station.

2.2.2 TOPOGRAPHIC DATA INTEGRATION

All datasets were reprojected to a common horizontal projection and vertical datum referencing NAD 1983 California State Plane Zone 3 (ft) and the NAVD 88 (GEOID09) (ft). The NGS Geodetic Tool Kit was used to convert datasets to GEOID09. The NGS VERTCON tool was used to obtain a conversion of 2.68 ft from NGVD29 to NAVD88.

A comparison of the ground survey and LiDAR datasets revealed shallow elevation returns in the LiDAR data typically associated with dense vegetation and water in upper Butano Creek and the Pescadero Marsh. cbec staff created a comprehensive topographic surface that incorporated all data by merging the ground based survey data with the LiDAR datasets. This process allowed for vegetation returns present within the LiDAR dataset to be corrected with the ground-based survey data, but only in areas where overlapping data exists. This final topographic surface (Figure 3) serves as the basis for the existing conditions hydraulic and sediment transport model geometry described in later sections of this technical memorandum.

2.3 Hydrodynamic Model Boundary Conditions

Streamflow data from the USGS gage (#11162500) on Pescadero Creek were used to develop the inflow boundary conditions on Pescadero and Butano Creeks. The Pescadero Creek gage is located 5.3 miles upstream from the mouth and measures flow from a 45.9 mi^2 watershed above the gage. Peak streamflow data from 1952 - 2013 were analyzed using the USGS PeakFQ flood frequency program to calculate the recurrence interval flood events for Pescadero Creek included in Table 1 (USGS, 2014). Flood hydrographs with peak discharge values that closely match calculated recurrence interval were selected from historical record to serve as the inflow boundary condition from 2-, 5-, 10-year flood events on Pescadero Creek.

Table 1. Magnitude of select flood events

Return Interval	Peak Discharge (cfs)	
	Pescadero Creek[1]	*Butano Creek*[2]
2	2175	870
5	4824	1930
10	6900	2760

Notes
1 - Pescadero Creek peak discharge values were estimated using 1952-2013 annual peak data record collected at gage #11162500.
2 - Butano Creek peak discharge values were estimated by applying the 0.4 ratio of watershed areas to the Pescadero Creek discharge values.

The USGS Butano Creek gage (#11162540) was historically located 2.2 miles upstream of Pescadero Road and measured flow from an 18.3 mi^2 watershed above the gage. Stream flow data measured at this gage between 1961 and 1974 were compared to flow measurements recorded for the same period at the Pescadero gage to develop a relationship / scaling factor between the Butano and Pescadero watersheds. Analysis of the overlapping daily average flow data for the two gages indicated a high correlation between the datasets, which corroborated the application of a 0.4 watershed scaling ratio (18.3/45.9 = 0.40) to synthesize Butano Creek flows. The 0.4 watershed ratio was applied to Pescadero Creek flood frequency analysis to determine the corresponding flood events on Butano Creek as shown in Table 1.

Once peak discharge values were determined for each creek, actual historical storm hydrographs that best represented the 2-year, 5-year, and 10-year flood events were chosen from the Pescadero Creek data record for both Pescadero and Butano Creek. The Butano Creek hydrographs were shifted forward by 3 hours (Curry et al., 1985) to account for the smaller drainage area resulting in a flashier system. These hydrographs were used for the upstream boundary conditions for the 1D hydraulic model. Additional local flow inputs occurring downstream of the gages were not included (e.g., Bradley Creek, Honsinger Creek, etc.).

Complex interaction between tides, stream discharge and marsh water levels effect the timing of the sand bar breaching at the mouth of Pescadero Creek. The details of these relationships are documented in past studies including PWA, 2011. For the purpose of this analysis, the sand bar was assumed to be in an open or breached condition, with a mean higher high tide (5.95 ft, NAVD) applied as a constant elevation at the downstream stage boundary.

Table 2. Tides at the Presidio, San Francisco, CA

Tidal Datum	Tide Level (ft, NAVD 88)
Highest observed water level (1/27/83)	8.74
Mean higher high water	5.92
Mean high water	5.31
Mean tide level	3.26
Mean sea level	3.2
Mean low water	1.21
Mean lower low water	0.08
Lowest observed water level (12/17/33)	-2.8

NOTES:
1 - Adapted from PWA, 2002. Tidal datums at the Presidio are based on measurements made from 1983-2001.
2 - Source: National Ocean Service (NOS) tidal station 941-4290 (www.co-ops.nos.noaa.gov)

2.4 Hydraulic Roughness

Hydraulic roughness values, Manning's coefficient (n), are used by hydrodynamic models to describe the efficiency of flow conveyance in the channel and floodplain areas. Higher values indicate "rougher" conditions, that results in greater flow depths and slower flow velocities. Roughness values are used to describe both the type/density of vegetation as well as channel bed forms (boulders, cobbles and undulations in the bed). Roughness values were estimated during the field surveys as well as through inspection of aerial images. Values were selected based upon guidance provided in published literature (Chow, 1959). Roughness values for the main channel ranged from 0.030 to 0.045, while values for floodplain areas ranged from 0.035 to 0.12. It is common to adjust roughness values during a model calibration effort. Data were not available to support a model calibration effort, therefore the initially selected values were not adjusted.

2.5 Sediment Transport Theory

The Engelund-Hansen total load equation was used to simulate sediment transport. This equation was selected through an iterative evaluation process by which several transport equations were tested to achieve results that were most similar to observed geomorphic trends within the study reach. The Engelund-Hansen equation was used to simulate the transport of nine (9) representative grain size classes in HEC-RAS. These grain size classes were:

- very fine sand (d_{gm} = 0.09 mm; 0.062 to 0.125 mm),

- fine sand (d_{gm} = 0.17 mm; 0.125 to 0.25 mm),
- medium sand (d_{gm} = 0.31 mm; 0.25 to 0.5 mm),
- coarse sand (d_{gm} = 0.51 mm; 0.5 to 1 mm),
- very coarse sand (d_{gm} = 1.41 mm; 1 to 2 mm),
- very fine gravel (d_{gm} = 2.83 mm; 2 to 4 mm),
- fine gravel (d_{gm} = 5.66 mm; 4 to 8 mm),
- medium gravel (d_{gm} = 11.3 mm; 8 to 16 mm), and
- coarse gravel (d_{gm} = 16 mm; 16 to 32 mm).

Grain sizes less than 0.062 mm, which are typically considered to be washload that does not interact with the bed, are not considered in the available sediment transport formulas and thus were not simulated in the HEC-RAS model.

2.6 Sediment Transport Model Boundary Conditions

Erosion and deposition was simulated for a ~10-year period by utilizing flow data recorded at the USGS gage on Pescadero Creek (1991 – 2000). Flow data for Butano Creek was synthesized by scaling Pescadero Creek flows by a factor of 0.4 and offset by 3 hours based on watershed size and a 12-year (1962 – 1974) period of overlapping flow data (Figure A-4). The HEC-RAS sediment transport model utilizes a quasi-steady model platform, which required the inflow hydrographs to be simplified from a 15-minute to an hourly time series. Flows less than 100 cfs on Butano Creek (250 cfs on Pescadero Creek) were excluded from the inflow time series to improve computational stability and because these lower flows were assumed to account for a relatively small proportion of the overall sediment load.

The incoming sediment load for Butano Creek was initially generated assuming an equilibrium load condition, in which the sediment transport model calculates an incoming sediment load that is equal to the transport capacity at the upper boundary for a given flow rate. This annualized equilibrium load was then scaled to match the estimated annual average sediment yield 80,000 tons/year (SFRWQCB In prep). Since sediment transport formulas do not consider the washload size fraction (<0.062 mm), which are typically understood to not affect long-term channel behavior, the incoming sediment load for Butano Creek was further reduced by 50% to account for the assumed proportion of the estimated annual average sediment load within the wash load size class. This adjustment provided an average annual sediment load for Butano Creek of approximately 40,000 tons/year for material larger than 0.062 mm in diameter.

The incoming sediment load for Pescadero Creek relied upon the model calculated equilibrium load. This load was not adjusted with the estimated annual sediment yield as the Pescadero Creek sediment supply is not known to influence erosion or depositional trends within the study reach (Butano Creek in the vicinity of Pescadero Road).

2.7 Bed Material, Thickness and Representative Grain Size

The grain size distribution from the bed material within the study reach were defined using sediment samples collected by West in 2012 and cbec in 2014. A total of 17 samples collected along Butano Creek were used to define the composition of the bed material within the model domain (Figure A-5). The particle size distribution for individual samples are provided in Appendix A of this memorandum. A comparison of the particle size distribution indicates a wide range of sediment sizes varying from coarse gravel in the upper reaches of Butano Creek to very fine sand within Pescadero Marsh (Figure A-6).

The grain size distribution of the incoming sediment load were defined through an iterative process by which several distributions were tested in the model to achieve a result that best represents the geomorphic trends observed within the project area. Based on the results of this study, the representative grain size and the relative distribution of the incoming load are included in Table 3.

Table 3. Representative grain size and relative distribution used as model input

Fraction	Size class	Geometric mean grain size (mm)	Percentage of size fraction for the incoming load
1	Very fine sand	0.09	5
2	Fine sand	0.17	5
3	Medium sand	0.31	15
4	Coarse sand	0.51	25
5	Very coarse sand	1.41	23.7
6	Very fine gravel	2.83	17.5
7	Fine gravel	5.66	8.5
8	Medium gravel	11.3	0.2
9	Coarse gravel	16	0.1

2.8 Model Assumptions and Limitations

The preparation and use of the HEC-RAS model for simulating project components was based on the assumptions and limitations listed below. Any application of model results should take these assumptions and limitations into consideration.

1. All simulations utilize hydrographs derived from flow data recorded by the USGS gage on Pescadero Creek (# 11162500). Flow boundary conditions for Butano Creek were scaled from these data based on watershed size and a short-term period of overlapping flow data. Long-term sediment transport simulations utilize a simplified quasi-steady representation of these flow data.
2. Despite every effort to use the most recent and reliable topographic data available, floodplain and marsh topography was partially derived from LiDAR data, whose accuracy may have been affected by ground vegetation and ponded water present at the time of the survey.
3. The HEC-RAS model was not calibrated for hydrodynamics as appropriate data were not available to support this type of effort. Roughness coefficients were estimated during a field survey and with aerial photography using published guidelines (Chow, 1959).

4. The HEC-RAS sediment transport model is a tool for assessing potential geomorphic change. Sediment transport results are not intended to be taken as absolute and should be interpreted to imply probable trends (not absolutes) with order-of-magnitude levels of accuracy.
5. All sediment transport simulations rely on the Engelund-Hansen sediment transport equation. This equation was selected through an iterative process by which several transport equations were tested with the model to achieve results that were most similar to patterns of erosion and deposition observed within the study reach.
6. The HEC-RAS sediment transport model was not calibrated for sediment transport and geomorphic change, as appropriate data were not available to support this type of effort. However, model boundary conditions were based on estimated annual sediment yield for the Butano watershed and optimized to ensure results represent geomorphic trends observed within the project reach.
7. The annualized sediment yield utilized to derive the sediment load boundary condition was adjusted to exclude the washload size fraction (<0.062 mm), which was assumed to account for 50% of the overall sediment load.
8. Modeling results are derived from simplified, depth-averaged, one-dimensional representations of complex, three-dimensional processes. Project components carried forward beyond this concept level of design will require additional analysis that incorporates more advanced two- and in some cases three-dimensional analysis.
9. The HEC-RAS model does not have the ability to simulate the ability of beaver dams or vegetation to affect channel behavior in the project reach.

Model results from the HEC-RAS sediment transport model are valuable tools that aid in the understanding of physical processes and trends associated with erosion and deposition of sediment in the project reach. HEC-RAS is a dynamically linked, quasi-steady, one-dimensional hydraulic and sediment transport model that provides continuous results for sediment transport over the course of a series of flow events or a given period of time. The model output allows the changing bed level to be viewed as an animation over the course of the simulation, which illustrates the evolution of erosion and deposition through time. By examining these animations, one can review results at a single location (cross section) or for the entire reach (profile) to develop a better understanding of the sediment transport processes. At the completion of a simulation, the resulting cumulative erosion or deposition is displayed graphically by the model as a variety of parameters, including the change in the channel/floodplain elevation.

It should be noted that, despite efforts to construct a comprehensive and functional model, the precision of the modeling results (e.g., bed level change of 0.03 feet) do not equate to absolute predictions, because the accuracy of the model is much lower than the precision. The modeling results presented are derived from simplified, depth-averaged, one-dimensional representations of complex, three-dimensional processes, and the results have been interpreted to imply probable trends (not absolutes) with order-of-magnitude levels of accuracy.

3 EXISTING CONDITIONS MODEL RESULTS

The current Pescadero Road bridge section is modeled with the bridge deck at 15.4 ft (NAVD), the low cord at 14.1 ft, the upstream channel thalweg at 9.5 ft, and the eastern span of the road lined with semi-permanent sand bags (Figure B-7). The low point in the sandbags was surveyed at 14.2 ft. During the ~2-year flood event that was simulated, the water surface elevation at the cross section upstream of the bridge/road is 14.0 ft. At this elevation the bridge is not overtopped, but the eastern span of Pescadero road would flood as the sandbags are overtopped. During the ~10-year flood event that was simulated, the water surface elevation at the upstream cross section is 16.0 ft, which would result in both the bridge and Pescadero Road being overtopped.

The profile graph (Figure B-8) gives another view to the current channel condition and how it may be effecting flooding at Pescadero Road bridge. This profile shows a buildup of sediment below the bridge making the historic channel elevated compared to the upper portion of the Butano Marsh. In this area, the channel has filled in completely and it cannot be distinguished from the adjacent floodplain areas. The transition to extremely low gradients in the marsh contribute to the deposition of sediment and in turn this accumulation of sediment is contributing to the decrease in capacity at the bridge opening. Table 3 shows the increase of channel flow area as water surface elevation increase in the 10-year flood event. Channel discharge refers to the amount of flow going through the bridge opening. Total discharge refers to the total amount of flow going through the bridge opening and over the road. The capacity of the bridge is exceeded when flows exceed approximately 500 cfs.

Table 3. Simulated total flow and flow going through the bridge opening in the existing condition during a 10-year event. The elevations provided reflect the rising and falling limbs of the hydrograph.

Water surface elevation (ft, NAVD88)	Channel discharge (cfs)	Total discharge (cfs)
13.8	400.0	400.0
14.0	483.8	483.8
15.7	755.5	1873.9
16.0	765.2	2389.6
16.0	770.3	2451.0
15.6	725.8	1607.9
15.5	569.6	1221.8
15.4	476.7	1007.7
15.1	565.1	817.5
14.5	608.4	658.3

Inundation maps help to show the potential extents of flooding. Figure B-9 shows the potential inundation extents at the maximum water surface elevation for 2-year event. Upstream of Pescadero road bridge the flood water extends across its floodplain along the width of the lower portions of the willow forest and inundates the fields south of Pescadero Road. At this water surface elevation the over topping of the road causes flooding north of the road and east of creek in the vicinity of Water Lane. Additionally this inundation map helps to illustrate the elevated historic channel downstream (north) of the Pescadero Road bridge and the tendency for flood waters to move west into the lower elevations of the Butano Marsh. Figure B-10 shows the potential flooding extents of a 10-year event. Not only would a bigger flood event further inundate areas already flooded in a 2-year event, but would also overtop Bean Hollow road, flood the current fire station and overtop the bridge itself. Additional results from the hydrodynamic and sediment transport models are provided in the body of the main report.

4 REFERENCES

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.

Hydrologic Engineering Center (HEC) 2012, User Manual and Model Documentation for HEC-RAS Version 4.1. http://www.hec.usace.army.mil/software/hec-ras/documentation.aspx

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.

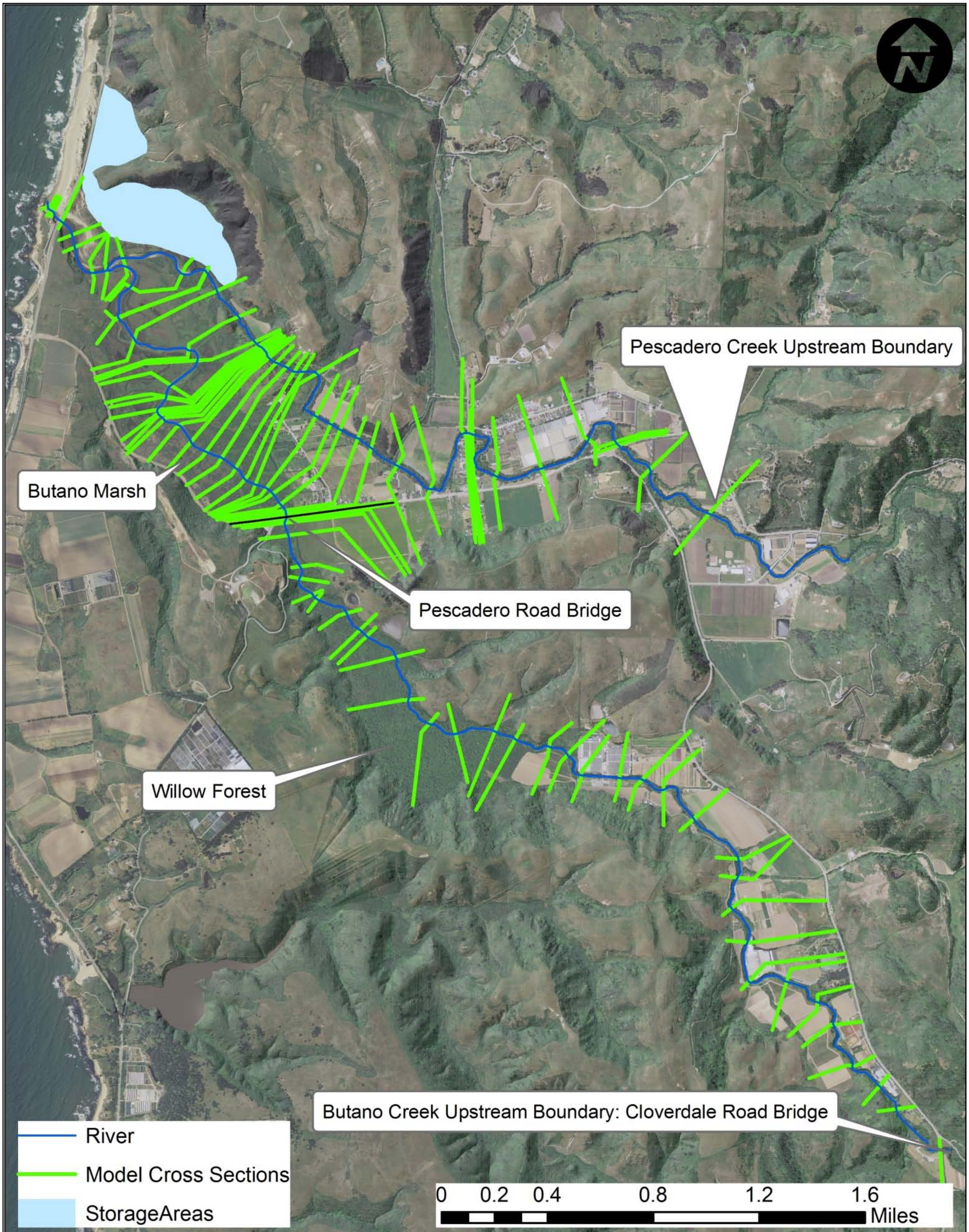
SFBRWQCB (San Francisco Bay Regional Water Quality Control Board). In preparation. Pescadero-Butano Watershed Sediment TMDL and Habitat Enhancement Plan. Staff Report.

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.

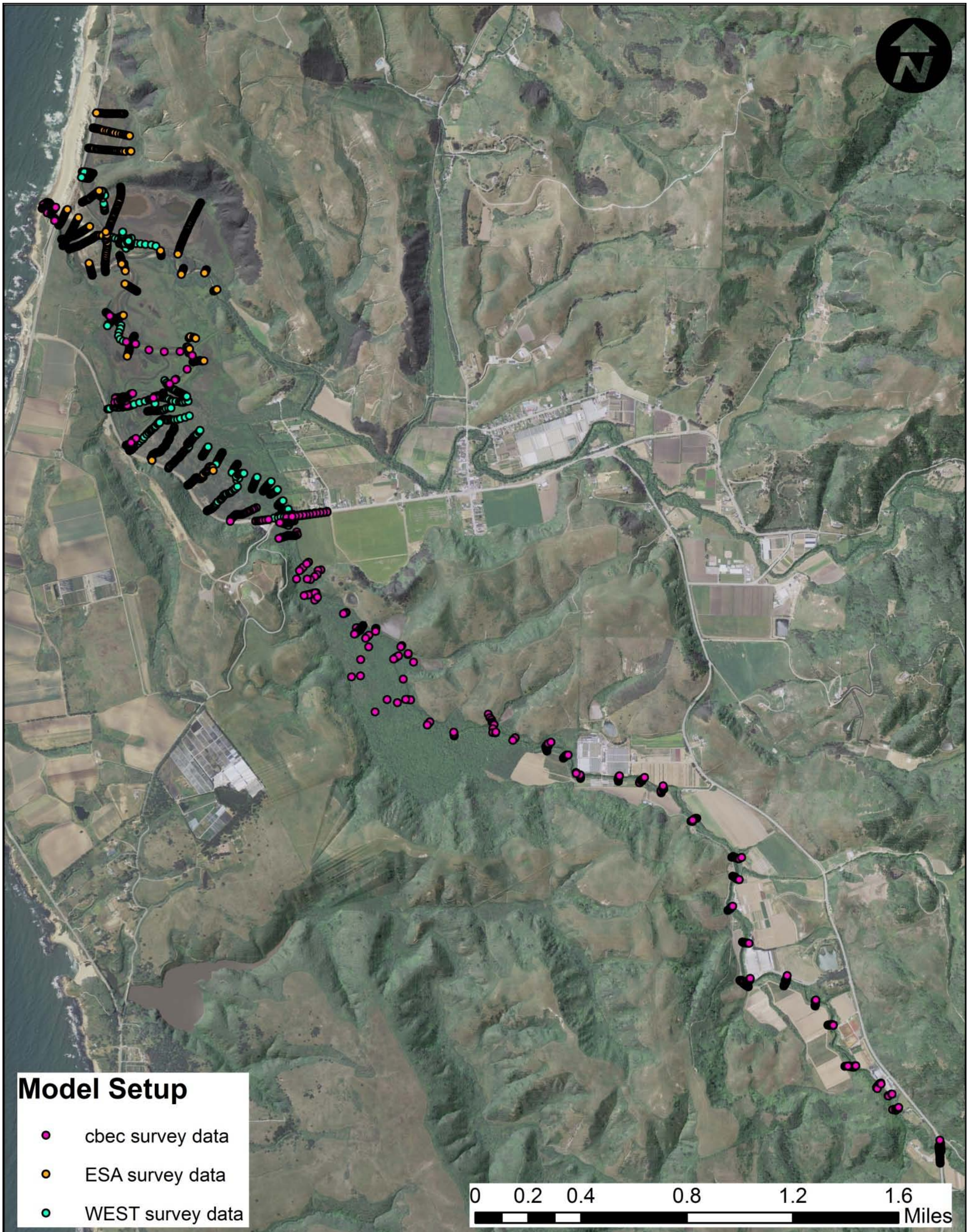
Swanson (Swanson Hydrology & Geomorphology) and WRC (WRC - Nevada). 2002. Memorandum - Preliminary Modeling Results - Pescadero Creek Road Raising Hydraulic Study. Prepared for the County of San Mateo Public Works Department, Redwood City California.

United States Geologic Survey(USGS) , 2014. User Manual and Model Documentation for PeakFQ Model Software. http://water.usgs.gov/software/PeakFQ/.

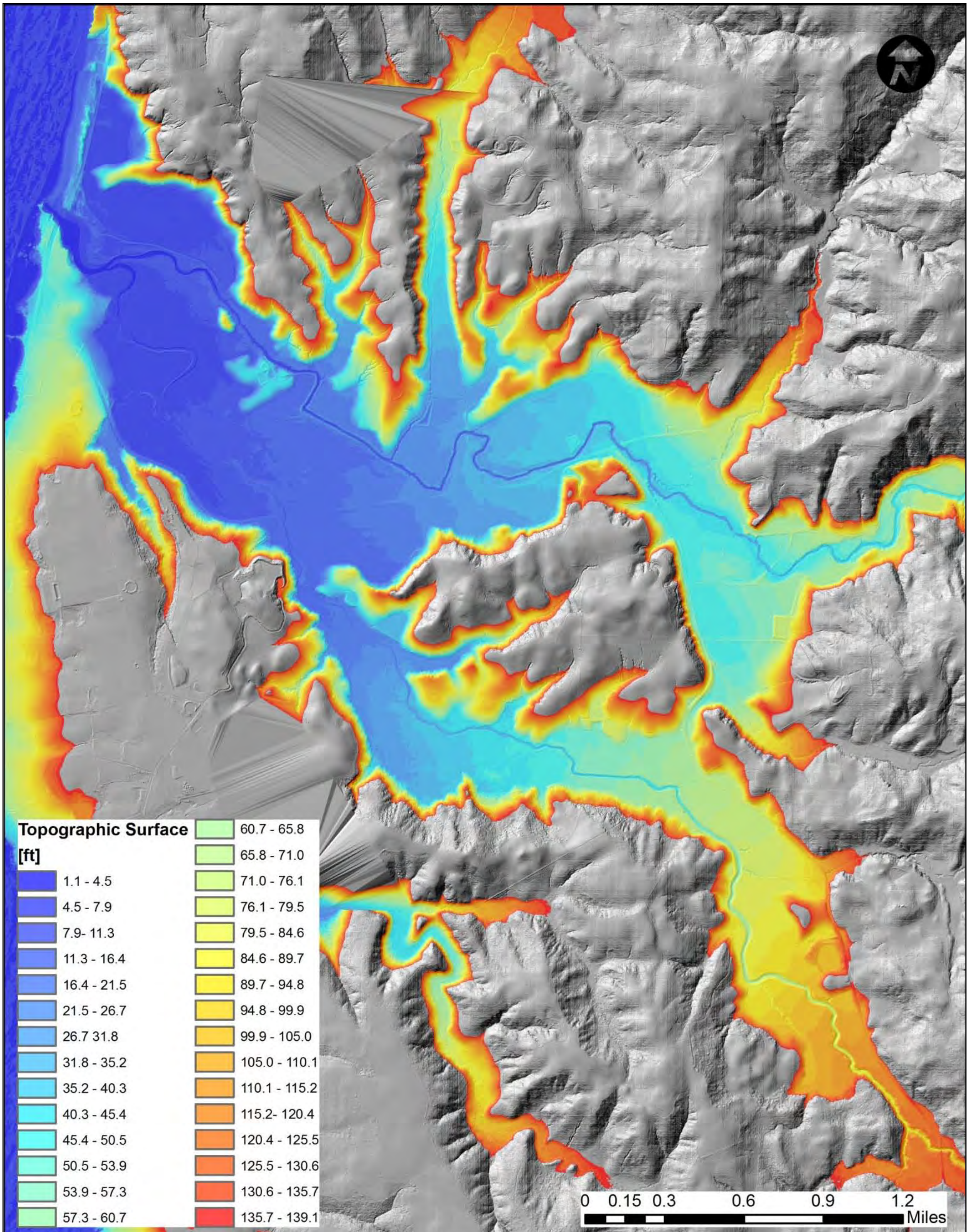
WEST (WEST Consultants, Inc.). 2013. Field Data Collection and LiDAR Assessment for Butano Creek. Prepared for NOAA's National Marine Fisheries Service Southwest Region.



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **HEC-RAS Model Domain**	
		Project No. 13-1032	Created By: DST	**Figure B-1**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Surveyed channel cross sections and water control features**
		Project No. 13-1032 / Created By: DST / **Figure B-2**



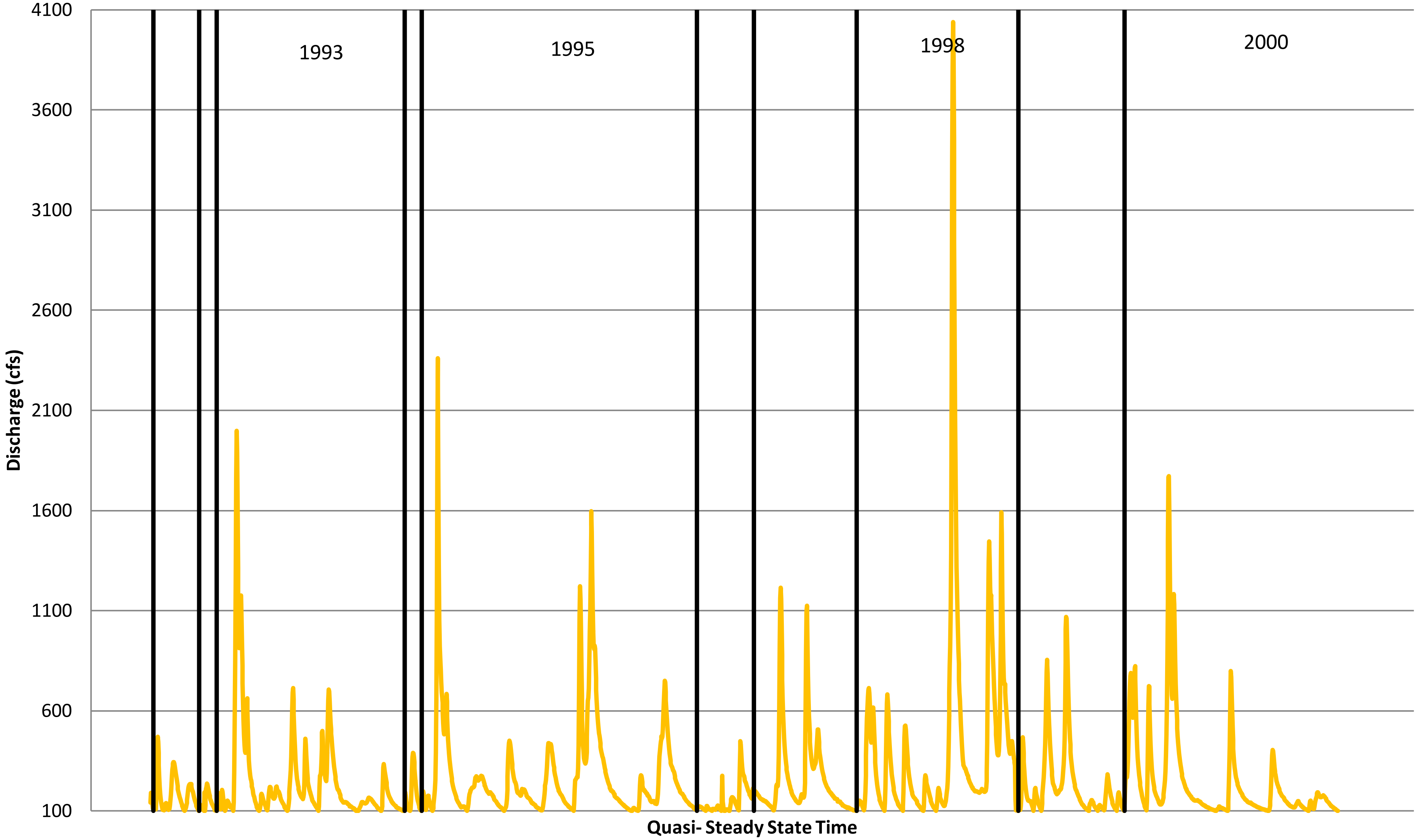
Notes:

cbec eco engineering

Solutions to Flooding at Pescadero Road

Project topographic surface

Project No. 13-1032 | Created By: DST | **Figure B-3**



Notes: quasi-steady state hydrograph represents flows over a 100 cfs converted from a continuous 15 minute flow data to an hourly time step.

cbec eco engineering

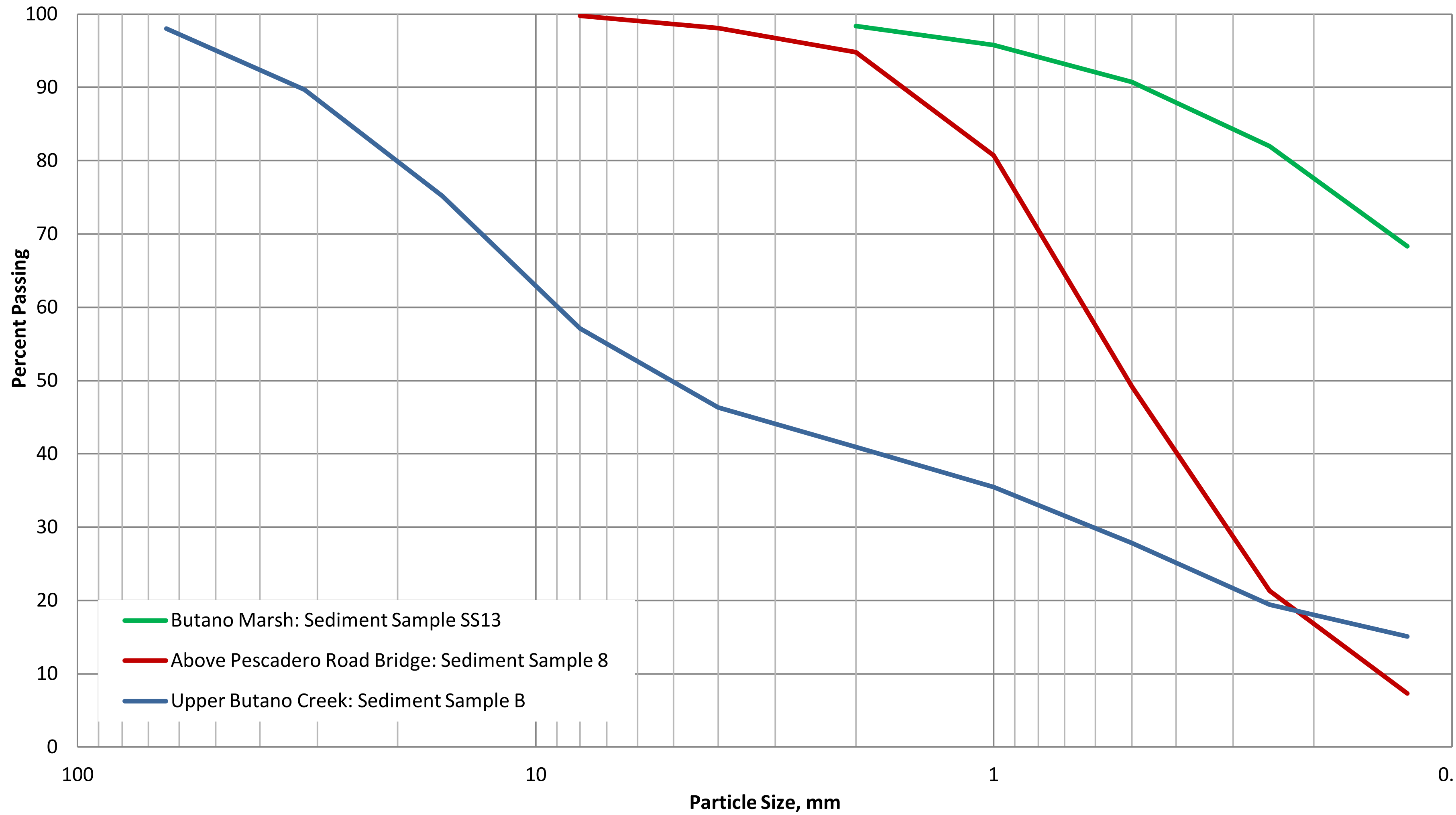
Solutions to Flooding at Pescadero Road

Quasi-Steady Hydrograph: 1991-2000

Project No. 13-1032	Created By: DST	**Figure B-4**

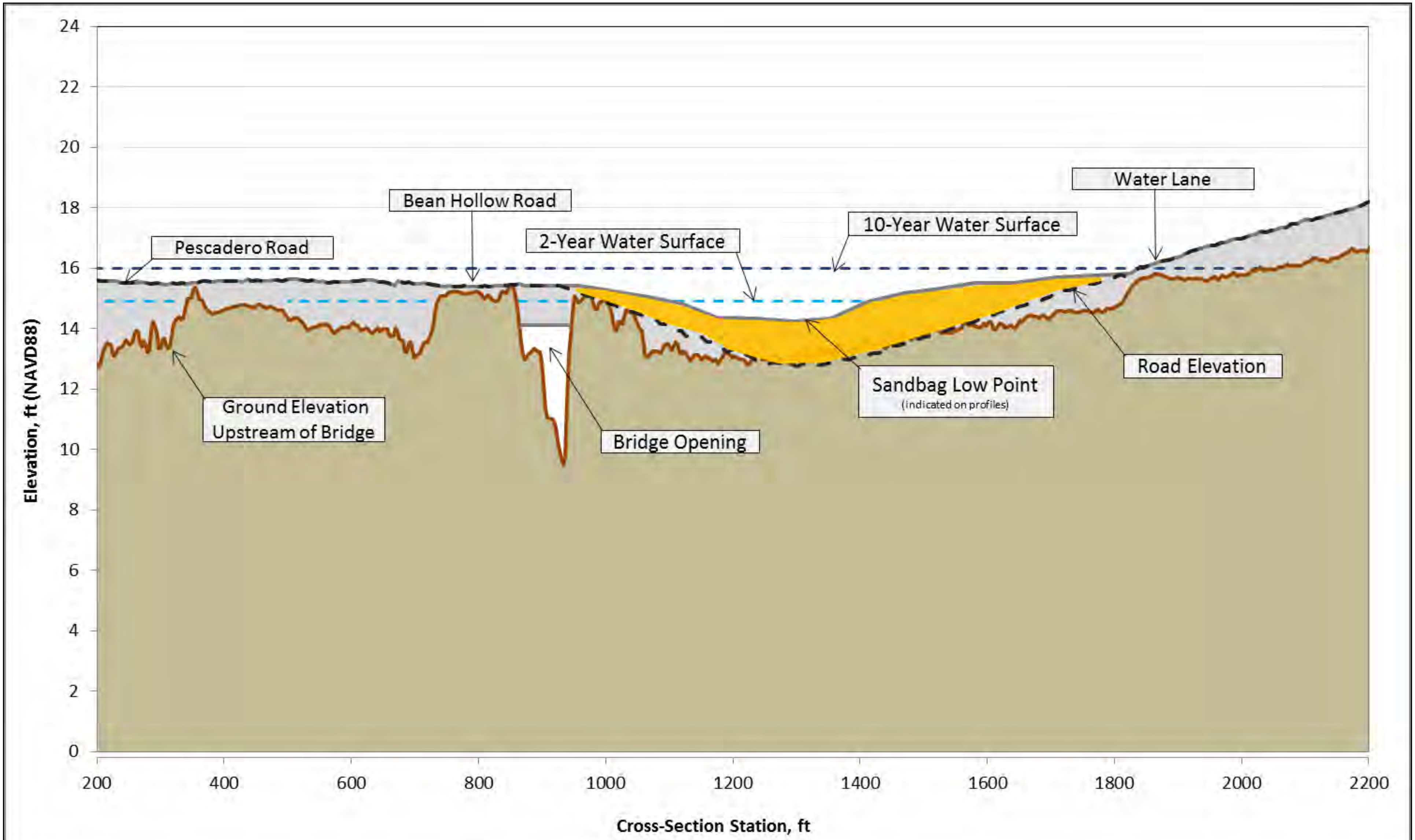
R:\Projects\13-1032_Pescadero\Reporting\Modeling_TM\figures\Fig04_QuasiSteadyHydrograph1990_2000.docx
10/17/2014

Notes: Background image: NAIP 2012		*Solutions to Flooding at Pescadero Road* **Butano Creek sediment samples**	
	Project No. 13-1032	Created By: DST	**Figure B-5**



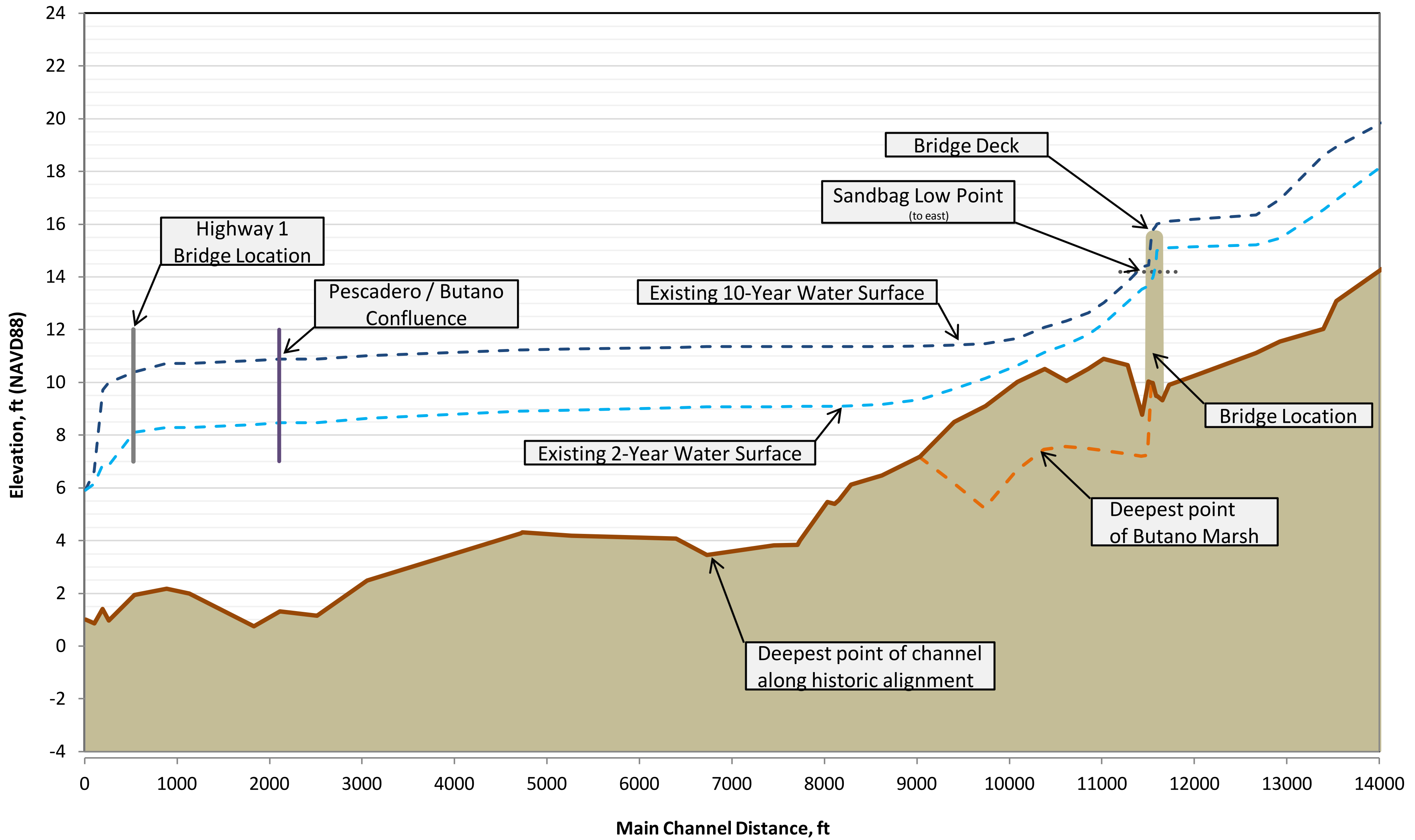
Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Butano Creek: Sediment Size Distribution**		
		Project No. 13-1032	Created By: DST	**Figure B-6**

R:\Projects\13-1032_Pescadero\Reporting\Modeling_TM\figures\Fig06_SedimentSizeAnalysis.docx
10/17/2014

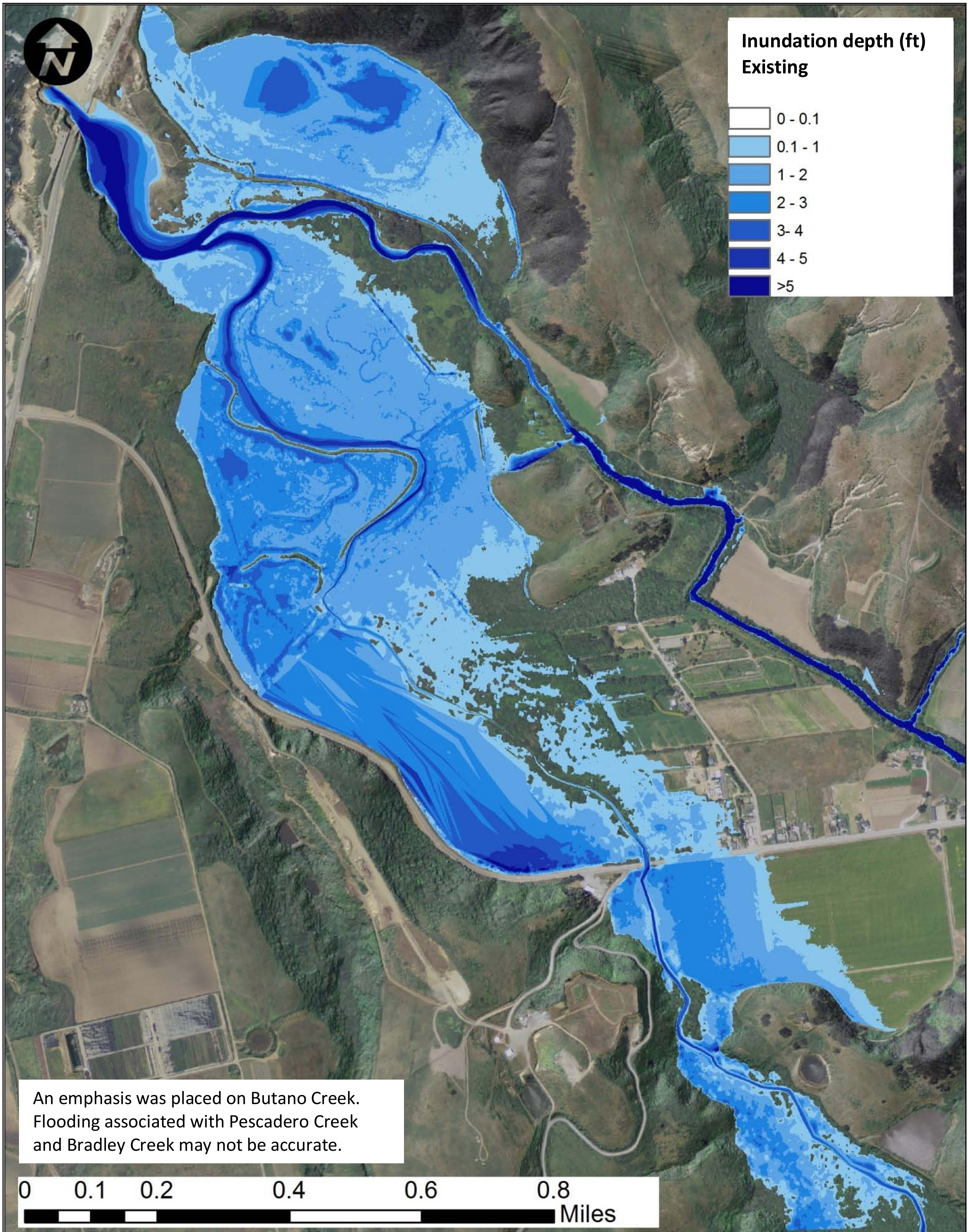


Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Existing condition cross section of the bridge and adjacent areas**		
		Project No. 13-1032	Created By: DST	**Figure B-7**

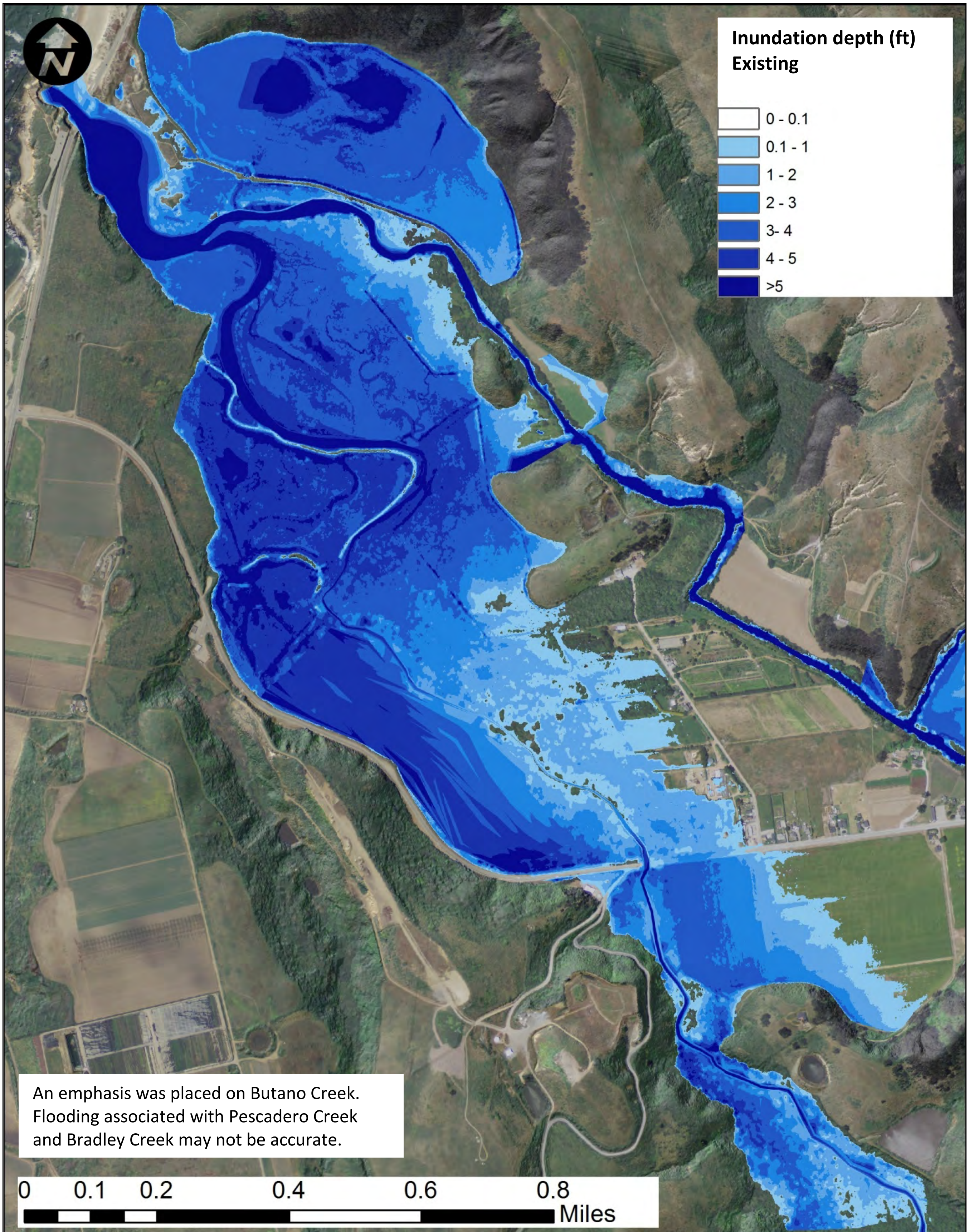
R:\Projects\13-1032_Pescadero\Reporting\Modeling_TM\figures\Fig07_ExistingConditionsBridgeSection.docx
10/17/2014



Notes:	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Existing condition peak water surface profile**		
		Project No. 13-1032	Created By: DM	**Figure B-8**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Existing condition 2-yr inundation**		
		Project No. 13-1032	Created By: DST	**Figure B-9**



Notes: Background image: NAIP 2012	cbec eco engineering	*Solutions to Flooding at Pescadero Road* **Existing condition 10-yr inundation**		
		Project No. 13-1032	Created By: DST	**Figure B-10**

APPENDIX A

WEST and cbec Sieve Analyses

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 01-02
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	3091.8
Washed Gross Dry Wt.:	3039.7
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	60.3
3/4"	280.1
3/8"	988.4
No.4	1451.8
No.10	1730.1
No.20	1990.6
No.40	2496.5
No.100	3008.9
No.200	3035.9
PAN:	3039.7

HYDROMETER

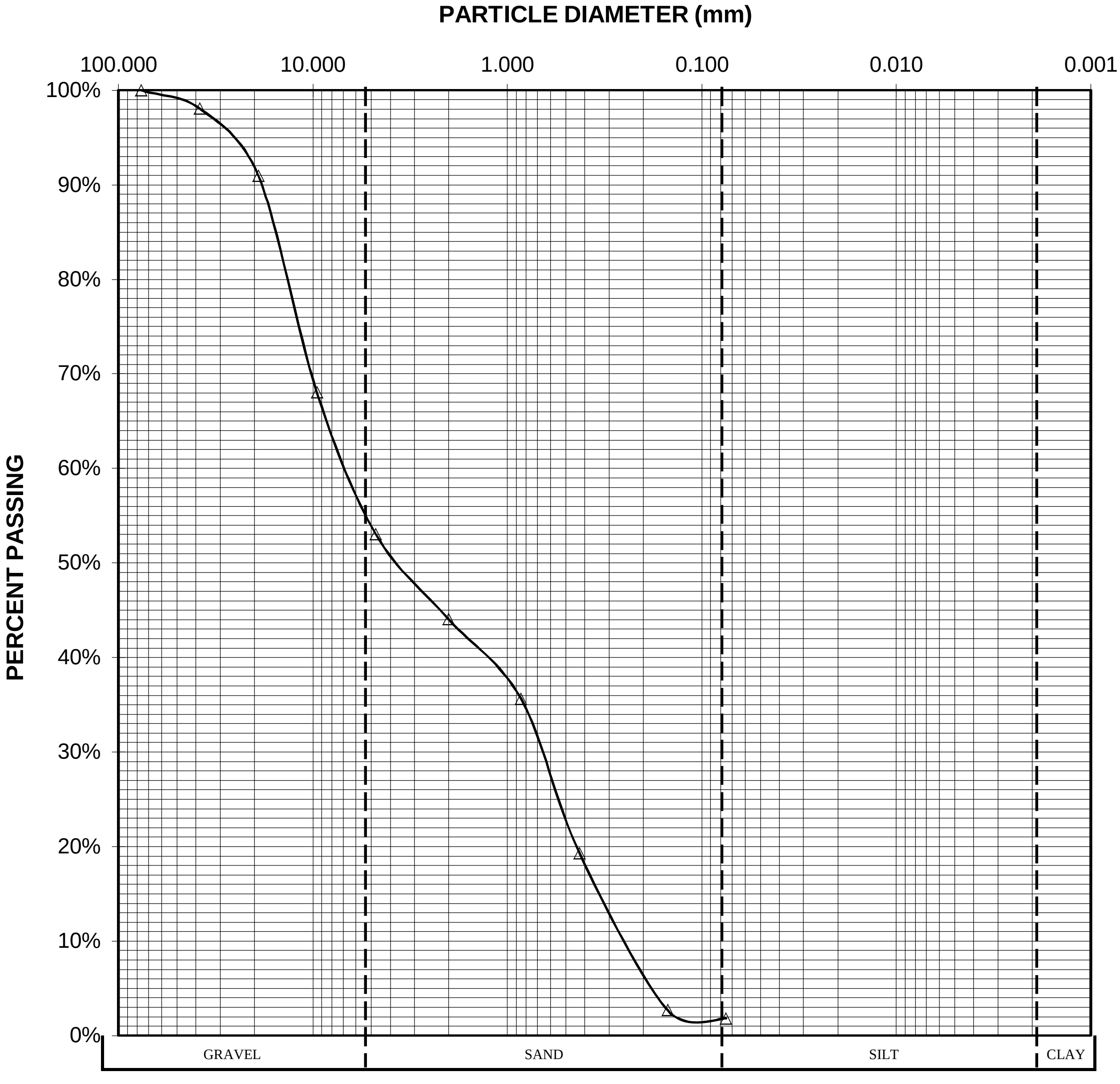
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 01-02	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	53.0%	1.8%



GRAVEL	SAND	FINES
47.0%	51.2%	1.8%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 03
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	3098.5
Washed Gross Dry Wt.:	3059.7
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	31.4
3/4"	432.1
3/8"	1069.2
No.4	1622.0
No.10	1983.9
No.20	2322.7
No.40	2644.6
No.100	3027.1
No.200	3055.9
PAN:	3059.7

HYDROMETER

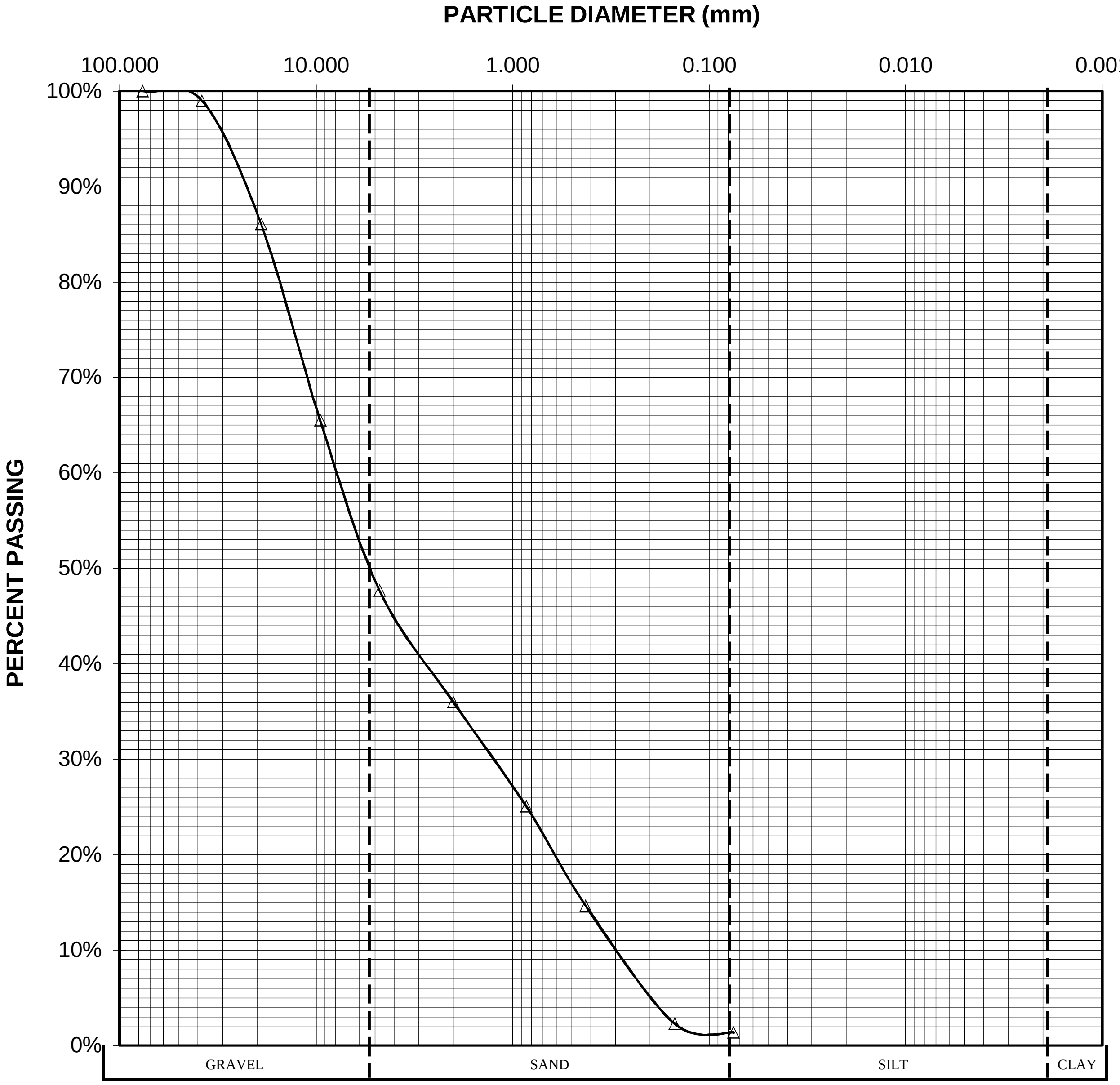
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 03	% PASSING	% PASSING
SOIL TYPE: GP	No. 4	No. 200
	47.7%	1.4%



GRAVEL	SAND	FINES
52.3%	46.3%	1.4%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 04
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	3082.2
Washed Gross Dry Wt.:	3050.2
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	281.4
3/8"	1103.9
No.4	1596.0
No.10	1943.4
No.20	2225.9
No.40	2575.0
No.100	3003.4
No.200	3044.8
PAN:	3050.2

HYDROMETER

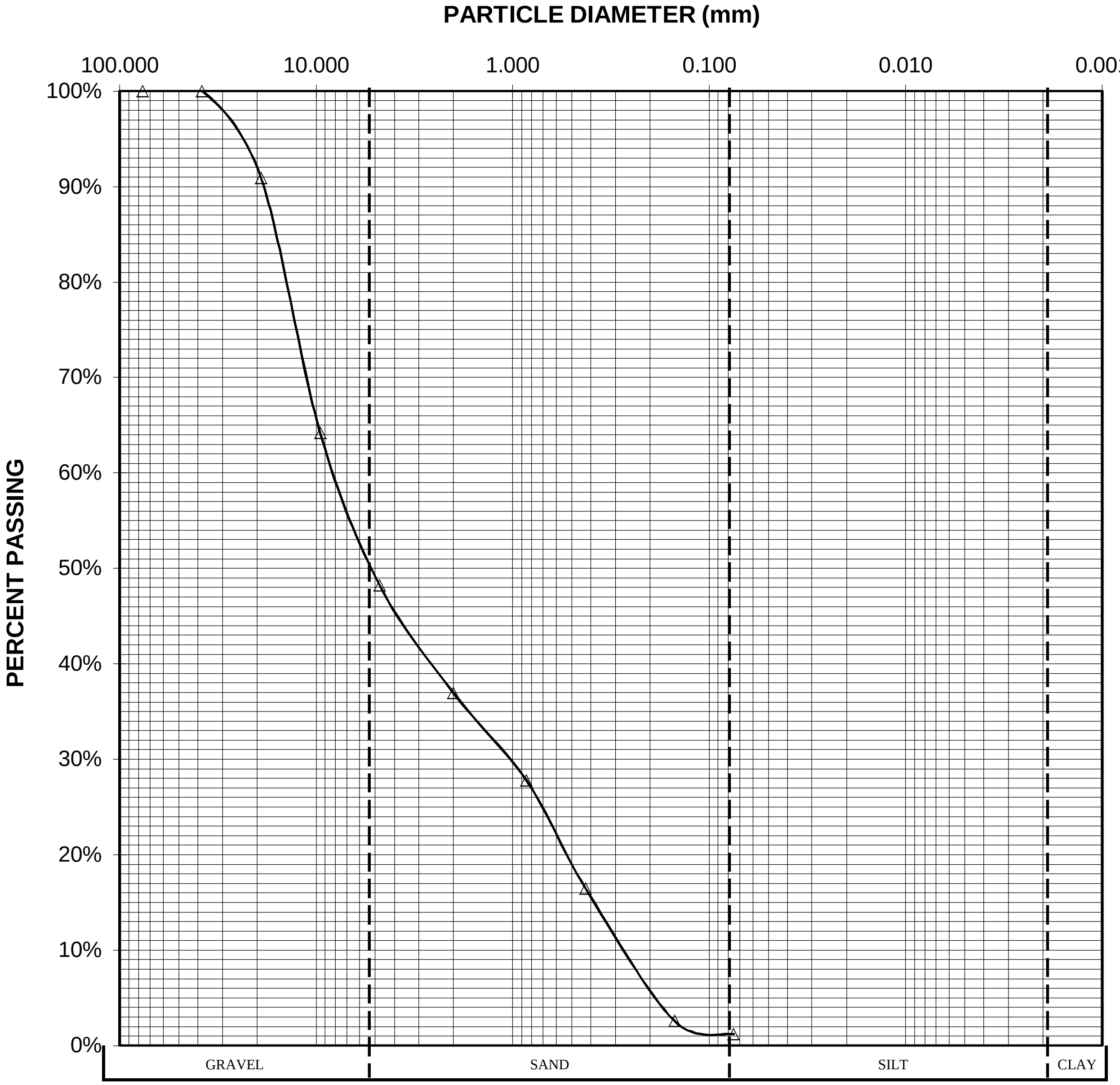
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 04	% PASSING	% PASSING
SOIL TYPE: GP	No. 4	No. 200
	48.2%	1.2%



GRAVEL	SAND	FINES
51.8%	47.0%	1.2%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 05
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	3029.1
Washed Gross Dry Wt.:	2986.8
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	126.6
3/8"	769.2
No.4	1361.2
No.10	1770.3
No.20	2080.7
No.40	2487.7
No.100	2947.3
No.200	2980.4
PAN:	2986.8

HYDROMETER

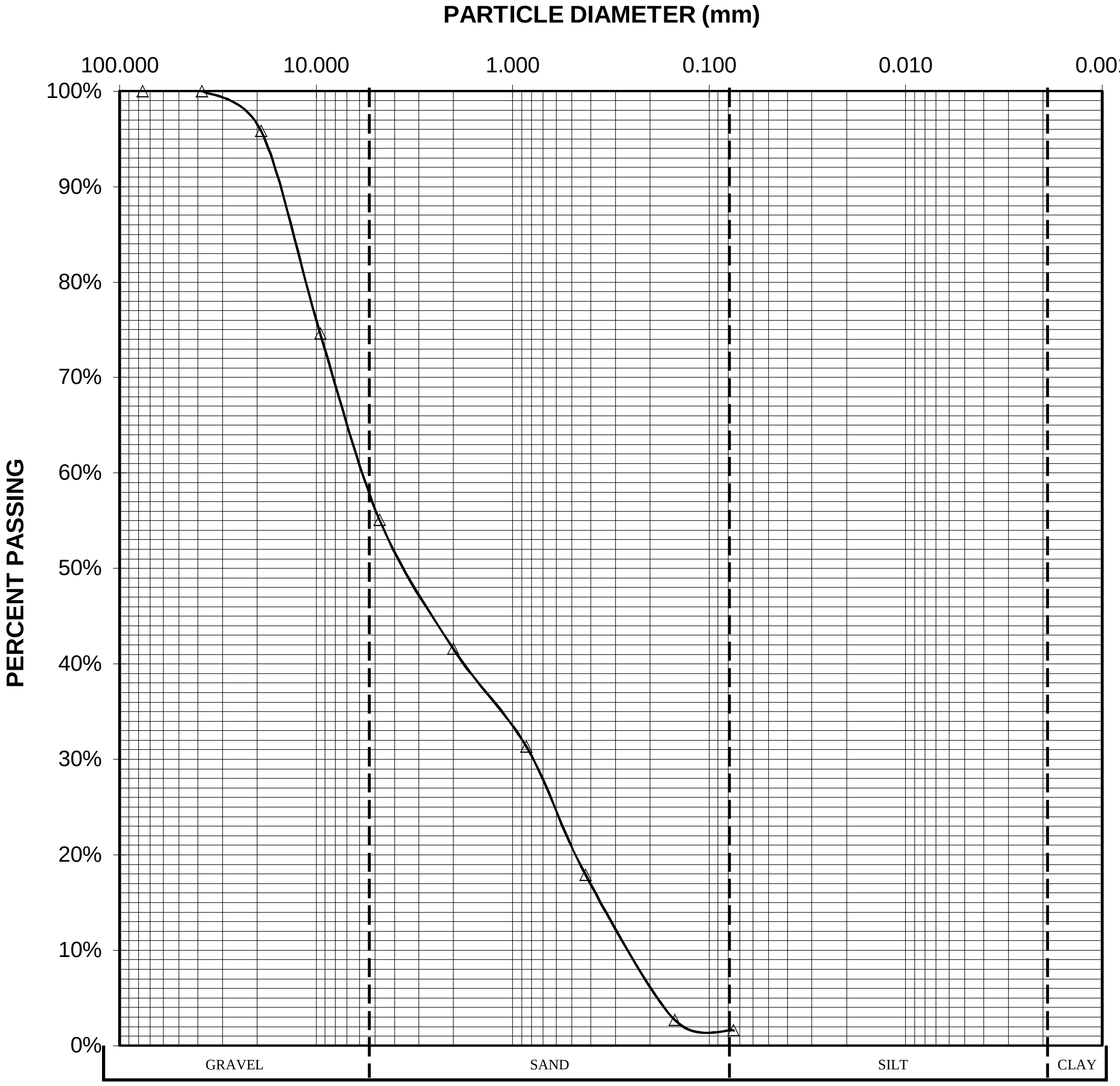
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 05	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	55.1%	1.6%



GRAVEL	SAND	FINES
44.9%	53.5%	1.6%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 06
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE	
Gross Dry Wt.:	3045.8
Washed Gross Dry Wt.:	3013.6
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	125.5
3/8"	619.8
No.4	1121.0
No.10	1428.2
No.20	1749.9
No.40	2305.8
No.100	2967.2
No.200	3008.7
PAN:	3013.6

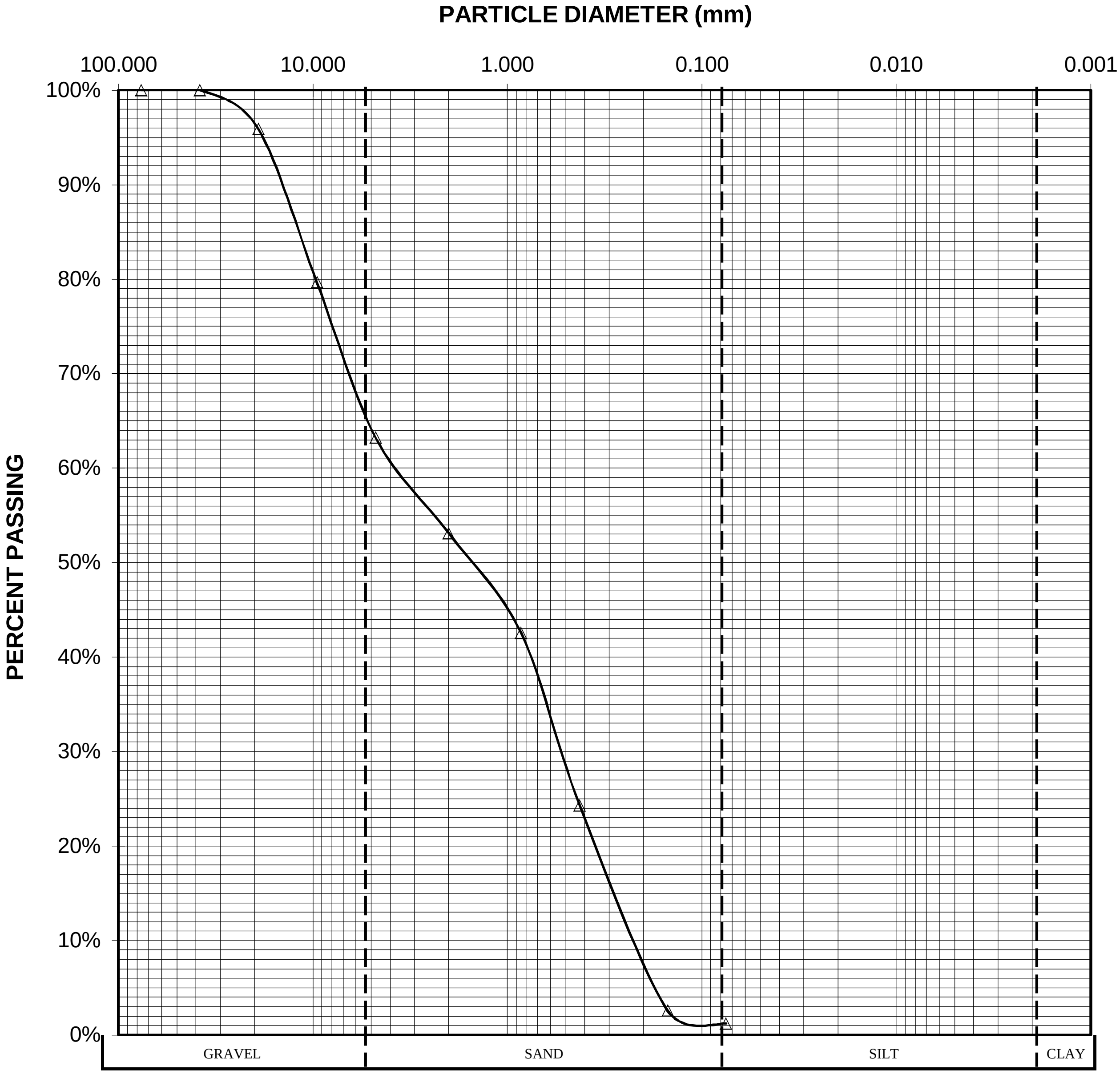
HYDROMETER	
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 06	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	63.2%	1.2%



GRAVEL	SAND	FINES
36.8%	62.0%	1.2%

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PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 07
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	2923.8
Washed Gross Dry Wt.:	2905.9
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	0.0
3/8"	194.4
No.4	546.9
No.10	978.5
No.20	1596.6
No.40	2394.6
No.100	2876.1
No.200	2901.9
PAN:	2905.9

HYDROMETER

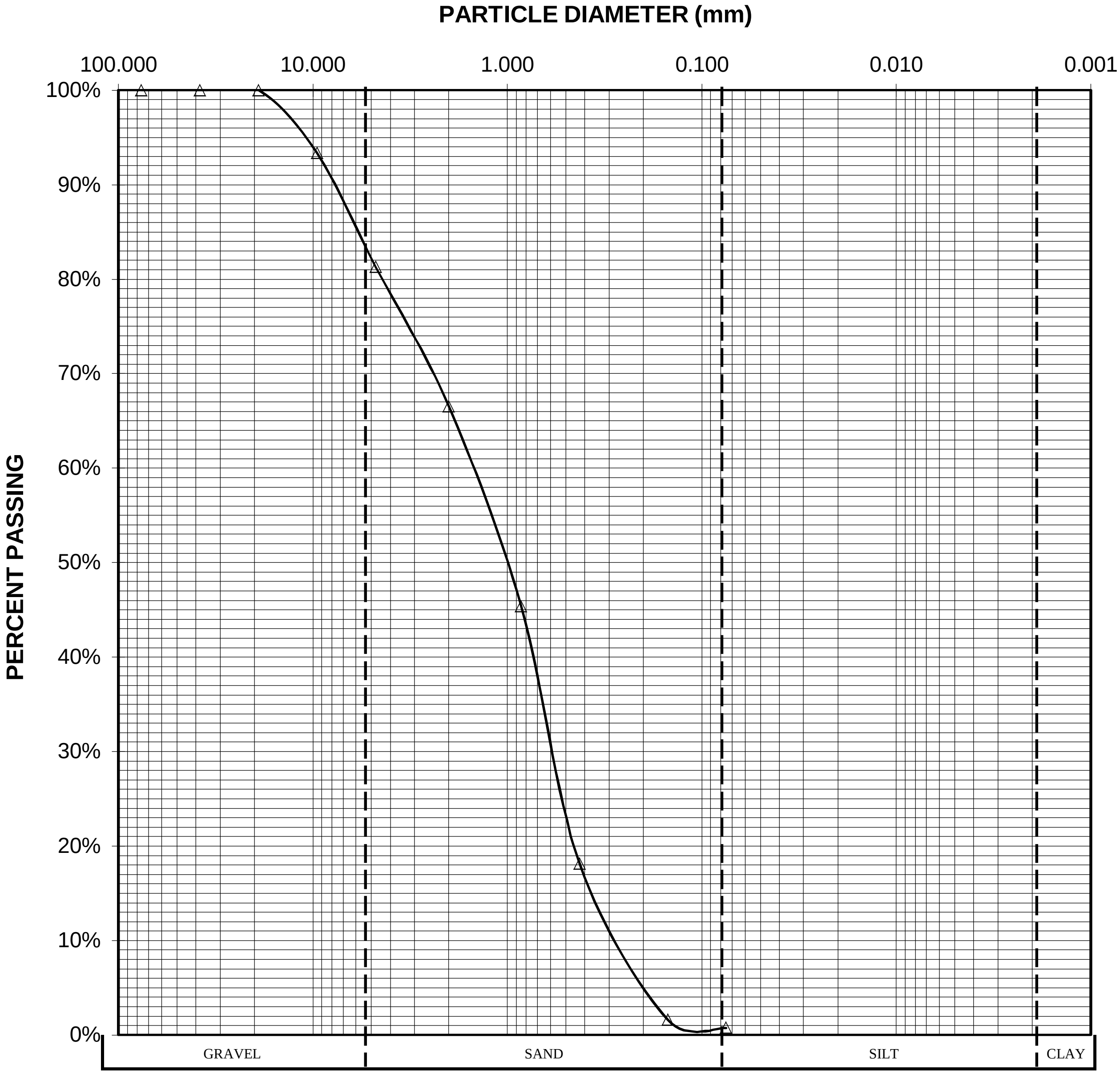
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 07	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	81.3%	0.7%



GRAVEL	SAND	FINES
18.7%	80.5%	0.7%

Bauldry Engineering, Inc.	Figure No.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	SED 08
Date:	March 11, 2014
Tested By:	SSC

Description:

SIEVE

Gross Dry Wt.:	1564.8
Washed Gross Dry Wt.:	1511.3
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	0.0
3/8"	0.0
No.4	10.2
No.10	80.9
No.20	336.7
No.40	903.2
No.100	1423.5
No.200	1502.7
PAN:	1511.3

HYDROMETER

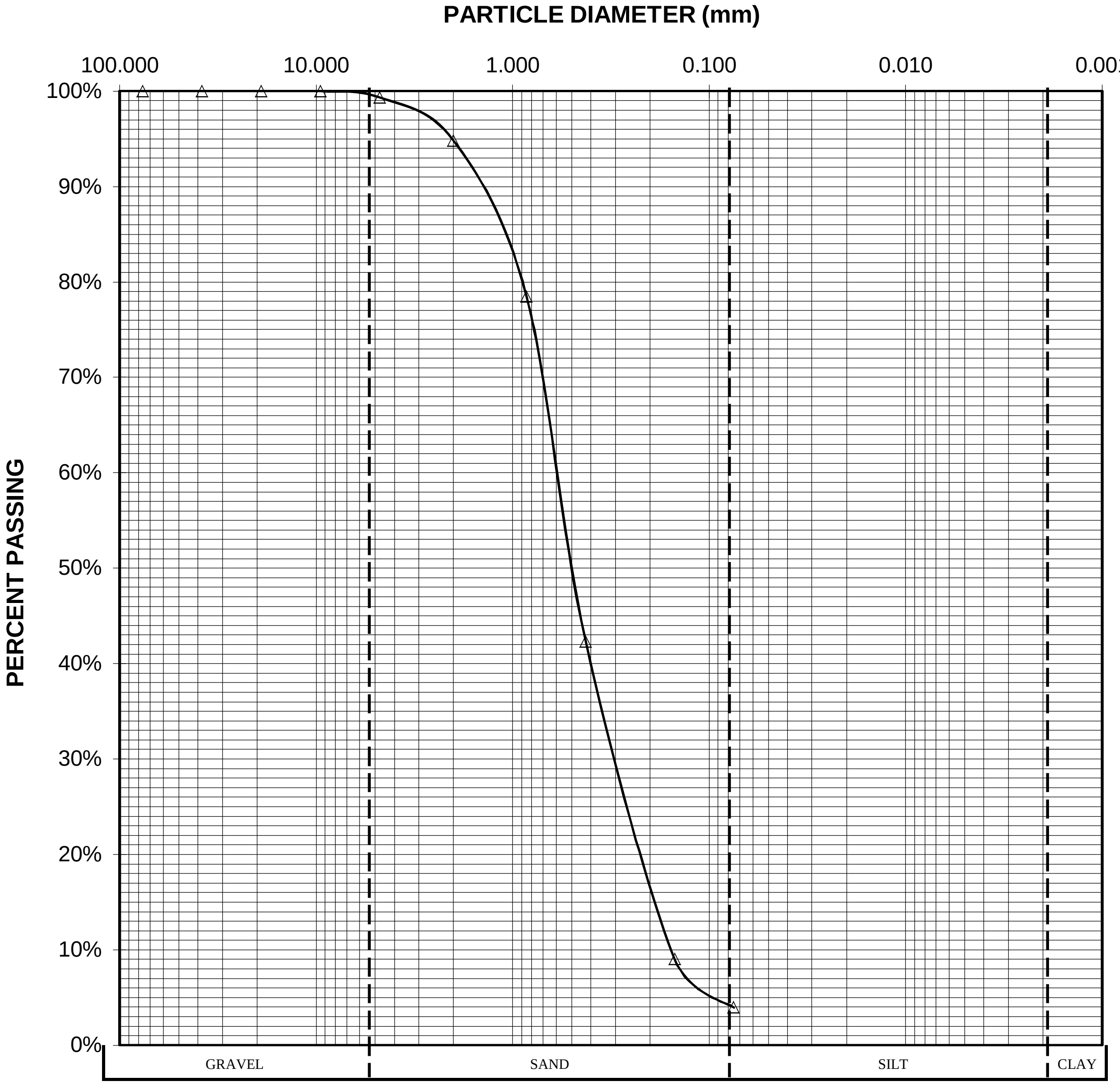
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 11, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: SED 08	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	99.3%	4.0%



GRAVEL	SAND	FINES
0.7%	95.4%	4.0%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	Sample A
Date:	March 31, 2014
Tested By:	SSC

Description: XS

SIEVE

Gross Dry Wt.:	3259.2
Washed Gross Dry Wt.:	3171.6
Tare No.:	

SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	241.1
3/8"	742.2
No.4	1206.8
No.10	1453.3
No.20	1665.8
No.40	2112.6
No.100	2516.9
No.200	2532.1
PAN:	2535.6

HYDROMETER

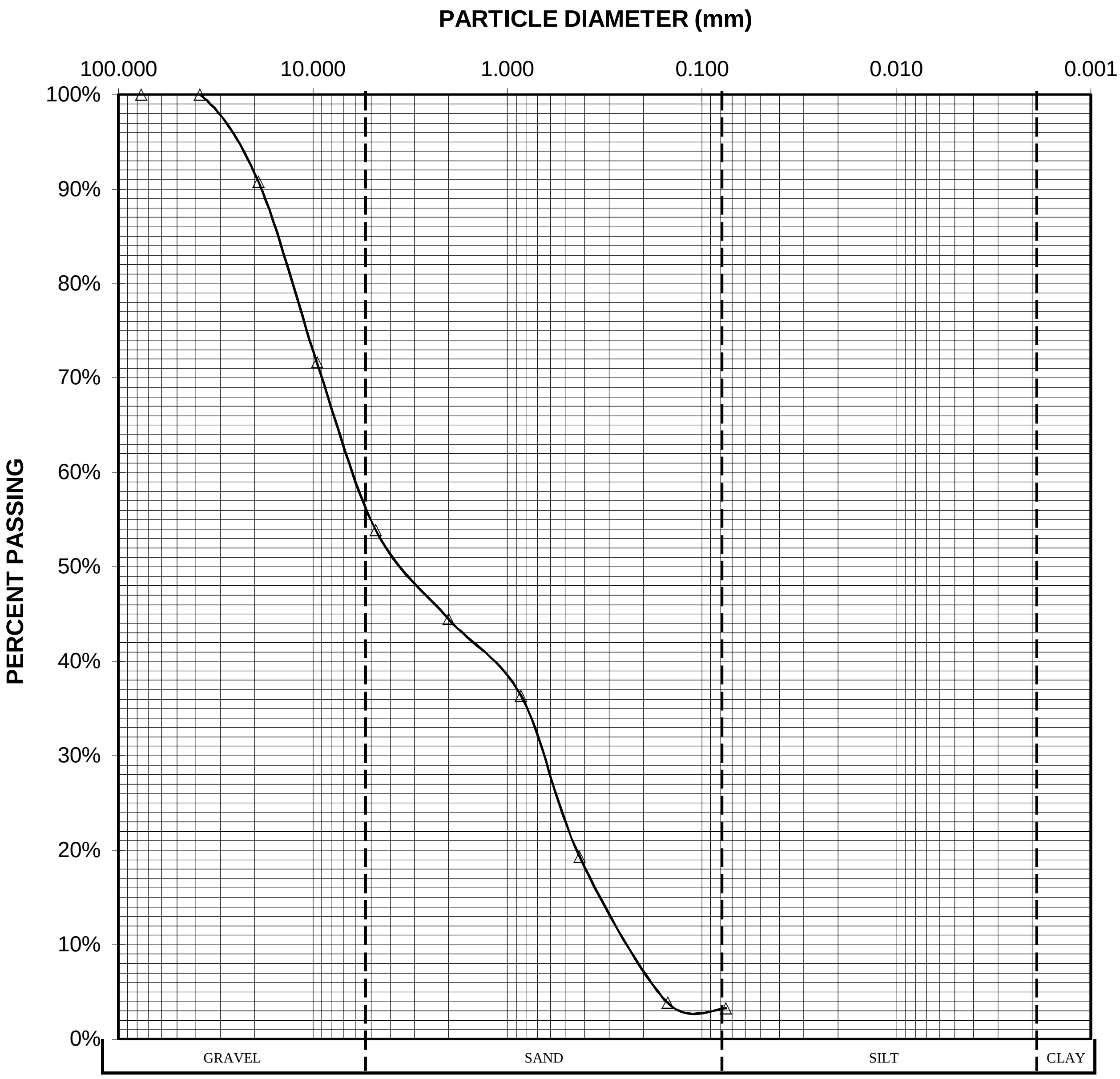
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 31, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: Sample A	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	53.9%	3.3%



GRAVEL	SAND	FINES
46.1%	50.6%	3.3%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	Sample B
Date:	March 31, 2014
Tested By:	SSC

Description: XS 9

SIEVE	
Gross Dry Wt.:	5135.9
Washed Gross Dry Wt.:	5028.1
Tare No.:	
SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	353.1
3/4"	938.3
3/8"	1991.4
No.4	2655.2
No.10	3034.5
No.20	3354.5
No.40	3789.4
No.100	4345.9
No.200	4386.9
PAN:	4391.9

HYDROMETER

Dry Wt. of Sample:

Specific Gravity of Soil:

Unit Wt. Correction α:

Temperature of Water:

Temp. Correction C_T:

K Value:

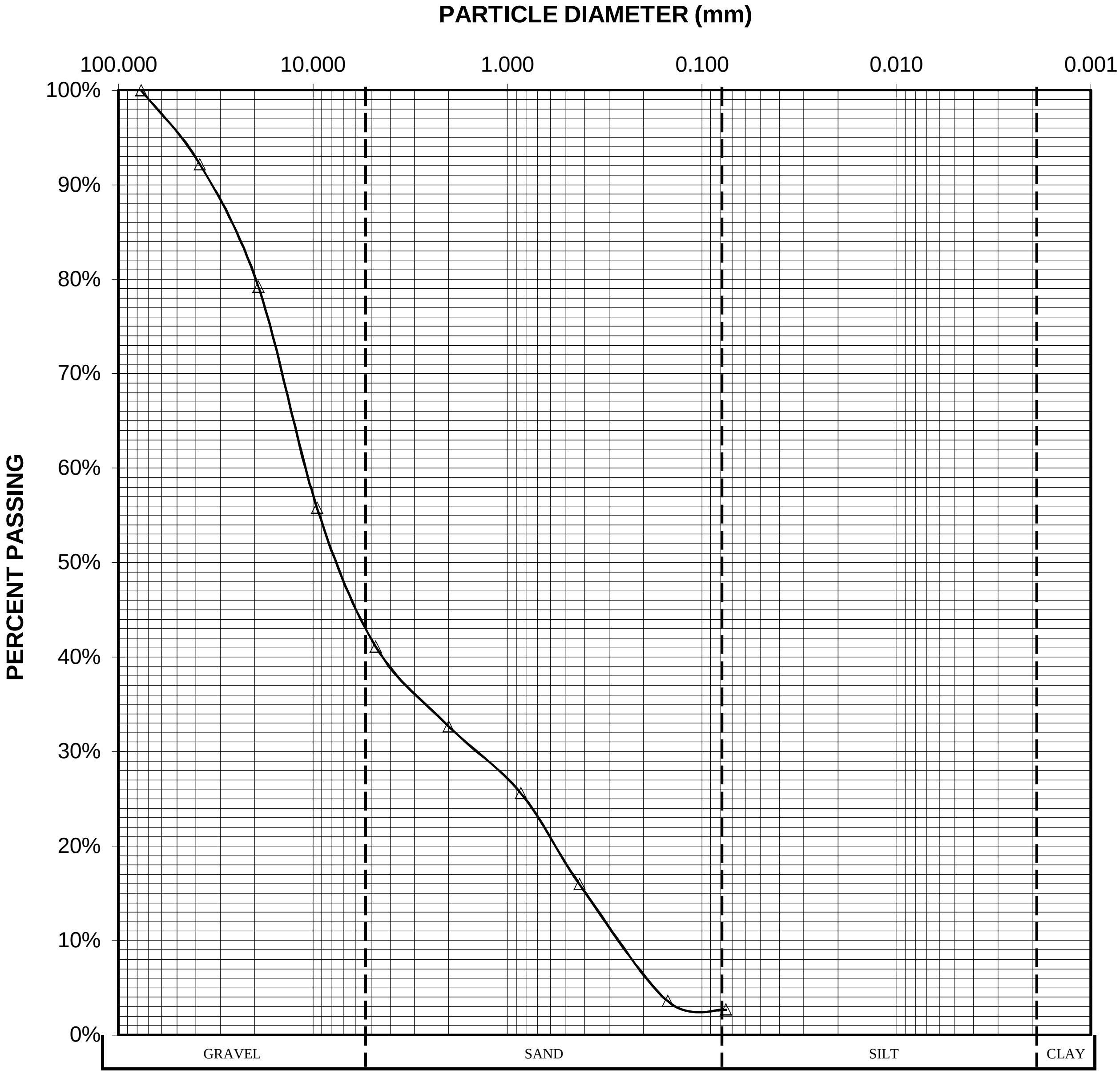
Hydro Zero Correction:

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 31, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: Sample B	% PASSING	% PASSING
SOIL TYPE: GP	No. 4	No. 200
	41.1%	2.7%



GRAVEL	SAND	FINES
58.9%	38.4%	2.7%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	Sample C
Date:	March 31, 2014
Tested By:	SSC

Description: XS 7

SIEVE	
Gross Dry Wt.:	3134.9
Washed Gross Dry Wt.:	3090.5
Tare No.:	
SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	0.0
3/4"	14.9
3/8"	140.1
No.4	371.0
No.10	747.6
No.20	1447.3
No.40	2083.8
No.100	2410.9
No.200	2444.7
PAN:	2449.2

HYDROMETER

Dry Wt. of Sample:

Specific Gravity of Soil:

Unit Wt. Correction α:

Temperature of Water:

Temp. Correction C_T:

K Value:

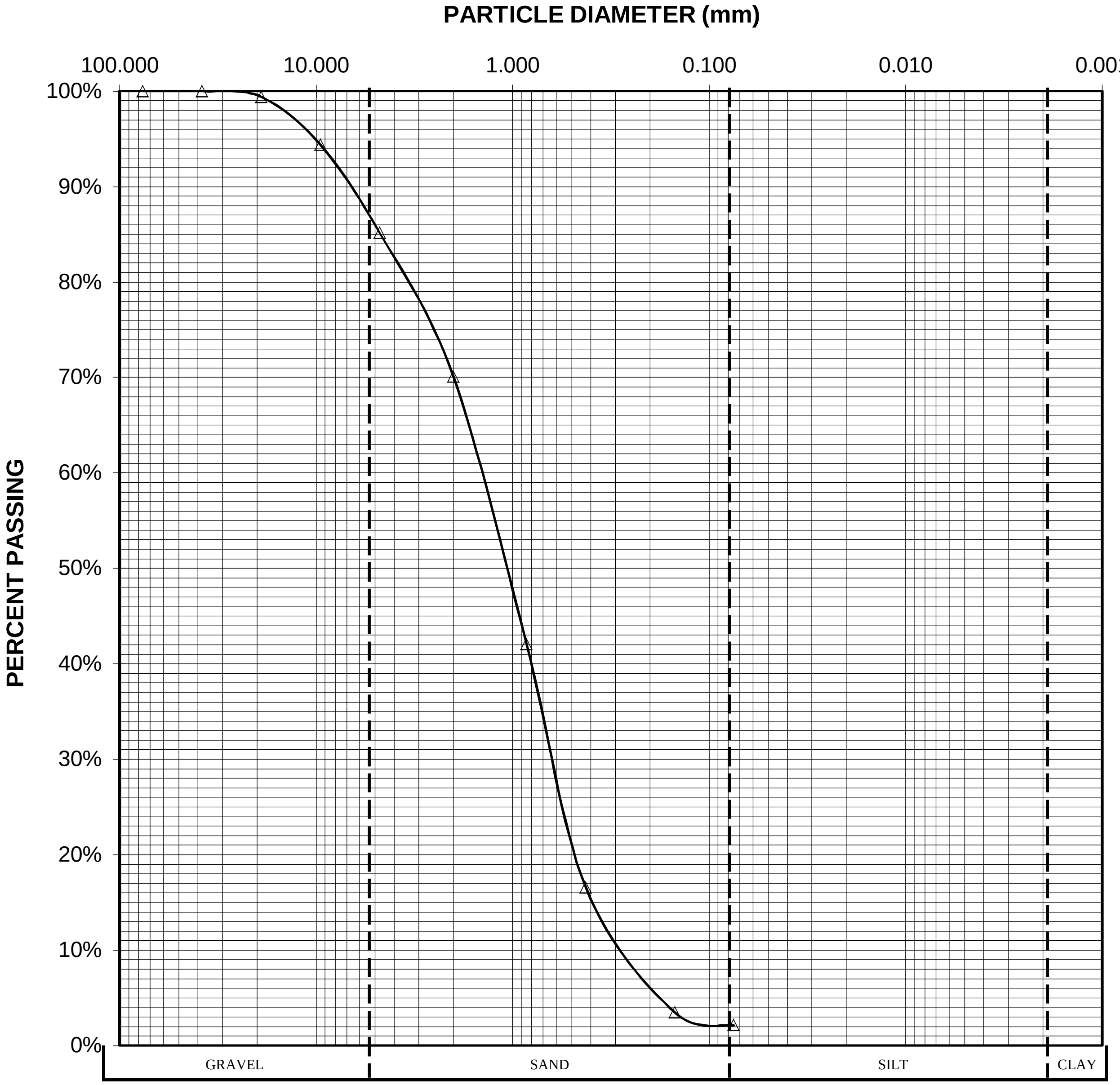
Hydro Zero Correction:

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 31, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: Sample C	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	85.1%	2.1%



GRAVEL	SAND	FINES
14.9%	83.0%	2.1%

Bauldry Engineering, Inc.

PARTICLE SIZE ANALYSIS

Project No.:	cbec
Project Name:	Pescadero Flooding-#13-1032
Sample:	Sample D
Date:	March 31, 2014
Tested By:	SSC

Description: XS 3

SIEVE	
Gross Dry Wt.:	4238.6
Washed Gross Dry Wt.:	4164.6
Tare No.:	
SIEVE NO.	CUMULATIVE WEIGHT
3"	0.0
1 1/2"	139.9
3/4"	448.1
3/8"	943.2
No.4	1310.4
No.10	1579.9
No.20	2010.6
No.40	3010.5
No.100	3494.5
No.200	3528.3
PAN:	3533.9

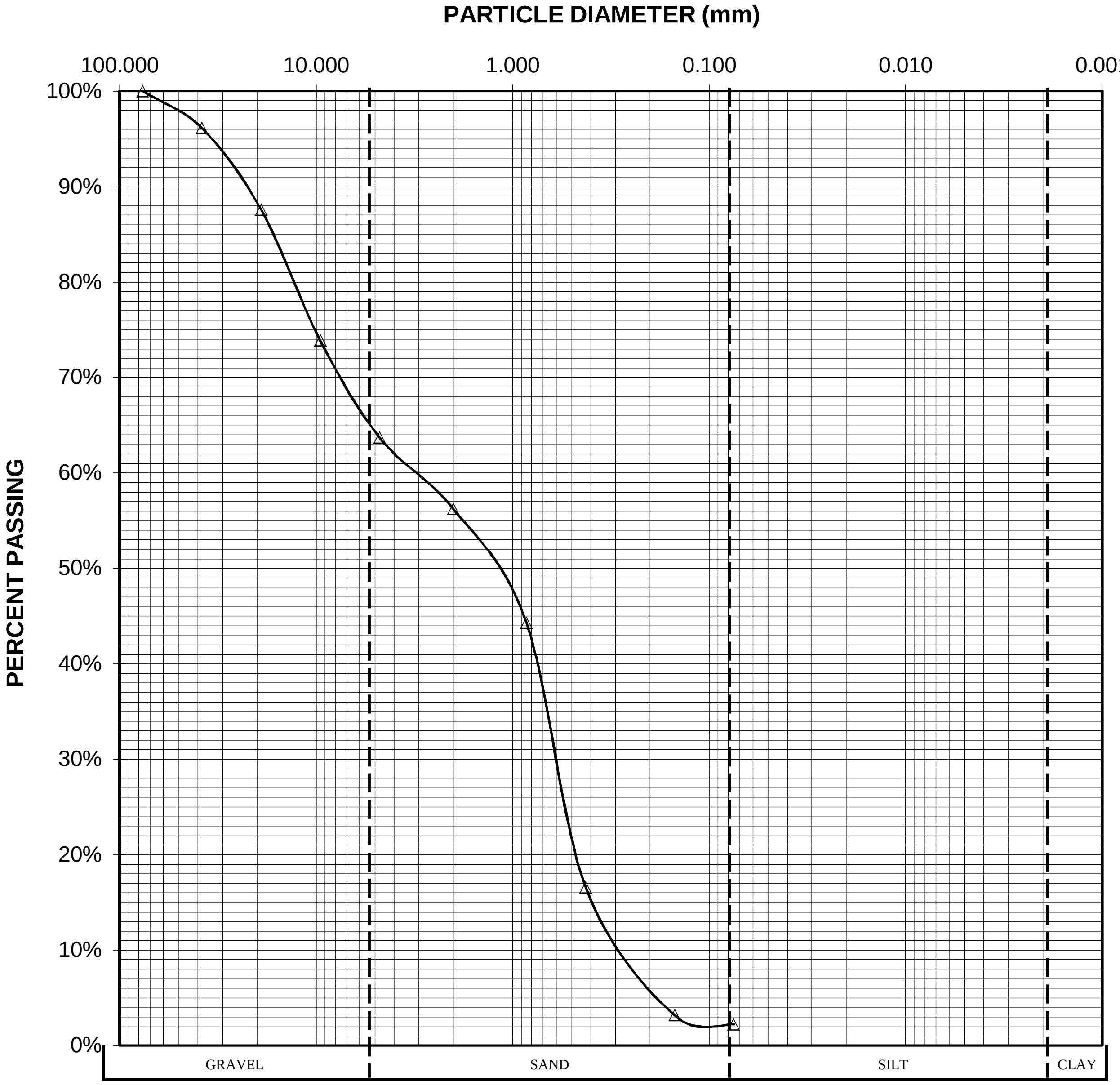
HYDROMETER	
Dry Wt. of Sample:	
Specific Gravity of Soil:	
Unit Wt. Correction α:	
Temperature of Water:	
Temp. Correction C_T:	
K Value:	
Hydro Zero Correction:	

TIME	ELAPSED TIME	HYDRO READING	EFFECT. DEPTH (L)

PROJECT: cbec #13-1032 Pescadero Flood.	REPORT DATE: March 31, 2014

PARTICLE SIZE ANALYSIS - ASTM D 422

SAMPLE: Sample D	% PASSING	% PASSING
SOIL TYPE: SP	No. 4	No. 200
	63.7%	2.2%



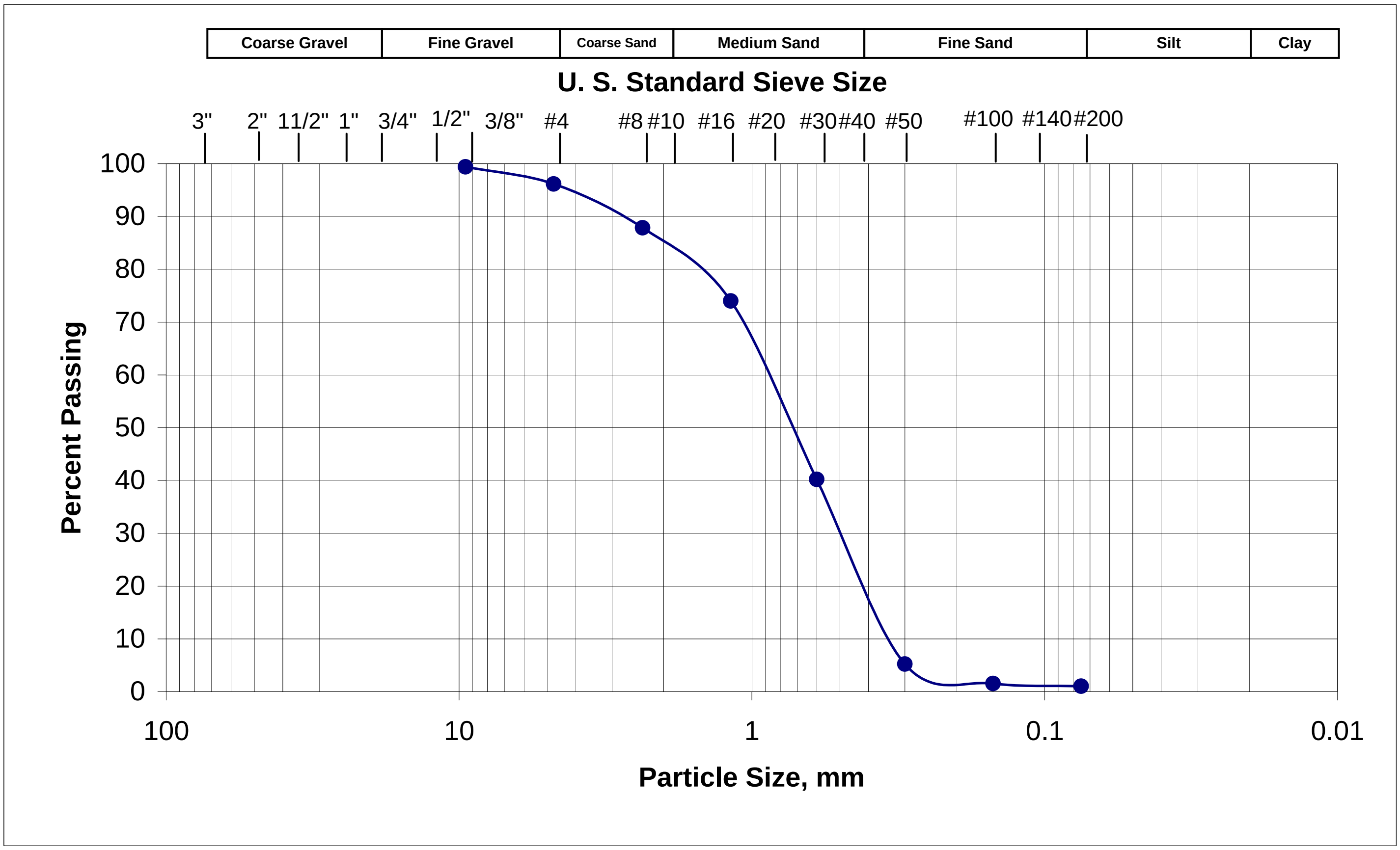
GRAVEL	SAND	FINES
36.3%	61.5%	2.2%

Bauldry Engineering, Inc.

SUMMARY OF LABORATORY TEST RESULTS

SAMPLE	SOIL TYPE	IN-SITU			DIRECT SHEAR		UNCONFINED COMPRESSION (psf)	GRAIN SIZE (%)				PASSING #200 (%)	EXPANSION INDEX	ATTERBERG			SOLUBLE SULFATES (ppm)
		WET DENSITY (pcf)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	COHESION (psf) (PEAK)	FRICTION ANGLE (PEAK)		GRAVEL	SAND	SILT	CLAY			LL (%)	PL (%)	PI	
Sample A	SP		11.9					46	51	3							
Sample B	GP		10.6					59	38	3							
Sample C	SP		7.7					15	83	2							
Sample D	SP		9.8					36	62	2							

SIEVE ANALYSIS TEST REPORT



SIEVE SIZE	SIZE, mm	PASSING
3 INCH	76.2	
2 INCH	50.8	
1 1/2 INCH	38.1	
1 INCH	25.4	
3/4 INCH	19.1	
1/2 INCH	12.7	
3/8 INCH	9.5	99
NO. 4	4.75	96
NO. 8	2.36	88
NO. 16	1.18	74
NO. 30	0.60	40
NO. 50	0.30	5
NO.100	0.15	2
NO 200	0.075	1

Test Method: ASTM C136

SAMPLE IDENTIFICATION: SS1 SAMPLE DEPTH, ft. : NA Lab Number: 3180

SAMPLE DESCRIPTION: Brown poorly graded sand Group Symbol: SW

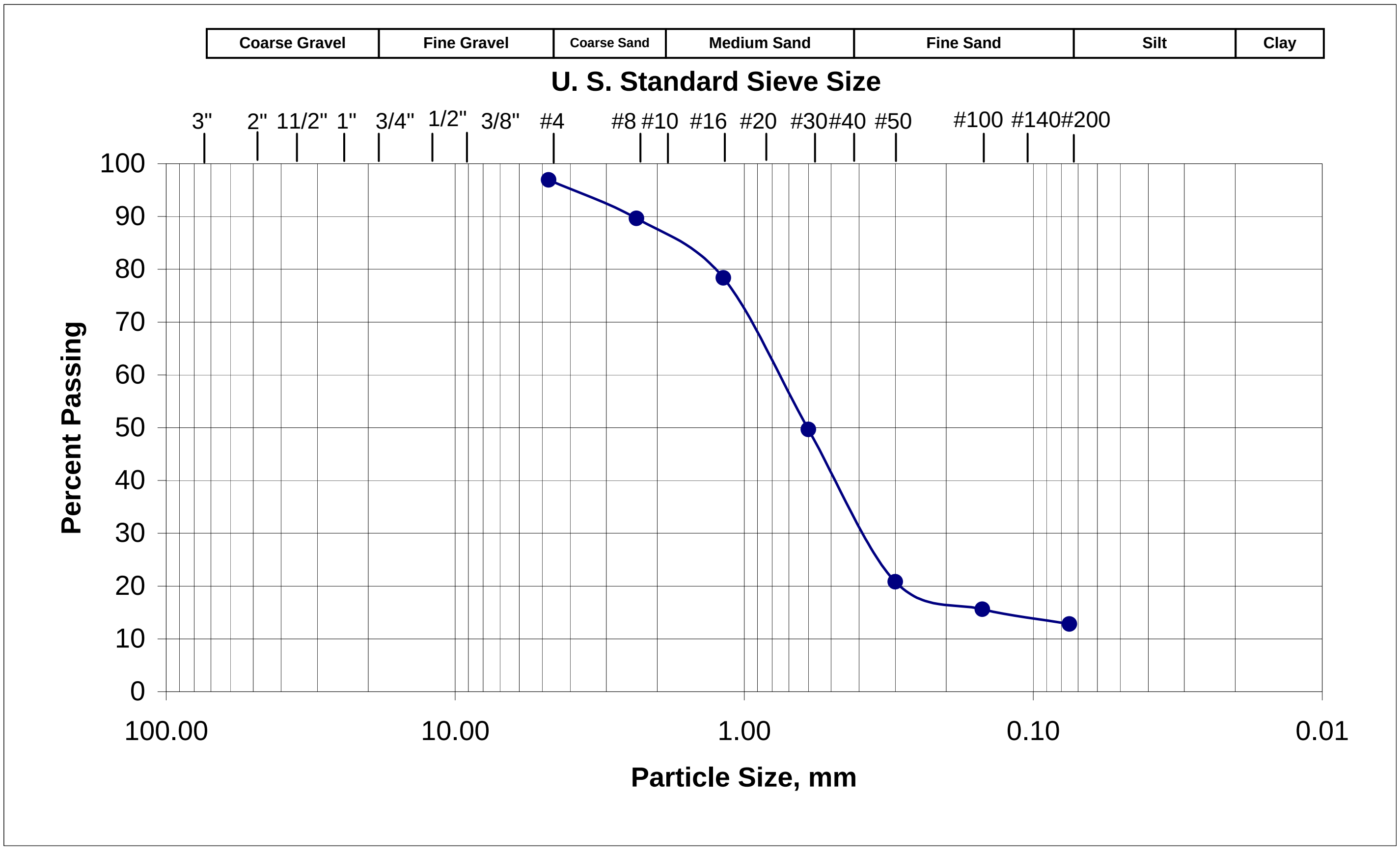
REMARKS: C_u = 2.5 C_c = 0.8

PROJECT NUMBER:	**6448-03-12**	October 16, 2012	**Pesacadero Creek**

CARLTON Engineering Inc.

Carlton Engineering, Inc.
3883 Ponderosa Road, Building B
Shingle Springs, California 95682

SIEVE ANALYSIS TEST REPORT



SIEVE SIZE	SIZE, mm	PASSING
3 INCH	76.2	
2 INCH	50.8	
1 1/2 INCH	38.1	
1 INCH	25.4	
3/4 INCH	19.1	
1/2 INCH	12.7	
3/8 INCH	9.5	
NO. 4	4.75	97
NO. 8	2.36	90
NO. 16	1.18	78
NO. 30	0.60	50
NO. 50	0.30	21
NO.100	0.15	16
NO 200	0.075	13

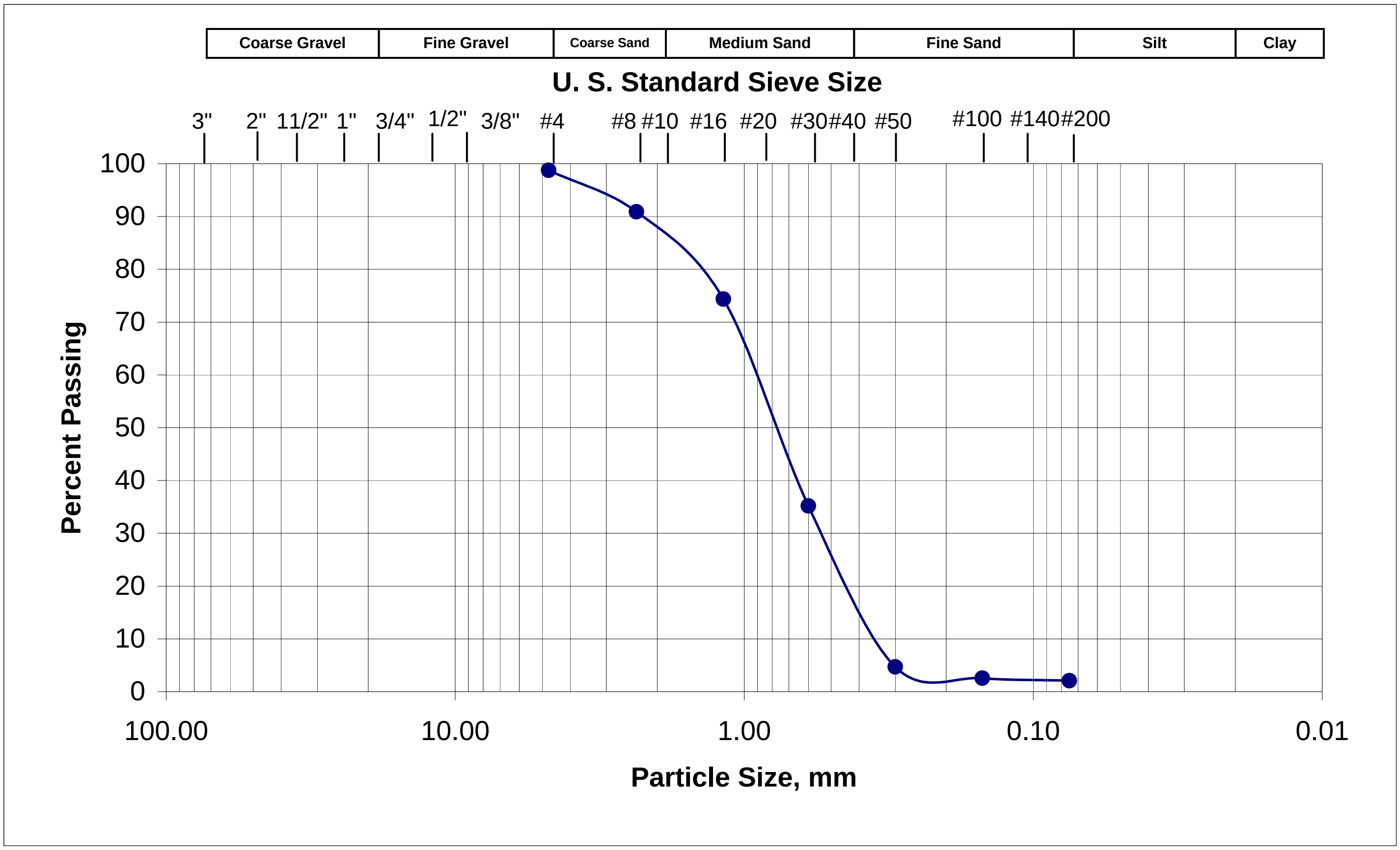
Test Method: ASTM C136

SAMPLE IDENTIFICATION: SS04 SAMPLE DEPTH, ft. : NA Lab Number: 3181
SAMPLE DESCRIPTION: Brown silty sand with organics Group Symbol: SM
REMARKS: C_u = 25.0 C_c = 7.1

PROJECT NUMBER:	**6448-03-12**	October 16, 2012	**Pesacadero Creek**

Carlton Engineering, Inc.
3883 Ponderosa Road, Building B
Shingle Springs, California 95682

SIEVE ANALYSIS TEST REPORT



SIEVE SIZE	SIZE, mm	PASSING
3 INCH	76.2	
2 INCH	50.8	
1 1/2 INCH	38.1	
1 INCH	25.4	
3/4 INCH	19.1	
1/2 INCH	12.7	
3/8 INCH	9.5	
NO. 4	4.75	99
NO. 8	2.36	91
NO. 16	1.18	74
NO. 30	0.60	35
NO. 50	0.30	5
NO.100	0.15	3
NO 200	0.075	2

Test Method: ASTM C136

SAMPLE IDENTIFICATION: SS09 SAMPLE DEPTH, ft. : NA Lab Number: 3183
SAMPLE DESCRIPTION: Brown poorly graded sands Group Symbol: SP
REMARKS: C_u = 3.6 C_c = 1.3

PROJECT NUMBER: **6448-03-12** October 16, 2012

Pesacadero Creek

Carlton Engineering, Inc.
3883 Ponderosa Road, Building B
Shingle Springs, California 95682

APPENDIX C

Construction Cost Estimates for Components of a Solution

Preliminary construction cost estimates are provided for each of the six components of a solution described in Section 7. The cost estimates focus on the construction aspects of each component. Budget amounts have not been estimated for additional planning, design, permitting, mitigation and future maintenance that will be required to implement various components of a project. These cost categories are highly dependent upon specific details of each project as well as which components or how many components are included in the integrated project to address both flood reduction and habitat enhancement. For example, upstream floodplain restoration efforts could potentially be used to cover some of the mitigation requirements of other components like channel dredging. As consensus is reached regarding which components of the integrated project will be pursued, and additional details are specified, these cost estimates will need to be revisited and expanded to include other potential costs of an integrated project or individual components of that project.

Disposal of Dredge Spoils

The cost estimates provided assume that dredge spoils will be transported to a disposal site that is located in close proximity to the dredged area. If the dredged volumes are small, they could potentially be disposed of in the quarry located off of Bean Hollow Road. It is possible that the volume of material generated by more extensive dredging could exceed the available capacity at the quarry. It is also possible that the quarry could not be used as a disposal site due to other environmental regulations and/or limitations. If the spoils are not contaminated, which has not been confirmed at this time, the material could be placed on agricultural fields in the area. The placement of this material on some fields in the area would reduce the frequency of inundation by creek waters. At this time no land owners have been contacted to investigate their interest in this type of arrangement.

If a disposal site cannot be identified in close proximity to the project, the spoils could be disposed of at the Ox Mountain Landfill in Half Moon Bay. This disposal site is approximately 20 miles from the project area, which would result in substantially higher hauling costs than have been included in the budget estimates. Furthermore the disposal fee of \$45/ yd^3 at the Ox Mountain facility would also increase project costs substantially. For example the disposal (i.e., the tipping fee, not including hauling costs) of 3,000 yd^3 as proposed in the dredge ROW component would cost \$135,000, not including any other project costs.

Table C-1. Preliminary construction cost estimate for Dredge within the ROW

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Clear woody vegetation	0.1	Ac	$ 60,000	$ 6,000	
Access construction	200	LF	$ 30	$ 6,000	improved access down embankment upstream and downstream of bridge
Site dewatering	1	LS	$ 40,000	$ 40,000	
Land based dredging (excavation)	3,000	CY	$ 5	$ 15,000	Use County's Gradall and labor. (1 minute/2 CY scoop, $50/hr for operator, $50/hr for fuel = $0.83/hr)
Dewater dredge material	1	LS	$ 45,000	$ 45,000	discharge dredge material into a separation unit. Includes separation unit rental and accounts for decreased productivity rate.
Dispose of dredge material	3,000	CY	$ 11	$ 33,000	includes 1 mile RT, or 0.33 hrs at $100/hr, with an 8 CY load. 375 loads * 0.33 hrs = $12,375. Add $50/load for disposal fees = $18,750. Say $11/CY.
Erosion control	1	LS	$ 10,000	$ 10,000	
Biological monitoring	1	LS	$ 13,500	$ 13,500	Assumes three days of construction requiring survey and exclusion for frogs, snakes, and steelhead. Crew of three.
TOTAL				**$168,500**	

Table C-2. Preliminary construction cost estimate for Dredge within the ROW and along historical alignment

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Breach sandbar	1	LS	$ 20,000	$ 20,000	
Clear woody vegetation	1	Ac	$ 60,000	$ 60,000	2,200 LF channel x 20'W = ~1 Ac
Site dewatering	1	LS	$ 40,000	$ 40,000	at bridge location
Terrestrial excavation	48,000	CY	$ 15	$ 720,000	4,450 LF of channel by 200 SF XS. Bridge dredging included. Includes haul to dewatering stockpile.
Dredge material dewatering	24,000	CY	$ 8	$ 197,280	Dewater material in stockpile. Based on $822,000/100,000 CY estimated additional cost for "barge dewatering."
Off-road low-pressure dump truck rental	16	Mo.	$ 11,000	$ 176,000	4 low-pressure dumps for 4 months
Off-site disposal	48,000	CY	$ 16	$ 768,000	includes 2 mile RT, or 0.5 hrs at $150/hr (low pressure dump), with an 8 CY load. 4,125 loads * 0.5 hrs = $309,375. Add $50/load for disposal fees = $206,250. Say $16/CY.
Access construction	200	LF	$ 30	$ 6,000	at bridge, plus potential surface maintenance of marsh access; low-pressure equipment assumed able to drive on surface of marsh.
Habitat structures	1	LS	$ 120,000	$ 120,000	Assume 10 structures at $12,000 per
Erosion control	1	LS	$ 30,000	$ 30,000	
Biological monitoring	1	LS	$ 100,000	$ 100,000	requires survey and exclusion of snakes, frogs, goby, and steelhead. Construction time is key unknown, assuming 21 days for this estimate. One biologist present at all times, and a crew of three required to capture and relocate about every three days of dredging.
TOTAL				**$2,237,280**	

Table C-3. Preliminary construction cost estimate for Dredge within the ROW and along marsh alignment

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Breach sandbar	1	LS	$20,000	$20,000	May not be necessary if water levels are low enough
Clear woody vegetation	0.25	Ac	$60,000	$15,000	500 LF channel x 20'W = 0.23 Ac
Site dewatering	1	LS	$40,000	$40,000	at bridge location (pump to main channel, over sandbag dam)
Terrestrial excavation	35,000	CY	$10	$350,000	4900 LF of channel. Bridge dredging included. Includes haul to dewatering stockpile.
Dredge material dewatering	17,500	CY	$8	$143,850	Assume half the material. Dewater material in stockpile. Based on $822,000/100,000 CY estimated additional cost for "barge dewatering."
Off-road low-pressure dump truck rental	2	Mo.	$11,000	$22,000	2 dumps for 1 months
Off-site disposal	35,000	CY	$16	$560,000	includes 2 mile RT, or 0.5 hrs at $150/hr (low pressure dump), with an 8 CY load. 5250 loads * 0.5 hrs = $393,750. Add $50/load for disposal fees = $262,500. Say $16/CY.
Access construction	300	LF	$30	$9,000	improved access down road embankment, plus access at bridge
Habitat structures	1	LS	$120,000	$120,000	Assume 10 structures at $12,000 per
Erosion control	1	LS	$30,000	$30,000	
Biological monitoring	1		$100,000	$100,000	requires survey and exclusion of snakes, frogs, goby, and steelhead. Construction time is key unknown, assuming 21 days for this estimate. One biologist present at all times, and a crew of three required to capture and relocate about every three days of dredging.
TOTAL				**$1,409,850**	

Table C-4. Preliminary construction cost estimate for Dredge within the ROW and ~800ft connector into marsh

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Clear woody vegetation	0.25	Ac	$60,000	$15,000	500 LF channel x 20'W = 0.23 Ac
Site dewatering	1	LS	$40,000	$40,000	at bridge location (pump to main channel, over sandbag dam)
Terrestrial excavation	6,000	CY	$15	$90,000	3,000 CY for ROW and 3,000 CY for connector
Dredge material dewatering	4,500	CY	$8	$36,000	Assume bridge dredge material and half excavated channel material. Dewater material in stockpile. Based on $822,000/100,000 CY estimated additional cost for "barge dewatering."
Off-site disposal	6,000	CY	$13	$75,000	includes 2 mile RT, or 0.5 hrs at $100/hr (regular dump), with an 8 CY load. 2125 loads * 0.5 hrs = $106,250. Add $50/load for disposal fees = $106,250. Say $12.5/CY.
Access road construction	300	LF	$30	$9,000	improved access down road embankment, plus access at bridge
Erosion control	1	LS	$10,000	$10,000	
Biological monitoring	1	LS	$20,000	$20,000	
TOTAL				**$295,000**	

Table C-5. Preliminary construction cost estimate for Causeway

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Bridge and roadway construction	1	LS	$10,000,000	$10,000,000	Rough estimate based upon current cost estimate of bridge at Crystal Springs Dam
Biological monitoring	1	LS	$60,000	$60,000	Assumes 20 days of terrestrial construction requiring survey and exclusion for frogs and snakes, and five days of in-channel construction requiring the same for steelhead.
TOTAL				**$10,060,000**	

Table C-6. Preliminary construction cost estimate for Floodplain Reconnection

Item	Quantity	Unit	Unit Cost	Item Total	Notes
Clear woody vegetation	0.75	Ac	$60,000	$45,000	~300LF x 20' road per ELJ site, plus incidentals at tie-back locations (20x8)
Site dewatering	5	LS	$40,000	$200,000	
Terrestrial excavation	1,200	CY	$40	$48,000	Assume 20' bank, 20' tie back, 8' width, both sides at each structure, difficult access, dispose material on site, or US of ELJ
ELJ construction	1	LS	$200,000	$200,000	
In-channel fill	1,000	CY	$50	$50,000	Fill for upstream of structures
Access road construction	1,500	LF	$20	$30,000	~300 LF per ELJ site
Erosion control	1	LS	$75,000	$75,000	
Biological monitoring	1	LS	$40,000	$40,000	assumes 15 days of construction, requiring survey and exclusion of frogs, snakes, and steelhead.
TOTAL				**$688,000**	

APPENDIX D

Project Advisory Group Participants and Meetings Held

The San Mateo County Resource Conservation District convened a Project Advisory Group to provide input throughout the project, including but not limited to: (1) helping develop the Request for Proposals (RFP) for a consultant team, (2) reviewing proposals and selecting consultants, (3) providing input on the project's final scope of work, (4) review the findings and deliverables, and (5) providing any additional input and community outreach.

Project Advisory Group Members

Ann Stillman, County of San Mateo Public Works
Carole Foster, County of San Mateo Public Works
Jim Robins, Integrated Watershed Restoration Program
William Stevens, National Marine Fisheries Service
Jim Howard, National Resource Conservation Service
John Klochak, U.S. Fish and Wildlife Service
Joanne Kerbavaz, State of California Department of Parks and Recreation
Tim Frahm, Trout Unlimited
Dante Silvestri, At-large representative from Pescadero
B. J. Burns, At-large representative from Pescadero
Mike Polacek, Pescadero Municipal Advisory Council
Jennifer Nelson, California Department of Fish and Wildlife

Additional Invited Participants for Specific Advisory Group Meetings

Setenay Frucht, San Francisco Bay Regional Water Quality Control Board
John Largier, U.C. Davis, Bodega Marine Laboratory (Pescadero Lagoon Science Panel)
Jay Chamberlin, State of California Department of Parks and Recreation

Meeting Schedule

Project Advisory Group Meetings
Conference Call to discuss TM#1 - September 24, 2013
Conference Call to discuss Revised Scope of Work - November 21, 2013
Meeting to discuss preliminary results - May 29, 2014
Web-meeting to discuss additional preliminary results - June 24, 2014
Conference Call to discuss final report outline – August 6, 2014
Conference Call to review comments on draft Report - September 17, 2014

Community Meetings
October 1, 2013
June 30, 2014
Late October or early November, 2014

Stillwater Sciences

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Hydrology | Hydraulics | Geomorphology | Design | Field Services