Public Draft Feasibility Report

SAFER Bay Project

Strategy to Advance
Flood protection, Ecosystems and
Recreation along San Francisco Bay

East Palo Alto and Menlo Park

(Task Order 1)

October 2016

SFCJPA.ORG

San Francisquito Creek
Joint Powers Authority

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SAFER BAY

East Palo Alto and Menlo Park

Project No. 222952-028

Task Order No. 1

PUBLIC DRAFT FEASIBILITY REPORT

October 2016

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Acronyms and Abbreviations

Alternative	A combination of reach options that satisfies project objectives in all reaches.
BFE	Base Flood Elevation
Caltrans	California Department of Transportation
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Mate
H:V	Ratio of Horizontal to Vertical
Highway 84 Bridge	Dumbarton Bridge
MHHW	Mean Higher High Water
NAVD	North American Vertical Datum of 1988
Option	A stand-alone feature in any one project reach that will address any of the project objectives. A combination of Options in all reaches (Alternative) is required to satisfy the overall project objectives.
PG&E	Pacific, Gas and Electric Company
Project	SAFER Bay Project
Reach	The project area was initially broken into a total of nine reaches. The proposed alternatives are composed of varying reach options.
ROW	Right-Of-Way
SAFER	Strategy to Advance Flood Protection, Ecosystems and Recreation along the San Francisco Bay
SBSPRP	South Bay Salt Ponds Restoration Project
SFCJPA	San Francisquito Creek Joint Powers Authority
SFHA	Special Flood Hazard Area
SFPUC	San Francisco Public Utilities Commission
SLR	Sea Level Rise
SWL	Still Water Level
UPRR	Union Pacific Railroad
USACE	United States Army Corps of Engineers
US/DS	Upstream/Downstream
WSE	Water Surface Elevation

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1 Introduction

1.1 Background and Overview

San Francisquito Creek Joint Powers Authority (SFCJPA) is a regional government agency founded by the cities of East Palo Alto, Menlo Park, and Palo Alto, the San Mateo County Flood Control District and Santa Clara Valley Water District in 1999 following a major flood the preceding year. The SFCJPA plans, designs and implements capital projects which are comprehensive in terms of geography and function because they cross jurisdictional boundaries and serve to reduce a proven flood threat, enhance ecosystems and recreational opportunities, and connect our communities.

The SFCJPA and its member agencies seek to protect people, property, and public infrastructure within the cities of East Palo Alto, Menlo Park, and Palo Alto from San Francisco Bay coastal flooding (while the focus of this document is on East Palo Alto and Menlo Park, an upcoming Feasibility Report concerns Palo Alto's shoreline). To accomplish this goal, SFCJPA is planning for the construction of new and/or improved flood risk reduction features along the Bay shoreline from the Menlo Park/Redwood City border south to San Francisquito Creek, where another SFCJPA flood protection ecosystem restoration project is under construction along the East Palo Alto/Palo Alto border. In addition to protecting East Palo Alto and Menlo Park, this project will protect neighboring areas of Redwood City and unincorporated San Mateo County, which could be inundated by coastal flooding via Menlo Park. The project, called the Strategy to Address Flood protection, Ecosystems and Recreation along the San Francisco Bay, and known by the acronym SAFER, also seeks to further provide habitat restoration for the Bay's tidal marsh ecosystem, and to enhance recreation opportunities along the Bay shoreline. The project footprint is shown on Figure 1.

Currently, the communities of East Palo Alto and Menlo Park have shorelines that are prone to tidal flooding. As such, many property owners within these communities must purchase flood insurance. The implementation of SAFER would remove these from FEMA's tidal floodplain; see Figure 2 for an overview of the recently released Preliminary FEMA Flood Insurance Rate Map[1] floodplains within the project area. Although the existing salt pond levees provide some degree of protection from coastal flooding, these levees are not certified by FEMA to provide flood protection from a projected 100-year event (that has a 1% annual chance of occurring in any given year).

Additionally, salt pond restoration efforts that require the breaching of outer Bay front levees are limited until flood protection is provided[2]. The SAFER Bay project would allow significant salt pond restoration activities to begin as part of this project and through work by other partnering agencies. For this reason, the South Bay Salt Ponds Restoration Project and the Don Edwards

[1] Preliminary Flood Insurance Rate Maps were released on August 13, 2015 and may be subject to change.
[2] While the salt pond levees are not certified by FEMA, they reduce the risk of flooding in the study area by muting the tidal effects. Activities to restore habitat through breaching these pond levees will require new flood risk reduction features to at least provide equivalent flood risk reduction that is currently provided by the pond levees.

National Wildlife Refuge have written in support of the SAFER project. The SAFER Bay project will also allow for improved connectivity between communities through enhancement to the recreational Bay Trail and other local trails.

Many agencies provided input in the development of this Feasibility Report, including:

- City of Menlo Park
- City of East Palo Alto
- City of Redwood City
- U.S. Fish and Wildlife Service
- Don Edwards National Wildlife Refuge
- California Department of Fish and Wildlife
- South Bay Salt Ponds Restoration Project (SBSPRP)
- California Department of Transportation (Caltrans)
- San Francisco Public Utilities Commission (SFPUC)
- Midpeninsula Regional Open Space District
- Pacific Gas and Electric (PG&E)
- Facebook, Inc.
- California Coastal Conservancy
- Bay Conservation and Development Commission (BCDC)

Public outreach was also conducted by the SFCJPA during the development of this Feasibility Report. Public outreach included presentations to the city councils of Menlo Park and East Palo Alto, to neighborhood associations, meetings in early 2015 and early 2016 hosted by the League of Women Voters of South San Mateo County, and three conferences on sea level rise adaptation hosted by San Mateo County and/or local members of Congress; and the project was covered in multiple local newspaper stories.

1.2 Purpose

The overall purpose of this Feasibility Report is to evaluate the flood protection alternatives along the San Francisco Bay shoreline within the project footprint and provide the justification to support the selection of a preferred alternative that will move forward into the California Environmental Quality Act (CEQA) analysis. The project was divided into nine reaches (designated as Reach 1 through Reach 9)[3] that are based on local geography, as shown on Figure 1. Within each reach; one or more options are presented, as shown on Figures 3 through 10. Typical cross sections for each reach are illustrated on Figures 11 through 24. A qualitative evaluation of each option is presented, and options within each reach are combined to create a range of alternatives that satisfy the overall project objectives. This report presents a preliminary ranking of alternatives based on multiple evaluation factors including construction cost and constructability, operation and maintenance, restoration and recreation benefits.

[3] Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

1.3 Project Objectives

The SAFER Bay project objectives, which take into account the substantial constraints of working in an area between developed land, public infrastructure and sensitive shoreline, serve as the basis to formulate and evaluate options and alternatives. The objectives include:

- Project will reduce the risk of flooding within the cities of East Palo Alto and Menlo Park from San Francisco Bay coastal waters and support the communities' desire to be removed from the FEMA floodplain, and include consideration of three feet of future Sea Level Rise (SLR),
- Project will enable adaptation to our changing climate by utilizing tidal marsh areas for flood protection in a way that sustains marsh habitat and facilitates marsh restoration associated with the South Bay Salt Ponds Restoration Project (SBSPRP) and other restoration efforts.
- Project will expand opportunities for recreation and community connectivity in collaboration with the Bay Trail Program and efforts to enhance local trails.
- Project will minimize future maintenance requirements.
- Project will create opportunities for partnership with agencies and organizations pursuing similar goals and objectives and with assets to be protected by the project.
- Project will not rely on projects by other entities to achieve these objectives.

Additionally, the SFCJPA plans for the SAFER project to align with regional efforts that promote adaption for sea level rise in the context of our developed shoreline areas. Thus SAFER's objectives support the objectives of documents such as the San Francisco Estuary Partnership's 2016 *Comprehensive Conservation and Management Plan*.

1.4 Constraints

The project constraints identify assets that options (or alternatives) cannot impact without recommending a way to minimize, maintain or improve the existing condition through the project. Project constraints set the boundaries for development of project features and can affect the project's ability to meet its objectives. The project constraints include:

- Wetlands
- Habitat for endangered species
- Existing roadways
- Interior drainage
- Existing utility infrastructure
- Property within and adjacent to the levee alignment

1.5 Design Criteria

The project design identifies the specific technical requirements of the study (feasibility phase). The project design criteria will satisfy:

- Current FEMA coastal flood protection requirements, which is the existing 100-year event (that has a 1% annual chance of occurring in any given year) with required freeboard for FEMA accreditation; and
- An additional three feet of tidal elevation to account for anticipated sea level rise.

Additional discussion of FEMA's design criteria, such as the evaluation of settlement and structural stability, applicable to the project components are summarized in more detail in Section 2.0.

1.6 Report Organization

Following the introduction in this section, this report is organized as follows:

- Section 2 provides a summary of the project technical considerations and requirements that each of the reach options must satisfy.
- Section 3 provides a summary of each reach and the potential options considered.
- Section 4 summarizes the screening and evaluation for each of the options.
- Section 5 presents development of the preliminary alternatives from the identified reach options.
- Section 6 presents the feasibility evaluation scoring matrix and calculation methodology.
- Section 7 presents feasibility level cost estimates for each alternative.
- Section 8 summarizes the overall results and preliminary ranking.
- Section 9 presents a list of references used for the preparation of this report.

2 Technical Considerations and Requirements

Project technical considerations and requirements have been identified to inform and direct the development of options in each reach. These requirements were based on project objectives and project constraints.

2.1 Coastal Hydraulics and Sea Level Rise

The current effective FEMA Flood Insurance Rate Maps (FIRMs) designate the entire East Palo Alto and Menlo Park's Bay shoreline within its Special Flood Hazard Area (SFHA) for the 100-year (1% annual chance) coastal flood event. This designation indicates that these communities are at risk of flooding and property owners with a federally backed mortgage are required to pay a premium to participate in FEMA's National Flood Insurance Program. Although a network of existing embankments provides some degree of protection from coastal flooding, these embankments are not currently certifiable as per FEMA's 44 Code of Federal Regulations (CFR) Section 65.10. The crest elevations are below FEMA's 100-year coastal flood event freeboard requirements and they do not meet FEMA's geotechnical requirements. Riverine flooding and SFHA floodplains associated with San Francisquito Creek are being addressed through a separate flood improvement project under construction through 2018.

In 2015, FEMA issued preliminary FIRMs for much of the Bay shoreline, including the SAFER project area, and this latest information has been incorporated into this Feasibility Report. The floodplain area shown in this Preliminary FEMA Flood Insurance Rate Map (FIRM) (Figure 2) is larger in extent and inundation depth than the effective FIRM.

The preliminary FEMA results for just offshore of the SAFER project area estimates the 100-year still water level (SWL) to be 11 ft (DHI, 2013), measured using the standard North American Vertical Datum of 1988 (NAVD 88). Per FEMA, the SWL is defined as including the effects of the astronomical tide, storm surge, and wave setup. For the SAFER Bay project area west of Willow Road, this is an increase of one foot from the existing base flood elevation (BFE) of 10 ft NAVD (FEMA, 2012). The existing SFHA is delineated by projecting the water surface elevation inland to where it intersects the ground surface elevation. For the SAFER Bay project area just north of Highway 84, also known as the Bayfront Expressway, and at the PG&E substation and east of University Avenue, the preliminary FEMA results increased the existing BFE of 11 ft NAVD (FEMA, 2012) to 12 ft NAVD.

FEMA's preliminary results also assess the contribution of wave runup, which is added to the SWL. Per FEMA, wave runup is defined as the maximum elevation of a wave breaking onto a beach. Both the SWL and wave runup are important elevations to determine crest elevations of flood control features. FEMA's Typical Transect Schematic is included in Figure 2a below, which illustrates the differences in types of coastal flooding and the applied FEMA zoning.

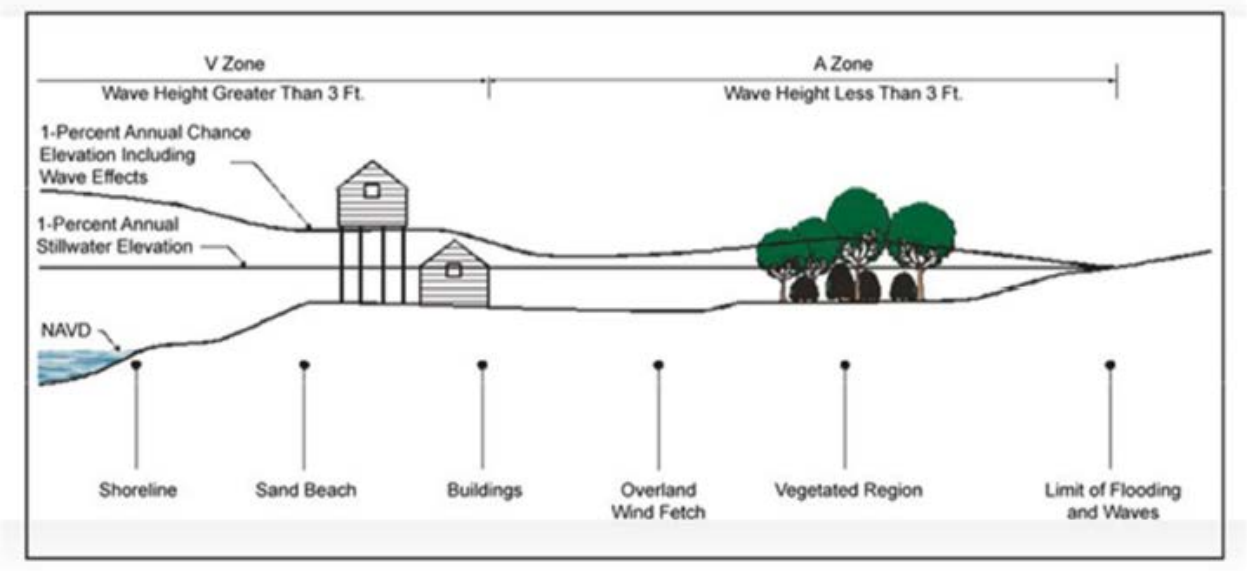


Figure 2a – FEMA's Typical Transect Schematic

To provide a margin of safety, FEMA requires that the crest top elevation of a certified levee be built above the 100-year water level by an additional amount called 'freeboard'. The FEMA freeboard requirement for coastal levees is a minimum of:

- Two feet above the SWL

and higher if either of the following two wave-influenced elevations exceeds two feet:

- One foot above the 100-year wave crest elevation, or
- One foot above the maximum wave runup elevation

Although FEMA does not currently consider sea level rise in its flood mapping, the SAFER Bay project design criteria includes consideration of three feet sea level rise and is shown in Minimum Design Elevation section of Tables 1 and 2. Planning for sea level rise is part of the California design guidelines (OPC, 2013) and the Bay Conservation and Development Commission (BCDC, 2011). BCDC in partnership with San Mateo County and the Coastal Conservancy released the *Final Report for Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore* in May 2016. The Final Report included sea level rise inundation maps for multiple events. Figures 2b and 2c have been included in this report for reference depicting the inundation for 36" of SLR with Mean Higher High Water (MHHW) elevation and 78" of SLR with MHHW, respectively.

Incorporating three feet of sea level rise into the design is consistent with the SAFER Bay project time frame (five decades) and the range of sea level rise projections over this time. For instance, NRC (2012), which was developed particularly for California and whose findings have been adopted by the state, projects three feet of sea level rise occurring between 2075 to 2105. In addition, the U.S. Army Corps of Engineers projects three feet of sea level rise to occur in a similar time period, between 2075 to 2095 (USACE, 2011).

Based on the predictions of extreme water level and wave events, as well as considering three feet of sea level rise, the approximate design elevations for the SAFER Bay project's levee crests are presented in Table 1. Beyond its relation to sea level rise, SAFER's minimum design elevation would protect people against a tide almost nine feet above the current daily high tide.

Table 1. Preliminary Minimum Design Elevations for Reaches 1,2,3,4,6,7,8,9

Minimum design elevation (1% SWL only)		
Elevation[2] or Height	Existing Conditions	Considering 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	11.0 ft	14.0 ft
Required freeboard above the SWL	2.0 ft	2.0 ft
Minimum design elevation[3]	***13.0 ft***	***16.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] All elevations are provided in NAVD 88.
[3] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

Table 2. Preliminary Minimum Design Elevations for Reach 5

Minimum design elevation (1% SWL only)		
Elevation[2] or Height	Existing Conditions	Considering 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	12.0 ft	15.0 ft
Required freeboard above the SWL	2.0 ft	2.0 ft
Minimum design elevation[3]	***14.0 ft***	***17.0 ft***

Note: SWL = still water level; TWL = total water level
[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.
[2] All elevations are provided in NAVD 88.
[3] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

The potential need for higher levee crest elevations to account for waves is verified by the technical documentation supporting the recent FEMA map revision process (e.g. Table 11 in BakerAECOM (2014)). This documentation, which also guides the design of new levees at Foster City (Schaaf & Wheeler, 2015), estimates levee height requirements up to three feet higher than the minimum SWL levee height. It is assumed that the SAFER Bay project has reduced wave exposure due to the proposed levee alignments location landward of the former salt ponds and less exposure than Foster City's levees.

In addition to wave exposure, wave runup depends on ground surface elevation, slope, and vegetation. By constructing a gentle slope in front of a proposed levee, the SAFER Bay project may be able to reduce or eliminate the influence of waves on raising the water elevation. However, FEMA certification of levees that use a gentle slope and reduce the levee top elevation is untested and thus will require additional evaluation and close coordination with FEMA during project design in order to obtain FEMA certification.

The need for assuming wave attenuation to achieve FEMA certification will depend on other considerations, including SAFER's ability to establish new tidal marsh from existing salt ponds, which would also attenuate waves. Maximum design elevations provided in Table 3 and 4 provide the maximum water surface elevation if enhanced levee slopes and/or future SBSPRP

projects do not reduce the wave runup onto the proposed levee/floodwall slope. The presented maximum water surface elevation will be refined during the design phase.

Table 3. Preliminary Maximum Design Elevations for Reaches 1,2,3,4,6,7,8,9 dependent upon Future Salt Pond Restoration Activities

Maximum Design Elevation (1% SWL & Waves)		
Elevation[3] or Height	Existing Conditions	With 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	11.0 ft	14.0 ft
Wave runup[2]	3.0 ft	3.0 ft
Required freeboard above the TWL	1.0 ft	1.0 ft
Maximum design elevation[4]	***15.0 ft***	***18.0 ft***

Note: SWL = still water level; TWL = total water level

[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.

[2] Initial wave runup, based on initial review of BakerAECOM (2014). Subject to change with future analysis.

[3] All elevations are provided in NAVD 88.

[4] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

Table 4. Preliminary Maximum Design Elevations for Reach 5 dependent upon Future Salt Pond Restoration Activities

Maximum Design Elevation (1% SWL & Waves)		
Elevation[3] or Height	Existing Conditions	With 3 ft of SLR
1% SWL elevation (100-year tidal floodplain)[1]	12.0 ft	15.0 ft
Wave runup[2]	3.0 ft	3.0 ft
Required freeboard above the TWL	1.0 ft	1.0 ft
Maximum design elevation[4]	***16.0 ft***	***19.0 ft***

Note: SWL = still water level; TWL = total water level

[1] As depicted on the San Mateo FEMA Preliminary Flood Insurance Rate Maps dated August 13, 2015.

[2] Initial wave runup, based on initial review of BakerAECOM (2014). Subject to change with future analysis.

[3] All elevations are provided in NAVD 88.

[4] Elevation provided is ultimate design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement, which will occur over the first year after construction.

2.2 Interior Drainage

There are several existing interior drainage channels that are located along the proposed levee alignments. These stormwater facilities are primarily manmade structures that have been constructed both above and below grade to convey stormwater. The interior drainage system in Menlo Park and East Palo Alto is initially collected by an underground storm drain piped network that discharge into these open channels which then eventually discharge into the San Francisco Bay. These open ditches are carefully managed by a series of gates and pump stations, which balance water surface elevations between the stormwater runoff and tidal cycle events.

These interior drainage structures will need to be evaluated during the design phase to verify that they are satisfying FEMA's 44 CFR Section 65.10 requirements and will function properly, without increasing stormwater flooding from the existing condition, with the SAFER Bay flood control levees and floodwalls installed. If issues with the structures are identified, remediation improvements will be included within the project design. These channels may also require

relocation as appropriate to meet regulatory requirements because of the potential threat they pose to levee integrity and the potential obstruction of maintenance activities. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and pipe/conduit.

The implementation of water pollution prevention programs and low impact development features at the County and City level are critical to reduce stormwater runoff and flooding. With the expansion of these programs, such as San Mateo's Green Streets and www.flowstobay.org, a reduction of stormwater runoff can reduce the volume of water that is eventually pumped or diverted into the San Francisco Bay.

2.3 Geotechnical Considerations

For additional geotechnical analysis information and recommendations, please refer to Appendix A – Geotechnical Report for the Feasibility Phase, dated May 2016.

The proposed flood protection earthen levees/floodwalls are located along the southwestern fringe of San Francisco Bay. A review of subsurface explorations collected as part of the search for existing information, and published information on geologic and geotechnical conditions in the site area indicate that beneath a fill layer, the area is underlain by soil deposits commonly referred to as Young Bay Mud. This soil is soft, weak and highly compressible. This was verified by performing geotechnical borings along the proposed alignments. The Young Bay Mud may also contain intermediate sand layers and lenses that could be potential underseepage paths or be susceptible to liquefaction during an earthquake. The available information indicates that the thickness of the Young Bay Mud layer is on the order of 10 to 20 feet throughout much of the alignment area. The thickness of the Young Bay Mud is greater in the area of the approach to the Dumbarton Bridge, possibly on the order of 40 feet or more.

The additional load from levee raises creates a number of considerations on the underlying soil, and in particular the Young Bay Mud, that need to be analyzed. The key considerations are as follows:

Stability – Depending on the height of new levee fill needed and the strength of the underlying soil, the Young Bay Mud may be too weak to allow the levees to be constructed to their final target heights without special considerations. Stability failures can occur if too much soil load is placed over a short period of time. This may mean that levees will need to be raised in stages to allow for time for the underlying soil to gain strength before additional fill is placed. Alternatively, measures may be needed to strengthen weak underlying soil or accelerate its strength gain.

Seepage – During periods when there is water against the levees, seepage can occur both through the levee embankment and through more pervious layers beneath the levee (under seepage). Both through seepage and under seepage can lead to levee erosion, piping and other detrimental consequences. Mitigation measures could include the proper specification and compaction of levee fill materials for through seepage control and the installation of seepage cutoff walls, pressure relief or drainage elements.

Settlement – The additional loading from new levees or levee raises will cause settlement over time due to the consolidation of the underlying Young Bay Mud. Levees will need to be initially

built to heights greater than their final elevations, to meet the required final design crest elevations.

2.4 Levees

It is possible and perhaps likely that levees would be constructed and raised in stages over the course of many years due to long-term impacts of SLR and budget limitations. Regardless of the timing or staging of levee raisings, a sufficient width along the alignment should be available to accommodate the full width of the levee that would eventually be constructed. Further, the base of the levee should be constructed to this full width so that future raises can be performed on top of the levee without the need for future lateral expansion.

For the purpose of evaluating alignment options, levees with the following minimum geometry have been considered:

- Minimum crest width of 20 feet.
- Waterside and landside slopes of 3H:1V (horizontal to vertical).
- Final levee crest height at Elevation 16-17[4] feet NAVD 88.

To account for levee settlement, overbuild of levee heights should also be considered in establishing levee geometries. It was computed that 1-3 ft of overbuild will be required throughout Reaches 1-9. At the Dumbarton Bridge, a maximum 3 ft of overbuild is recommended due to the thicker Young Bay Mud. Typical cross sections, Figure 11 – 24, document the computed the maximum overbuild required for each reach if the levee was constructed to account for SLR. For planning purposes, a 100-foot wide linear base area would be needed to accommodate a levee that will ultimately be built to these dimensions.

2.5 Floodwalls

Where spatial or other constraints exist that do not allow for the construction of a levee, floodwalls can be considered. Even though a floodwall needs much less lateral space than a levee, some amount of space would still be needed for the wall footing. For the purpose of evaluating options, we have considered an inverted T-shaped floodwall, where the footing width is approximately equal to the wall height. Thus, a 12-foot high floodwall would require a 12-foot wide footing plus additional width for construction access.

2.6 Flood Risk Reduction Structures

There are several existing roadways that cross the proposed flood protection alignment. Where it is impractical to raise these roadways to an elevation sufficient to provide flood protection, a passive flood risk reduction structure, such as a flood gate has been considered[5]. A passive structure is defined as a feature that can be closed at beginning of a storm event and left alone without any additional management except to reopen at the end of the storm event. FEMA certified flood risk reduction structures, including passive and active roadway gates, railroad

[4] Elevation 17 NAVD 88 only applies to Reach 5
[5] The existing grade elevation at the proposed flood gate locations, based on available LiDAR data, is at or above the projected MHHW elevation with SLR for the study horizon (50 years).

gates, and tide gates, have been constructed throughout the United States by the USACE and non-federal flood control agencies. The flood risk reduction structures will be designed to provide the same level of protection as the surrounding levees and floodwalls. Access waterside of the structures would be limited while the structures are closed. The selection of gate structures will require further discussions with the SFCJPA and local agency staff during the design phase of each reach to select the type and preferences of the gated structures.

Additionally, tidal gates were also considered at locations where the levee/floodwall alignment crossed the existing drainage ditch system. There are several existing tidal gates that will be impacted by the proposed flood protection alignment. These tidal gates manage water surface elevations between stormwater runoff and changing tidal conditions. Tidal gates are typically defined as active structures that require some type of management during a storm event to manage flood water elevations. Additionally, operations of these gates may require modification as sea levels continues to rise.

2.7 Penetrations

Penetrations and encroachments (pipelines, power poles, mail boxes, planter boxes, etc.) into the levee prism are generally not recommended, although they may be necessary. Where crossings occur, they will ideally be located above the design water surface elevation, within the freeboard area of the levee. Additional alternatives may be considered if raising the penetration above the design water surface elevation is not feasible.

2.7.1 Pipes and Conduits

It is generally not recommended that pipes and conduits be located beneath or within 10 feet of the toes of levees or floodwalls. Such pipes and conduits can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. Consideration should be given to relocating existing pipes and conduits that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and pipe/conduit. Pipeline utilities that may be of concern include existing and/or abandoned stormwater, sewer, electrical, fiber optic, and water underground pipelines. Additional coordination with the pipelines owners to determine impacts to the pipeline will be investigated during the future design phase.

2.7.2 Utility Poles and Towers

It is not recommended that utility poles and towers be located within 10 feet of the toes of levees or floodwalls. Such encroachments can serve as pathways that increase the potential for seepage, erosion and other related consequences that can impact the integrity of the levee or floodwall. The presence of such encroachments can also interfere with access for normal maintenance and operations and flood-fighting activities. Consideration should be given to relocating such existing elements that are within this zone to other areas. Where such relocation is not feasible, measures should be taken to protect the levee/floodwall and utility poles and towers.

2.8 Bay Trail

In locations where the proposed flood risk reduction alignment overlaps or indirectly impacts the Bay Trail, reconstruction and improvements of the trail may be necessary.

2.9 Maintenance

As a standard of practice, a minimum easement for maintenance, inspection and flood-fighting of 10 to 20 feet is required on the landside of levees. It is recommended that minimum 10-foot wide easements be obtained along the landside toe of the project, where the land is not already held in fee title by a member agency of the SFCJPA and space is limited. As an alternative to this, in areas where there are space limitations, an access road along the levee crown with intermittent access ramps to access points along the landside toe may suffice.

Temporary construction easements will also be required for this project, and have been assumed to be 15 additional feet beyond the limits of the maintenance easement. In areas where the landside toe of the proposed levee lands within existing structures or property, there may be an opportunity to minimize required temporary easements by performing construction activities on the levee crown. This design variance will require further investigation during final design.

2.10 Real Estate

The SFCJPA is responsible for procurement of all lands, easements, relocations, rights-of-way, and disposal areas that are necessary for construction, operation, and maintenance of the project. During the design phase for each reach, real estate easements will be established and coordinated through the JPA to its member agencies. A public outreach strategy will be developed with the JPA and member agencies to discuss most appropriate outreach methods to discuss impacts to private property owners.

2.11 Borrow Locations

Borrow material is required to complete the levee construction in the proposed alternative alignments. This borrow material will be obtained locally wherever possible and must meet specific suitable fill requirements. It was assumed that the levee borrow can be collected on a 50 mile round trip.

2.12 Disposal and Storage Area

Any excess levee cut material is expected to be used for construction of transition zones. Any excess will be stored on site for use in future restoration work. Site identification for excess storage will be determined during the design phase.

2.13 Staging Area

Potential staging areas will be identified during the design phase.

2.14 Transition Zone Habitat

Transition zone habitat restoration on the outboard levee slope is an important component of the SAFER Bay project's ecosystem restoration approach. The transition zone provides multiple beneficial functions for both flood risk reduction (e.g., erosion protection for outboard levee slope, wave energy dissipation) and tidal marshes (e.g., high-tide refuge habitat for California

Ridgway's rails [*Rallus obsoletus obsoletus*][6], and salt marsh harvest mice [*Reithrodontomys raviventris*]). Transition zone habitat also provides accommodation space for transgression of the adjacent tidal marshes in response to SLR.

In particular, the Restoration Alternative would include the construction of transition zone habitat at Ponds R1/R2 and potentially at the Mosley Tract (Figure 28). This would both provide high tide refuge habitat along restored marshes at R1/R2 and enhance future tidal marsh habitat that will eventually colonize the City of San Jose-owned Mosley Tract. The project is evaluating varying transition zone slopes, up to slopes consistent with the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013), and this location may allow a large, gentle slope because the majority of the transition zone fill would be placed in existing salt pond/open water habitat, with little impact to tidal marsh.

The project should also consider, in collaboration with the resource agencies, the installation of transition zone habitat adjacent to existing tidal marshes in reaches 7 (Cooley Landing Marsh), 8 (Laumeister Marsh), and 9 (Faber Marsh). These marshes provide suitable habitat for Ridgway's rail and salt marsh harvest mouse; Laumeister and Faber Marshes currently support a relatively high abundance of Ridgway's rail among South San Francisco Bay marshes. While these marshes (especially Laumeister and Faber) do contain marsh gumplant dominated, high tide refuge habitat in their interiors, they lack a broad transition zone along the landward edge. Therefore, as sea level rises high tide refuge habitat in these marshes will likely decline in the absence of restored transition zone along their landward edges. Figure 30 shows the footprint of what a representative transition zone would occupy adjacent to SAFER Bay's levee alignment. The slope shown on Figure 30 (15H:1V with a width of 150 ft) to provides new transitional habitat and results in short-term impacts on existing tidal marsh.

2.14.1 Ecological Importance of the Transition Zone

Historically, nearly 70 percent of the transition zone between tidal and terrestrial habitats in the South Bay was composed of low-gradient seasonal wetlands grading into tidal marsh. The transition zone ranged in width from hundreds to thousands of feet wide and provided essential habitat for numerous species (Goals Project 1999; Beller et al. 2013; Goals Project 2015). Today, the transition zone around San Francisco Bay marshes consists almost entirely of a narrow area about ten feet wide that starts with high marsh and is severely constrained by steep artificial levee faces (Collins and Goodman-Collins 2010). The SAFER Bay project provides a rare opportunity to increase the amount of low-gradient transition zone habitat in the South Bay.

A number of guiding documents strongly recommend increasing the abundance of transition zone habitat adjacent to tidal marshes, including, the *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* (USFWS 1984), the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (USFWS 2013), *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline* (BCDC 2011), *The Baylands Ecosystem Habitat Goals* (Goals Project 1999), and *The Baylands and Climate Change* (Goals Project 2015). This is primarily because:

[6] formerly California clapper rail [Rallus longirostris obsoletus]

- Broad transition zones are essential for the survival and recovery of the endangered salt marsh harvest mouse and California Ridgway's rail because they provide refugia from predators during high tides (USFWS 1984; Shellhammer 2012; USFWS 2013). Transition zones are most critical during extreme high-tide events when tidal marshes are inundated and predation pressure is highest.
- Transition zones provide essential habitat for endangered marsh plants, including salt marsh bird's beak (*Chloropyron molle* ssp*. molle*) and California sea blight (*Suaeda californica*),
- Transition zones increase the habitat diversity and biodiversity (including a higher number of species) of the tidal marsh edge because multiple plant and animal communities overlap along the hydrologic gradient provided within a broad transition zone. (USFWS 2013; Goals Project 1999).
- Transition zones provide accommodation space for the landward transgression of tidal marsh with sea level rise.

2.14.2 Importance of the Transition Zone to Levee Function and Sustainability

Building broad transition zones adjacent to tidal marshes will also increase the flood protection capacity and sustainability of the project levees. These zones dissipate destructive wave energy and thereby reduce flood risk and erosion to the outboard levee slope. Furthermore, stormwater or treated wastewater could be discharged over or through the low-gradient outboard levee slope and used to recreate seasonal wetland/bayland ecotone habitats that occurred historically, thereby further increasing the habitat diversity and ecological function of the transition zone.

2.14.3 Horizontal Levee-Transition Zone Slope Alternatives and Trade-Offs

The *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* recommends that transition zones should be constructed when levees adjacent to marshes are rebuilt in order to provide endangered species with appropriate habitat under a range of sea-level rise scenarios (USFWS 2013). Where feasible, the SAFER Bay project will propose horizontal levees to enable the restoration of a diverse suite of transition zone habitats, including alkali meadow/grassland, seasonal wetlands, salinas, and coastal scrub as shown on Figure 25. This habitat mosaic is based upon historical ecological investigations in the South Bay (Collins and Grossinger 2004; Grossinger et al 2007; Grossinger 2009) and upon collaboration between H. T. Harvey & Associates and the San Francisco Estuary Institute (H. T. Harvey & Associates and SFEI 2012). This habitat mosaic would provide high tide refugia cover for endangered species including the salt marsh harvest mouse and California Ridgway's rail during extreme high tides, and these benefits would persist as sea level rises. Habitat diversity and ecological functions/services increase as outboard levee slopes decrease or become gentler, as shown on Figure 26.

2.14.4 Integration with the South Bay Salt Pond Restoration Project and Project Permitting

As described above, the incorporation of transition zone features into the SAFER Bay project will provide crucial habitat and further the recovery goals for endangered species. In addition to incorporating habitat restoration opportunities along specific reaches, the project will facilitate the implementation of future phases of the SBSPRP by providing crucial flood protection in

areas where tidal restoration and managed ponds associated with the SBSPRP are planned. This nexus is an essential element of the project's tidal marsh mitigation/permitting strategy. As noted above, Reach 5 between Highway 84 and Pond R2 could provide the best opportunity for this vital nexus.

Also, levees associated with the SAFER Bay project will provide the foundations for installation of transition zone habitats within SBSPRP restoration areas. This coupling of wetland restoration and enhancement with the project will also facilitate project permitting, as the integration of tidal marsh and transition zone habitat restoration into the project is expected to offset impacts to wetland and endangered species habitats.

2.15 Tidal Marsh Restoration and Enhancement

Hereafter, the term "tidal marsh restoration" refers to the establishment of tidal marsh habitat and functions where tidal marsh previously existed, resulting in a net gain in tidal marsh surface area (USACE 2015). In contrast, the term "tidal marsh enhancement" includes the improvement of existing tidal marsh habitat functions with no change in tidal marsh surface area (USACE 2015). The SAFER Bay project includes several large-scale opportunities for both the restoration and enhancement of high quality tidal marsh habitat on the bayward side of proposed flood protection. Such opportunities will be incorporated into the project description both to restore the flood risk reduction functions of tidal marshes and to create a self-mitigating project with net, long-term benefits to sensitive bayland habitats and species. The primary restoration opportunity involves integrating, into the SAFER Bay project, a portion of the SBSPRP's proposed tidal marsh restoration within the Ravenswood Pond Complex. The SAFER Bay project also provides unique, large-scale opportunities to enhance existing tidal marshes by constructing extensive transition zone habitat adjacent to these marshes. As described above (see Section 2.11 Transition Zone Habitat), the SAFER Bay project will consider incorporating transition zone habitat into the project to further endangered species recovery goals (Ridgway's rail and salt marsh harvest mouse) and increase the resilience of existing marshes to climate change. The overall quantity and quality of wetland habitats in the South Bay will increase significantly due to the large-scale restoration efforts associated with the SBSPRP that will be further enhanced by restoration associated with the SAFER Bay project. The collaborative effort between these two projects will increase the resilience of the South Bay's wetland habitats and the populations of wildlife that depend on those habitats.

2.15.1 Integration with the South Bay Salt Pond Restoration Project, Highway 84, and the PG&E Ravenswood Electrical Substation

The SAFER Bay project will facilitate the implementation of portions of the SBSPRP by providing crucial flood risk reduction at the Ravenswood Pond Complex in areas where the SBSPRP proposes both tidal marsh restoration and pond management. This nexus is an essential element of the project's tidal marsh mitigation/permitting strategy. Between Highway 84 and Ponds R1 and R2, provides the best opportunity for this vital nexus. The SBSPRP proposes to restore Ponds R1 and R2 to tidal marsh under both the Tidal Habitat Emphasis and Managed Pond Emphasis alternatives (EDAW 2007). However, this restoration cannot increase flood risk to Highway 84 and the PG&E substation north of the Highway. To implement this restoration of approximately 613 acres of tidal marsh within R1 and R2, the SAFER Bay project

would protect Highway 84 and the PG&E substation to at least the same level of flood protection as currently provided by the outboard (Bay front) levees around Ponds R1 and R2. Alternatively, SAFER could protect these assets to the project's overall objectives of FEMA certification plus sea level rise. This magnitude of restoration would be more than adequate to compensate for the project's unavoidable impacts to jurisdictional tidal marsh and managed pond habitats.

Therefore, the SAFER Bay project description should incorporate tidal marsh restoration of Ponds R1 and R2 into the project in partnership with the SBSPRP. All SAFER Bay project alternatives considered (Refer to Section 5 discussion and development of alternatives) would provide the flood risk reduction necessary for tidal marsh restoration at Ponds R1 and R2. However, the Restoration and Recreation Alternatives would also provide the opportunity for future tidal marsh restoration within the bayward pond cell (53 acres) at Pond SF2, improving tidal marsh connectivity along the bayshore.

3 Development of Options

The project area was divided into nine reaches to group similar topography, hydraulic conditions and constraints within each reach. In each reach, options were identified that satisfied one or more of the study objectives. Options that satisfied at least one study objective without violating study constraints were retained for further evaluation and formulation of overall study alternatives. Options that violated study constraints or were deemed infeasible were dropped from further consideration. The options identified in each reach are described in this section.

3.1 Reach 1 – Haven Area

Reach 1 begins at the border of a San Mateo County unincorporated area, Menlo Park and Redwood City and ends at Marsh Road. See Figure 3.

3.1.1 Option 1

Option 1 consists of a floodwall along the west side of Marsh Road, extending from the Reach 2 levee across the Silicon Valley Clean Water pump station property to the existing high ground near the Highway 101/84 Interchange. A flood gate with the same crest elevation as the floodwall will be provided across Haven Avenue. This option does not provide flood protection for the portion of Menlo Park situated north of Highway 101 and west of Marsh Road and will require coordination with Redwood City and Menlo Park if it is to be selected for implementation.

3.1.2 Option 2

Option 2 consists of raising the existing levee located along the Bayfront Canal from Reach 2 to the Redwood City border and a floodwall along Sleepy Hollow Lane and Haven Avenue (between the industrial center and RV Park), that will tie into the existing flood proofed sound wall located along Highway 101 near East Bayshore Road. See Typical Sections A and B on Figures 11 and 12 for cross sections of this option. A flood gate with the same crest elevation as the floodwall will be provided across East Bayshore Road. If Redwood City were to construct a flood risk reduction levee outboard of Bayfront Canal that connects to the east-west portion of this option, then the floodwall along Sleepy Hallow Lane and Haven Avenue would not be necessary.

The Bayfront Canal and Atherton Channel (see Figure 3) will require new water control structures to maintain existing conveyance capacity and provide interior drainage.

3.2 Reach 2 – Bedwell Bayfront Park

Reach 2 extends from Marsh Road to South Bay Salt Pond R3. See Figure 4.

3.2.1 Option 1

Option 1 consists of two levees, a western levee along Marsh Road from Reach 1 to high ground within Bedwell Bayfront Park and an eastern levee from the western limit of Reach 3 to

the existing high ground within the Bedwell Bayfront Park[7]. Tidal gates between Ponds R5 and R4 and between Ponds S5 and R3 are planned by SBSPRP to allow a balance and transfer of flows. Water control structures will be required to maintain interior drainage from the Caltrans ditch and Bayfront Canal. Additional geotechnical assessment will be required during the design phase to verify the levee tie-in. See Typical Sections A and B on Figures 13 and 14 for cross sections of this option.

The two levees will allow for SBSPRP restoration activities to occur. Levee construction between Ponds R5/S5 and Ponds R3/R4 would be compatible with restoration actions planned by the Phase 2 of the SBSPRP. This includes protection of Ponds R5 and S5 from potential coastal flooding from Pond R4, as R4 is planned for tidal restoration and Ponds R5 and S5 are slated to be managed habitat in the SBSPRP programmatic plan. Moreover, levee construction along Pond R4 would dovetail with the SBSPRP's Phase 2 design to construct transition zone habitat along this reach of Pond R4 by providing an engineered levee along which the SBSPRP could construct transition zone habitat. Transition zone habitat will allow for restored marsh in Pond R4 to be more resilient to SLR, consistent with the long-term goals of the SBSPRP. Transition zone habitat in this location would create high-tide refugia for California Ridgway's rails and salt marsh harvest mice and thereby help meet the objectives of the *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service [USFWS] 2013; referred to as *Tidal Marsh Recovery Plan).*

3.2.2 Option 2

Option 2 would raise the existing levee located adjacent to the Bayfront Expressway and Pond S5. This option's alignment would be constrained by the existing drainage channel, which collects water from the Bayfront Expressway and the Menlo Park neighborhood just south of the Bayfront Expressway via the Chrysler Pump Station. This option would not result in the ecological benefits of Option 1 because this option would integrate less directly with the SBSPRP restoration actions by not providing a levee separating tidal marsh restoration actions from the managed Pond S5. It would also result in fewer opportunities to create transition zone habitat.

3.3 Reach 3 – South Bay Salt Pond Ravenswood Pond R3

Reach 3 extends from South Bay Salt Pond R3 to the existing pedestrian/bicycle undercrossing near the Facebook campus. See Figure 5.

3.3.1 Option 1

Reach 3 only consists of one option as there is only one feasible alignment in this area. This option consists of raising the existing levee located adjacent to the Bayfront Expressway. Levee construction along the southern extent of Pond R3 would facilitate management actions compatible with the SBSPRP by improving flood protection for the existing managed pond.

[7] The levee will incorporate in-kind traveled way surfacing and tie into high ground along Marsh Road and the SBSPRP levee to maintain access. Flood protection will not be provided to the wastewater equalization basins.

Moreover, the SBSPRP's tidal habitat emphasis option calls for tidal habitat restoration in Pond R3 and the restoration of transition zone habitat along the landward/southern edge of Pond R3. Therefore, levee construction along the southern extent of Pond R3 would facilitate the SBSPRP's tidal marsh emphasis option. The creation of transition zone habitat along Pond R3 would allow for marsh resiliency to SLR and would help meet the objectives of the *Tidal Marsh Recovery Plan* by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice, particularly if transition zone habitat were included in Pond R3 restoration design See Typical Section on Figure 15 for a cross section of this option

3.4 Reach 4 – Facebook Campus

Reach 4 extends from the pedestrian/bicycle under crossing near the Facebook campus, traverses around the campus, and ends at the before the Ravenswood Pump Station Outfall. Reach 4 protects the existing Facebook campus by providing flood protection along the perimeter boundaries to the west, north and east. Both options would preserve the existing pedestrian/bicycle undercrossing near Willow Road and Highway 84, and maintain function of the Ravenswood Pump Station. See Figure 6.

3.4.1 Option 1

Option 1 augments the existing levee surrounding the campus with a floodwall. A raised recreational pathway would be constructed along either the inboard or outboard side of the floodwall. See Typical Section B, Option 1 on Figure 17 for a cross section of this option.

Floodwall construction would reduce impacts to existing tidal marsh habitat, but would preclude the incorporation of high quality transition zone habitat into flood-protection for the Facebook campus. This will limit the transition zone habitat quality associated with the SBSPRP's potential tidal restoration of Pond R3.

3.4.2 Option 2

Option 2 would raise the existing levee to provide the required flood protection for the campus. Widening required for the levee raise could occur either bayward into the tidal marsh of Ravenswood Slough (see Typical Section A, Option 2 on Figure 16 for a cross section of this option) or setback, where feasible into the Facebook access road (Hacker Way). Such a setback levee would minimize tidal marsh impacts, but would require reconfiguration of Hacker Way and the adjacent Facebook parking lot. Therefore, a setback into the Facebook access road is very unlikely and was not presented in a cross section diagram.

Although widening the levee bayward in this location may result in a loss of tidal marsh and transition zone habitat, the slough dead-ends at Highway 84, and is not currently high-quality tidal marsh. The current levee is steep but does provide some transitional habitat due to recent revegetation efforts. However, construction of a new levee would allow for the creation of a broader transition zone that meets the goals of the *Tidal Marsh Recovery Plan* and the SBSPRP, should the SBSPRP move forward with tidal restoration of Pond R3. If the SBSPRP were to eventually restore tidal marsh in Pond R3, the levee between Pond R3 and Ravenswood Slough could be removed, restoring a large tidal marsh contiguous with Ravenswood Slough and the SAFER levee. The Facebook levee could then be used to create a large, gradual transition zone that will make the current management of non-tidal pond habitat

or future tidal marsh restoration in Pond R3 more resilient to SLR. Therefore, this option provides a greater opportunity to restore transition zone habitat that would be more resilient to SLR compared to the floodwall described in Option 1.

3.5 Reach 5 – Highway 84

Reach 5 extends from the eastern extent of Reach 4 at the Ravenswood Pump Station Outfall, along Highway 84, either following around the PG&E Ravenswood Electrical Substation or in front of the substation entrance with a flood gate. This reach would then cross Highway 84 and then connect at the Union Pacific Railroad (UPRR) right-of-way (ROW). Depending of the selection of the Reach 5 option, Reach 6 may or may not be required. See Figure 7.

The decision of where to cross Highway 84 – and thus the length of it to additionally protect – and whether SAFER replicates the roadway's existing protection or provides substantially greater protection against a 100-year tide plus sea level rise, will be determined based on factors such as cost, marsh impacts and restoration benefits, and the level of involvement by project partners. The crossing locations described in the following paragraphs include: at University Avenue, beneath the Dumbarton Bridge, or at some point in between.

3.5.1 Option 1

Option 1 consists of levees along both sides of Highway 84 and a flood gate that crosses Highway 84. This flood gate would likely only be raised or closed through hydrostatic pressure during tides where there is substantial water on the roadway. This option would also require companion road closure gates at the eastern and western ends of the Dumbarton Bridge and require Caltrans to operate these gates according to a traffic control plan that diverts traffic away from the Highway 84 Bridge (Dumbarton Bridge) when the flood gate is closed. The levees may extend around the PG&E substation. See Typical Section A, Option 1 on Figure 18 for a cross section of this option.

Depending upon the length of levee and/or floodwall, this option could provide a direct collaboration link between the SAFER project and the SBSPRP's restoration of tidal salt marsh habitat. The long-term programmatic plan the SBSPRP calls for tidal habitat restoration in Ponds R1 and R2. The levee along Pond R2 (and potentially around the PG&E substation, should PG&E collaborate with SAFER and SBSPRP) would directly facilitate the SBSPRP's restoration of tidal salt marsh in R1 and R2. Flood protection at least equal to existing protection around Highway 84, its frontage roads, and the PG&E substation is necessary for tidal restoration of R1 and R2. Moreover, transition zone habitat could also be restored on the SAFER levee, further benefiting tidal salt marsh associated species, such as the California Ridgway's rail and harvest mouse, by creating high-tide refugia. Thus, the creation of transition zone habitat along R2 would further the objectives of the *Tidal Marsh Recovery Plan* and allow for marsh resiliency to SLR.

Option 1 would expose SBSPRP's Pond SF2 and the SFPUC Ravenswood Station to more significant coastal flooding.

3.5.2 Option 2

Option 2 consists of levees along both sides of Highway 84, and to limit the extent of these levees, the highway would be raised from the intersection with University Avenue eastward at a

maximum 50:1 (horizontal to vertical) slope. The levees would tie into Highway 84 at an elevation required to provide adequate flood protection. A levee would then be constructed along the east side of University Avenue to the UPRR ROW. See Typical Section B, Option 2 on Figure 19 for a cross section of this option.

The levee would provide long-term flood protection to the SAFER project area and a portion of Highway 84. On its own, this alignment would not provide habitat enhancement. Pond SF2 and the SFPUC Ravenswood Station would be more exposed to coastal flooding.

3.5.3 Option 3

Option 3 consists of levees and/or floodwalls along both sides of Highway 84 that tie into the Highway 84 Bridge abutment or cross just beneath the bridge. A flood gate may be required across the entrance to the PG&E substation if it is determined that the PG&E substation will not be protected by levees/floodwalls. The levee/floodwall along the south side of Highway 84 will transition to a levee along the east side of University Ave, extending to the UPRR ROW. See Typical Section B, Option 3 on Figure 19 for a cross section of this option.

This option could provide a direct coordination link between the SAFER project and the SBSPRP's restoration of tidal salt marsh habitat. The long-term programmatic plan the SBSPRP calls for tidal habitat restoration in Ponds R1 and R2. The levee along Pond R2 (and potentially around the PG&E substation, should PG&E collaborate with SAFER and SBSPRP) would directly facilitate the SBSPRP's restoration of tidal salt marsh in R1 and R2. Flood protection around Highway 84, its frontage roads, and the PG&E substation is necessary for tidal restoration of R1 and R2. Moreover, transition zone habitat could also be restored on the SAFER levee, further benefiting tidal salt marsh associated species, such as the California Ridgway's rail and harvest mouse, by creating high-tide refugia. Thus, the creation of transition zone habitat along R2 would further the objectives of the *Tidal Marsh Recovery Plan* and allow for marsh resiliency to SLR.

Pond SF2 and the SFPUC Ravenswood Station would be more exposed to coastal flooding.

3.5.4 Option 4

Option 4 consists of a levee along the north side of Highway 84, crosses the highway either with a floodgate as in Option 1 above or beneath the Dumbarton Bridge as in Option 3 above. From there, it extends across Pond SF2, crosses the UPRR right-of-way, and ties directly into the northern end of Reach 7. Similar to Option 3 and potentially Option 1, this option provides the same direct link to SBSPRP's tidal marsh restoration of R1 and R2; assuming that the PG&E substation is also protected to at least its current level of protection. See Typical Section D, Option 4 on Figure 11 for a cross section of this option.

Although some outboard diked non-tidal marsh would be lost to the east and south of Pond SF2, Option 4 would likely avoid the other options' impacts to habitat at the west and north side of Pond SF2 and improve flood protection to a portion this non-tidal pond managed for shorebird habitat and the Ravenswood Pump Station. Furthermore, a SAFER levee that enables the restoration of Ponds R1 and R2, and especially one that bisects Pond SF2, would open up the South Bay's constriction point at the Dumbarton narrows and thus reduce water surface elevation regionally (the amount of this broader benefit is being studied at this time). Finally,

Option 4 would eliminate the need for flood protection in Reach 6. See Typical Sections A, C and D on Figure 18, 20, and 21 for cross sections of this option.

3.5.5 PG&E Ravenswood Electrical Substation

The PG&E Ravenswood Electrical Substation, Figure 7, is located north of Highway 84 near the Dumbarton Bridge between the highway and Pond R2 and is not protected against SAFER's objective of 100 year tide plus FEMA freeboard and SLR. As described in the above options for Reach 5, a collaboration between the SAFER project, SBSPRP and PG&E would result in protection for the substation by a levee constructed around its perimeter that is connected to the parallel levee along Highway 84. An alternate option exists whereby the SAFER project would not install a new levee around the substation that achieves the project's protection objectives and instead install only a floodgate across the PG&E road entrance that connects to the parallel levee along Highway 84. This would reduce SAFER's levee length by over 2,000 feet. Under this option, access to the substation would be maintained through the new floodgate, and the substation would continue to receive the level of protection currently provided by the Ponds rather than protection to SAFER's standard.

3.6 Reach 6 – Northern East Palo Alto

Reach 6 extends from University Avenue to Fordham Street. **Reach 6 was merged into Reach 5** after further development of the Reach 5 options determined that for some of the alternative Reach 6 was not necessary to provide closed flood protection. Cost estimates for this Reach 6 are combined with Reach 5. See Figure 7.

3.6.1 Option 1

Option 1 consists of a new levee beginning at the Reach 6 terminus on University Avenue, continuing down University Avenue with a flood gate at the railroad crossing, then heading east along the SFPUC access road and ending at the northern extent of Reach 7.

3.6.2 Option 2

Option 2 consists of constructing a new levee south of the existing UPRR. This option would require raising a portion of University Avenue to accommodate the new railroad height where the railroad crosses the roadway. A long railroad transition would be required eastward and westward there to eventually match the existing railroad grade at a slope consistent with UPRR standards. See Typical Section D on Figure 21 for cross section of this option.

3.7 Reach 7 - Ravenswood Open Space Preserve

Reach 7 extends from north of Fordham Street to Bay Road, between the Midpeninsula Regional Open Space District's Ravenswood Open Space Preserve and the eastern edge of residential and industrial areas of East Palo Alto. East Palo Alto's Ravenswood / 4 Corners Specific Plan proposed a new loop road connecting University Avenue to Demeter Street which would share a similar alignment as the northern portion of Reach 7's levee (The Planning Center, 2013). Coordination with East Palo Alto will occur during the design phase of Reach 7 to properly bring together plans for the levee and roadway. Additional coordination will need to occur regarding several gravity storm drains that convey water from the East Palo Alto neighborhoods to the Bay. See Figure 8.

3.7.1 Option 1

The Option 1 alignment is located on the western side of 391 Demeter Street, thereby not providing flood protection for this high ground area, but would provide the opportunity to convert the area into transition zone habitat. Creating transition zone habitat would make the adjacent tidal marsh more resilient to SLR and benefit California Ridgway's rail and salt marsh harvest mice by creating high-tide refugia, consistent with the objectives of the *Tidal Marsh Recovery Plan*. The Bay Trail could be re-located from its current alignment to the new levee. Then the former Bay Trail levee could be lowered and breached to provide hydraulic connectivity to the marsh and transition zone to the west. The high ground area is identified as a capped contaminated area and would require additional analysis to verify contaminants did not enter the Bay. See Typical Section on Figure 22 for a cross section of this option.

3.7.2 Option 2

There is an area of existing high ground known as the '391 Demeter Street' parcel. The East Palo Alto Ravenswood / 4 Corners Specific Plan shows that this area is planned for future commercial and industrial development. Option 1 is consistent with the Zoning Plan by providing a new levee on the eastern side of 391 Demeter Street, thereby providing flood protection to the industrial development planned for that area. Transition zone habitat can be incorporated into the levee design that would make adjacent tidal marsh more resilient to SLR and benefit California Ridgway's rail and salt marsh harvest mice by creating high-tide refugia, consistent with the objectives of the Tidal Marsh Recovery Plan. See Typical Section on Figure 22 for a cross section of this option.

3.8 Reach 8 – Laumeister Marsh

Reach 8 extends from Bay Road to Runnymede Street. An overhead power transmission line closely follows this reach and would like require re-location and/or elevation of this line's towers. Both options would require a flood gate across or raising Bay Road to preserve access to the Cooley Landing Park. See Figure 9.

3.8.1 Option 1

Option 1 consists of a new levee, setback from the marsh and into the existing industrial parcels. One drawback of Option 1, compared to Option 2, is that it is situated closer to the former Rhone-Poulenc Superfund site, with increased potential for encountering contaminated soil. See Typical Section Figure 23 for a cross section of this option.

Tidal marsh impacts would be reduced relative to Option 1. The restoration of transition zone habitat adjacent to Laumeister Marsh would significantly enhance California Ridgway's and salt marsh harvest mouse habitat in this area. This option would significantly increase habitat quality and quantity for rails and harvest mice compared to Option 1 due to the greater room for transition zone habitat and reduced impacts to tidal marsh via the levee setback. This would further the objectives of the Tidal Marsh Recovery Plan by creating more high-tide refugia for California Ridgway's rails and salt marsh harvest mice and would significantly increase the adjacent marsh's ability to adapt to SLR.

3.8.2 Option 2

Option 2 consists of a new levee built on the Bay side of the existing levee with restored transition zone habitat along the Baylands Nature Preserve/Laumeister Marsh from Bay Road to Runnymede Street.

The restoration of high-quality transition zone habitat adjacent to the tidal salt marshes of the Laumeister Marsh would significantly enhance California Ridgway's rail and salt marsh harvest mouse habitat in this area by increasing the amount of high-tide refugia for these species, as per the objectives of the Tidal Marsh Recovery Plan. In addition to providing high-tide refugia for rails and harvest mice, a transition zone would allow for improved marsh resiliency to SLR. See Typical Section on Figure 23 for a cross section of this option.

3.9 Reach 9 – Faber Tract

Reach 9 extends from Runnymede Street to the O'Connor Pump Station, which is the terminus of the SFCJPA's Bay to Highway 101 creek project for flood protection, ecosystem restoration and recreation. The issues requiring coordination in this area include Faber marsh habitat and the gravity outfall at the end of Runnymede Street and Runnymede drainage ditch just west of the proposed levee alignment that drains to the O'Connor Pump Station and conveys approximately 40% of East Palo Alto's storm water. See Figure 10.

3.9.1 Option 1

Option 1 consists of a new levee with restored transition zone habitat along the Faber Tract from the Runnymede Street Outfall to the O'Connor Pump Station at Friendship Bridge avoiding the East Palo Alto Sanitary District (EPASD) existing sewer line.

Restoration of transition zone habitat adjacent to Faber Tract would significantly enhance California Ridgway's and salt marsh harvest mouse habitat in this area. The creation of transition zone habitat along the Faber Tract would increase tidal marsh resiliency to SLR and would help meet the objectives of the Tidal Marsh Recovery Plan by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice. See Typical Section on Figure 24 for a cross section of this option.

3.9.2 Option 2

Option 2 consists of a new levee, setback from the marshes into the Runnymede drainage ditch. Restored transition zone habitat adjacent to the Faber Tract would significantly enhance California Ridgway's rail and salt marsh harvest mouse habitat in this area. This option would increase habitat quality and quantity for rails and harvest mice compared to Option 1. The creation of transitional zone habitat along Faber Tract would allow for greater marsh resiliency to SLR (compared to Option 1) and would help meet the objectives of the Tidal Marsh Recovery Plan by creating high-tide refugia for California Ridgway's rails and salt marsh harvest mice.

However, this setback would intrude into an existing stormwater drainage channel and storage area for the City of East Palo which is already significantly undersized for the contributing watershed. Any encroachment into the channel and storage area reduces critical stormwater storage and will cause additional flooding elsewhere within the City of East Palo Alto, which is not acceptable. Relocation of the stormwater system is not possible due to the limited available space available or without causing major impacts to residential homeowners. In addition, the

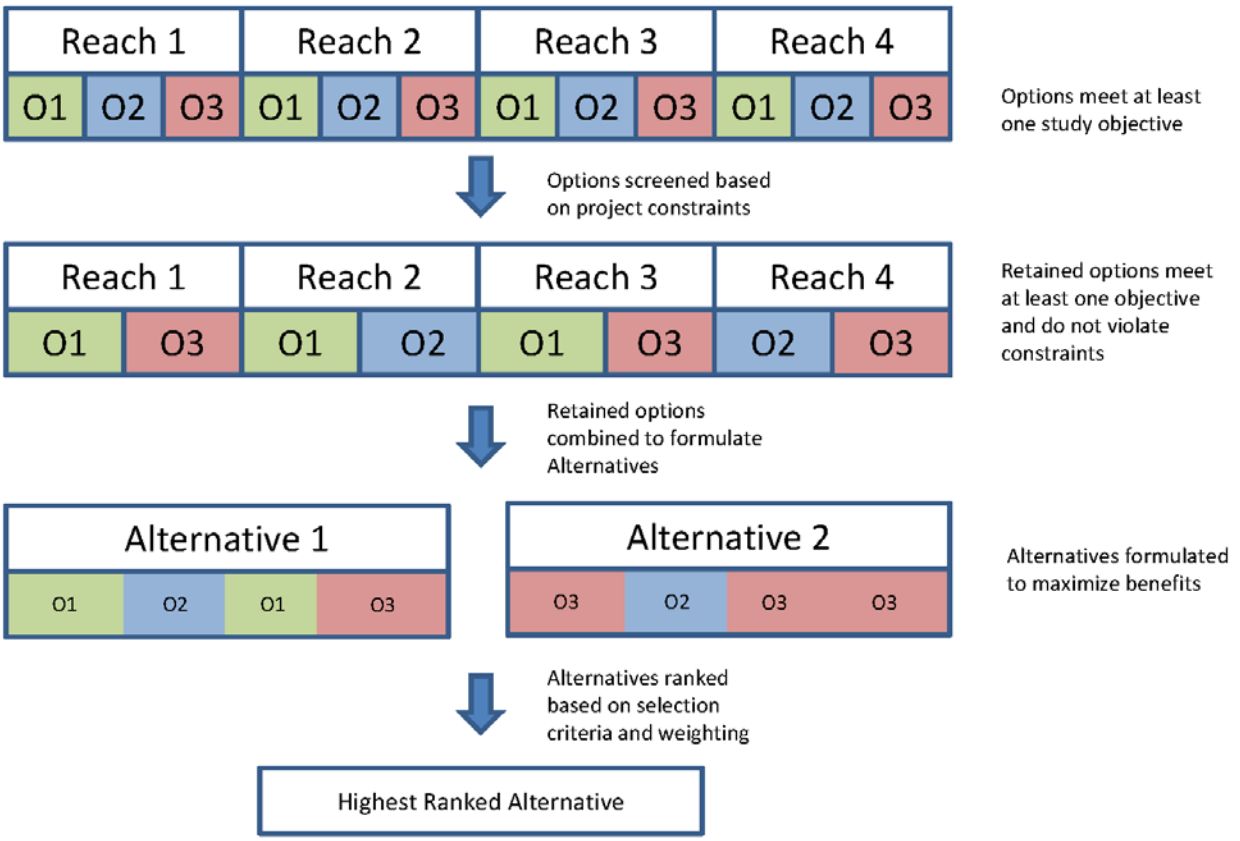
sanitary sewer main for East Palo Alto runs along the inboard toe of the existing levee and would need to be relocated. See Typical Section on Figure 24 for a cross section of this option.

4 Evaluation of Options

4.1 Initial Screening and Evaluation of Options

As presented earlier in this study, an option is a stand-alone feature in any individual project reach that will address at least one of the project objectives. An option does not need to satisfy all project objectives, but should not violate project constraints. Alternatives will be formulated by combining retained options so that an alternative addresses all of the project objectives for all of the project reaches (See Flow Chart 1 for an example alternative evaluation process). In Section 5 the alternatives will be evaluated against screening criteria to determine the highest ranking alternative. The reaches and options presented in Section 3 were evaluated to determine which options provide the best relative benefit to the overall objectives of the project, while not violating project constraints. Because of the very large number of option combinations, the strategy was not to develop an exhaustive list of all possible permutations or combinations of all potential options in development of alternatives. Rather, the strategy was to identify options that meet study objectives, constraints, and criteria, and formulate alternatives using a rationale that maximizes the ability to meet overall project objectives and requirements. This section provides a qualitative evaluation of the individual options in each reach, and identifies which are retained for further consideration and which are dropped from further study.

Flow Chart 1. Alternative Formulation and Evaluation Process



4.2 Reach 1

4.2.1 Option 1 (Floodwall at Marsh Road) - *Retained*

Option 1 has a significantly lower cost than option 2 due to a shorter alignment and lack of water control structures. Option 1 is located in an area with numerous existing underground and overhead utilities. Option 1 has no opportunity for recreation or restoration, and will not provide flood protection to all of Menlo Park. It does not intersect with the existing drainage from the Bayfront Canal, but it does intersect the proposed diversion from the Bayfront Canal to Ponds R5 and S5. Redwood City has proposed this diversion to reduce stormwater flooding in Redwood City.

4.2.2 Option 2 (Levee along Bayfront Canal) - *Retained*

This provides recreation by extending the Bay Trail. This option is constrained by two water channels that exist on both sides of the alignment. The Bayfront Canal, the channel on the inboard side, is part of the stormwater drainage system for Redwood City, Atherton, and Menlo Park. Where the levee crosses Bayfront Canal, it would cut off the west-to-east drainage pathway, so an alternative conveyance pathway would need to be identified for the Canal's drainage. A floodwall or combination of levee raise and floodwall may be necessary for this option. A floodwall is not recommended due to negative visual/recreation impacts. A FloodBreak levee topper was ruled out because of the potential cost, required maintenance, and unfamiliarity for the extensive length of this reach. Option 2 allows Redwood City the opportunity to tie their flood protection infrastructure to the SAFER Bay project in the future.

4.3 Reach 2

4.3.1 Option 1 (Levees to Bedwell Bayfront Park) - *Retained*

This appears to be the lower cost option because it is a shorter alignment and set back further from existing infrastructure than Option 2. Option 1 also provides a greater opportunity for restoration because it aligns with the goals of the SBSPRP by providing flood protection to the proposed retention ponds along this reach. The eastern Option 1 levee alignment is also in the location the SBSPRP's proposed transition zone restoration/horizontal levee and could be integrated with this aspect of the SBSPRP.

4.3.2 Option 2 (Levee along Bayfront Expressway) - *Dropped*

This option is constrained by two water channels and would cross potential stormwater diversion from the Bayfront Canal to Ponds R5 and S5. This option was removed from further consideration due to cost and potential habitat impacts caused by the levee fill in the salt pond.

4.4 Reach 3

4.4.1 Option 1 - *Retained*

This is the only option for this reach that is considered viable.

4.5 Reach 4

4.5.1 Option 1 (Floodwall) - *Retained*

This option partially limits the views from the Facebook Campus and the BCDC Shoreline Trail. The floodwall would be approximately 3-4 feet in height on top of the existing levee. A new bike path would be constructed behind the new floodwall, raised in elevation from its current height to retain a view of the bay from the bike path. Option 1 has no opportunity for transition zone restoration, but would reduce impacts to existing tidal marsh habitat in Ravenswood Slough.

4.5.2 Option 2 (Levee) - *Retained*

This option provides opportunity for transition zone habitat restoration, maintains the existing recreation opportunities of the BCDC Shoreline Trail, and can be built at similar cost as Option 1. However, the levee would extend outward from the campus and thus would impact existing tidal marsh habitats. These impacts could be reduced by a slightly steeper outboard levee slope and revegetation of transition zone habitat. Tidal marsh impacts could be further reduced by setting back the levee into the Facebook access road, if feasible.

4.6 Reach 5

4.6.1 Option 1 (Levee along and Flood Gate across Highway 84) - *Retained*

Dependent upon the location of the flood gate crossing, this option could provide protection for Highway 84 and the PG&E substation (should PG&E choose to collaborate with SAFER and the SBSPRP). This option is consistent with the SBSPRP Programmatic EIR/S and would enable tidal restoration of Ponds R1 and R2. There is an existing gas line impacted by this alignment. The section along University Avenue would extend and connect to the Bay Trail. This option would also require companion road closure gates at the eastern and western ends of the Dumbarton Bridge and require Caltrans to operate these gates. The costs of this option will be significantly impacted by the selected location of the flood gate across Highway 84.

4.6.2 Option 2 – (Raise Highway 84) - *Dropped*

Design and construction of this option would require extensive coordination and cooperation with Caltrans to construct while minimizing impacts on Highway 84 traffic. Option 2 was removed from further consideration based on high cost, extensive Caltrans coordination, difficulty of construction, and lack of restoration opportunity. The section along University Avenue would extend and connect to the Bay Trail.

4.6.3 Option 3 (Levee around Highway 84) - *Dropped*

This option provides protection for Highway 84 and the PG&E substation (should PG&E choose to collaborate with SAFER and the SBSPRP). This option is consistent with the SBSPRP Programmatic EIR/S and would enable full tidal restoration of Ponds R1 and R2. An existing gas line, as well as the overall length, would make Option 3 the highest cost option. The section along University Avenue would extend and connect to the Bay Trail. Option 3 was removed from further consideration, as Option 4 provides greater flood risk management opportunities to protect the SFPUC facility and habitat benefits, with less impacts and lower cost.

4.6.4 Option 4 (Levee at Highway 84 and Bay) - *Retained*

This option provides the greatest opportunity for restoration by protecting Highway 84 and potentially the PG&E substation (enabling tidal marsh restoration in Ponds R1 and R2), the eastern portion of Pond SF2 pond, and the SFPUC Ravenswood Station (which may have restoration options due to the new levee). Option 4 would eliminate the need for Reach 6 thereby reducing the overall project cost. Pond SF2 is composed of three pond cells. The levee alignment protects the two landward pond cells, but would allow future tidal marsh restoration of the bayward pond cell. The section along Pond SF2 and SFPUC would provide the best opportunity for recreation by extending and connecting the Bay Trail along the Bay shoreline.

4.7 Reach 6

Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

4.8 Reach 7

4.8.1 Option 1 (Setback Levee) - *Dropped*

This option would reduce tidal marsh impacts and increase transition zone habitat restoration opportunities relative to Option 2. It would convert a property that is planned for commercial development to a combination of transition zone and tidal marsh habitat. However, this option was dropped because of concerns the property may include contaminated fill which would require further treatment. Therefore, it was judged infeasible to restore the site to transition zone habitat.

4.8.2 Option 2 (Outboard Levee) - *Retained*

This option would be less costly because this alignment coincides with the one presented in the East Palo Alto Ravenswood / 4 Corners Specific Plan and minimizes impacts to developable real estate. If a levee is used along the southern portion of this reach, this option would impact the entire tidal marsh area located west of the restored Cooley Landing salt pond by filling this marsh's tidal slough connection to the Bay. A floodwall might be feasible to avoid filling this channel or, if the channel is filled, mitigation might include breaching and/or lowering the current Bay Trail berm to restore tidal connectivity to existing marsh west of the Bay Trail levee.

4.9 Reach 8

4.9.1 Option 1 (Outboard Levee) - *Dropped*

This option reduces tidal marsh impacts and provides a greater opportunity for transition zone habitat restoration. However, this option may have a greater potential for dealing with contaminated soil from the nearby Rhone-Poulenc/Zoecon/Sandoz Superfund site. Additionally, a second hazardous waste facility that underwent closure, the former Romic Environmental Technologies Corporation Facility, has recently developed a conceptual remedial design plan. This option was dropped because there were only minimal differences between the Option 1 and Option 2 levee alignments.

4.9.2 Option 2 (Setback Levee) - *Retained*

This option potentially minimizes impacts to landside real estate. However, this option would have greater tidal marsh impacts to the Laumeister Marsh relative to Option 1. The alignment has since been refined after learning more information regarding the contaminated Rhone-Poulenc/Zoecon/Sandoz soil site. Additional information is needed to determine design impacts near the Romic site. The setback levee is limited to southeast side of the contaminated site.

4.10 Reach 9

4.10.1 Option 1 (Outboard Levee) - *Retained*

This option would be less costly because this alignment avoids an existing drainage channel and sewer main, but has tidal marsh habitat impacts associated with placement of fill in the Faber Tract.

4.10.2 Option 2 (Setback Levee) - *Dropped*

This option minimizes impact to Faber Tract associated with placement of fill and provides greater opportunity for transition zone habitat restoration. However, this option encroaches into the already limited and critical stormwater storage for the City of East Palo Alto and is therefore dropped.

5 Development of Alternatives

Section 5 describes the formulation rationale used to develop the preliminary alternatives from the retained options in each reach, and identifies the preliminary alternatives that will be carried forward for further evaluation and ranking.

5.1 Alternative Formulation Rationale

To efficiently combine retained options into alternatives, the following formulation rationales were developed:

- Cost of Construction – In each reach, the overall cost of each option was qualitatively considered, and the option that had the lower/lowest anticipated overall cost was identified. The "*Low Cost Alternative*" was formulated to combine those options that present the lowest overall cost.
- Wetland Restoration Potential/Wetland Impact Minimization – In each reach, options with higher opportunity for tidal wetland habitat restoration were considered, and the options with the higher/highest potential for restoration (or lowest wetland habitat impact) were identified. The "*Restoration Alternative*" was formulated to combine those options that maximize restoration opportunities.
- Recreation Potential - The San Francisco Bay Trail traverses much of the Project area. In each reach, options with greater opportunity for maintaining or improving the Bay Trail recreation opportunities were considered, and the options with the higher/highest recreation potential were identified. The "*Recreation Alternative*" was formulated to combine those options that maximize recreation opportunities.

All options considered and alternatives formulated meet the objective of reducing flood risk in the study area. The Restoration and Recreation alternatives both satisfy the partnership objectives of the study.

5.2 Summary of Preliminary Alternatives

A summary of the retained options that satisfy the formulation rationale for the lowest cost, greatest opportunity for tidal wetland restoration (or to minimize wetland impact), and the greatest opportunity for recreation are provided in Table 5 below. Overall, Reaches 1, 4 and 5 are the only reaches with more than one retained option for comparison.

In addition to the three alternatives formulated based on the rationale presented in Section 5.1, a fourth alternative was formulated. Following initial review of the Low Cost, Restoration, and Recreation alternatives, the study team determined that there may be an optimized alternative that is a combination of the Low Cost and Recreation/Restoration alternatives. While the Low Cost alternative was found to be much lower in capital cost than the Recreation/Restoration alternatives, a new alternative was developed to provide a lower cost than the Recreation/Restoration alternatives, but provide some level of restoration opportunities that the Low Cost alternative did not. This *Optimized Alternative* was formulated so that the tradeoff between higher project capital cost and restoration opportunities could be evaluated and ranked against the pure Low Cost and Restoration/Recreation alternatives.

Table 5. Summary of Preliminary Alternative Reach Options

Alternatives		Options by Reach								
	Reach	1	2	3	4	5	6[2]	7	8	9
1	Lowest Cost	Op 1	Op 1	Op 1	Op 1	Op 1	X	Op 2	Op 2	Op 1
2	Restoration[1]	Op 2	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1
3	Recreation	Op 2	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1
4	Optimized	Op 1	Op 1	Op 1	Op 2	Op 4	X	Op 2	Op 2	Op 1

X Not applicable

[1] Note that the Restoration Alternative includes construction of transition zone habitat along the bayward side of the new levees in reaches 5, 7, 8, and 9.

[2] Reach 6 was merged into Reach 5 after further development of the Reach 5 options.

6 Evaluation of Alternatives

6.1 Evaluation Methodology

The four alternatives developed in Section 5, lowest cost, greatest opportunity for tidal wetland restoration (or to minimize wetland impact), the greatest opportunity for recreation, and the optimized alternative were compared against Evaluation Factors in a scoring matrix. The scoring matrix utilizes Evaluation Factors and specific qualitative and quantitative Consideration Scoring Metrics and assigned weighting factors to identify the highest ranking alternative.

Evaluation Factors are the primary selection criteria for the preferred plan and were developed based on input from the SFCJPA during the SAFER Bay project kick-off meeting in December of 2013. Each Evaluation Factor was broken down further into Consideration Scoring Metrics. The Consideration Scoring Metrics are the elements that were assessed and scored based on both quantitative and qualitative evaluations. In March of 2016, the SFCJPA and planning team held a workshop to review and refine the Evaluation Factors and Consideration Scoring Metrics, and assign weighting to each. The individual scores for the Consideration Scoring Metrics and applied weighting result in the calculated score at the Evaluation Factor level. The calculated scores for the Evaluation Factors and applied weighting result in the overall alternative ranking.

The final Evaluation Factors, Consideration Scoring Metrics, and percentage weighting factors are summarized in Table 6 below.

Table 6. Feasibility Evaluation Scoring Matrix and Calculation Methodology

Evaluation Factor	Wt %	Consideration Scoring Metric	Wt%
Construction Cost and Constructability	30%	Construction Cost	50%
		Lifecycle Cost	5%
		Construction Schedule	5%
		Construction Considerations and Access	20%
		Real Estate Acquisition	20%
Operation and Maintenance	20%	O&M Cost	30%
		Debris and Sediment Management	30%
		Passive/Active	20%
		Flood Fighting Accessibility	20%
Restoration	30%	Acres of Restored and Enhanced Tidal Marsh Habitat	40%
		Interagency Coordination	20%
		Potential Impacts/Mitigation Requirements	40%
Recreation	20%	Bay Trail	50%
		Interpretive/Viewing	50%

6.2 Consideration Scoring Metrics

The Consideration Scoring Metrics were defined and applied for each reach. A description of each Consideration Scoring Metric is summarized below.

Construction Cost and Constructability Evaluation Factor

- Construction Cost: What reach option is the least expensive and most expensive? (Preliminary costs are summarized in Section 7 and Appendix C.)
- Lifecycle Performance: What is the anticipated lifecycle performance of the proposed flood risk reduction feature? Will the proposed feature need replacement in a set number of years more quickly than another proposed feature?
- Construction Schedule: How quickly will the reach option be able to be constructed? Is there significant coordination, permit and/or environmental challenges that may slow down the construction schedule?
- Construction Considerations: Are there construction considerations that make the reach option difficult to construct? Will construction access be challenging due present water, nearby traffic, limited right-of-way? Is there complex levee/floodwall tie-in overlap?
- Real Estate and Access: Who is impacted by the required real estate and access for the proposed flood risk reduction feature? Does the reach option utilize existing SFCJPA member owned right-of-way or will private real estate need to be acquired? Is access adjacent to the toe of levee or floodwall clear from obstructions or will more right-of-way needs to be acquired?

Operation and Maintenance Evaluation Factor

- Operation and Maintenance (O&M) Performance: Will the flood risk reduction feature require significant management from O&M staff or will it only require periodic inspection? What skill set of staff or agency would be required to perform the O&M?
- Debris and Sediment Management: Will the proposed flood risk reduction feature collect debris or sediment? Will additional clean out maintenance be required?
- Passive/Active: Will the constructed flood risk reduction feature require staff to open/close flood gates during flooding events? A passive system would include a levee or floodwall that does not require any action (other than monitoring) during an event. Active system includes some sort of structure that must be managed during the event in order for it to provide and maintain flood protection.
- Flood Fighting Accessibility: How easy will it be to have O&M staff inspect, access, evaluate and flood fight during a major flood event? Is the landside toe of the levee visible during flooding? Is there a drainage ditch/canal that runs along parallel with the levee hiding the toe? Will there be water on both sides of the levee during an event? Are there homes or other structures right adjacent to the levee? How will vehicles access the levees?

Restoration Evaluation Factor

- Acres of Enhanced Tidal Marsh Habitat: How much potential acres of enhanced tidal marsh habitat are potentially available with the proposed reach option?
- Interagency Coordination: What interagency coordination will be required if this reach option is selected? Will this reach option require additional permits due to interagency oversight? Are there any foreseen challenges with coordination?
- Potential Impacts/Mitigation Requirements: What potential environmental impacts are impacted by the proposed alternative? Wetlands, plants, harvest mouse, clapper rail, etc.? What type and where would we consider mitigation requirements?

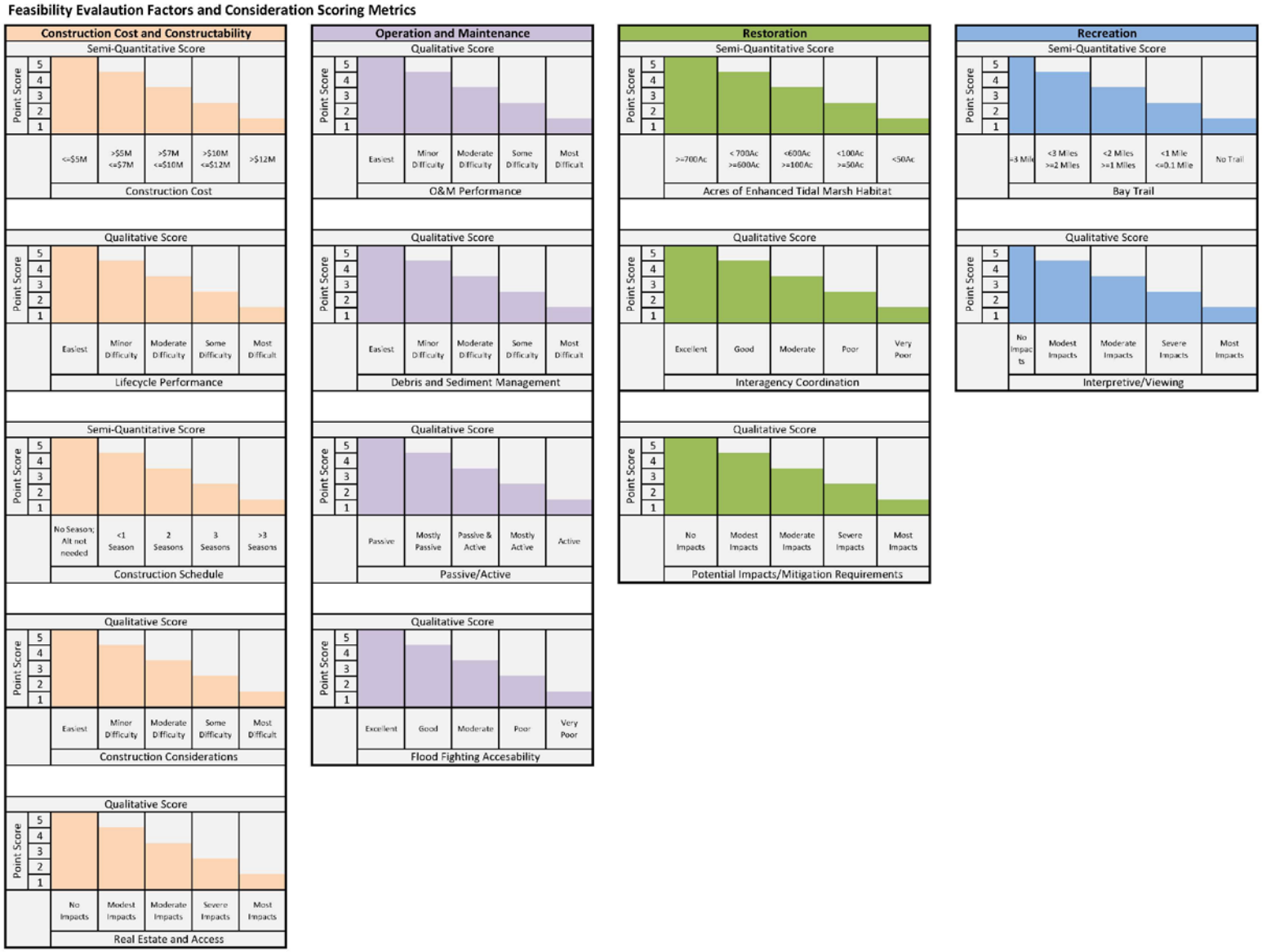
Recreation Evaluation Factor

- Bay Trail: Will the Bay Trail access, safety, and/or overall pedestrian experience decrease with the proposed reach option?
- Interpretive Viewing: Will the viewshed be impacted by the proposed reach flood risk reduction feature?

For each Consideration Scoring Metric, a score of 1 through 5 was applied to each reach option considering the qualitative or quantitative benefit that each reach option provides. The scoring matrix was also populated by utilizing feasibility level cost estimates summarized in Section 7 to determine the final scoring and highest ranking alternative. Table 7 illustrates how scores of 1 through 5 were assigned for each Consideration Scoring Metric.

The scoring matrix was normalized utilizing the point score of 1 through 5 and then by applying the weighting factors shown in Table 6. The individual reach calculation tables are included in Appendix B.

Table 7. Feasibility Evaluation Factors and Consideration Scoring Metrics



7 Feasibility Level Cost Estimates

Feasibility level opinions of probable construction cost were developed for each option and summarized for each alternative. Quantities were based on output from Civil3D as well as typical cross sections determined from averaged levee heights and design geometry captured in Figures 11 through 24. Cost opinions assume that the levee is constructed to a full height accounting for SLR. Fill volumes account for settlement which is documented on each typical cross section figure. Gate type structures (road crossing and tide) are assumed to be same average cost for similar type. Total cost for each alternative assuming a 30% contingency is summarized in Table 8. Individual Reach Feasibility Level Cost Estimates and quantity breakdown is included in Appendix C.

Table 8. Feasibility Level Cost Estimates per Alternative

	Alternatives[1]	Total Estimated Cost (assuming 30% contingency)
1	Lowest Cost	$89,747,000
2	Restoration	$115,790,000
3	Recreation	$115,790,000
4	Optimized	$104,860,000

1 The cost of constructing transition zones is not included within these provided costs.

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8 Summary of Results and Preliminary Ranking

Each option was ranked 1-5, averaged, and tabulated into Table 9 below. The lowest cost alternative received an average score of 3.1 and is illustrated in Figure 31. The restoration alternative received and average weighted score of 3.0 and is illustrated in Figure 32. The recreation alternative received an average weighted scope of 3.0 and is illustrated in Figure 33. The optimized alternative received an average score of 3.2 and is illustrated in Figure 34. The optimized alternative was the highest ranking alternative.

Table 9. Feasibility Evaluation Factors and Consideration Scoring Metrics

Feasibility Evaluation Scoring Matrix and Calculation - SAFER Bay Task Order 1 Alternatives				**Low Cost**	**Restoration**	**Recreation**	**Optimized**
Evaluation Factor	Wt %	Considerations	Wt%	Alt 1	Alt 2	Alt 3	Alt 4
Construction Cost and Constructability	35%	Construction Cost	50%	2.6	2.0	2.0	2.5
		Lifecycle Cost	5%	4.4	3.9	3.9	4.3
		Construction Schedule	5%	3.0	2.8	2.8	2.9
		Construction Considerations and Access	20%	3.6	3.8	3.8	3.6
		Real Estate Acquisition	20%	3.0	3.0	3.0	3.0
				3.0	2.7	2.7	2.9
Operation and Maintenance	20%	O&M Cost	30%	4.4	3.9	3.9	4.3
		Debris and Sediment Management	30%	4.3	3.8	3.8	4.1
		Passive/Active	20%	3.3	3.3	3.3	3.3
		Flood Fighting Accessibility	20%	3.1	2.6	2.6	2.9
				3.9	3.5	3.5	3.7
Restoration	25%	Acres of Enhanced Tidal Marsh Habitat	40%	1.5	1.8	1.8	1.8
		Interagency Coordination	20%	3.0	3.4	3.4	3.1
		Potential Impacts/Mitigation Requirements	40%	4.1	4.5	4.5	4.6
				2.9	3.2	3.2	3.2
Recreation	20%	Bay Trail	50%	2.3	2.3	2.3	2.4
		Interpretive/Viewing	50%	3.3	3.6	3.6	3.4
				2.8	2.9	2.9	2.9
Total Alternative Score	**100%**			**3.1**	**3.0**	**3.0**	**3.2**
		Overall Ranking Order:		**2**	**3**	**3**	**1**

9 References

- Bay Conservation and Development Commission (BCDC). 2011. Resolution No. 11-08: Alternative of Bay Plan Amendment No. 1-08 Adding New Climate Change Findings and Policies to the Bay Plan; And Revising the Bay Plan Tidal Marsh and Tidal Flats; Safety of Fills; Protection of the Shoreline; and Public Access Findings and Policies.
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Figures

REACH 1

REACH 2**

REACH 3

REACH 4

REACH 5**

REACH 6*

REACH 7**

REACH 8**

REACH 9**

- Reach 1, Option 1
- Reach 1, Option 2
- Reach 2, Option 1
- Reach 2, Option 2
- Reach 3, Option 1
- Reach 4, Option 1 & 2
- Reach 5, Option 1
- Reach 5, Option 2
- Reach 5, Option 3
- Reach 5, Option 4
- Reach 6, Option 1
- Reach 6, Option 2
- Reach 7, Option 1
- Reach 7, Option 2
- Reach 8, Option 1
- Reach 8, Option 2
- Reach 9, Option 1
- Reach 9, Option 2

* Reach 6 has been merged into Reach 5

** Dropped Options shown in Grey

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

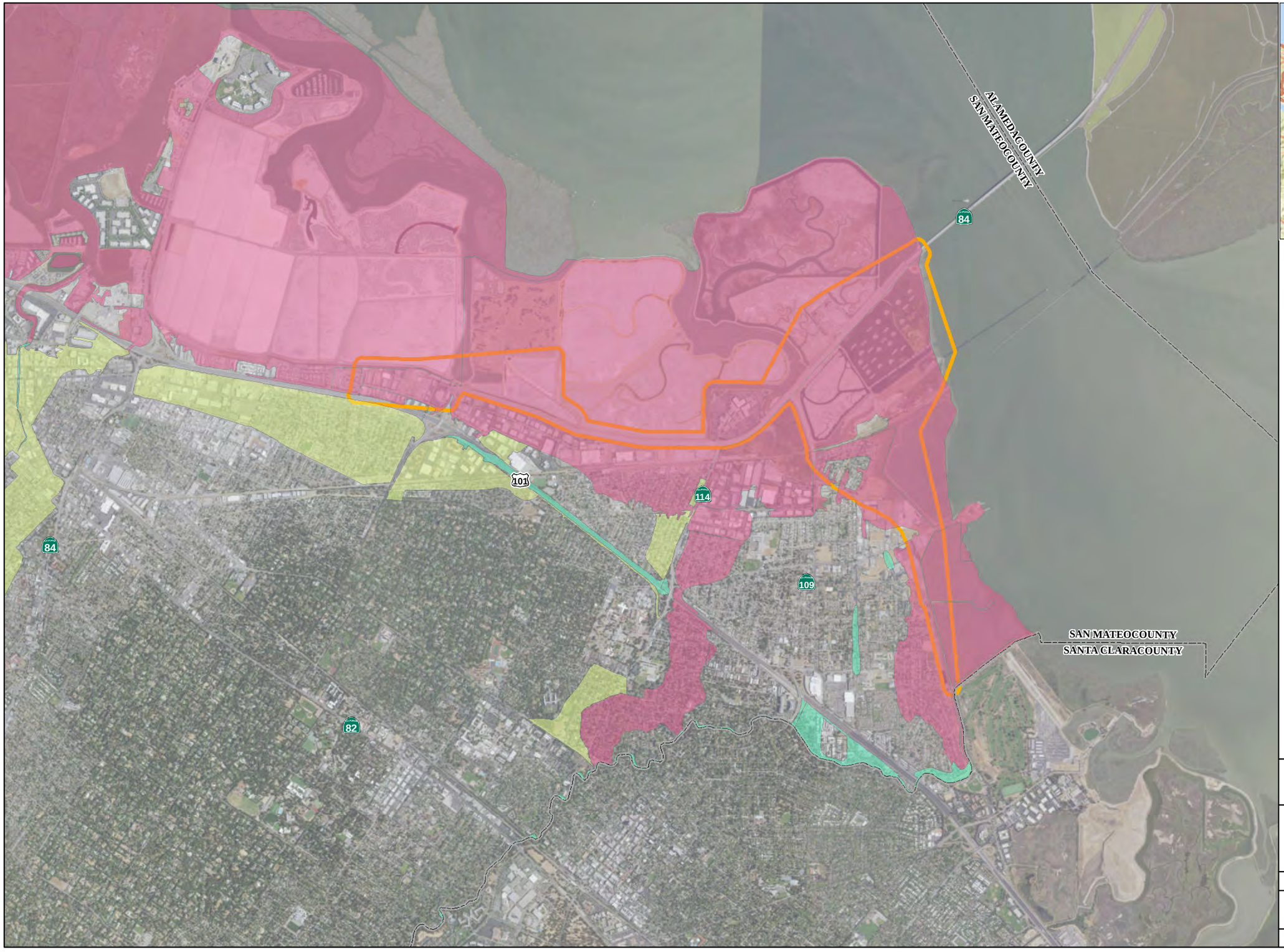
Feasibility Report
Project Reaches and Options

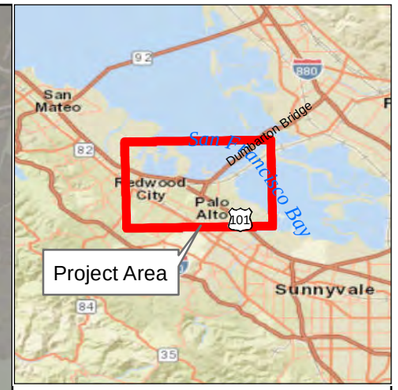
Figure 1

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

SEPT 2016





Flood Zone

- A, 0.1 PCT ANNUAL CHANCE FLOOD HAZARD
- AE, 0.1 PCT ANNUAL CHANCE FLOOD HAZARD WHERE BASE FLLOD ELEVATIONS ARE PROVIDED
- X, 0.2 PCT ANNUAL CHANCE FLOOD HAZARD
- County Boundary
- Project Area

N

0 3,000 Feet

1 inch = 3,000 feet

SAFER Bay Levee Project

PRELIMENARY FEMA FLOOD INSURANCE RATE MAP FLOODPLAINS (8/13/15)

Figure 2

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

SAN MATEO COUNTY
Inundation Mapping

MHHW + 36" SEA LEVEL RISE

SLR + STORM SURGE SCENARIOS LISTED BELOW COULD BE APPROXIMATED BY THE INUNDATION SHOWN ON THIS MAP.

0" SLR + 50-YEAR STORM SURGE
6" SLR + 25-YEAR STORM SURGE
12" SLR + 10-YEAR STORM SURGE
18" SLR + 2-YEAR STORM SURGE
24" SLR + 1-YEAR STORM SURGE

Shoreline Overtopping Potential

0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet

No Overtopping

Sea Level Rise Inundation

0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet

Disconnected Areas > 1 Acre

0 0.2 0.4 0.6 0.8 Miles

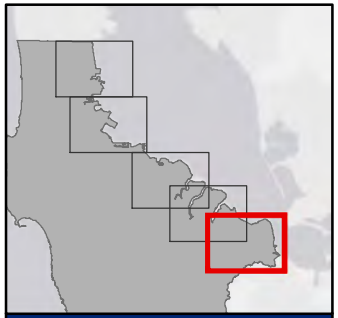
0 1,000 2,000 3,000 4,000 Feet

N

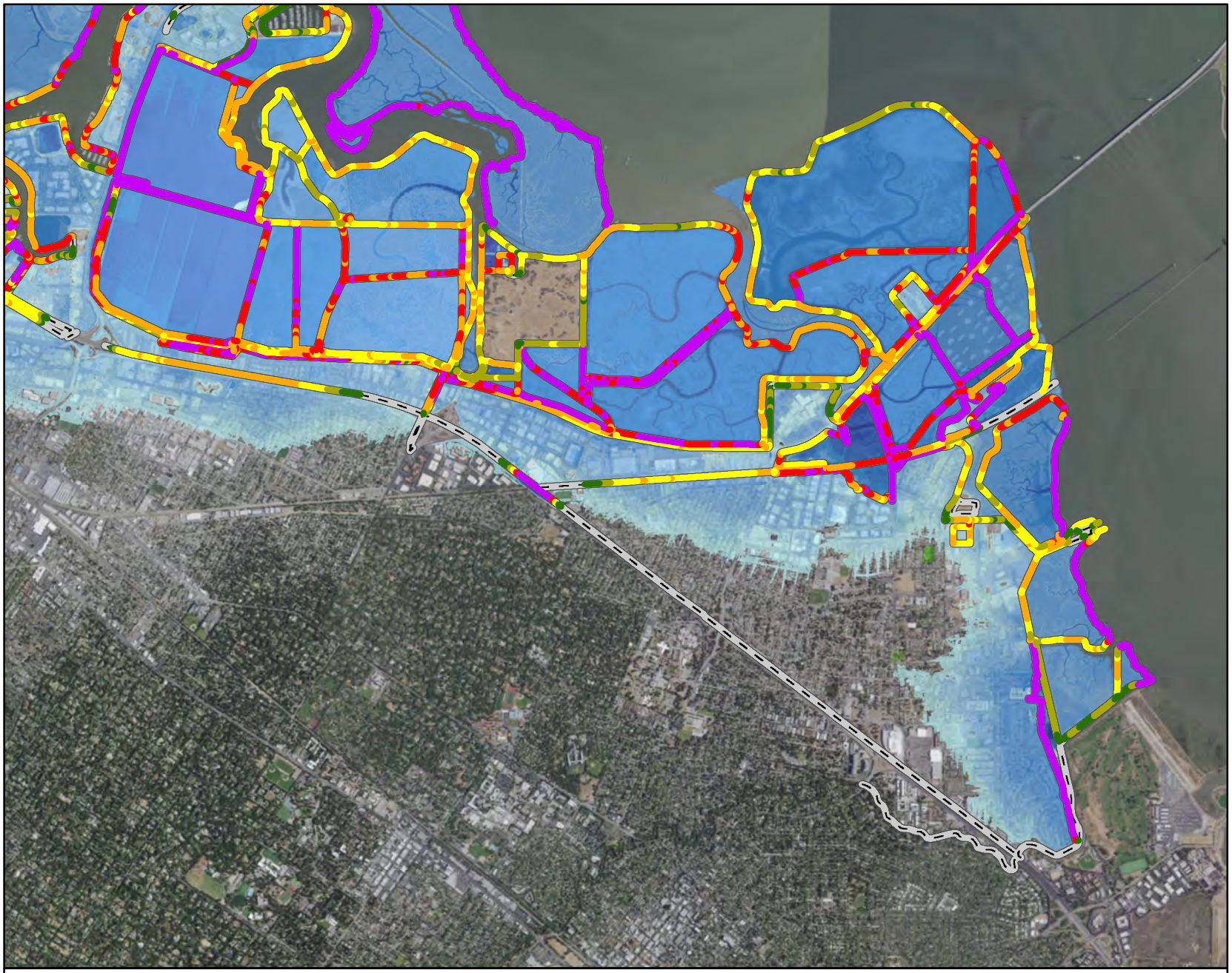
Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

May, 2016



The inundation maps and the associated analyses provide a regional-scale illustration of inundation and coastal flooding due to specific sea level rise and storm surge scenarios, and are intended to improve sea level rise awareness and preparedness. The maps are not detailed to the parcel-scale and should not be used for navigation, permitting, regulatory, or other legal uses. Flooding due to sea level rise and storm surges is possible in areas outside of those predicted in these maps, and the maps do not guarantee the safety of an individual or structure. Nor do the maps model flooding from other sources, such as riverine or surface water flooding from rainfall-runoff events. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of flooding. The maps relied on a 1-meter digital elevation model created from LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and coastal structures that may impact coastal inundation, it is possible that structures may not be fully represented, especially those that are narrower than the 1-meter horizontal map scale. The maps are based on model outputs and do not account for all of the complex and dynamic San Francisco Bay processes or future conditions such as erosion, subsidence, future construction or shoreline protection upgrades, or other changes to San Francisco Bay or the region that may occur in response to sea level rise. More context about the maps and analyses, including a description of the data and methods used, are documented in the Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore Report (May 2016).



SAN MATEO COUNTY
Inundation Mapping

MHHW + 78" WATER LEVEL

SLR + STORM SURGE SCENARIOS LISTED BELOW COULD BE APPROXIMATED BY THE INUNDATION SHOWN ON THIS MAP.

36"SLR + 100-YEAR STORM SURGE
42"SLR + 50-YEAR STORM SURGE
48"SLR + 25-YEAR STORM SURGE
54"SLR + 10-YEAR STORM SURGE
60"SLR + 2-YEAR STORM SURGE
66"SLR + 1-YEAR STORM SURGE

Shoreline Overtopping Potential

0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet

No Overtopping

Sea Level Rise Inundation

0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet

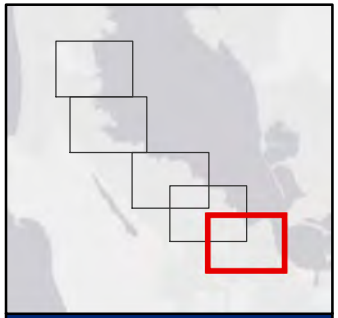
Disconnected Areas > 1 Acre

0 0.2 0.4 0.6 0.8 Miles
0 1,000 2,000 3,000 4,000 Feet

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

May, 2016



The inundation maps and the associated analyses provide a regional-scale illustration of inundation and coastal flooding due to specific sea level rise and storm surge scenarios, and are intended to improve sea level rise awareness and preparedness. The maps are not detailed to the parcel-scale and should not be used for navigation, permitting, regulatory, or other legal uses. Flooding due to sea level rise and storm surges is possible in areas outside of those predicted in these maps, and the maps do not guarantee the safety of an individual or structure. Nor do the maps model flooding from other sources, such as riverine or surface water flooding from rainfall-runoff events. The contributors and sponsors of this product do not assume liability for any injury, death, property damage, or other effects of flooding. The maps relied on a 1-meter digital elevation model created from LiDAR data collected in 2010 and additional survey data (where available). Although care was taken to capture all relevant topographic features and coastal structures that may impact coastal inundation, it is possible that structures may not be fully represented, especially those that are narrower than the 1-meter horizontal map scale. The maps are based on model outputs and do not account for all of the complex and dynamic San Francisco Bay processes or future conditions such as erosion, subsidence, future construction or shoreline protection upgrades, or other changes to San Francisco Bay or the region that may occur in response to sea level rise. More context about the maps and analyses, including a description of the data and methods used, are documented in the Sea Level Rise and Overtopping Analysis for San Mateo County's Bayshore Report (May 2016).

Legend

- Flood Gate
- Water Control Structure
- Reach 1, Option 1
- Reach 1, Option 2
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 1
SAFER Bay

Haven Industrial Area (From City of Menlo Park and Redwood City border to Marsh Road)

FIGURE 3

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Bedwell Bayfront Park

EXISTING GATE STRUCTURE

WATER CONTROL STRUCTURE

Marsh Rd

SECTION A

800'

EXISTING GATE STRUCTURE

Haven Ave

Pond

EXISTING CULVERT

JURISDICTIONAL WETLANDS

Pond S5

Pond R5

WATER CONTROL STRUCTURE

Pond R4

1,400'

SECTION B

WATER CONTROL STRUCTURE

Pond R3

1,160'

CHRYSLER PUMP STATION

EXISTING BAY FRONT CANAL

Bayfront Expy

Constitution Dr

Independence Dr

Chrysler Dr

Jefferson Dr

Chilco St

Scott Dr

Bayshore Fwy

Legend

- Water Control Structure
- Reach 2, Option 1
- Reach 2, Option 2 (dropped)
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 2
SAFER Bay

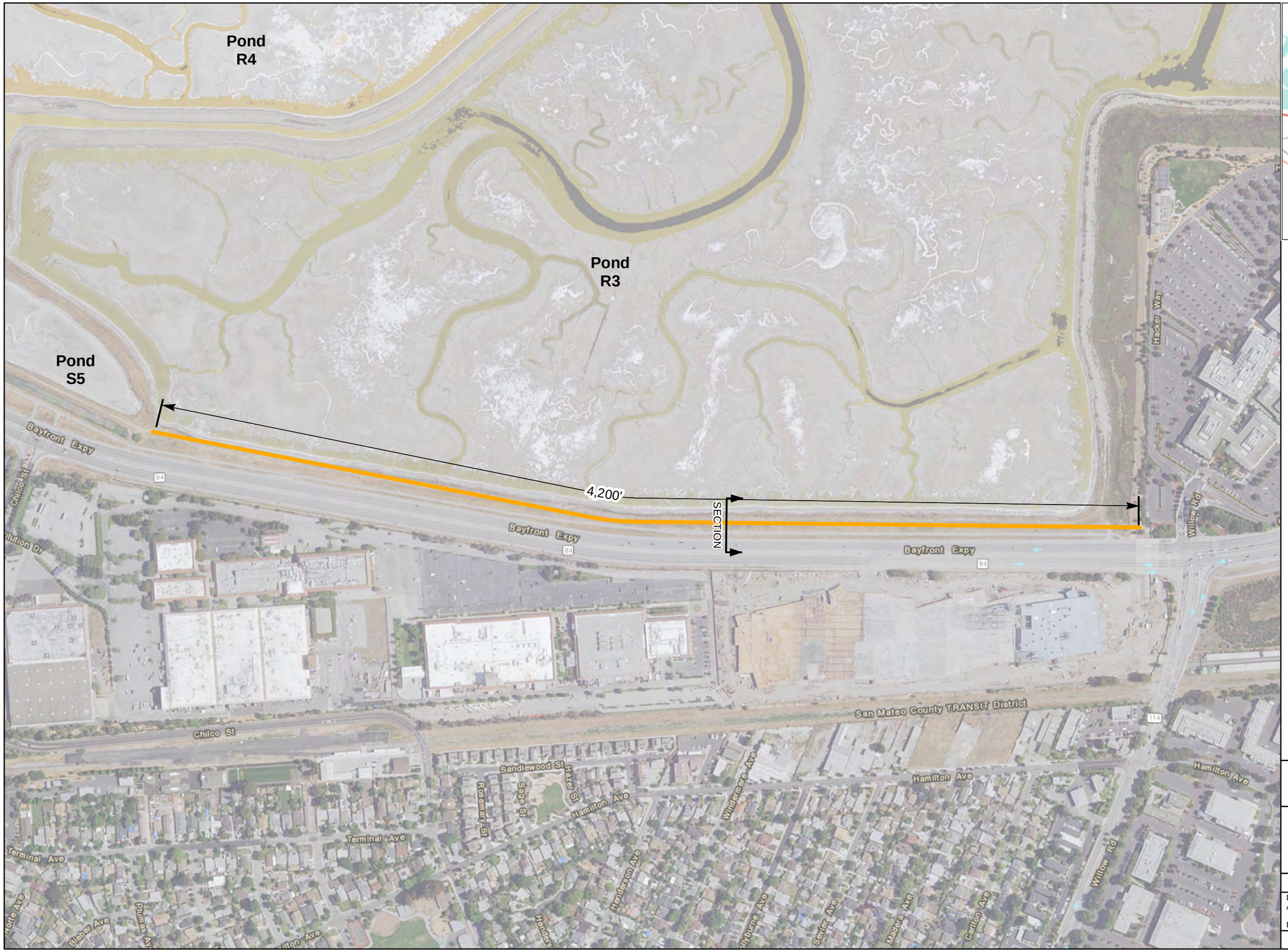
Bedwell Bayfront Park (From Marsh Road to SBSP Pond R3)

FIGURE 4

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



Legend

Reach 3, Option 1

Cross-Section

N

0 400 Feet

1 inch = 400 feet

Reach 3
SAFER Bay

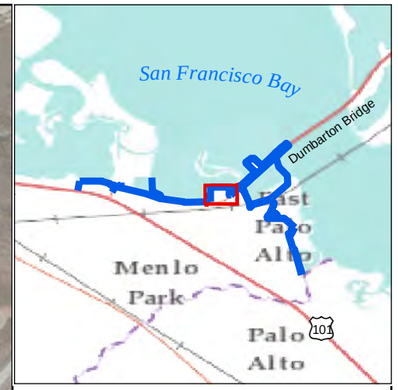
SBSP Ravenswood Pond R3
(From SBSP R3
to Facebook Campus)

FIGURE 5

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



Legend

- Reach 4, Option 1 and 2
- Cross-Section

N

0 200 Feet

1 inch = 200 feet

Reach 4
SAFER Bay

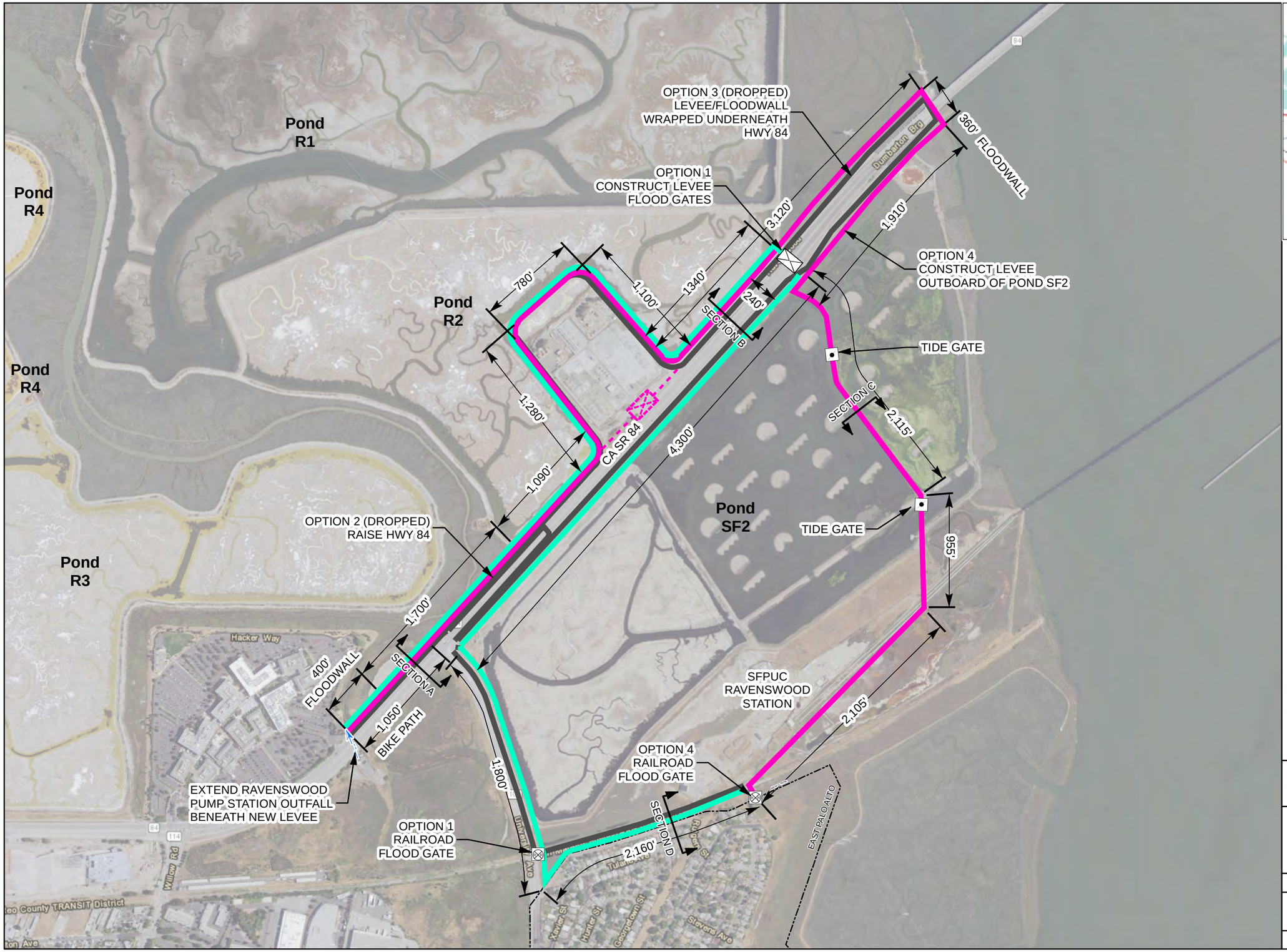
Facebook Campus
(From west edge of Facebook Campus to Ravenswood Pump Station Outfall)

FIGURE 6

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



Legend

- Ravenwood Pump Station Outfall
- Flood Gate
- Railroad Flood Gate
- Tide Gate
- Cross-Section
- Reach 5, Option 1
- Reach 5, Option 4
- Option to Protect Hwy 84 only
- Reach 5, Option 2 and 3 Reach 6, Option 2 (dropped)
- City Limits

Reach 6 options merged with Reach 5 options.

N

0 800 Feet

1 inch = 800 feet

Reach 5 SAFER Bay

Highway 84 (From Ravenswood Pump Station Outfall to Railroad Crossing)

FIGURE 7

Data Sources: Base Map-ESRI Maps and Data 2014; All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Pond SF2

WATER CONTROL STRUCTURE

MENLO PARK
EAST PALO ALTO

SECTION

1,470'

RAVENSWOOD OPEN SPACE PRESERVE

WATER CONTROL STRUCTURE

960'

OPTION 2 LEVEE

391 DEMETER STREET

WATER CONTROL STRUCTURE

600'

1,240'

COOLEY LANDING

University Ave
San Mateo County TRANSIT District
Tulane Ave
Rutgers St
Fordham St
Temple Ct
Stevens Ave
Xavier St
Hunter St
Georgetown St
Purdue Ave
Illinois St
Fordham St
Gonzaga St
Notre Dame Ave
Demeter St
Pulgas Ave
Tara St
Bay Rd
Emmett Way
Annapolis St
Baylor St
Michigan Ave
101
109

Legend

- Tide Gate
- Water Control Structure
- Reach 7, Option 1 (Dropped)
- Reach 7, Option 2
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 7
SAFER Bay

Existing Tidal Marshes (From end of Fordham Street to Bay Road)

FIGURE 8

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Legend

- Reach 8, Option 1 (Dropped)
- Reach 8, Option 2
- Cross-Section
- City Limits

N

0 400 Feet

1 inch = 400 feet

Reach 8
SAFER Bay

Laumeister Marsh
(From Bay Road
to Runnymede St)

FIGURE 9

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016

Legend

- Reach 9, Option 1
- Reach 9, Option 2 (Dropped)
- Cross-Section
- City Limits

N

0 200 Feet

1 inch = 400 feet

Reach 9
SAFER Bay

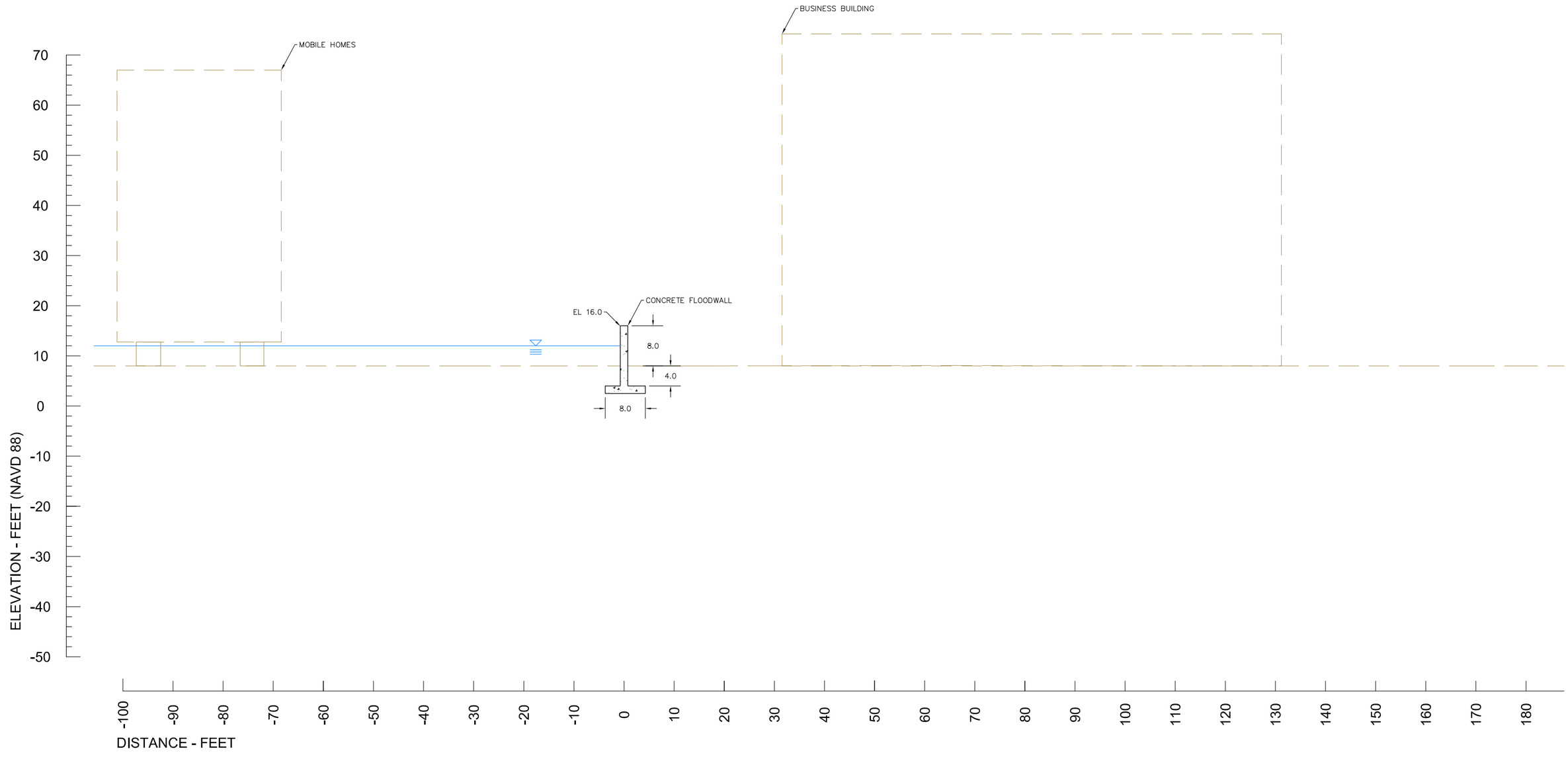
Faber Tract
(From Runnymede St to O'Connor St)

FIGURE 10

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

OCTOBER 2016



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 1 - SECTION A

SAFER BAY PROJECT

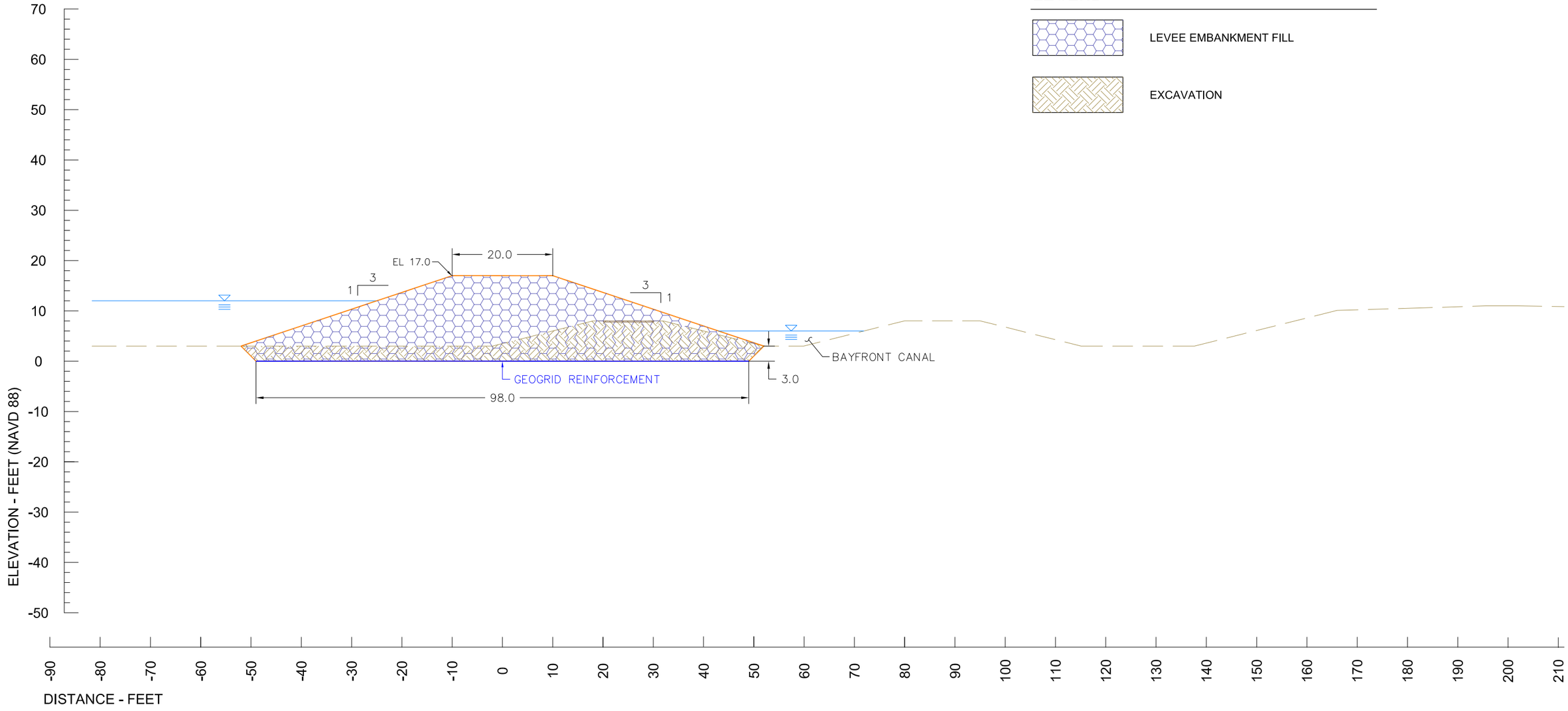
CALIFORNIA

Date
OCT 2016

Figure
11

LEGEND

- LEVEE EMBANKMENT FILL
- EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUTION SETTLEMENT

20 0 20 40
SCALE IN FEET

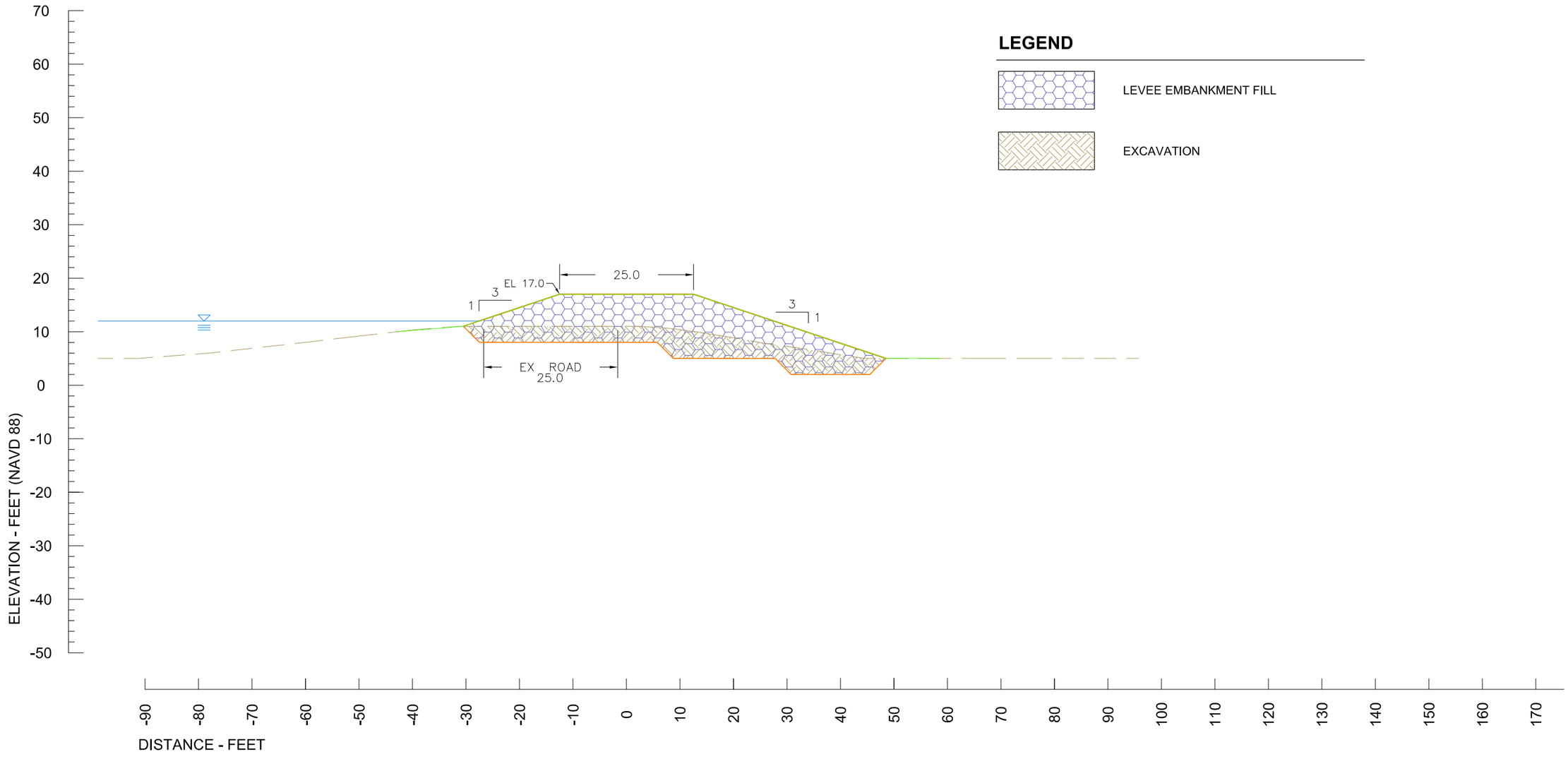
ANALYSIS CROSS-SECTION
REACH 1 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
12



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

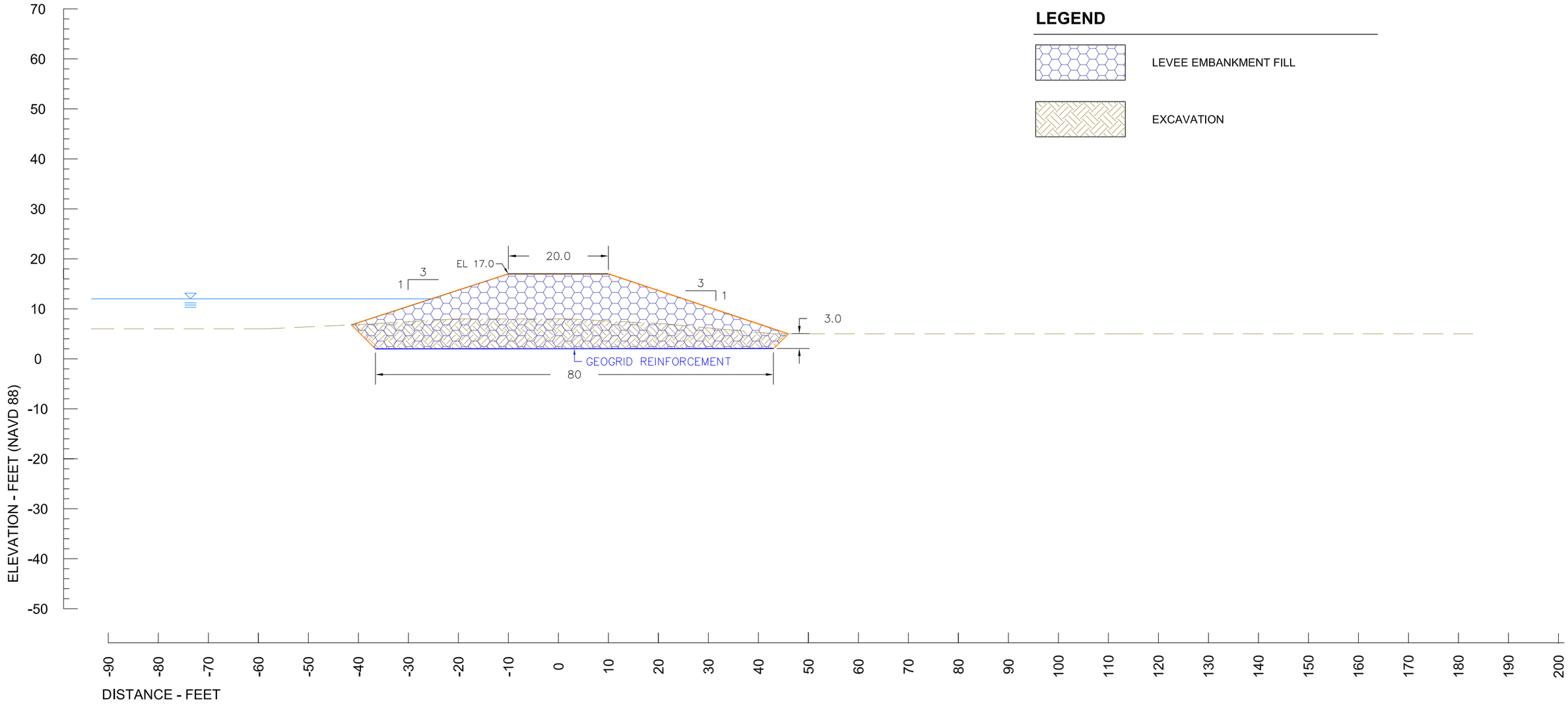
ANALYSIS CROSS-SECTION
REACH 2 - SECTION A

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
13



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 2 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

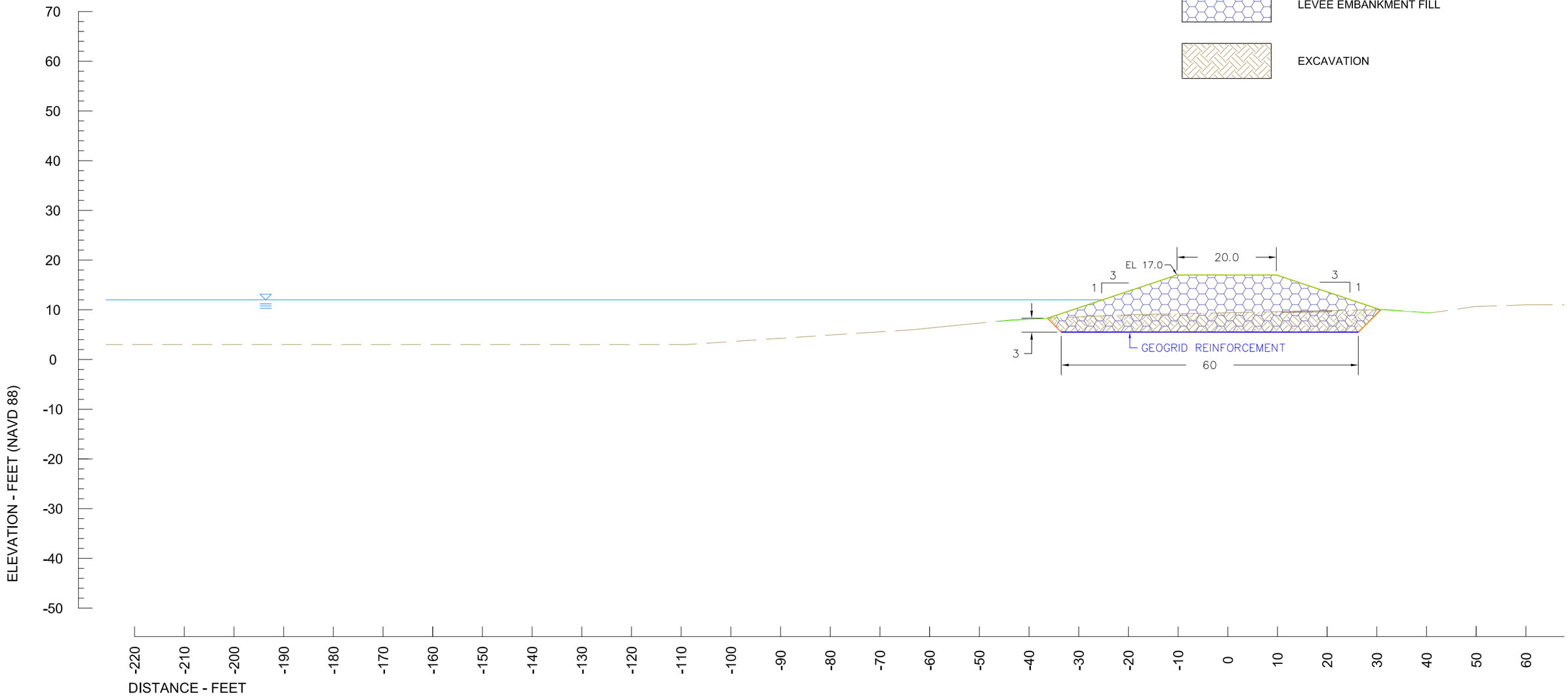
Date
OCT 2016

Figure
14

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 3 - OPTION 1

SAFER BAY PROJECT

CALIFORNIA

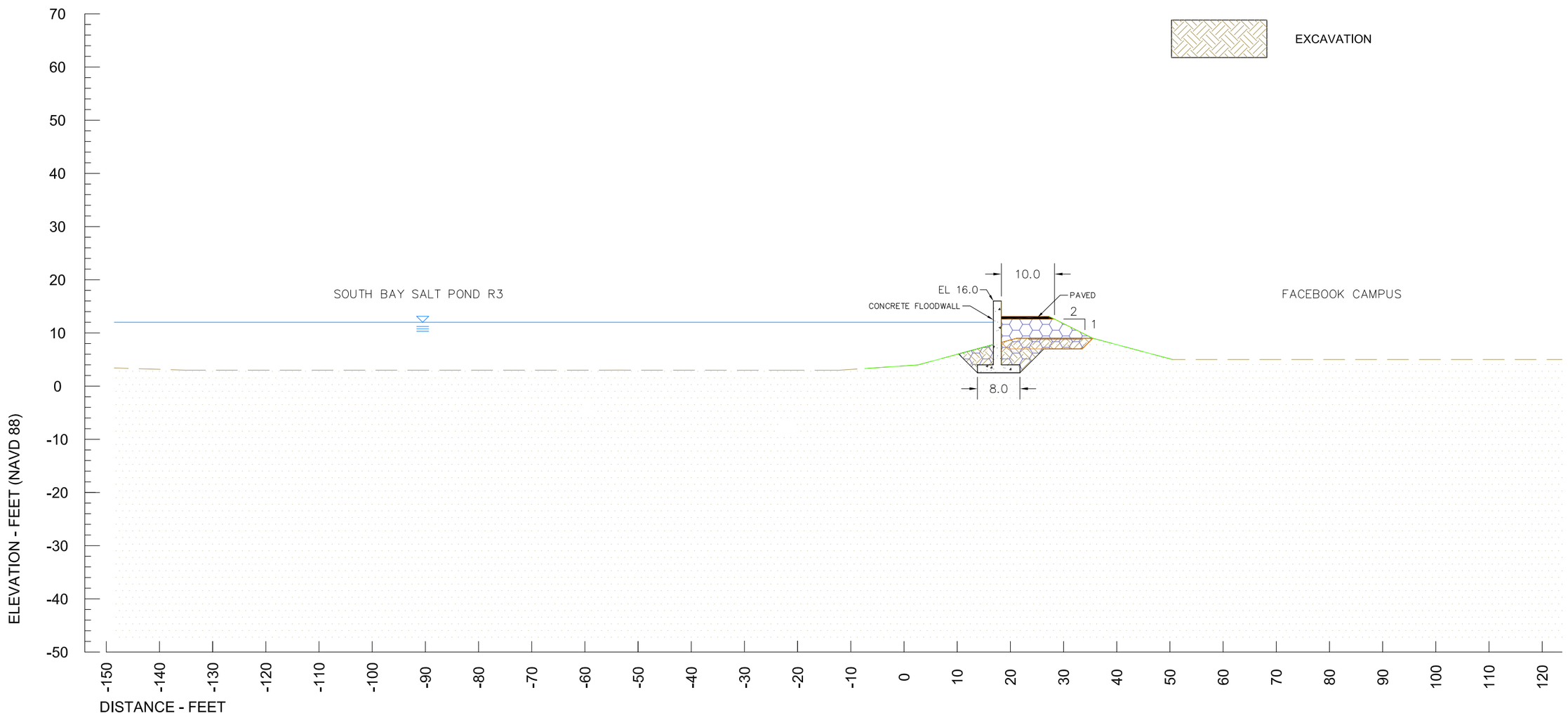
Date
OCT 2016

Figure
15

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 4 - OPTION 1

SAFER BAY PROJECT

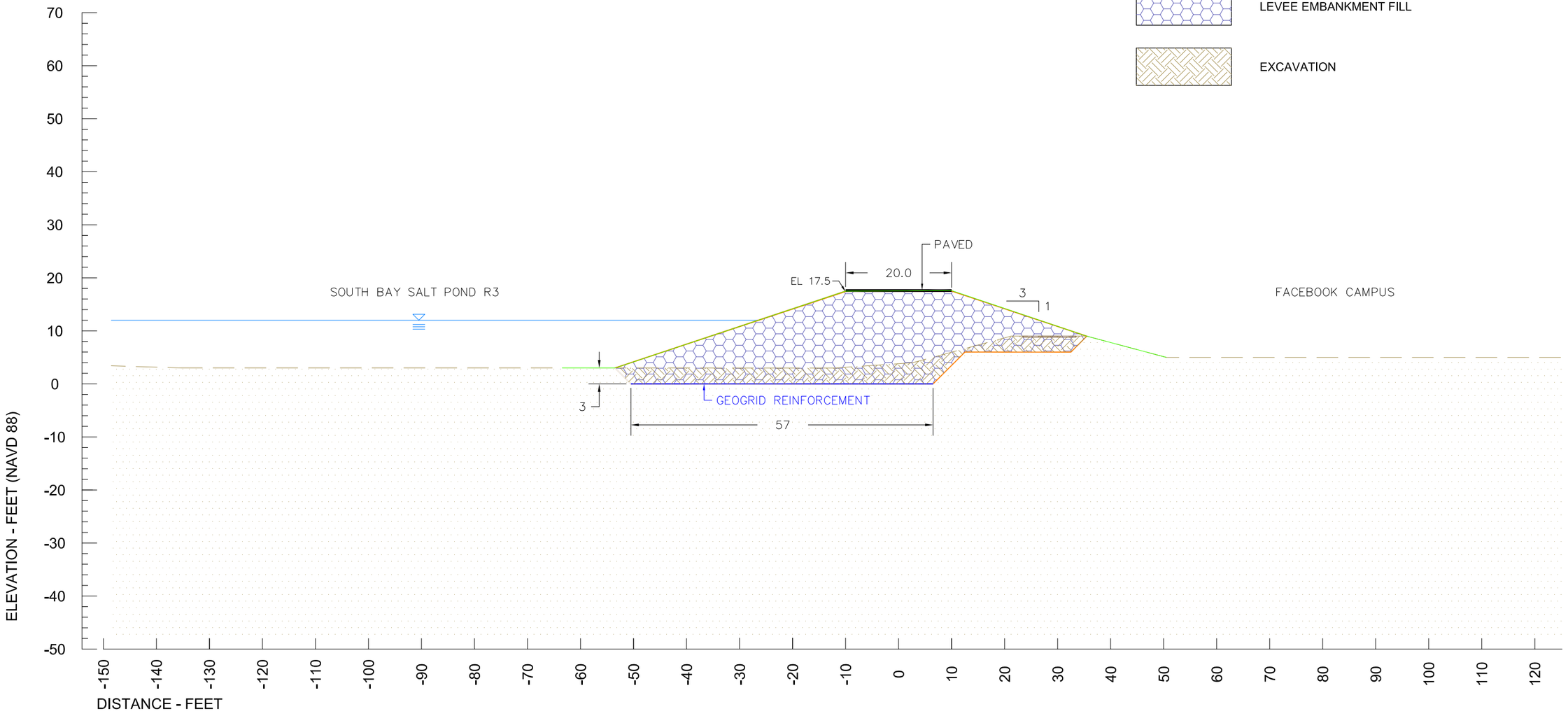
CALIFORNIA

Date
OCT 2016

Figure
16

LEGEND

- LEVEE EMBANKMENT FILL
- EXCAVATION



NOTES:
1. CROSS SECTION LOOKS NORTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1.5 FT OF POST CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 4 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

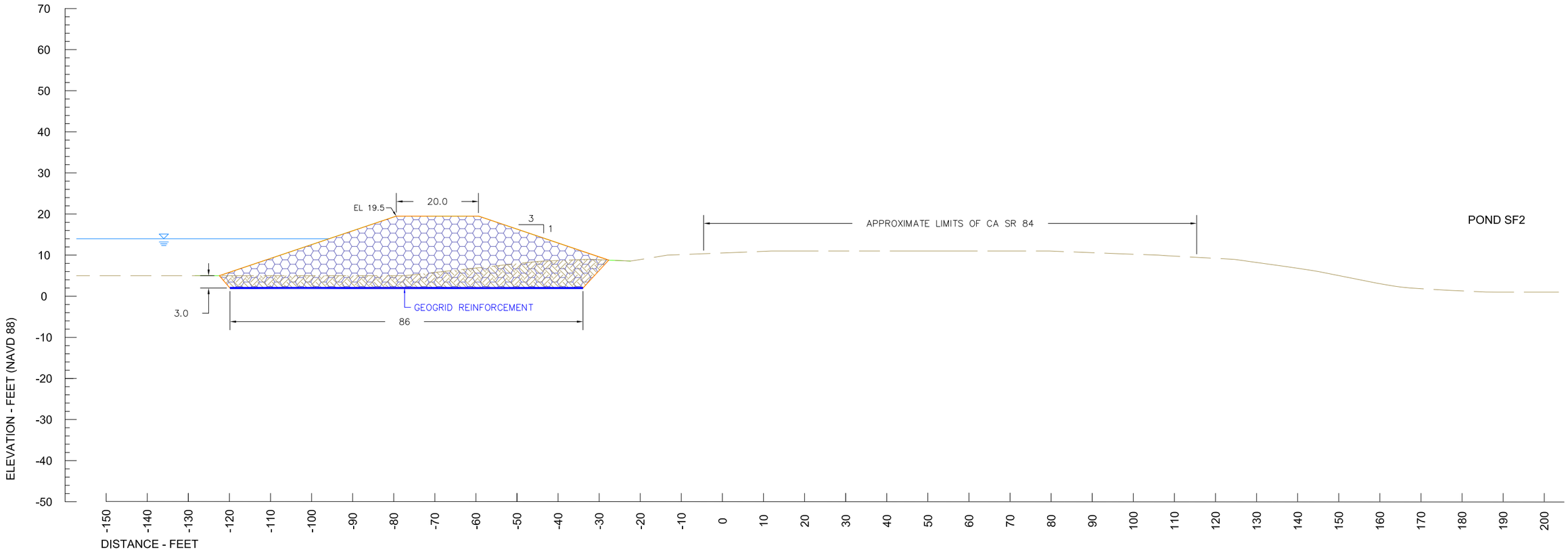
Date
OCT 2016

Figure
17

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 2.5 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 5 - SECTION A

SAFER BAY PROJECT

CALIFORNIA

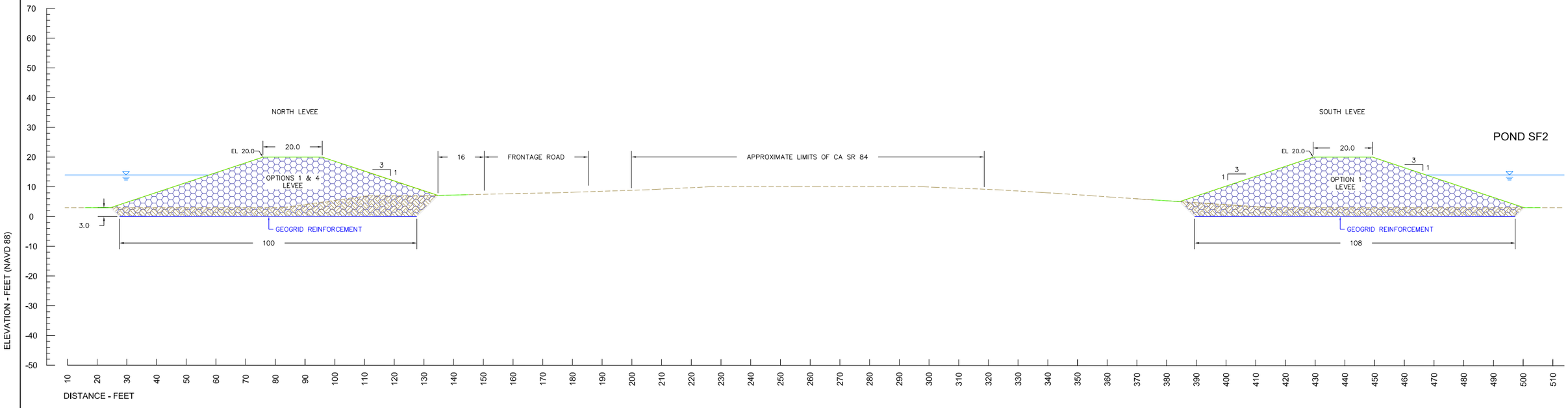
Date
OCT 2016

Figure
18

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 3 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 5 - SECTION B

SAFER BAY PROJECT

CALIFORNIA

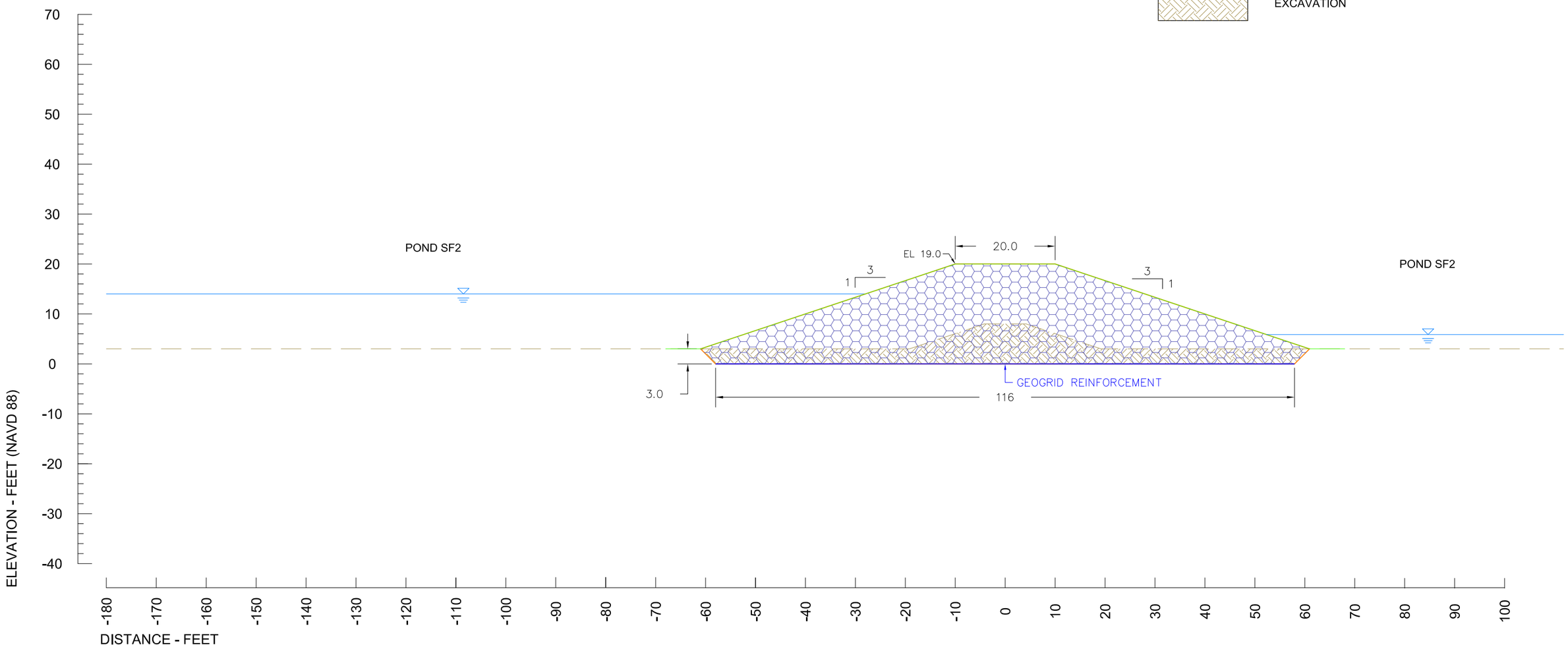
Date
OCT 2016

Figure
19

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 3 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 5 - SECTION C

SAFER BAY PROJECT

CALIFORNIA

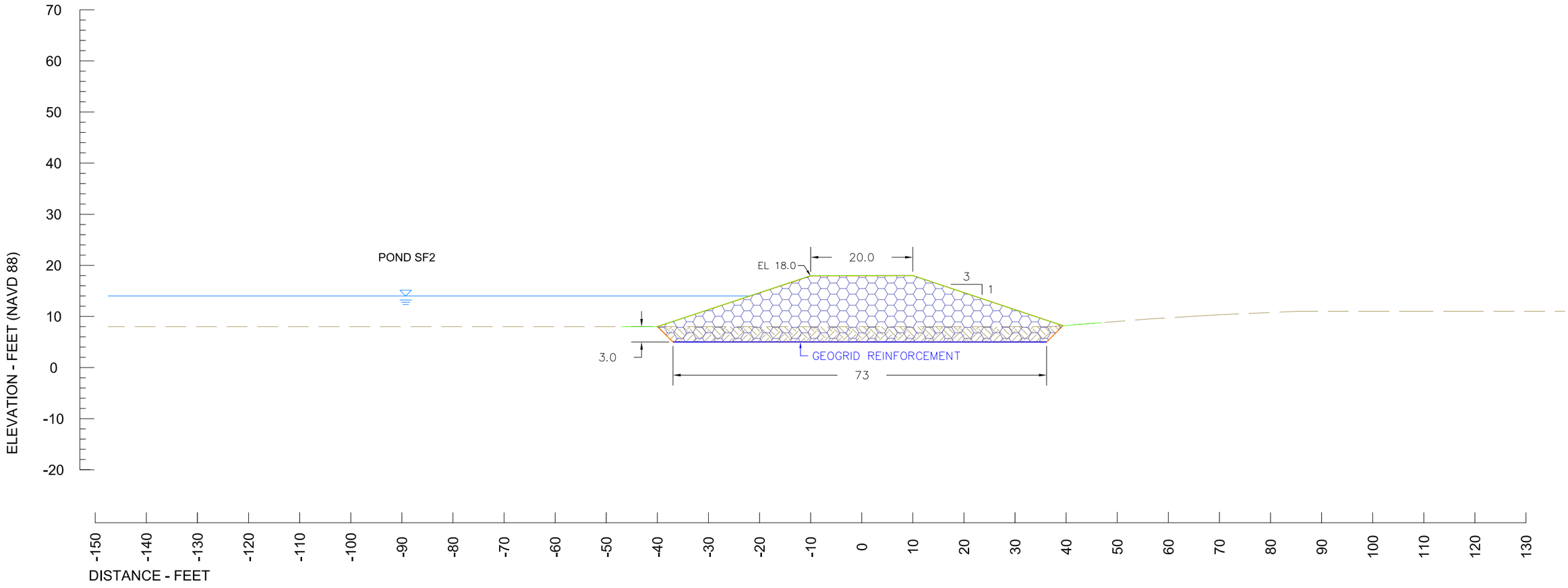
Date
OCT 2016

Figure
20

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS EASTWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 5 - SECTION D

SAFER BAY PROJECT

CALIFORNIA

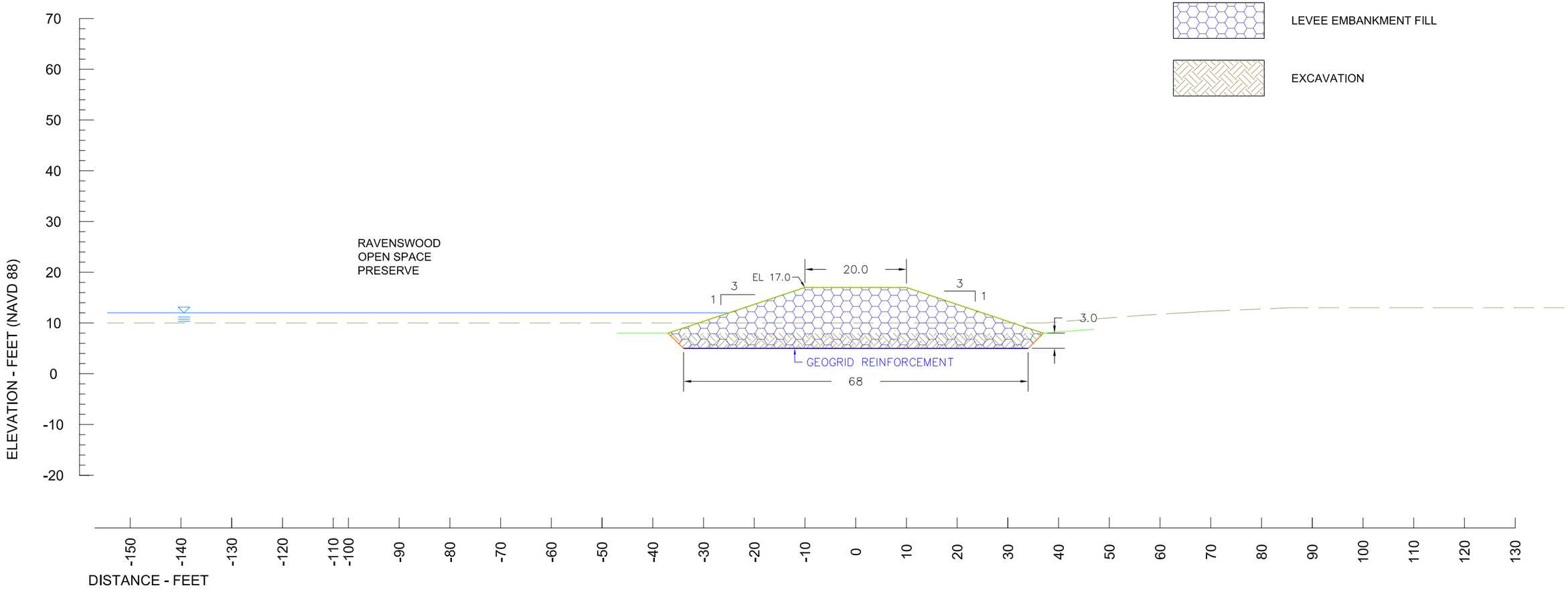
Date
OCT 2016

Figure
21

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 7 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

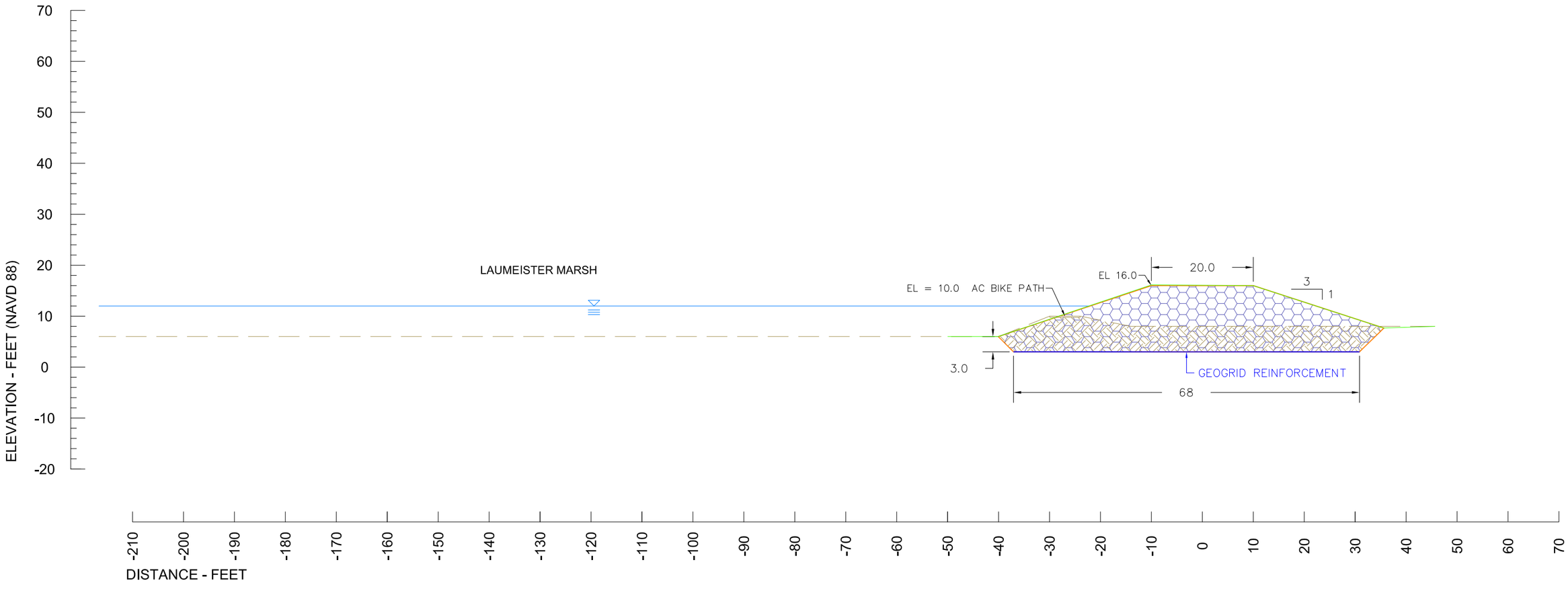
Date
OCT 2016

Figure
22

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 8 - OPTION 2

SAFER BAY PROJECT

CALIFORNIA

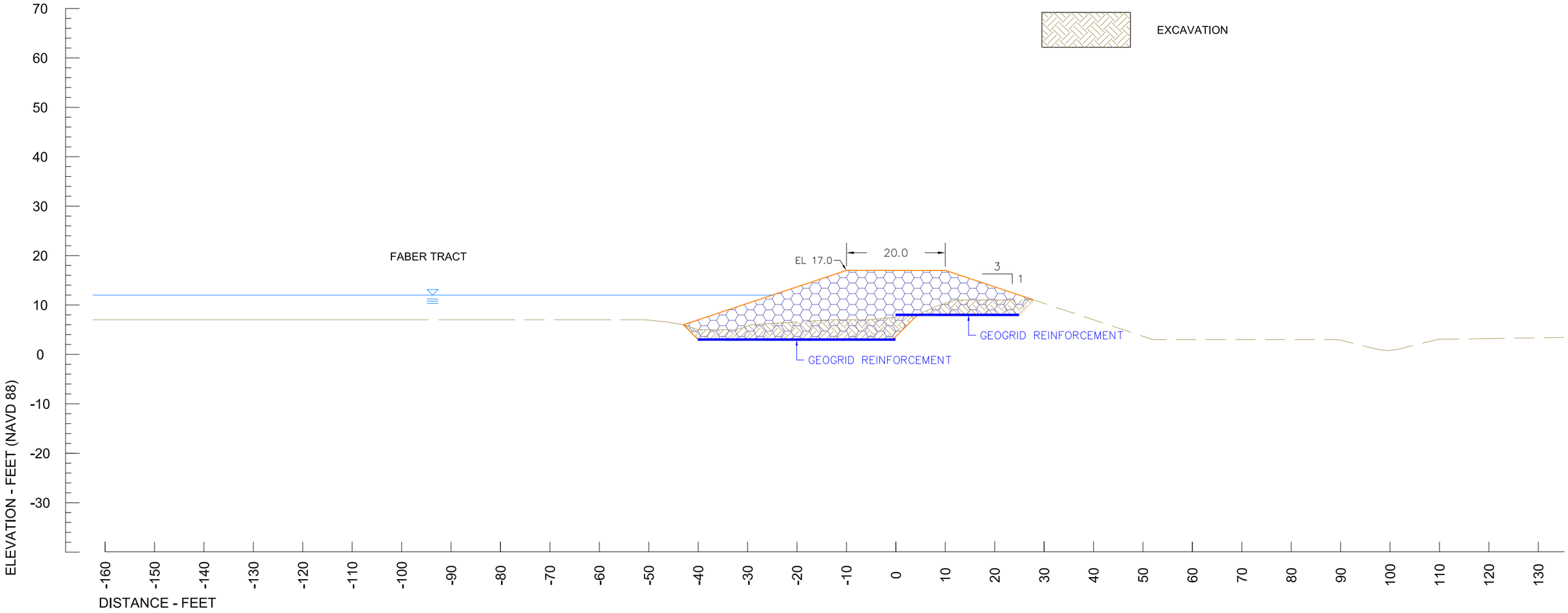
Date
OCT 2016

Figure
23

LEGEND

LEVEE EMBANKMENT FILL

EXCAVATION



NOTES:
1. CROSS SECTION LOOKS SOUTHWARD
2. ALL MEASUREMENTS ARE IN FEET
3. LEVEE HEIGHT ASSUMES 1 FT OF POST-CONSTRUCTION SETTLEMENT

20 0 20 40
SCALE IN FEET

ANALYSIS CROSS-SECTION
REACH 9 - OPTION 1

SAFER BAY PROJECT

CALIFORNIA

Date
OCT 2016

Figure
24

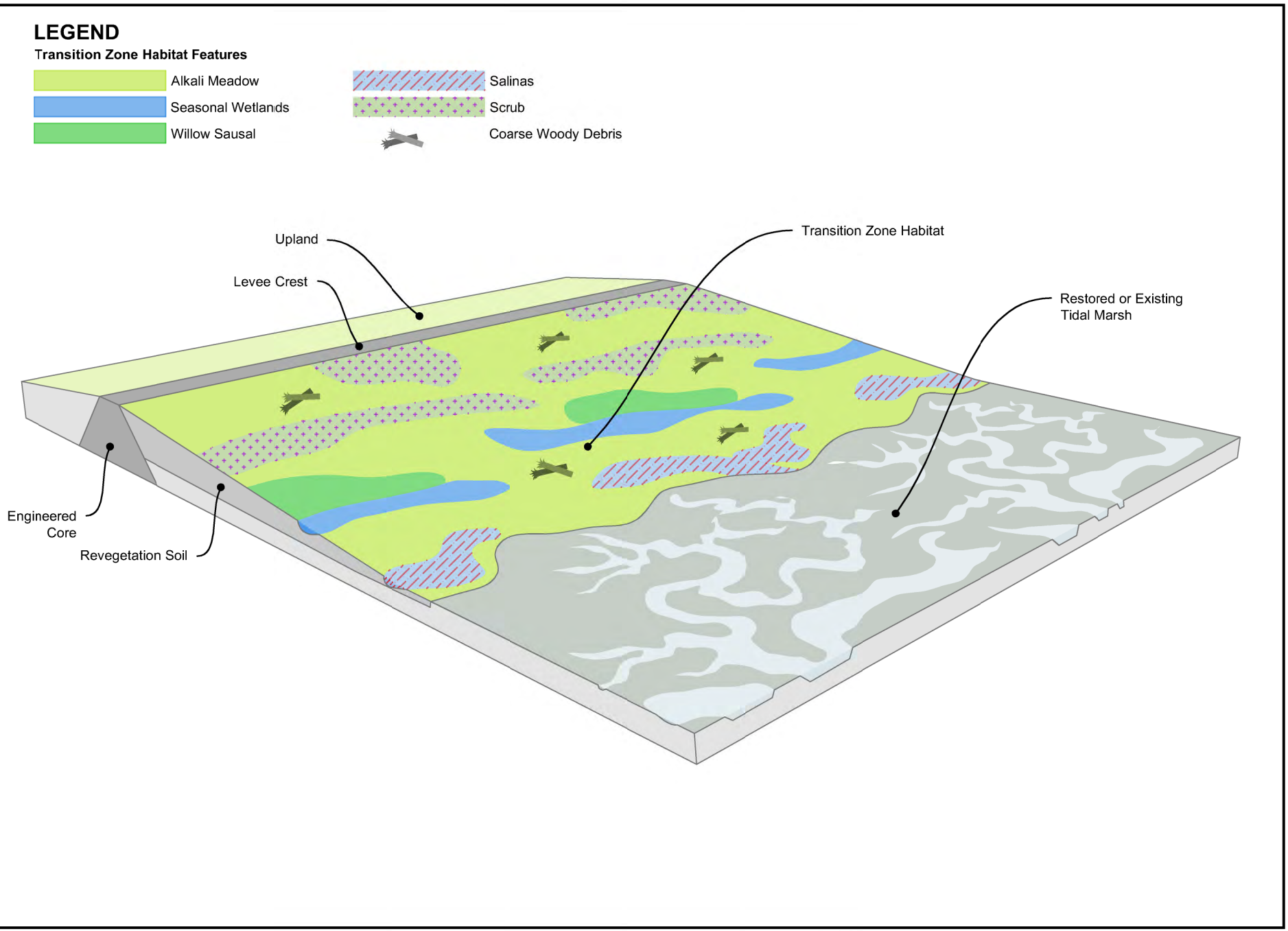


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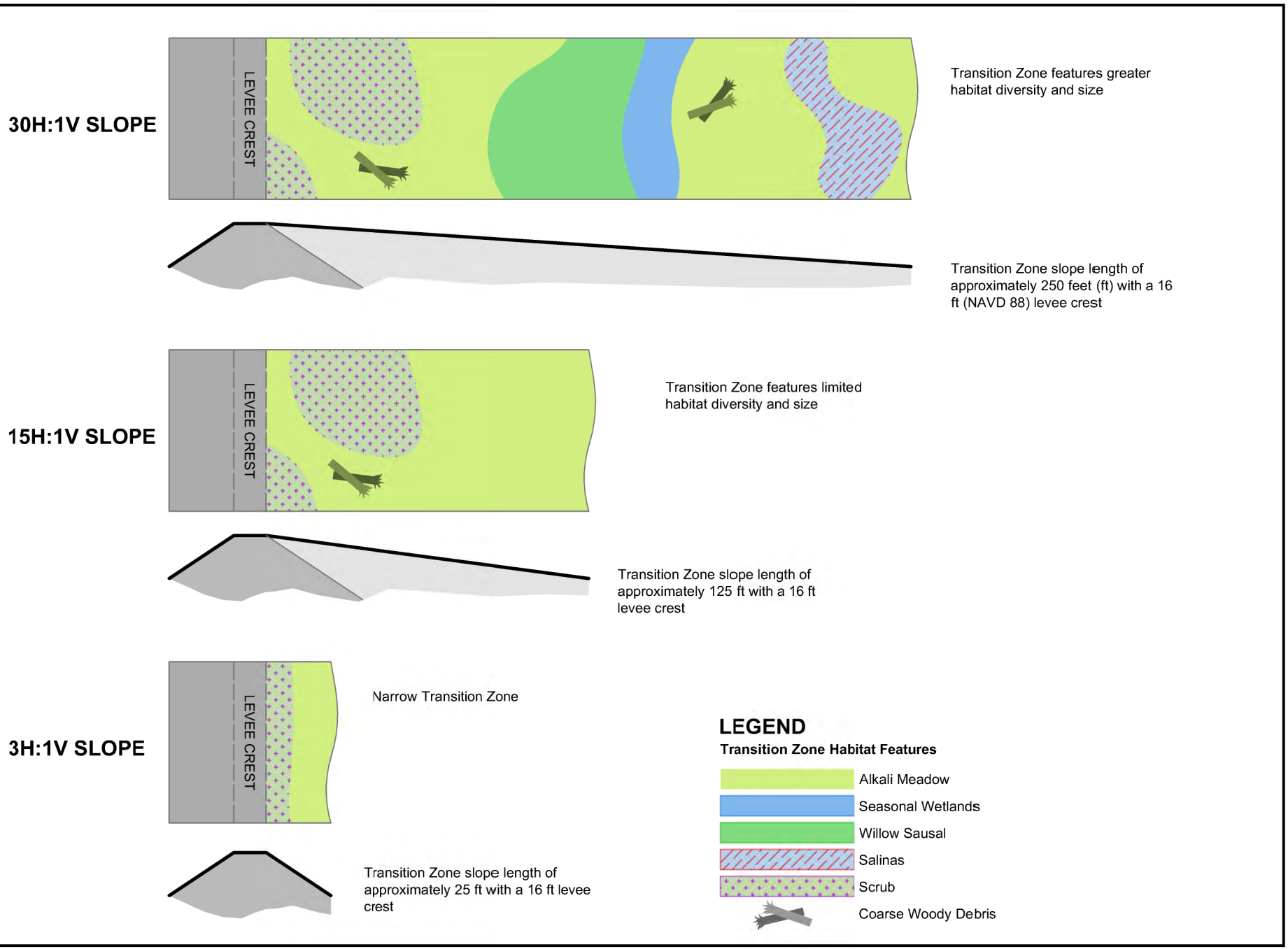
Figure 25: **Transition Zone Habitat Features**

SAFER Bay Project (3550-01)
August 2014



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Ecological Consultants

Figure 26: **Example Transition Zone Slopes and Habitat Diversity**
SAFER Bay Project (3550-01)
August 2014

N:\Projects3500\3550-01\Reports\Fig Xa Reach 5 - Option 1.mxd

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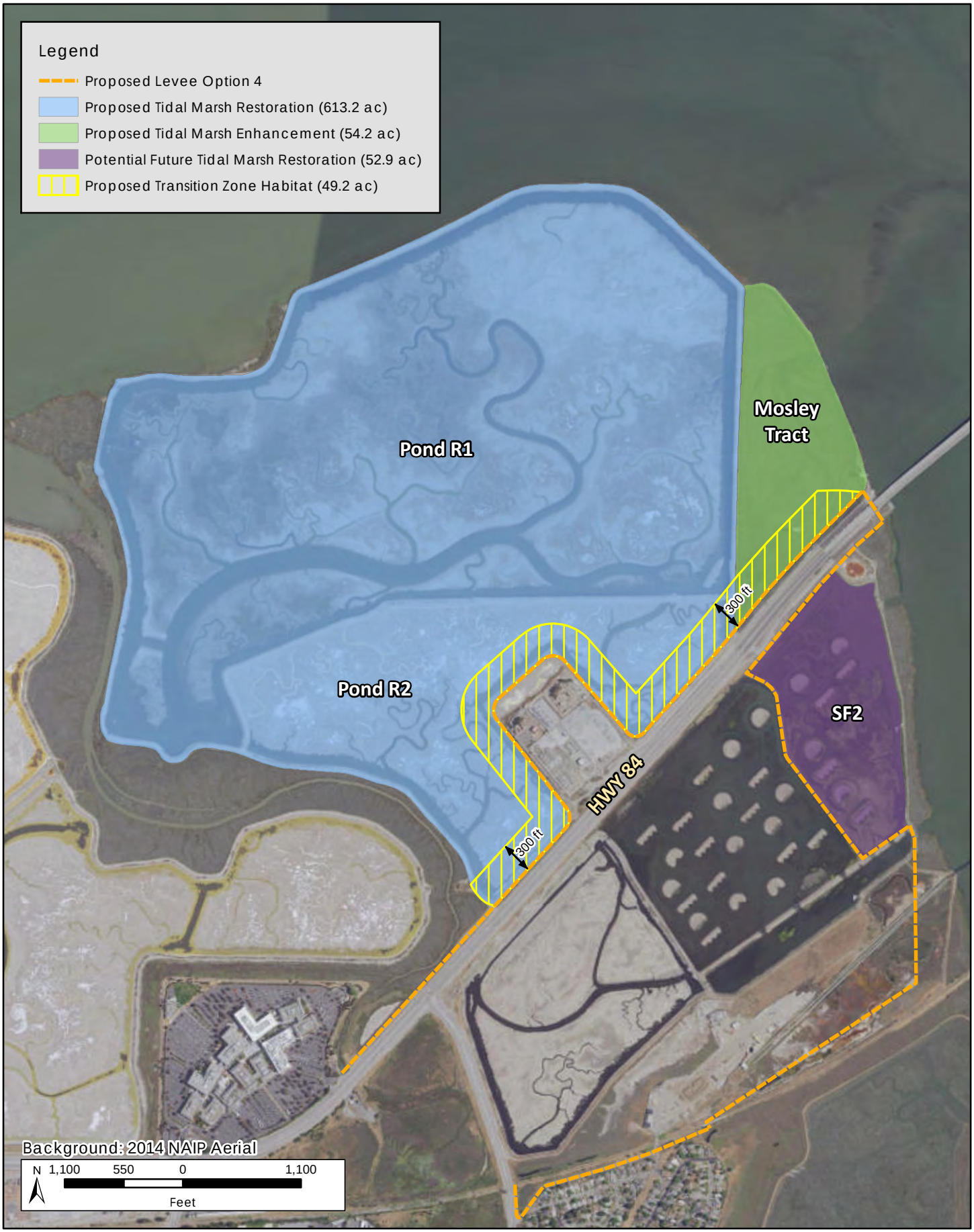
Figure **27 -** Low Cost Alternative - Proposed Tidal Marsh Restoration
Reach 5, Option 1
SAFER Bay Project (3550-01)
October 2016



N:\Projects3500\3550-01\Reports\Fig Xb Reach 5 - Option 4.mxd

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Figure **28 -** Restoration Alternative - Proposed Tidal Marsh Enhancement and Transition Zone Habitat Areas - Reach 5, Option 4

SAFER Bay Project (3550-01)

October 2016

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Figure **29 -** Recreation Alternative - Proposed Tidal Marsh Restoration and Transition Zone Habitat Areas - Reach 5, Option 4

SAFER Bay Project (3550-01)

October 2016

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Figure **30-** Restoration Alternative - Proposed Tidal Marsh Enhancement and Transition Zone Habitat Areas - Reach 7, 8 & 9

SAFER Bay Project (3550-01)

October 2016

Legend

- Reach 1, Option 1
- Reach 2, Option 1
- Reach 3, Option 1
- Reach 4, Option 2
- Reach 5, Option 1
- Reach 7, Option 2
- Reach 8, Option 2
- Reach 9, Option 1

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

Feasibility Report
Low Cost
Altenative

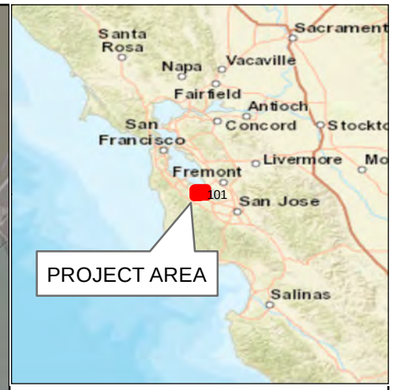
Figure 31

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

Dumbarton Bridge



Legend

- Reach 1, Option 2
- Reach 2, Option 1
- Reach 3, Option 1
- Reach 4, Option 2
- Reach 5, Option 4
- Reach 7, Option 2
- Reach 8, Option 2
- Reach 9, Option 1

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

Feasibility Report
Restoration
Altenative

Figure 32

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

Legend

- Reach 1, Option 2
- Reach 2, Option 1
- Reach 3, Option 1
- Reach 4, Option 2
- Reach 5, Option 4
- Reach 7, Option 2
- Reach 8, Option 2
- Reach 9, Option 1

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

Feasibility Report
Recreation
Altenative

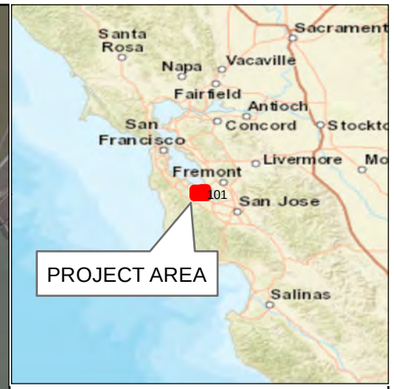
Figure 33

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

JUNE 2016

Dumbarton Bridge



Legend

- Reach 1, Option 1
- Reach 2, Option 1
- Reach 3, Option 1
- Reach 4, Option 2
- Reach 5, Option 4
- Reach 7, Option 2
- Reach 8, Option 2
- Reach 9, Option 1

N

0 2,000 Feet

1 inch = 2,000 feet

SAFER Bay

Feasibility Report
Optimized
Altenative

Figure 34

Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

SEPT 2016