

SAFER Bay Project

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

Public Draft Feasibility Report

(Task Order 2)

San Francisquito Creek Joint Powers Authority

Palo Alto, California

June 2019



SFCJPA.ORG

San Francisquito Creek
Joint Powers Authority

615 B Menlo Avenue
Menlo Park, CA 94025

This page intentionally left blank.

SAFER BAY

Palo Alto

Project No. 100222067

Task Order No. 2

PUBLIC DRAFT FEASIBILITY REPORT

June 2019

Prepared By:

Libby Mesbah, Lance Jones, Edwin Woo (HDR Engineering, Inc.)

Matt Brennan (ESA PWA)

Max Busnardo (H.T. Harvey & Associates)

Reviewed By:

Sergio Jimenez



2365 Iron Point Road, Suite 300
Folsom, CA 95630

This page intentionally left blank.

Table of Contents

Acronyms and Abbreviations.....	vii
1 Introduction	1
1.1 Background and Overview	1
1.2 Public Outreach.....	2
1.3 Purpose.....	3
1.4 Objectives	3
1.5 Constraints	4
1.6 Design Criteria	4
1.7 City of Palo Alto Framework.....	4
1.8 Report Organization	5
2 Technical Considerations and Requirements.....	6
2.1 Project Risk Assessment.....	6
2.2 Topographic Data.....	7
2.3 Coastal Hydraulics and Sea Level Rise	7
2.4 Interior Drainage	11
2.5 Low Impact Development.....	12
2.6 Geotechnical Considerations	13
2.7 Levees.....	14
2.8 Floodwalls	15
2.9 Gates.....	15
2.10 Penetrations	15
2.11 Pipes and Conduits	15
2.12 Utility Poles and Towers.....	16
2.13 Bay Trail	16
2.14 Maintenance.....	16
2.15 Real Estate.....	17
2.16 Borrow Locations	17
2.17 Disposal and Storage Area	17
2.18 Palo Alto Closed Landfill	17
2.19 Palo Alto Municipal Airport	18
2.20 Staging Area	18
2.21 Transition Zone Habitat.....	18

2.21.1	Ecological Importance of the Transition Zone.....	18
2.21.2	Importance of the Transition Zone to Levee Function and Sustainability.....	19
2.21.3	Horizontal Levee-Transition Zone Slope Alternatives and Trade-Offs.....	19
2.22	Tidal Marsh Restoration, Tidal Marsh Enhancement and Permitting	20
2.22.1	Integration with the South Bay Salt Pond Restoration Project.....	21
2.23	City of Palo Alto's Storm Drain Capital Improvement Projects	21
2.24	Other Local Structural Impacts.....	22
3	Development of Potential Options.....	25
3.1	Reach 10 – Palo Alto Airport and Water Treatment Plant.....	25
3.1.1	Option 1.....	25
3.1.2	Option 2.....	25
3.1.3	Option 3.....	26
3.1.4	Option 4.....	26
3.2	Reach 11 – Closed Landfill and Palo Alto Flood Basin	26
3.2.1	Option 1.....	26
3.2.2	Option 2.....	27
3.2.3	Option 3.....	28
4	Evaluation of Potential Options	29
4.1	Initial Screening and Evaluation of Options.....	29
4.2	Reach 10.....	30
4.2.1	Option 1 (Palo Alto Airport with Flood Gates and Levee Extension through southern Duck Pond) - Retained.....	30
4.2.2	Option 2 (Palo Alto Airport with Flood Gates) - Retained	30
4.2.3	Option 3 (Palo Alto Airport with Flood Gate) - Retained	31
4.2.4	4.2Option 4 (Palo Alto Airport with Levee around Duck Pond) - Dropped	31
4.3	Reach 11.....	31
4.3.1	Option 1 (Palo Alto Flood Basin) - Retained.....	31
4.3.2	Option 2 (Interior Creeks Levees/Floodwalls) - Retained	32
4.3.3	Option 3 (Partial Palo Alto Flood Basin) - Retained.....	32
5	Development of Alternatives	34
5.1	Alternative Formulation Rationale	34
5.2	Summary of Preliminary Alternatives	34
6	Evaluation of Alternatives.....	36
6.1	Evaluation Methodology.....	36

6.2 Consideration Scoring Metrics 37

7 Feasibility Level Cost Estimates 40

8 Alternative Ranking 43

8.1 Additional Evaluation Needed 43

8.1.1 Landfill Evaluation 43

8.1.2 Federal Aviation Administration (FAA) / Palo Alto Municipal Airport Coordination 43

8.1.3 Reach 11 – Detailed Hydraulic, Structural and Creek Accreditation Assessment 43

9 References..... 45

Tables

Table 1. Preliminary Minimum Design Elevations for Reaches 10 and 11	10
Table 2. Preliminary Maximum Design Elevations for Reaches 10 and 11 dependent upon future outboard conditions	11
Table 3. Proposed City of Palo Alto’s Capital Improvement Projects	21
Table 4. Summary of Preliminary Alternative Reach Options.....	34
Table 5. Feasibility Evaluation Scoring Matrix and Calculation Methodology.....	36
Table 6. Feasibility Evaluation Factors and Consideration Scoring Metrics	39
Table 7. Feasibility Level Cost Estimates per Alternative.....	40
Table 8. Feasibility Evaluation Factors and Consideration Scoring Metrics	44

Figures

Overall

- Figure 1 SFCJPA SAFER Bay Proposed Reach Alignments
- Figure 2 Feasibility Report Project Reaches and Options
- Figure 3 Preliminary FEMA Flood Insurance Rate Map Floodplains, dated July 8, 2015

Plan Views

- Figure 4 Alignment Reach and Option From San Francisquito Creek to City of Mountain View

Typical Cross Sections

- Figure 4-1 Reach 10 – Analysis Cross Section G8
- Figure 4-2 Reach 10 – Analysis Cross Section G9
- Figure 4-3 Reach 11 – Analysis Cross Section G10
- Figure 4-4 Reach 11 – Analysis Cross Section G11
- Figure 4-5 Reach 11 – Analysis Cross Section G12
- Figure 4-6 Reach 11 – Analysis Cross Section G13
- Figure 4-7 Reach 11 – Analysis Cross Section G14
- Figure 4-8 Reach 11 – Analysis Cross Section G15
- Figure 4-9 Reach 11 – Analysis Cross Section G16
- Figure 4-10 Reach 11 – Analysis Cross Section G17A
- Figure 4-10 Reach 11 – Analysis Cross Section G17B
- Figure 4-12 Reach 11 – Analysis Cross Section G18

Environmental

- Figure 5 Transitional Zone Habitat Features
- Figure 6 Example Transition Zone Slopes and Habitat Diversity

Alternatives

Figure 7 Low Cost Alternative

Figure 8 Restoration Alternative

Figure 9 Recreation Alternative

Figure 10 Proposed Tidal Marsh Restoration and Enhancement – Low Cost Alternative

Figure 11 Proposed Tidal Marsh Restoration and Enhancement – Restoration Alternative

Figure 12 Proposed Tidal Marsh Restoration and Enhancement – Recreation Alternative

Appendices

Appendix A Interior Drainage Assessment for the SAFER Bay Reach 11, May 2018

Appendix B Geotechnical Report for the Feasibility Phase, July 2016

Appendix C Individual Reach Feasibility Evaluation Factors and Consideration Scoring Metrics

Appendix D Individual Reach Feasibility Level Cost Estimates

This page intentionally left blank.

Acronyms and Abbreviations

Alternative	A combination of reach options that satisfies project objectives in all reaches.
BCDC	Bay Conservation and Development Commission
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
Flood Basin	Palo Alto Flood Basin
H:V	Ratio of Horizontal to Vertical
MHHW	Mean Higher High Water
NAVD88	North American Vertical Datum of 1988
O&M	Operations and Maintenance
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.
Reach	The project area is broken into multiple alignment segments individually referred to as a reach with similar conditions. Alignment options are proposed for each reach.
ROW	Right-Of-Way
RWQCP	Regional Water Quality Control Plant
SAFER Bay	Strategy to Advance Flood Protection, Ecosystems and Recreation along the San Francisco Bay
SBSRP	South Bay Salt Ponds Restoration Project
SCVWD	Santa Clara Valley Water District
SFCJPA	San Francisco Creek Joint Powers Authority
SFHA	Special Flood Hazard Area
SLR	Sea Level Rise
SWL	Still Water Level
USACE	United States Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

This page intentionally left blank.

1 Introduction

1.1 Background and Overview

The 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 multi-jurisdictional projects that reduce flooding, enhance ecosystems and recreational opportunities, and connect our communities.

As part of the SFCJPA's long-term plan to protect people, property, and public infrastructure within the cities of East Palo Alto, Menlo Park, and Palo Alto, this report develops an initial approach to address sea level rise and inundation along Palo Alto's shoreline. This plan, the Strategy to Advance Flood protection, Ecosystems and Recreation along the San Francisco Bay (SAFER Bay) Project, is designed to protect against a sea level up to ten feet above today's daily high tide. This is equal to a 100-year (1%) water and wave event with three feet of Sea Level Rise (SLR) and a margin of safety known as freeboard. The SAFER Bay Project is a collaboration of federal, state, local and private entities. It focuses on structural and natural approaches to protecting against SLR; other strategies, such as managed retreat, are beyond the scope of this evaluation.

A Public Draft Feasibility Report for East Palo Alto and Menlo Park was issued in October 2016 and is available at www.sfcjpa.org. Comments on it were received from the Bay Development and Conservation Commission (BCDC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB), and this Public Draft SAFER Bay Report for the City of Palo Alto incorporates many of their suggestions, as well as comments from City staff.

Separate SAFER Bay Feasibility Reports were developed for each side of the Santa Clara –San Mateo County line because of differing timing and funding mechanisms for the project north and south of the San Francisquito Creek, which is the County boundary. Additionally, design feature complexities in the Palo Alto area required additional time to work through critical planning and design decisions that impacted the evaluation of possible alternatives.

The SAFER Bay Project ties directly to the SFCJPA's recently completed San Francisquito Creek Flood Protection, Ecosystem Restoration and Recreation Project in the tidal portion of the creek from S.F. Bay through Highway 101. Considered collectively, the SFCJPA projects, shown in Figure 1, provide a comprehensive multi-benefit plan for the shoreline for several decades. In addition to aligning with the SFCJPA's adjoining creek project and SAFER Bay shoreline project in San Mateo County, Palo Alto's SAFER Bay alternatives also may align with or contribute to coastal protection for the neighboring City of Mountain View. The SAFER Bay Project footprint is shown on Figure 2.

The shoreline of Palo Alto was historically a tidal marsh and is prone to flooding. Development in the high risk flood area requires flood insurance coverage in accordance with the Flood Disaster Protection Act of 1973, as amended by the National Flood Insurance Reform Act of 1994. Implementation of SAFER Bay is expected to remove properties from Federal Emergency Management Agency's (FEMA) tidal floodplain; see Figure 3 for an overview of the latest FEMA Flood Insurance Rate Map¹ floodplains within the project area (dated July 8, 2015).

¹ Preliminary Flood Insurance Rate Maps were released on July 8, 2015 and may be subject to change.

Seamless coastal flood protection along Palo Alto's coastline may also require adequate flood protection provided by interior riverine levees. The Barron, Adobe and Matadero Creeks currently flow through Palo Alto and discharge into the Palo Alto Flood Basin. Portions of these riverine levees currently do not provide flood protection from a projected 100-year event (that has a 1% annual chance of occurring in any given year). Therefore, removal of all properties from FEMA high risk area may not be fully achievable due to the many existing riverine levees in Palo Alto that are not accredited by FEMA. This is further discussed in Sections 3.2 and 4.3 when options and alternatives are evaluated and compared.

South Bay Salt Pond restoration efforts to breach outer Bay front levees to reconnect the restored marsh area to the estuary can't occur until flood protection is upgraded². The SAFER Bay Project would allow for significant salt pond restoration activities. For this reason, the South Bay Salt Ponds Restoration Project and the Don Edwards National Wildlife Refuge have written in support of the SAFER Bay Project. The SAFER Bay Project will also allow for improved connectivity between communities through enhancements to the recreational Bay Trail and other trails.

1.2 Public Outreach

Many agencies provided valuable input and/or funding for the SAFER Bay Project, including:

- City of Palo Alto
 - Public Works
 - Palo Alto Airport
 - Palo Alto Landfill
 - Utilities/Regional Water Quality Control Plant (RWQCP)
 - Office of Sustainability
 - Community Services Department
- City of East Palo Alto
- City of Menlo Park
- City of Mountain View
- City of Redwood City
- Federal Aviation Administration (FAA)
- U.S. Fish and Wildlife Service (USFWS)
- California Department of Fish and Wildlife (CDFW)
- South Bay Salt Ponds Restoration Project (SBSRP)
- California Department of Transportation (Caltrans)
- Midpeninsula Regional Open Space District
- California Coastal Conservancy
- Bay Conservation and Development Commission (BCDC)
- Facebook
- Pacific Gas & Electric
- Resilient by Design Challenge

² While the salt pond levees are not accredited by FEMA, they reduce the risk of flooding in the study area by muting tidal effects. Activities to restore habitat through breaching these pond levees will require new flood risk reduction features to mitigate increased tidal flood risk from levee breaching.

The SFCJPA has discussed the overall SAFER Bay Project with members of the public for the past several years, but recognizes that additional public outreach is needed. To that end, the SFCJPA will obtain stakeholder input through:

1. Continued public meetings with League of Woman's Voters, local neighborhood associations, and conferences. The SFCJPA anticipates that the City of Palo Alto will lead the public engagement effort for its residents.
2. Specific one-on-one meetings with key stakeholders, such as South Bay Salt Ponds Restoration Project, BCDC, Regional Water Quality Control Board, California Department of Fish and Wildlife, National Marine Fisheries Service and US Fish and Wildlife Service.

1.3 Purpose

The purpose of this Public Draft Feasibility Report is to identify potential strategies for sea level rise (SLR) adaptation flood protection, and other benefits along the San Francisco Bay shoreline of cities within the SFCJPA. This report provides a preliminary evaluation of potential alternatives based constraints and objectives to support the selection of a preferred alternative that can move forward with analysis under the California Environmental Quality Act (CEQA).

The Palo Alto SAFER Bay Project is divided into two reaches (designated as Reach 10 and Reach 11)³ as shown on Figure 1. Within each reach; one or more potential options to achieve the flood protection objective described below are presented, as shown on Figure 2. Typical cross sections for each reach are illustrated on Figures 4-1 through 4-12. 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.

1.4 Objectives

The following SAFER Bay Project objectives, which take into account the substantial constraints of working in an area between developed or developable land, public infrastructure, and protected shoreline habitat, serve as the basis to formulate and evaluate alternatives:

- Reduce the risk of coastal flooding against a sea level up to ten feet above today's daily high tide, and allow for increased protection later, to support the community's desire to be removed from the current FEMA floodplain and protect against SLR.
- Enable adaptation to our changing climate by restoring and utilizing tidal marsh areas for flood protection in a way that sustains that habitat in concert with other restoration efforts.
- Expand opportunities for recreation and community connectivity in collaboration with the regional Bay Trail Program and local efforts to enhance trails.
- Minimize future maintenance requirements.
- Create partnerships with agencies, organizations and businesses to share in the project's benefits, impacts and costs.

³ Reaches 1 -9 are cover the coastline of Menlo Park and East Palo Alto and are described in the October 2016 *Public Draft Feasibility Report, SAFER Bay Project East Palo Alto and Menlo Park*.

- Not rely on actions by other entities to achieve removal from the FEMA floodplain.

The SAFER Bay Project integrates with other efforts that promote adaption for SLR in the context of our developed shoreline areas. SAFER Bay's objectives align with objectives in *State of California Sea Level Rise Guidance (2018 Update)*, *Safeguarding California Plan: 2018 Update California's Climate Adaptation Strategy*, as well as local objectives described in San Francisco Estuary Partnership's 2016 *Comprehensive Conservation and Management Plan*. The Resilient by Design Challenge for the South Bay Sponge Conceptual Design was considered in this evaluation.

1.5 Constraints

The project constraints identify assets that any climate change adaption and flood protection action should not impact without recommending ways to minimize, maintain, or improve the existing condition. Project constraints help define boundaries for implementation and can affect the project's ability to meet its objectives.

The currently identified project constraints include:

- Wetlands
- Habitat for endangered species
- Existing transportation infrastructure (roads and airport)
- Interior drainage
- Existing utility infrastructure
- Public or private property used for other purposes within and adjacent to the levee alignment
- Existing levees at Barron, Adobe, and Matadero Creeks do not provide 1% annual chance flood protection and are not currently considered part of the SAFER Bay Project at this time
- The SAFER Bay Project is working with entities planning shoreline work south Palo Alto, but may not rely on those projects to meet the SAFER Bay Project objectives.

1.6 Design Criteria

The project design criteria identify the specific technical requirements of the study (feasibility phase). The project design criteria will protect against a sea level up to ten feet above today's daily high tide, which is equal to:

- 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 freeboard to account for future SLR.

The process and selection of SAFER Bay Project design criteria are provided in Section 2.0.

1.7 City of Palo Alto Framework

In November 2016, the City of Palo Alto adopted *Sustainability and Climate Action Plan 2016 Framework*. This framework is for facility-specific and programmatic issues responding to SLR using six guiding principles:

- (1) For the City of Palo Alto capital projects, use sea level rise assumptions consistent with the State of California adopted guidance, with a minimum of 55 inches based on Bay Conservation Development Corporation (BCDC, a State agency) numbers.

- (2) Continue to monitor latest climate change and sea level rise science and adapt as needed if sea level rise occurs at a more rapid pace and/or higher levels than projected
- (3) Ensure engineering solutions are adaptable to changing climate predictions
- (4) Consider tools to protect, adapt and retreat as appropriate and cost-effective
- (5) For areas that are to be protected, consider additional tools in case severity and speed of sea level rise increase, such as designing structure that can get wet and locating sensitive equipment higher in a building
- (6) Continue to collaborate with regional planning efforts on studies of climate impacts and strategies to respond to sea level rise

Reference: <https://www.cityofpaloalto.org/civicax/filebank/documents/64814>

The design criteria and objectives of this project related to sea level rise meet or exceed the worst-case scenarios from current State of California and City of Palo Alto guidance for the life of the SAFER Bay project. Furthermore, the adaptive capacity of levees is such that additional raising can be accomplished in the future if indicated based on the pace of SLR, a topic that will be presented during the public engagement process.

1.8 Report Organization

The remainder of this report is organized as follows:

- Section 2 provides a summary of the project flood risk assessment, 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 Project Risk Assessment

Palo Alto's existing Bayfront flood protection system is comprised of a levee network between San Francisquito Creek and the Mountain View border. These levees do not meet current FEMA standards for height or construction quality. As a result, there are approximately 2,700 Palo Alto properties in a FEMA designated Special Flood Hazard Area that are potentially subject to tidal flooding from a 1% (100-year) tide event in San Francisco Bay, assuming no SLR. In addition there are critical City facilities and infrastructure as well as a regional facility located within the designated tidal floodplain, including:

- Regional Water Quality Control Plant
- Palo Alto Airport
- City of Palo Alto Municipal Service Center
- Palo Alto Utility Control and Engineering Center
- City of Palo Alto Animal Services
- City of Palo Alto offices at Elwell Court
- Palo Alto Municipal Golf Course
- Palo Alto Baylands and Byxbee Park
- Palo Alto's closed landfill
- U.S. Post Office and a Private School
- Regional utility corridors (e.g. PG&E gas mains and electric transmission lines)
- Palo Alto Utility Substations
- Stormwater Pump Stations
- U.S. Highway 101

Sea level rise will result in an increase in the number of properties designated as being in the floodplain unless measures are taken to adapt and protect the shoreline and/or specific properties. Such measures may lead to possible changes in the shoreline as decisions must be made regarding which assets to protect. Sea level rise also poses emergency response and safety challenges, which are addressed in the City's Threat and Hazard Identification and Risk Assessment as well as the Local Hazard Mitigation Plan.

Projections of current coastal flooding, SLR and vulnerable assets in Palo Alto are shown in Exhibit 1.

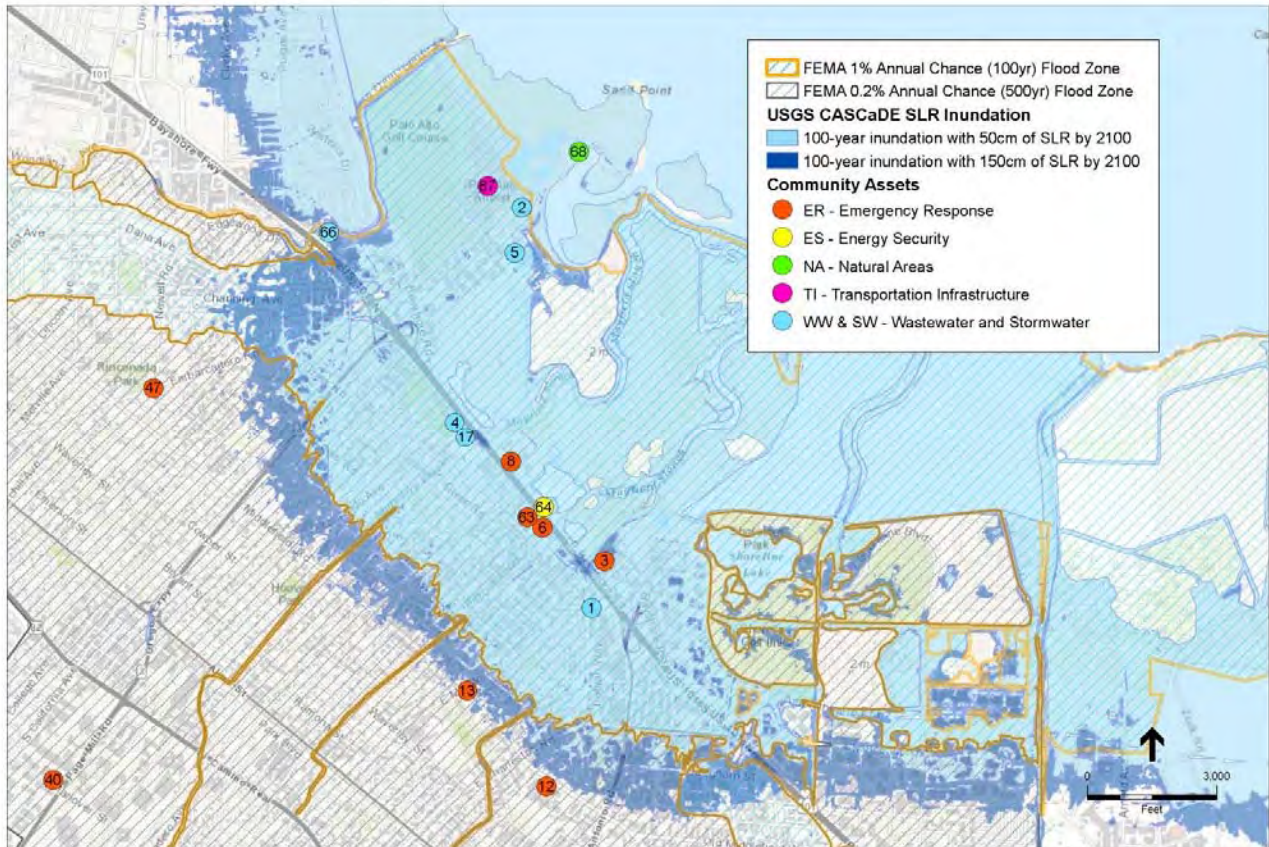


Exhibit 1. Palo Alto Community Assets at Risk from Sea Level Rise and Associated Flooding
Sources: City of Palo Alto, Sustainability and Climate Action Plan, 2016

The SLR risk evaluation points to many vulnerabilities in Palo Alto that this report addresses.

2.2 Topographic Data

The 2010 U.S. Geological Survey (USGS) Topographic LiDAR: San Francisco Bay, California was utilized as the topographic data source for this feasibility level analysis. All elevations referenced in this document are reflective of North American Vertical Datum of 1988 (NAVD88). This data set is an LAZ (compressed LAS) format file containing LIDAR point cloud data.⁴ Additional topographic data will be collected as part of the design phase of this project.

2.3 Coastal Hydraulics and Sea Level Rise

The current effective FEMA Flood Insurance Rate Maps (FIRMs) designate the entire Palo Alto Bay shoreline within its Special Flood Hazard Area (SFHA) for the 100-year (1% annual chance) coastal flood event. This designation indicates that portions of the community are at risk of flooding and property owners with a federally insured mortgage are required to pay a premium

⁴ Additional LiDAR metadata information can be reviewed at https://coast.noaa.gov/htdata/lidar1_z/geoid12a/data/1406/2010_usgs_SanFranBay_metadata.html

to participate in FEMA's National Flood Insurance Program. Although a network of existing embankments/levees 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 downstream of Highway 101 are being addressed through a separate flood improvement project under construction, with planned completion early 2019.

FEMA issued preliminary FIRMs in 2015 for much of the Bay shoreline that includes the SAFER project area; these preliminary maps have not yet been adopted for the entire SAFER Bay Project area. The floodplain area shown in the 2015 Preliminary FEMA FIRM (Figure 3) is larger in extent and inundation depth than the currently effective FIRM from 2009. This report uses the 2015 Preliminary FIRM to be conservative. The City of Palo Alto is part of the voluntary Community Rating System (CRS) that was approved in 2017⁵.

The preliminary FEMA results for just offshore of the SAFER Bay Project area estimates the 100-year still water level (SWL) to be 11 ft (DHI, 2013), measured using the standard NAVD88. Per FEMA, the SWL is defined as including the effects of the astronomical tide, storm surge, and wave setup. Because the Palo Alto shoreline lacks FEMA-accredited levees, the existing SFHA is delineated by projecting the 100-year water surface elevation inland to where it intersects the ground surface elevation.

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 wave-propelled water rushing up onto a shoreline. 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 Exhibit 2 below, which illustrates the differences in types of coastal flooding and the applied FEMA zoning.

⁵ Information regarding FEMA's Community Rating System can be found at: https://www.fema.gov/media-library-data/1503240360683-30b35cc754f462fe2c15d857519a71ec/20_crs_508_oct2017.pdf

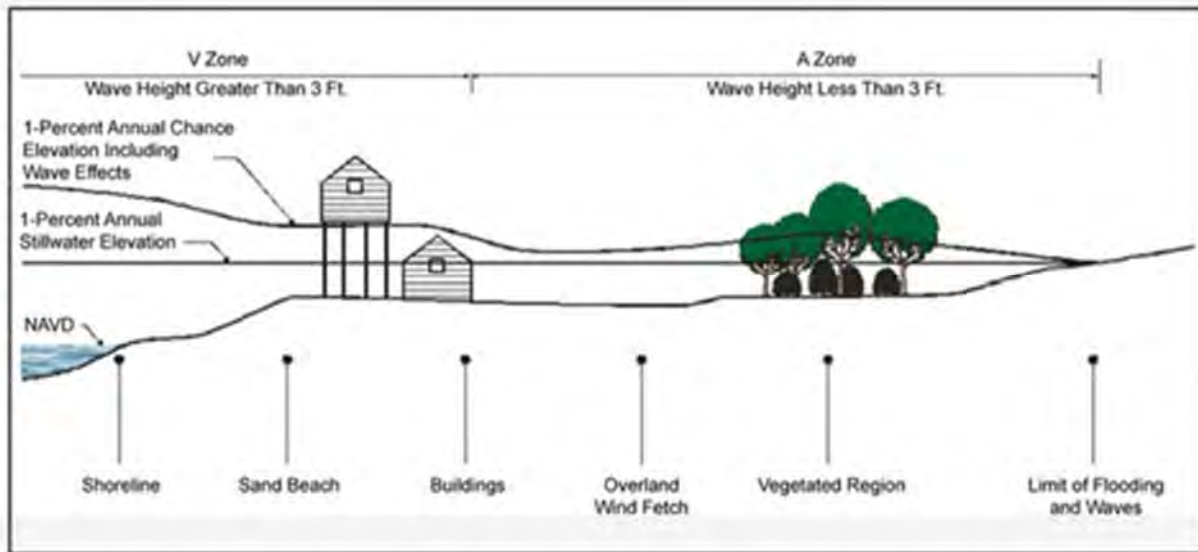


Exhibit 2. FEMA’s Typical Transect Schematic

To provide a margin of safety, FEMA requires that the crest elevation of an accredited 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 this minimum is exceeded by either of the following wave-influenced freeboard elevations:

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

The SAFER Bay project design criteria includes consideration of three feet SLR and is shown in Minimum Design Elevation section of Tables 1 and 2. Planning for SLR is part of the California design guidelines (OPC, 2018) and the Bay Conservation and Development Commission (BCDC, 2011). BCDC in partnership with the Metropolitan Transportation Commission and Bay Area Toll Authority released the *Adapting to Rising Tides Bay Area Sea Level Rise Analysis and Mapping Project* in September 2017 (BCDC et al., 2017). The Final Report included SLR inundation maps for multiple events.

Incorporating three feet of SLR into the design is consistent with the SAFER Bay project time frame (five decades) and the range of SLR projections over this time. For instance, California state guidance (OPC, 2018) recommends three feet of SLR for medium-high risk aversion decision making by 2070. In addition, the U.S. Army Corps of Engineers (USACE) projects three feet of SLR 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 SLR, the approximate design elevations for the SAFER Bay project’s levee crests are presented in Table 1. In addition to its relation to SLR, SAFER’s minimum design elevation

considering three feet of SLR would protect people from water levels almost nine feet above the current daily high tide.

Table 1. Preliminary Minimum Design Elevations for Reaches 10 and 11

Minimum design elevation (1% SWL only)		
Elevation² 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
<i>Minimum design elevation³</i>	<i>13.0 ft</i>	<i>16.0 ft</i>

Note: SWL = still water level

¹As depicted on the Santa Clara FEMA Preliminary Flood Insurance Rate Maps dated July 8, 2015.

²All elevations are provided in NAVD 88.

³Elevation provided is long-term design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement.

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 Baker/AECOM (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 much of Reach 10 and Reach 11 have reduced wave exposure due to the proposed levee alignments' location landward of existing tidal marsh and existing embankments, and thereby less wave-exposed 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, such as the transition zone habitat described below, the SAFER Bay project may be able to reduce the influence of waves on raising the water elevation. However, FEMA accreditation of levees that use a gentle slope to reduce the levee crest elevation is untested and thus will require additional evaluation and close coordination with FEMA during project design to obtain FEMA accreditation.

The need for assuming wave attenuation to achieve FEMA accreditation will depend on other outboard considerations, including the selected levee alignments for Reach 10 and Reach 11, and the establishment and long-term sustainability of tidal marsh in front of levees, which would also attenuate waves. Maximum design elevations provided in Table 2 provide the maximum water surface elevation if enhanced levee slopes, levee alignments, and/or future marsh conditions 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 2. Preliminary Maximum Design Elevations for Reaches 10 and 11 dependent upon future outboard conditions

Maximum Design Elevation (1% SWL & Waves)		
Elevation³ 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	5.0 ft	5.0 ft
Required freeboard above the TWL	1.0 ft	1.0 ft
Maximum design elevation⁴	17.0 ft	20.0 ft

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

¹As depicted on the Santa Clara FEMA Preliminary Flood Insurance Rate Maps dated July 8, 2015.

² Initial wave runup, based on initial review of Baker/AECOM (2014). Subject to change with future analysis.

³ All elevations are provided in NAVD 88.

⁴ Elevation provided is long-term design elevation and does not account for settlement. Levees will be built to a higher elevation to account for settlement.

2.4 Interior Drainage

A substantial portion of the precipitation that falls on Palo Alto and connected watersheds adjacent to the City’s south area is collected by small channels and stormwater infrastructure and then drains or is pumped into Matadero, Barron, and Adobe Creeks and then ultimately into the San Francisco Bay. The 2015 Storm Drain Master Plan Update divides Palo Alto into three drainage areas: Part 1 which drains west to San Francisquito Creek; Part 2 is mainly the Matadero Creek watershed with sections draining north and west to San Francisquito Creek and east to Barron Creek; and Part 3 includes the Adobe Creek watershed, the majority of the Barron Creek watershed, and the area that drains to the Airport Pump Station (Schaaf & Wheeler 2015). Matadero, Barron and Adobe creeks flow northeast through the City, underneath Highway 101, and discharge to the Palo Alto Flood Basin (Flood Basin). The Flood Basin is 600 acres of former tidal marsh now encircled by embankments that prevent Bay waters from entering the basin. This exclusion of Bay waters preserves the basin’s storage capacity for discharge from the creeks. When water levels in the flood basin exceed water levels in the Bay, water drains from the basin to the Bay via a set of sixteen 5-ft by 5-ft box culverts. Flap gates on the outboard side of the culverts prevent Bay waters from entering the basin, except for very minor exchange permitted during the dry season. The Santa Clara Valley Water District (SCVWD) oversees flood management of the creeks and the flood basin.

Although though the Matadero, Barron, and Adobe creeks’ floodwalls and levees are accredited by FEMA for much of their length, in their lower reaches, for several thousand feet upstream of Highway 101, the creeks do not currently have FEMA accreditation. This is due, in part, to this area being within the coastal SFHA. In these un-accredited lower reaches, alternate hydraulic evaluation and freeboard criteria were used to select floodwall crest design elevations (SCVWD, 2002).

Two of the SAFER levee alignment options for Reach 11, which includes the Flood Basin, reduce or completely eliminate the flood storage capacity of the flood basin. These options are

considered because of potential benefits from shorter levee length and/or the created opportunity for restoring tidal exchange and tidal marsh. On their own, these decreases to the flood basin's storage capacity would increase water levels in the lower reaches of the creeks. Therefore, this feasibility study's assessment of these options also includes the addition of a pump station and/or raising the creeks' floodwalls to match the existing freeboard. This assessment was done using SCVWD's hydraulic models of the flood basin and creeks. These models were modified to represent the SAFER levee options, preliminarily size the pump station, and characterize the change in freeboard that would need to be offset with higher floodwalls. The details of this hydraulic assessment can be found in Appendix B.

The interior drainage system in the vicinity of the Palo Alto Airport and northeast of Highway 101 is collected by an underground storm drain piped network that converges at the City's Airport pump station (Schaaf & Wheeler, 2015). This pump station then discharges into the San Francisco Bay.

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. If issues with the structures are identified, remediation improvements will be included within the project design.

2.5 Low Impact Development

Stormwater in the Palo Alto area is generated primarily from sheet flow over impervious surfaces during precipitation events. A substantial amount of stormwater does not infiltrate to the ground to recharge groundwater, but instead is conveyed via storm drain system and discharges to the Bay. If low impact development (LID) or green infrastructure were constructed or retrofitted, less stormwater would require management. Regulatory impetus for action is from the 2015 reissued Municipal Regional Stormwater Permit that specifies LID and green infrastructure planning requirements for private and public development. The design criteria for LID is an approximate two-year storm event, so would not be expected to have a significant effect on larger flooding events or SLR.

The City of Palo Alto is preparing a Green Infrastructure Plan that is scheduled to be completed February 2019. Santa Clara Valley Urban Runoff Pollution Prevention Program has completed a Stormwater Resource Plan to identify and prioritize regional projects, green streets and low impact development for watersheds in northern Santa Clara County. In addition, SCVWD is developing a One Water Plan that that considers rainwater as a water source to be managed to improve flood protection, water supply and ecosystem health. As these efforts are in the planning stages, the amount of stormwater in the area that can reasonably be expected to be captured and put to other beneficial uses is not currently known.

One evaluation of the San Francisquito Creek area was completed by San Mateo County's Office of Sustainability (SMC, 2018). This evaluation was performed as part of the San Mateo Plain Groundwater Assessment, and evaluated the ability of LID to use stormwater to augment groundwater recharge. A constraints analysis was performed to evaluate the best areas to recharge stormwater considering geographic, hydrogeologic and regulatory factors (SMC 2018). These factors were:

- Hydrologic soil groups, excluding areas with slow or very slow infiltration rates

- Land surface slope of less than 5%
- Thin or non-existent shallow confining layer and
- Minimum of 500 feet away from any open contamination/cleanup site.

The locations that best met the above criteria were generally to the west of the Bay margin, but not in highly sloped upland areas, with a significant portion adjacent to San Francisquito Creek in San Mateo County. If LID were retrofitted in all available places, an additional 25% of runoff from impervious areas was assumed, resulting in green infrastructure projects accounting for approximately 200 acre feet of water per year that would not be discharged to the Bay (SMC 2018). Although sizable, the 200 acre feet of water per year is 0.28 cubic feet of water per second, and would be considered negligible in a storm event. Therefore, LID and green infrastructure, although helpful from both a water quality and quantity standpoint, will not be a single solution to flood management or SLR.

Although LID and green infrastructure are not considered means to ameliorate flooding or effects of SLR, LID and green infrastructure specific to Palo Alto will be revisited when the above efforts are complete. In any case, LID and green infrastructure can play an important role in reducing stormwater flows on a localized level, and continued close coordination with planned LID and green infrastructure projects as indicated for the SAFER Bay Project.

2.6 Geotechnical Considerations

The proposed flood protection alignments are located along the southwestern fringe of San Francisco Bay. Geotechnical explorations were performed as part of this feasibility phase of the project. A review of 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. The Young Bay Mud may also contain intermediate sand layers and lenses that could be potential under seepage paths or be susceptible to liquefaction during an earthquake. The available information indicates that the thickness of the Young Bay Mud layer ranges from about 3 to 23 feet throughout much of the alignment area. The thickness of the Young Bay Mud is greatest in the northern portion of the Flood Basin where it approaches about 23 feet. Additionally, artificial fill is known to be present along the Palo Alto bay margin, and can contain significant debris including wood, concrete and metal. The closed Palo Alto landfill is a site-specific consideration that is discussed in more detail in Section 8.

To protect vulnerable assets that cannot easily be relocated, new levees can be constructed, or existing levees will be raised and broadened with earthen embankments. Where significant spatial or other constraints exist, alternative flood protection systems, such as floodwalls, may be evaluated.

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 sufficient time for the underlying soil to gain strength before additional fill is placed. Alternatively, measures may be needed to strengthen the 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. It is likely the levees will need to be initially built to heights greater than their final elevations, in order to meet their design crest elevations.

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

2.7 Levees

As part of adaptive management response to SLR, 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 preliminarily 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).
- Assumed final levee crest height at Elevation 16 feet NAVD 88.

To account for levee settlement, overbuild of levee heights should also be considered in establishing levee geometries. In addition, levee geometry that can accommodate additional raising as an adaptation strategy is considered. From the geotechnical analysis performed as part of the Feasibility Phase, it was estimated that 1 to 2.5 feet of overbuild will be required throughout Reaches 10-11. Typical cross sections, Figures 4-1 to 4-11, present the estimated levee dimensions (including overbuild) required for each reach if the levee was constructed to account for SLR. For planning purposes, an 80 to 120-foot wide alignment would be needed to accommodate a levee base that will ultimately be built to these dimensions. The actual width of alignment needed along each segment of levee would need to be determined during later phases of the design. The actual levee width needed would depend on a number of factors

including the actual site grades from future topographic and bathymetric surveys and finalized levee alignments and target levee crest elevations.

2.8 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.

2.9 Gates

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 gate structure has been considered. A passive structure is defined as a feature that can be closed at the beginning of a storm event and left alone without any additional management except to reopen at the end of the storm event. 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.

2.10 Penetrations

Penetrations and encroachments 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.

2.11 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 pipeline owners to determine impacts to the pipeline will be investigated during the future design phase.

The Palo Alto RWQCP is currently in the design phase of a new 63" HDPE to augment the existing 54" RCP discharge pipeline and outfall from the RWQCP across the airport parking lot at the southern end of the airport runway discharging into the San Francisco Bay. The proposed

pipeline alignment will cross and potentially overlap with potential SAFER Bay levee alignments. Per multiple discussions with the City and their designer, the pipeline has been designed to take into account the typical loading associated with the weight of a levee prism. Special consideration will need to be taken in designing a SAFER Bay levee in this area. The new outfall construction work is anticipated to occur in 2019 and 2020.

The City of East Palo Alto has an existing sanitary sewer line located at the toe of the existing levee adjacent to the Golf Course and San Francisquito Creek. The sanitary sewer line will need to be relocated to avoid conflicts with the proposed levee footprint.

2.12 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.

2.13 Bay Trail

In locations where the proposed flood control alignment overlaps or indirectly impacts the Bay Trail, reconstruction and improvements of the trail may be necessary. The trail surface will be designed to provide a seamless tie-in into the surrounding surface condition. Bay Trail improvements described in the Baylands Comprehensive Conservation Plan will be considered as well as recommendations included in Palo Alto's Bicycle Transportation Plan.

2.14 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. 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.

2.15 Real Estate

The SFCJPA and partners are 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.

2.16 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. BCDC initiated a process in late 2017 to amend the San Francisco Bay Plan to address the need to place an increasing amount of Bay Fill for projects to restore and enhance natural habitat. A public hearing on the proposed amendment is planned for June 2019. For costing purposes, it was assumed that the levee borrow can be collected on a 50 mile round trip.

2.17 Disposal and Storage Area

Any excess levee cut material is expected to be used for construction of transition zones. Any excess soil (soil that does not meet geotechnical criteria for new/augmented levees) is assumed to be stored on site for use in future restoration work. Site identification for excess storage will be determined during the design phase.

2.18 Palo Alto Closed Landfill

The City of Palo Alto operated a Class III refuse disposal site with a permitted footprint of 137 acres, of which 126 acres were used for refuse disposal operations from the 1930's until 2011. The landfill's Final Closure and Post-Closure Maintenance Plan was prepared in accordance with Title 27 of the CCR and several sections relate to flood control and/or changes to the landfill cover or perimeter levees. These sections include Section 3.5 Closure Design, 4.3 Emergency Response Plan, 4.4 Inspection and Monitoring Activities, and 4.5 Cover System Repair.

The landfill was closed in phases and the entire area was slated for reuse as parkland as part of the Byxbee Landfill Park Master Plan in 1989. The park has been developed and opened to the public in phases. Byxbee Park was opened in 2011, and the remaining portions of the landfill were capped by 2015, with the opening of the remaining closed landfill areas for recreational purposes in 2016.

Ten acres of the closed landfill have been set aside for a potential compost processing facility to convert yard trimmings, food waste, and other organic waste and sewage sludge from the regional wastewater treatment plant.

<https://www.cityofpaloalto.org/civicax/filebank/documents/43938>

The closed and capped landfill will require additional evaluation to determine the impact of any proposed levee, floodwall or other SLR adaptation structures along the edge of the former landfill footprint. In particular, portions of the closed landfill are adjacent to the Palo Alto Flood Basin and if an alignment alternative is selected that opens the Flood Basin to tidal action, additional considerations associated with wind and wave action as well as exposure of landfill

cap materials to Bay waters along the landfill edge will be evaluated. The City must adhere to the closure and post closure requirements.

A timeline of the history of waste and the Baylands is available at:

<https://www.cityofpaloalto.org/civicax/filebank/documents/35365>

2.19 Palo Alto Municipal Airport

The Palo Alto Airport is a vulnerable facility with additional requirements for safety and efficient use of navigable airspace. An obstruction aeronautical study is required by the Federal Aviation Administration (FAA) to evaluate any proposed structures, and make a determination of permanent and temporary impacts.

The FAA Obstruction Evaluation / Airport Airspace Analysis (Form FAA 7460-1 – Notice of Proposed Construction or Alteration) should be submitted when design details are known, and additional filings are required to the FAA to assess temporary construction impacts a minimum of 45 days prior to the start of work. The SFCJPA will continue to solicit input and continue close coordination with the airport for the SAFER Bay Project. Additionally, due to the oversight of the FAA, projects should not be locally "approved" when it is subject to FAA review. Ahead of the selection and design stage of Reach 10 options, advanced coordination with the FAA will be required prior to initiating any alternative.

2.20 Staging Area

Potential staging areas for construction materials and equipment will be identified during the design phase.

2.21 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 control (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.

The City of Palo Alto is soon to be releasing the Baylands Comprehensive Conservation Plan in December 2018 which will provide additional guidance on habitat restoration in the Baylands (including transition zone habitat).

2.21.1 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 alkali meadow/grasslands, seasonal wetlands, and salinas 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

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

1999; Beller et al. 2013; Goals Project 2015). Today, the transition zone around San Francisco Bay marshes consists almost entirely of a narrow area of ruderal/low-quality habitat about ten feet wide that 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:

- 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 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 space for the landward transgression of tidal marsh with sea level rise.
- 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*).

2.21.2 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 bayland ecotone habitats that occurred historically (i.e., seasonal wetlands and willow sausal), thereby further increasing the habitat diversity and ecological function of the transition zone.

2.21.3 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 (also known as horizontal levees) should be designed at a slope of 30H:1V or gentler during rebuilding of levees to provide endangered species with appropriate habitat under a range of SLR scenarios (USFWS 2013). The construction of SAFER Bay project levees with a slope of 30H:1V, or gentler, would allow restoration of a diverse suite of transition zone habitats, including alkali meadow/grassland, seasonal wetlands, salinas, and coastal scrub as shown on Figure 5. 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 decrease with increasing outboard levee slopes, as shown on Figure 6. Low-gradient slopes (e.g., 30H:1V or gentler) would provide the full suite of transition zone habitat functions. Intermediate grade levee slopes (e.g., 15H:1V) would provide a lesser degree of habitat complexity, and habitat function would decline more rapidly with SLR. Steep levee slopes of 3H:1V, by contrast, would provide very limited transition zone habitat diversity and no space to accommodate habitats relative to rising sea levels.

In addition to creating habitat and benefiting flood protection, habitat transition zones also offer the potential to polish wastewater effluent, by removing additional nutrients and pollutants before the wastewater enters the Bay. Palo Alto's RWQCP is currently assessing the feasibility of providing treated effluent to transition zone habitat that would front the SAFER levee (ESA, in prep).

2.22 Tidal Marsh Restoration, Tidal Marsh Enhancement and Permitting

The terms "restoration" and "enhancement" are defined in accordance with USACE guidelines (USACE 2015). The term "tidal marsh restoration" refers to the establishment of tidal marsh habitat and functions where tidal marsh previously existed but does not currently exist, 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 RWQCB's definitions for these terms are generally consistent with USACE's, but the RWQCB has a policy of no net loss of wetland acreage and no net loss of wetland functions.

The SAFER Bay Project would impact regulated habitats including tidal marsh and non-tidal wetlands and other waters. These habitats are regulated by the USACE (under Clean Water Act Section 404), RWQCB (under Clean Water Act Section 401 and the San Francisco Bay Basin Water Quality Control Plan (Basin Plan), and BCDC (under McAtteer-Petris Act).

Potential actions undertaken as part of the SAFER Bay Project could affect habitat for federal and state listed endangered/threatened species including the California Ridgway's rail and salt marsh harvest mouse, regulated by the USFWS (under Federal Endangered Species Act) and the CDFW (under California Endangered Species Act). Therefore, the SAFER Bay Project will be required to provide wetland habitat mitigation to obtain governmental approvals.

Pursuant to Title 23, California Code of Regulations, Section 3856, 401 Water Quality Certifications require the identification of compensatory mitigation for impacts to wetlands within RWQCB jurisdiction; this includes provision of the total estimated quantity of wetlands proposed to be created, restored, and enhanced as mitigation. This allows the RWQCB to track changes in the quantity of wetlands and determine if their No Net Loss of Wetlands Policy is being followed. Additionally, under CEQA, all individual and cumulative significant environmental

impacts associated with a project must be mitigated. These two requirements are typically addressed through Mitigation Plans.

The primary opportunity to create tidal marsh as part of the SAFER Bay Project occurs within Menlo Park and East Palo Alto. However, there are several large-scale, tidal marsh restoration and enhancement opportunities on the bayward side of some of proposed SAFER alignments in Palo Alto. These opportunities include the tidal marsh restoration of part or all of the Flood Basin, and tidal marsh enhancement via the installation of transition zone habitat along the bayward side of new flood control levees adjacent to existing tidal marsh. These types of opportunities will be incorporated into the CEQA project description and it is anticipated that the SAFER Bay Project will restore the flood control functions of tidal marshes and create a self-mitigating project with net, long-term benefits to sensitive bayland habitats and species.

Tidal marsh restoration and enhancement opportunities are described in more detail within each potential project alternatives in Section 5.

2.22.1 Integration with the South Bay Salt Pond Restoration Project

The SAFER Bay Project proposes to construct flood protection levees that will enable restoration of tidal marsh in the Ravenswood Salt Pond Complex in East Palo Alto and Menlo Park, in accordance with the SBSPRP. In contrast, there are no direct opportunities for synergy between Palo Alto and the SBSPRP because the two projects occur in different locations along the bayshore. The SBSPRP Phase 2 proposes to restore tidal marsh in salt ponds A1 and A2W within the Alviso Pond Complex (USFWS/California State Coastal Conservancy 2016). This restoration effort is located to south of Palo Alto by the City of Mountain View’s Charleston Slough muted tidal wetland. The SBSPRP’s selected alternative (Alternative Mountain View B) will not restore full tidal action to Charleston Slough, but rather, will raise the levee between Pond A1 and Charleston Slough. Nonetheless, the construction of levees/transition zones in Palo Alto could facilitate tidal restoration at Charleston Slough.

2.23 City of Palo Alto’s Storm Drain Capital Improvement Projects

The City of Palo Alto has multiple storm drain Capital Improvement Plan (CIP) projects planned to resolve identified storm drain conveyance shortfalls. Some of the City’s proposed CIP projects overlap with the proposed SAFER Bay levee alignments. During the early design stages of the SAFER Bay project, close coordination with the City’s CIP projects will be required. The City’s proposed CIP projects are listed below for reference (Table 3).

Table 3. Proposed City of Palo Alto’s Capital Improvement Projects

CIP Project ID	CIP Name	Description
1	Corporation & E. Bayshore	Pipe upsizing and add pump station
3	Bayshore & Fabian	Pipe upsizing
4	Bayshore & Fabian Pump Station	Add pump station
5	Charleston & Adobe Cr	Pipe upsizing and add pump station
6	E Meadow Circle	New pipe
7	E Meadow Dr	Pipe upsizing

CIP Project ID	CIP Name	Description
8	Fabian	Pipe upsizing
9	Hamilton & Rhodes	Pipe upsizing
11	Loma Verde & Maddux	Pipe upsizing
12	Louis	Pipe upsizing and canal improvements
13	Louis to Matadero Creek	New pipe and outfall
14	Colorado Pump Station Removal	Remove pump station
Unknown	Byxbee Park Completion east of Hwy 101	Park improvements

2.24 Other Local Structural Impacts

Modification to some structures within the Baylands Nature Preserve may be proposed by the SAFER Bay Project. It is important to understand the history and function of these structures, which are described briefly below.

Palo Alto Flood Basin-This was constructed in 1956 as a flood control measure for Adobe, Matadero and Barron Creeks. A tide gate was placed at the confluence of Adobe Creek, Matadero Creek, and the San Francisco Bay, so that the flood basin could be maintained at approximately 2 feet below sea level, creating storage for incoming stormwater and creek flow. The tide gate consists of several weirs and one operator-controlled sluice gate that enables tidal flows into the basin to improve water quality and for mosquito abatement. Three agencies oversee the tide gates: City of Palo Alto, SCVWD and the Santa Clara County Vector Control District. Since the trash grate and weirs separate the mouth of the flood basin from the San Francisco Bay estuary, large fish cannot swim freely between the Bay and the basin, unless the sluice gate is open. The tide gates are set to minimize tidal inundation of the basin, resulting in predominant freshwater conditions in the basin. Fish migration may be impeded during winter storms due to the management of the basin for flood protection.

Antenna Field: The City of Palo Alto purchased the final 36.5 acres in 2016 from International Telephone and Telegraph (ITT). The City had acquired other portions of the radio and telegraph facility from ITT beginning in 1977. The complex had operated since the early 1920s, and the final acquisition includes two buildings and abandoned piping and power lines. The City intends to use the area as recreational open space. In 2017 the City improved the road leading to the site and removed abandoned utility poles, power lines, transformers, pipes and other debris. The City's Public Works Department acted in 2017 and 2018 to stabilize and secure the premises until a final decision on the fate of the buildings is made. The overall antenna field has some buried structures that could affect alternative implementation and/or effectiveness that could need further evaluation.

(Source: <https://www.paloaltoonline.com/news/2017/09/13/palo-alto-looks-to-fix-up-abandoned-baylands-site> and <https://paloaltoonline.com/news/2017/05/31/palo-alto-expands-its-control-over-baylands>)

Duck Pond- This pond was constructed in the 1920s as a saltwater swimming pool. Due to siltation, it was converted to a Duck Pond by the 1940's. (Source: <https://www.cityofpaloalto.org/news/displaynews.asp?NewsID=466&TargetID=36>).

Emily Renzel Marsh and Pond- The Emily Renzel freshwater marsh and 15-acre pond were built in 1992 as a requirement of the RWQCB to increase beneficial reuse of treated wastewater effluent. The site is designed to receive one million gallons of treated RWQCP effluent daily. The City of Palo Alto initiated maintenance of this marsh in April 2018 to repair the four-foot berm around the pond and remove vegetation that is constricting flows during the first of two construction seasons. This maintenance will allow the City's target volume of treated effluent that is released to the Renzel Marsh Pond to travel to Matadero Creek, flow to the Palo Alto flood basin and then into San Francisco Bay. (Source: <https://www.cityofpaloalto.org/news/displaynews.asp?NewsID=4227&TargetID=145>)

The shape of the pond is controlled by proximity to Highway 101 on the west side and on the east, and a buried semicircular concrete structure from the former antenna field (Karin North, City of Palo Alto 2018 personal communication).



Exhibit 3 Other Structural Elements, Palo Alto Baylands

Source: <https://www.cityofpaloalto.org/civicax/filebank/documents/64484>

Other existing community facilities are located in the Baylands beyond any proposed levee alignments. These structures were not considered critical facilities in the Risk Evaluation (Section 2) but nevertheless are important to the community and will be subject to adverse impacts of SLR unless they are relocated or elevated. These facilities include the Lucy Evans Baylands Interpretive Center and Boardwalk, Palo Alto Sailing Station, Save the Bay Native Plant Nursery, Baylands Nature Preserve Ranger Station, Environmental Volunteers EcoCenter, Baylands Ranger Maintenance Shop, and the Bixbee Restrooms. The Lucy Evans Baylands Interpretive Center Boardwalk is currently being reconstructed, and the new boardwalk is being raised to match the grade at the Interpretive Center and generally meets the City's recommendation for 55 inches of SLR. All of these structures fall within Palo Alto's Baylands Nature Preserve (Palo Alto, 2008).

3 Development of Potential Options

This evaluation focused on potential structural options to protect identified critical infrastructure and property. Based on similar topography, hydraulic conditions and constraints, the project area was divided into two reaches (Figure 2). Potential options within each reach that satisfy one or more of the study objectives were identified. 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 the two Palo Alto reaches are described in this section. The reaches are numbered based on the overall SAFER Bay Project as described previously and shown in Figure 1.

3.1 Reach 10 – Palo Alto Airport and Water Treatment Plant

Reach 10 ties into the San Francisquito Creek project's new levee downstream of Friendship Bridge, continues along the leveed edge of the golf course and wraps around the waterside of the Palo Alto Airport, and follows adjacent to Embarcadero Road along the RWQCP and the capped landfill, as shown on Figure 4.

3.1.1 Option 1

Option 1 consists of a levee tying into the San Francisquito Creek Levee Improvement Project and extending along the Palo Alto Golf Course, extending past the Palo Alto Airport's runway protection zone, and then turning southeast and running parallel with the runway approximately 380 feet from the runway centerline. This levee segment parallel to the runway would be centered on the existing San Francisquito Creek Trail alignment. At the southeast end of the runway, the levee would jog south and then cut across the wetland area located between the airport parking lot and the Duck Pond. Once the levee crosses Embarcadero Road, the levee follows adjacent to Embarcadero Road, passing the RWQCP, the capped landfill, Byxbee Park Hills and ends at the Adobe Creek Loop Trail. This option would require either flood gates at each end of the runway, or a raise of the runway entirely above the proposed levee crest. See Typical Sections on Figures 4-1 and 4-2 for cross sections of this option.

3.1.2 Option 2

Option 2 consists of a levee tying into the San Francisquito Creek Levee Improvement Project and extending along the Palo Alto Golf Course, extending past the Palo Alto Airport's runway protection zone, and then turning southeast and running parallel with the runway approximately 150 feet from the runway centerline. Locating the levee closer to the runway (as compared to Option 1) would allow space for transition zone restoration. At the southeast end of the runway, the levee would continue along the edge of pavement around the airport parking area, maintaining airport access via a flood gate. The levee would then turn south and continue down Embarcadero Road, passing the RWQCP and would then tie into high ground at the capped landfill. This option would require either flood gates at each end of the runway or a raise of the runway entirely above the proposed levee crest.

3.1.3 Option 3

Option 3 consists of a levee tying into the San Francisquito Creek Levee Improvement Project and extending along the Palo Alto Golf Course, extending past the Palo Alto Airport's runway protection zone, and then turning southeast and running parallel with the runway approximately 150 feet from the runway centerline (matching with Option 2 alignment). Locating the levee closer to the runway (as compared to Option 1) would allow space for transition zone restoration. At the southeast end of the runway, the levee would continue straight across the wetland area between the airport parking lot and Palo Alto Duck Pond (matching with Option 1 alignment). This combined alignment reduces the proposed levee overlap with an existing 54" treated effluent outfall from the RWQCP and a proposed 63" outfall storm drain outfall. The levee alignment would then turn south and continue down Embarcadero Road, passing the RWQCP and would then tie into high ground at the capped landfill. This option would require a flood gate at the east end of the runway or a raise of the runway entirely above the proposed levee crest.

3.1.4 Option 4

Option 4 is an alignment variation that can be applied to both Option 1 and 2. Similar to Option 3, at the southeast end of the runway, the levee would turn east and wrap around the Palo Alto Duck Pond and Palo Alto Baylands Ranger Station rather than be located along the airport parking area, and connect with Embarcadero Road. A pipeline connecting the Duck Pond to the San Francisco Bay would need to be designed to control flows into the leveed basin. The levee would continue down Embarcadero Road, maintaining airport access via a flood gate and pass the RWQCP, and would then tie into high ground at the capped landfill. This variation of protection along Reach 10 also allows for a shift in the runway alignment to remove conflicts with levee encroachments both ends of the runway (rather than flood gates or elevating the runway).

3.2 Reach 11 – Closed Landfill and Palo Alto Flood Basin

Reach 11 extends from high ground at the capped landfill to a tie-in at the City of Mountain View border near Coast Casey Forebay (Figure 4).

3.2.1 Option 1

Option 1 consists of a levee extending from high ground at the capped landfill, following the existing Flood Basin perimeter levee and along the western side of Charleston Slough, to a tie-in at the City of Mountain View border near Coast Casey Forebay. At this time, it is understood that the City of Mountain View is planning a tidal flood protection project that will include a levee or flood control structure that terminates in this location (ESA PWA, 2012). The existing flood gates located at the northern end of the basin would need to be re-designed to accommodate a levee raise. An assessment of the flood gates' performance with future sea level rise indicates that adding a large pump station may be needed to adapt to the current basin configuration to sea level rise (Schaaf & Wheeler, 2016). See Figure 4-4, for a schematic cross section of the raised levee at the northern end of the basin.

Option 1 would not result in significant habitat enhancement or restoration opportunities relative to current conditions. The incorporation of a broad transition zone around the Flood Basin would

be constrained by the bay and existing marsh to the north and Charleston Slough to the east. Moreover, Option 1 would impact/fill diked salt marsh habitat within the basin along roughly 2 miles of miles of levee improvements.

3.2.2 Option 2

Option 2 consists of a levee extending from high ground at the capped landfill, running southwest along the Emily Renzel Wetlands, then along the north side of Matadero Creek to East Bayshore Road. A second levee will extend from East Bayshore Road along the south side of Matadero Creek and around the City of Palo Alto's operations and maintenance campus then continue along East Bayshore Road to Adobe Creek. A third levee will continue on the southern side of Adobe Creek along the Adobe Creek Loop Trail from East Bayshore Road to a tie in at the City of City Mountain View border near the Coast Casey Forebay. See Figure 4-6, for a schematic cross section of a raised levee along the southern side of Adobe Creek.

In addition to these levees, in order to at least preserve the existing level of flood protection developed areas along creek channels, raising of the existing floodwalls along both banks of Matadero, Barron, and Adobe Creeks upstream and west of Highway 101, to the upstream extent of coastal flood influence would be required.

The top of Matadero, Barron, and Adobe creeks' floodwalls start at elevations of about 12 ft NAVD88 (9.3 ft NGVD29) and increase with elevation moving upstream. See Figure 4-8, for a schematic cross section of floodwalls along Matadero Creek. These extend for several thousand feet upstream of Highway 101, but do not currently have FEMA accreditation. Raising the Matadero, Barron, and Adobe floodwalls for Option 2 could be coordinated with a larger effort to obtain FEMA accreditation for these reaches of the creeks that flow in to the Flood Basin.

Option 2 represents a significant opportunity for large-scale tidal marsh and transition zone habitat restoration (Figure 5). The Flood Basin would be re-connected to tidal exchange through a horizontal levee solution which would, over time, restore the basin to tidal marsh. To restore the basin to tidal marsh, the outer levee would be breached in strategic locations to create a natural, dendritic slough channel network and the remainder of the levee may be lowered over time. Material from the levees could be used to fill/block existing borrow ditches and facilitate a dendritic slough channel network. Additionally, the basin is adjacent to Charleston Slough to the east, which may be restored to tidal marsh by the City of Mountain View in collaboration with the SBSRP. Removing the levee between the Flood Basin and Charleston Slough would create a large, contiguous marsh with freshwater input from Matadero, Barron, and Adobe Creeks. This freshwater input to the marshes would supply sediment and create a gradient of freshwater, brackish, and salt marshes. Moreover, this option would provide ample space for restoration of a broad 30H:1V transition zone along the outboard side of the new levee, which would transition into the restored tidal salt marsh. The large transition zone would allow for tidal marsh migration in response to sea level rise. This option provides the greatest opportunity to restore transition zone habitat through horizontal levee design and this option would further the objectives of the *Tidal Marsh Recovery Plan*.

This option would require careful evaluation to protect wildlife in the nearby saltwater slough.

3.2.3 Option 3

Option 3 consists of a new levee extending from high ground at the capped landfill across the Flood Basin to a tie-in at the City of Mountain View border near the Coast Casey Forebay. See Figure 4-6, for a schematic cross section of the levee within the Flood Basin. The northern portion of the Flood Basin would be opened to tidal action and restored to tidal marsh habitat. The reduced Flood Basin would be constructed with new tide gates and a pump station (similar in size or larger than Option 1) that would convey discharges from Matadero, Barron, and Adobe Creeks to the Bay. To maintain the existing level of flood protection from creek flooding, existing floodwalls along both banks of Matadero, Barron and Adobe Creeks upstream and west of Highway 101, to the upstream extent of coastal flood influence may need to be raised. Alternatively, the flood management approach could be modified to rely exclusively on pumping and storage. For instance, the new levee could be shifted closer to the Bay, thereby preserving more storage capacity, and/or the pump station's capacity could be increased.

The City may consider the prioritization of flood management, cost, and restored habitat in greater detail if Option 3 is pursued further. This more in-depth evaluation is listed in Section 8.1 as a recommended future study.

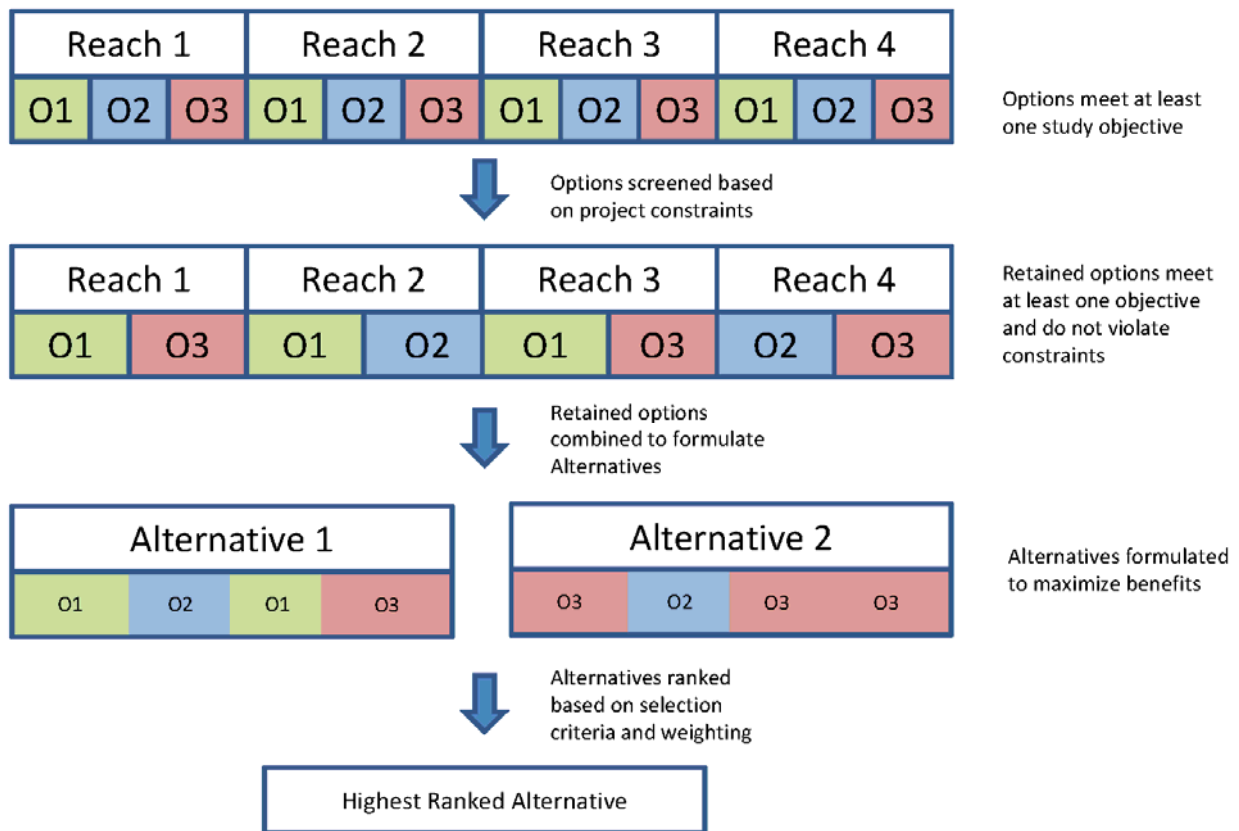
Similar to Option 2, Option 3 would provide the opportunity to restore a substantial area of tidal marsh in the Flood Basin (Figure 5) and have opportunities for a broad restored transition zone and connectivity with restored Charleston Slough.

4 Evaluation of Potential Options

4.1 Initial Screening and Evaluation of Options

As mentioned earlier, 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.

Flow Chart 1. Alternative Formulation and Evaluation Process



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. For this Public Draft Feasibility Report, two reaches, Reaches 10 and 11, are identified with multiple options for each. Each reach option is described in detail below.

4.2 Reach 10

4.2.1 Option 1 (Palo Alto Airport with Flood Gates and Levee Extension through southern Duck Pond) - Retained

The segment of Option 1 parallel to the airport runway would result in a greater surface area of tidal marsh impact relative to Option 2. However, this segment of Option 1 would not result in substantial opportunities for broad transition zone habitat outboard of the proposed levee and thus the ecological function of existing tidal marsh habitat would not be enhanced. This is because the existing tidal marshes adjacent to the runway are relatively narrow (~400-500 ft wide) and would constrain the incorporation of a broad transition zone; a broad transition zone would not leave ample width of tidal marsh along the shoreline. Access to the parking lot and vehicle access on Embarcadero Road would also constrain the width of the levee alignment and opportunities for incorporation of transition zone habitat.

There are opportunities to restore transition zone habitat on the outboard side of the Option 1 levee alignment between Embarcadero Road and the Palo Alto Baylands. This transition zone restoration would benefit endangered marsh species by improving high tide refugia in this location. Option 1 would require only one flood gate at the San Francisquito Creek end of the runway. This flood gate could be manually or automatically deployed during a flood event; however, this would require temporary closure of the airport while the gates are up. There is an opportunity to lower the existing levee height along the San Francisquito Creek side by installing a taller flood gate. By lowering the existing levee height, clearance at the end of the runway could be improved but the gate may result in more frequent temporary closures since it would need to be activated more often.

There is also an existing City of East Palo Alto sanitary sewer line located at the toe of the levee adjacent to the golf course and San Francisquito Creek. The sanitary sewer line will need to be relocated to avoid conflict with the proposed levee footprint in Reach 10.

4.2.2 Option 2 (Palo Alto Airport with Flood Gates) - Retained

Option 2 would greatly reduce the surface area of impacts to tidal marsh habitat, relative to Option 1, by setting the levee landward of its current location parallel to the runway. Moreover, as noted above this levee setback would allow space for the incorporation of a transition zone adjacent to a relatively narrow segment of tidal marsh. This would allow for a gently sloping, relatively wide transition zone (i.e., 30H:1V, ~300 ft wide, along the length of the portion of the levee parallel to the runway (approximately 2,700 feet). The potential to place high-quality transition zone habitat in this location represents a unique opportunity for endangered species conservation, as the adjacent Palo Alto Baylands provides tidal marsh habitat for both California Ridgway's rail and salt marsh harvest mice. Those species are currently exposed to high predation rates during king tides and the restoration of high-tide refugia would benefit the rail and mice populations by reducing predation risk. The large transition zone would also allow for

the landward migration of this narrow strip of tidal marsh as sea level rises, thereby preserving tidal marsh habitat connectivity along the Bay shoreline. This option provides a greater opportunity to restore transition zone habitat that would be more resilient to sea level rise compared to Option 1, and this option would advance the objectives of the *Tidal Marsh Recovery Plan (USFWS 2013)*. The RWQCP outfall is adjacent to this area, which would facilitate the use of treated effluent to support the establishment needs of the transition zone while also providing additional treatment of the effluent discharge. Option 2, however, would result in loss of seasonal wetlands (diked tidal marsh) as a result of the habitat conversion to high marsh and transitional habitat. Thus, this option represents an ecologically beneficial trade-off between seasonal wetlands and tidal marsh/transitional habitat.

Option 2 would also require a total of two flood gates, one at each end of the runway. These flood gates could be manually or automatically deployed during a flood event. As with Option 1, this would require a temporary closure of the airport while the gates are up. There is an opportunity to lower the existing levee height along the San Francisquito Creek side by installing a taller flood gate. By lowering the existing levee height, clearance at the end of the runway could be eliminated or significantly improved. As with Option 1, the gate may need to be activated more often.

The City of East Palo Alto sanitary sewer line will also need to be relocated as described in Option 1.

4.2.3 Option 3 (Palo Alto Airport with Flood Gate) - Retained

Option 3 is a combination of Options 1 and 2 alignments. Option 3 would require one flood gate at the San Francisquito Creek end of the runway similar to Option 1 while allowing for a transition zone along the length of the portion of the levee parallel to the runway like Option 2. Option 3 allows for a reduced overlap length with the existing and proposed RWQCP pipeline and outfall. A portion of the marsh area south of the Palo Alto Duck Pond would be filled to allow for the levee alignment to extend straight to Embarcadero Road. The City of East Palo Alto sanitary sewer line will also need to be relocated as described in Option 1.

4.2.4 4.2Option 4 (Palo Alto Airport with Levee around Duck Pond) - Dropped

Option 4 would increase impacts to tidal marsh habitat relative to Options 1 and 2. This Option would provide flexibility for the incorporation of transition zone habitat along the southern portion of the Option 4 alignment where the outboard tidal marsh is relatively wide (~1400 ft). This would be the highest cost alternative due to the added length of levee required. The City of East Palo Alto sanitary sewer line will also need to be relocated as described in Option 1.

4.3 Reach 11

4.3.1 Option 1 (Palo Alto Flood Basin) - Retained

Option 1 does not provide habitat enhancement or restoration opportunities relative to current conditions. The incorporation of a broad transition zone around the Flood Basin would be constrained by tidal marsh (e.g., Hooks Island) and tidal mudflat in the Bay to the north and Charleston Slough to the east. Option 1 would impact/fill diked salt marsh habitat within the Flood Basin along roughly 2 miles of miles of levee improvements. The benefit of Option 1 is

that by retaining the existing basin size, future floodwall and/or pump station improvements to protect against sea level rise would be smaller than Option 2 or Option 3 would require.

4.3.2 Option 2 (Interior Creeks Levees/Floodwalls) - Retained

Option 2 represents a significant opportunity for large-scale tidal marsh and transition zone habitat restoration. The Flood Basin would be re-connected to tidal exchange which would, over time, restore the basin to tidal marsh. To restore the northern portion of the basin, the outer levee would be breached in strategic locations to create a natural, dendritic slough channel network. The remainder of the perimeter levees would be lowered. Material from the levees would be used to fill/block existing borrow ditches and facilitate a dendritic slough channel network. Additionally, freshwater input to the restored tidal marsh from Matadero and Adobe Creeks would supply sediment and create a gradient of freshwater, brackish, and salt marshes. This option would provide ample space for restoration of a broad, wide transition zone (i.e., 30H:1V, ~300 ft) along the bayward side of new levee, which would transition into the restored tidal salt marsh.

The large transition zone would allow for tidal marsh migration in response to sea level rise. Bridges could be built over the breached locations to allow for continued use of the Bay Trail. This option provides the greatest opportunity to restore transition zone habitat and this option would advance the objectives of the *Tidal Marsh Recovery Plan* (USFWS 2013). However, this option does not satisfy the project objective to remove properties from the FEMA floodplain unless additional floodwall raises are performed along portions of Matadero, Adobe, and Barron Creeks, which is currently not included as part of the SAFER Bay Project.

4.3.3 Option 3 (Partial Palo Alto Flood Basin) - Retained

Similar to Option 2, Option 3 would restore a substantial area of tidal marsh with opportunities for a broad restored transition zone and connectivity with restored Charleston Slough. As with Option 2, this option also does not satisfy the project objective to remove properties from the FEMA floodplain unless additional floodwall raises are performed along portions of Matadero, Adobe, and Barron Creeks, which is currently not included as part of the SAFER Bay Project.

This page intentionally left blank.

5 Development of Alternatives

Section 5 describes the rationale used to develop potential alternatives from the options in each reach, and identifies preliminary alternatives to move forward.

5.1 Alternative Formulation Rationale

To efficiently combine 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 4 below.

Table 4. Summary of Preliminary Alternative Reach Options

Alternatives	Options by Reach	
	10	11
Lowest Cost	Opt 3	Opt 3
Restoration	Opt 2	Opt 2
Recreation	Opt 1	Opt 1

This page intentionally left blank.

6 Evaluation of Alternatives

6.1 Evaluation Methodology

The three alternatives developed in Section 5, lowest cost, greatest opportunity for tidal wetland restoration (or to minimize wetland impact), and the greatest opportunity for recreation 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 preferred alternative.

Evaluation Factors are the primary selection criteria for the highest ranking alternative and were developed based on input from the SFCJPA during the SAFER Bay project kick-off meeting in December of 2014, and revisited in 2017 after the Public Draft Feasibility Study for East Palo Alto and Menlo Park was released. 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. 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 5 below.

Table 5. 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 E.)
- Lifecycle Performance: What is the anticipated lifecycle performance of the proposed flood control feature? Will the proposed feature need replacement sooner 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, or limited right-of-way? Is there a complex levee/floodwall tie-in overlap?
- Real Estate and Access: Who is impacted by the required real estate and access for the proposed flood control 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 need to be acquired?

Operation and Maintenance Evaluation Factor

- Operation and Maintenance (O&M) Performance: Will the flood control 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 control feature collect debris or sediment? Will additional clean out maintenance be required?
- Passive/Active: Will the constructed flood control 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 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 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 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 environmental resources are potentially impacted by the proposed alternative? Wetlands, plants, harvest mouse, Ridgeway's rail, etc.? What mitigation activities would be required and where would they take place?

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 flood control 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 preferred alternative. Table 6 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 5. The individual reach calculation tables are included in Appendix D.

Table 6. Feasibility Evaluation Factors and Consideration Scoring Metrics

Construction Cost and Constructability						Operation and Maintenance						Restoration						Recreation					
Semi-Quantitative Score						Qualitative Score						Semi-Quantitative Score						Semi-Quantitative Score					
Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1
	<=\$25M	>\$25M <=\$30M	>\$30M <=\$50M	>\$50M <=\$100M	>\$100M		Easiest	Minor Difficulty	Moderate Difficulty	Some Difficulty	Most Difficult		>=500Ac	<500Ac >=300Ac	<300Ac >=150Ac	<150Ac >=50Ac	<50Ac		Excellent	Good	Moderate	Poor	Very Poor
Construction Cost						O&M Performance						Acres of Enhanced Tidal Marsh Habitat						Bay Trail					
Qualitative Score						Qualitative Score						Qualitative Score						Qualitative Score					
Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1
	Easiest	Minor Difficulty	Moderate Difficulty	Some Difficulty	Most Difficult		Easiest	Minor Difficulty	Moderate Difficulty	Some Difficulty	Most Difficult		Excellent	Good	Moderate	Poor	Very Poor		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts
Lifecycle Performance						Debris and Sediment Management						Interagency Coordination						Interpretive/Viewing					
Semi-Quantitative Score						Qualitative Score						Qualitative Score						Qualitative Score					
Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1
	No Season: All not needed	<1 Season	2 Seasons	3 Seasons	>3 Seasons		Passive	Mostly Passive	Passive & Active	Mostly Active	Active		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts
Construction Schedule						Passive/Active						Potential Impacts/Mitigation Requirements						Potential Impacts/Mitigation Requirements					
Qualitative Score						Qualitative Score						Qualitative Score						Qualitative Score					
Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1
	Easiest	Minor Difficulty	Moderate Difficulty	Some Difficulty	Most Difficult		Excellent	Good	Moderate	Poor	Very Poor		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts
Construction Considerations						Flood Fighting Accessibility						Potential Impacts/Mitigation Requirements						Potential Impacts/Mitigation Requirements					
Qualitative Score						Qualitative Score						Qualitative Score						Qualitative Score					
Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1	Point Score	5	4	3	2	1
	No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts		No Impacts	Modest Impacts	Moderate Impacts	Severe Impacts	Most Impacts
Real Estate and Access						Real Estate and Access						Real Estate and Access						Real Estate and Access					

7 Feasibility Level Cost Estimates

Feasibility level opinions of probable construction cost were developed for each option and summarized for each alternative. Quantities are based on output from Auto CAD Civil3D, an industry standard software program capable of producing 3-dimensional models. Earthwork quantities were estimated by multiplying the areas of a typical cross section by the length for which the typical cross section is applicable. Each typical cross section was prepared by using Civil3D to estimate the average existing terrain for a given levee length, then preparing a levee design that is typical for the same reach of levee. The geometry for each typical section is shown in Figures 4-1 through 4-11.

Unit prices for each material were estimated from reviewing construction costs for similar flood protection projects within the same area and comparing those costs to published cost estimating tools such as RS Means.

Total cost for each alternative assuming a 30% contingency and 10.8% escalation is summarized in Table 7. Individual Reach Feasibility Level Cost Estimates and quantity breakdown is included in Appendix E.

Table 7. Feasibility Level Cost Estimates per Alternative

Alternatives	Total Estimated Cost (assuming 30% contingency and 10.8% escalation)
Lowest Cost	\$106,973,000
Restoration	\$287,195,000
Recreation	\$117,643,000

Additional general cost assumptions include:

- Top of levee design elevations are El 16.0 NAVD 88 for all levees.
- 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.
- Headwalls will be constructed at the upstream and downstream face of the bridges to contain flow of water. Bridges will not be raised.
- Contractor General Conditions are not included.
- Levees will incorporate 2 layers of geogrid reinforcement near the base of levees.
- Existing floodwalls will be removed and replaced except for Reach 11 Option 3 below.
- Concrete within creeks will not be replaced.
- Pump stations are designed to convey approximately 2,200 cfs.

- New bike paths are assumed to be constructed of a 6-inch thick layer of asphalt concrete without aggregate base, similar what was constructed for the SF Bay to Highway 101 Project.
- This cost estimate does not include transition zones.
- Reach 11 Option 3 does not include the added cost of floodwalls. It is assumed that floodwalls will not need to be raised.

This page intentionally left blank.

8 Alternative Ranking

Each option was ranked 1-5, averaged, and tabulated into Table 8 below. The lowest cost alternative received an average score of 3.0 and is illustrated in Figure 7. The restoration alternative received an average weighted score of 2.8 and is illustrated in Figure 8. The recreation alternative received an average weighted score of 2.7 and is illustrated in Figure 9.

The lowest cost alternative was the highest ranking alternative. Proposed tidal marsh restoration and enhancement opportunities are also included in Figure 10 for the low cost alternative, Figure 11 for the restoration alternative and Figure 12 for the recreation alternative.

8.1 Additional Evaluation Needed

8.1.1 Landfill Evaluation

Additional information regarding the construction of the capped landfill and underground piped network is required to verify where the levee footprint and perimeter service road can be placed without causing damage to the capped landfill. Ideally, the levee prism would be placed as close as possible to the capped landfill to reduce infill of the Palo Alto Flood Basin; however, a levee prism paired with a transition zone may be considered to provide additional habitat as well as reduce overall wave action against the levee slope. A more in depth design analysis is required to better understand the capped landfill location and the overall functionality of the system.

8.1.2 Federal Aviation Administration (FAA) / Palo Alto Municipal Airport Coordination

Additional coordination with the FAA and the Palo Alto Municipal Airport is needed to discuss in more detail flood protection features within the airport flight path and adjacent to the runway. Additionally, coordination on the timing of survey efforts, geotechnical investigation, and construction is required.

8.1.3 Reach 11 – Detailed Hydraulic, Structural and Creek Accreditation Assessment

Coastal levee alignment options for Reach 11, particularly Option 2 and Option 3 that eliminate or reduce flood storage capacity in the Flood Basin, would affect flood management for the interior creeks which drain through Reach 11 to discharge to the Bay. For screening these options' feasibility, this study used a simplified hydraulic assessment and did not consider the structural details of the existing floodwalls or the potential community concerns about floodwall height. If Option 2 or Option 3 is considered for further planning and design, more detailed hydraulic and structural assessments, as well as finer increments of sea level rise, are recommended. Option 1 could also benefit from more detailed assessment.

Table 8. Feasibility Evaluation Factors and Consideration Scoring Metrics

Feasibility Evaluation Scoring Matrix and Calculation - SAFER Bay Task Order 2 Alternatives				Low Cost	Restoration	Recreation
Evaluation Factor	Wt %	Considerations	Wt%	Alt 1	Alt 2	Alt 3
Construction Cost and Constructability	30%	Construction Cost	50%	3.0	2.5	3.0
		Lifecycle Cost	5%	2.0	3.0	3.0
		Construction Schedule	5%	2.5	3.0	3.0
		Construction Considerations and Access	20%	3.0	1.5	3.5
		Real Estate Acquisition	20%	2.0	1.5	3.5
					2.7	2.2
Operation and Maintenance	20%	O&M Cost	30%	2.5	2.5	2.5
		Debris and Sediment Management	30%	3.0	5.0	3.0
		Passive/Active	20%	2.5	3.5	2.5
		Flood Fighting Accessibility	20%	2.5	2.5	2.0
			2.7	3.5	2.6	
Restoration	30%	Acres of Enhanced Tidal Marsh Habitat	40%	3.5	4.0	1.5
		Interagency Coordination	20%	3.0	1.0	2.5
		Potential Impacts/Mitigation Requirements	40%	3.0	3.0	1.0
			3.2	3.0	1.5	
Recreation	20%	Bay Trail	50%	3.5	2.5	4.5
		Interpretive/Viewing	50%	3.0	2.0	4.0
			3.3	2.3	4.3	
Total Alternative Score	100%			3.0	2.7	2.8

Overall Ranking Order:	1	3	2
-------------------------------	----------	----------	----------

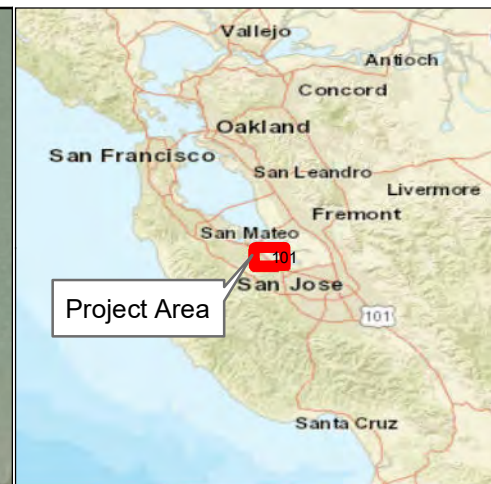
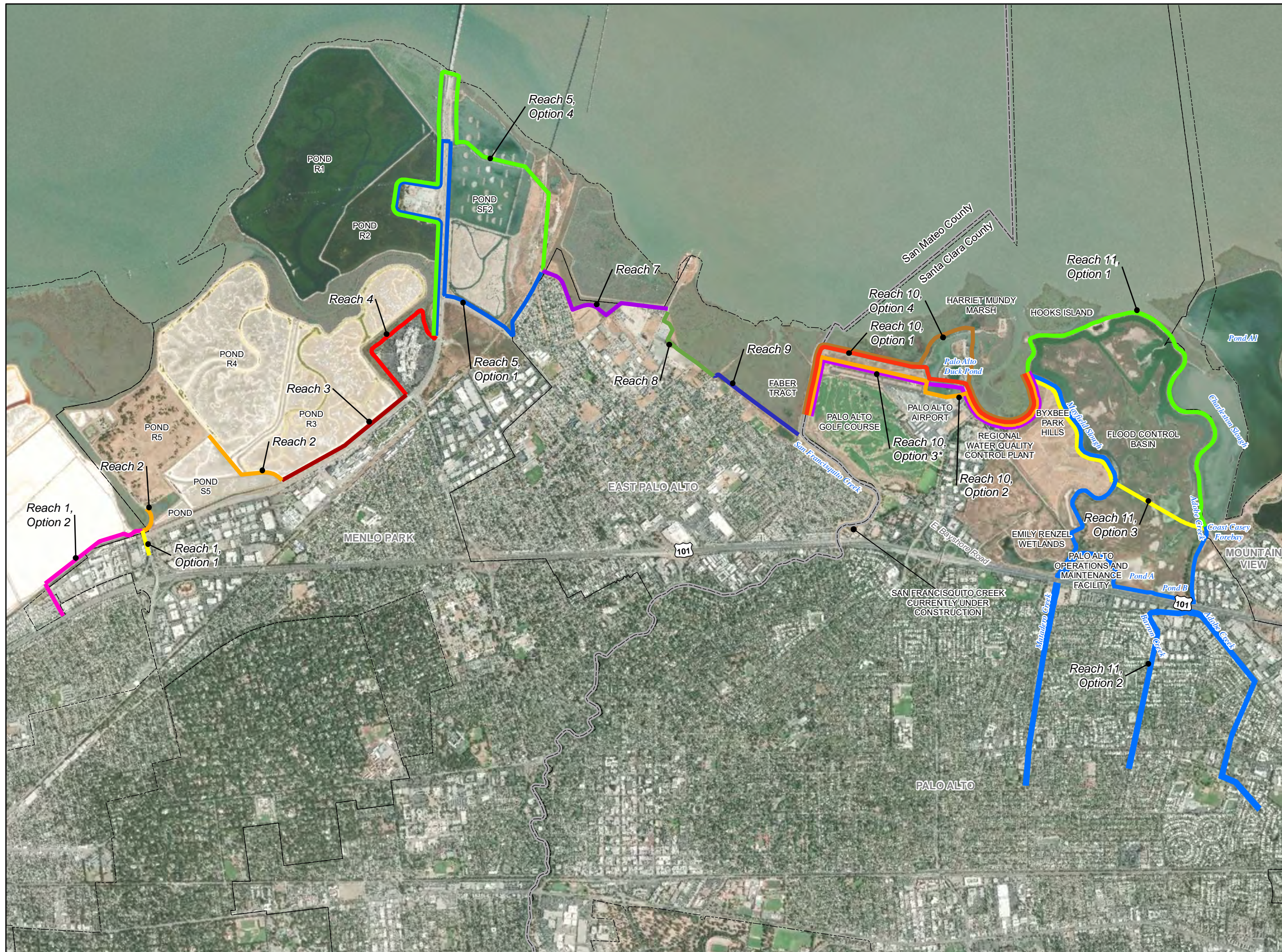
9 References

- 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.
- Bay Conservation and Development Commission (BCDC), NOAA's Office for Coastal Management (NOAA OCM), Metropolitan Transportation Commission, and Bay Area Toll Authority. 2017. Adapting to Rising Tides Bay Area Sea Level Rise Analysis and Mapping Project. Final Report.
- Beller, E.E., Salomon, M., and R.M. Grossinger. 2013. An assessment of the South Bay historical tidal-terrestrial transition zone. Produced for the U.S. Fish and Wildlife Service Coastal Program. San Francisco Estuary Institute. Richmond, California. Publication No. 693. https://www.sfei.org/sites/default/files/biblio_files/SFEI_SouthBay_Tzone_memo_2013-1.pdf
- California Natural Resources Agency, 2018. *Safeguarding California Plan: 2018 Update California's Climate Adaptation Strategy*, January. <http://resources.ca.gov/docs/climate/safeguarding/update2018/safeguarding-california-plan-2018-update.pdf>
- Collins, J.N. and R.M. Grossinger. 2004. Syntheses of Scientific Knowledge for Maintaining and Improving Functioning of the South Bay Ecosystem and Restoring Tidal Salt Marsh and Associated Habitats over the Next 50 Years at Pond and Pond-complex Scales. Report to the Science Team of the South Bay Salt Pond Restoration Project. San Francisco Estuary Institute, Oakland, CA.
- Collins, J.N. and D. Goodman-Collins. 2010. Data collection protocol: Plant community structure of intertidal--upland ecotone. San Francisco Estuary Wetlands Regional Monitoring Program. San Francisco Estuary Institute. Richmond, California.
- Danish Hydraulics Institute (DHI). 2013. Regional Coastal Hazard Modeling Study for South San Francisco Bay Final Draft Report. Prepared for FEMA Region IX.
- EM 1110-2-2705, Structural Design of Closure Structures for Local Flood Control Protection Projects (USACE 1994).
- EM 1110-2-2902, Conduits, Culverts and Pipes (Change 1) (USACE 1998)
- ER 1110-2-100, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures (USACE 1995).
- ESA PWA. 2012. Shoreline Regional Park Community: Sea Level Rise Study Feasibility Report and Capital Improvement Program. Prepared for the City of Mountain View.
- Federal Emergency Management Agency (FEMA), Baker/AECOM. 2014. A South San Francisco Bay Coastal Flood Hazard Study, Santa Clara County, California Study Report. Contract Number: HSFEHQ-09-D-0368; Task Order: HSFE09-09-J-0001; MIP Case Number: 11-09-2194S (Baker/AECOM 2014).
- FEMA. 2012. Flood Insurance Rate Map (FIRM) for San Mateo County, California, and Incorporated Areas.

- Goals Project. 1999. Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco, Calif./S.F. Bay Regional Water Quality Control Board, Oakland, California.
- Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystems Habitat Goals Science Update 2015. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.
- Grossinger, R.M., C.J. Striplen, R.A. Askeveld, E. Brewster, and E.E. Beller. 2007. Historical landscape ecology of an urbanized California valley: Wetlands and woodlands in the Santa Clara Valley. *Landscape Ecology* 22:103-120.
- Grossinger, R.M. 2009. The Historical Ecology of the South Santa Clara County from Coyote Creek to the Pajaro Basin. Committee for Green Foothills Conference: South Valley Landscapes: Where and Why They Should Be Preserved. San Francisco Estuary Institute.
- H.T. Harvey & Associates and SFEI. 2012. U. S. Army Corps of Engineers South San Francisco Bay Shoreline Study California Rapid Assessment Method (CRAM) Habitat Evaluation. Prepared for ESA PWA and California Coastal Conservancy.
- National Research Council (NRC) 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Prepared by Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies.
- Ocean Protection Council (OPC). 2018. State of California Sea-Level Rise Guidance 2018 Update. Developed by Coastal and Ocean Working Group of the California Climate Action Team. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf
- Palo Alto. 2008. Palo Alto Baylands Master Plan, 4th Edition.
- San Francisco Bay Conservation and Development Commission (BCDC). 2011. Living with a rising bay: Vulnerability and adaptation in San Francisco Bay and its shoreline. Staff Report. Approved on 6 October 2011. San Francisco, California.
- San Francisco Estuary Partnership, 2016. 2016 Comprehensive Conservation and Management Plan for the San Francisco Estuary (Estuary Blueprint), <http://www.sfestuary.org/wp-content/uploads/2016/10/CCMPFinalOct2016.pdf>
- Santa Clara Valley Water District. 2002. Matadero/Barron Creeks Long-Term Remediation Planning Study, Final Engineer's Report.
- Schaaf and Wheeler. 2015. Storm Drain Master Plan Update. Prepared for City of Palo Alto.
- Schaaf and Wheeler. 2016. Palo Alto Flood Basin Hydrology. Corrected Final Report. Prepared for the Santa Clara Valley Water District.
- Shellhammer, H. 2012. Chapter 13: Small Mammals. Ecology, Conservation, and Restoration of Tidal Marshes, the San Francisco Estuary. Pages 195-303 in Palaima, A. (editor) University of California Press, Berkeley, California. 265 pages.
- U.S. Army Corps of Engineers (USACE). 2011. Sea-Level Change Consideration for Civil Works Programs. EC 1165-2-212.
- U.S. Army Corps of Engineers (USACE). 2015. Final 2015 Regional Compensatory Mitigation and Monitoring Guidelines for South Pacific Division. January 12.

- U.S. Fish and Wildlife Service [USFWS]. 1984. Salt marsh harvest mouse and California clapper rail recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon.
- U.S. Fish and Wildlife Service [USFWS]. 2013. Recovery plan for tidal marsh ecosystems of Northern and Central California. Region 8 U.S. Fish and Wildlife Service, Sacramento, California.
- U.S. Fish and Wildlife Service [USFWS]/California State Coastal Conservancy. 2016. South Bay Salt Pond Restoration Project- Final Environmental Impact Statement/Report.

Figures



- SAFER Bay North**
- Reach 1, Option 1
 - Reach 1, Option 2
 - Reach 2
 - Reach 3
 - Reach 4
 - Reach 5, Option 1
 - Reach 5, Option 4
 - Reach 7
 - Reach 8
 - Reach 9

- SAFER Bay South**
- Reach 10, Option 1
 - Reach 10, Option 2
 - Reach 10, Option 3
 - Reach 10, Option 4
 - Reach 11, Option 1
 - Reach 11, Option 2
 - Reach 11, Option 3
- 0 0.5 Miles
1 in = 0.5 miles

**SAFER Bay Project
Task Order 2**

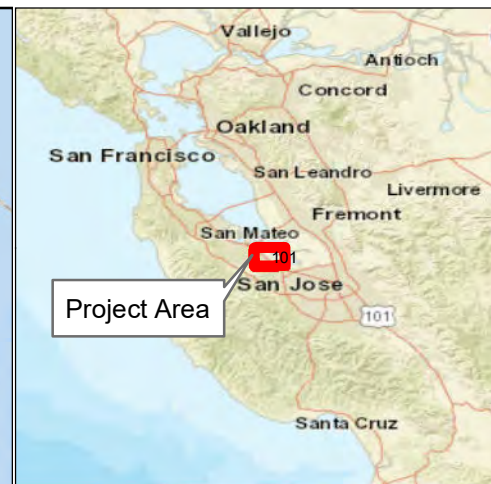
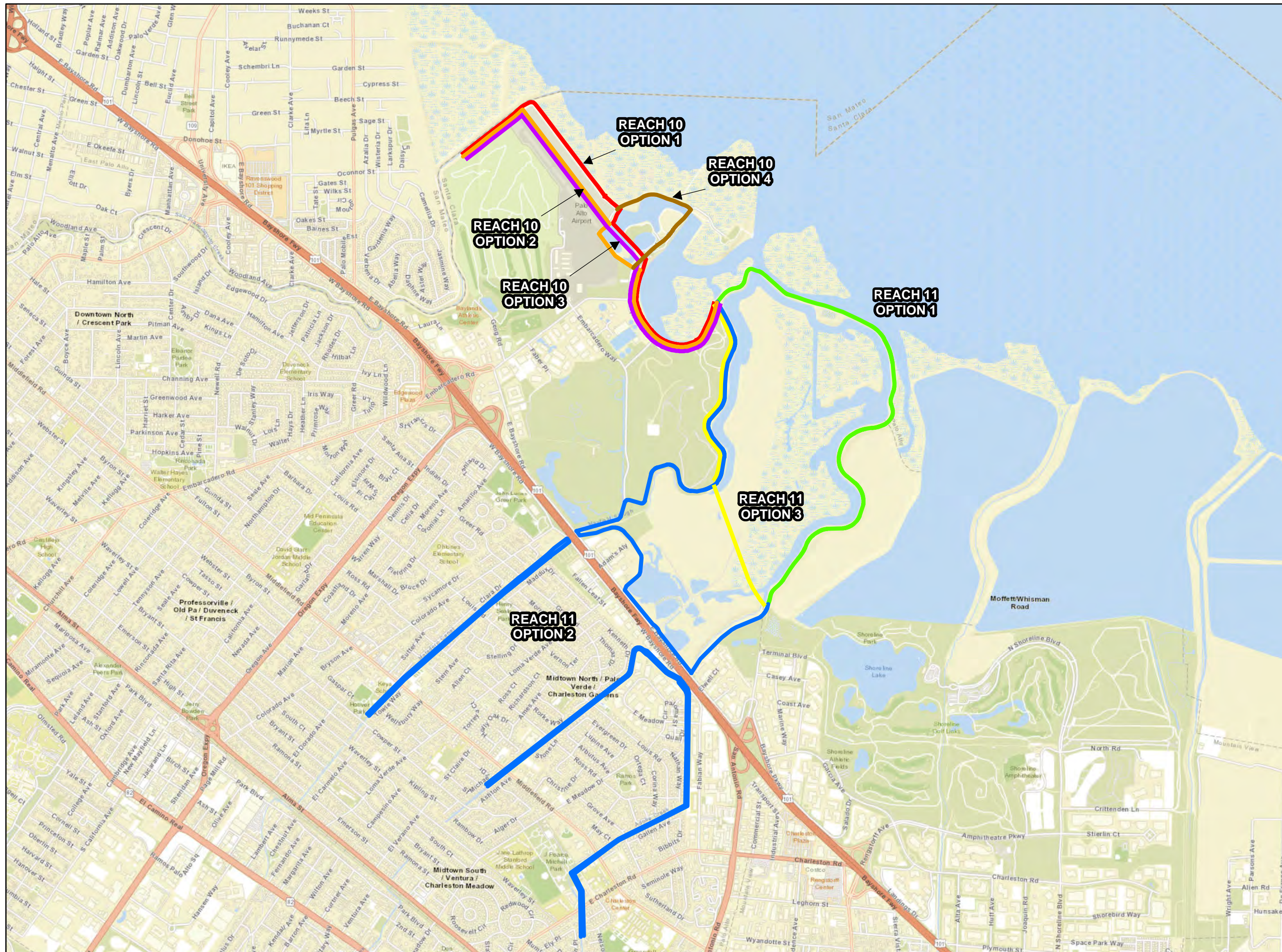
**Proposed Reach
Alignments**

Figure 1

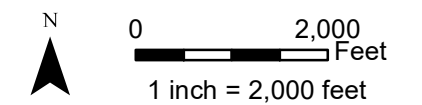
Data Sources: Base Map-ESRI Maps and Data 2017;
All other data - HDR 2018

Datum: NAD83 California State Plane, Zone 3 US ft

NOVEMBER 2018



- Reach, Option**
- Reach 10_Option 1
 - Reach 10_Option 2
 - Reach 10_Option 3
 - Reach 10_Option 4
 - Reach 11_Option 1
 - Reach 11_Option 2
 - Reach 11_Option 3



**SAFER Bay Project
Task Order 2**

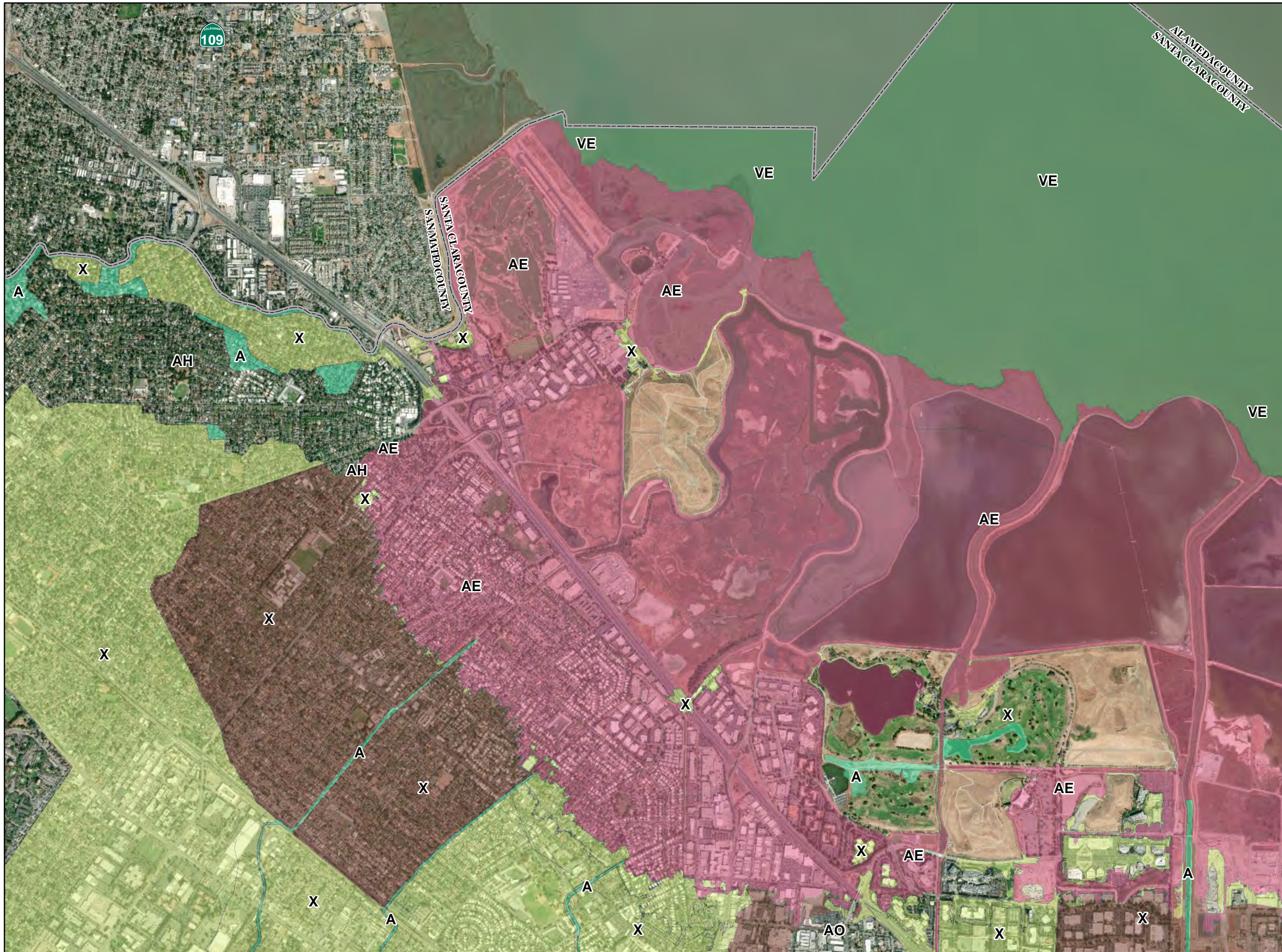
**Feasibility Report
Project Reaches
and Options**

Figure 2

Data Sources: Base Map-ESRI Maps and Data 2017;
All other data - HDR 2018

Datum: NAD83 California State Plane, Zone 3 US ft

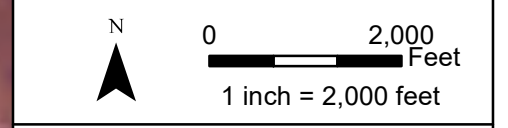
NOVEMBER 2018



County Boundary

Flood Zone

- A
- AE
- VE
- X, 0.2 PCT ANNUAL CHANCE FLOOD HAZARD
- X, AREA WITH REDUCED FLOOD RISK DUE TO LEVEE



**SAFER Bay Project
Task Order 2**

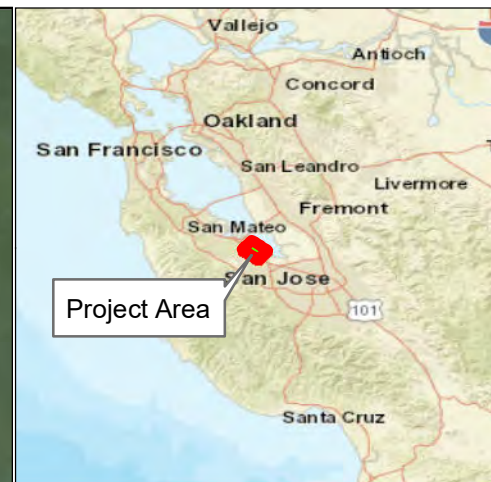
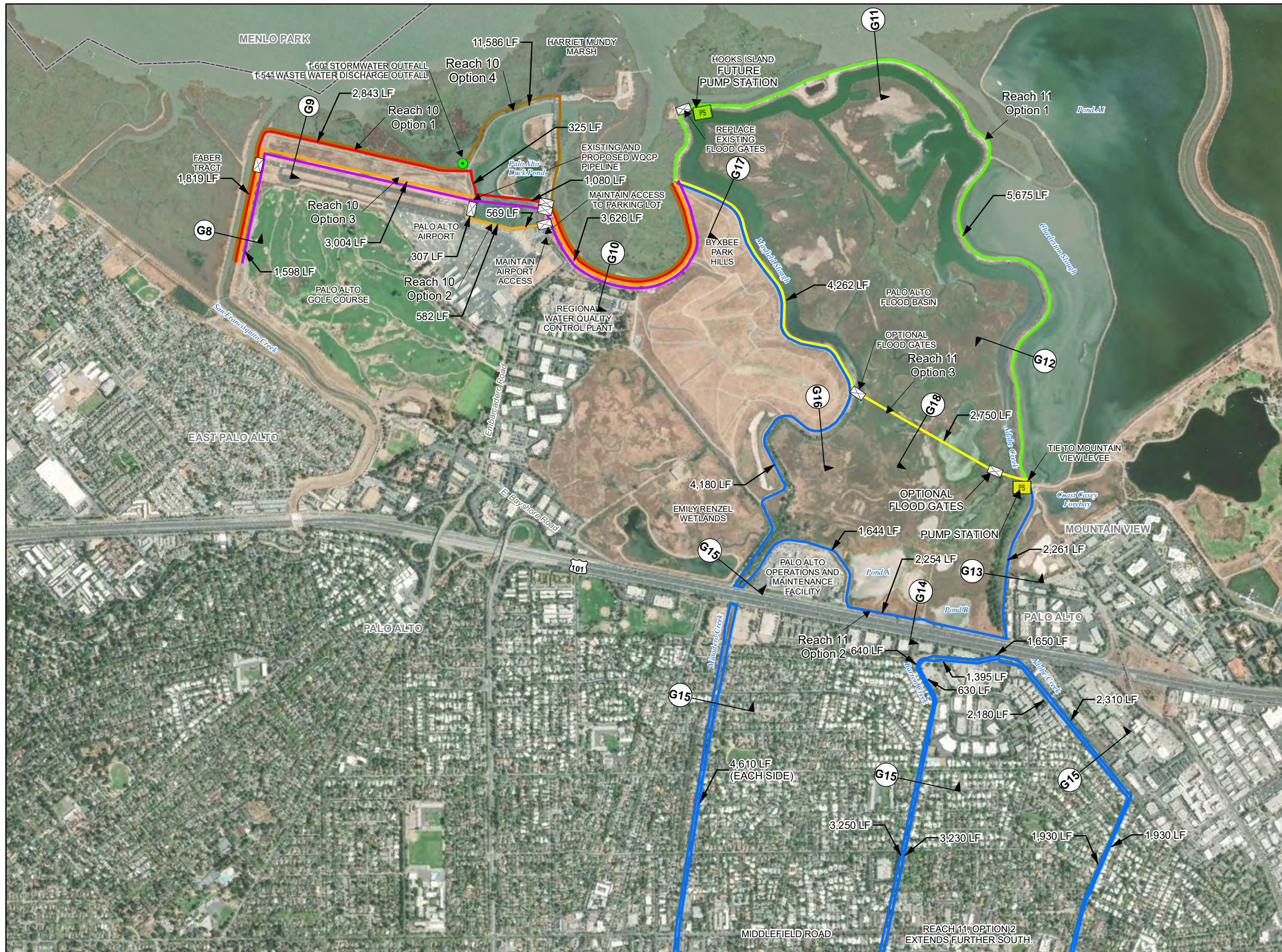
**Preliminary FEMA
Flood Insurance
Rate Map Floodplains
(7/8/16)**

Figure 3

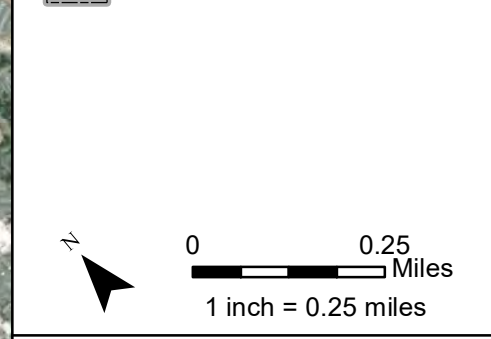
Data Sources: Base Map-ESRI Maps and Data 2017; FEMA: 2016; All other data - HDR 2018

Datum: NAD83 California State Plane, Zone 3 US ft

NOVEMBER 2018



- Existing Discharge Outfall
 - X Flood Gates
 - PS Pump Station, Reach 11 Option 1
 - PS Pump Station, Reach 11 Option 3
- Reach, Option**
- Reach 10, Option 1 (9,768 ft)
 - Reach 10, Option 2 (9,614 ft)
 - Reach 10, Option 3 (9,376 ft)
 - Reach 10, Option 4 (11,586 ft)
 - Reach 11, Option 1 (11,849 ft)
 - Reach 11, Option 2 (44,315 ft)
 - Reach 11, Option 3 (6,927 ft)
- City Limits



SAFER Bay Project

**Alignment Reach and Option
From San Francisquito Creek
to City of Mountain View**

Figure 4

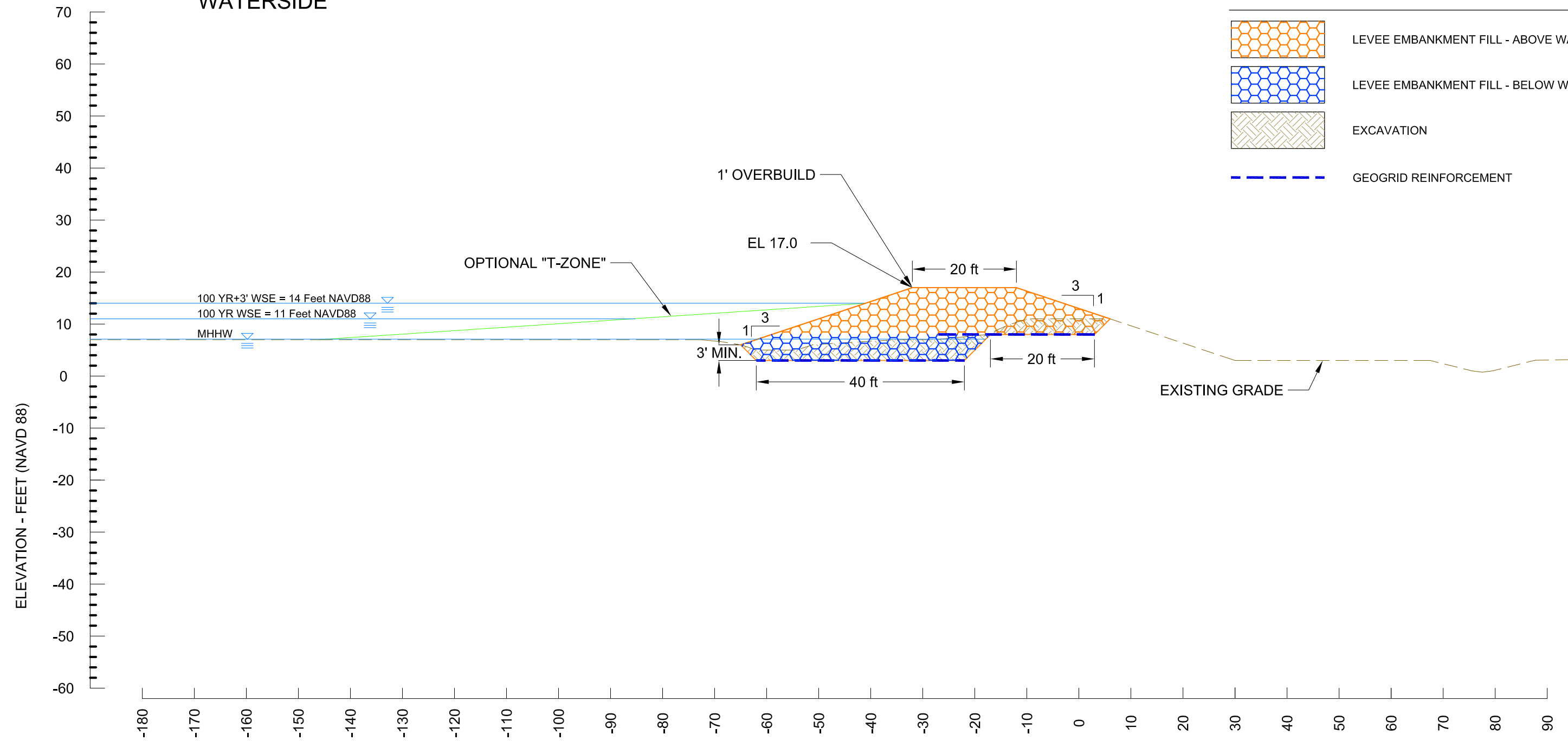
Data Sources: Base Map-ESRI Maps and Data 2014;
All other data - HDR 2014

Datum: NAD83 California State Plane, Zone 3 US ft

NOVEMBER 2018

LANDSIDE

WATERSIDE



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.



ANALYSIS CROSS SECTION G8

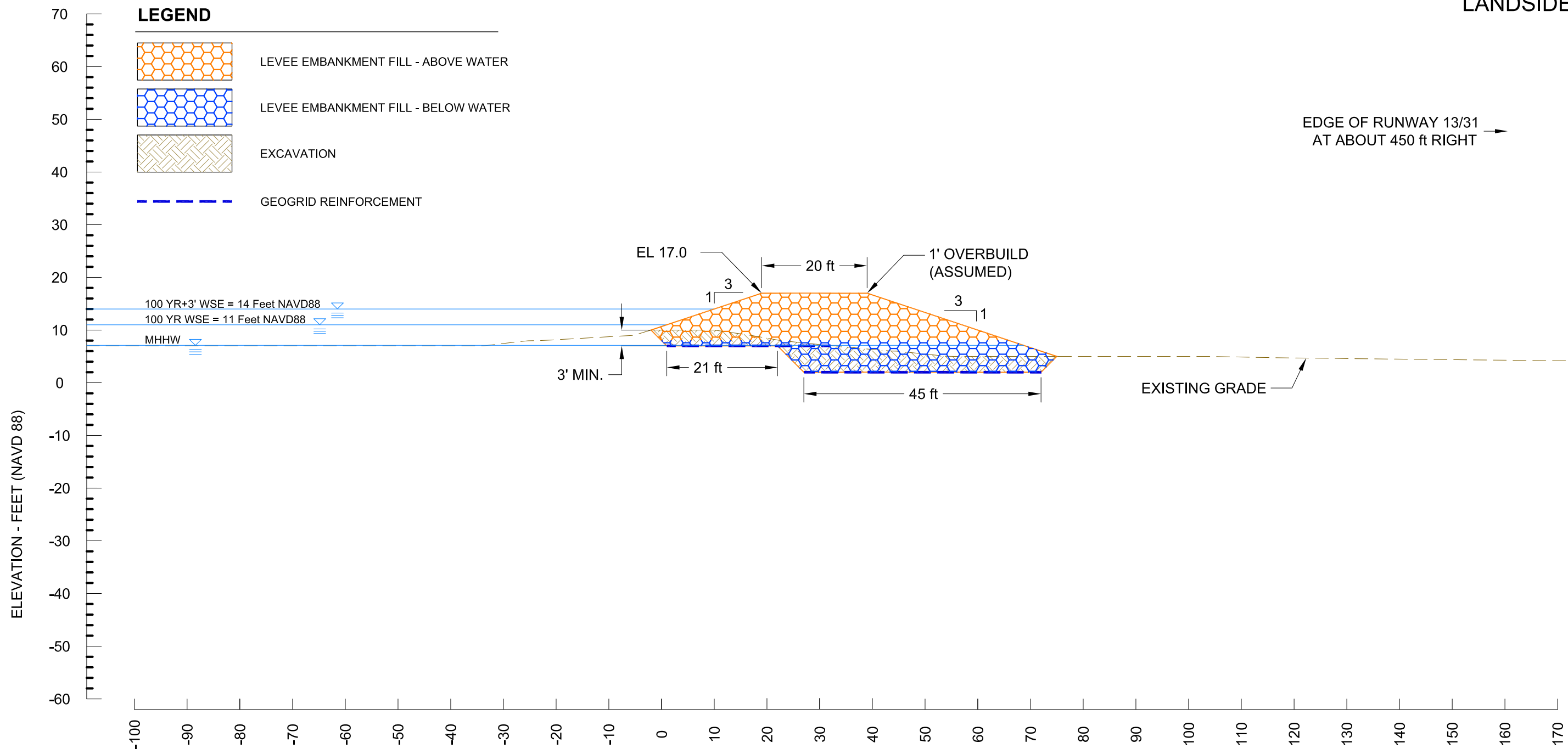
SAFER BAY PROJECT
TASK ORDER NO. 2
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
DEC 2018

Figure
4-1

WATERSIDE

LANDSIDE



NOTES:
 1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.



ANALYSIS CROSS SECTION G9

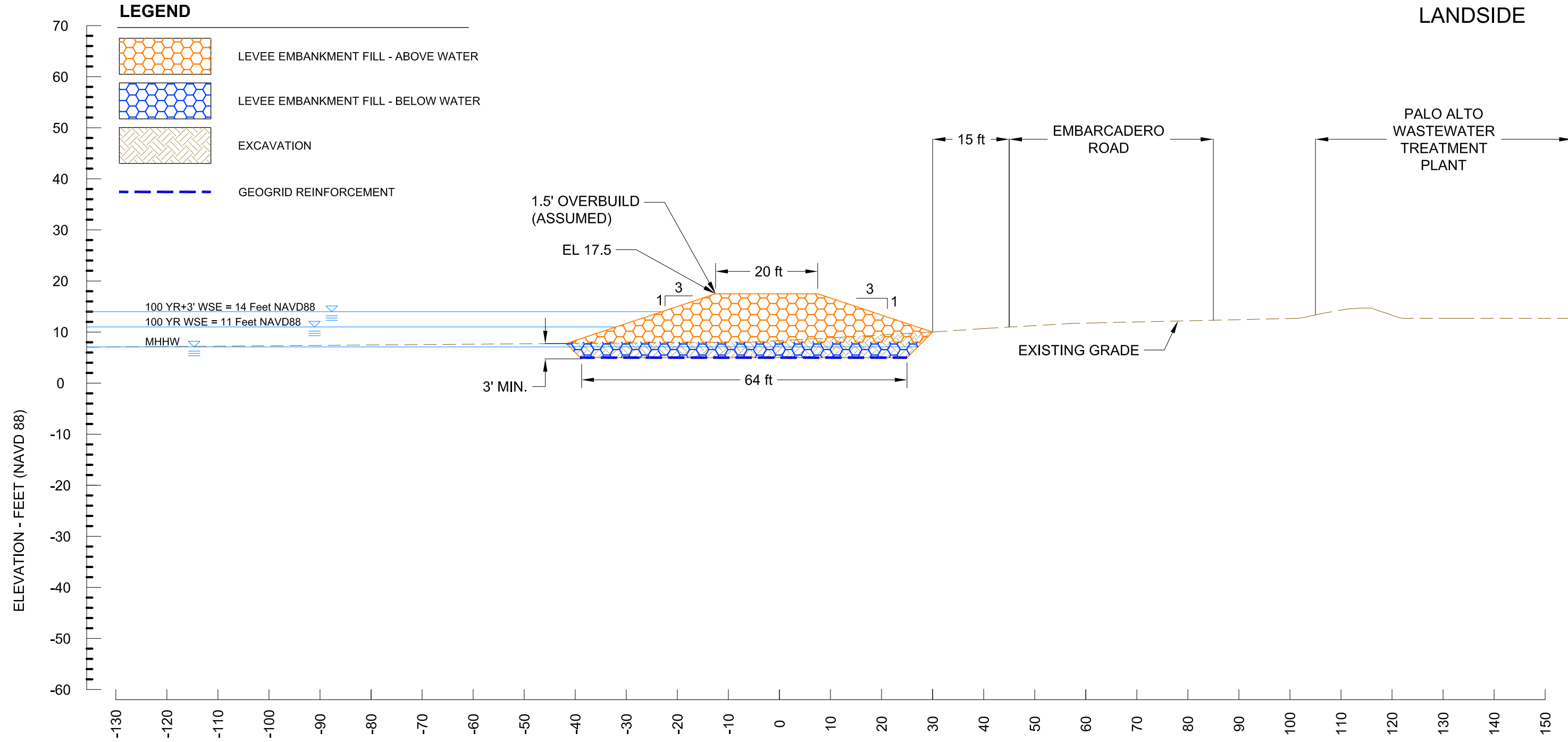
SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

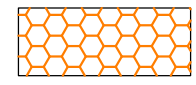
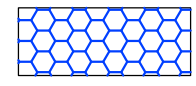


Figure
 4-2

WATERSIDE

LANDSIDE



LEGEND

-  LEVEE EMBANKMENT FILL - ABOVE WATER
-  LEVEE EMBANKMENT FILL - BELOW WATER
-  EXCAVATION
-  GEOGRID REINFORCEMENT

ELEVATION - FEET (NAVD 88)

- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

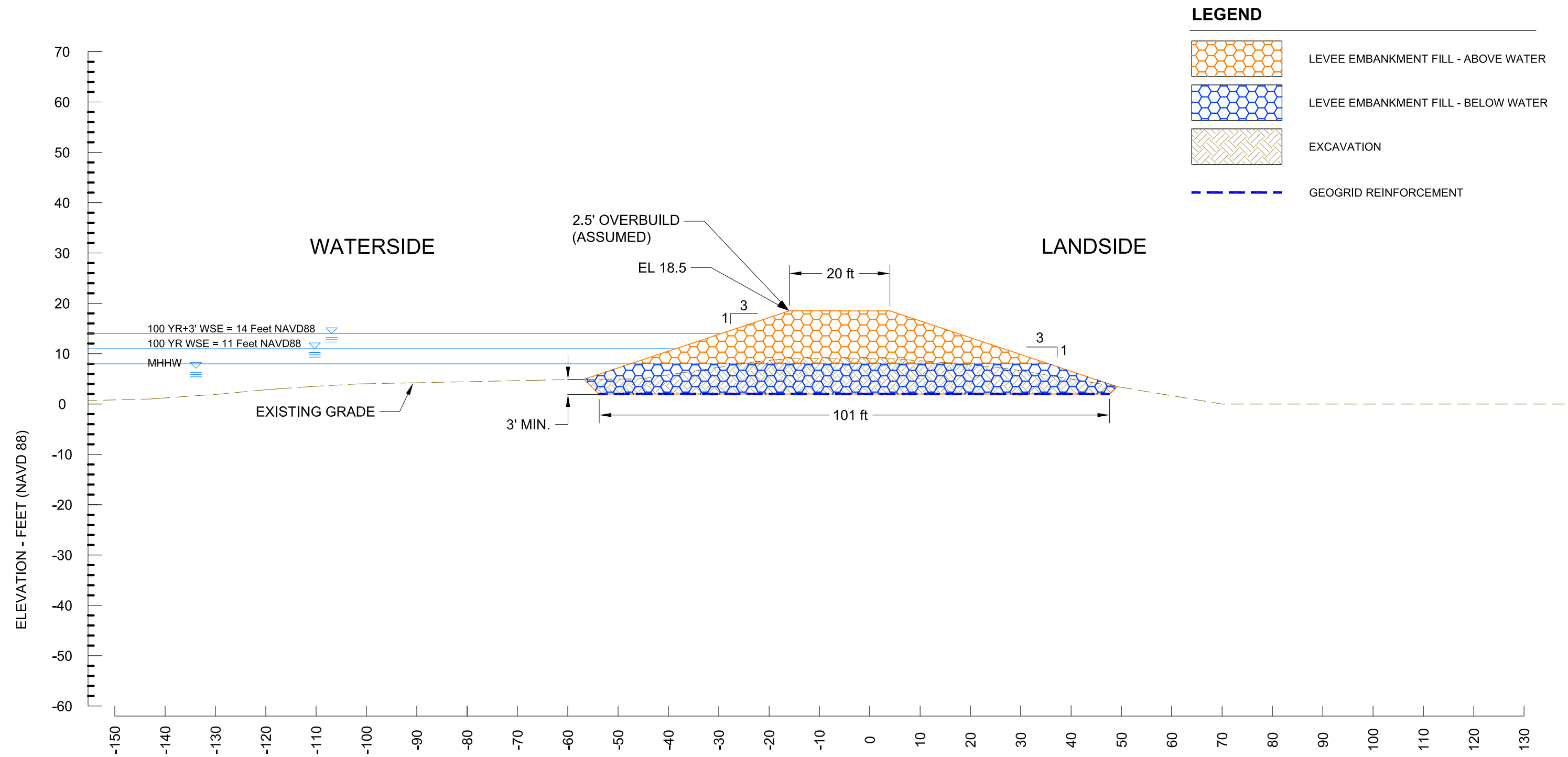


ANALYSIS CROSS SECTION G10

SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-3



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

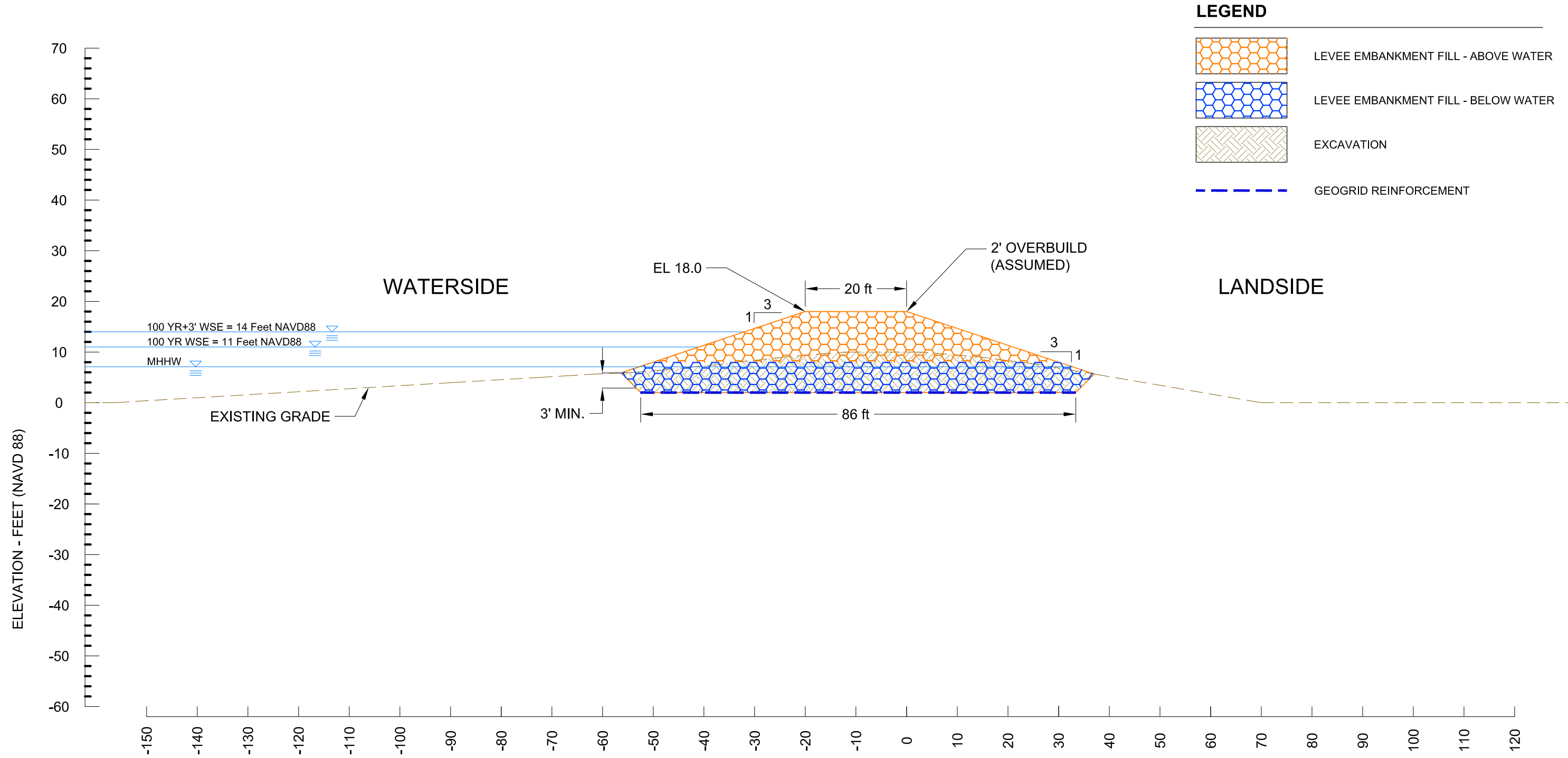


ANALYSIS CROSS SECTION G11

SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-4



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.



ANALYSIS CROSS SECTION G12

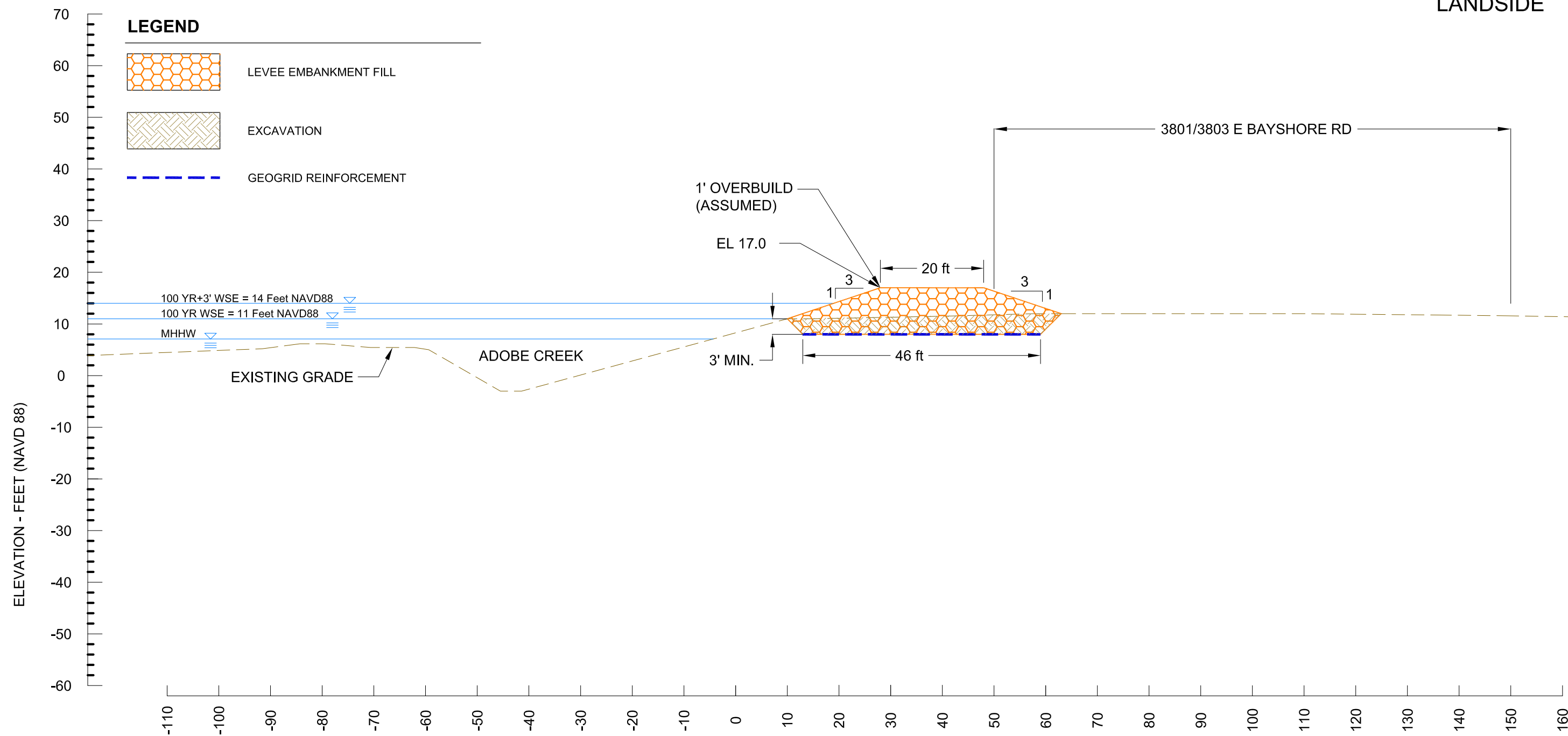
SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-5

WATERSIDE

LANDSIDE



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.



ANALYSIS CROSS SECTION G13

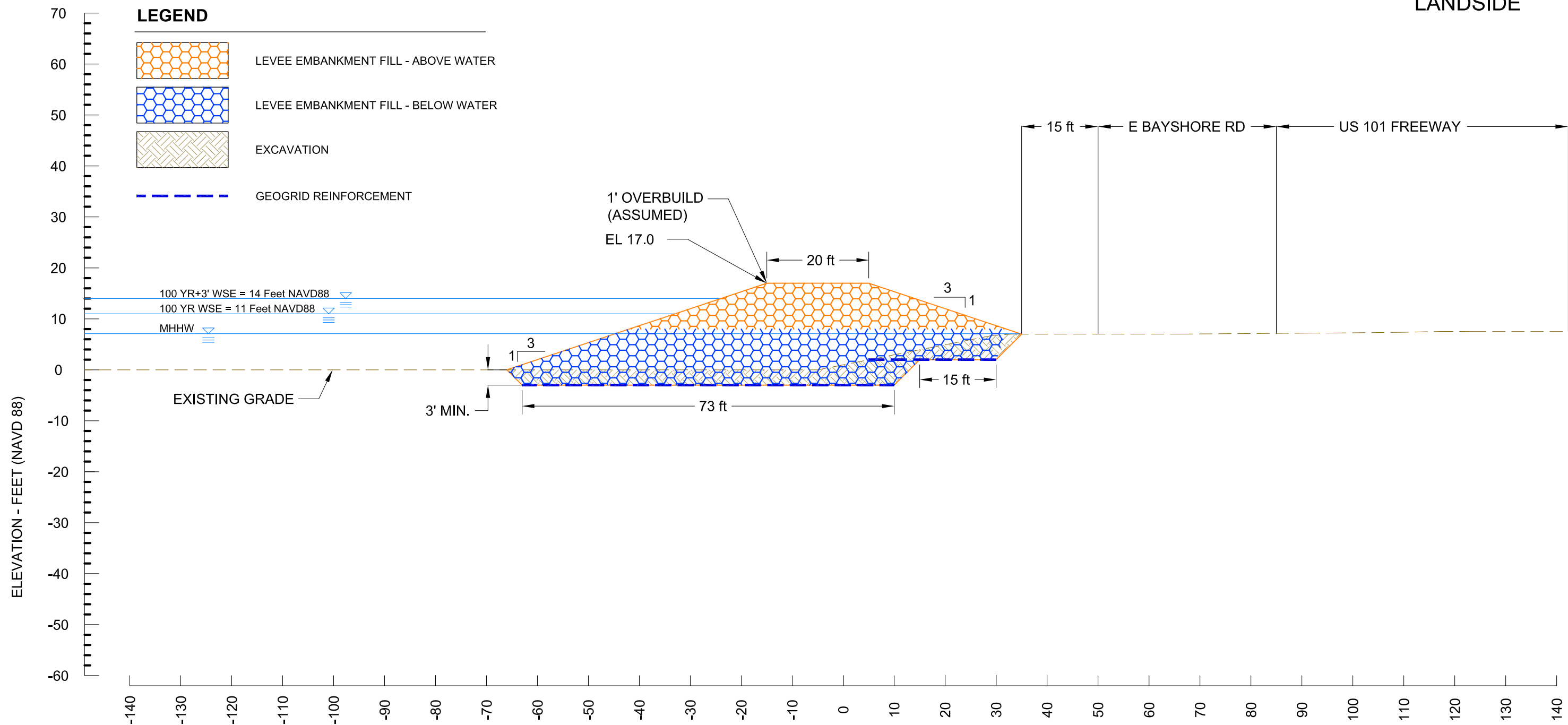
SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-6

WATERSIDE

LANDSIDE



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

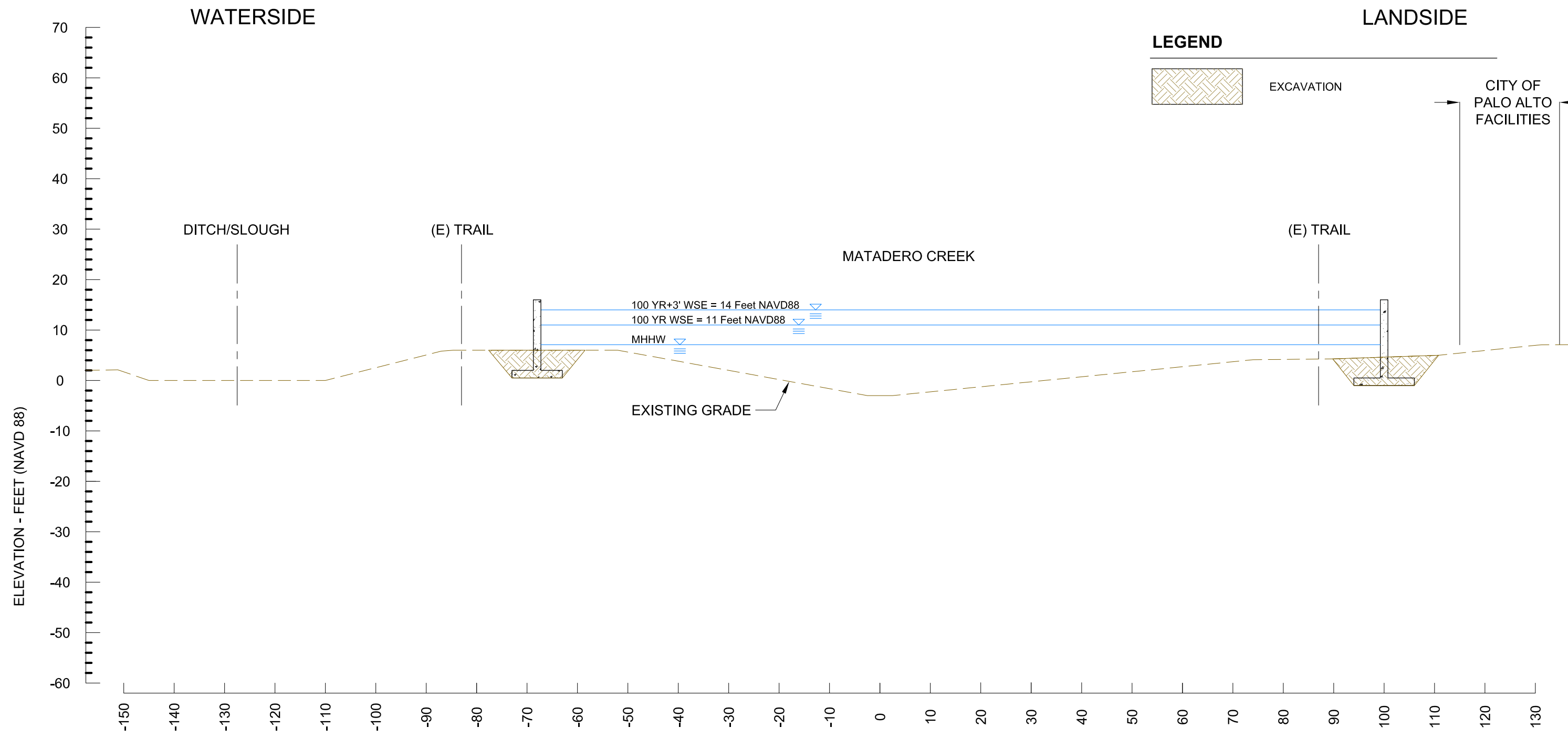


ANALYSIS CROSS SECTION G14

SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-7



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.

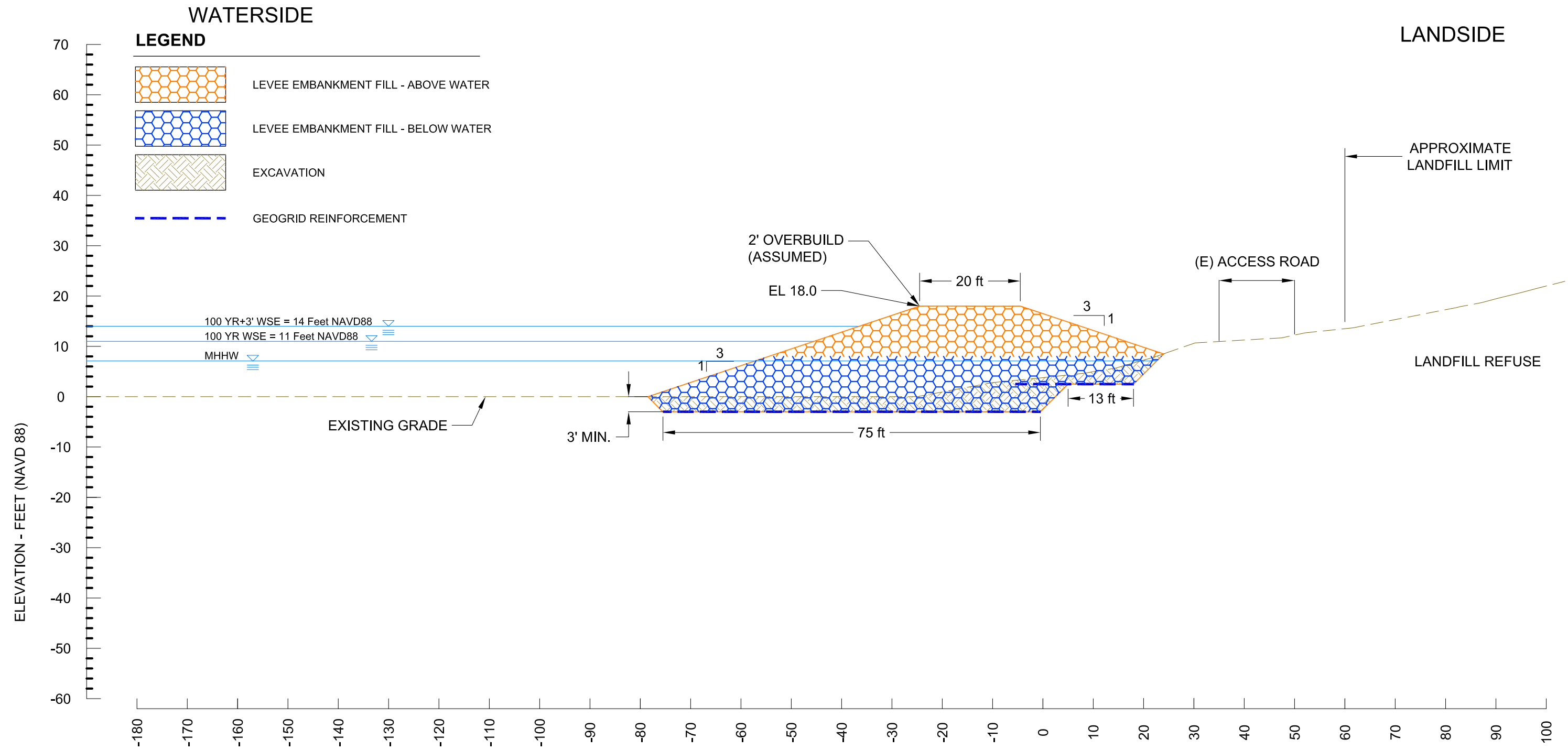


ANALYSIS CROSS SECTION G15

SAFER BAY PROJECT
TASK ORDER NO. 2
MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
DEC 2018

Figure
4-8



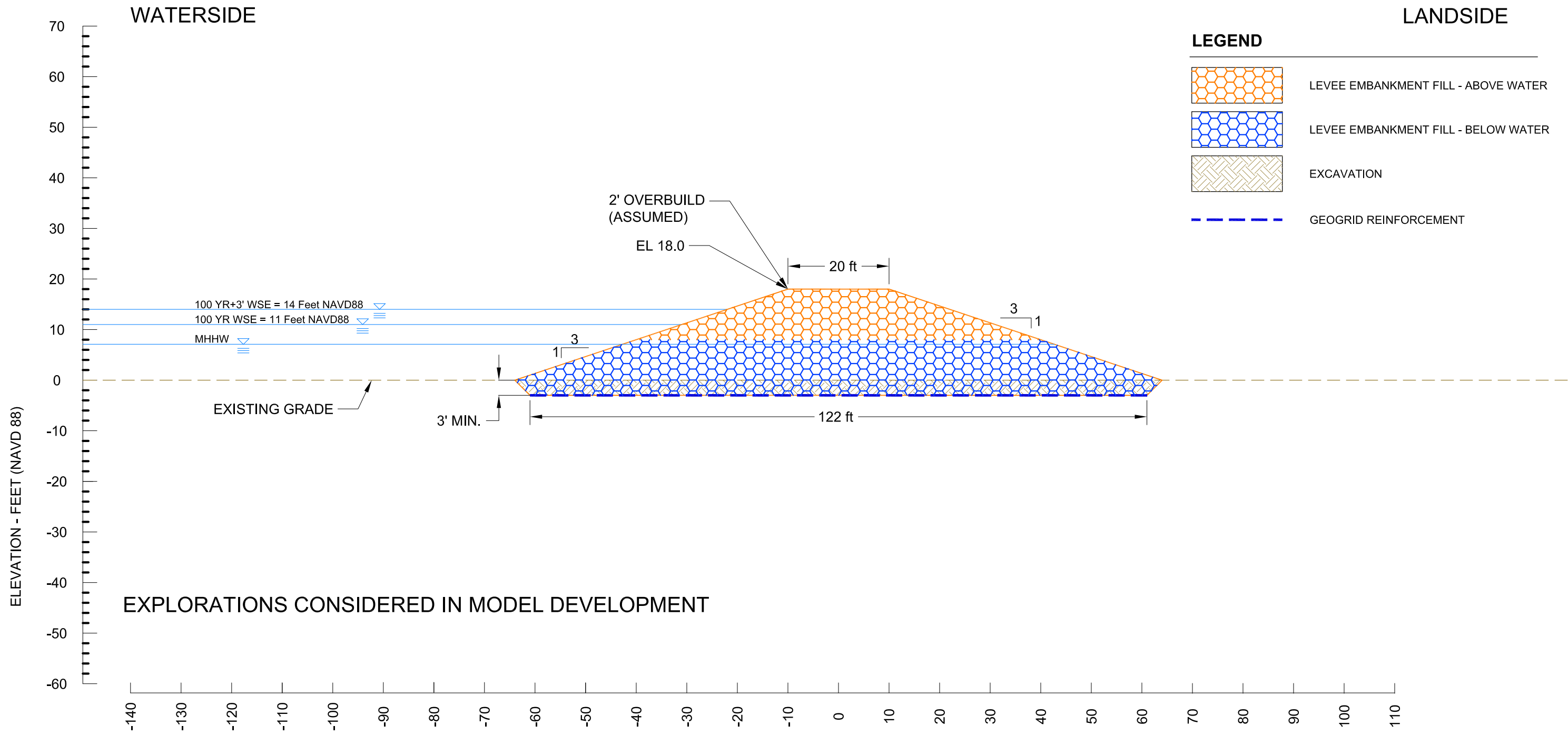
- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE LANDSIDE STEADY-STATE STABILITY.



ANALYSIS CROSS SECTION G16

SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date	DEC 2018
Figure	4-9



EXPLORATIONS CONSIDERED IN MODEL DEVELOPMENT

- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED PRIMARILY TO IMPROVE END-OF-CONSTRUCTION STABILITY



ANALYSIS CROSS SECTION G18

SAFER BAY PROJECT
 TASK ORDER NO. 2
 MENLO PARK AND EAST PALO ALTO, CALIFORNIA

Date
 DEC 2018

Figure
 4-12

LEGEND

Transition Zone Habitat Features

- Alkali Meadow
- Seasonal Wetlands
- Willow Sausal
- Salinas
- Scrub
- Coarse Woody Debris

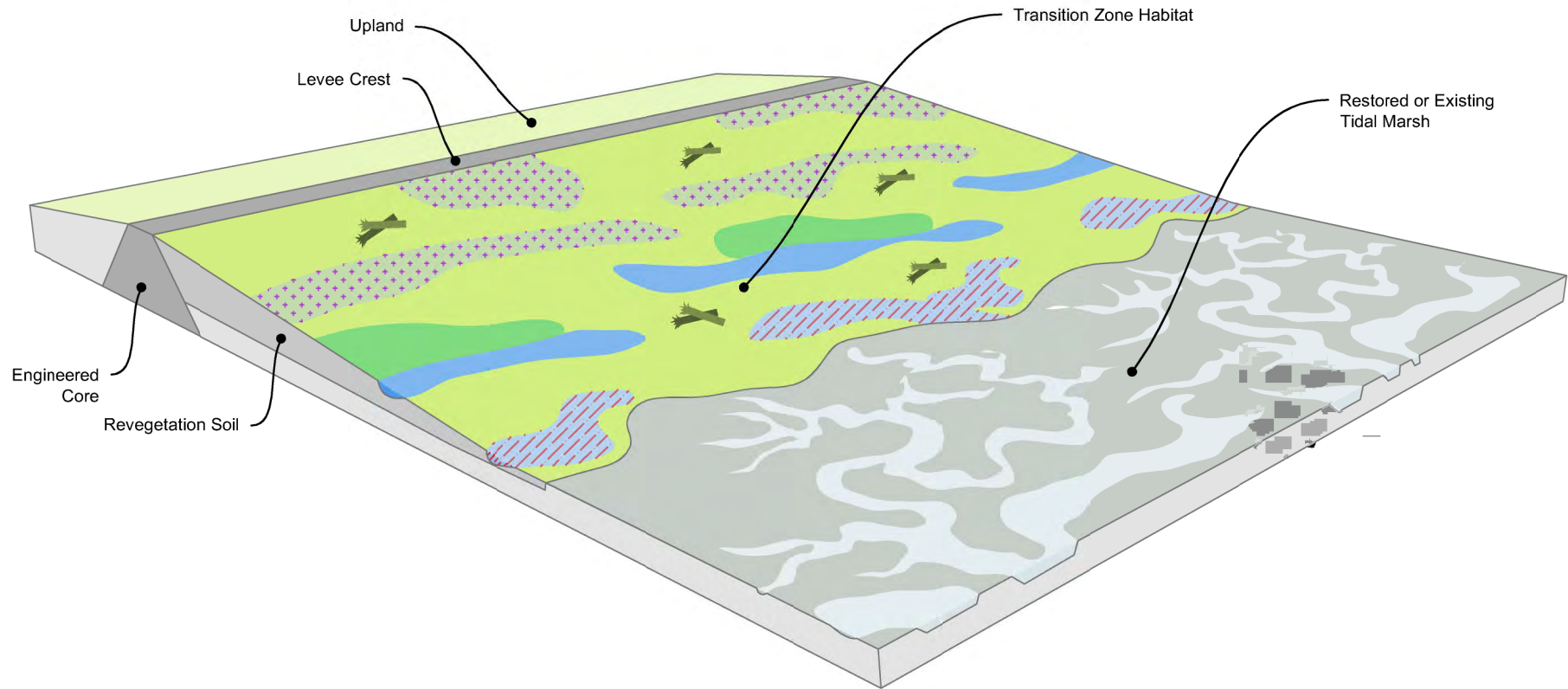
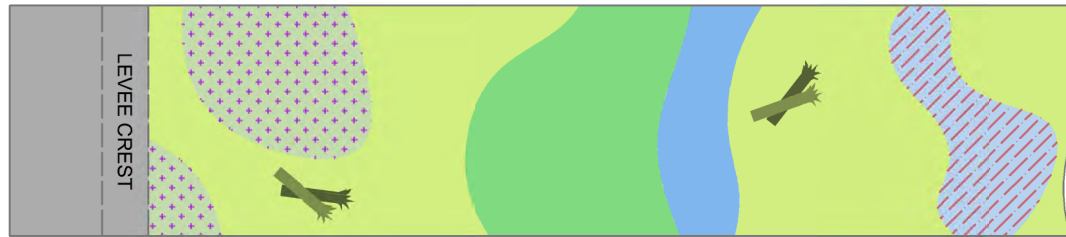


Figure 5 - Transition Zone Habitat Features
May 2018

30H:1V SLOPE

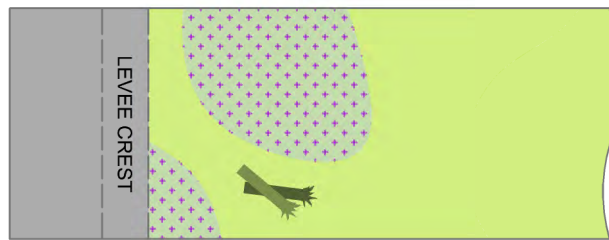


Transition Zone features greater habitat diversity and size



Transition Zone slope length of approximately 250 feet (ft) with a 16 ft (NAVD 88) levee crest

15H:1V SLOPE

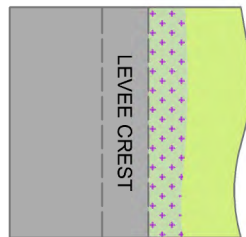


Transition Zone features limited habitat diversity and size



Transition Zone slope length of approximately 125 ft with a 16 ft levee crest

3H:1V SLOPE



Narrow Transition Zone



Transition Zone slope length of approximately 25 ft with a 16 ft levee crest

LEGEND

Transition Zone Habitat Features

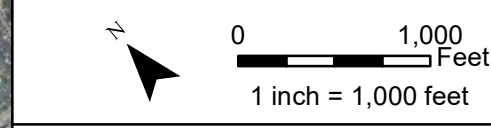
- Alkali Meadow
- Seasonal Wetlands
- Willow Sausal
- Salinas
- Scrub
- Coarse Woody Debris





Low Cost

- Reach 10, Option 3
- Reach 11, Option 3
- City Limits



**SAFER Bay Project
Task Order 2**

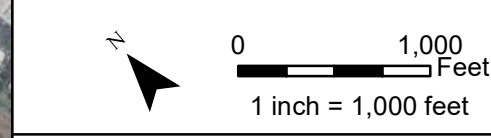
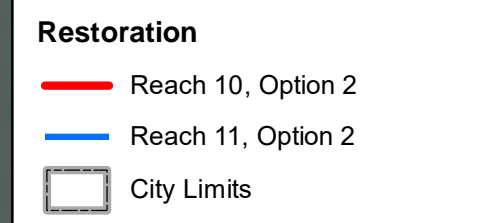
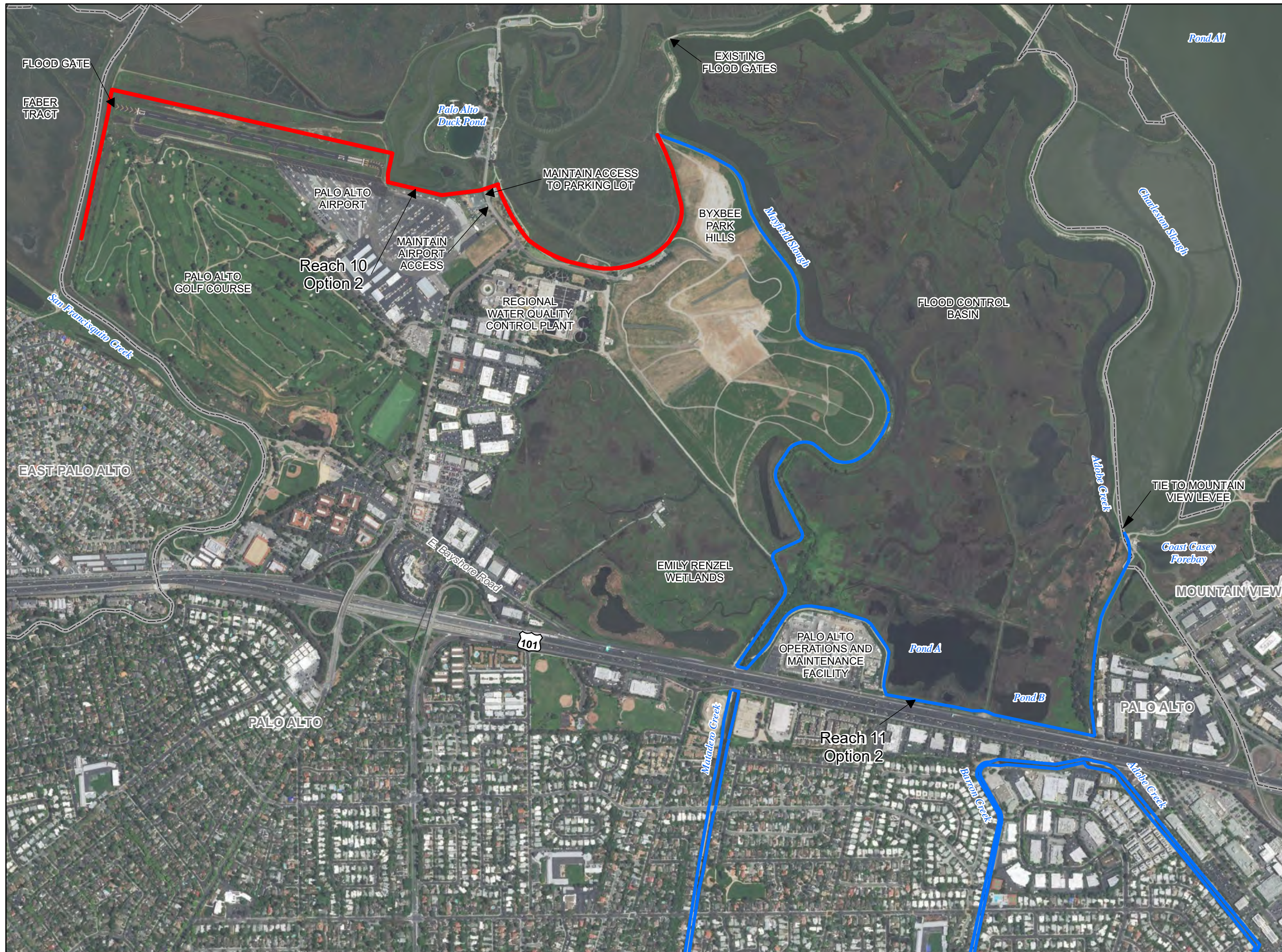
**Feasibility Report
Low Cost Alternative**

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

NOVEMBER 2018



**SAFER Bay Project
Task Order 2**

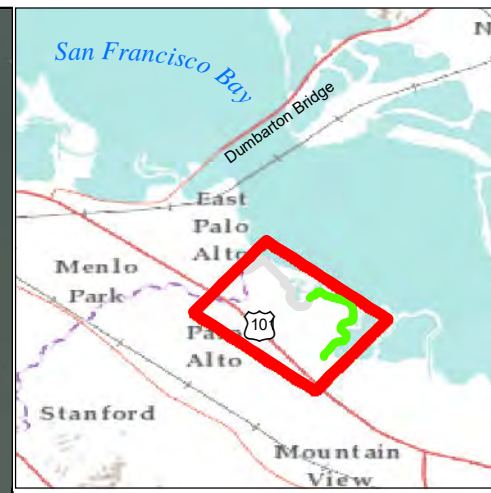
**Feasibility Report
Restoration Alternative**

Figure 8

Data Sources: Base Map-ESRI Maps and Data 2017;
All other data - HDR 2018

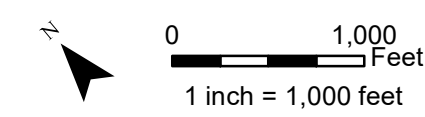
Datum: NAD83 California State Plane, Zone 3 US ft

NOVEMBER 2018



Recreation

- Reach 10, Option 1
- Reach 11, Option 1
- City Limits



**SAFER Bay Project
Task Order 2**

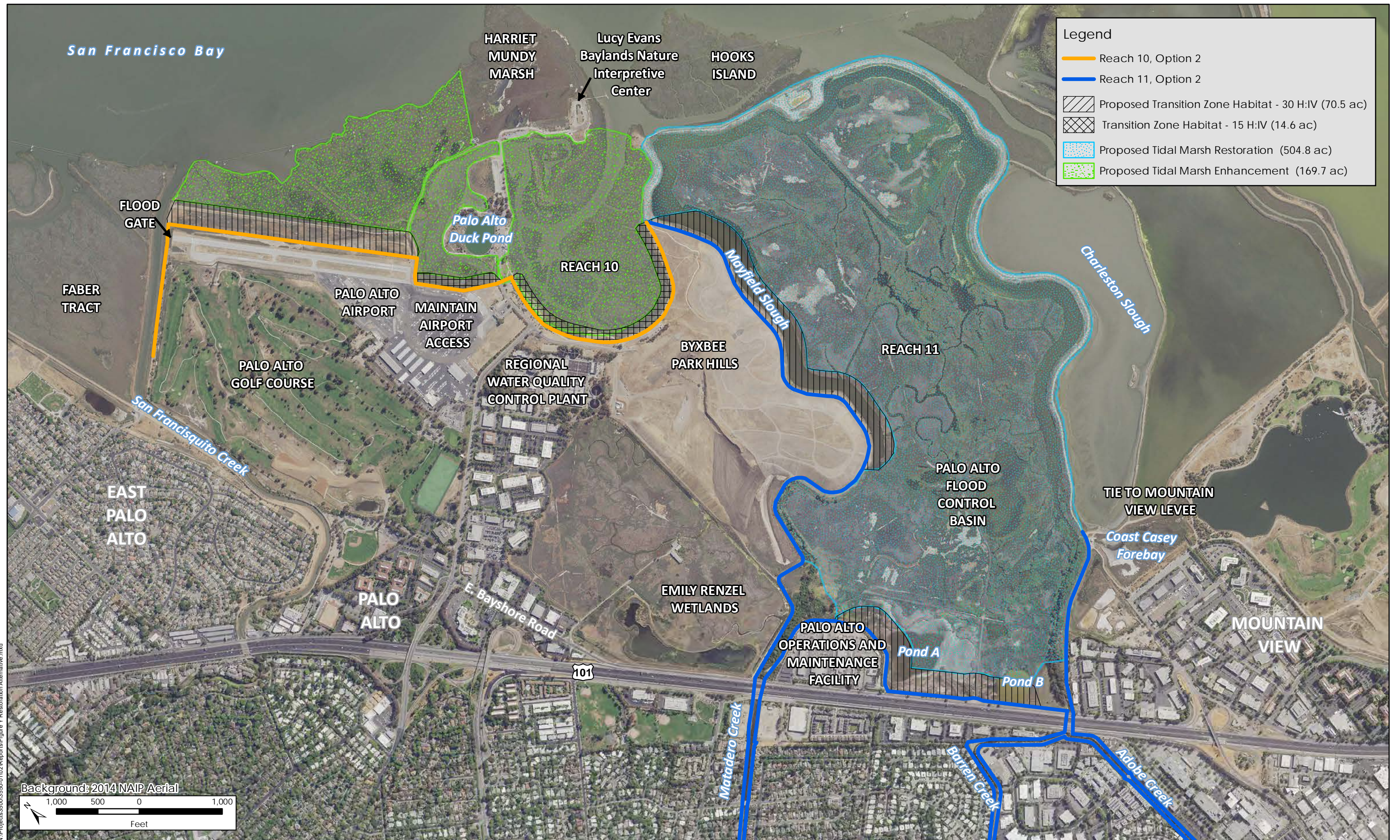
**Feasibility Report
Recreation Alternative**

Figure 9
 Data Sources: Base Map-ESRI Maps and Data 2017;
 All other data - HDR 2018
 Datum: NAD83 California State Plane, Zone 3 US ft
 NOVEMBER 2018



Figure 10. Low Cost Alternative - Proposed Tidal Marsh Restoration
 SAFER Bay Project San Francisquito Creek to Adobe Creek (3550-02)
 December 2017

N:\Projects\3550\0102\Reports\Figure X - Low Cost Alternative_20171215.mxd



N:\Projects\3550\3550-0102\Reports\Figure Y Restoration\Alternative.mxd



Figure 12. Recreation Alternative - Proposed Tidal Marsh Restoration
 SAFER Bay Project San Francisquito Creek to Adobe Creek (3550-02)
 December 2017

Appendix A – Interior Drainage Assessment for SAFER Bay Reach 11, May 2018



550 Kearny Street
Suite 800
San Francisco, CA 94108
415.896.5900 [phone](tel:415.896.5900)
415.896.0332 [fax](tel:415.896.0332)

www.esassoc.com

memorandum

date May 1, 2018
to Libby Mesbah, PE (HDR)
from Matt Brennan, PhD, PE
subject Interior Drainage Assessment for SAFER Bay Reach 11

INTRODUCTION

The Strategy to Advance Flood protection, Ecosystems, and Recreation along San Francisco Bay (SAFER Bay) project seeks to protect the City of Palo Alto and other nearby municipalities from coastal flood hazards. In support of the SAFER Bay feasibility study for Palo Alto, this memo documents ESA's assessment of interior drainage behind SAFER Bay's Reach 11.

Within the Reach 11 project footprint, three creeks drain into a flood detention basin and then onto San Francisco Bay. SAFER Bay is considering three possible options for Reach 11's coastal levee alignment, each with a different configuration for the lower reach of the creeks and the flood basin. To inform the feasibility study, this interior drainage assessment evaluates the potential changes to interior drainage as a function of the Reach 11 levee options.

Key design criteria that the SAFER Bay project is seeking to meet include:

- Current FEMA coastal flood protection requirements, which is the existing 100-year event (that has a 1% annual chance of being exceeded 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.

Meeting these design criteria is constrained by the need to maintain the existing level of interior drainage capacity. For purposes of this feasibility study, this interior drainage assessment uses hydraulic modeling to predict changes in creek water levels associated with each option and to characterize the additional measures that may be needed to maintain the existing level of interior drainage capacity. The additional measures considered include a pump station from the flood basin to the Bay and raising floodwalls along the lower portions of the creeks to maintain the existing freeboard between the peak water levels and the top of floodwalls for the design flood event.

The intent of this modeling assessment is to assist the feasibility study with evaluating the levee alignment options. As such, these measures are only represented at a conceptual level. Additional refinements to the options' descriptions and modeling will be needed to advance any of these options to the next stage of design.

Setting

For SAFER's Reach 11, interior drainage includes three creeks that flow across the proposed coastal levee alignment to drain into San Francisco Bay (Figure 1). Matadero Creek, Adobe Creek, and Barron Creek have a combined watershed area of almost 30 square miles. To help reduce the flood hazard from this discharge, the Palo Alto Flood Basin (PAFB) was constructed in 1956 at the mouth of these creeks, just before the creeks enter the Bay. The basin was constructed in response to extensive flooding in 1955 that inundated large portions of Palo Alto. The basin is defined by a ring levee that blocks Bay water levels from entering the basin's 600 acres. By blocking out Bay water, the basin maintains lower water levels at the creek mouths and provides storage volume for creek discharge. Particularly when the creeks' discharge coincides with high tides in the Bay, the basin reduces flood stage water levels in the creeks. Once Bay water levels drop below the basin's water levels, water drains from the basin to the Bay through a set of sixteen 5-ft by 5-ft culverts set into the northern levees. The outboard side of these culverts have flap gates which prevent Bay waters from flowing into the basin.

Currently, the top of the creeks' floodwalls start at elevations of about 9.3 ft NGVD and increase with elevation moving upstream. For several thousand feet upstream of Highway 101, the creeks' floodwalls do not currently have FEMA accreditation. In the lower reaches of the creeks, the design floodwall freeboard requirements are not set to FEMA standards, but rather according to USACE risk-based procedure (SCVWD, 2002).

Flood management for the creeks and PAFB is the responsibility of Santa Clara Valley Water District (SCVWD).

MODELING APPROACH

To assess the potential effect of the SAFER Reach 11 options on the creeks drainage, ESA used four existing HEC-RAS models that have been developed for the PAFB and the creeks as part of SCVWD's ongoing management of these water bodies. The PAFB model was provided by Schaaf & Wheeler and is the model used in their recent assessment for SCVWD (Schaaf & Wheeler, 2016). The creek models were provided by SCVWD and are updated versions of the models used for planning flood management improvements for Matadero and Barron Creeks (SCVWD, 2002).

The models cover separate domains which are linked by synchronizing the boundary conditions. All of the models use discharge boundary conditions based on the same watershed hydrology models. For the creeks, these discharges are set along the creek channels, according to increasing watershed area moving from head to mouth. For the PAFB, the cumulative discharge at the creek mouths are used as boundary condition inputs to the basin. The Matadero Creek and Adobe Creek models end at the PAFB. Their connection to the basin is represented by the water level used for the downstream boundary condition. The downstream boundary of the Barron Creek model is its confluence with Adobe Creek, so the predicted water level in Adobe Creek at the creeks' confluence is used as Barron Creek's downstream water level.

To assess performance for future conditions, three feet was added to the Bay water level boundary conditions, consistent with the SAFER Bay design criteria. Then the effects of this increase were predicted for upstream conditions by the models.

For purposes of this assessment, the vertical datum used for the existing models, NGVD, was retained. For reference, since other parts of the SAFER Bay study are using NAVD, the conversion from NGVD to NAVD is:

$$0 \text{ ft NGVD} = 2.7 \text{ ft NAVD}$$

Unless otherwise mentioned in the model setup sections below, all other model parameters (e.g. geometry, Manning's n) were not modified from the prior models' configurations.

PAFB Model

The PAFB model domain mostly comprises the flood basin itself, represented as a storage area. Short sections of channel are appended onto the basin to represent creek inflow locations and the adjacent portion of the Bay where the basin discharges. The tide gates are represented as water control structures with operational rules connecting the basin storage area with the Bay channel segment.

To account for the timing of creek discharge filling the basin's storage capacity relative to the timing tide gate discharge draining the basin, the model is run in unsteady mode for several days. Based on a statistical analysis of several model runs which consider different combinations of high tide peak and timing, average coincident water level in the flood basin at the time of peak creek inflow is assumed to be 4.7 ft NGVD (SCVWD, 2002).

Boundary conditions that are specified include 100-year creek hydrographs for Matadero Creek and Adobe Creek. The Adobe Creek hydrograph includes contributions from Barron Creek since Barron Creek joins Adobe Creek just upstream of the basin. The combined 100-year creek discharge to the basin peaks at approximately 6,000 cfs.

Creek Models

The creek models' domain spans the entire creeks' length, starting from their upstream heads to the PAFB. Storage does not play a role in peak water levels, therefore the creek models were run in steady mode.

For some modeled scenarios, the predicted water levels exceed the elevation of the top of bank specified by the model's geometry. In this case, the model assumes that the model domain extends vertically upward from the top of bank, and all water is contained within these virtual 'floodwalls'. While not representative of the actual conditions, this model configuration allows the models to predict how high the floodwalls would need to be raised to contain the predicted water levels.

The 100-year values at all creeks were sourced from previous models provided by SCVWD, while 10-year values were provided by or interpolated from peak discharge values from FEMA's Flood Insurance Study report (2015).

For Barron Creek, the water levels at cross section Station 13290 (location corresponding to creek junction) in the Adobe Creek model were used as the downstream water level boundary conditions.

FEASIBILITY LEVEL MODELING ASSESSMENT OF REACH 11 OPTIONS

Option 1

Description

The Option 1 alignment (Figure 1, in green) consists of a levee extending from high ground at the capped landfill, following the existing Palo Alto Flood Basin (basin) perimeter levee and along the western side of Charleston Slough, to a tie-in at the City of Mountain View border near Coast Casey Forebay. The existing flood gates located at the northern end of the basin would need to be re-designed to accommodate a levee raise. An assessment of the flood gates’ performance with future sea level rise indicates that adding a large pump station may be needed to adapt to the current basin configuration to sea level rise (Schaaf & Wheeler, 2016). Option 1 would not result in significant habitat enhancement or restoration opportunities relative to current conditions.

Model Setup

For existing conditions under Option 1, the models were run according to their prior configuration.

For future conditions, with 3 ft of SLR, the PAFB model was run with increasing amounts of pumping capacity until the pumping capacity was sufficient to offset the increase in peak water levels due to sea-level rise. The pump capacity needed to achieve this was 1,500 cfs.

Since pumping at the PAFB was used to maintain the same downstream water levels for the creeks, the predictions for creek water levels remain unchanged for future conditions with sea-level rise.

Table 1. HEC-RAS Model Boundary Conditions for Option 1

Model	Discharge Boundary Condition	Downstream Water Level ft NGVD, Recurrence Interval
<i>Baseline Conditions & Future Conditions (+3 ft SLR)</i>		
Adobe Creek	100-year	4.7
Matadero Creek	100-year	4.7
Barron Creek	100-year	6.0

Model Results

As described above, Option 1 assumes that water level predictions are unchanged from existing conditions, or ‘baseline’. These baseline 100-year water surface profiles, which correspond to Option 1 predictions, are shown in the figures presented for the other options: Matadero Creek in Figure 2, Adobe Creek in Figure 4, and Barron Creek in Figure 6. The baseline water levels typically have 2-4 feet of freeboard below the left and right top-of-bank, with the freeboard is smallest on the upstream side of bridges. Under some bridges, flows are predicted to become supercritical. Downstream of these bridges, there is a hydraulic jump, which causes a water surface drop and then recover.

Option 2

Description

The Option 2 alignment (Figure 1, in blue) consists of a levee extending from high ground at the capped landfill, running southwest along the Emily Renzel Wetlands, then along the north side of Matadero Creek to East Bayshore Road. A second levee will extend from East Bayshore Road along the south side of Matadero Creek and around the City of Palo Alto’s operations and maintenance campus then continue along East Bayshore Road to Adobe Creek. A third levee will continue on the southern side of Adobe Creek along the Adobe Creek Loop Trail from East Bayshore Road to a tie in at the City of City Mountain View border near the Coast Casey Forebay.

In addition to these levees, to preserve the existing level of flood protection for developed areas along creek channels, floodwalls will need to be raised along both banks of Matadero, Barron, and Adobe Creeks upstream and west of Highway 101, to the upstream extent of coastal flood influence. Raising the floodwalls for Option 2 could be coordinated with a larger effort to obtain FEMA accreditation for these reaches of the creeks.

Option 2 provides an opportunity for large-scale tidal marsh and transition zone habitat restoration. Since the PAFB would no longer be used for flood storage, the basin would be re-connected to tidal exchange which would, over time, restore the basin to tidal marsh. To restore the basin, the outer levee would be breached in strategic locations to create a natural, dendritic slough channel network and the remainder of the levee may be lowered. This option would provide ample space for restoration of a broad 30H:1V transition zone along the outboard side of new levee, which would transition into the restored tidal salt marsh. The large transition zone allows for tidal marsh migration due to sea level rise. This option provides the greatest opportunity to restore transition zone habitat.

Model Setup

Since this option calls for the PAFB to be breached and full tide range of the Bay to be conveyed to the mouth of the creeks, the PAFB model was not used for this option. Instead, the downstream water level boundary condition was set in accordance with the extreme bay water levels estimated for the recent FEMA coastal flood hazard mapping update (DHI, 2013).

Without the flood basin determining water levels, the lower portions of the creeks are subject to flooding by correlated high creek discharge and Bay storm surge. The location along the creek where each of these flood sources dominants was predicted by executing two runs for each creek, and at each location along the creek, selecting the water level that was highest. The two model runs were: the 100-year discharge and the 10-year Bay water level; and the 10-year discharge and the 100-year Bay water level. This approach is consistent with Santa Clara County guidance (Santa Clara County, 2007).

Table 2 summarized the discharge and downstream water level boundary conditions used in the model runs.

Table 2. HEC-RAS Model Boundary Conditions for Option 2

Model	Discharge Boundary Condition	Downstream Water Level ft NGVD, Recurrence Interval
<i>Existing Conditions</i>		
Adobe Creek	100-year	7.4, 10-year
	10-year	8.1, 100-year
Matadero Creek	100-year	7.4, 10-year
	10-year	8.1, 100-year
Barron Creek	100-year	8.0, 10-year
	10-year	8.3, 100-year
<i>Future Conditions (+3 ft SLR)</i>		
Adobe Creek	100-year	10.4, 10-year
	10-year	11.1, 100-year
Matadero Creek	100-year	10.4, 10-year
	10-year	11.1, 100-year
Barron Creek	100-year	11.2, 10-year
	10-year	11.32, 100-year

Model Results

The predicted 100-year water level profiles for Matadero, Adobe, and Barron Creeks are shown in Figure 2, Figure 4, and Figure 6. Changing water levels at the Palo Alto Flood Basin downstream boundary shifts water levels upward for about 6,000 feet of channel for Matadero Creek and Adobe Creek, and for about 5,000 for Barron Creek, which starts partway up Adobo Creek. By subtracting these water levels for Option 2 from the baseline water level profiles, the change in freeboard was estimated, a surrogate for the increase in floodwall height that would be needed to preserve the existing interior drainage capacity. The changes in freeboard along the lower creek profiles are shown in Figure 3, Figure 5, and Figure 7. The largest changes occur at the downstream end of the creeks and taper off upstream. For present day conditions, the change in the creeks’ freeboard is 2.5 to 3.5 feet just upstream of Highway 101. With three feet of sea-level rise, the change in freeboard is 5-6 feet.

Option 3

Description

The Option 3 alignment (Figure 1, in yellow) consists of a new levee extending from high ground at the capped landfill across the Palo Alto Flood Basin to a tie-in at the City of Mountain View border near the Coast Casey Forebay. The northern two-thirds of the Flood Basin would be breached to the Bay and restored to tidal marsh habitat. The remaining Flood Basin would be constructed with new tide gates and a pump station that would convey Matadero, Barron, and Adobe Creeks' discharge to the Bay. For this configuration of reduced storage capacity and added pump capacity, raising floodwalls is also recommended to maintain the existing level of flood protection along Matadero, Barron and Adobe Creeks upstream and west of Highway 101, to the upstream extent of coastal flood influence. Raising the floodwalls for Option 3 could be coordinated with a larger effort to obtain FEMA accreditation for these reaches of the creeks. Alternatively, the flood management approach could be modified to rely exclusively on pumping and storage. For instance, the new levee could be shifted closer to the Bay, thereby preserving more storage capacity, and/or the pump station's capacity could be increased. Alternatives such as this would have a different balance of flood management, cost, and restored habitat that could be characterized in greater detail if Option 3 is pursued further.

Similar to Option 2, Option 3 would provide the opportunity to restore a substantial area of tidal marsh in northern portion of the PAFB and have opportunities for a broad restored transition zone and connectivity with restored Charleston Slough.

Model Setup

The PAFB model was modified such that the storage area representing the basin was reduced in size to match the smaller inboard area upstream of the new levee across the basin. Because the storage capacity decreases to about one third its original size, water levels within the basin would rise during the 100-year creek discharge, starting during existing conditions.

Therefore, to mitigate for this rise, pumping capacity was added to the model to discharge from the basin to the Bay even when Bay water levels were higher than basin water levels. The pump capacity was incrementally increased until even for the worst case scenario of coincident high tide and creek discharge, the increase in water level within the reduced basin as compared to the full basin was about one foot. The modeled pumping capacity to achieve this was 2,400 cfs.

For cases when the tide and discharge were not coincident, e.g. when there was a 3-hour or greater lag between the tide and discharge peaks, the additional pump capacity was able to reduce water levels relative to baseline. Therefore, even though worst-case peak water levels increase slightly, the overall flood risk is estimated to be

equivalent or less since about 75%¹ of the time, when the tide and discharge peaks were at least 3 hours apart, the water levels with the pumping would be lower.

Based on this assessment of the PAFB performance when reduced size but supplemented with pumping, the creek models were evaluated with the downstream boundary condition elevated one foot for existing conditions and two feet for future conditions with 3 ft of sea-level rise. The creek model boundary conditions are summarize in Table 3.

Table 3. HEC-RAS Model Boundary Conditions for Option 3

Model	Discharge Boundary Condition	Downstream Water Level ft NGVD, Recurrence Interval
<i>Baseline Conditions</i>		
Adobe Creek	100-year	5.7
Matadero Creek	100-year	5.7
Barron Creek	100-year	6.5
<i>Future Conditions (+3 ft SLR)</i>		
Adobe Creek	100-year	7.7
Matadero Creek	100-year	7.7
Barron Creek	100-year	8.6

Model Results

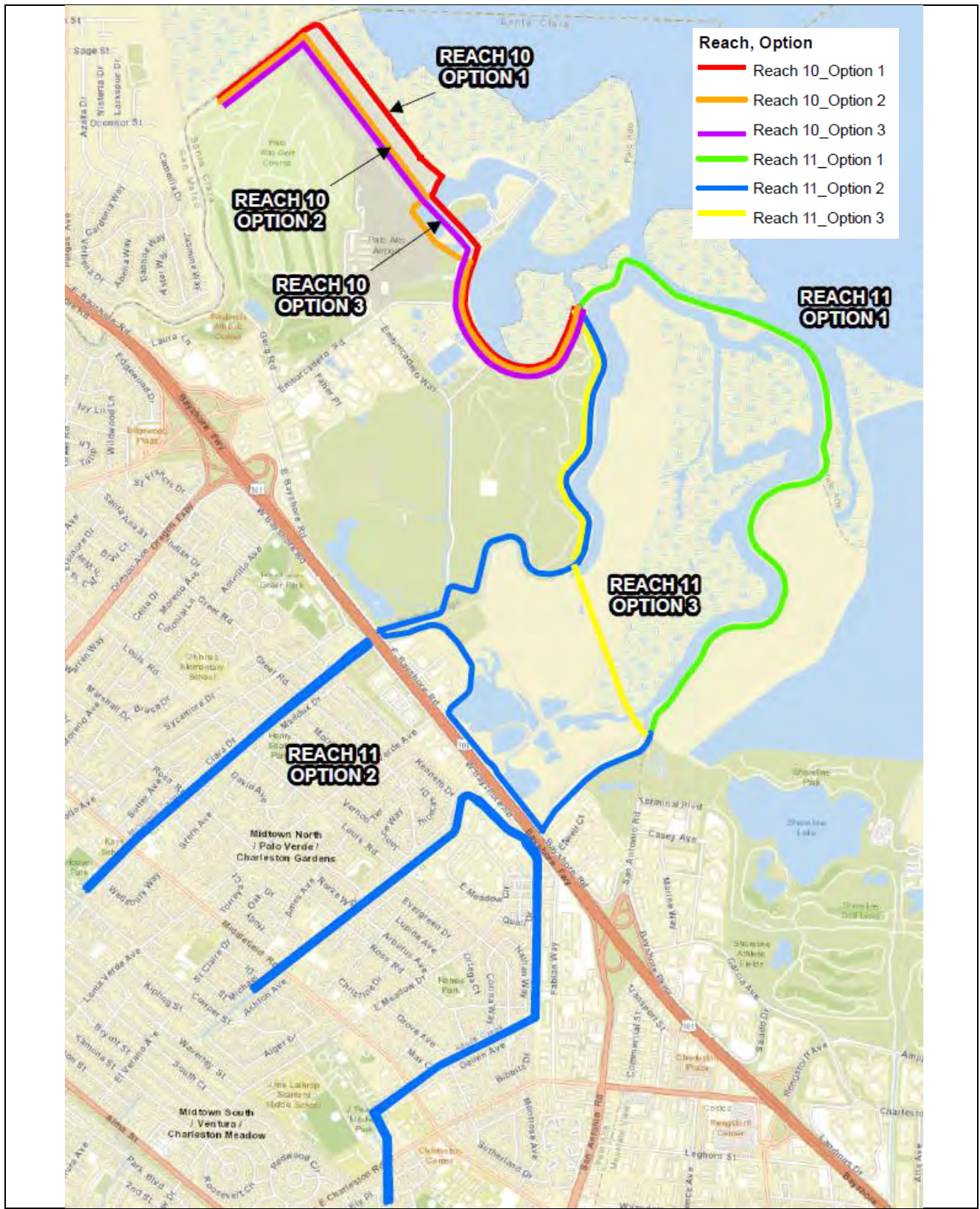
The predicted 100-year water level profiles for Matadero, Adobe, and Barron Creeks are shown in Figure 8, Figure 10, and Figure 12. Changing water levels at the Palo Alto Flood Basin downstream boundary shifts water levels upward for about 5,000 feet of channel for Matadero Creek and Adobe Creek, and for about 4,500 for Barron Creek, which starts partway up Adobe Creek. By subtracting these water levels for Option 2 from the baseline water level profiles, the change in freeboard was estimated, a surrogate for the increase in floodwall height that would be needed to preserve the existing interior drainage capacity. The changes in freeboard along the lower creek profiles are shown in Figure 9, Figure 11, and Figure 13. The largest changes occur at the downstream end of the creeks and taper off upstream. For present day conditions, the change in the creeks’ freeboard is 0.5 to 1.0 feet just upstream of Highway 101. With three feet of sea-level rise, the change in freeboard is 2-3 feet.

¹ Tides repeat approximately every 24 hours. So for any given event when the tides and discharge are uncorrelated random variables, the chance that the peaks are within 3 hours of being coincident is a 6-hour window in the 24-hour tide cycle. The other 18 hours, or 75% of the time, the peaks will be separate enough that pumping reduces water levels in PAFB as compared to baseline.

REFERENCES

- Danish Hydraulics Institute (DHI). 2013. Regional Coastal Hazard Modeling Study for South San Francisco Bay Final Draft Report. Prepared for FEMA Region IX.
- ESA PWA. 2012. Shoreline Regional Park Community: Sea Level Rise Study Feasibility Report and Capital Improvement Program. Prepared for the City of Mountain View.
- Federal Emergency Management Agency (FEMA), 2015, Flood Insurance Study for Santa Clara County, California and Incorporated Areas, Volume 2 of 4.
- Santa Clara County. 2007. Drainage Manual.
- Santa Clara Valley Water District (SCVWD). 2002. Matadero/Barron Creeks Long-Term Remediation Planning Study – Final Engineer’s Report.
- SCVWD. 2016. Palo Alto Tidal Flood Management Project, Draft-Final Engineering Feasibility Report.
- Schaaf & Wheeler. 2016. Palo Alto Flood Basin Hydrology. Prepared for Santa Clara Valley Water District.

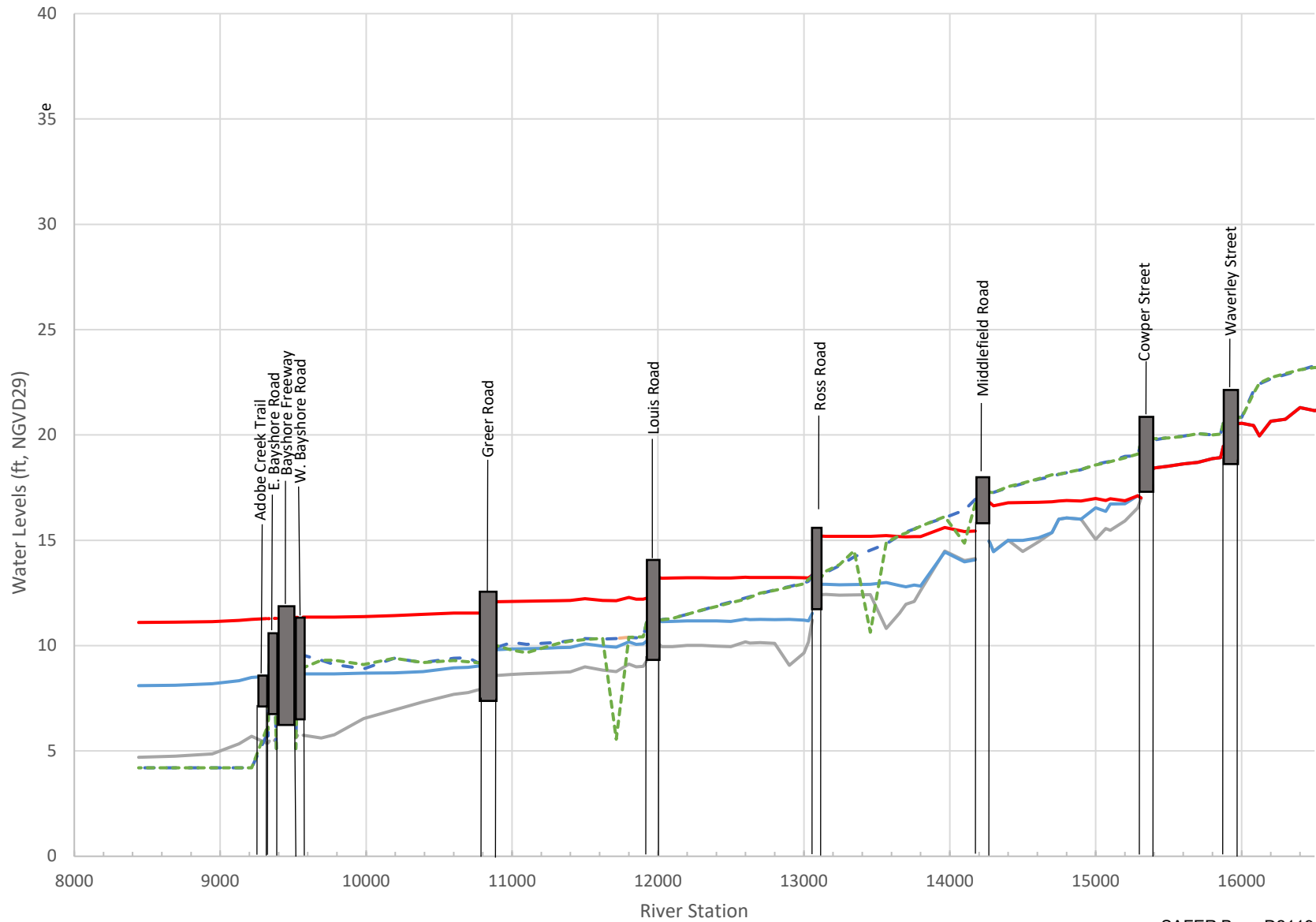
FIGURES



SOURCE: HDR

SAFER Bay . D211919.02

Figure 1
SAFER Bay Reaches 10 & 11



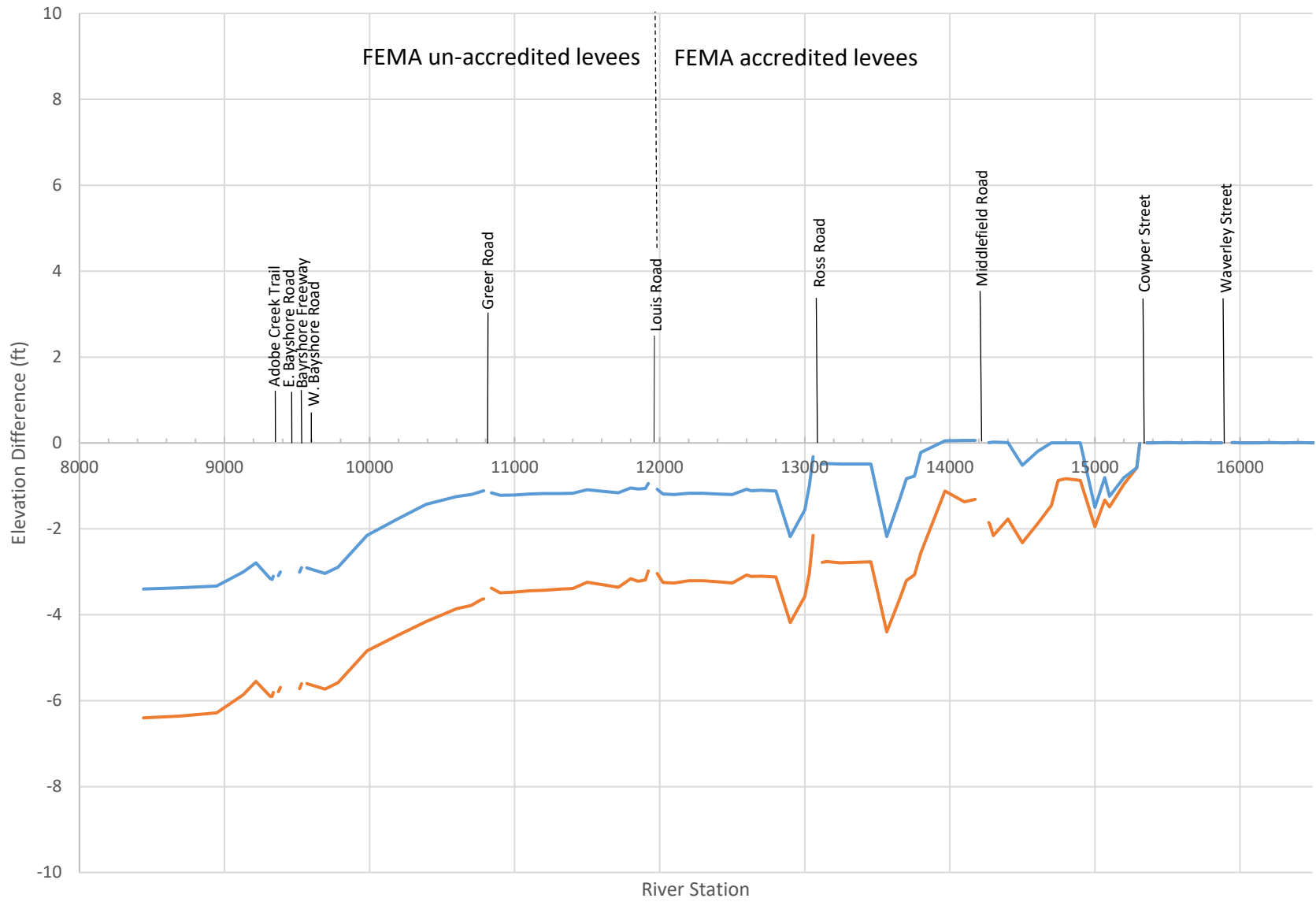
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 2

Water Levels - Matadero Creek Option 2

— Baseline — OPT2 Present Day — OPT2 Future (+3 ft SLR) - - - LOB Elevation - - - ROB Elevation



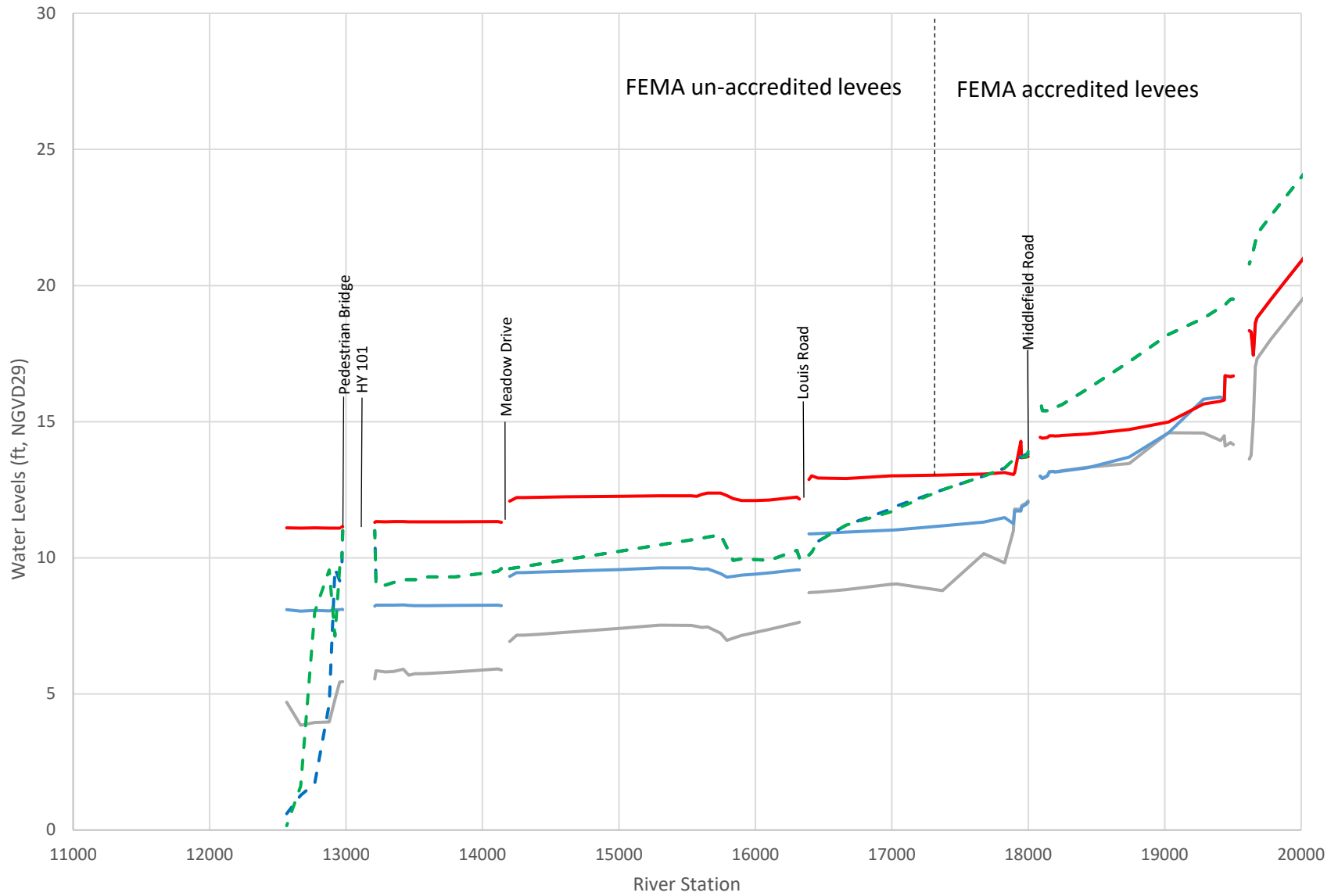
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 3

Change in Freeboard - Matadero Creek
Option 2

— OPT2 Future (+3 ft SLR) - Baseline — OPT2 Existing - Baseline



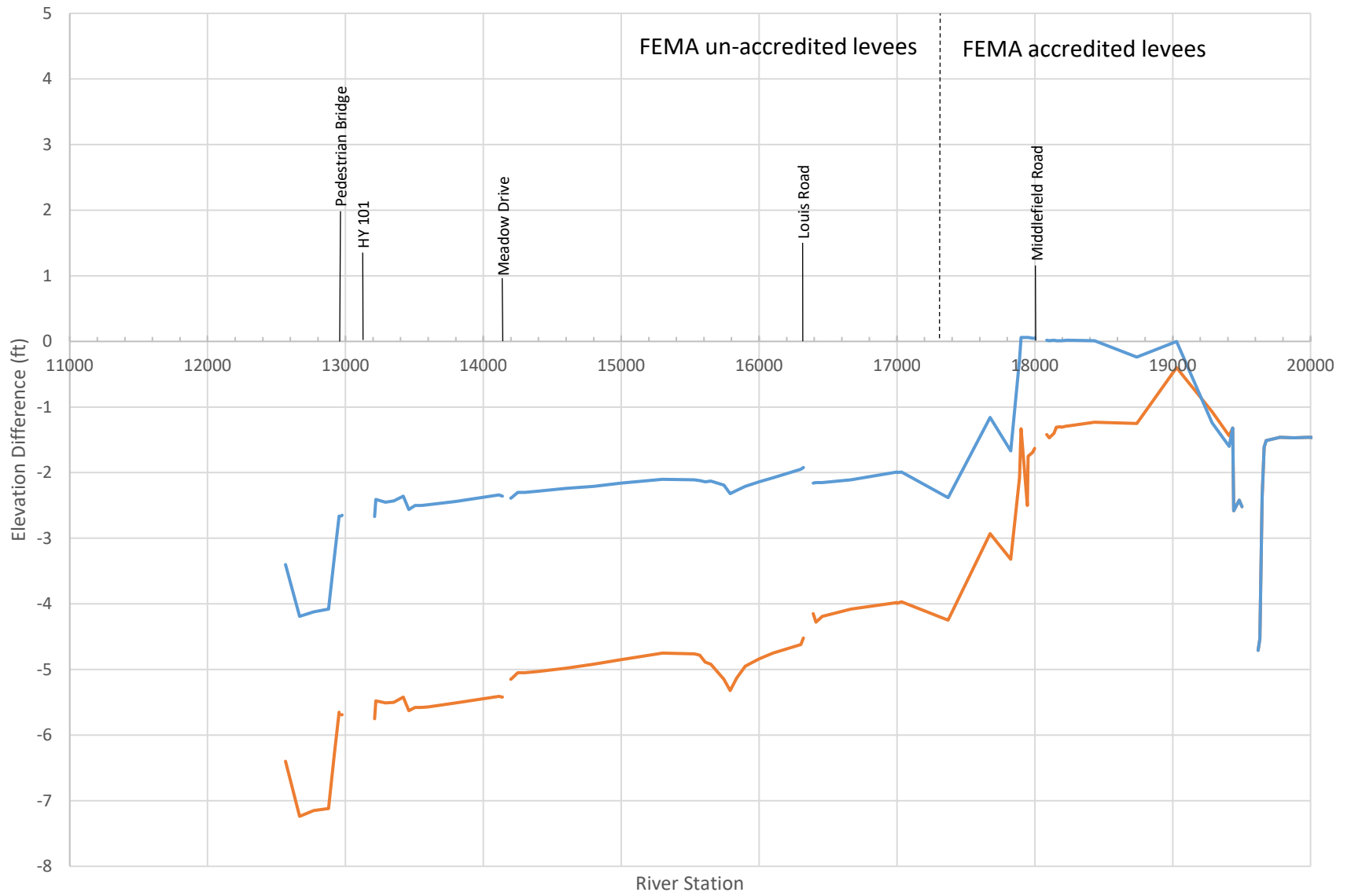
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 4

Water Levels - Adobe Creek Option 2

— Baseline — OPT2 Present Day — OPT2 Future (+3 ft SLR) - - - LOB Elevation - - - ROB Elevation



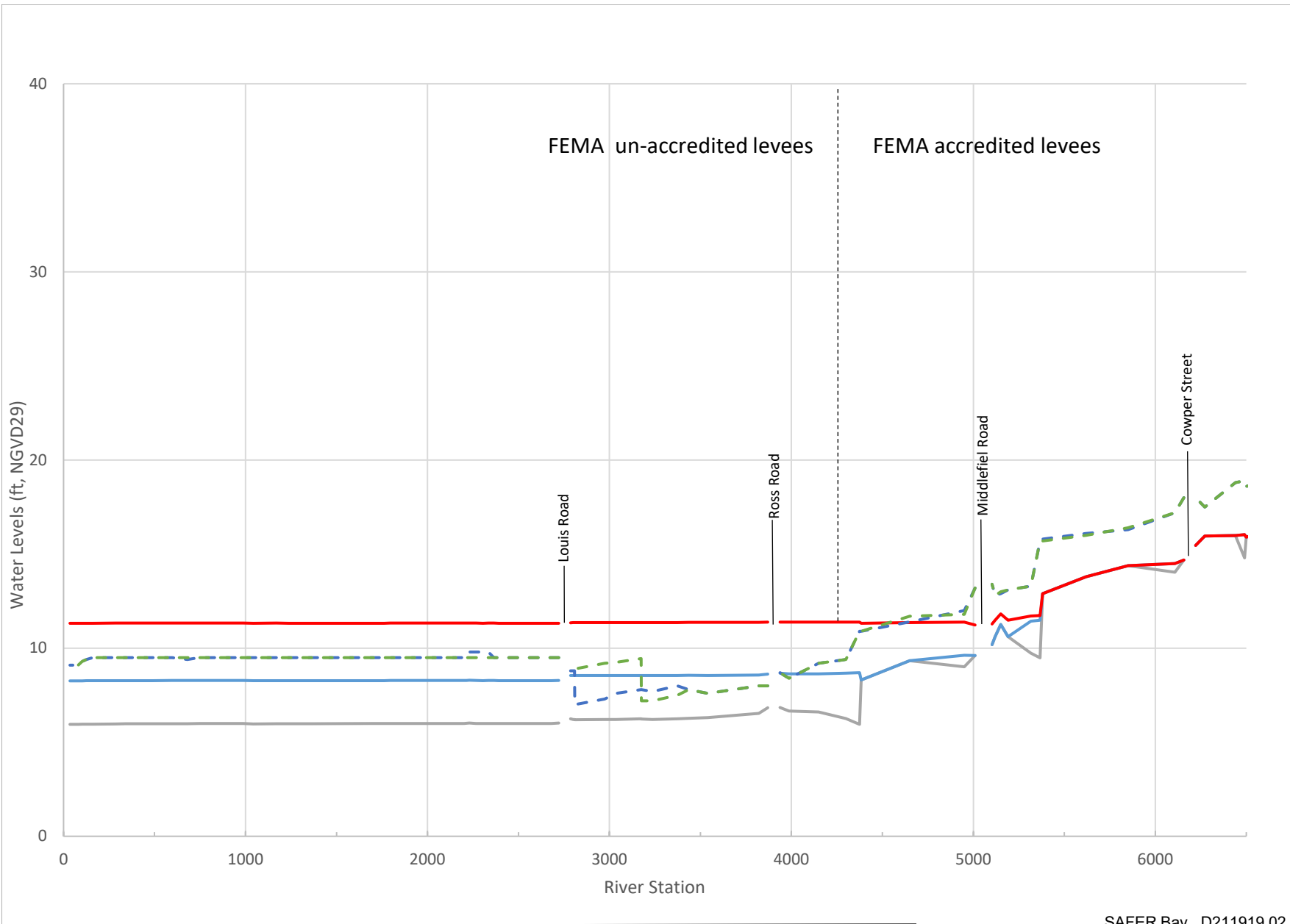
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 5

Change in Freeboard - Adobe Creek
Option 2

— OPT2 Future (+3 ft SLR) - Baseline — OPT2 Existing - Baseline



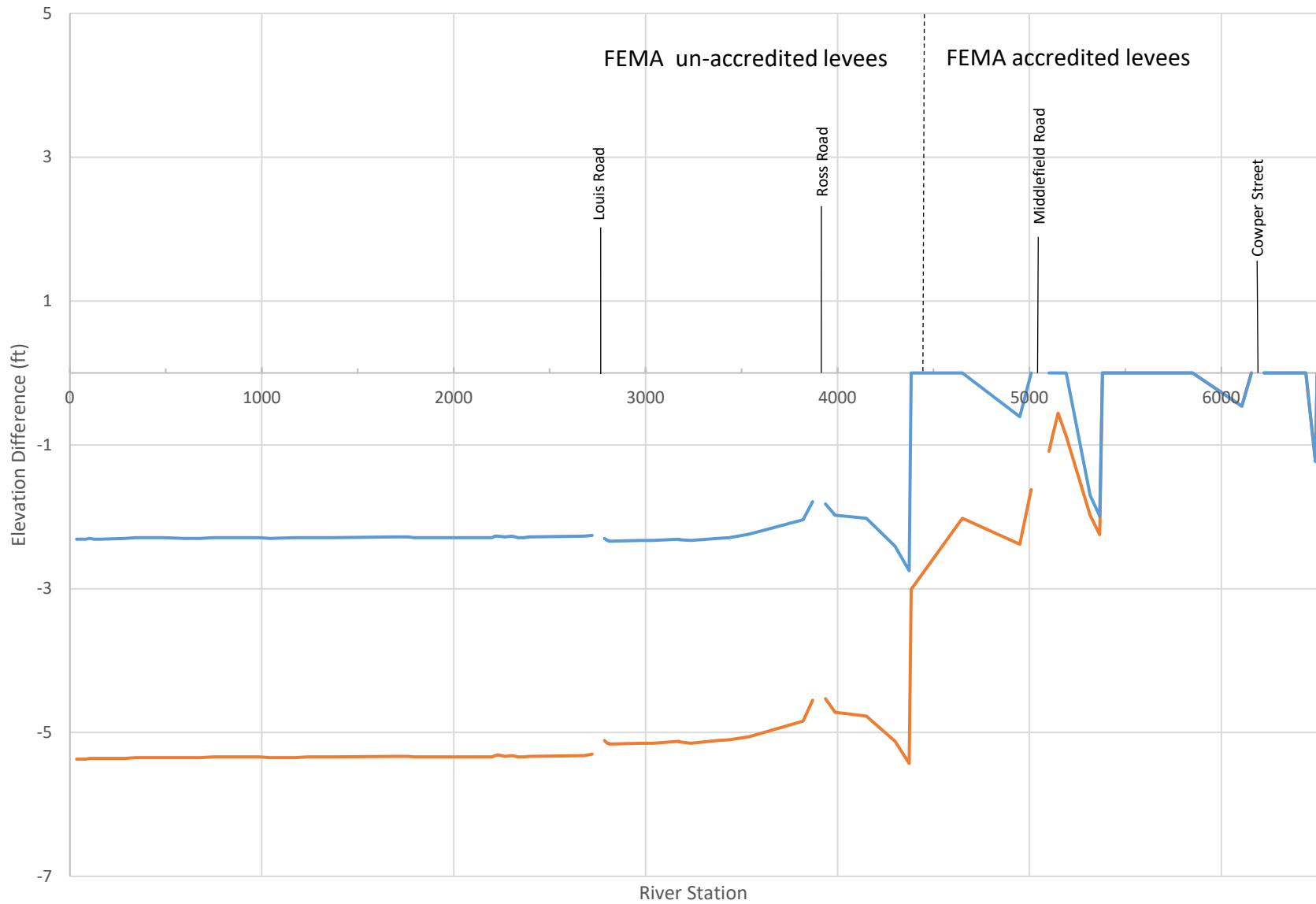
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 6

Water Levels - Barron Creek Option 2

— Baseline — OPT2 Present Day — OPT2 Future (+3 ft SLR) - - - LOB Elevation - - - ROB Elevation



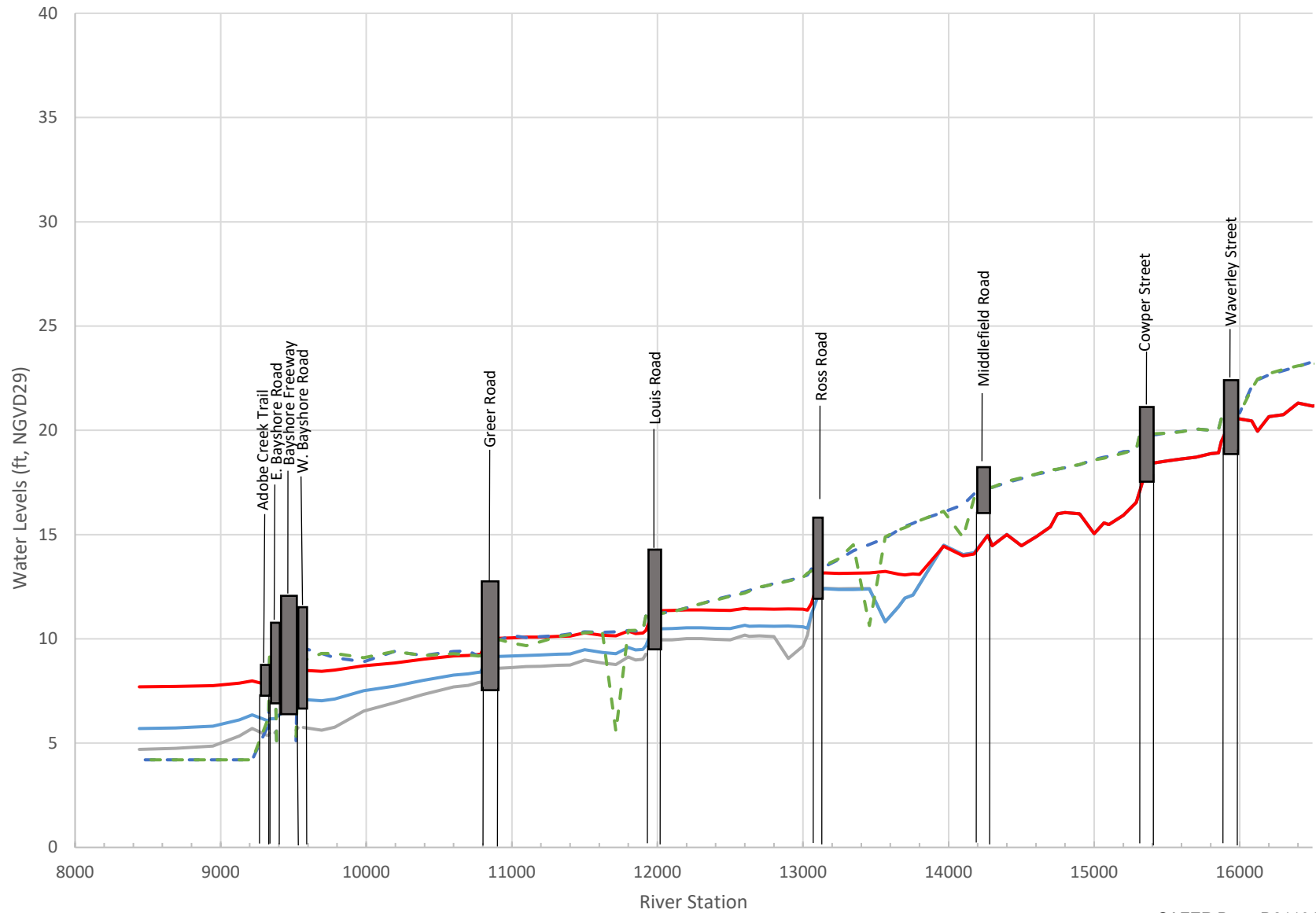
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 7

Change in Freeboard - Barron Creek
Option 2

— OPT2 Future (+3 ft SLR) - Baseline — OPT2 Existing - Baseline



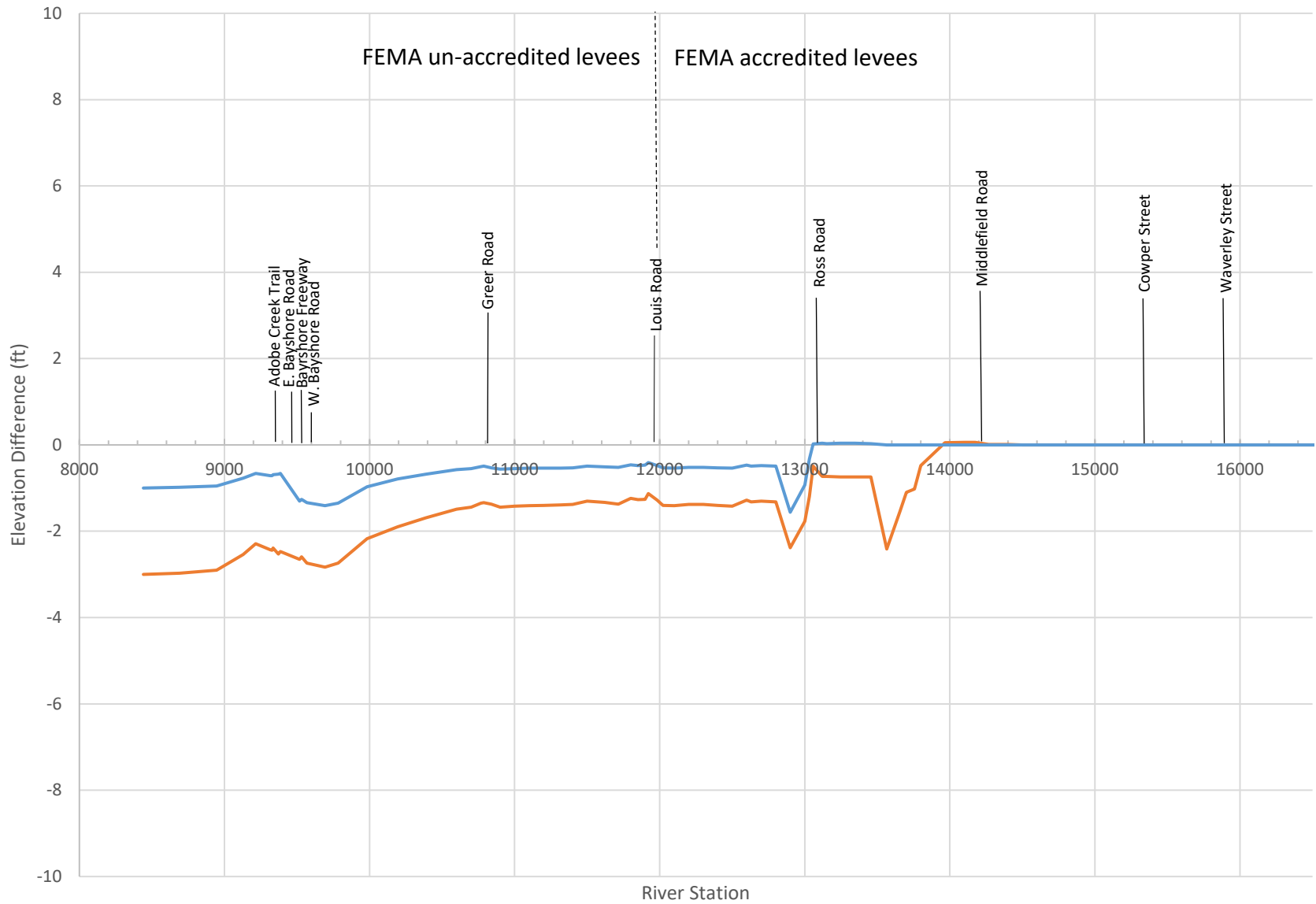
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 8

Water Levels - Matadero Creek Option 3

— Baseline — OPT3 Present Day — OPT3 Future - - - LOB Elevation - - - ROB Elevation

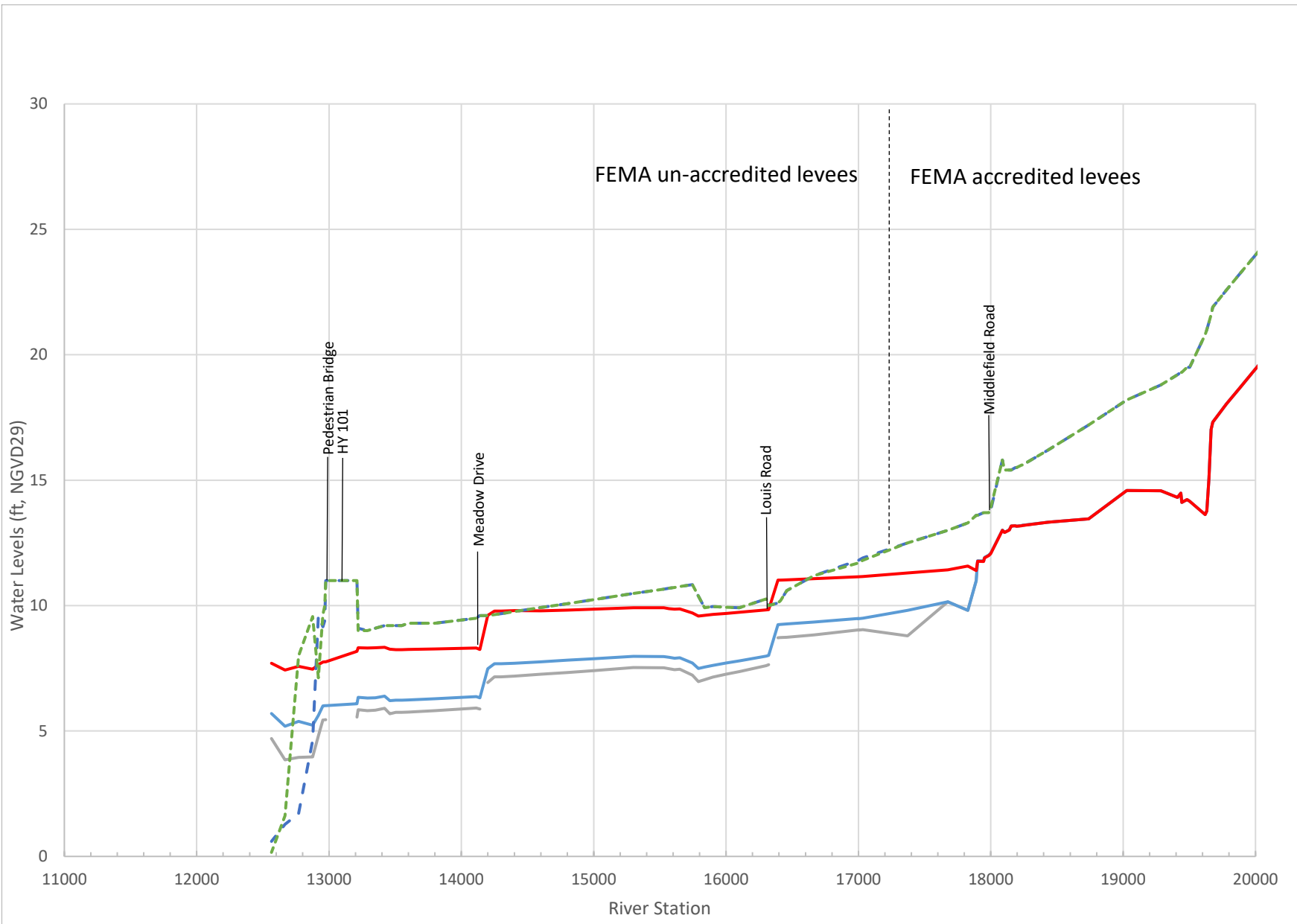


SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 9
Change in Freeboard - Matadero Creek
Option 3

— OPT3 Future - Baseline — OPT3 Existing - Baseline



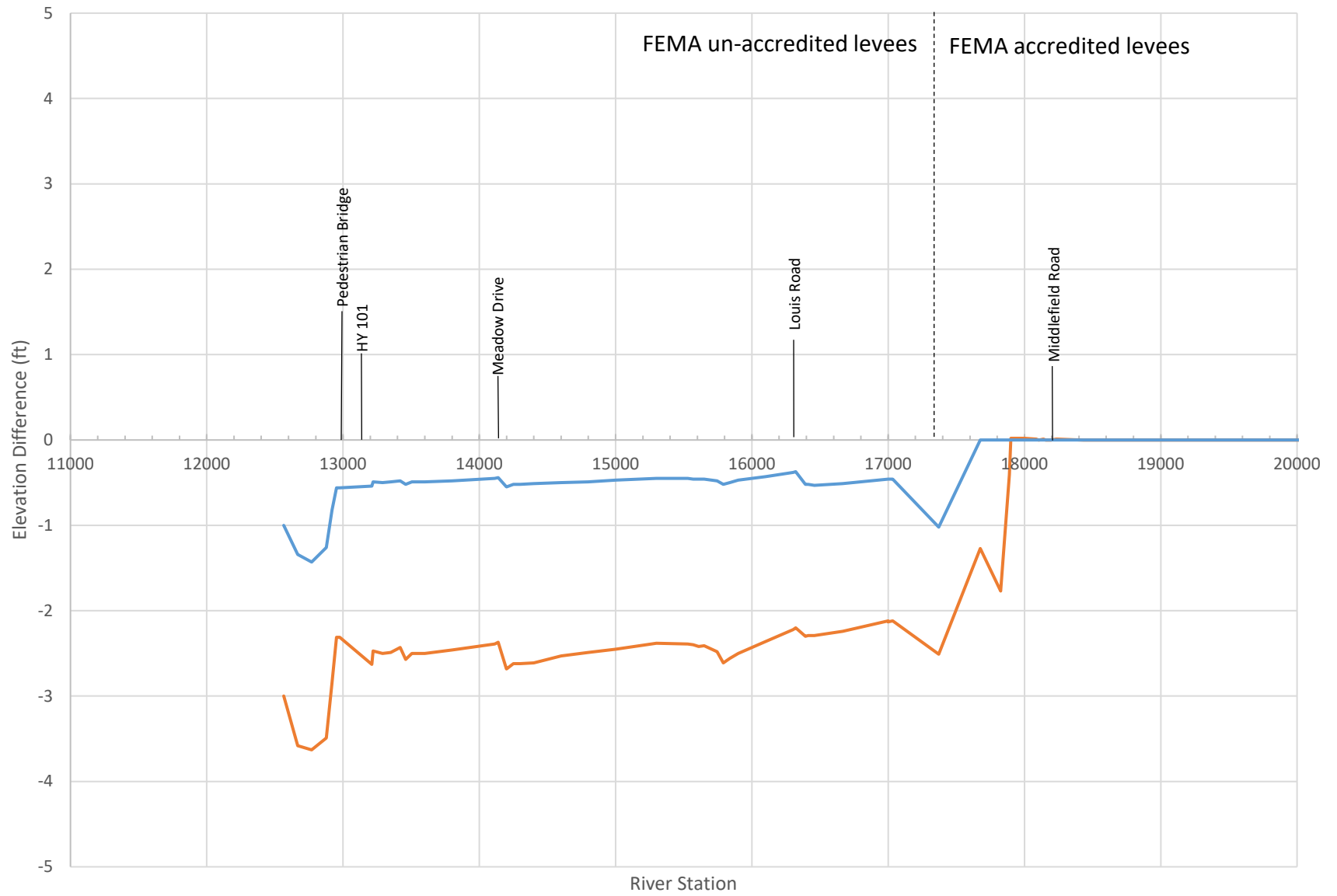
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 10

Water Levels - Adobe Creek Option 3

— Baseline — OPT3 Present Day — OPT3 Future - - - LOB Elevation - - - ROB Elevation



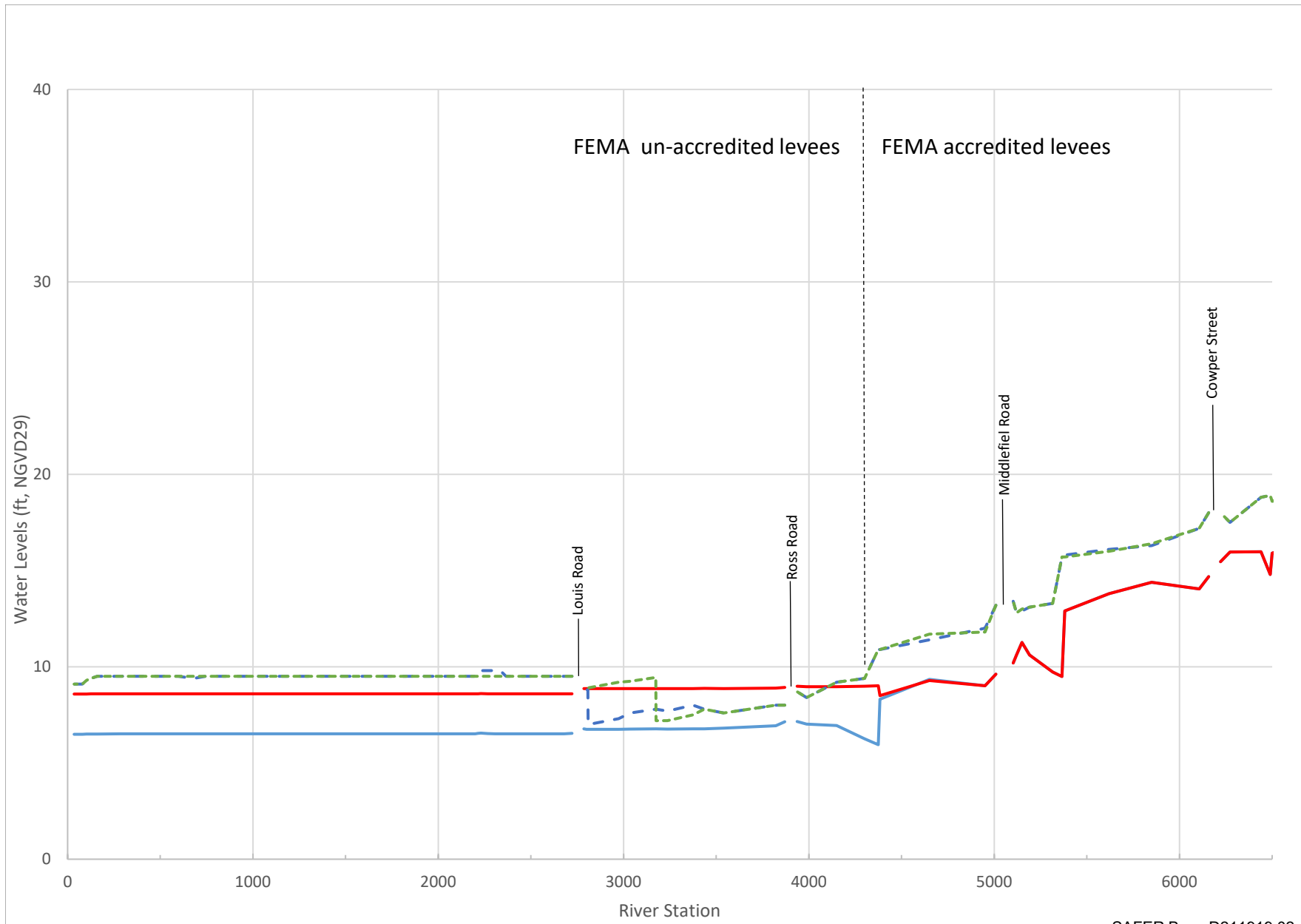
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 11

Change in Freeboard - Adobe Creek
Option 3

— OPT3 Future - Baseline — OPT3 Existing - Baseline



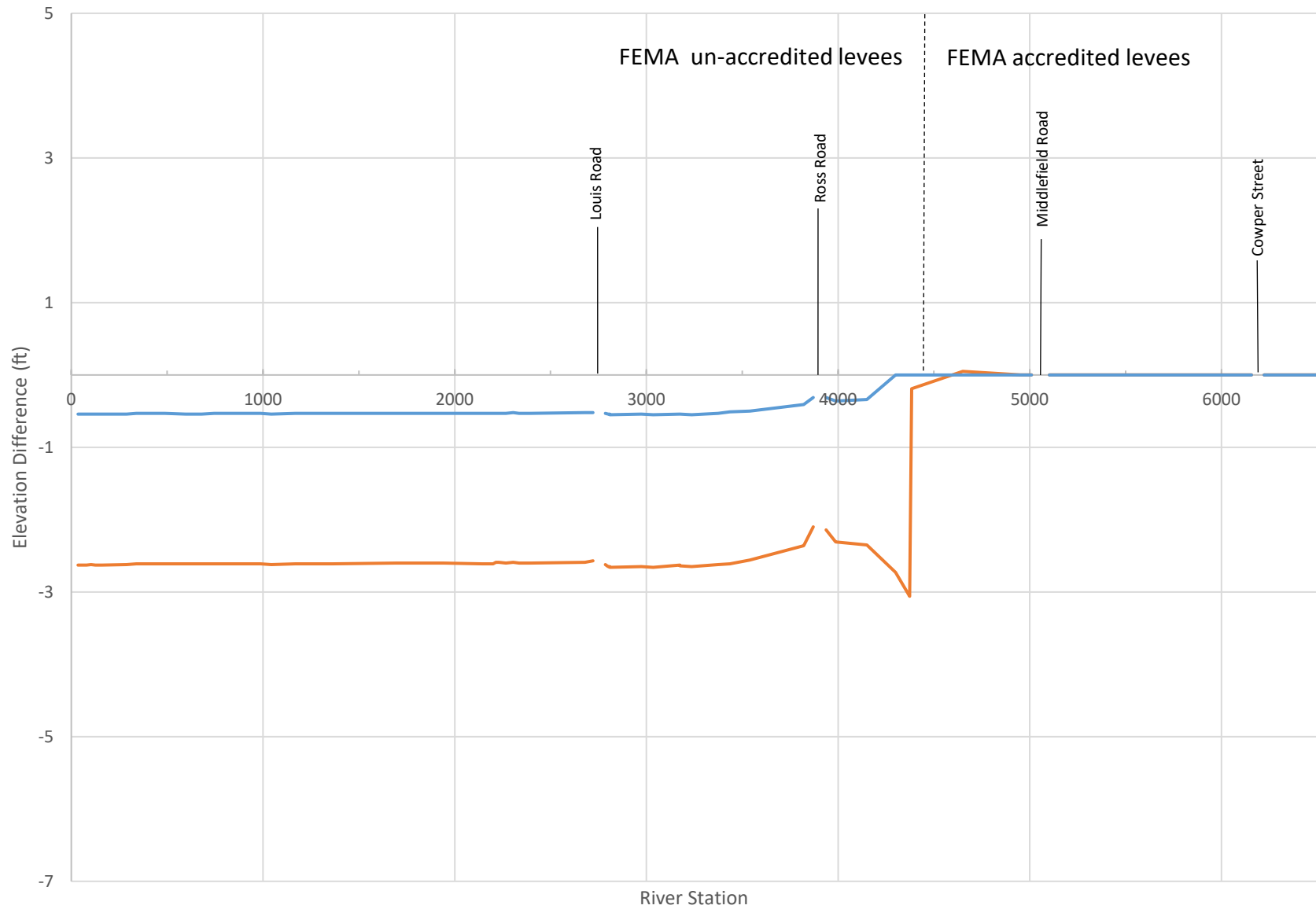
SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 12

Water Levels - Barron Creek Option 3

— Baseline — OPT3 Present Day — OPT3 Future - - - LOB Elevation - - - ROB Elevation



SOURCE: HEC-RAS modeling

SAFER Bay. D211919.02

Figure 13

Change in Freeboard - Barron Creek
Option 3

— OPT3 Future - Baseline — OPT3 Existing - Baseline

Appendix B - Geotechnical Report for the Feasibility Phase, July 2016



Geotechnical Report for the Feasibility Phase
SAFER Bay Project
Task Order No. 2

San Francisquito Creek Joint Powers Authority

San Francisquito Creek to Palo Alto/Mountain View Border

July 2016



SAN FRANCISQUITO CREEK
JOINT POWERS AUTHORITY
SFCJPA.ORG

San Francisquito Creek
Joint Powers Authority
615 B Menlo Avenue
Menlo Park, CA 94025

This page intentionally left blank.

DRAFT

SAFER BAY PROJECT

Project No. 243911-028

Task Order No. 2

GEOTECHNICAL REPORT FOR THE FEASIBILITY PHASE

July 2016

Prepared By:

Victor Crosariol, PE, Edwin Woo, PE, GE

Reviewed By:

Mark Stanley, PE, GE

Approved By:

Sergio Jimenez, PE



1111 Broadway, Suite 1670, Oakland, CA 94607

DRAFT

This page intentionally left blank.



Table of Contents

1	Introduction	1
1.1	Background	1
1.2	Purpose and Scope of Services	2
2	Coastal Flood Protection Considerations and Requirements	3
3	Data Review and Field Exploration	5
3.1	Review of Existing Data	5
3.2	Field Exploration	6
3.3	Laboratory Testing	7
4	Geologic Setting	8
4.1	Regional Geology	8
4.2	Regional Seismicity	8
5	Site Conditions	10
5.1	Surface Conditions	10
5.2	Site Geology	10
5.3	Subsurface Conditions	10
5.4	Groundwater	11
6	Feasibility Level Analyses and Conclusions	12
6.1	Geotechnical Considerations	12
6.2	Levee Design Criteria	12
6.3	Cross Sections for Geotechnical Analysis	13
6.4	Levee Geometry Template	15
6.5	Levee Settlement	15
6.6	Levee Stability	16
6.7	Levee Seepage and Underseepage	18
6.8	Seismic Considerations	19
6.8.1	Seismicity	19
6.8.2	Liquefaction and Seismic Stability	19
7	Feasibility Level Recommendations	21
7.1	Levees	21
7.2	Floodwalls	22
7.3	Floodgates	23
7.4	Penetrations	23

7.5	Open Channels	23
7.6	Utility Poles and Towers.....	23
7.7	Maintenance.....	24
8	Construction Considerations	25
9	Limitations.....	26
10	References.....	27

Tables

Table 1.	Preliminary Coastal Hydraulic Analysis Elevations and Heights	4
Table 2.	Existing Data Considered for Feasibility Level Evaluations.....	5
Table 3.	Regional Faults and Seismicity	9
Table 4.	Summary of YBM Thickness	11
Table 5.	Slope Stability Analysis Results	17
Table 6.	Steady State Underseepage Analysis Results	19

Figures

Figure 1	Overall Project Site Plan
Figures 2a through 2c	Site Plans
Figures 3a through 3i	Analysis Cross-Sections

Appendices

Appendix A	Logs of Test Borings and Cone Penetrometer Tests
Appendix B	Laboratory Test Results
Appendix C	Stability Analyses Results
Appendix D	Seepage Analyses Results



1 Introduction

1.1 Background

San Francisquito Creek Joint Powers Authority (SFCJPA) and its member agencies seek to protect the Cities of East Palo Alto, Menlo Park, and Palo Alto from San Francisco Bay coastal flooding. To accomplish this goal, SFCJPA is undertaking what is referred to as the SAFER Bay (**S**trategy to **A**dvance **F**lood protection, **E**cosystems and **R**ecreation along the Bay) project. SFCJPA is planning for the construction of new and/or improved flood control features along the Bay shoreline from the Menlo Park/Redwood City border (including unincorporated areas) south to the Palo Alto/Mountain View border. The project also seeks to further habitat restoration for the Bay's tidal marsh ecosystem, and to enhance recreation opportunities along the Bay shoreline. Under Task Order No. 1, the project team performed a geotechnical feasibility study for the portion of the SAFER Bay project along the shoreline of Menlo Park and East Palo Alto, which extends from the Menlo Park/Redwood City border to San Francisquito Creek. The results of the Task Order No. 1 study were presented in a Geotechnical Report for the Feasibility Phase dated May 2016. This current report has been prepared under Task Order No. 2, and covers the portion of the SAFER Bay project along the shoreline of Palo Alto, from San Francisquito Creek to the Palo Alto/Mountain View border. Figure 1 presents the footprint of the overall SAFER Bay Task Order No. 2 project (also referred to as SAFER Bay South).

The project team performed a preliminary alignment alternatives evaluation for the SAFER Bay South project, the results of which were presented in a Preliminary Alternatives Report dated May 2015. The purpose of the preliminary alternatives evaluation was to develop, evaluate and present conceptual flood protection alternatives along the Bay shoreline within the project footprint. The Safer Bay South project was divided into two reaches, designated Reaches 10 and 11, that were delineated based on local geography and hydrology, as shown on Figures 1 and 2a through 2c. Reaches 1 through 9 are included in the SAFER Bay North project.

The set of preliminary alternatives has been brought forward to the Feasibility Study Phase, which is being prepared concurrently with this Geotechnical Report. Two or more flood protection alignment options have been considered for each reach. The alignment alternatives were generally located along the interface of developed and undeveloped (such as marsh and pond) areas, with the purpose of providing flood protection to developed areas. The primary flood protection system considered is levees. Where spatial or other constraints exist, alternative flood protection systems, such as floodwalls or flood gates, were considered. More detailed discussion of the alignment alternatives and flood protection systems considered were presented in the Preliminary Alternatives Report.

During this phase, the preliminary alternatives are being evaluated, incorporating the results of this geotechnical study, to identify recommended flood protection alternative(s) that will be carried forward for more detailed study, and eventual implementation during subsequent project phases.



1.2 Purpose and Scope of Services

The purpose of the Geotechnical Report for the Feasibility Phase is to present geotechnical findings and considerations for the identified flood protection alternatives, in support of the overall Feasibility Study.

The scope of geotechnical services included:

- Collecting and reviewing available information on subsurface geotechnical conditions along the project alignment, including logs of past borings and laboratory test results;
- Performing a feasibility level subsurface exploration program consisting of test borings and cone penetrometer tests (CPTs) at selected locations, and laboratory testing, to obtain additional information on subsurface conditions along the proposed alignments;
- Performing geotechnical analyses to support the development of feasibility level designs for the flood protection alternatives being considered;
- Developing and presenting feasibility level geotechnical considerations and recommendations for the flood protection alternatives being considered.

2 Coastal Flood Protection Considerations and Requirements

As described in more detail in the Preliminary Alternatives Report, flood protection elements of the project are to satisfy:

- Current FEMA coastal flood protection requirements, which is the existing 100-year (or 1% annual chance of exceedance) frequency flood event with required freeboard; and
- An additional three feet of tidal elevation to account for anticipated Sea Level Rise (SLR).

As discussed in the Preliminary Alternatives Report, the existing FEMA flood study places all of Palo Alto's Bay shoreline within the Special Flood Hazard Area (SPHA) for the 1% annual chance of exceedance coastal flood event. FEMA has recently released Preliminary Flood Insurance Rate Maps (FIRMs) for Santa Clara County in July 2015 designating the 1% annual chance of exceedance still water elevation and wave transect information for present day conditions. Just offshore of the SAFER project area, this FEMA study estimates that the 1% annual chance of exceedance still water level to be ranging from 11 to 12 feet, North American Vertical Datum of 1988 (NAVD). This is an increase from the current effective FEMA Flood Insurance Rate Maps currently implemented. The existing SFHA is delineated by projecting the base flood elevation (BFE) inland to where it intersects the ground surface elevation.

These Preliminary FIRMs and accompanying Flood Insurance Study (FIS) also document the assessment of waves. Waves are added to the still water level to predict the 1% annual chance of exceedance total water level. If the total water level is more than one foot higher than the still water level, the required levee crest elevation will also need to be higher.

The FEMA freeboard requirements for coastal levees are the higher of:

- Two feet above the 1% annual chance of exceedance still water level
- OR
- One foot above the higher of 1% annual chance of exceedance wave crest elevation or the maximum wave run up elevation

Additional hydraulic analyses will need to be undertaken in future phases of the project to estimate the wave run up elevations that will be used for the final design. The design wave run up elevations will also be affected by restoration improvements that are being planned for the areas on the bayside of the project alignment. Until such hydraulic analyses are performed, it cannot be determined whether the still water or wave run up elevation will control the design.

For the purpose of this geotechnical feasibility study, we have based the design water surface elevations on the still water elevation of 11 feet (NAVD) to assess steady state seepage and stability. If the wave run up elevations result in higher flood protection requirements, then adjustments will need to be made at a later time to address overtopping and erosion.

Although FEMA does not currently consider sea level rise in its flood mapping, the SAFER study design criteria includes a three-foot increase in water surface elevation for sea level rise. The



approximate feasibility-level assumed elevations for the SAFER project's levee crests are presented in Table 1.

Table 1. Preliminary Coastal Hydraulic Analysis Elevations and Heights

Elevation or Height	Existing	With 3 feet SLR
1% SWL elevation	11.0 feet NAVD	14.0
Freeboard for SWL	2.0 feet	2.0 feet
SWL + freeboard	13.0 feet NAVD	16.0 feet NAVD
Minimum design elevation (rounded to 0.5')	13 feet NAVD	16 feet NAVD
Wave run up	TBD	TBD
TWL=SWL+ run up	TBD	TBD
Freeboard for TWL	1.0 feet	1.0 feet
TWL + freeboard	TBD	TBD
Maximum design elevation (rounded to 0.5')	TBD	TBD

Note: SWL = still water level; TWL = total water level; TBD = to be determined; NAVD = North American Vertical Datum, 1988; SLR = Sea Level Rise

DRAFT

3 Data Review and Field Exploration

3.1 Review of Existing Data

Prior to conducting field exploration, efforts were made to obtain boring logs of historical exploration and laboratory test data from the member agencies of SFCJPA, Caltrans, and those publicly available through GeoTracker (an online environmental database managed by the State of California Water Resources Control Board). The locations, depths, quality, and relevance of available previous exploration data were taken into consideration in planning our subsurface investigation. These past explorations are summarized in Table 2 below and their approximate locations are shown on Figures 2a through 2c.

Table 2. Existing Data Considered for Feasibility Level Evaluations

Data Source	Type	Original Exploration Designation	Project Exploration Designation	Exploration Depth (feet)	Date Advanced
Lowney Associates (2002)	Geotechnical Boring	EB-5	LNy-EB-5	40.0	February 2002
GEI Consultants, Inc. (2012)	Geotechnical Boring	B-5	GEI-B-5	51.5	February 2010
	Cone Penetration Test	B-6 CPT-4	GEI-B-6 GEI-CPT-4	51.5 80.1	January 2010
Earth Systems Consultants (1983)	Geotechnical Boring	B-1	ES-B-1	44.5	September 1983
		B-5	ES-B-5	50.0	
¹ William C. Ellis (1981)	Groundwater Monitoring Well	G-1A	G-1A	53.5	January 1981
¹ Unknown (1983)	Groundwater Monitoring Well	G-3A	G-3A	50.0	May 1983
¹ Emcon Associates (1988)	Groundwater Monitoring Well	G-8/88	G-8-88	46.5	August 1988
		G-9/88	G-9-88	28.0	
		G-10/88	G-10-88	47.5	
		G-12/88	G-12-88	48.5	
		G-13/88	G-13-88	29.0	
		G-14/88	G-14-88	37.5	
		G-15/88	G-15-88	48.5	
		G-16/88	G-16-88	31.0	
		G-17/88	G-17-88	49.0	
		G-19/88	G-19-88	27.0	
Kleinfelder, Inc. (2002)	Geotechnical Boring	B-1	KLF-B-1	20.0	February 2002
		B-2	KLF-B-2	20.0	
Caltrans (2009)	Geotechnical Boring	R-09-001	R-09-001	88.5	March 2009
		R-09-004	R-09-004	88.5	
Caltrans (2009)	Cone Penetration Test	CPT-09-002	CPT-09-002	87.5	March 2009
		CPT-09-003	CPT-09-003	87.0	
Caltrans (2009)	Geotechnical Boring	A-09-120	A-09-120	5.0	March 2009
		A-09-125	A-09-125	10.0	
		A-09-179	A-09-179	36.5	
		A-09-182	A-09-182	35.0	
		A-09-184	A-09-184	35.0	
Caltrans (1957)	Geotechnical Boring	B-2	MC-B-2	82.5	March 1957



Data Source	Type	Original Exploration Designation	Project Exploration Designation	Exploration Depth (feet)	Date Advanced
		B-4	MC-B-4	87.5	
		B-4	AC-B-4	80.8	

1. Monitoring well logs for the former landfill were provided by the City of Palo Alto (2016)

3.2 Field Exploration

HDR’s field investigation consisted of advancing five test borings and four cone penetrometer tests (CPTs) in accessible areas along the proposed alignments in areas of identified data gaps for geotechnical site characterization. Prior to performing the subsurface investigations, HDR obtained the required Santa Clara Valley Water District (SCVWD) geotechnical drilling permits, and property owner access permissions specific to each exploration location. HDR also contacted Underground Service Alert (USA) to check for the presence of underground utilities.

As this is a feasibility level geotechnical investigation, only a limited number of relatively widely spaced explorations were undertaken to supplement existing geotechnical data to develop general site characterizations for evaluations of flood control features. Further, data gaps remain along portions of the project alignment where site access could not be obtained. These include: 1) the area in the vicinity of Palo Alto Airport, where exploration rig access was not allowed within specific airspace zones during airport operating hours due to Federal Aviation Administration (FAA) safety regulations; and 2) within the Palo Alto Flood Control Basin, along Reach 11, Option 3, where standing water and soft ground did not allow for conventional drill rig access.

Pitcher Drilling Company (Pitcher) advanced five test borings, designated B-07 through B-11, from January 21 through 25, 2016. Boring numbers B-01 through B-06 were previously designated for the SAFER Bay North project or not used because of site access constraints. The borings were advanced using truck-mounted Failing 1500 drilling equipment. All borings were drilled using rotary wash drilling methods to depths ranging from 41.5 to 56.5 feet. Test borings were backfilled with cement grout in accordance with SCVWD geotechnical drilling permit conditions.

Representative soil samples were collected at approximately 2- to 5-foot intervals, as appropriate to the soil type and stratification encountered. Disturbed samples were obtained by driving either a Standard Penetration Test (SPT) split-barrel sampler without liners or a Modified California split-barrel sampler with 6-inch long liners. Resistance blow counts were obtained with both Modified California and SPT samplers by dropping a 140-pound automatic trip hammer through a 30-inch free fall. Relatively undisturbed Shelby Tube samples were obtained using direct push or Pitcher Barrel rotary sampling methods, as appropriate to soils encountered in the borings. Soil samples collected from the borings were initially classified and described by an HDR field engineer in general accordance with ASTM D2488. The samples were transported to our sample storage area and a geotechnical laboratory for further examination, laboratory testing, and confirmation of classification. The field log classifications were then edited based upon the results of the laboratory examination and testing, as necessary.



Gregg Drilling and Testing, Inc. (Gregg) advanced four CPTs, designated C-09 through C-12, on January 12, 2016. CPT numbers CPT-01 through C-08 were either previously designated for the SAFER Bay North project or not used because of site access constraints. A 30-ton truck-mounted CPT rig was used to advance the CPTs to depths of approximately 60 to 65 feet. All CPTs were backfilled with cement grout in accordance with SCVWD geotechnical drilling permit conditions. An HDR engineer was on-site to facilitate and observe the CPT activities.

The approximate locations of the exploratory borings and CPTs are shown on Figures 2a through 2c. The locations of the explorations were determined by tape measuring from existing site features and are accurate only to the degree implied by the method used. Logs of the exploratory borings and CPTs and additional details of the exploration program are presented in Appendix A.

3.3 Laboratory Testing

Selected soil samples obtained from the exploratory borings were delivered to Cooper Testing Laboratory (Cooper) in Palo Alto, California for geotechnical laboratory testing. Laboratory testing included index testing for soil classification and advanced testing to evaluate geotechnical engineering properties. Field soil descriptions were updated as needed based on laboratory testing results in accordance with ASTM D2487. The laboratory tests performed included the following:

- Sieve Analysis and Hydrometer (ASTM D422)
- Percent Passing No. 200 Sieve (ASTM D1140)
- Atterberg Limits (ASTM D4318)
- Moisture Content and Density (ASTM D7263b)
- Triaxial Compression – Unconsolidated Undrained (ASTM D2850)
- Consolidation (ASTM D2435)

The results of the laboratory tests are presented on the boring logs at the appropriate sample depths and/or in Appendix B.

4 Geologic Setting

4.1 Regional Geology

The project site is located in the southern part of the San Francisco Bay Area in the Coast Ranges geomorphic province of California, which is characterized by northwest-southeast trending valleys and ridges. These valleys and ridges are controlled by folds and faults that resulted from the collision of the Pacific and North American plates, subduction of the Pacific Plate beneath the North American Plate, and subsequent strike-slip faulting along the San Andreas Fault zone and the plate boundary fault systems. Bedrock underlying the region is primarily of the Franciscan Complex, characterized by a diverse assemblage of sandstone, shale, chert, greenstone and mélangé.

Geologic formations in the San Francisco Bay Region range in age from Jurassic (190 to 135 million years ago) to recent Holocene (less than 11 thousand years ago). The Franciscan Complex is the oldest, and underlies younger surficial deposits throughout the San Francisco Bay Region. The Franciscan Complex consists mainly of marine-deposited sedimentary and volcanic rocks in close association with bodies of serpentine. Following deposition, the Franciscan rocks were regionally uplifted and, in the process, extensively faulted and folded.

The Bay Area has experienced several episodes of uplift and faulting during late Tertiary time (about 25 to 2 million years ago). This produced a series of northwest-trending valleys and mountain ranges, including the Berkeley Hills, the San Francisco Peninsula and the intervening San Francisco Bay. Uplifted areas were eroded. In what is now San Francisco Bay, sea levels rose, inundating the valleys. As a result, Pleistocene and recent estuarine marine sediments were deposited in the San Francisco Bay, and stream and marshland sediments were deposited in low-lying areas adjacent to the Bay.

4.2 Regional Seismicity

Geologists and seismologists recognize the San Francisco Bay Area as one of the most active seismic regions in the United States. Active faults extending through the Bay Area have produced 11 large (moment magnitude, M_w 6.0 or greater) earthquakes over the last two centuries that have damaged buildings and other infrastructure. The faults causing such earthquakes are part of a system of faults along the boundary of the Pacific and North American plates and locally include the San Andreas, Calaveras, and Hayward faults. The major fault in the system is the San Andreas Fault that extends for at least 450 miles along the coast of California.

The 2014 Working Group on California Earthquake Probabilities (WGCEP) published an updated report evaluating the probabilities of significant earthquakes occurring in the Bay Area over the next three decades (Field et al, 2015). The WGCEP estimated that there is a 72 percent probability that at least one moment magnitude 6.7 or greater earthquake will occur in the San Francisco Bay region before 2044. This probability is an aggregate value that considers principal Bay Area fault systems and unknown faults (background values) including the potential for multi-fault ruptures. The principal active faults in the Bay Area include the San Andreas,



Hayward, Calaveras, and the San Gregorio faults. Earthquakes occurring along these faults are capable of generating strong ground shaking at the project site.

Table 3 summarizes the approximate distances between the site and the six closest known mapped active or potentially active faults based on the 2008 update to the United States National Seismic Hazard Maps online Fault Parameter database (USGS, 2008a). The online information is documented by the United States Geological Survey (USGS) Open File Report 2008–1128 (Petersen et al., 2008). The project site is not located within an Alquist-Priolo Earthquake Fault Zone.

Table 3. Regional Faults and Seismicity

Fault (segments)	Approximate Distance from Site, mi (km)	Direction from Site	Maximum Moment Magnitude
Monte Vista –Shannon	6.0 (9.7)	Southwest	6.5
¹ San Andreas (SAO+SAN+SAP+SAS)	8.1 (13.0)	Southwest	7.9
² Hayward-Rodgers Creek (RC+HN+HS)	11.0 (17.7)	Northeast	7.3
³ Calaveras (CN+CC+CS)	15.3 (24.6)	Northeast	7.0
San Gregorio Connected	18.6 (29.9)	Southwest	7.5
San Andreas (SAS)	19.9 (32.0)	South	7.1

1. San Andreas segments: SAO = Offshore, SAN = North Coast, SAP = Peninsula, SAS = Santa Cruz Mountains
2. Hayward-Rodgers Creek segments: RC = Rodgers Creek, HN = North Hayward, HS = South Hayward
3. Calaveras segments: CN = Northern, CC = Central, CS = Southern

Earthquakes on these or other active faults (including unmapped faults) could cause strong ground shaking at the site. Earthquake intensities vary throughout the Bay Area depending upon the magnitude of the earthquake, the distance of the site from the causative fault, the type of materials underlying the site, and other factors.

5 Site Conditions

5.1 Surface Conditions

The proposed project alignment is located along the bay margin of the City of Palo Alto, and extends from San Francisquito Creek to the Palo Alto/Mountain View border. The proposed alignment is generally located near the edge of developed areas. Areas on the bayside of the alignment generally consist of marsh, other open space, or waterways (creek, slough, bay). Areas on the landside of the alignment are generally developed with features that include the Palo Alto Golf Course, Palo Alto Airport, Palo Alto Wastewater Treatment Plant (WWTP), Byxbee Park (site of a former landfill), commercial development, Palo Alto flood basin, roadways, and open space. A berm, levee, road or trail exists along much of the proposed alignments, and consist of asphalt concrete paved, gravel or unpaved segments. Where the flood protection system is to consist of levees (the majority of the alignment), it is anticipated that the levee footprint will generally span over the existing berm, levee, road or trail, and extend bayward into marsh or open space. A project survey has not yet been performed. Based on publically available topographic information, existing site grades along the berm, levee or trail of the proposed alignment generally range from about Elevation 7 to 11 feet (USGS, 2011). Existing site grades in the adjacent marsh or open space are generally comparable or lower than those in the adjacent berms, levees, roads or trails, but are estimated to range from about Elevation 3 to 7 feet. Bathymetry is not available for the marsh and slough/creek areas. Thus, much of the data reported for the lower elevation areas (below approximately Elevation 5 feet) are rough approximations and need to be verified during subsequent phases of the project.

5.2 Site Geology

Brabb et al (1998) mapped surficial deposits beneath the fill along the project alignment as Holocene age Bay Mud deposits consisting predominantly of gray, green and blue clay and silty clay. This is consistent with a map by Dibblee and Minch (2007), who mapped surficial deposits along the project alignment as Holocene age San Francisco Bay Mud generally consisting of estuarine organic clay and silty clay, and an older map by Dibblee (1966), who mapped surficial deposits along the project alignment as Recent Quaternary age Bay Mud and clay deposits.

5.3 Subsurface Conditions

Fill was encountered in all of the borings and CPTs performed for this feasibility study, as well as in the past borings by others in the immediate project area. In existing berm, levee, road or trail areas, fill was encountered to depths ranging from about 5.5 to 12 feet at their respective exploration locations. The fill encountered is variable in composition but generally consists of medium stiff to stiff lean to fat clay, sandy lean clay, and elastic silt, and medium dense clayey sand. With the exception of some of the Caltrans borings along Highway 101 between Matadero and Adobe Creeks, Young Bay Mud (YBM) was encountered beneath the fill in all of the explorations performed. The YBM generally consists of very soft to medium stiff, moderately to highly compressible fat clay and elastic silt, with sand. The thickness of the YBM layer varies considerably along the project alignment, ranging from about 3 to 23 feet, as summarized by reach in Table 4. Beneath the YBM, alluvial deposits generally consisting of interlayered stiff to



very stiff lean clay with varying amounts of sand and silt, and loose to dense clayey sand and sand with clay and gravel, were encountered to the maximum depth explored of about 88.5 feet.

Table 4. Summary of YBM Thickness

Reach	Approximate YBM Thickness (feet)	Explorations
Reach 10, Options 1 and 2	6.5 to 12 feet	LNY-EB-5, GEI-B-5, GEI-B-6, GEI-CPT-4, ES-B-1, ES-B-5, G-1A, G-9-88, B-07, C-09
Reach 11, Option 1	12.5 to 23 feet	B-08, C-10, B-09, C-11, B-10, C-12
Reach 11, Option 2	0 to 17.5 feet	C-12, B-14, G-13-88, G-14-88, G-15-88, G-16-88, KLF-B-1, KLF-B-2, R-09-001, R-09-004, CPT-09-002, CPT-09-003, A-09-120, A-09-125, A-09-179, A-09-182, A-09-184, MC-B-2, MC-B-4, AC-B-4
Reach 11, Option 2a	17.5 to 22 feet	G-12-88, G-13-88, G-3A, G-10-88, B-08
Reach 11, Option 3	12.5 to 17.5 feet	C-12, G-13-88
Reach 11, Option 3a	17.5 to 22 feet	G-13-88, G-12-88, G-3A, G-10-88, B-08

5.4 Groundwater

The depth to groundwater could not be determined in all of the borings performed for this feasibility study because of the rotary wash drilling methods used. Groundwater was encountered at the time of drilling at depths of about 5.5, 6 and 7 feet, corresponding to Elevations 5.5, 4, and 3 feet, in Borings B-08, B-09, and B-10, respectively. In addition, water judged to be perched water was encountered at a depth of about 2.5 feet, corresponding to Elevation 8.5 feet, in Boring B-07 at the time of drilling. The borings may not have been left open for a sufficient period of time to establish equilibrium ground water conditions. These groundwater levels are generally consistent with those reported on the past boring logs. Given the proximity of the project alignment to the bay, it is anticipated that groundwater levels are likely to be tidally influenced. Fluctuations in the ground water level could occur due to changes in seasons, variations in rainfall, and other factors.

6 Feasibility Level Analyses and Conclusions

6.1 Geotechnical Considerations

As described above, the proposed project alignment is located along the margin of San Francisco Bay. The geotechnical explorations performed for this feasibility study and past explorations by others indicate that beneath the fill layer, the large majority of the area is underlain by YBM. This soil is soft, weak and highly compressible. The YBM also contains intermediate sand layers and lenses that, if continuous, could be potential underseepage paths.

To provide for coastal flood protection, new levees will be constructed or existing levees will be raised and broadened with earthen embankments. Where spatial or other constraints exist, alternative flood protection systems, such as floodwalls, may be required.

Placement of fill to build new levees or raise levee crown elevations may impact the underlying soil, and in particular the YBM. Three key considerations to be evaluated are:

Settlement – The additional loading from new levees or levee raises will cause settlement over time primarily due to the consolidation of the underlying YBM. Where the YBM has sufficient strength, the levees will need to be initially built to heights greater than their final target elevations and allowed to settle to meet their design crest elevations.

Stability – Depending on the height of new levee fill needed and the strength of the underlying soil, the YBM may be too weak to allow the levees to be constructed to their target elevations 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 sufficient time for the underlying soil to consolidate and gain strength before additional fill is placed. Alternatively, measures may be needed to strengthen the 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 underseepage can lead to levee and foundation erosion, piping, slope instability and other detrimental consequences. If uncontrolled, these could result in levee breach. Mitigation measures should include constructing levees with properly moisture conditioned and compacted low permeability fine grained soils to control through seepage, and/or installation of seepage cutoff walls, pressure relief wells, drained or undrained berms for underseepage control, where required.

6.2 Levee Design Criteria

Project geotechnical design criteria were established to evaluate the levees for acceptable performance with respect to levee height/settlement, stability, and underseepage. The criteria used are based on published federal and state regulations and technical guidance documents. For levees to be accredited by FEMA, evidence must be provided that adequate design and operation and maintenance (O&M) systems are in place to provide reasonable assurance that protection from the base flood with a 1-percent annual chance of exceedance (i.e., 100-year

flood) exists. These requirements are outlined in the Code of Federal Regulations, 44CFR65.10 (FEMA, 2006), and in the California Code Regulations (CCR), Title 23 (CVFPB, 2009).

In general, the United States Army Corps of Engineers (USACE) criteria were followed for the design of levees, as presented in USACE Engineering Manual 1110-2-1913 *Design and Construction of Levees* (USACE, 2000), based on the requirements of 44CFR65.10. State guidelines, as presented in the State of California Department of Water Resources (DWR) Urban Levee Design Criteria (2012), were also referenced. These include design criteria for levee height/settlement, stability, through seepage/underseepage, summarized as follows.

Levee height/settlement – As discussed in Section 2, levees are to be designed to achieve a minimum levee crest height of Elevation 13 feet to meet FEMA current 100-year event flood protection requirements, and Elevation 16 feet to provide an additional 3 feet of SLR freeboard. Settlement analyses were conducted to evaluate levee overbuilt geometries to attain the minimum FEMA and SLR elevation 25 years after initial construction.

Stability – Levee stability analyses were performed for the following conditions and for the required minimum factors of safety:

- End of Construction: minimum factor of safety of 1.3;
- During a flood event, with the water level set at Elevation 14 feet (FEMA 100-year flood elevation plus 3 feet for sea level rise) and steady-state seepage conditions: minimum factor of safety of 1.4; and
- For rapid drawdown conditions, where the water level drops from Elevation 14 feet to the waterside ground surface elevation (full flood drawdown): minimum factor of safety of 1.0.

Through Seepage/Underseepage – If the steady state phreatic surface daylights on the landside levee slope as a result of through seepage (also referred to as breakout), it may be detrimental if the levee is constructed of permeable or erodible materials. Potential detrimental effects of through seepage include a reduction in slope stability, sloughing and erosion of the landside levee slope surface, and internal erosion through piping. Low-plasticity or non-plastic soils are more susceptible to erosion than soils with medium to high plasticity. The proposed levees should be constructed with properly conditioned and compacted low permeability fine grained soil with a low potential for through seepage erosion. In future phases of the project, material property requirements for levee fill will need to be established taking into consideration their potential for through seepage. For the FEMA plus SLR flood event with the water level set at Elevation 14 feet and steady-state seepage conditions, an exit gradient of 0.5 at the landside toe was taken as the acceptable criterion.

6.3 Cross Sections for Geotechnical Analysis

As previously discussed, the South project alignment was divided into two reaches with reach options. Based on the site and subsurface conditions, cross sections were developed for geotechnical analysis at nine locations, to represent the range of geometric and foundation conditions along different alignment segments. The locations of cross sections and associated levee segments, denoted as G9 through G17, are shown on Figures 2a through 2c. Cross

sections G1 through G8 were previously designated for the SAFER Bay North project. The nine analysis cross sections are shown on Figures 3a through 3i. A summary of each cross section and the reach limits that it represents is presented as follows:

- Cross section G9 – Within Reach 10, represents the approximately 3,500-foot long segment that is located along the east side and southern end of the Palo Alto Airport runway (both Options 1 and 2). The segment of Reach 10 along San Francisquito Creek can be represented with a raised levee that is a continuation of the San Francisquito Creek project levee.
- Cross section G10 – Within Reach 10, represents the approximately 3,000-foot long segment of Reach 10 (both Options 1 and 2) beginning at the southern end of the Palo Alto Airport runway, following along the Palo Alto WWTP to just before the Byxbee Park landfill.
- Cross section G11 – Within Reach 11, Option 1, represents the northern approximately 6,000 feet of this option.
- Cross section G12 – Within Reach 11, Option 1, represents the southern approximately 5,600 feet of this option.
- Cross section G13 – Within Reach 11, Option 2, represents approximately 2,400 feet of levee that is situated along Adobe Creek, between the southern end of Charleston Slough and Highway 101.
- Cross section G14 – Within Reach 11, Option 2, represents approximately 4,400 feet of levee that is situated along East Bayshore Road and the south and east sides of the Palo Alto Operations and Maintenance Facility.
- Cross section G15 – Within Reach 11, Option 2, represents the approximately 1,000-foot length along Matadero Creek and the west side of the Palo Alto Operations and Maintenance Facility. Unlike other cross sections and segments, this one is modeled with flood walls and not levees because of site constraints. Since levee raising or construction is not planned along this segment, levee settlement and stability analyses were not performed for this cross section. Seepage analyses were performed using flood walls in lieu of levees.
- Cross section G16 – Within Reach 11, Option 2a, represents approximately 10,000 feet along the north side of the Byxbee Park landfill, Reach 11, Option 2a along the east side of the Byxbee Park landfill, and Reach 11, Option 2, between the landfill and the northern end of the Palo Alto Operations and Maintenance Facility.
- Cross section G17 – Within Reach 11, Option 3, represents the entire approximately 2,800-foot length of this reach and option across the Palo Alto flood control basin.

The levee geometries were developed based upon a standard levee template adjusted for settlement as described in the following section.

6.4 Levee Geometry Template

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 feet.
- Extend at least 3 feet below existing grade, following excavation of an exploration trench across the base of the levee.

The minimum levee template was modified where appropriate based upon levee settlement and stability analyses. Analysis was performed for each representative cross section to evaluate the magnitude of settlement and height of levee overbuild to meet the levee crown target elevation and meet the minimum levee stability criteria. For the reasons discussed in the Section 6.1, as well as economic reasons, it is possible that levees would be constructed and raised in stages over the course of many years. 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.

An important component of the SAFER Bay Project's ecosystem restoration approach is the inclusion of transition zone habitat restoration on the outboard levee slope. SFCJPA and the project team are in the process of determining where transition zones will be included along the project alignment. After the locations of such zones are better established, we can incorporate them into our geotechnical models for analyzing settlement. In general, it is anticipated that although some of the transition zones themselves may settle a significant amount (comparable to the magnitudes of settlement of their adjacent levees); the added influence of the transition zone loading on levee crest settlement is relatively small. Estimated levee crest settlements are discussed in the section below.

6.5 Levee Settlement

Overbuilding of levees was considered in establishing levee geometries for analyses to account for consolidation of the underlying YBM. For example, for a location where the existing ground surface is at Elevation 8 feet, and 2 feet of settlement is estimated, a 10-foot high levee would need to be constructed to an initial levee crest elevation of 18 feet that, over time, will settle to the target crest Elevation of 16 feet.

Based on our settlement analyses, it is estimated that the levees with the standard levee template geometry would need to be wider and overbuilt by about 1 to 2.5 feet, to achieve a target crest elevation of 16 feet. In general, the required overbuild heights are greatest within the northern portion of Reach 11, Option 1 where the thickest YBM was encountered, and along the eastern edge of the Byxbee Park landfill (Reach 11, Options 2a and 3a) and across the Palo Alto Flood Basin (Reach 11, Option 3) where the YBM is relatively thick and the existing ground

surface elevation is relatively low. Feasibility level recommendations of the required overbuild heights along each reach are presented in Section 7 below.

6.6 Levee Stability

Slope stability analysis was performed for each representative cross section using the limit equilibrium software program SLOPE/W (GEO-SLOPE, 2015). Stability analyses were performed for the following three conditions:

- Levee end-of-construction condition, judged to be the most critical condition for stability. The weight of the levees will induce consolidation settlement and strength gain in the YBM with time, which will also increase levee stability with time. For the cases where the levee cannot be constructed to its full final height while maintaining a satisfactory factor of safety for stability, construction will need to be undertaken in at least two stages. For these cases, the end-of-construction condition was analyzed at the end of each stage. Both the landside and waterside slopes were analyzed and the more critical case is reported.
- Steady state seepage stability of the levee during a flood event with design water level set at Elevation 14 feet (FEMA 100-year flood elevation plus 3 feet for sea level rise). These analyses were performed assuming steady-state seepage conditions (seepage analyses discussed below), with the levee at its greatest constructed height at the end of construction, and without a transition zone – all conservative assumptions.
- For rapid drawdown conditions, where the water level is assumed to suddenly drop from the design flood level of Elevation 14 feet to the waterside ground surface, with no transition zone.

For each representative cross section, the end-of-construction levee stability was first analyzed with an overbuilt geometry in a single stage ((final target crest elevation plus additional overbuild height to account for settlement). Thus, stability analysis was performed for levees constructed to initial crest heights of Elevation 17 to 18.5 feet using fine grained (clay) levee fill soils. Engineering properties of the levee fill are based on engineering judgment of what is typical for levees in the South Bay. These properties will need to be verified during final design.

The results of feasibility level stability analyses for the SAFER Bay South segments are presented in Table 5 and Appendix C. These analyses indicate that the proposed levees along the segments represented by cross sections G9, G10, G13, and G14 can be constructed to their final target crest heights (single stage) while maintaining the required factor of safety against end-of-construction instability. The segments represented by cross sections G11, G12, G16, and G17 contain greater thicknesses of YBM and/or the existing ground surface elevations are relatively lower, thus requiring more fill to achieve their target crest heights. The analyses indicate that the foundation soils underlying these segments are weak and the levee cannot be constructed in a single stage and maintain the required factor of safety against end-of-construction instability (or in the case of G12, only marginally meet the required factor of safety). The analyses show that these levees will likely need to be constructed in at least two stages to allow for consolidation and associated foundation strength gain prior to constructing the levees



to their final target height. Analyses indicate the levees can be constructed using a two-stage approach by providing sufficient time between stages to allow the YBM to consolidate and achieve the needed strength gain. Given the YBM conditions present at the site, it is estimated that the large majority of settlement and strength gain from the first stage of filling will have occurred after 25 years. For these analyses, it has been assumed that the second stage of filling would occur 25 years after initial construction. As an additional measure to improve end-of-construction stability for the four sections requiring staged construction, a layer of geotextile or geogrid was included in the stability model at the base of the levee.

Landside long-term steady state seepage static stability analyses were performed for a design water surface at Elevation 14 feet. The development of steady-state seepage models and the corresponding steady-state pore pressures used for these stability analyses are discussed below in Section 6-7. On this basis, these feasibility level analyses indicate that all of the proposed levee configurations meet the USACE minimum factor of safety of 1.4 for this analysis condition (USACE, 2000). In the case of Sections G11, G12, G16 and G17, the addition of a geotextile or geogrid along the base of the levee was needed to improve the calculated factor of safety to at least 1.4.

Waterside rapid drawdown was performed using the staged undrained strength method and the initial undrained soil shear strengths prior to strength gain due to consolidation (Duncan, Wright, and Wong, 1990), which has been incorporated into SLOPE/W. According to USACE (2000), a factor of safety of 1.0 is appropriate for waterside levee slopes following a relatively short duration flood stage, which we consider to be appropriate for these analyses. On this basis, feasibility level analyses indicate that all of the proposed levee configurations meet this factor of safety. The rapid drawdown stability criteria and drawdown levels should be revisited after the system hydraulic loading is better defined, in order to confirm that the feasibility level criteria are appropriate for final design.

Table 5 and Figures C-1 through C-44 present factor of safety results for end-of-construction, steady-state, and waterside rapid drawdown stability analyses.

Table 5. Slope Stability Analysis Results

Analysis Cross Section	End-of-Construction Minimum Required FOS = 1.3				Landside Steady-state Stability Minimum Required FOS = 1.4	Waterside Rapid Drawdown Minimum Required FOS = 1.0	Geogrid or Geotextile Included for Steady-state and Waterside Rapid Drawdown?
	Full Levee Without Geogrid or Geotextile	Full Levee With Geogrid or Geotextile	Staged Construction (All With Geogrid or Geotextile)				
			Stage 1	Stage 2			
G9	1.96	--	--	--	1.78	1.65	No
G10	2.70	--	--	--	2.76	1.50	No
G11	1.18	1.23	1.48	1.37	1.48	1.28	Yes
G12	1.32	1.40	1.72	1.53	1.45	1.25	Yes
G13	1.66	--	--	--	2.76	1.27	No
G14	1.35	--	--	--	1.53	1.28	No
G16	1.15	1.21	1.44	1.39	2.31	1.18	Yes

Analysis Cross Section	End-of-Construction Minimum Required FOS = 1.3				Landside Steady-state Stability Minimum Required FOS = 1.4	Waterside Rapid Drawdown Minimum Required FOS = 1.0	Geogrid or Geotextile Included for Steady-state and Waterside Rapid Drawdown?
	Full Levee Without Geogrid or Geotextile	Full Levee With Geogrid or Geotextile	Staged Construction (All With Geogrid or Geotextile)				
			Stage 1	Stage 2			
G17	1.22	1.30	1.58	1.49	1.61	1.21	Yes

Bold – Meets Criteria

6.7 Levee Seepage and Underseepage

Steady-state seepage analyses were performed for each representative cross section for a design water surface at Elevation 14 feet, using the finite element computer program SEEP/W (GEO-SLOPE, 2015). Boundary conditions used for the SEEP/W modeling are as follows:

- Nodes along the waterside ground surface and levee slope or floodwall were set to a constant-head of 14 feet, corresponding to the design water surface.
- Nodes along the waterside vertical edge were set to a no flow boundary condition.
- Nodes along the bottom of the model were set to a no flow boundary condition.
- Nodes on the landside vertical edge were set to a constant head equal to the lower of the landside levee toe elevation or the elevation of the landside edge of the model.
- Nodes on the landside levee slope and the landside ground surface were modeled as potential seepage surfaces.
- The following exceptions to the above general boundary conditions were implemented for Sections G15 and G16, to account for unique site features as described below:
 - At Section G15, an existing drainage ditch is located about 40 feet landside of the north floodwall. Nodes within the ditch are set to a constant head boundary condition of 2 feet. This simulates the ditch being filled with water up to Elevation 2 feet, which corresponds to the elevation of the landside edge of the model and is a conservatively low-end estimate of the groundwater table elevation.
 - At Section G16, the existing landfill is located on the landside vertical edge of the model. To account for unknown mounding of the leachate surface within the landfill, the landside vertical edge of the model was set to a no flow boundary condition.

For each cross section, the soil stratigraphy used for end-of-construction and rapid drawdown stability analysis was also used for steady-state seepage and stability analyses. The analyses have been performed based on engineering judgment to select fine grained (clay) levee fill soil permeability properties that are order of magnitude values typical for levees in the South Bay. These properties will need to be verified during final design.



The results of the seepage analyses are presented in Table 6 and Figures D-1 through D-16. The analysis results indicate that the average vertical exit gradients at the landside levee toe are less than 0.5, which is the USACE criterion (USACE, 2000). Based on these preliminary analyses, it is anticipated that levee through seepage and underseepage will not be significant issues for these proposed levees when constructed in accordance with current levee design practice. However, more detailed subsurface explorations and topographic survey of low lying areas will need to be performed as part of final design to meet minimum FEMA and USACE guidance and complete the characterization of foundation conditions. Final design level studies could find that remedial measures to address underseepage deficiencies may be required.

Table 6. Steady State Underseepage Analysis Results

Analysis Cross Section	Gradient Calculation Location	Calculated Average Exit Gradient
G9	Levee Landside toe	< 0.01
G10	Levee Landside toe	< 0.01
G11	Levee Landside toe	0.11
G12	Levee Landside toe	0.27
G13	Levee Landside toe	0.08
G14	Levee Landside toe	0.43
G15	Left side (west) floodwall foundation	0.11
	Left side drainage ditch	0.44
	Right side (east) floodwall	0.15
G16	Levee toe	0.05
G17	Levee toe	0.14

6.8 Seismic Considerations

6.8.1 Seismicity

The site is located in a seismically active region of California. Significant earthquakes in the Bay Area have been associated with movements along well-defined fault zones. Earthquakes occurring along any of a number of other Bay Area faults have the potential to produce strong ground shaking at the site.

6.8.2 Liquefaction and Seismic Stability

Soil liquefaction is a phenomenon in which saturated (submerged), cohesionless soil experiences a temporary loss of strength due to buildup of excess pore water pressure during cyclic loading induced by an earthquake. The soils most susceptible to liquefaction are loose, clean, saturated, poorly (uniformly) graded sand, and non- to low-plasticity silt or silty sand. Denser soils are more resistant to seismic liquefaction than looser soils. Soils with significant fines content are more resistant to seismic liquefaction than clean sands. Also, during an earthquake, unsaturated granular soils (above the groundwater table) might experience dynamic densification due to reorientation and compaction of the soil particles.

The majority of the current and past explorations performed along the project alignment indicate that the site is predominantly underlain by soil with relatively high clay content and/or consists of relatively dense granular (sand and gravel) material that is considered to have a low potential for liquefaction. Zones of loose to medium dense granular material were encountered in some of

the borings and CPTs. As these zones were only encountered in some of the borings and CPTs, and at various depths, it is judged that these zones of potentially liquefiable soil are of limited lateral extent.

Following the guidance presented in the Urban Levee Design Criteria (ULDC, 2012) by the California Department of Water Resources (DWR), the potential for liquefaction was evaluated using a 100-year return period seismic event corresponding to the 100-year return period event used for flood protection assessment. A 100-year return period event with a peak ground acceleration of 0.27 times the acceleration of gravity (0.27g) corresponding to an M_w 6.6 earthquake was selected for analyses. These input values were selected using the USGS 2008 PSHA Interactive Deaggregation tool with a $V_{s,30}$ (average shearwave velocity in the top 30 meters of the soil profile) of 183 m/s (600 ft/s) (USGS, 2008b). On this basis, we estimate liquefaction-induced settlements of less than about 1 inch could occur in explorations CPTs C-09, -10, -11, and -12 and Boring B-09. Developing estimates of the magnitudes of vertical or lateral deformations due to liquefaction is beyond the scope of this feasibility level study. However, because of the isolated nature of these potentially liquefiable soil zones, we judge that the effects of liquefaction and other seismically-induced vertical or lateral deformations on the proposed levees (and floodwalls) would be relatively small. We note that even if the effects of liquefaction or other seismically-induced deformations were more severe, the ULDC does not recommend that mitigation of the levee and underlying soil must be undertaken. Rather, it recommends that a rough estimate of the seismic damage to the levee (or floodwall) system be made, and a post-earthquake remediation plan be prepared and put in place including immediate restoration of flood protection to a minimum 10-year event and plans restore full protection in a period of 6 months or prior to the next flood season, whichever is less. The ability to restore flood protection for levees underlain by YBM needs to be carefully evaluated and if needed, measures to improve seismic stability may be appropriate.

7 Feasibility Level Recommendations

7.1 Levees

From a geotechnical perspective, earthen levees can be used to provide flood protection along the majority of the proposed project alignment. The main exception will be for the segment represented by cross section G15 along Matadero Creek. Due to site constraints, it is anticipated that floodwalls will be used in lieu of levees. Also, there are relatively short segments where levees and floodwalls are not practical and alternative flood protection systems may be required. Such systems consist primarily of floodgates, and are discussed below.

Our feasibility level recommendations for overbuilt levee crest elevations and construction staging are summarized below, by project reach. There may be other site, design, permit and construction considerations that could modify these recommendations and should be addressed during future phases of the project. For each reach, the estimated target crest elevation is presented. This target crest elevation overbuild accounts for settlement, with the goal that the levee will have final crest height at Elevation 16 feet. The minimum levee geometry (crest width, slope inclination and extent below existing ground surface following trench excavation) should be established following the levee template guidance outlined above in Section 6.4.

- Reach 10, Options 1 and 2 – Along San Francisquito Creek, and along the east and south sides of the Palo Alto Airport runway, construct levee in a single stage to a crest height at Elevation 17 feet (represented by cross section G9).
- Reach 10, Options 1 and 2 – Along the Palo Alto Duck Pond and along the Palo Alto WWTP to just before the Byxbee Park landfill, construct levee in a single stage to a crest height at Elevation 17.5 feet (represented by cross section G10).
- Reach 11, Option 1 – For the segment along the northern boundary of the Palo Alto Flood Control Basin from the northern tip of the Byxbee Park landfill to the north end of Charleston Slough, construct the levee in minimum of two stages. Construct levee to a crest height at Elevation 15 feet in the first stage and to Elevation 18.5 feet in the second stage (represented by cross section G11). For the segment along the eastern boundary of the Palo Alto Flood Control Basin along Charleston Slough, the feasibility level analyses suggests that the levee can be constructed to its target crest height while achieving a marginally acceptable factor of safety for stability. However, for this feasibility level, it is recommended that two-stage construction should be considered. On this basis, construct levee to a crest height at Elevation 14 feet in the first stage and to Elevation 17.5 feet in the second stage (represented by cross section G12).
- Reach 11, Option 2 – For the segment along Adobe Creek from Coast Casey Forebay to Highway 101, construct levee to a crest height at Elevation 17 feet (represented by cross section G13). For the segment along Highway 101 and the south and east sides of the Palo Alto Operations and Maintenance Facility, construct levee to a crest height at Elevation 17 feet (represented by cross section G14). For the segment along Matadero Creek along the west side of the Palo Alto Operations and Maintenance Facility,

construct flood walls in lieu of levees to Elevation 16 feet (represented by cross section G15). For the segment along Matadero Creek from the Palo Alto Operations and Maintenance Facility, and around the southern and eastern sides of the Byxbee Park landfill (includes Reach 11, Option 2a), construct levee in minimum of two stages. Construct levee to a crest height at Elevation 15 feet in the first stage and to Elevation 18.5 feet in the second stage (represented by cross section G16).

- Reach 11, Option 2a – This segment is grouped with the portion of Reach 11, Option 2 that extends from the Palo Alto Operations and Maintenance Facility and along the south side of Byxbee Park landfill. For this segment, construct levee in minimum of two stages. Construct levee to a crest height at Elevation 15 feet in the first stage and to Elevation 18.5 feet in the second stage (represented by cross section G16).
- Reach 11, Option 3 - Construct the levee in minimum of two stages. Construct levee to a crest height at Elevation 15 feet in the first stage and to Elevation 18.5 feet in the second stage (represented by cross section G17).
- Reach 11, Option 3a – This segment is the same as Reach 11, Option 2a. For this segment, construct levee in minimum of two stages. Construct levee to a crest height at Elevation 15 feet in the first stage and to Elevation 18.5 feet in the second stage (represented by cross section G16).

For the purpose of feasibility level planning and cost estimating, we recommend that a geotextile or geogrid be included at the base of the levee for segments that will require two-stage construction. The location and extent of the geotextile/geogrid is shown on the cross section figures (Figures 3a through 3i).

7.2 Floodwalls

Where spatial or other constraints exist that do not allow for the construction of levees, 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 as well as for construction. For feasibility level planning purposes, we anticipate that flood walls be considered in lieu of levees for the following segment:

- Reach 11, Option 2 – For the segment along Matadero Creek along the west side of the Palo Alto Operations and Maintenance Facility. Two flood walls will be needed, one on either side of the creek. The east flood wall will be situated between the creek and the Palo Alto Operations and Maintenance Facility, and the west flood wall will be situated between the creek and the drainage channel/ditch. For planning purposes, it is estimated that flood walls will need to be constructed to Elevation 16 feet (same as the target height of the levees).
- Reach 11, Option 2 – Floodwalls currently exist along the segments of this reach that are west of Highway 101, and which extend upstream along Matadero, Barron, and Adobe Creeks. Hydraulic analyses have not yet been performed. For current planning purposes, it is anticipated that the existing floodwalls would be raised, as needed, should

this option be further considered. No geotechnical analyses of raised floodwalls have been performed at this time.

For the purpose of evaluating options that consist of new floodwalls, an inverted T-shaped floodwall can be considered, where the footing width is approximately equal to the wall height. Thus, a 12-foot high floodwall (measured from the bottom of the wall foundation to the top of the wall) would require a 12-foot wide footing plus additional width for construction. Special considerations will be required where floodwalls transition into levees, which are beyond the scope of these feasibility level studies.

7.3 Floodgates

It is anticipated that further levee raisings will not be allowed at the northern and southern ends of the Palo Alto Airport runway due to FAA restrictions on structures within air space zones. At these locations, passive floodgate structures are being considered to provide flood protection. With such systems, the floodgates are deployed only during times of high water. Other locations where passive floodgate structures may be required include the access roads to the Palo Alto Duck Pond. There are several existing roadways that cross the proposed flood protection alignments. Floodgate transitions to floodwalls and levees require special considerations, which are beyond the scope of these feasibility level studies.

7.4 Penetrations

Penetrations and encroachments into the levee prism are generally not recommended, although they may be necessary. Where crossings occur, they should be located above the design water surface elevation, within the freeboard area of the levee. An assessment of all levee penetrations should be conducted to determine their location, depth, material type and age, and to determine if penetrations will require remediation/relocation as part of the flood protection system.

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.

7.5 Open Channels

There are several existing drainage channels that are located along the proposed levee alignments. These ditches may need to be relocated as appropriate to meet drainage and/or regulatory requirements.

7.6 Utility Poles and Towers

It is generally 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.

7.7 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. 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.

DRAFT

8 Construction Considerations

Much of the proposed levee alignment options are located along low lying areas such as marshland and ponds. This will be the case where the future levee footprint will extend beyond the footprint of existing levees or where levees are proposed along alignments where existing levees currently do not exist. We anticipate that this will especially be the case along the Reach 11, Option 3 alignment across the Palo Alto Flood Basin, and along Reach 11, Option 3a alignment (same as Reach 11, Option 2a) along the east side of the Byxbee Park landfill and which will encroach into Mayfield Slough. These low lying areas are often wet or in shallow water, and have soft, weak and unstable subgrades. Special construction measures will likely be required to properly prepare subgrades to construct levees in these low lying areas. Such measures may include, but not necessarily limited to, localized dewatering or diverting of water, moisture conditioning of subgrade soil (most likely measures to dry overly wet soil), and use of special construction equipment designed for use in these types of site conditions.

Consideration is being given to placing geotextiles or geogrids on soil subgrades beneath new levees as a feasibility level recommendation to improve levee stability. Such geotextiles or geogrids could also be helpful to facilitate construction in areas with soft, weak and unstable subgrades.

9 Limitations

This report has been prepared for the use of San Francisquito Creek Joint Powers Authority (SFCJPA) and its consultants for specific application to this project in accordance with generally accepted geotechnical engineering practice. No warranty, express or implied, is made. The analyses and recommendations submitted are based on the data available to HDR at the time of this geotechnical investigation and on the data collected during the field investigation. This report does not reflect subsurface soil variations that may occur between the locations of the explorations or variations in groundwater conditions which may occur over a period of time. Variations in conditions may become evident during construction, at which time re-evaluation of the conclusions may become necessary. In the event of design changes in the project after the final report is submitted, the recommendations should be reviewed and possibly modified with HDR's participation.

Historical explorations and testing were not performed by HDR and HDR cannot vouch for the accuracy of data and information obtained by others. Data by others should not be relied upon unless the originator of that data is available to confirm its accuracy.

This geotechnical study did not include an investigation regarding the existence, location, or type of possible hazardous materials. If any hazardous materials are encountered during construction of the project, the proper regulatory officials should be notified immediately.

10 References

- Brabb, E.E., Graymer, R.W., Jones, D.L. (1998), "Geology of the Onshore Part of San Mateo County, California," U.S. Geological Survey Open-File 98-137.
- California Department of Transportation (Caltrans). (2009), Miscellaneous Logs of Test Borings (LOTBs) from various projects along California State Route 101 in Santa Clara County, California. Data provided for the SAFER Bay Project by Caltrans District 4 in 2016.
- California Department of Water Resources. (2012), "Urban Levee Design Criteria," May.
- Central Valley Flood Protection Board (CVFPB). (2009), California Code of Regulations (CCR), Title 23: Waters, Subdivision 1.
- City of Palo Alto. (2016), Miscellaneous Monitoring Well Logs for the Former Palo Alto Landfill. Package provided by the City of Palo Alto and includes well logs from William C. Ellis (1981), Unknown consultant (1983), and Emcon Associates (1988).
- Danish Hydraulics Institute (DHI). (2013), Regional Coastal Hazard Modeling Study for South San Francisco Bay Final Draft Report. Prepared for FEMA Region IX.
- Dibblee, T.W. (1966), "Geologic Map and Sections of the Palo Alto 15' Quadrangle, California, California Division of Mines and Geology (now known as California Geological Survey).
- Dibblee, T.W. and Minch, J.A. (2007), "Geologic Map of the Palo Alto and Mountain View Quadrangles," Dibblee Geological Foundation, Dibblee Foundation Map DF-350.
- Earth Systems Consultants. (1983), "Geotechnical Report, Baylands Bike Trail, CIP 82-31, Palo Alto and East Palo Alto, California." San Mateo and Santa Clara Counties, California. Earth Systems File No. C3-1284-C1. Prepared for City of Palo Alto. November 1983.
- Federal Emergency Management Agency (FEMA). (2006), "44 CFR Section 65.10: Mapping of Areas Protected by Levee Systems." October, 2006 Edition.
- Federal Emergency Management Agency (FEMA). (2012), Flood Insurance Rate Map (FIRM) for Santa Clara County, California, and Incorporated Areas.
- GEI Consultants, Inc. (2012), "San Francisquito Creek Flood Protection Project, Geotechnical Evaluation Report." San Mateo and Santa Clara Counties, California. GEI Project No. 092850. Prepared for HDR. May 2012.
- GEO-SLOPE. (2015), GeoStudio 2012 August 2015 Release, Version 8.15.4.11512. English, GEO-SLOPE International, Ltd., Calgary, Alberta, Canada.
- HDR. (2015), "Preliminary Alternatives Report, SAFER Bay Project, Task Order 2, San Francisquito Creek Joint Powers Authority," May.
- Kleinfelder, Inc. (2002), "Geotechnical Investigation for the Proposed MSC Fueling Facility at the Municipal Service Center in Palo Alto, California," March 27.

Lowney Associates. (2002), "Geotechnical Report, San Francisquito Creek Levee Project, Palo Alto and East Palo Alto, California." San Mateo and Santa Clara Counties, California. Lowney Report No. 109-17B. Prepared for Santa Clara Valley Water District. July 2002.

Petersen, Mark D., Frankel, Arthur D., Harmsen, Stephen C., Mueller, Charles S., Haller, Kathleen M., Wheeler, Russell L., Wesson, Robert L., Zeng, Yuehua, Boyd, Oliver S., Perkins, David M., Luco, Nicolas, Field, Edward H., Wills, Chris J., and Rukstales, Kenneth S. (2008), Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008–1128, 61 p.

USACE. (2000), Design and Construction of Levees. Engineer Manual No. 1110-2-1913. April 30.

USGS. (2008a), "2008 National Seismic Hazard Maps - Source Parameters" based on the United States National Seismic Hazard Maps (NSHMP). <http://geohazards.usgs.gov/cfusion/hazfaults_2008_search/query_main.cfm> (March 25, 2016).

USGS. (2008b), "2008 PSHA Interactive Deaggregation" based on the United States National Seismic Hazard Maps (NSHMP). <<http://geohazards.usgs.gov/deaggint/2008/>> (March 28, 2016).

USGS. (2011), National Elevation Dataset. USGS NED. Raster Digital Data: *ned19_n37x50_w122x25_ca_sanfrancisocoast_2010 1/9 arc-second 2011 15 x 15 minute IMG*. Downloaded from: <http://viewer.nationalmap.gov/basic/>.



Figures





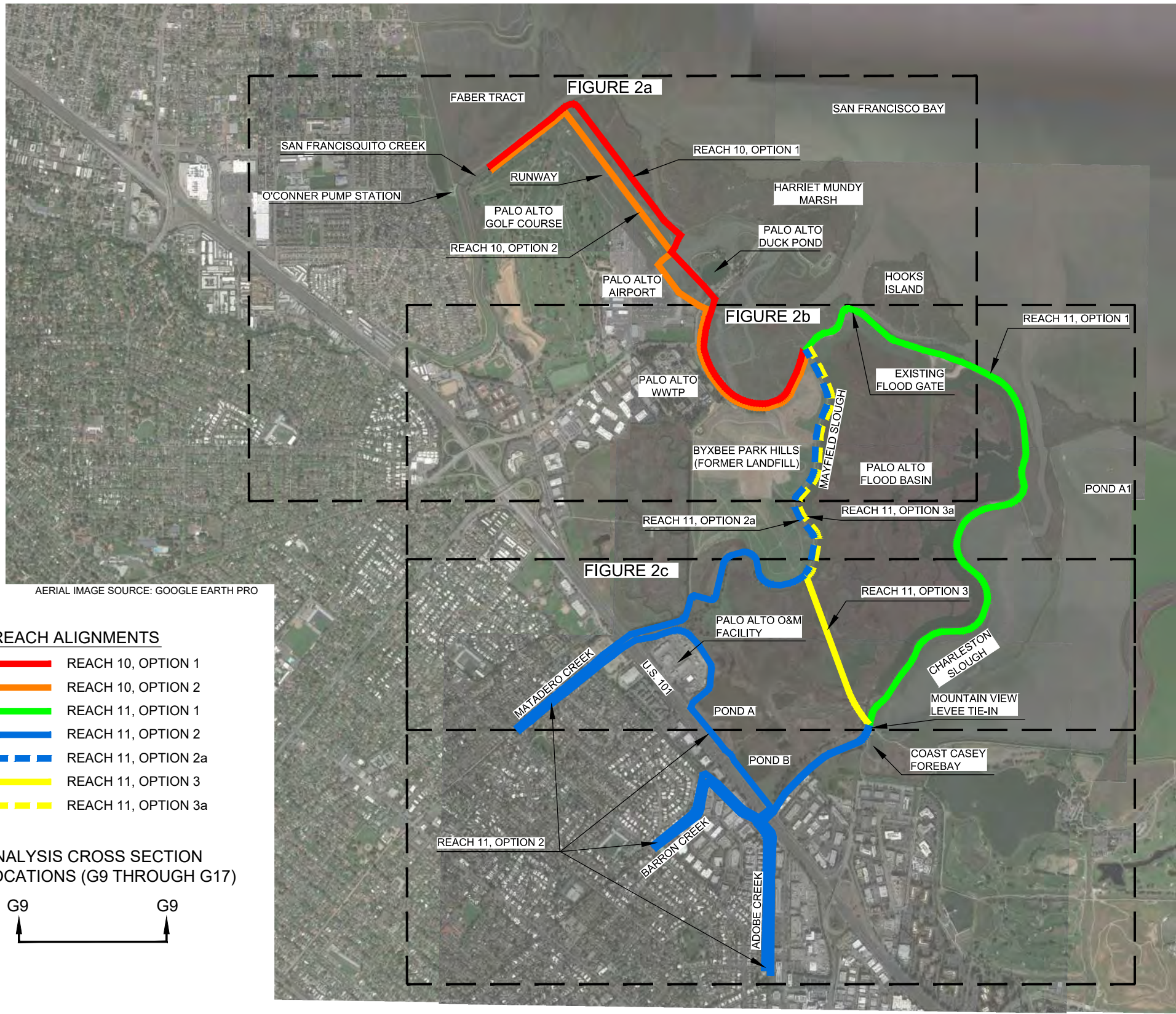
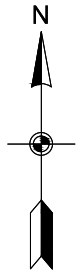
This page intentionally left blank.














Figure 1	Overall Project Site Plan
Figures 2a through 2c	Site Plans
Figures 3a through 3i	Analysis Cross-Sections










This page intentionally left blank.



**EXPLORATION LOCATIONS
(FIGURE 2a TO 2c):**

- B-07  EXPLORATORY BORING BY HDR (2016)
- C-09  CONE PENETRATION TEST BY HDR (2016)
- GEI-B-5  EXPLORATORY BORING BY GEI (2012)
- GEI-CPT-4  CONE PENETRATION TEST BY GEI (2012)
- R-09-001
A-09-120  EXPLORATORY BORINGS BY CALTRANS (2009 [R, A])
- CPT-09-002  CONE PENETRATION TEST BY CALTRANS (2009)
- KLF-B-1  EXPLORATORY BORING BY KLEINFELDER (2002)
- LNY-EB-5  EXPLORATORY BORING BY LONEY ASSOCIATES (2002)
- G-1A
G-3A
G-9/88  MONITORING WELL FOR FORMER LANDFILL, PROVIDED BY CITY OF PALO ALTO (WILLIAM C. ELLIS, 1981 [G-1A], UNKNOWN, 1983 [G-3A], EMCON ASSOCIATES, 1988 [G-X/88])
- ES-B-5  EXPLORATORY BORING BY EARTH SYSTEMS (1983)
- AC-B-4
MC-B-4  EXPLORATORY BORINGS BY CALTRANS (1957 [AC, MC])

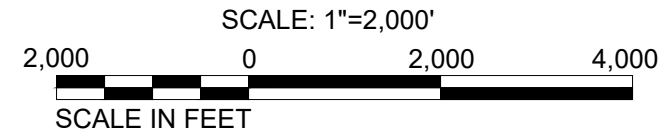
REACH ALIGNMENTS

-  REACH 10, OPTION 1
-  REACH 10, OPTION 2
-  REACH 11, OPTION 1
-  REACH 11, OPTION 2
-  REACH 11, OPTION 2a
-  REACH 11, OPTION 3
-  REACH 11, OPTION 3a

**ANALYSIS CROSS SECTION
LOCATIONS (G9 THROUGH G17)**



NOTES:
ALL EXPLORATION LOCATIONS SHOWN ON FOLLOWING FIGURES ARE APPROXIMATE. LOCATIONS WERE ESTIMATED USING A COMBINATION OF GPS COORDINATES, OLD SITE PLANS, AERIAL PHOTOGRAPHY, AND FIELD MEASUREMENTS (NONE OF THE LOCATIONS HAVE BEEN SURVEYED BY HDR OR ITS CONSULTANTS).

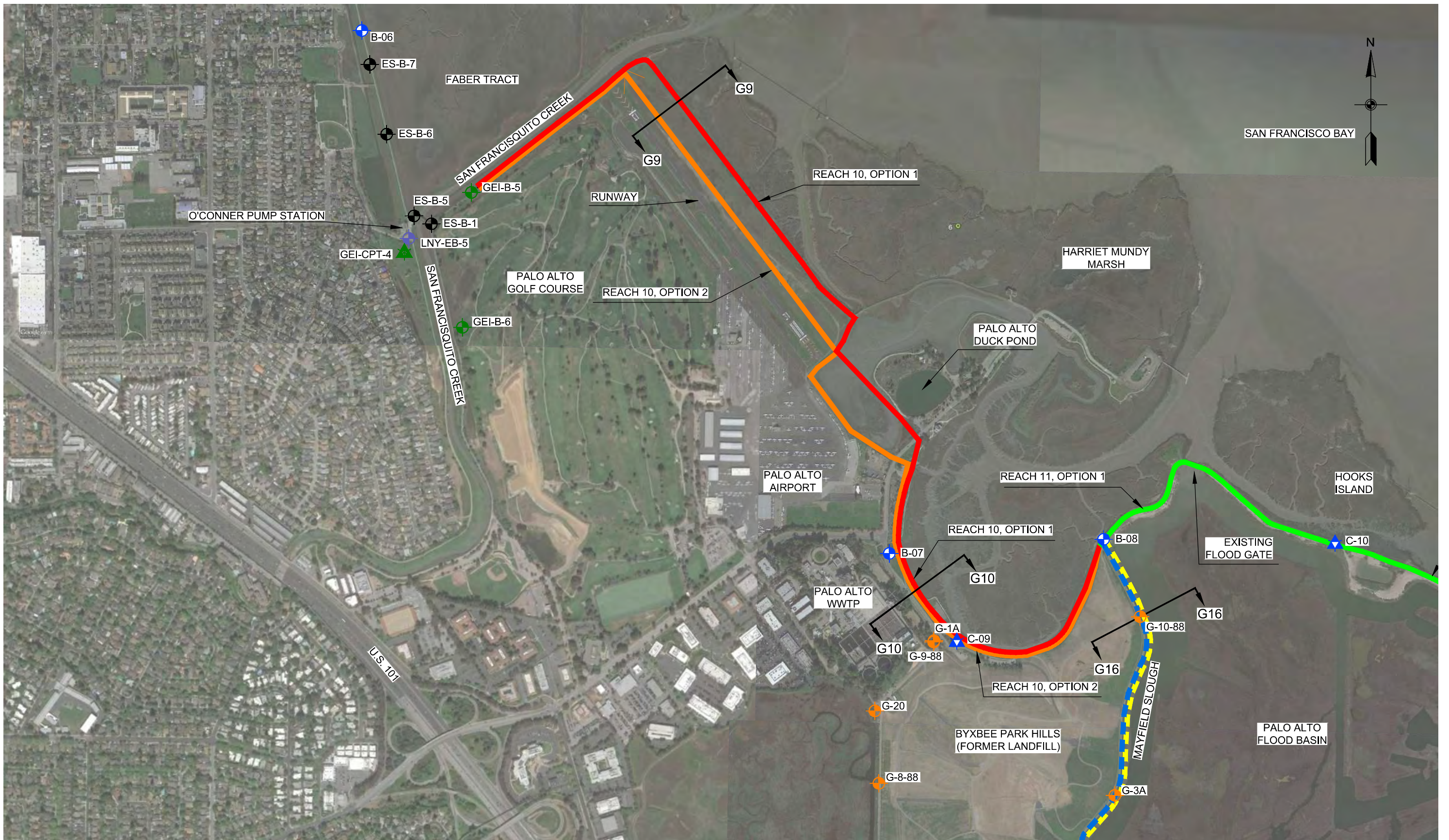


OVERALL PROJECT SITE PLAN

SAFER BAY PROJECT
TASK ORDER NO. 2
PALO ALTO, CALIFORNIA

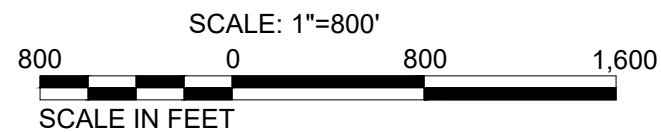
Date
JULY 2016

Figure



AERIAL IMAGE SOURCE: GOOGLE EARTH PRO

NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

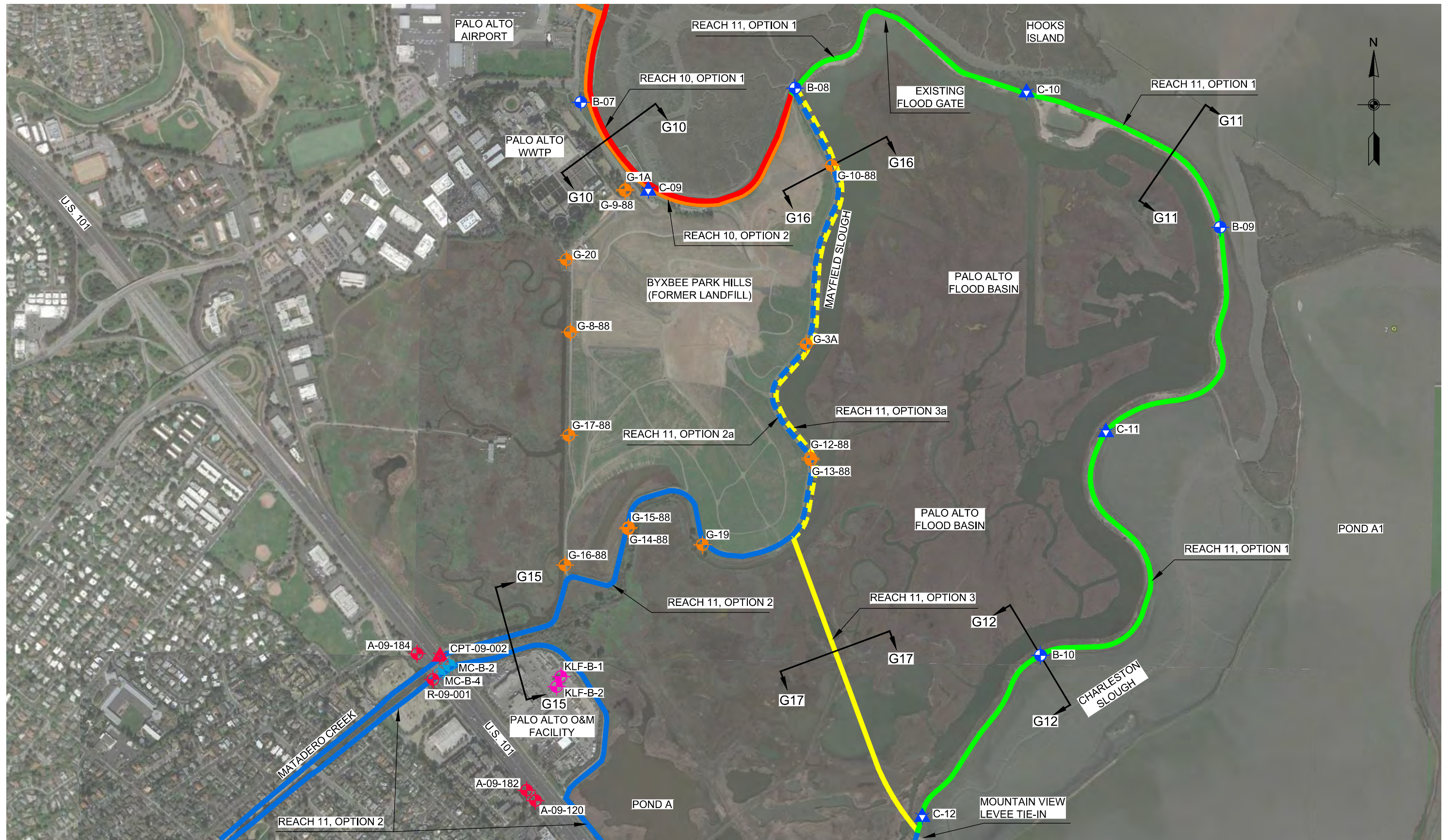


SITE PLAN SHEET 1

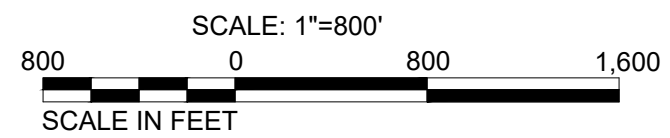
SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 2a



AERIAL IMAGE SOURCE: GOOGLE EARTH PRO
 NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

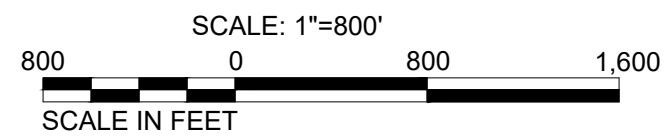


SITE PLAN SHEET 2
 SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date	JULY 2016
Figure	2b

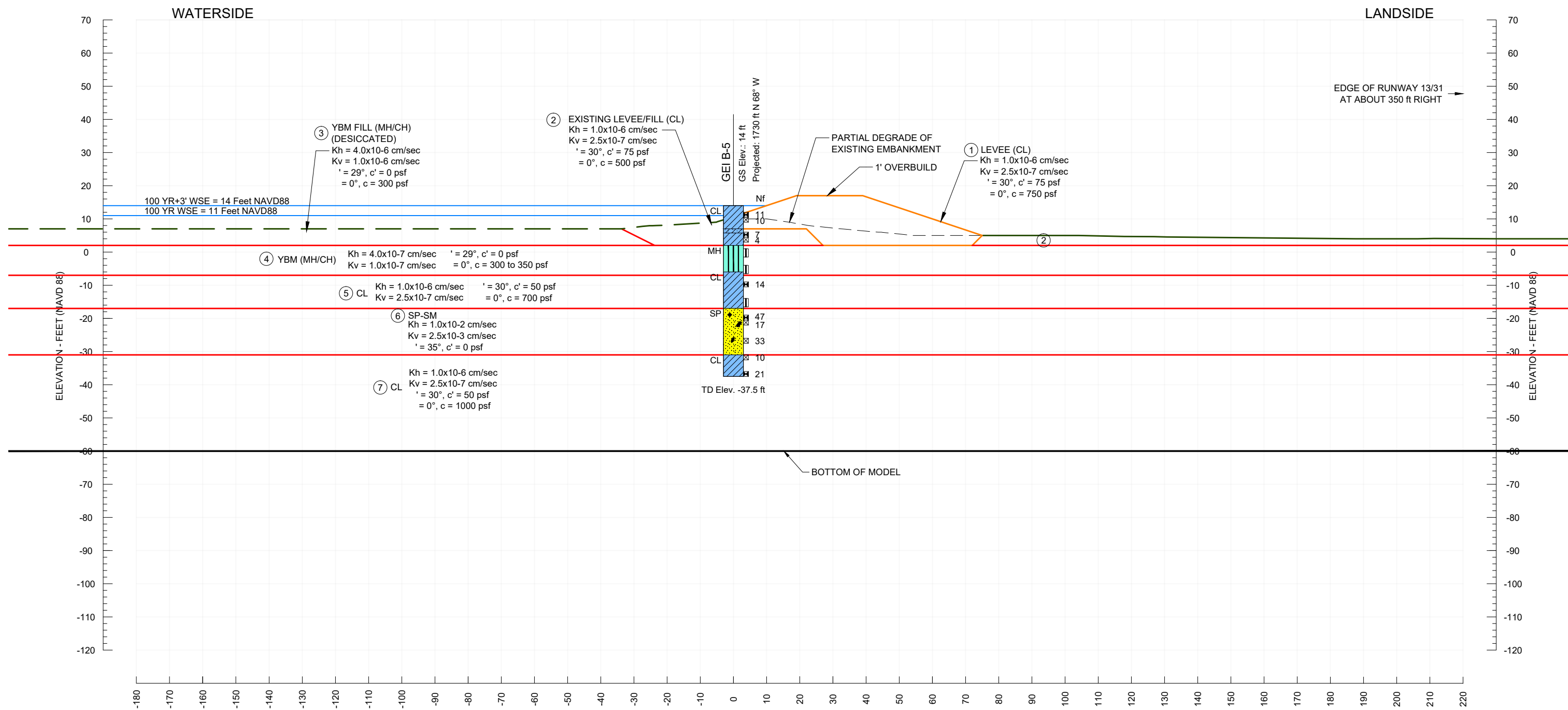


AERIAL IMAGE SOURCE: GOOGLE EARTH PRO
 NOTE: REFER TO FIGURE 1 FOR AN EXPLANATION OF EXPLORATION LOCATION SYMBOLS

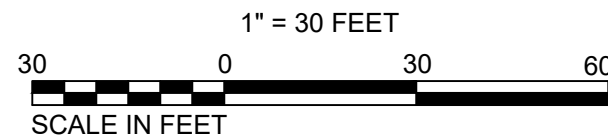


SITE PLAN SHEET 3
 SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016
 Figure
 2c



NOTES:
 1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

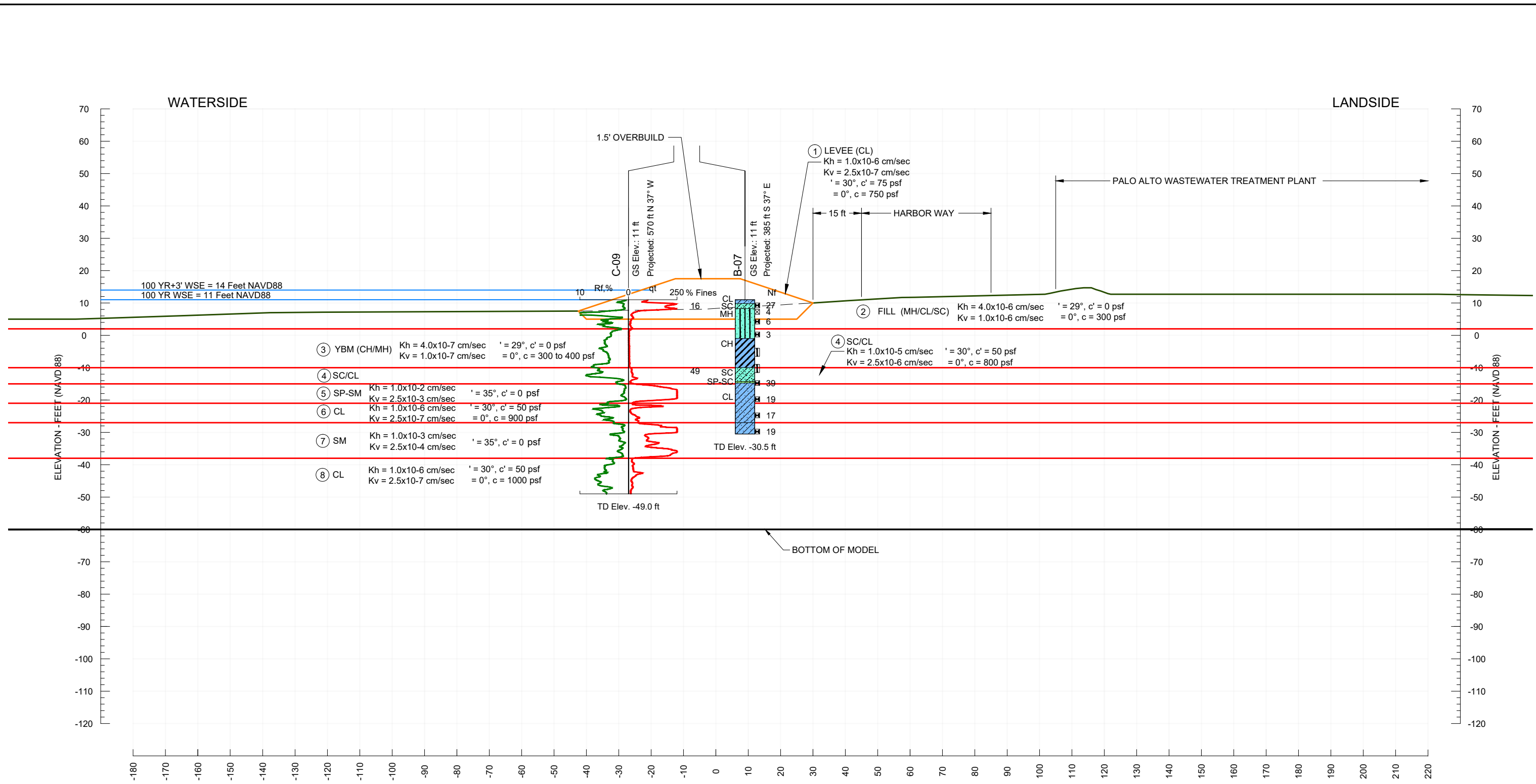


ANALYSIS CROSS SECTION G9

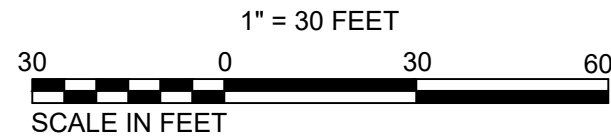
SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 3a



NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

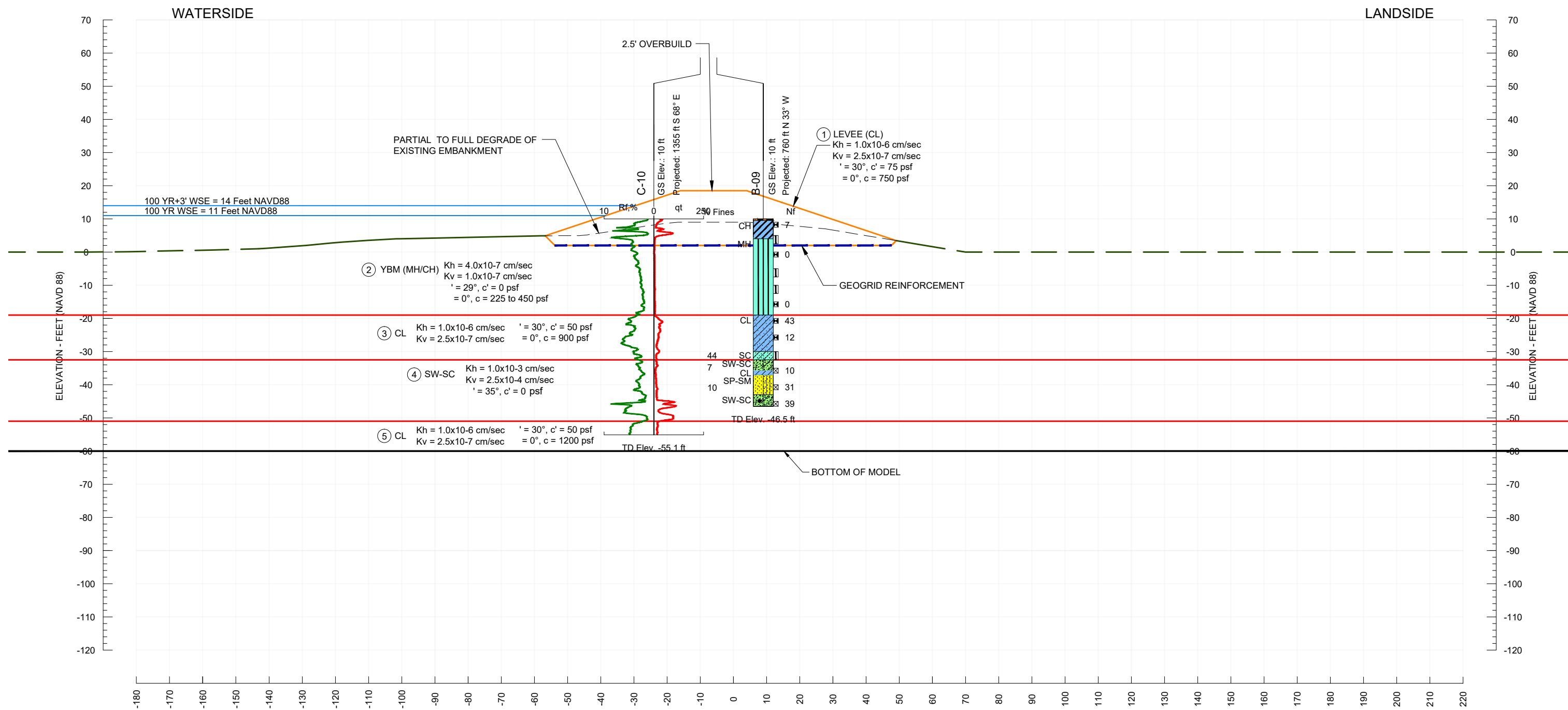


ANALYSIS CROSS SECTION G10

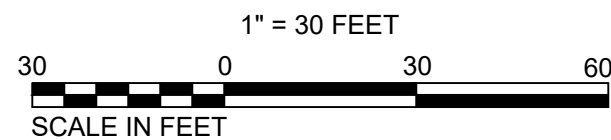
SAFER BAY PROJECT
TASK ORDER NO. 2
PALO ALTO, CALIFORNIA

Date
JULY 2016

Figure
3b



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED TO IMPROVE STABILITY.

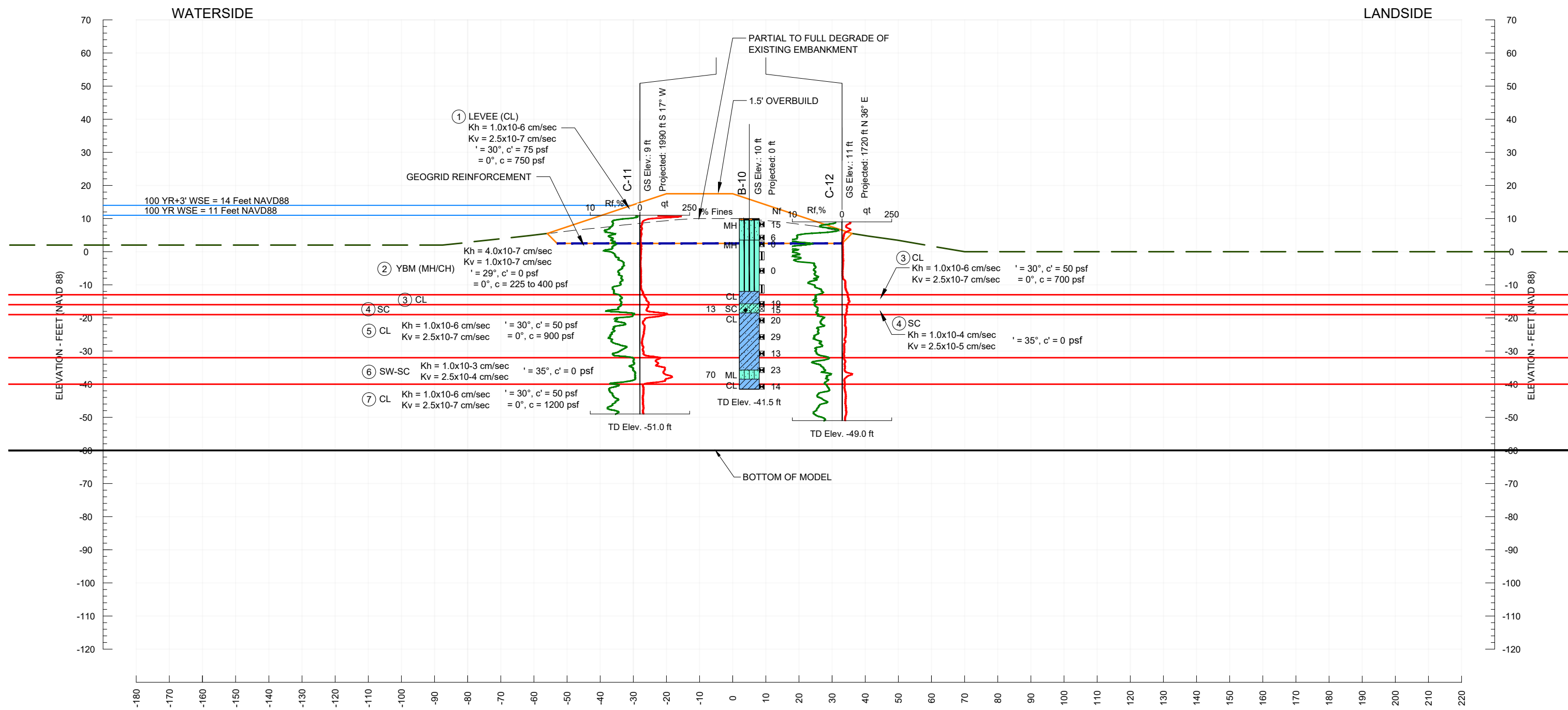


ANALYSIS CROSS SECTION G11

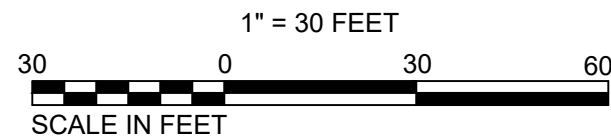
SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 3c



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED TO IMPROVE STABILITY.

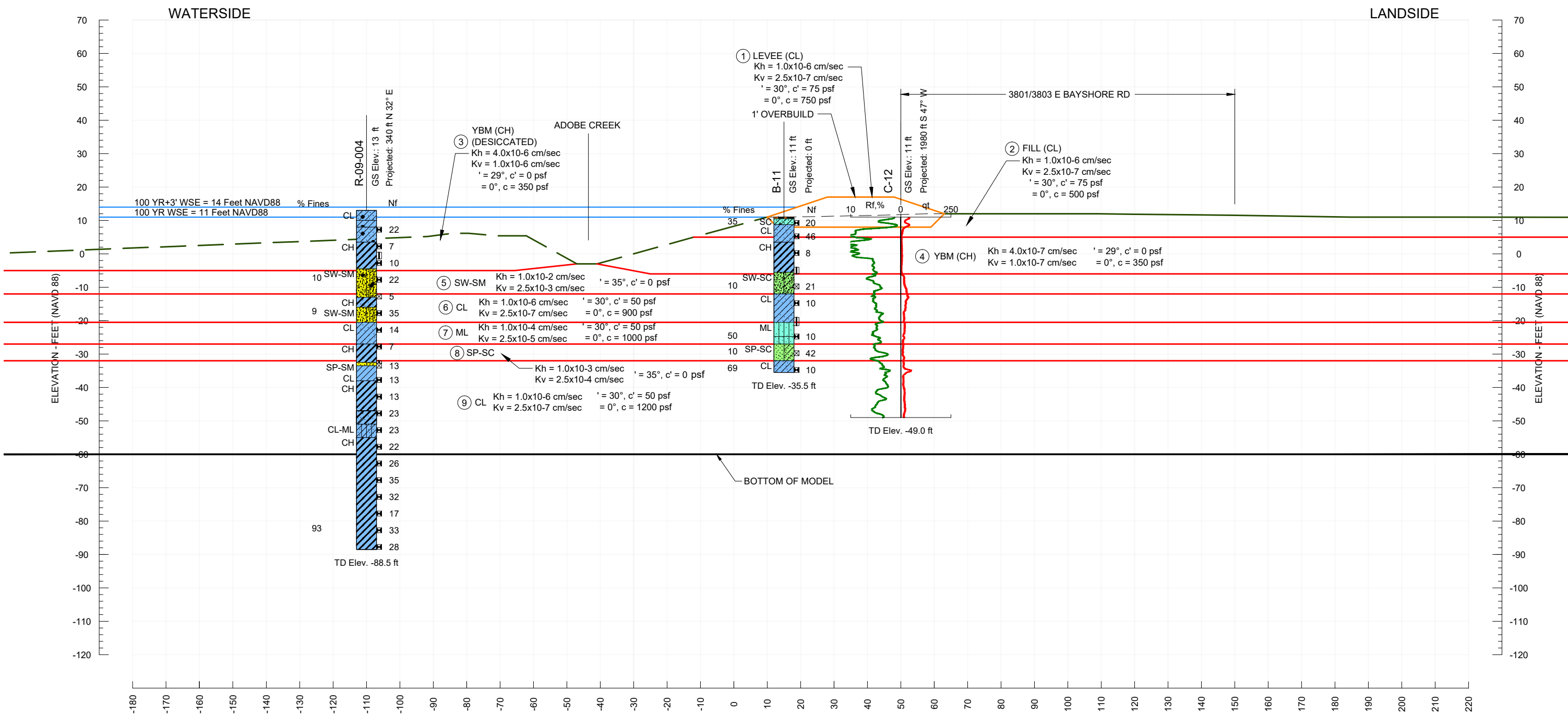


ANALYSIS CROSS SECTION G12

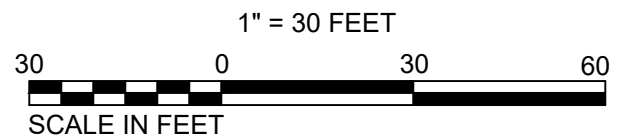
SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 3d



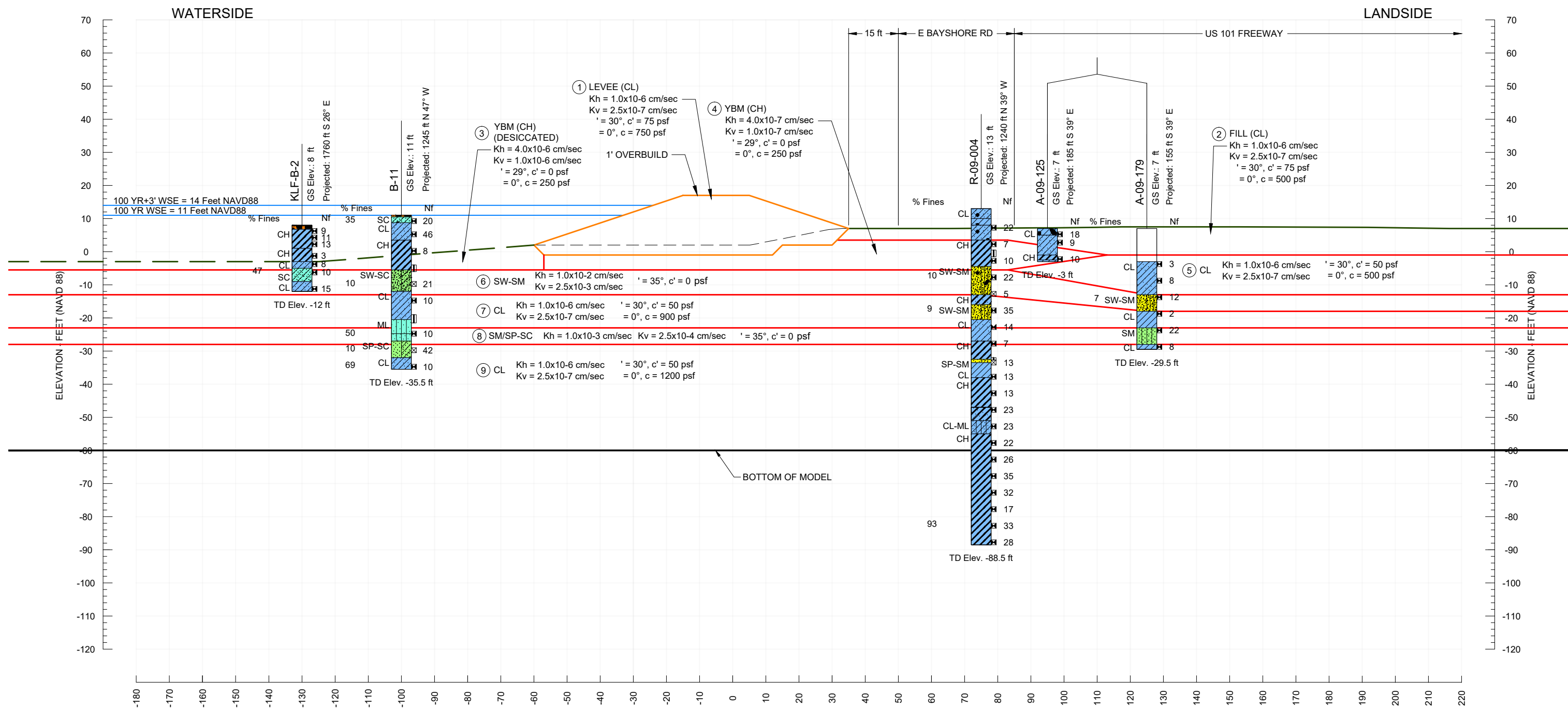
NOTES:
 1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.



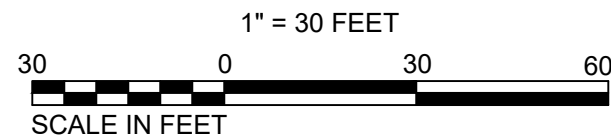
ANALYSIS CROSS SECTION G13

SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date	JULY 2016
Figure	3e



NOTES:
 1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

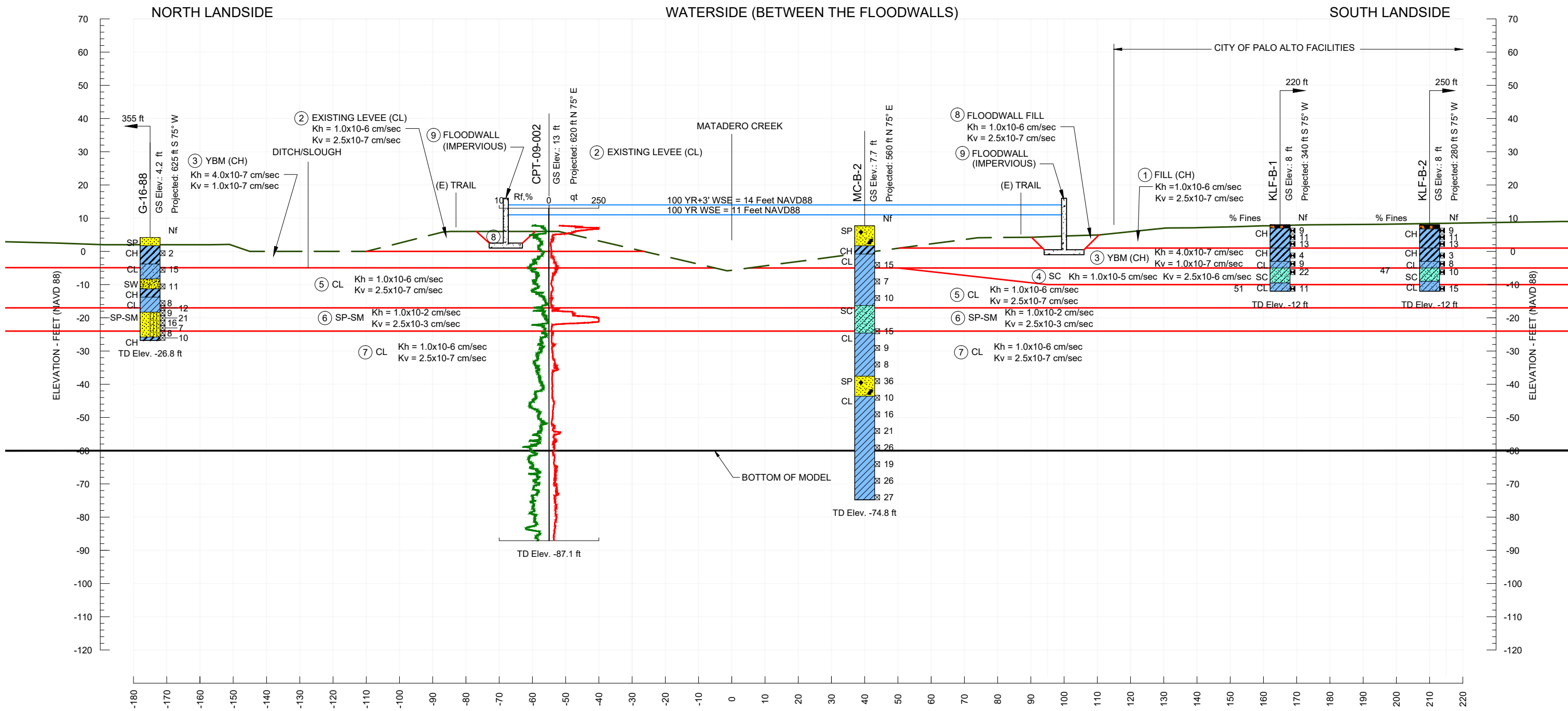


ANALYSIS CROSS SECTION G14

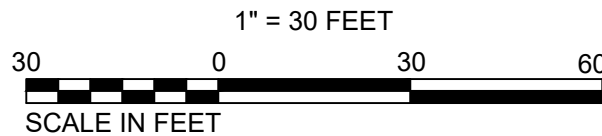
SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 3f



NOTES:
 1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.

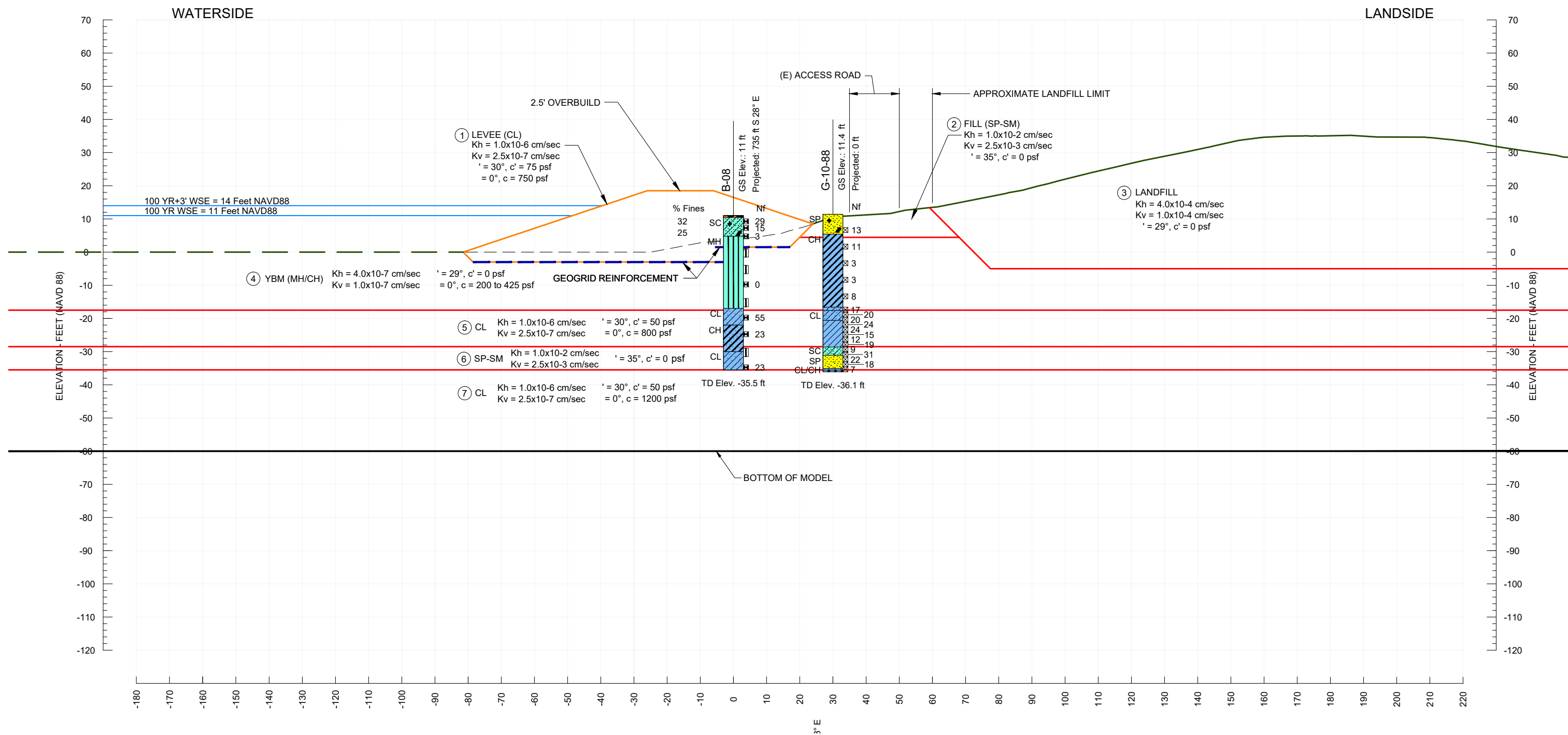


ANALYSIS CROSS SECTION G15

SAFER BAY PROJECT
 TASK ORDER NO. 2
 PALO ALTO, CALIFORNIA

Date
 JULY 2016

Figure
 3g



- NOTES:
1. LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 2. GEOGRID REINFORCEMENT INCLUDED TO IMPROVE STABILITY.

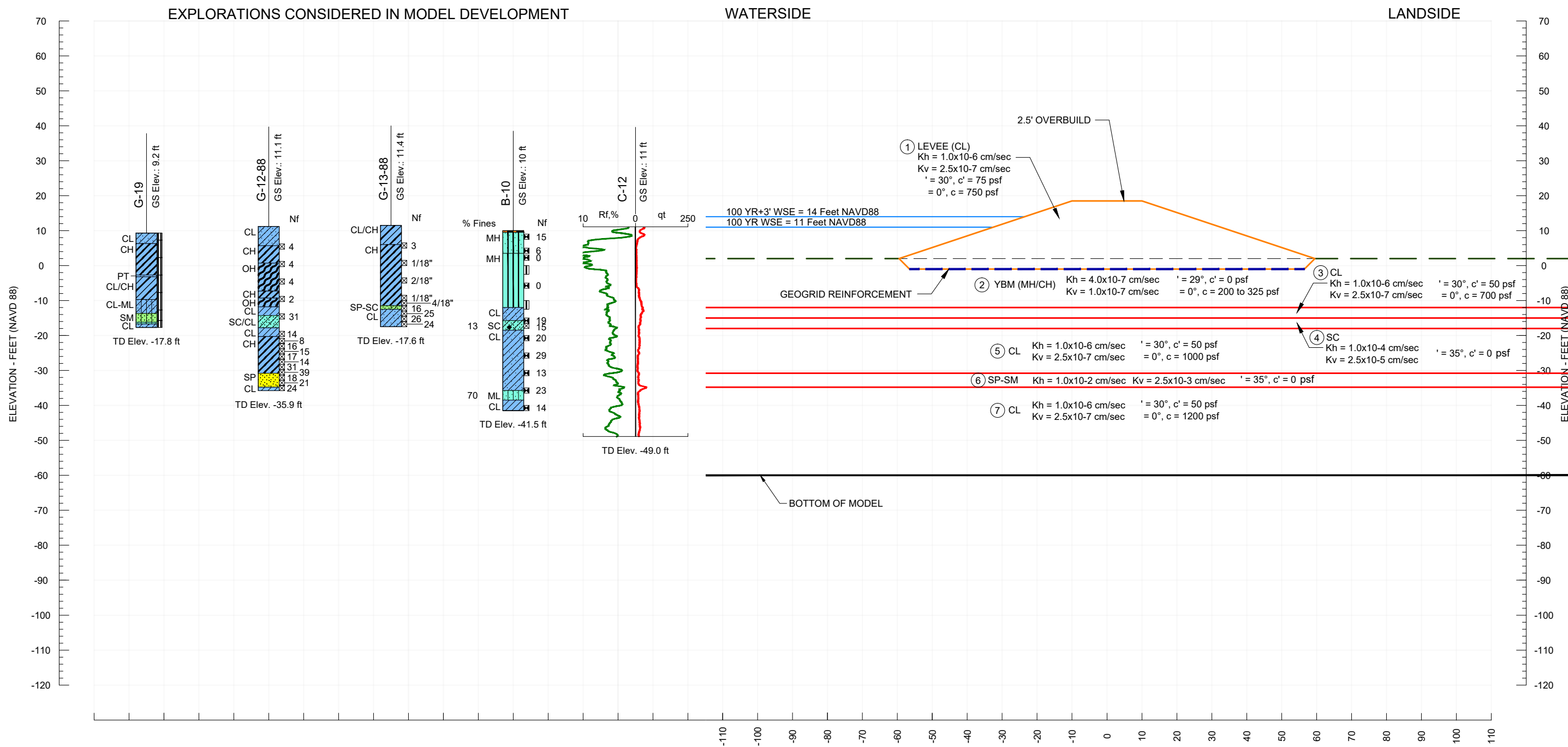


ANALYSIS CROSS SECTION G16

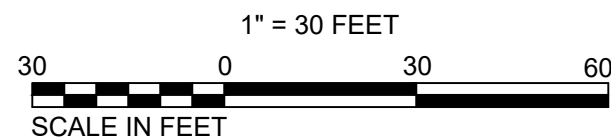
SAFER BAY PROJECT
TASK ORDER NO. 2
PALO ALTO, CALIFORNIA

Date
JULY 2016

Figure
3h



- NOTES:
- LEVEE CONFIGURATION SHOWN ASSUMES COMPLETE LEVEE PLUS OVERBUILD IS CONSTRUCTED IN A SINGLE STAGE.
 - GEOGRID REINFORCEMENT INCLUDED TO IMPROVE STABILITY.



ANALYSIS CROSS SECTION G17

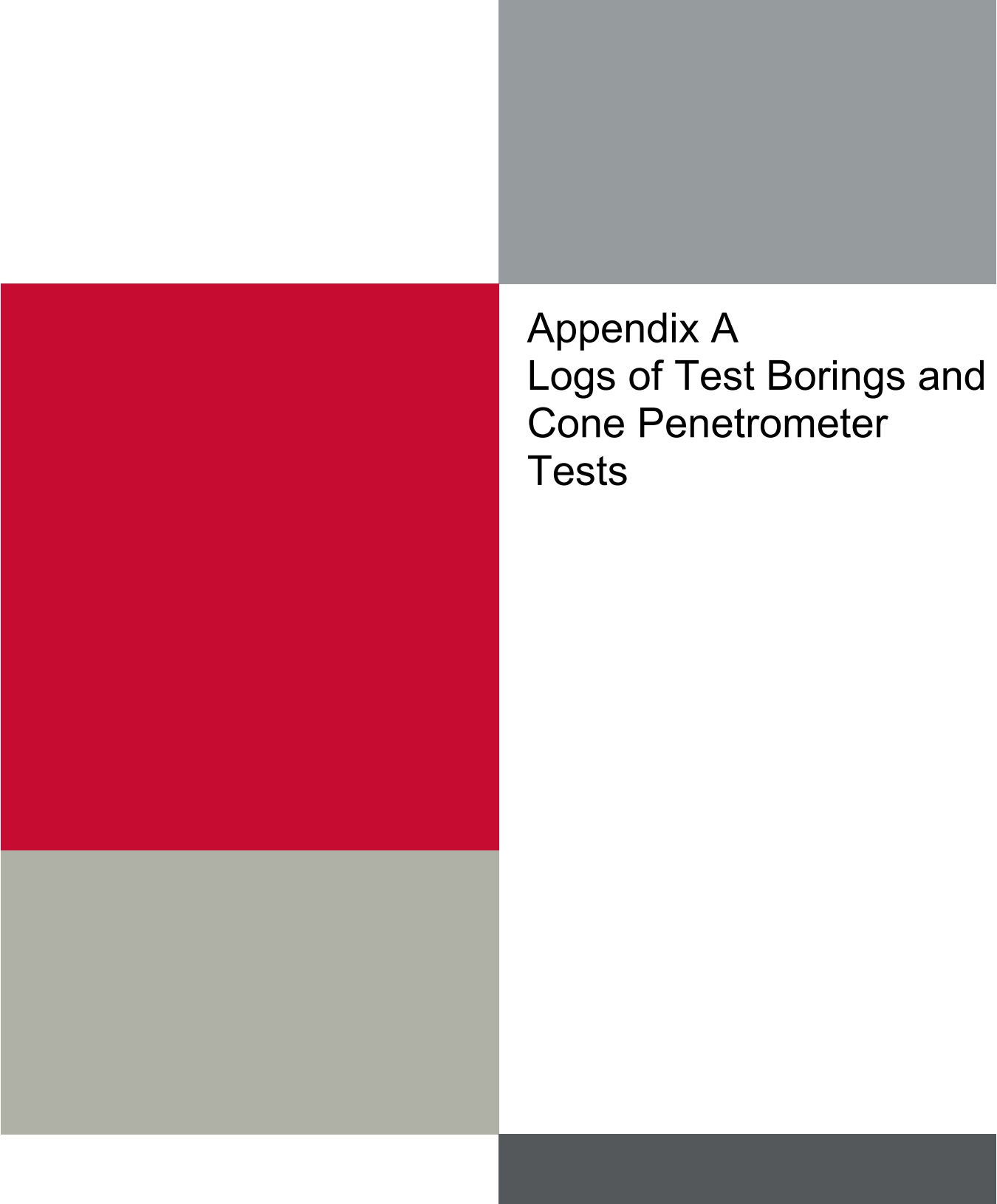
SAFER BAY PROJECT
TASK ORDER NO. 2
PALO ALTO, CALIFORNIA

Date
JULY 2016

Figure
3i



This page intentionally left blank.



Appendix A Logs of Test Borings and Cone Penetrometer Tests



This page intentionally left blank.

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

MATERIAL TYPES	CRITERIA FOR ASSIGNING SOIL GROUP NAMES			GROUP SYMBOL	SOIL GROUP NAMES & LEGEND	
COARSE-GRAINED SOILS >50% RETAINED ON NO. 200 SIEVE	GRAVELS >50% OF COARSE FRACTION RETAINED ON NO. 4. SIEVE	CLEAN GRAVELS <5% FINES	$C_u \geq 4$ AND $1 \leq C_c \leq 3$	GW	WELL-GRADED GRAVEL	
			$C_u < 4$ AND/OR $1 > C_c > 3$	GP	POORLY-GRADED GRAVEL	
		GRAVELS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR MH	GM	SILTY GRAVEL	
			FINES CLASSIFY AS CL OR CH	GC	CLAYEY GRAVEL	
	SANDS >50% OF COARSE FRACTION PASSES NO. 4. SIEVE	CLEAN SANDS <5% FINES	$C_u \geq 6$ AND $1 \leq C_c \leq 3$	SW	WELL-GRADED SAND	
			$C_u < 6$ AND/OR $1 > C_c > 3$	SP	POORLY-GRADED SAND	
		SANDS AND FINES >12% FINES	FINES CLASSIFY AS ML OR MH	SM	SILTY SAND	
			FINES CLASSIFY AS CL OR CH	SC	CLAYEY SAND	
FINE-GRAINED SOILS >50% PASSES NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT<50	INORGANIC	$PI > 7$ AND PLOTS > "A" LINE	CL	LEAN CLAY	
			$PI < 4$ OR PLOTS < "A" LINE	ML	SILT	
		ORGANIC	LL (oven dried)/LL (not dried) < 0.75	OL	ORGANIC CLAY OR SILT	
	SILTS AND CLAYS LIQUID LIMIT>50	INORGANIC	PI PLOTS > "A" LINE	CH	FAT CLAY	
			PI PLOTS < "A" LINE	MH	ELASTIC SILT	
		ORGANIC	LL (oven dried)/LL (not dried) < 0.75	OH	ORGANIC CLAY OR SILT	
HIGHLY ORGANIC SOILS	PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR			PT	PEAT	

OTHER SYMBOLS

MATERIALS	SAMPLERS
Asphalt Aggregate Base Boulders & Cobbles Fill Topsoil Concrete Grout/Fill Bentonite/Grout Seal Sand Pack + Solid Pipe Sand Pack + Slotted Pipe	SPT (2" OD) Modified California (3" OD) California (2.5" OD) Shelby Tube Pitcher Barrel HQ Core Grab/Bulk INITIAL WATER LEVEL MEASUREMENT (WITH DATE) STABILIZED WATER LEVEL MEASUREMENT (WITH DATE)

GRAIN SIZES

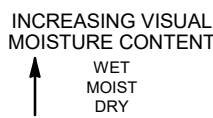
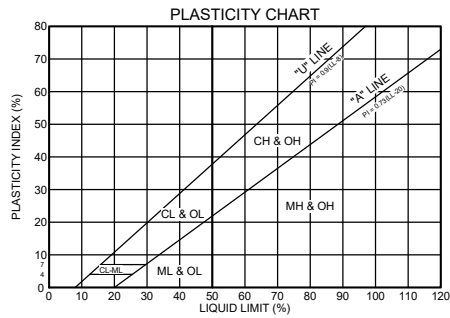
U.S. STANDARD SIEVE	200 40 10 4 3/4" 3" 12"					
	SAND			GRAVEL		COBBLES
SILTS AND CLAYS	FINE	MEDIUM	COARSE	FINE	COARSE	

PENETRATION RESISTANCE

SAND & GRAVEL		SILT & CLAY		
RELATIVE DENSITY	BLOWS/FOOT*	CONSISTENCY	BLOWS/FOOT*	UNC. COMP. STRENGTH (KSF)
VERY LOOSE	0 - 4	VERY SOFT	0 - 1	0 - 1/2
LOOSE	5 - 10	SOFT	2 - 4	1/2 - 1
MEDIUM DENSE	11 - 30	MEDIUM STIFF	5 - 8	1 - 2
DENSE	31 - 50	STIFF	9 - 15	2 - 4
VERY DENSE	OVER 50	VERY STIFF	16 - 30	4 - 8
		HARD	OVER 30	OVER 8

* NUMBER OF BLOWS OF 140 LB HAMMER FALLING 30 INCHES TO DRIVE A 2 INCH O.D. (1-3/8 INCH I.D.) SPLIT-BARREL SAMPLER THE LAST 12 INCHES OF AN 18-INCH DRIVE (ASTM-1586 STANDARD PENETRATION TEST).

- | LABORATORY TESTS | PROPERTIES |
|--------------------------------------|-----------------------------------|
| AT ATTERBERG LIMITS | c COHESION |
| CD CONSOLIDATED DRAINED TRIAXIAL | DD DRY DENSITY |
| CN CONSOLIDATION | EI EXPANSION INDEX |
| CR CORROSION | LL LIQUID LIMIT |
| CU CONSOLIDATED UNDRAINED TRIAXIAL | MC MOISTURE CONTENT |
| DS DIRECT SHEAR | N _v FIELD BLOW COUNT |
| HY HYDROMETER | PI PLASTICITY INDEX |
| PR PERMEABILITY | S _u UNDRAINED STRENGTH |
| RV R-VALUE | |
| SA SIEVE ANALYSIS | |
| TC CYCLIC TRIAXIAL | |
| UC UNCONFINED COMPRESSION | |
| UU UNCONSOLIDATED UNDRAINED TRIAXIAL | |
| -200 % PASSING NO. 200 SIEVE | |
-
- | UNDRAINED SHEAR STRENGTH | UNDRAINED SHEAR STRENGTH |
|-------------------------------------|--------------------------|
| V FIELD VANE | P POCKET PENETROMETER |
| T TORVANE | Q UNCONFINED COMPRESSION |
| U UNCONSOLIDATED UNDRAINED TRIAXIAL | |



Boring Legend



SAFER Bay, Task Order 2
Palo Alto, CA

Date	JUL 2016
Figure	A-1

LEGEND_APR 2016 222952 AND 243911_SAFER BAY_WITH LAB_20160414.GPJ_FOLSOM_OAKLAND_FEB 2016_WIP_GDT 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-07

Sheet 1 of 2 Sheets

Start Date: 1/21/2016	End Date: 1/21/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 4/7/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: SCVWD	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 11.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Tri-cone / 4"		Total Depth Drilled: 41.5 ft.	Latitude: 37.453453° Longitude: -122.109806° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,991,596 ft. Easting: 6,094,407 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 20	Initial Groundwater Depth: 2.5 ft (1/21/2016; 7:35 A)	
		Disturbed: 18 Undisturbed: 2	Static Groundwater Depth: Not Established	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No	Laboratory					Su (ksf)	REMARKS								
									Fines	L	P	DD	MC										
10			10		[Hatched Pattern]	FILL (af) SANDY LEAN CLAY (CL): very dark brown mottled dark gray, moist, medium plasticity, fine to coarse sand, trace fine gravel, grass at surface.	83	S1 L1	16					Begin drilling with 6" SFA.									
			11	27											CLAYEY SAND with Gravel (SC): medium dense, gray, moist, fine to coarse angular gravel, fine to coarse sand, trace silt, 2" AC at 2.5'.	L2					Water encountered at 2.5'.		
			16												SANDY ELASTIC SILT (MH): soft, very dark gray mottled brown, moist, medium plasticity, fine to coarse sand, trace fine angular gravel, 1" AC at 4.5'.	44	S2 S3					Hole collapse at 5'; advance starter casing to 5.5'; change to mud rotary with 4" tri-cone. 2" gravel in Sample L3 (may be slough).	
			0		[Diagonal Pattern]	- medium stiff, medium to high plasticity, decreased sand and gravel content, dark gray mottled reddish-brown (oxidation staining), trace organics.	50			83	43	88	31	0.80 T	Plastic garbage in cuttings at 10'.								
			1	4																			
			3													- soft, with rubber, plastic, glass, abundant organics, moderate organic odor from borehole.	33	L5					
			2		[Diagonal Pattern]	YOUNG BAY MUD (Qbm) FAT CLAY (CH): medium stiff, dark olive gray, moist, high plasticity, little to no sand, strong organic odor.	100	L6		109	66			0.80 T	Advance casing to 13.5' to prevent caving of fill layer; change to 4-7/8" drag bit.								
			3	6																			
			3																				
			0		[Diagonal Pattern]	- soft, trace yellow organics.	100			55	76	52	82	0.32 T	UU and CN tests at 17'.								
			1	3																			
			1																				
			2																				
			0		[Diagonal Pattern]	- medium stiff, dark gray.	100	L7		49	42	21	95	25	3.00 P 1.75 T	UU test at 22'.							
			1	3																			
			2																				
			1		[Diagonal Pattern]	ALLUVIUM (Qal) CLAYEY SAND to SANDY LEAN CLAY (SC/CL): stiff, bluish gray, moist, fine sand, medium plasticity.	100			49	42	21	95	25	3.00 P 1.75 T	UU test at 22'.							
			1	3																			
			2																				
			1		[Diagonal Pattern]	Poorly Graded SAND with Clay (SP-SC): dense, dark gray, wet, fine to medium sand.	89	S4 L8						4.5+ P									
			1	39																			
			2																				
			16			SANDY LEAN CLAY (CL): hard, olive gray mottled reddish brown (oxidation staining), moist, medium plasticity, fine to coarse sand.	89	S5 L9															
			23																				

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE_2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-07

Sheet 2 of 2
 Sheets

ELEV	DEPTH	SAMPLE	Blows/ft or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PI	DD	MC		
-20		X	5 7 12	19	[Hatched Legend Box]	- stiff, increased oxidation staining.	50	L10 L11		42	21	101	26	3.00 P 1.40 T	
-35		X	5 7 10	17		- medium stiff, olive gray mottled brown at 35.5'. - stiff, trace fine gravel at 36'. - increased sand content at 36.5'.	83	L12 L13						0.88 T 1.30 T	
-40		X	3 8 11	19		LEAN CLAY with Sand (CL): stiff, brown with black specks, moist, medium plasticity, coarse sand.	56	L14 L15				99	26	2.00 P 1.50 T	

Bottom of boring at 41.5 feet depth.

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-08

Sheet
 of 1
 2 Sheets

Start Date: 1/21/2016	End Date: 1/21/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 4/7/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: SCVWD	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 11.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"		Total Depth Drilled: 46.5 ft.	Latitude: 37.453874° Longitude: -122.103472° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,991,718 ft. Easting: 6,096,248 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 20 Disturbed: 16 Undisturbed: 4	Initial Groundwater Depth: 5.5 ft (1/21/2016; 1:00 P) Static Groundwater Depth: Not Established	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No	Laboratory					Su (ksf)	REMARKS	
									Fines	L	U	DD	MC			
10	10	X	10	29		7" Aggregate Base. FILL (af) CLAYEY SAND with Gravel (SC): medium dense, very dark brown, moist, fine to coarse sand, fine angular to rounded gravel, medium plasticity fines, rusted metal fragment at 2.5'. - with black clay inclusions. - dark greenish gray, loose, wet, fine to coarse angular gravel, high plasticity fines, slight organic odor.	83	L1 L2	32	42	21				Begin drilling with 6" SFA. Groundwater encountered at 5.5'. Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit. UU test at 12'. Lost bottom 5" of sample during retrieval. UU test at 16'. Shells up to 1/2" in cuttings. UU and CN tests at 27'. Driller reported harder drilling and material change at 28'.	
	7	X	7	15			50	L3 L4					1.50 P			
	8	X	8													
	5	X	2	3				100	S1 L5 L6	25				0.82 T		
	5	X	1													
	2	X	2													
	10		0-75				- soft.	83	L7		98	56		0.40 P		
	0		psi													
	15		0-75				- dark gray.	100	L8			52	81			0.28 T
	-5		psi													
	20	X	0	0			- medium stiff, dark gray mottled black.	100	L9 L10 L11				55	77		0.80 T 0.28 T
	-10	X	0				- soft, dark gray.									
	0	X	0													
	-15	X	0-100			- medium stiff, trace shell fragments.	100	L12		86	43			0.50 P		
	-15	X	psi													
						ALLUVIUM (Qal) LEAN CLAY with Sand (CL): hard, olive gray, moist, medium plasticity, medium to coarse sand.						56 54	74 78	0.75 P 0.70 T		

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-08

Sheet 2 of 2
 Sheets

ELEV	DEPTH	SAMPLE	Blows/ft or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PI	DD	MC		
-20		X	13 24 31	55			50	L13 L14						4.50 P	
-35		X	5 10 13	23		SANDY FAT CLAY (CH): stiff to very stiff, olive gray mottled reddish yellow (oxidation staining), moist, high plasticity, medium to coarse sand.	47	L15 L16	60	33	92	32	2.50 P 1.60 T		
-40						- very stiff.		L17					3.50 P		
-30			225 psi			LEAN CLAY with Sand (CL): stiff, dark grayish brown, moist, medium plasticity, medium to coarse sand.	100						2.00 P 1.30 T		
-45		X	3 11 12	23		- yellowish brown.	67	L18 L19			103	24	1.30 T		

Bottom of boring at 46.5 feet depth.

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-09

Sheet 1 of 2 Sheets

Start Date: 1/25/2016	End Date: 1/25/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 4/7/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: SCVWD	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 10.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"		Total Depth Drilled: 56.5 ft.	Latitude: 37.450757° Longitude: -122.090822° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,990,521 ft. Easting: 6,099,900 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 17	Initial Groundwater Depth: 6 ft (1/25/2016; 11:59 A) Static Groundwater Depth: Not Established	
		Disturbed: 13	Undisturbed: 4	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PL	DD	MC		
			3 3 4	7		6" Aggregate Base. FILL (af) FAT CLAY (CH): medium stiff, dark grayish brown and dark gray mottled reddish yellow (oxidation staining), moist, high plasticity, trace sand.	31	L1						2.00 P	Begin drilling with 6" SFA.
5	5		175-200 psi			GROUNDWATER		L2							Groundwater encountered at 6'. UU test at 6.7'.
			0 0 0	0		YOUNG BAY MUD (Qbm) ELASTIC SILT (MH): soft, very dark gray, moist, high plasticity, little to no sand, trace organics, moderate organic odor.	67	L3 L4		81	44	70	51		Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.
			0-100 psi			- very soft, abundant black and brown woody organics.	100	L3 L4				54	79	0.20 T	
-5	15		0-100 psi				33	L5							Lost bottom up to 20" of sample during retrieval; very soft soil slides readily in tube (likely disturbed).
-10	20		0-100 psi			- slight organic odor.	100	L6		105	62				UU and CN tests at 22'.
-15	25		0 0 0	0		- soft, trace organics.	100	L7 L8				61	64	0.28 T	Soil cuttings in drilling fluid appeared more stiff at 27'. Driller reported harder drilling and material change at 29'.
						ALLUVIUM (Qal) SANDY LEAN CLAY (CL): very stiff, bluish gray.									

HDR SOIL BORING LOG 2016 R2: 222952 AND 243911 SAFER BAY WITH LAB 20160414.GPJ; HDR_FOL_SOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-09

Sheet 2 of 2
 Sheets

ELEV	DEPTH	SAMPLE	Blows/ft or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PI	DD	MC		
			7 19 24	43		moist, medium plasticity, fine sand. - hard. - possible sand lens (see remarks).	58	L9 L10				105	23	3.50 P 4.5+ P	Possible sand lens between 33' and 34' based on cuttings in drilling fluid (approximate depths reported by driller). UU test at 42'. Driller reported sand and gravel in cuttings between 43' and 45'. Driller reported that the clay layer at 46' is likely "thin" based on cuttings in drilling fluid.
-25	-35		0 6 6	12		- grayish brown mottled yellow, stiff.	67	L11 L12					1.25 P 1.50 P		
-30	-40					CLAYEY SAND (SC): stiff, olive, moist, medium plasticity fines..		L13					2.00 P		
			175 psi			- 2" pocket of poorly graded sand at 42.5'.	100		44	28	10				
			300 psi			Well-Graded SAND with Clay (SW-SC): medium dense, olive brown, moist, fine to coarse sand, fine gravel.						106	21		
-35	-45		11 7 3	10		LEAN CLAY (CL): grayish brown mottled yellow, moist, medium plasticity.	44	S1 S2	7						
-40	-50		11 12 19	31		Poorly Graded SAND with Silt (SP-SM): dense, dark grayish brown, moist, fine to medium sand, low plasticity fines.		S3	10						
-45	-55		11 19 20	39		Well-Graded SAND with Clay and Gravel (SW-SC): dense, dark brown, wet, fine to coarse sand, fine to coarse angular to subrounded gravel, medium plasticity fines, intermittent clayey sand pockets.	67	S4							

Bottom of boring at 56.5 feet depth.

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-10

Sheet 1 of 2 Sheets

Start Date: 1/25/2016	End Date: 1/25/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 4/7/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: SCVWD	Weather Conditions: Clear, moderate	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 10.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"		Total Depth Drilled: 51.5 ft.	Latitude: 37.440583° Longitude: -122.095926° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,986,842 ft. Easting: 6,098,356 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 22 Disturbed: 20 Undisturbed: 2	Initial Groundwater Depth: 7 ft (1/25/2016; 8:13 A) Static Groundwater Depth: Not Established	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No	Laboratory					Su (ksf)	REMARKS	
									Fines	L	U	DD	MC			
			6 7 8	15		6" Aggregate Base. FILL (af) ELASTIC SILT with Sand (MH): stiff, grayish brown slightly mottled reddish brown (oxidation staining), moist, high plasticity, fine to coarse sand.	56	L1 L2		82	43	76	37	2.50 P 1.40 T	Begin drilling with 6" SFA.	
5	5		0 3 3	6		- soft, decreased sand content. - pockets of dark gray Young Bay Mud.	67	L3 L4					0.50 P 0.40 T			
			0 0 0	0		YOUNG BAY MUD (Qbm) ELASTIC SILT (MH): soft, gray, moist, high plasticity, little to no sand, abundant pockets of black organics, strong organic odor.	83	L5 L6					0.50 P 0.40 T	Groundwater encountered at 7'.		
0	10		0- 100 psi				93	L7		101	57			Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.		
												59 56	68 74	0.28 T	UU and CN tests at 12'. Driller reported brown clay cuttings between 13' and 14'.	
-5	15		0 0 0	0		- decreased black organics, trace wood fragments.	100	L8 L9					52	83	0.40 T	
-10	20		100- 175 psi			- with black organics.	100	L10					54	78	0.50 P	UU test at 20'.
			500 psi			ALLUVIUM (Qal) SANDY LEAN CLAY (CL): hard, greenish gray, moist, low to medium plasticity, no dilatancy, fine sand.									4.5+ P	Material contact at 22' estimated from Shelby Tube push pressure.
-15	25		7 8 11 1 6 9	19 15		- increased sand content. CLAYEY SAND with Gravel (SC): medium dense, dark gray, moist, fine to coarse sand, trace fine gravel, medium plasticity fines.	64 44	L11 L12 S1						13		
						LEAN CLAY with Sand (CL): stiff, grayish brown mottled yellow, moist, medium plasticity, fine to medium sand, trace fine angular gravel.										

HDR SOIL BORING LOG 2016 R2: 222952 AND 243911 SAFER BAY WITH LAB 20160414.GPJ; HDR_FOL_SOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-10

Sheet 2 of 2
 Sheets

ELEV	DEPTH	SAMPLE	Blows/ft or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PI	DD	MC		
			3 8 12	20	[Hatched Legend]		56	L13 L14		42	21	99	27	1.30 P 1.10 T	
-25	-35		9 13 16	29		- very stiff, gray mottled light gray, no gravel.	31	L15						3.50 P	
-30	-40		1 5 8	13		- stiff, yellowish brown.	64	L16 L17				97	29	1.50 P 1.30 T	
-35	-45		5 8 15	23			72	L18 L19	70						
-40	-50		2 6 8	14	[Hatched Legend]	LEAN CLAY (CL): stiff, grayish brown, moist, medium plasticity, trace sand.	78	L20 L21				96	29	1.50 P 1.16 T	

Bottom of boring at 51.5 feet depth.

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ: HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB: 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID:
B-11

Sheet
 of **1**
2 Sheets

Start Date: 1/22/2016	End Date: 1/22/2016	Logged By: V. Crosariol	Checked By: E. Woo	Date Checked: 4/7/2016
Drilling Company (Rig Type): Pitcher Drilling Co. (Failing 1500)		Inspector: SCVWD	Weather Conditions: Cloudy, drizzle	
Drill Method: SFA / Mud Rotary		Drilled By: Oscar Espinosa	Elevation Top of Boring: 11.0 ft. Vertical Datum: NAVD88	
Drill Bit (Type/Size): Drag Bit / 4 7/8"		Total Depth Drilled: 46.5 ft.	Latitude: 37.432997° Longitude: -122.104338° Horizontal Datum: NAD83	
Hammer Type: Automatic		Hole Backfill: Cement grout	Northing: 1,984,122 ft. Easting: 6,095,867 ft. Coordinate System: California State Plane Zone 3	
Hammer Efficiency: 67 %	Rod Type: FEDP	Total Number of Samples: 16 Disturbed: 14 Undisturbed: 2	Initial Groundwater Depth: Not Established Static Groundwater Depth: Not Established	

ELEV	DEPTH	SAMPLE	Blows/6" or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No	Laboratory					Su (ksf)	REMARKS
									Fines	LL	PL	DD	MC		
10			9 9 11	20		Grass and topsoil over 4" Aggregate Base.									Begin drilling with 6" SFA.
						FILL (af) CLAYEY SAND with Gravel (SC): medium dense, brown to dark brown, moist, fine to coarse sand, fine gravel, medium plasticity fines.	67	L1 L2	35				2.50 P 1.20 T		
5			17 25 21	46		SANDY LEAN CLAY (CL): stiff to very stiff, dark brown mottled olive, yellow, and black, moist, medium plasticity, fine to coarse sand. - hard, trace gravel, oxidation staining.	78	L3 L4			115	11	4.5+ P 4.5+ P		Install casing to 8.5'; change to mud rotary with 4-7/8" drag bit.
						YOUNG BAY MUD (Qbm) FAT CLAY (CH): medium stiff, dark gray, moist, high plasticity, high toughness, trace fine to coarse sand.									
0			3 3 5	8			22	L5			95	29	0.64 T		UU and CN tests at 16'. Shelby Tube refusal at 17'.
-5			200 psi 400- 650 psi				92	L6		52	31		100 93	26 29	
						ALLUVIUM (Qal) Well-Graded SAND with Clay (SW-SC): medium dense, dark gray, wet, fine to coarse sand, trace fine gravel, medium plasticity fines.									Driller reported material change at 23'.
						- grayish brown, increased gravel content.	44	S1	10						
-15			2 3 7	10		LEAN CLAY with Sand (CL): medium stiff, light brown mottled gray, moist, low to medium plasticity, fine sand.	67	L7 L8		36	17	100	26	1.00 P 0.80 T	

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOL_SOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16



Project: SAFER Bay, Task Order 2
 Project Location: Palo Alto, CA
 Project Number: 10022067

Boring ID: B-11

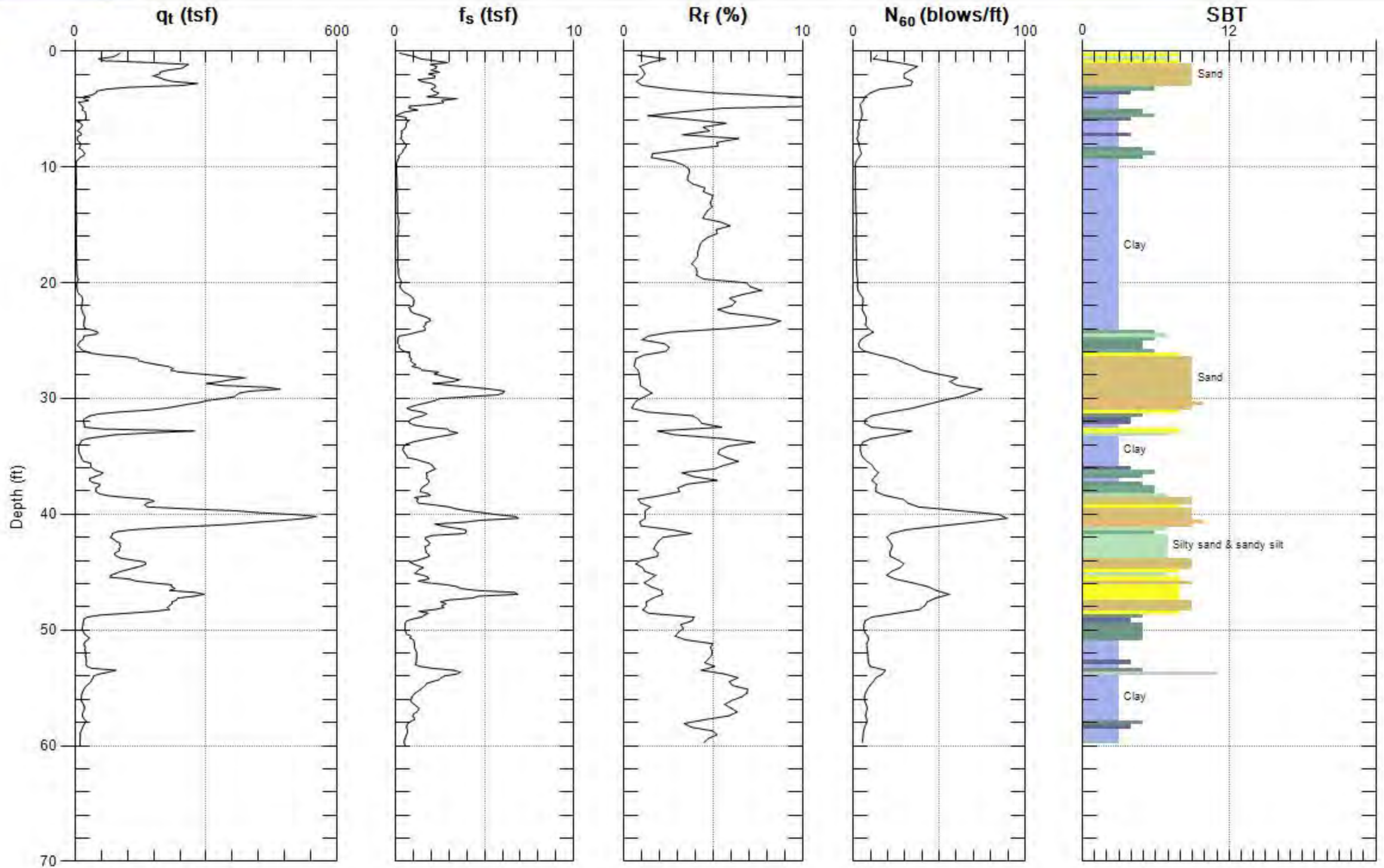
Sheet 2 of 2
 Sheets

ELEV	DEPTH	SAMPLE	Blows/ft or Press.	N _r	LEGEND	DESCRIPTION OF MATERIALS	% REC	Samp No.	Laboratory					Su (ksf)	REMARKS	
									Fines	LL	PI	DD	MC			
-20			275-300 psi			SILT with Sand (ML): medium stiff, light brown, moist, low plasticity, rapid dilatancy, fine sand.	100	L9								
-35			2	10		SANDY SILT (ML): medium stiff, brown, moist, low plasticity fines, rapid dilatancy, fine to medium sand.	83	S2 L10 L11	50							
-25			4 6			Poorly Graded SAND with Clay (SP-SC): dense, brown and dark gray, wet, fine to coarse sand, trace fine gravel, medium plasticity fines, intermittent pockets of clean sand.		S3	10							Driller reported material change at 38'.
-40			17 17 25	42		SANDY LEAN CLAY (CL): medium stiff, olive gray mottled brown, moist, low to medium plasticity, fast dilatancy, fine sand.	89	L12 L13	69	32	13	102	26	1.00 P		Driller reported material change at 43'.
-30			4 3 7	10												
-45																

HDR SOIL BORING LOG 2016_R2: 222952 AND 243911 SAFER BAY WITH LAB_20160414.GPJ; HDR_FOLSOM_OAKLAND_JUNE 2016_WIP.GLB; 6/16/16

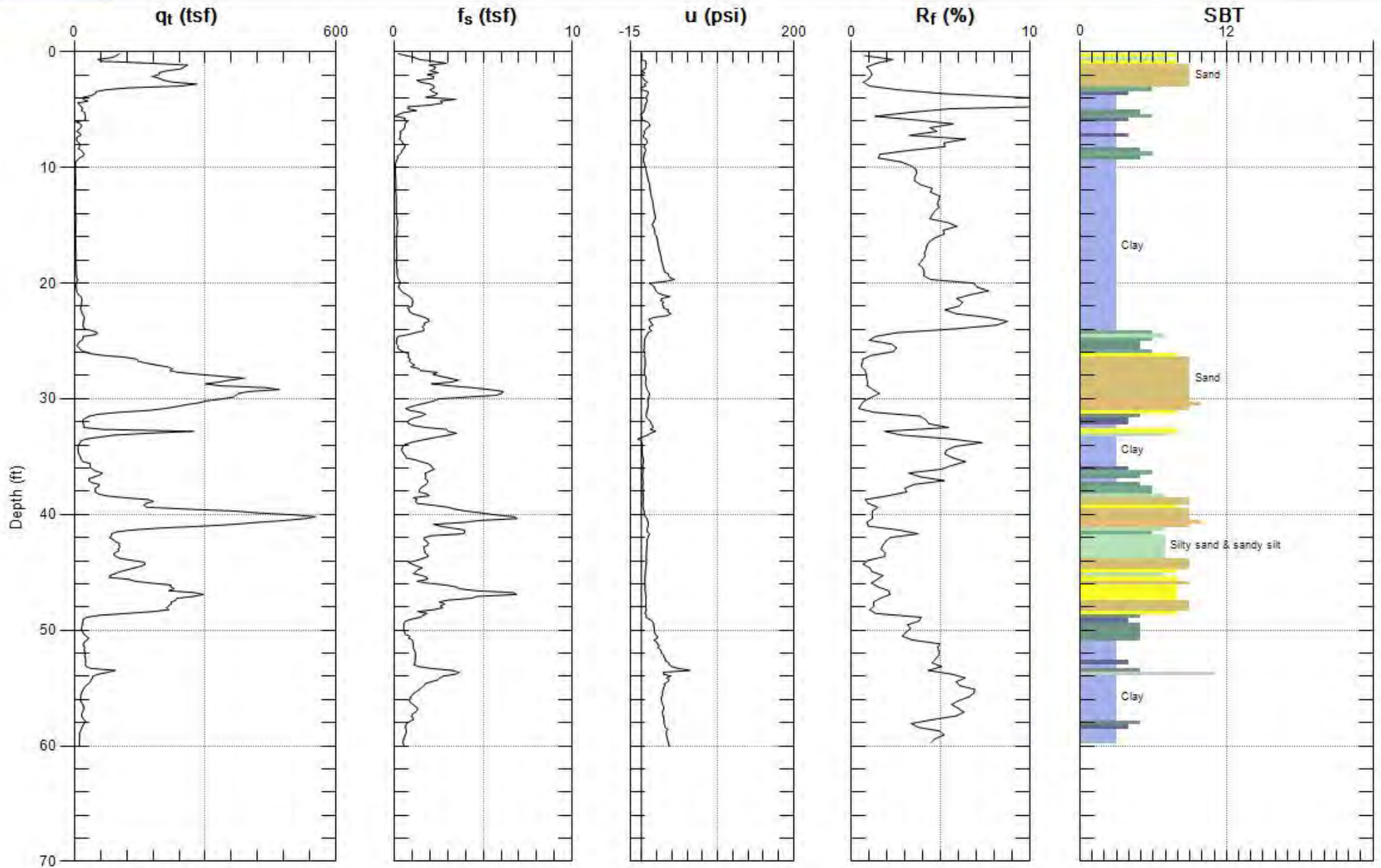


This page intentionally left blank.



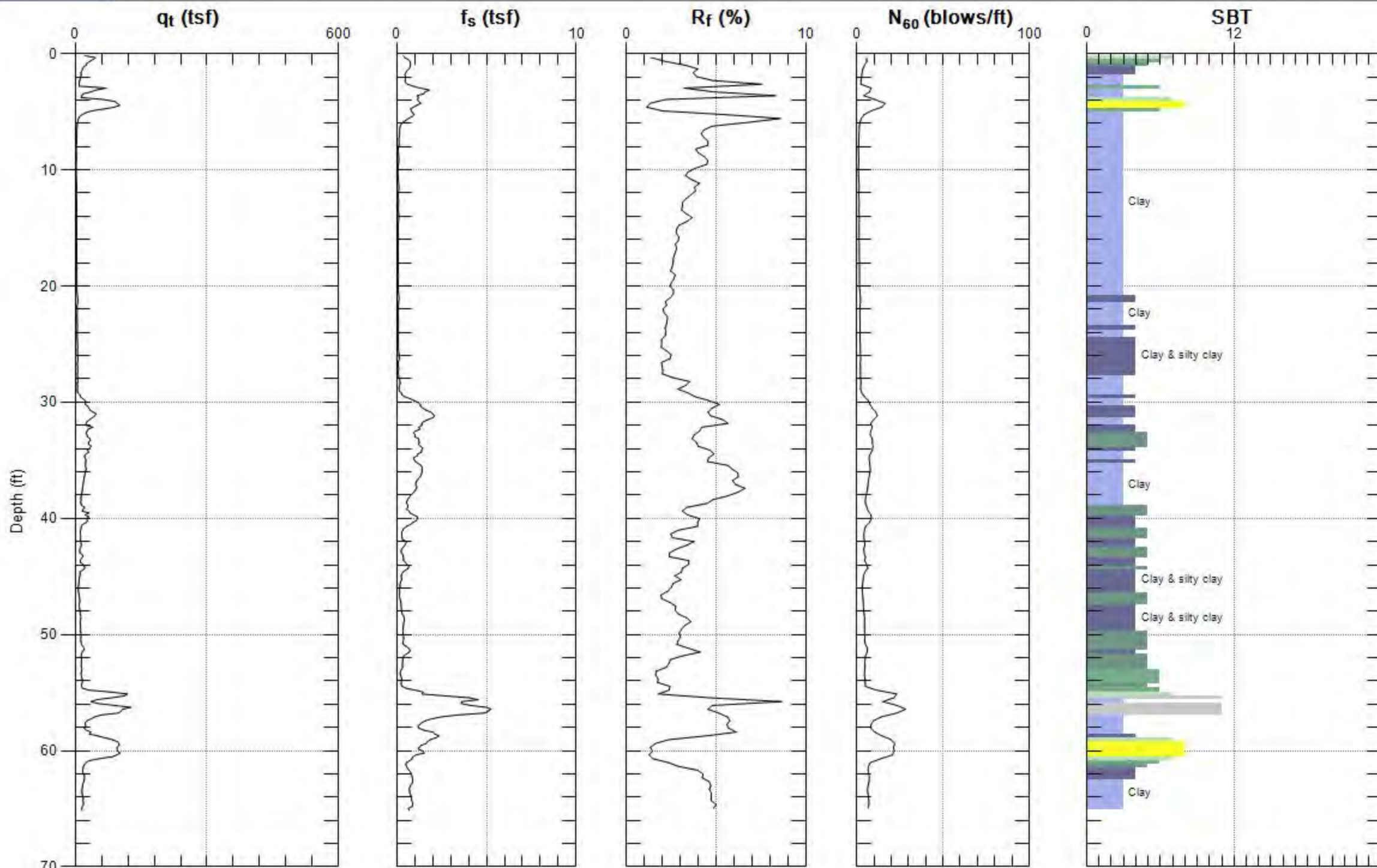
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



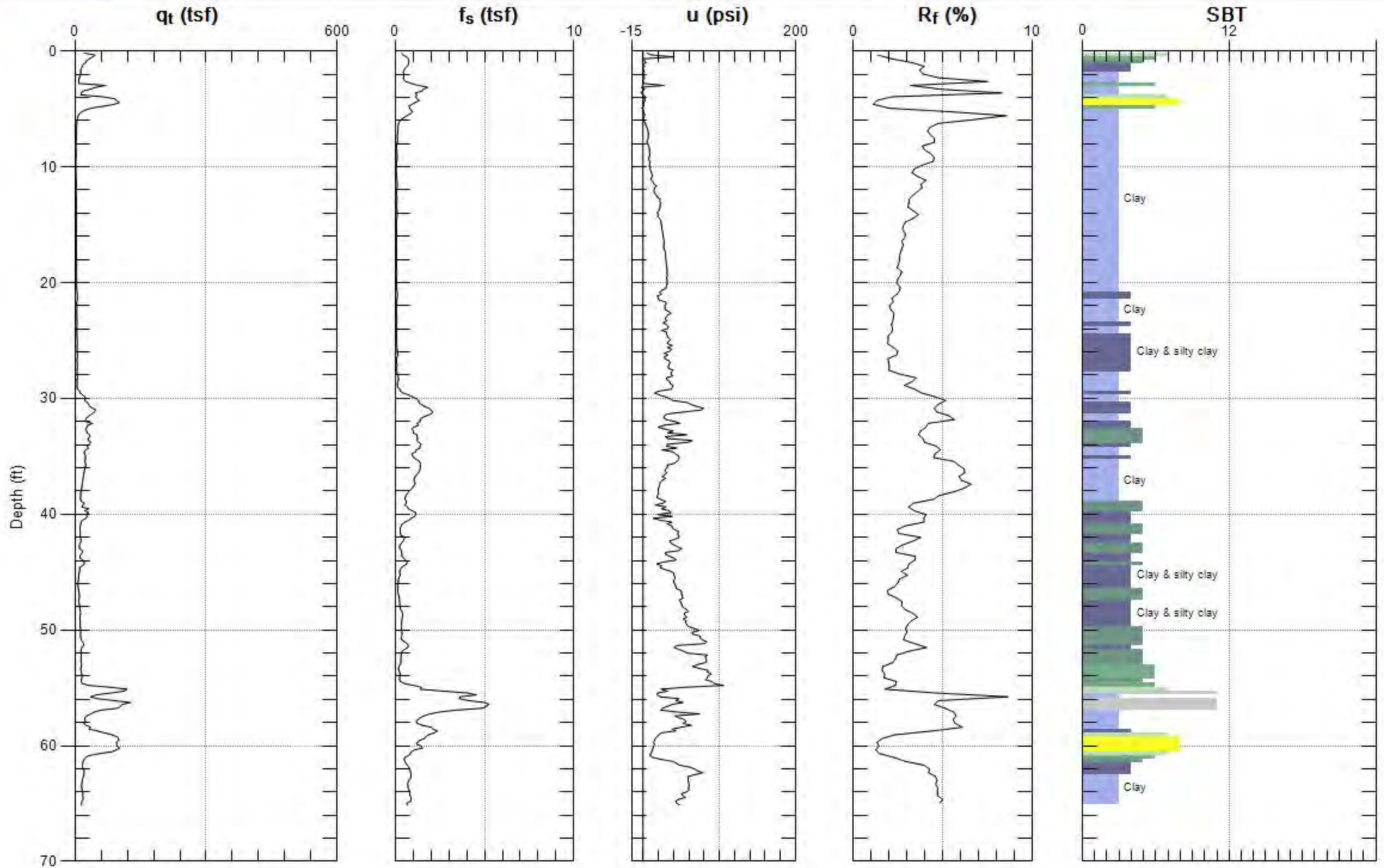
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



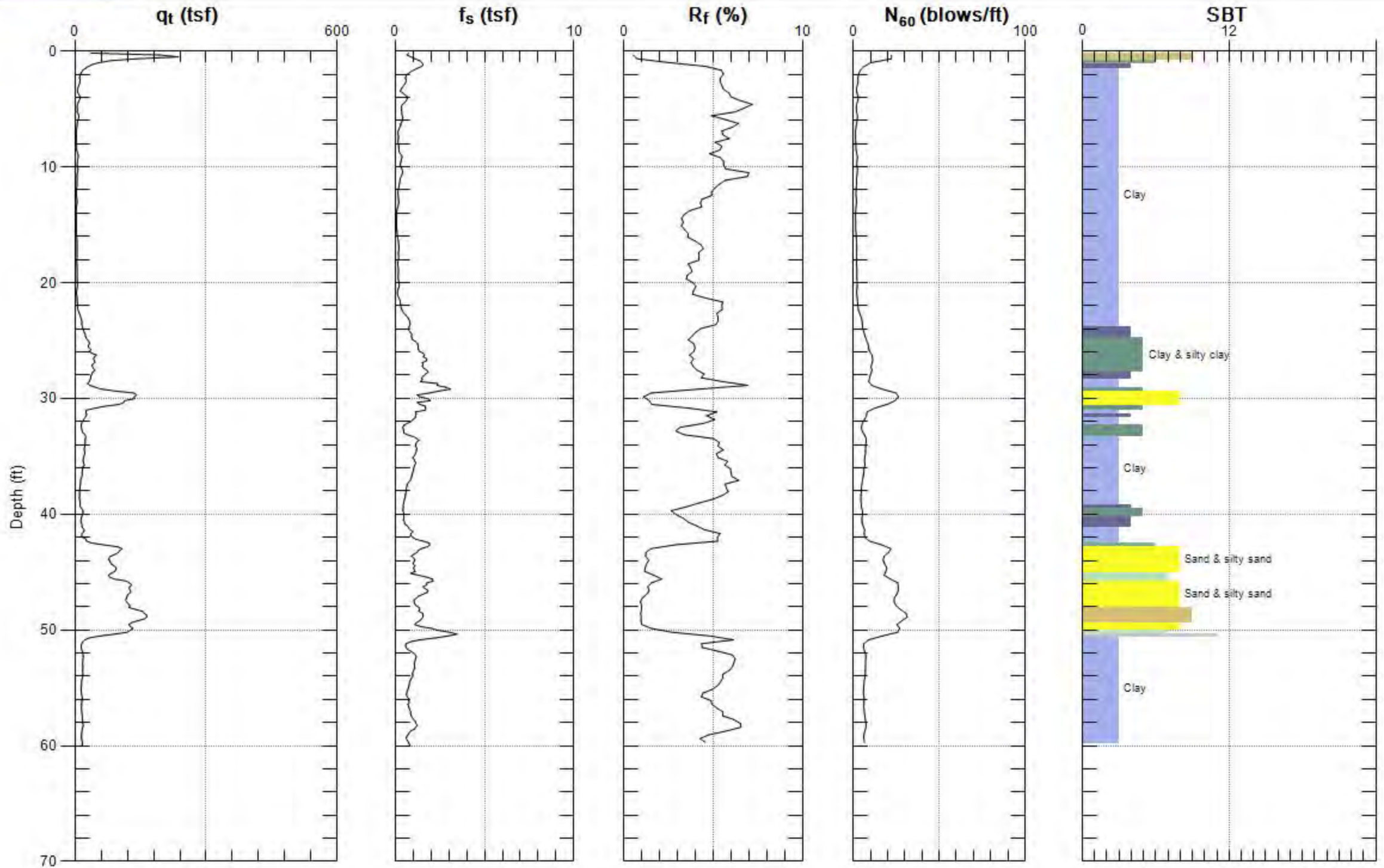
Max. Depth: 65.125 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



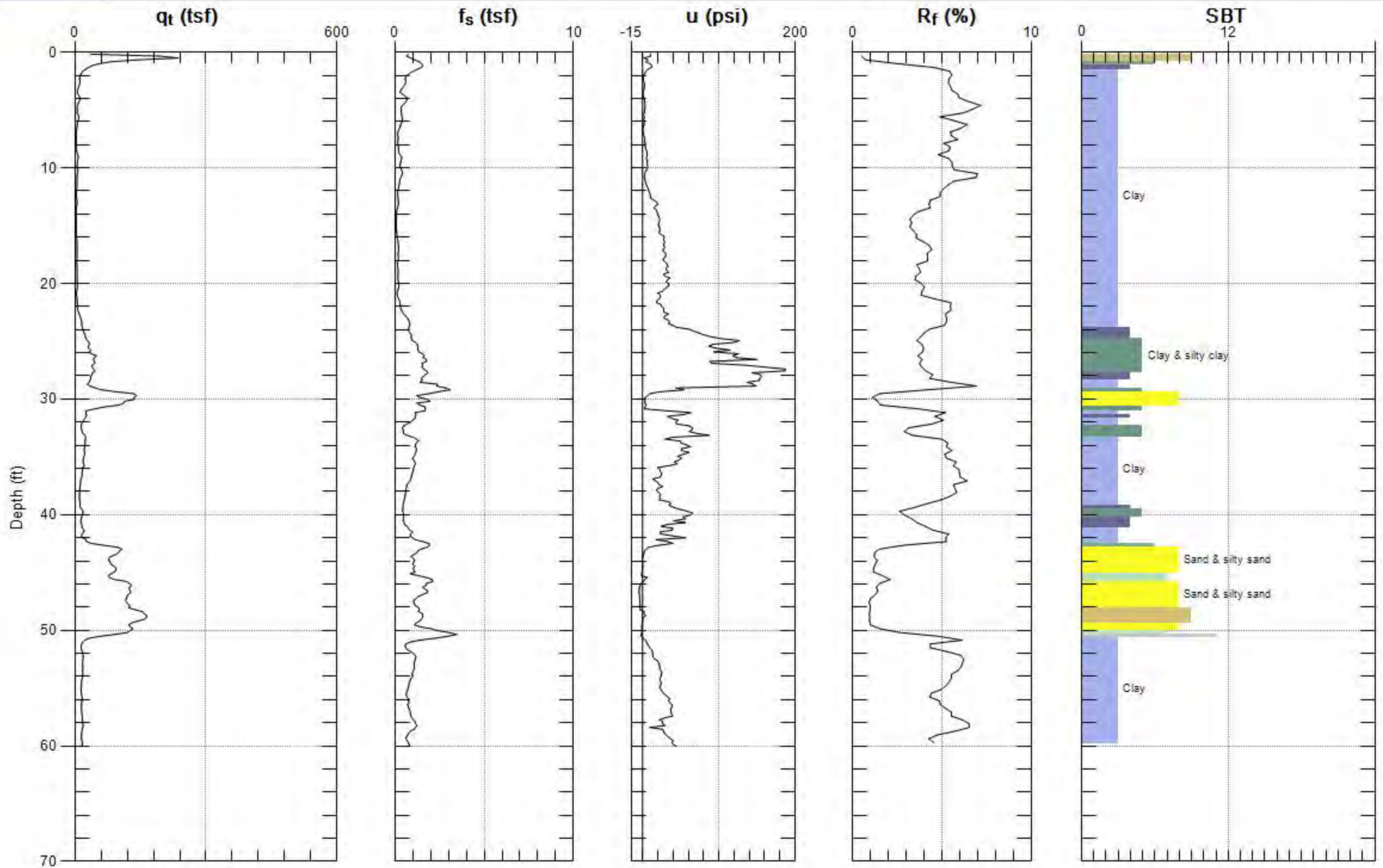
Max. Depth: 65.125 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



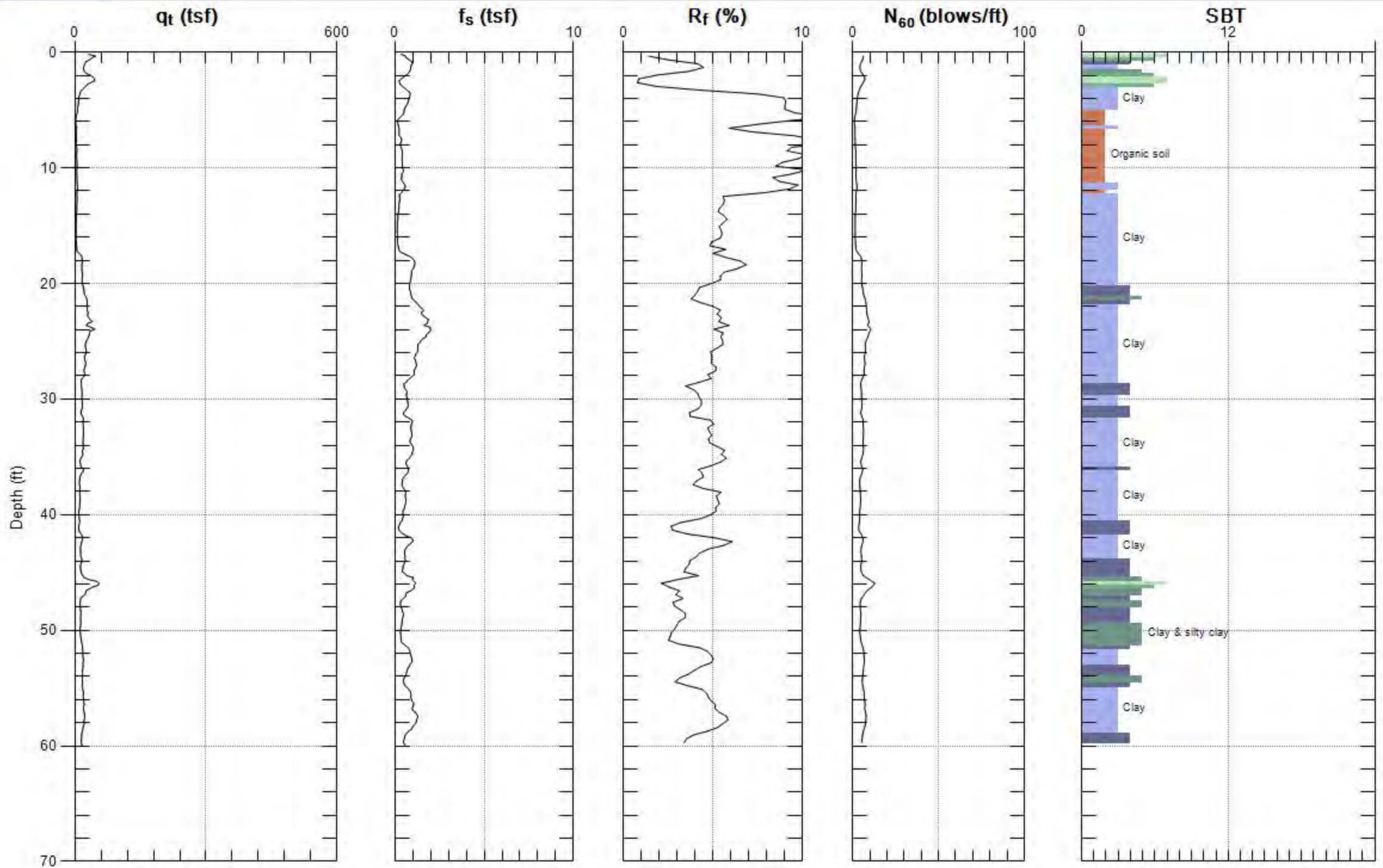
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



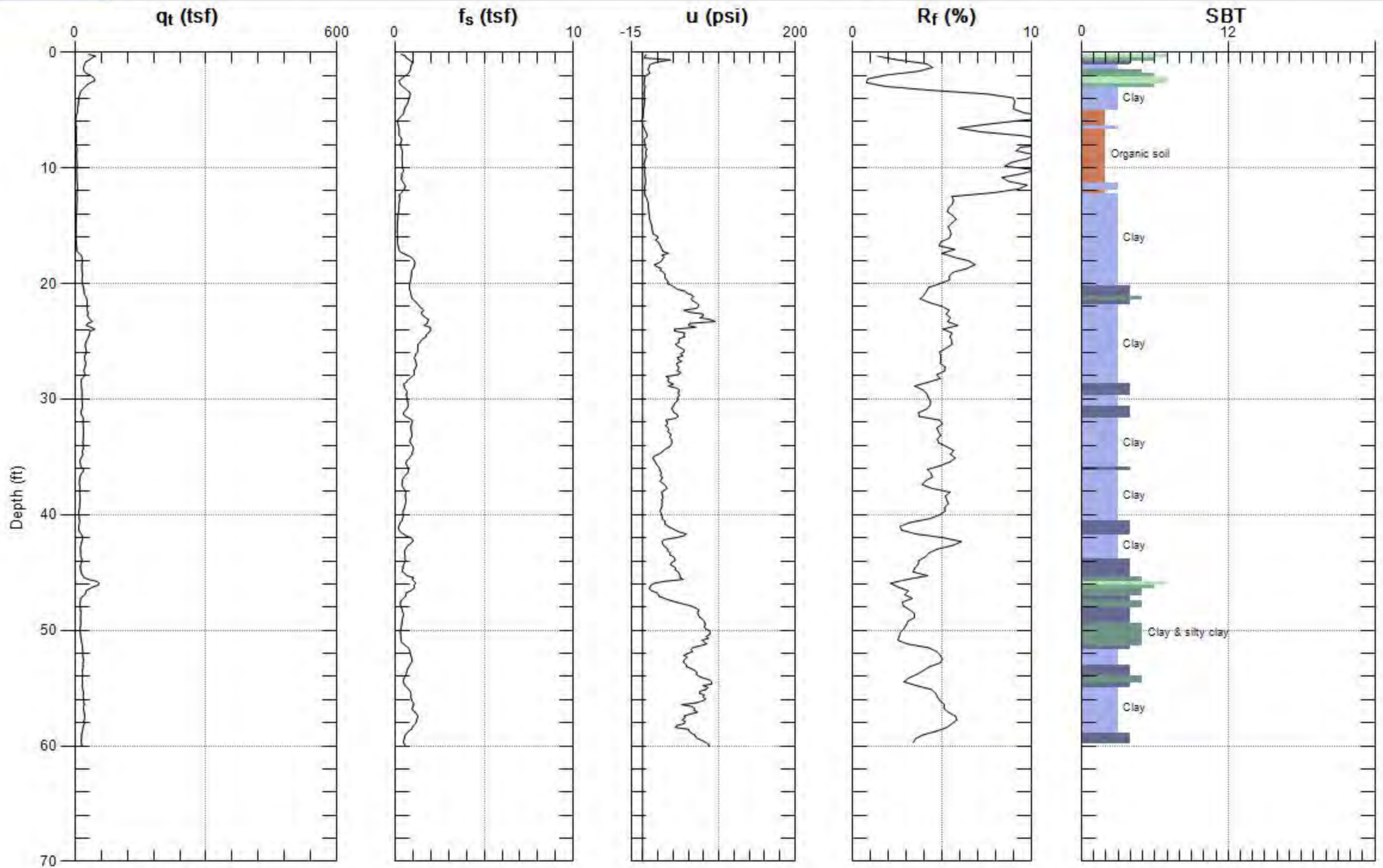
Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)





Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 60.039 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

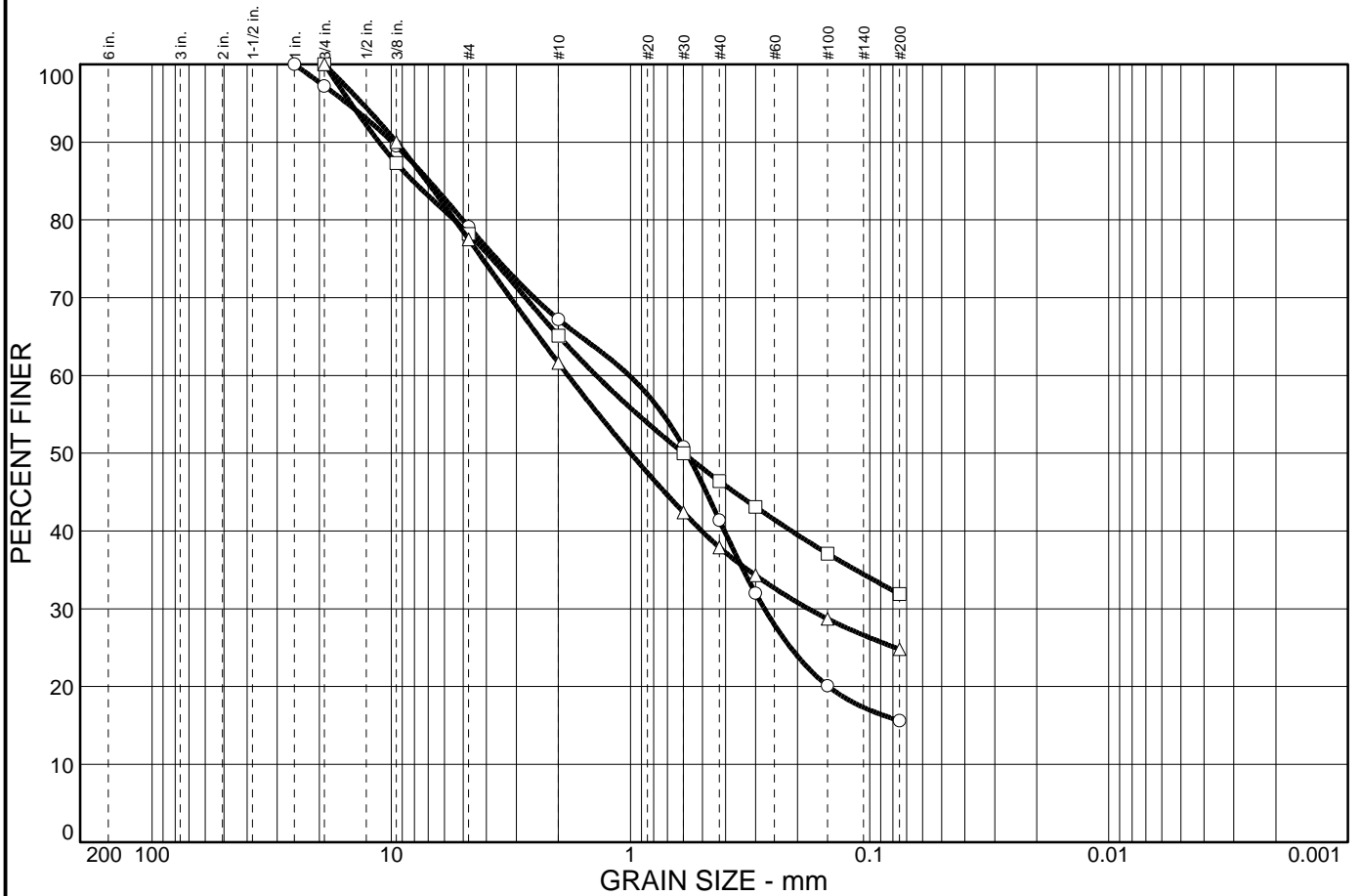


Appendix B Laboratory Test Results



This page intentionally left blank.

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		20.9	63.5		15.6				
□		21.8	46.3		31.9	SC		21	42
△		22.5	52.7		24.8				

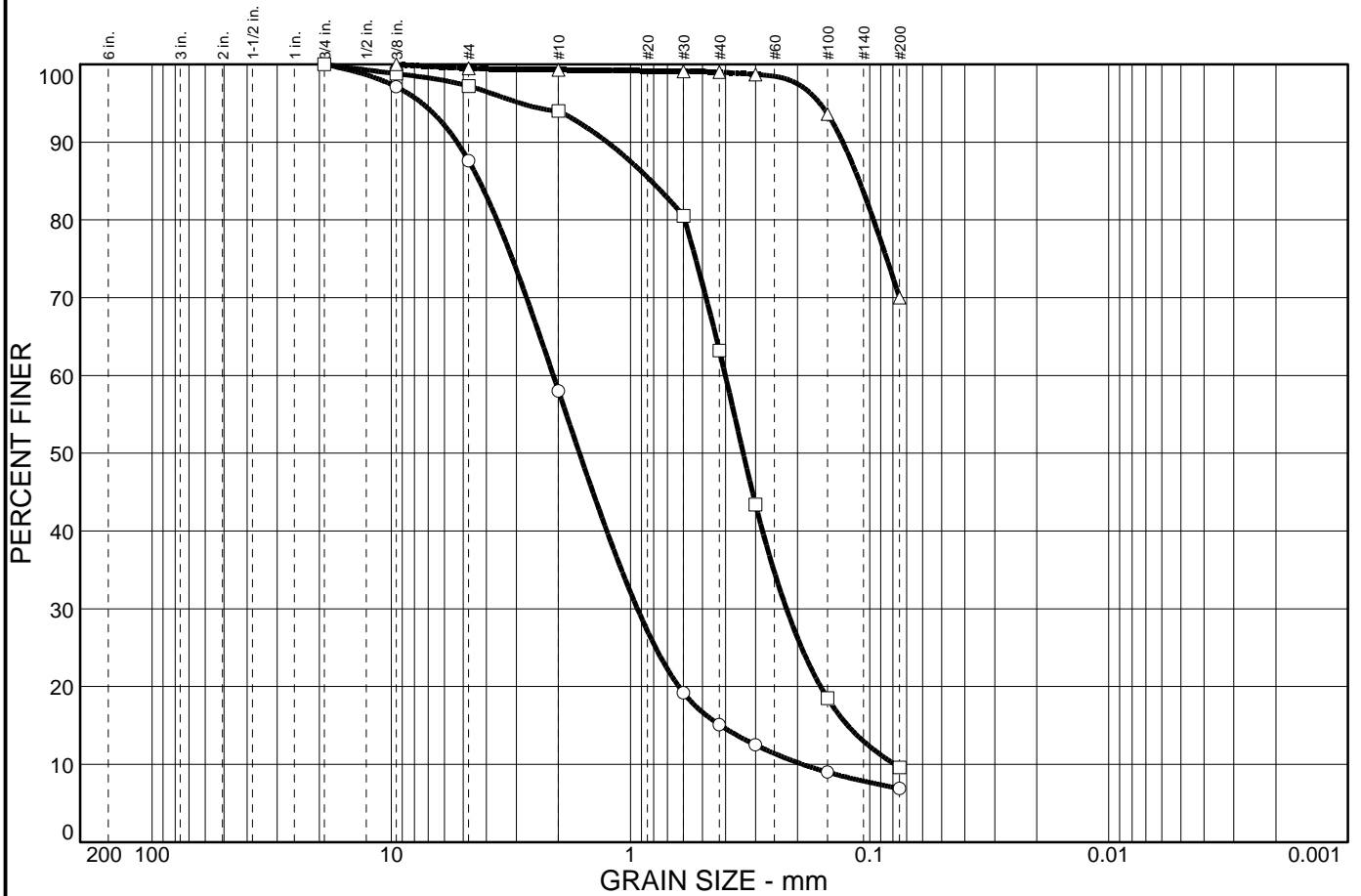
SIEVE inches size	PERCENT FINER			SIEVE number size	PERCENT FINER			SOIL DESCRIPTION
	○	□	△		○	□	△	
1"	100.0			#4	79.1	78.2	77.5	○ Dark Olive Brown Clayey SAND w/ Gravel
3/4"	97.2	100.0	100.0	#10	67.2	65.1	61.6	
3/8"	89.5	87.3	90.0	#30	50.8	50.0	42.4	
				#40	41.4	46.4	37.9	□ Olive Brown Lean Clayey SAND w/ Gravel
				#50	32.0	43.1	34.3	
				#100	20.1	37.1	28.7	△ Dark Greenish Gray Clayey SAND w/ Gravel
				#200	15.6	31.9	24.8	
GRAIN SIZE								
D ₆₀	1.01	1.39	1.83					REMARKS: ○ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.
D ₃₀	0.275		0.180					
D ₁₀								
COEFFICIENTS								
C _c								△
C _u								

- Source: B-07
- Source: B-08
- △ Source: B-08

Sample No.: L1+L2
 Sample No.: L1+L2
 Sample No.: S1

Elev./Depth: 1.5-2.3'
 Elev./Depth: 1.5-2.5'
 Elev./Depth: 5.5-6.0'

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		12.4	80.7		6.9				
□		2.8	87.6		9.6				
△		0.5	29.5		70.0	ML			

SIEVE inches size	PERCENT FINER			SIEVE number size	PERCENT FINER			SOIL DESCRIPTION
	○	□	△		○	□	△	
3/4"	100.0	100.0		#4	87.6	97.2	99.5	○ Olive Brown Well-Graded SAND w/ Clay □ Olive Brown Poorly Graded SAND w/ Silt △ Olive Brown Sandy SILT
3/8"	97.1	98.8	100.0	#10	58.0	94.0	99.3	
				#30	19.2	80.5	99.1	
				#40	15.1	63.2	99.0	
				#50	12.5	43.4	98.7	
				#100	9.0	18.5	93.6	
				#200	6.9	9.6	70.0	
GRAIN SIZE								
D ₆₀	2.10	0.402						
D ₃₀	0.935	0.223						
D ₁₀	0.190	0.0785						
COEFFICIENTS								
C _c	2.18	1.57						
C _u	11.04	5.11						
REMARKS:								
○								
□								
△								

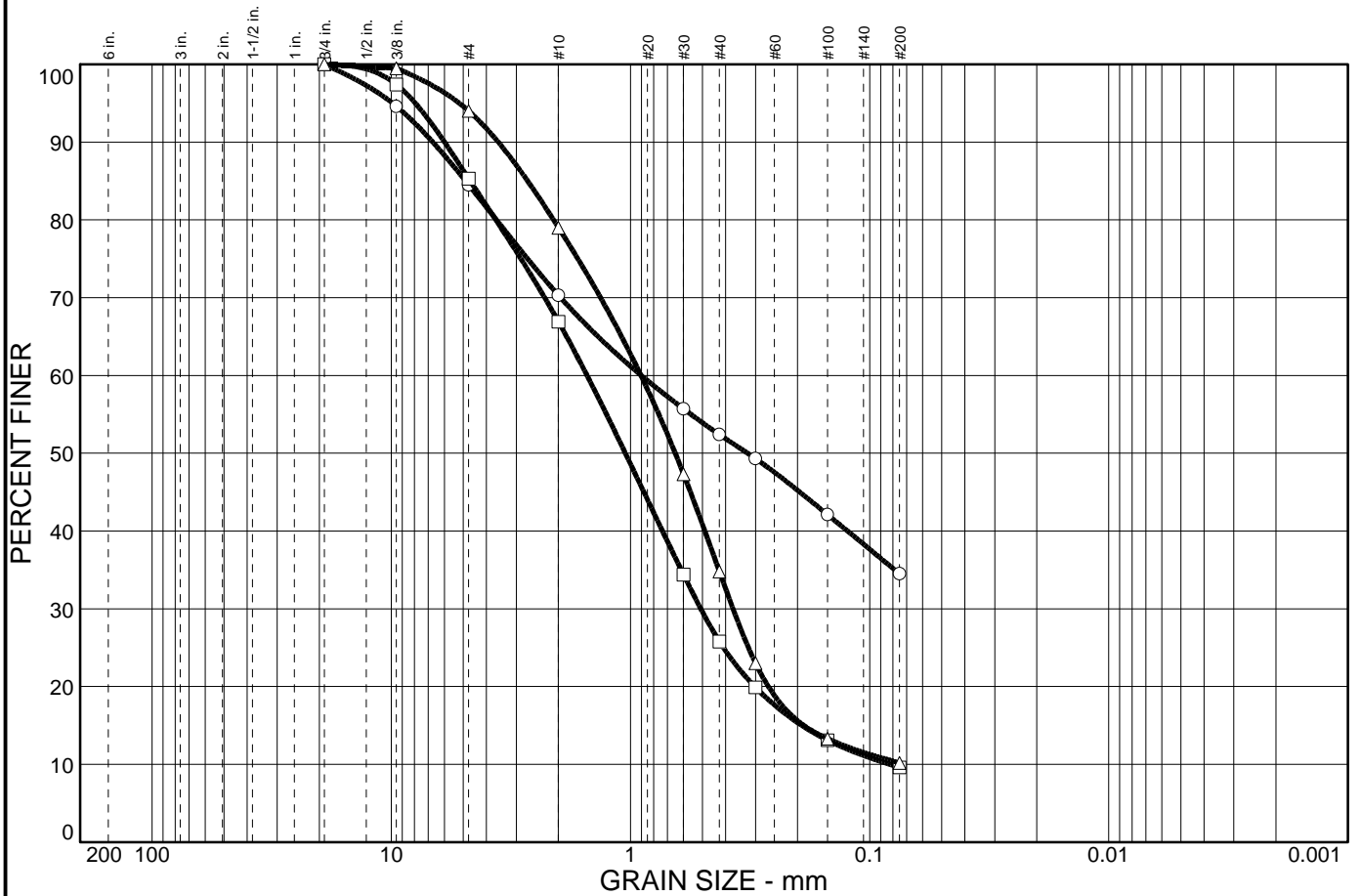
- Source: B-09
- Source: B-09
- △ Source: B-10

- Sample No.: S1
- Sample No.: S3
- Sample No.: L19

- Elev./Depth: 45-45.8'
- Elev./Depth: 50-51.5'
- Elev./Depth: 46-46.5'

COOPER TESTING LABORATORY	Client: HDR Engineering, Inc. Project: SAFER Bay-Task Order 2 - 028-243911 Project No.: 855-012	Figure
----------------------------------	---	--------

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		15.5	50.0	34.5					
□		14.7	75.7	9.6					
△		6.0	83.8	10.2					

SIEVE inches size	PERCENT FINER		
	○	□	△
3/4"	100.0	100.0	100.0
3/8"	94.6	97.4	99.5
GRAIN SIZE			
D ₆₀	0.901	1.52	0.904
D ₃₀		0.508	0.373
D ₁₀		0.0824	
COEFFICIENTS			
C _c		2.06	
C _u		18.44	

SIEVE number size	PERCENT FINER		
	○	□	△
#4	84.5	85.3	94.0
#10	70.3	66.9	79.0
#30	55.7	34.4	47.3
#40	52.4	25.8	34.8
#50	49.3	19.9	23.0
#100	42.1	13.1	13.3
#200	34.5	9.6	10.2

SOIL DESCRIPTION

- Reddish Brown Clayey SAND w/ Gravel
- Olive Brown Well-Graded SAND w/ Clay
- △ Olive Brown Poorly Graded SAND w/ Clay

REMARKS:

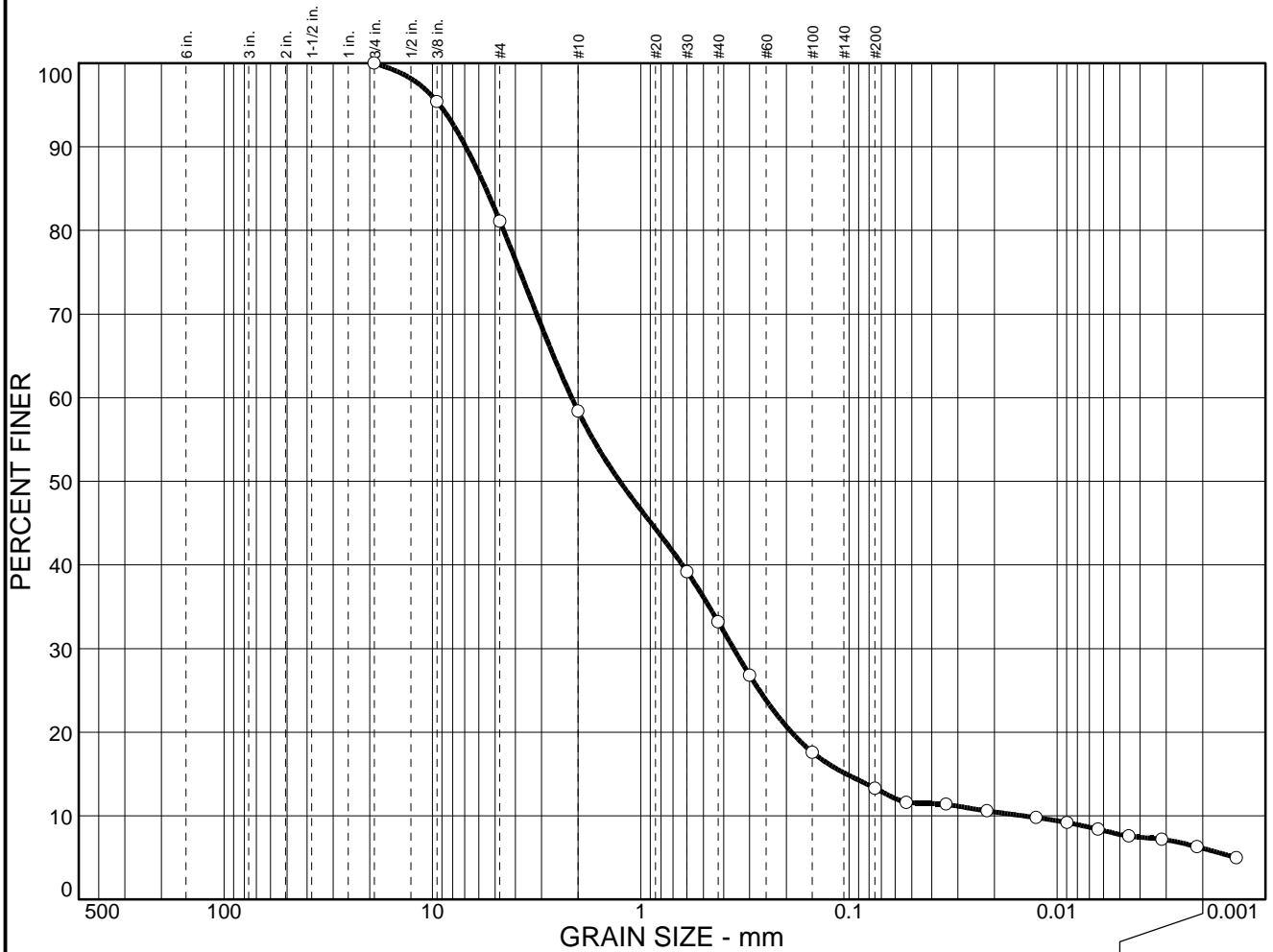
○

□

△

○ Source: B-11 □ Source: B-11 △ Source: B-11	Sample No.: L1 Sample No.: S1 Sample No.: S3	Elev./Depth: 1.5-2' Elev./Depth: 20-21.5' Elev./Depth: 40-41.5'
--	--	---

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	18.9	67.8	7.2	6.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	95.4		
#4	81.1		
#10	58.4		
#30	39.2		
#40	33.2		
#50	26.8		
#100	17.6		
#200	13.3		
#270	11.6		
0.0341 mm.	11.4		
0.0217 mm.	10.6		
0.0126 mm.	9.8		
0.0090 mm.	9.2		
0.0064 mm.	8.4		
0.0045 mm.	7.6		
0.0031 mm.	7.2		
0.0021 mm.	6.3		
0.0014 mm.	5.0		

Soil Description

Olive Brown Clayey SAND w/ Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅= 5.54 D₆₀= 2.15 D₅₀= 1.26
D₃₀= 0.358 D₁₅= 0.103 D₁₀= 0.0144
C_u= 148.66 C_c= 4.14

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

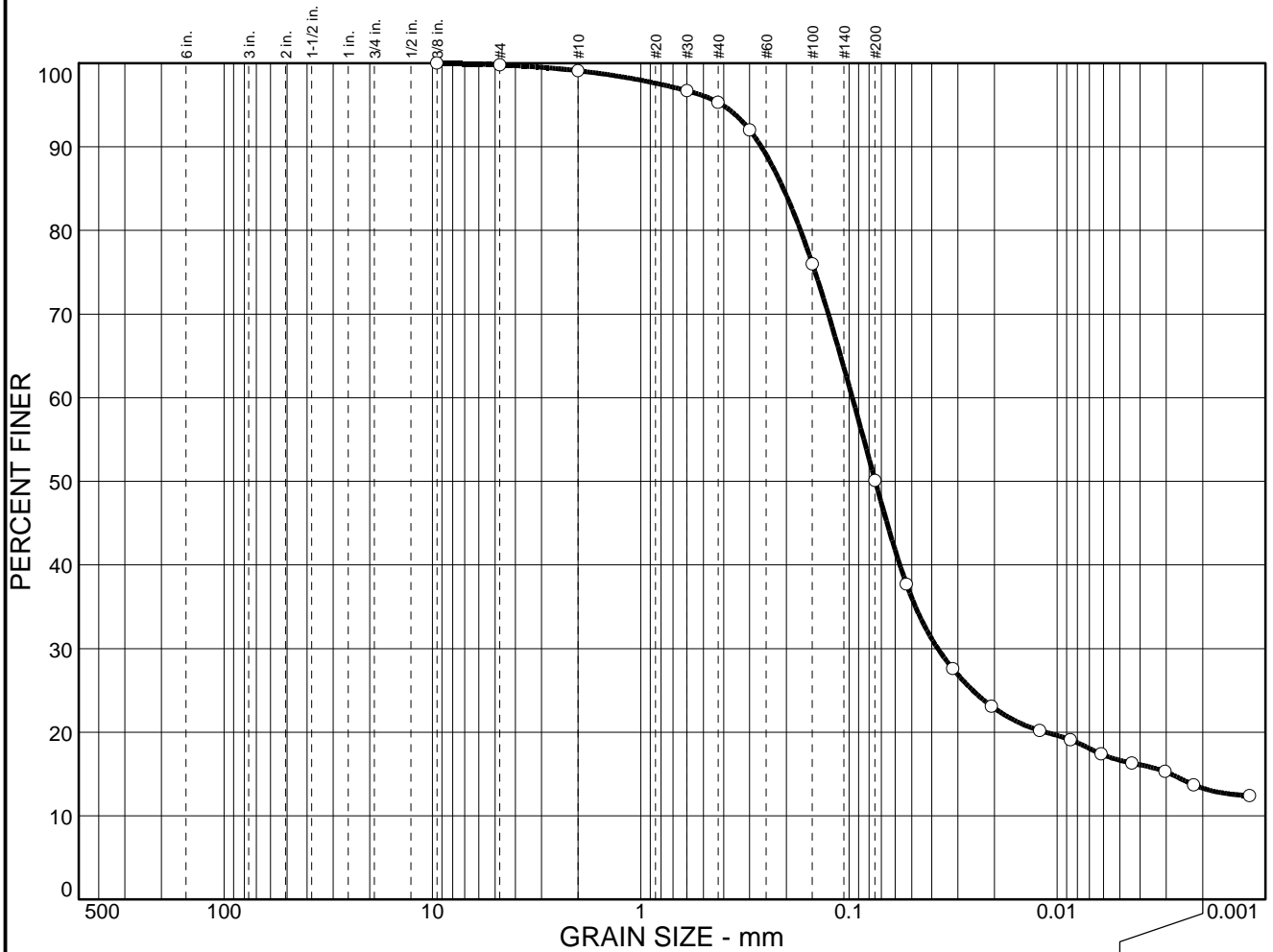
Sample No.: S1
Location:

Source of Sample: B-10

Date: 2/22/16
Elev./Depth: 26.5-28'

COOPER TESTING LABORATORY	<p>Client: HDR Engineering, Inc.</p> <p>Project: SAFER Bay-Task Order 2 - 028-243911</p> <p>Project No: 855-012</p>
	Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.2	49.7	36.8	13.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
#4	99.8		
#10	99.1		
#30	96.7		
#40	95.3		
#50	92.0		
#100	76.0		
#200	50.1		
#270	37.7		
0.0318 mm.	27.6		
0.0207 mm.	23.1		
0.0121 mm.	20.2		
0.0086 mm.	19.1		
0.0062 mm.	17.4		
0.0044 mm.	16.3		
0.0030 mm.	15.3		
0.0022 mm.	13.7		
0.0012 mm.	12.4		

Soil Description

Olive Brown Sandy SILT

Atterberg Limits

PL= LL= PI=

Coefficients

D₈₅=0.207 D₆₀=0.0965 D₅₀=0.0748
D₃₀=0.0375 D₁₅=0.0028 D₁₀=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

* (no specification provided)

Sample No.: L11
Location:

Source of Sample: B-11

Date: 3/1/16
Elev./Depth: 36-36.5'

COOPER TESTING LABORATORY	<p>Client: HDR Engineering, Inc. Project: SAFER Bay-Task Order 2 - 028-243911 Project No: 855-012</p>
	Figure



This page intentionally left blank.



#200 Sieve Wash Analysis ASTM D 1140

Job No.: <u>855-012</u>	Project No.: <u>028-243911</u>	Run By: <u>MD</u>
Client: <u>HDR Engineering, Inc.</u>	Date: <u>3/1/2016</u>	Checked By: <u>DC</u>
Project: <u>SAFER Bay-Task Order 2</u>		

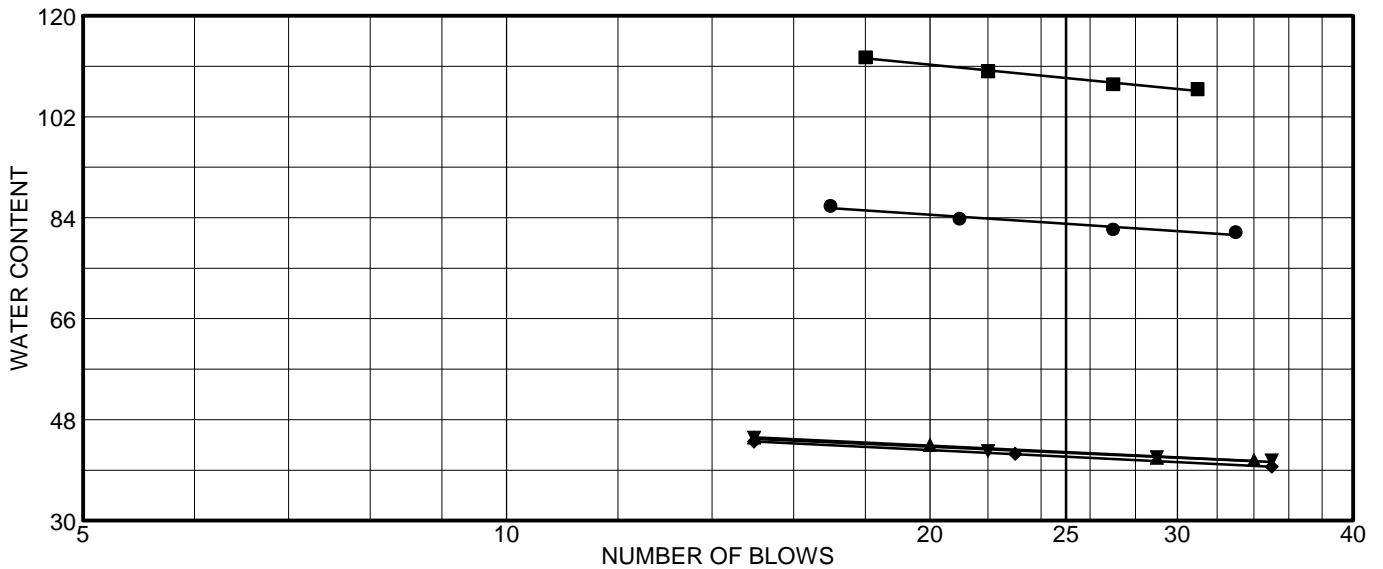
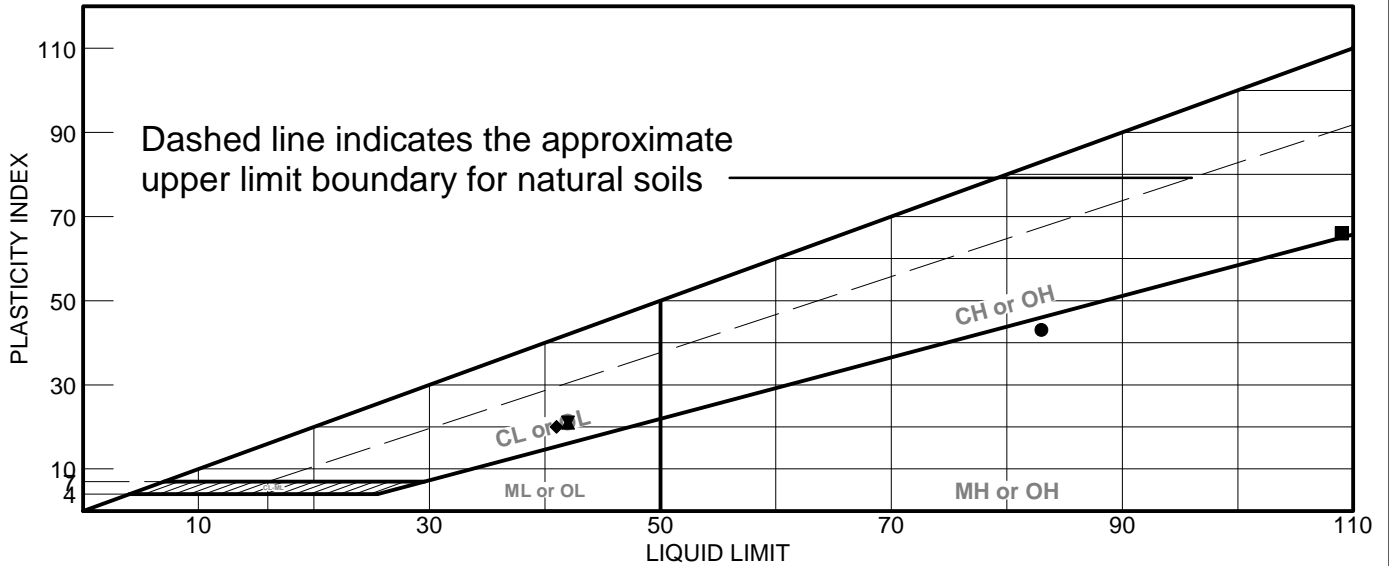
	Boring: Sample: Depth, ft.:	B-07 L7 20-22.5	B-09 L13 40-42.5	B-11 L13 46-46.5				
	Soil Type:	Greenish Gray Lean Clayey SAND	Olive Lean Clayey SAND	Gray Sandy Lean CLAY				
Wt of Dish & Dry Soil, gm		798.9	505.7	505.9				
Weight of Dish, gm		173.2	172.6	172.0				
Weight of Dry Soil, gm		625.7	333.2	333.9				
Wt. Ret. on #4 Sieve, gm		5.6	4.2	0.0				
Wt. Ret. on #200 Sieve, gm		317.8	186.6	103.2				
% Gravel		0.9	1.2	0.0				
% Sand		49.9	54.8	30.9				
% Silt & Clay		49.2	44.0	69.1				

Remarks: As an added benefit to our clients, the gravel fraction may be included in this report. Whether or not it is included is dependent upon both the technician's time available and if there is a significant enough amount of gravel. The gravel is always included in the percent retained on the #200 sieve but may not be weighed separately to determine the percentage, especially if there is only a trace amount, (5% or less).



This page intentionally left blank.

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Gray Sandy Elastic SILT	83	40	43			
■	Dark Greenish Gray Fat CLAY (Bay Mud)	109	43	66			
▲	Greenish Gray Lean Clayey SAND	42	21	21			
◆	Olive Brown and Greenish Gray Mottled Sandy Lean CLAY	41	21	20			
▼	Olive Brown Lean Clayey SAND w/ Gravel	42	21	21	46.4	31.9	SC

Project No. 855-012 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 2 - 028-243911

● Source: B-07	■ Sample No.: L4	▲ Elev./Depth: 7-7.5'
▲ Source: B-07	◆ Sample No.: L6	▼ Elev./Depth: 15-17.5'
◆ Source: B-07	▼ Sample No.: L7	
▼ Source: B-07		

Remarks:

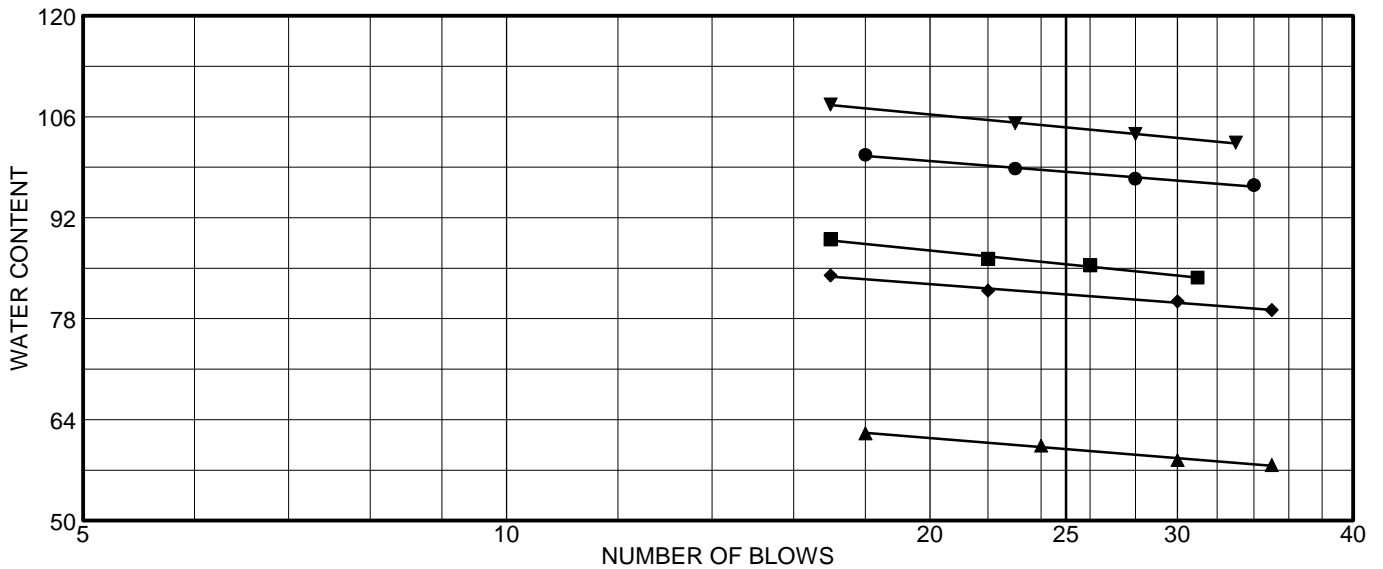
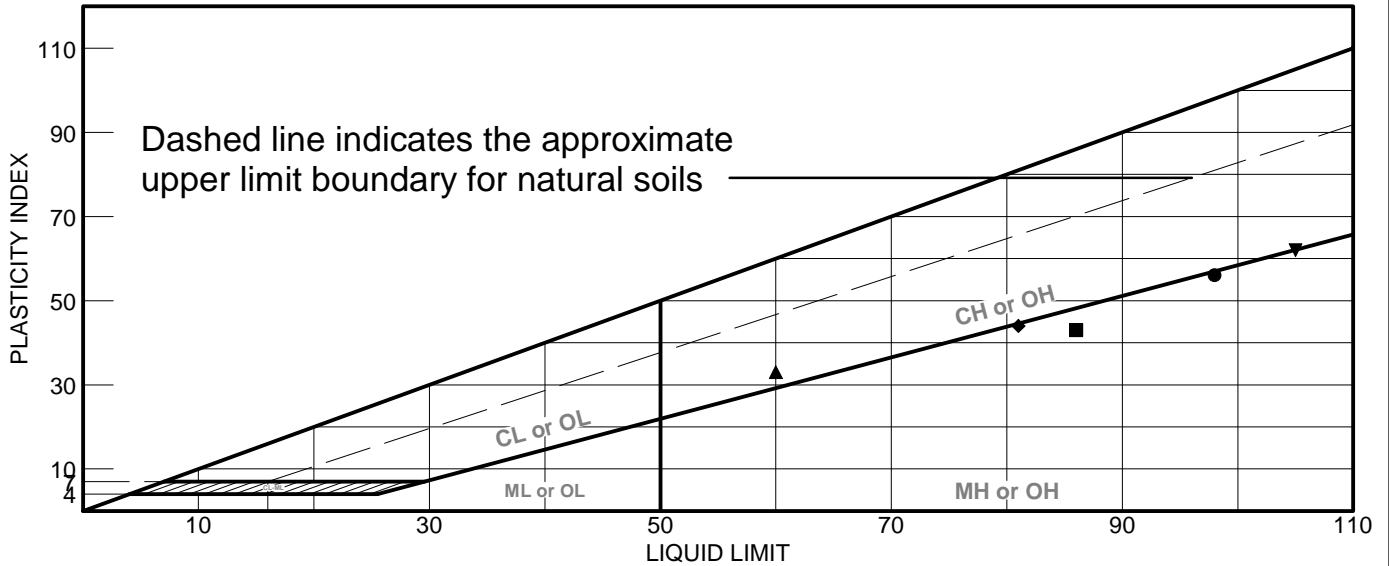
- Sample was prepared using the wet prep method.
- Sample was prepared using the wet prep method.
- ▲ Sample was prepared using the wet prep method.
- ◆ Sample was prepared using the wet prep method.
- ▼ Sample was prepared using the wet prep method.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Gray Elastic SILT w/ Sand	98	42	56			
■	Dark Gray Elastic SILT (Bay Mud)	86	43	43			
▲	Olive Brown Sandy Fat CLAY	60	27	33			
◆	Greenish Gray Mottled Dark Gray Elastic SILT (Bay Mud)	81	37	44			
▼	Greenish Gray Elastic SILT (Bay Mud)	105	43	62			

Project No. 855-012 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 2 - 028-243911

● Source: B-08	■ Source: B-08	▲ Source: B-08	◆ Source: B-09	▼ Source: B-09
Sample No.: L7	Sample No.: L12	Sample No.: L16	Sample No.: L2	Sample No.: L6
Elev./Depth: 10-12.5'	Elev./Depth: 25-27.5'	Elev./Depth: 36-36.5'	Elev./Depth: 5-7.5(Tip-9")	Elev./Depth: 20-22.5'

Remarks:

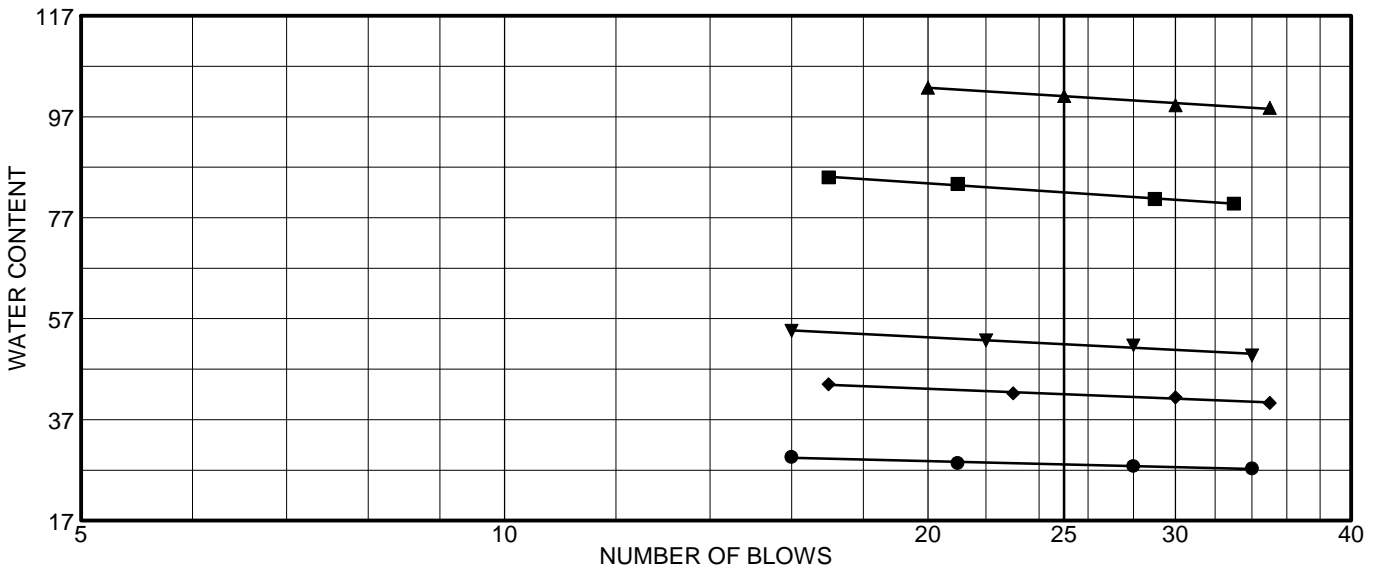
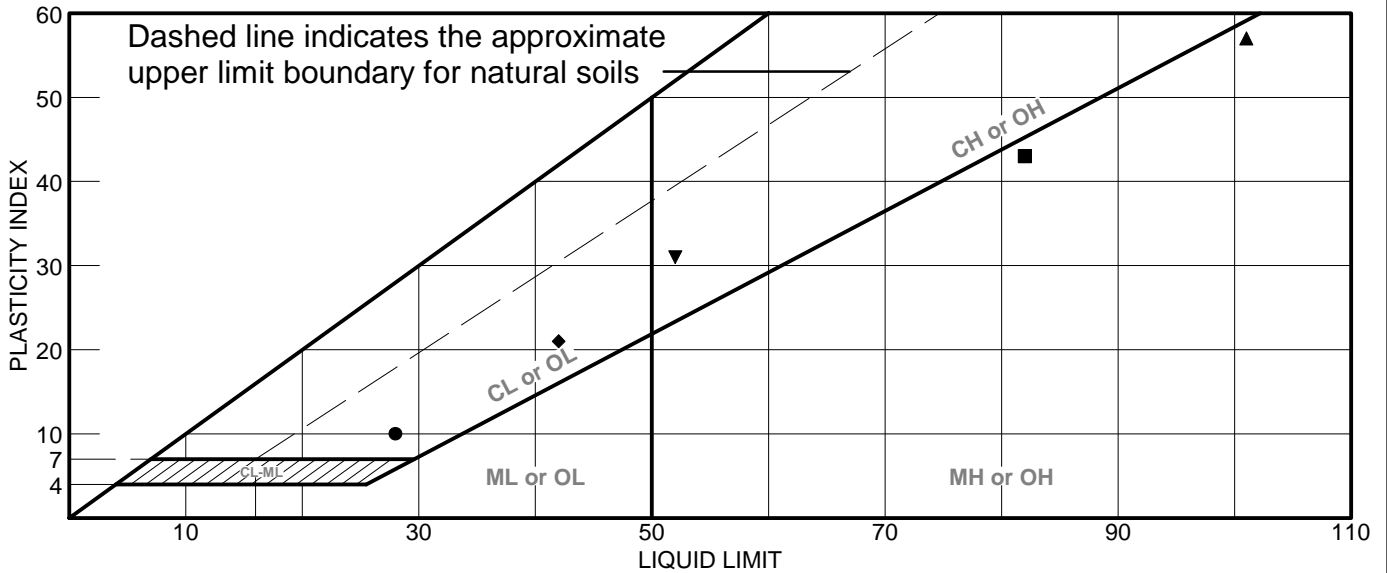
- Sample was prepared using the wet prep method.
- Sample was prepared using the wet prep method.
- ▲ Sample was prepared using the wet prep method.
- ◆ Sample was prepared using the wet prep method.
- ▼ Sample was prepared using the wet prep method.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Olive Lean Clayey SAND	28	18	10			
■	Olive Brown Sandy Elastic SILT	82	39	43			
▲	Dark Greenish Gray Elastic SILT w/ organics (Bay Mud)	101	44	57			
◆	Olive Brown Sandy Lean CLAY	42	21	21			
▼	Greenish Gray Sandy Fat CLAY w/ soil nodules	52	21	31			

Project No. 855-012 **Client:** HDR Engineering, Inc.

Project: SAFER Bay-Task Order 2 - 028-243911

● Source: B-09	◆ Sample No.: L13	▲ Elev./Depth: 40-42.5'
■ Source: B-10	▼ Sample No.: L2	▲ Elev./Depth: 2-2.5'
▲ Source: B-10	◆ Sample No.: L7	▲ Elev./Depth: 10-12.5'
◆ Source: B-10	▼ Sample No.: L14	▲ Elev./Depth: 31-31.5'
▼ Source: B-11	◆ Sample No.: L6	▲ Elev./Depth: 15-17'

Remarks:

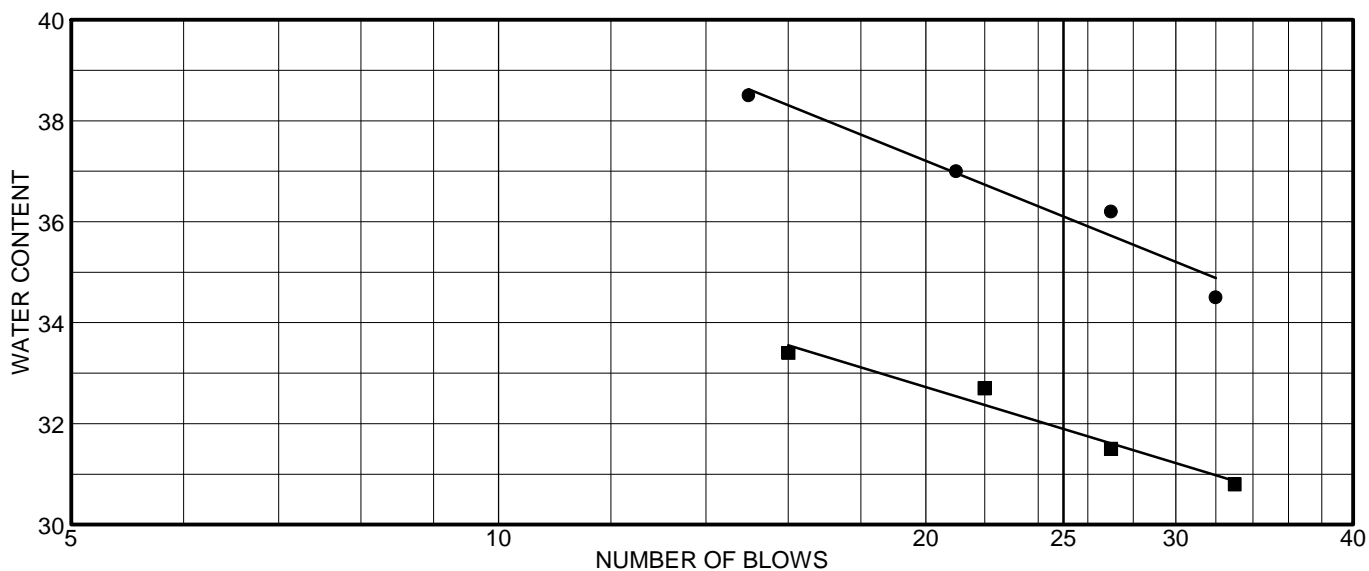
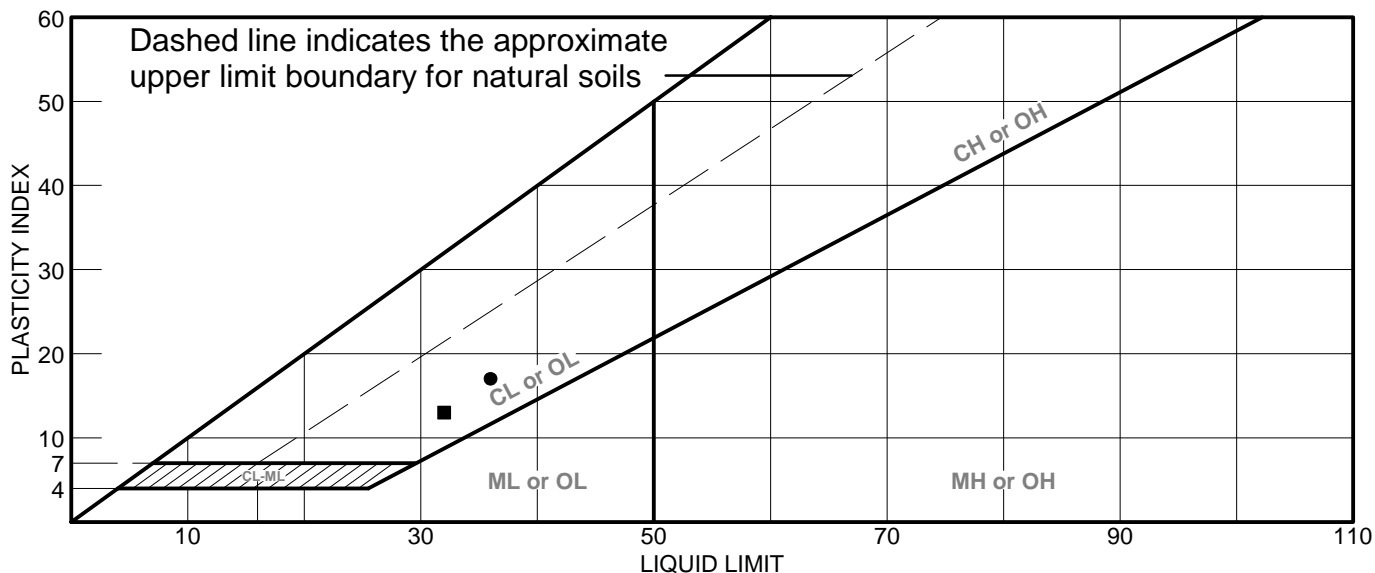
- Sample was prepared using the wet prep method.
- ▲ Sample was prepared using the wet prep method.
- ◆ Sample was prepared using the wet prep method.
- ▼ Sample was prepared using the wet prep method.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Olive Brown Sandy Lean CLAY	36	19	17			
■	Gray Sandy Lean CLAY	32	19	13			

Project No. 855-012 **Client:** HDR Engineering, Inc.
Project: SAFER Bay-Task Order 2 - 028-243911

● Source: B-11 **Sample No.:** L8 **Elev./Depth:** 26-26.5'
■ Source: B-11 **Sample No.:** L13 **Elev./Depth:** 46-46.5'

Remarks:
 ● Sample was prepared using the wet prep method.
 ■

Figure



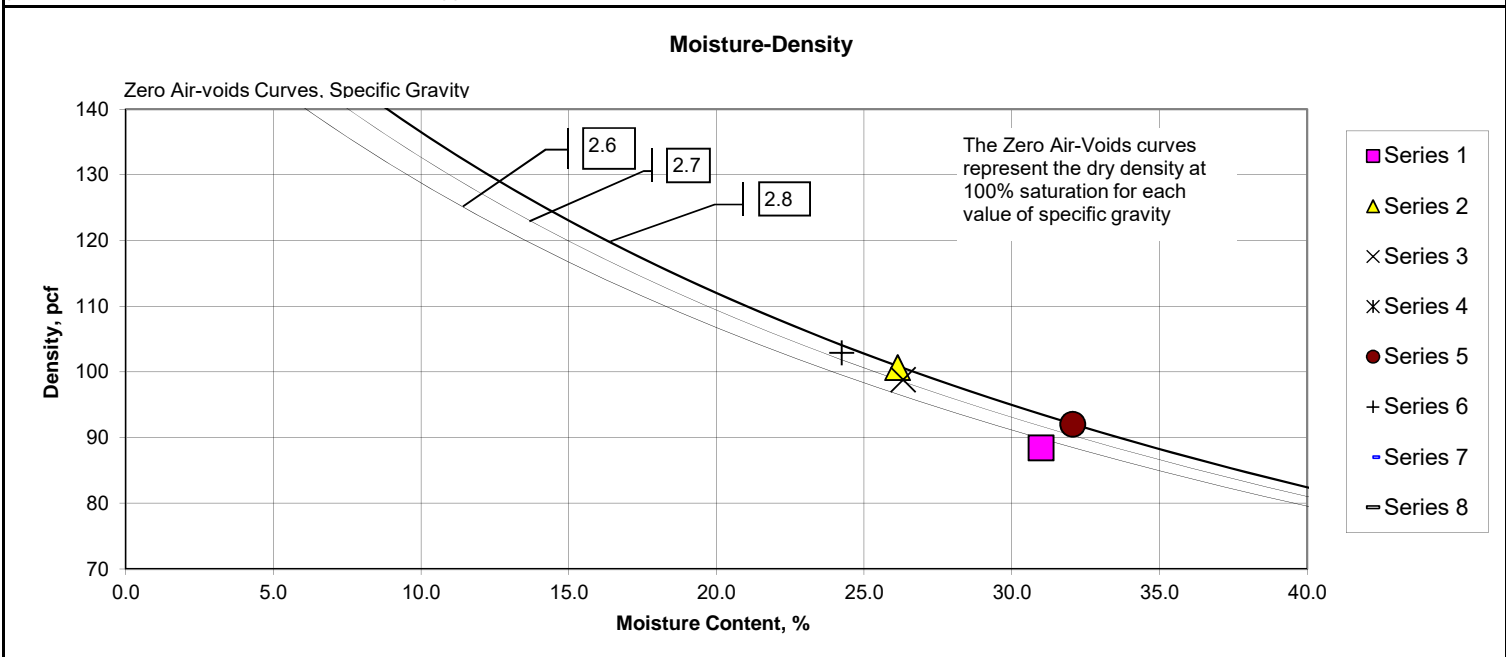
Moisture-Density-Porosity Report

Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 855-012a	Project No. 028-243911	By: RU
Client: HDR Engineering, Inc.	Date: 02/19/16	
Project Name: SAFER Bay- Task Order 2	Remarks:	

Boring:	B-07	B-07	B-07	B-08	B-08	B-08	B-09	B-09
Sample:	L4	L11	L15	L11	L16	L19	L4	L8
Depth, ft:	7-7.5	31-31.5	41-41.5	21-21.5	36-36.5	46-46.5	11-11.5	26-26.5
Visual Description:	Dark Gray Sandy Elastic SILT	Olive Brown and Greenish Gray Mottled Sandy Lean	Olive Brown CLAY w/ Sand	Gray CLAY	Olive Brown Sandy Fat CLAY	Olive Brown CLAY w/ Sand	Gray CLAY w/ organics	Gray CLAY
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Moisture, %	31.0	26.1	26.3	76.8	32.1	24.2	79.0	64.3
Wet Unit wt, pcf	115.8	126.9	124.7	97.8	121.5	127.8	96.7	101.0
Dry Unit wt, pcf	88.4	100.6	98.8	55.3	92.0	102.9	54.0	61.5
Dry Bulk Dens.pb, (g/cc)	1.42	1.61	1.58	0.89	1.47	1.65	0.86	0.98
Saturation, %	88.6	99.1	95.5	99.4	99.6	96.9	98.8	97.6
Total Porosity, %	49.5	42.5	43.5	68.4	47.4	41.2	69.1	64.9
Volumetric Water Cont., θ_w, %	43.8	42.1	41.6	68.0	47.2	39.9	68.3	63.3
Volumetric Air Cont., θ_a, %	5.7	0.4	1.9	0.4	0.2	1.3	0.8	1.6
Void Ratio	0.98	0.74	0.77	2.16	0.90	0.70	2.24	1.85
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (G_s) was used then the saturation, porosities, and void ratio should be considered approximate.





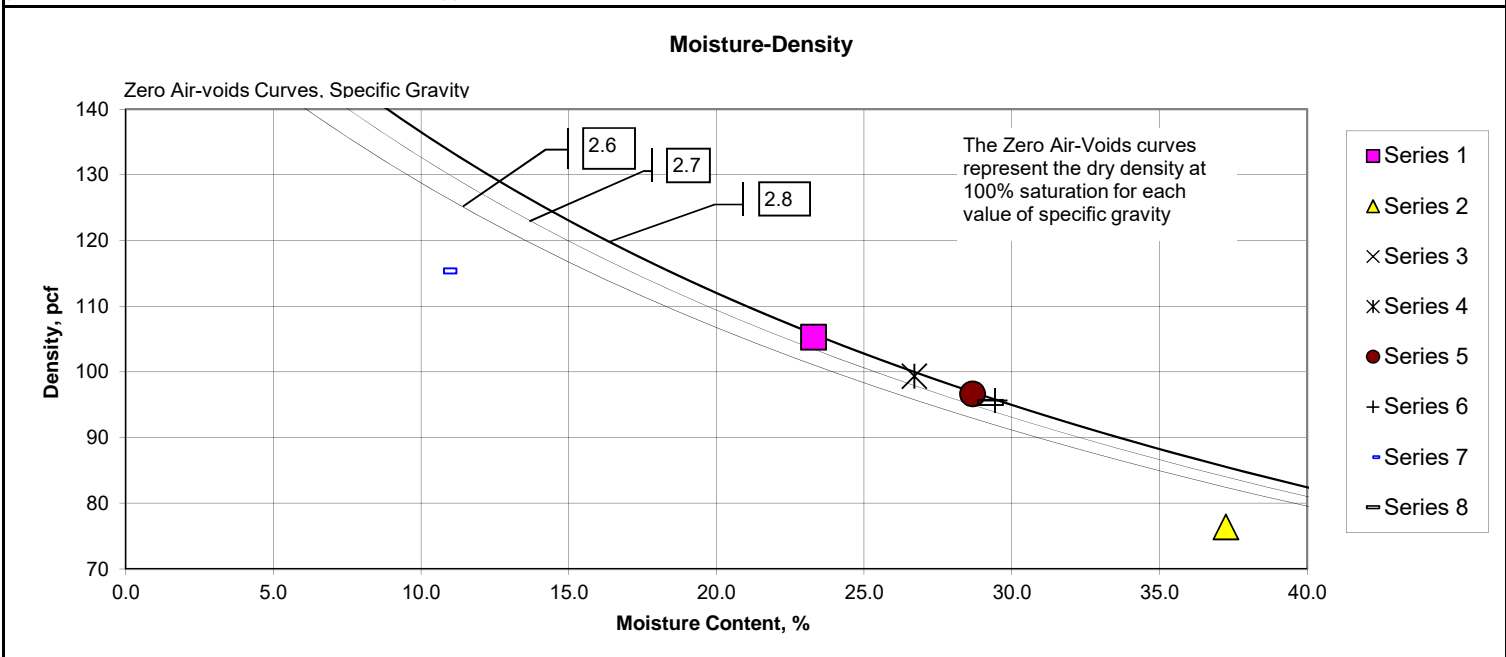
Moisture-Density-Porosity Report

Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 855-012b	Project No. 028-243911	By: RU
Client: HDR Engineering, Inc.	Date: 02/19/16	
Project Name: SAFER Bay-Task Order 2	Remarks:	

Boring:	B-09	B-10	B-10	B-10	B-10	B-10	B-11	B-11
Sample:	L10	L2	L9	L14	L17	L21	L4	L5
Depth, ft:	31-31.5	2-2.5	16-16.5	31-31.5	41-41.5	51-51.5	6-6.5	11-11.5
Visual Description:	Greenish Gray Sandy CLAY	Olive Brown Sandy Elastic SILT	Gray CLAY	Olive Brown Sandy Lean CLAY	Olive Brown CLAY w/ Sand	Dark Olive Brown CLAY w/ Sand	Dark Yellowish Brown Sandy CLAY	Gray CLAY w/ Sand
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Moisture, %	23.3	37.2	82.7	26.7	28.7	29.43238	10.8	29.3
Wet Unit wt, pcf	129.7	104.8	95.4	125.8	124.3	123.72594	127.7	123.2
Dry Unit wt, pcf	105.2	76.4	52.2	99.3	96.6	95.59119	115.3	95.3
Dry Bulk Dens.pb, (g/cc)	1.69	1.22	0.84	1.59	1.55	1.53	1.85	1.53
Saturation, %	98.5	80.8	98.5	98.2	99.1	99.3	58.3	98.1
Total Porosity, %	39.8	56.3	70.1	43.2	44.8	45.4	34.1	45.5
Volumetric Water Cont., θ_w, %	39.2	45.5	69.1	42.4	44.3	45.0	19.9	44.7
Volumetric Air Cont., θ_a, %	0.6	10.8	1.0	0.8	0.4	0.3	14.2	0.8
Void Ratio	0.66	1.29	2.35	0.76	0.81	0.83	0.52	0.84
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (G_s) was used then the saturation, porosities, and void ratio should be considered approximate.





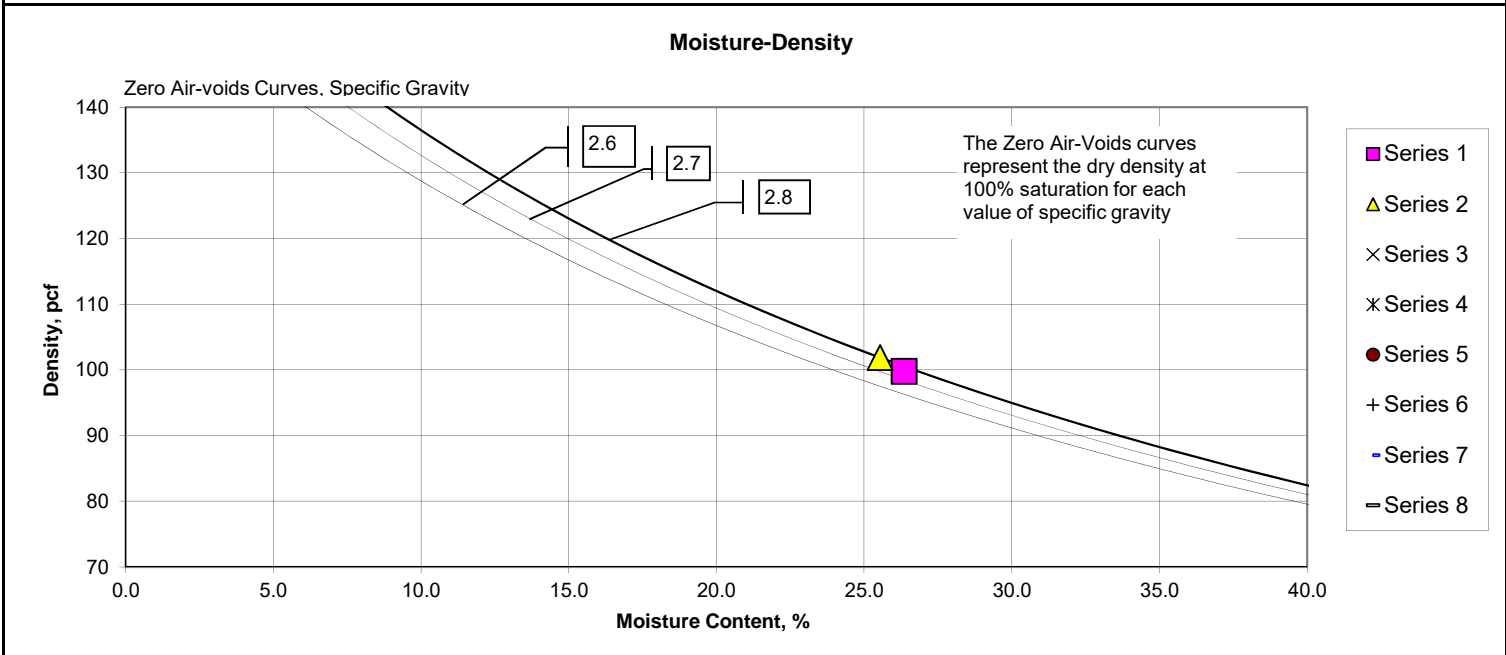
Moisture-Density-Porosity Report

Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: <u>855-012c</u>	Project No. <u>028-243911</u>	By: <u>RU</u>
Client: <u>HDR Engineering, Inc.</u>	Date: <u>02/19/16</u>	
Project Name: <u>SAFER Bay-Task Order 2</u>	Remarks:	

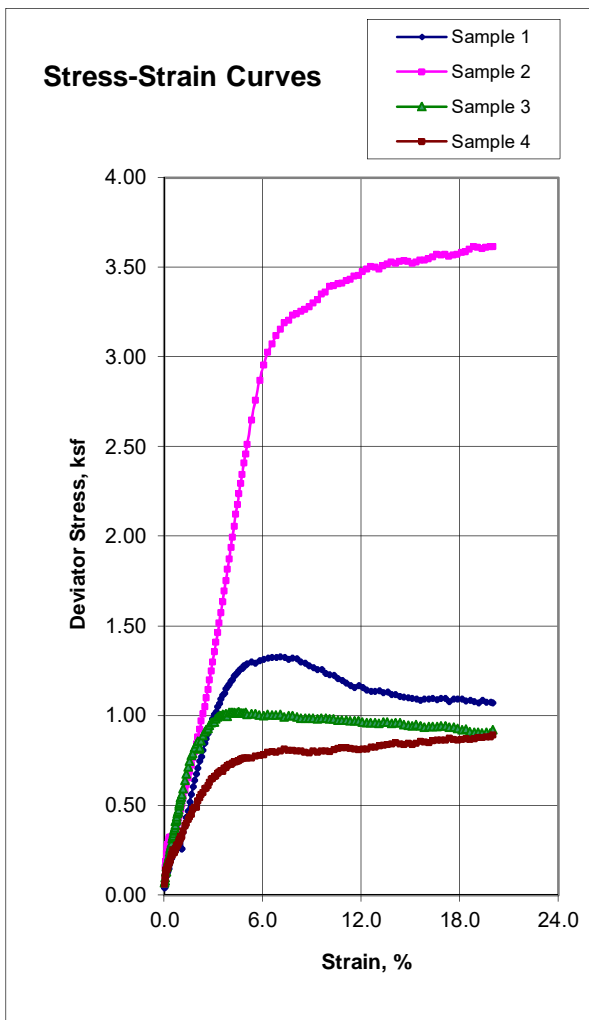
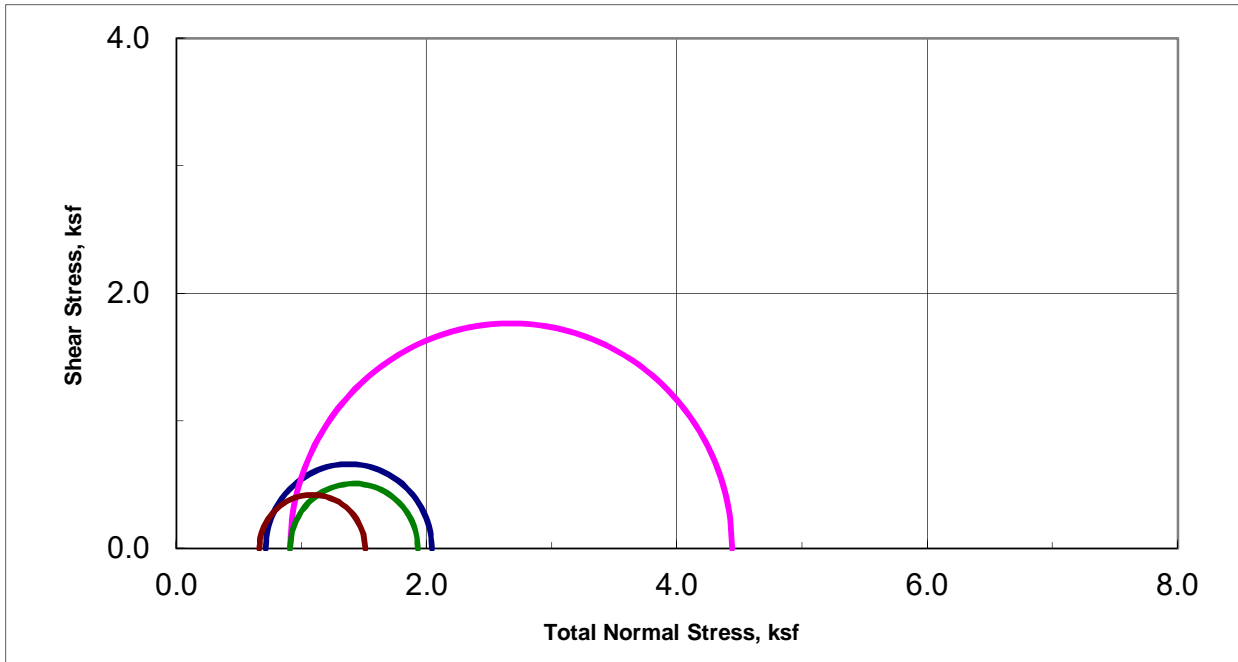
Boring:	B-11	B-11						
Sample:	L8	L13						
Depth, ft:	26-26.5	46-46.5						
Visual Description:	Olive Brown Sandy Lean CLAY	Gray Sandy Lean CLAY						
Actual G_s								
Assumed G_s	2.80	2.80						
Moisture, %	26.4	25.5						
Wet Unit wt, pcf	126.0	127.9						
Dry Unit wt, pcf	99.7	101.8						
Dry Bulk Dens.pb, (g/cc)	1.60	1.63						
Saturation, %	97.9	99.7						
Total Porosity, %	43.0	41.8						
Volumetric Water Cont., θ_w, %	42.1	41.6						
Volumetric Air Cont., θ_a, %	0.9	0.1						
Void Ratio	0.75	0.72						
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (G_s) was used then the saturation, porosities, and void ratio should be considered approximate.





Unconsolidated-Undrained Triaxial Test
 ASTM D2850

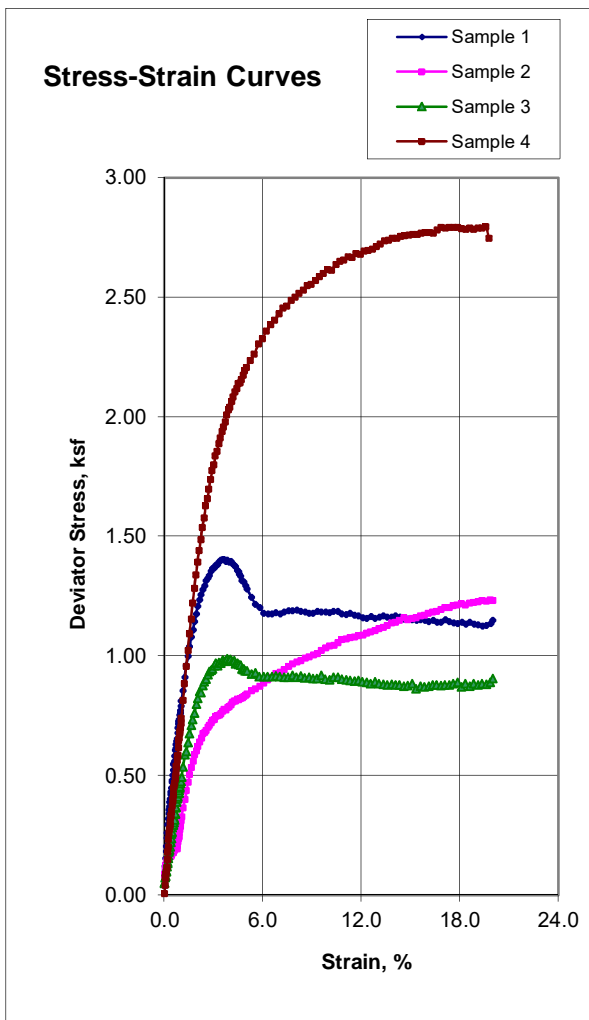
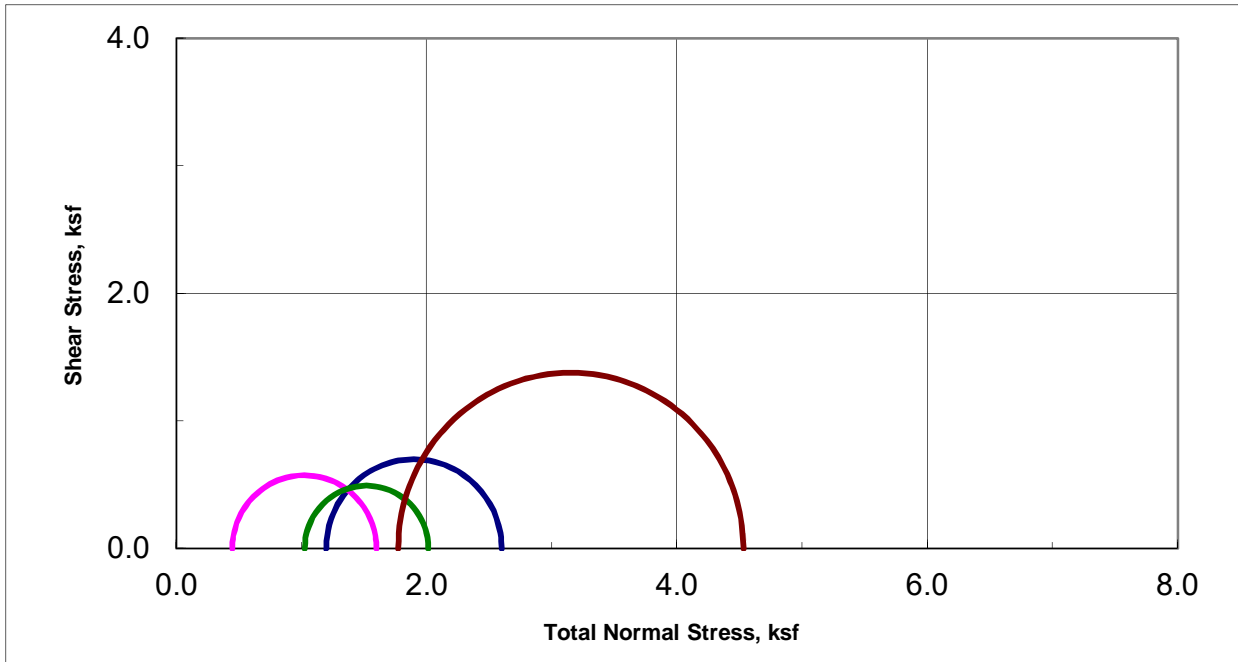


Sample Data				
	1	2	3	4
Moisture %	75.8	25.2	76.3	81.2
Dry Den,pcf	55.0	95.5	55.0	52.5
Void Ratio	2.063	0.765	2.063	2.213
Saturation %	99.1	88.8	99.8	99.1
Height in	6.07	6.10	6.06	6.07
Diameter in	2.86	2.85	2.86	2.85
Cell psi	4.9	6.3	6.3	4.6
Strain %	7.07	15.00	4.54	15.00
Deviator, ksf	1.329	3.532	1.022	0.846
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.061	0.061	0.060	0.061
Job No.:	855-012a			
Client:	HDR Engineering, Inc.			
Project:	028-243911			
Boring:	B-07	B-07	B-08	B-08
Sample:	L6	L7	L7	L8
Depth ft:	15-17.5(Tip-3.5")	20-22.5(Tip-7")	10-12.5(Tip-5.5")	15-17.5
Visual Soil Description				
Sample #				
1	Dark Greenish Gray Fat CLAY (Bay Mud)			
2	Greenish Gray Lean Clayey SAND			
3	Dark Gray Elastic SILT w/ Sand (Bay Mud)			
4	Gray CLAY w/ Sand			
Remarks:				

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.



Unconsolidated-Undrained Triaxial Test
 ASTM D2850

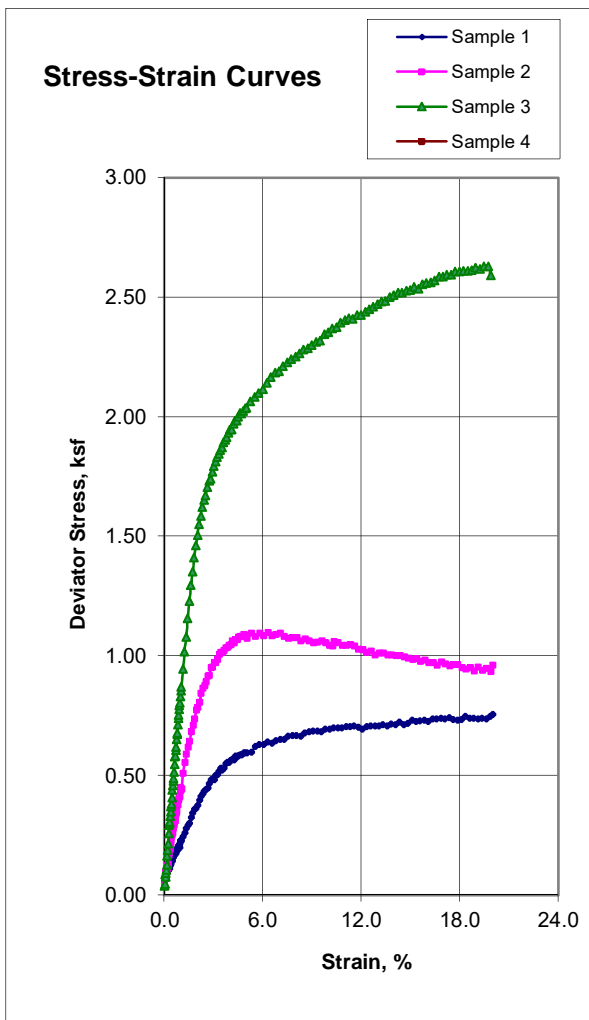
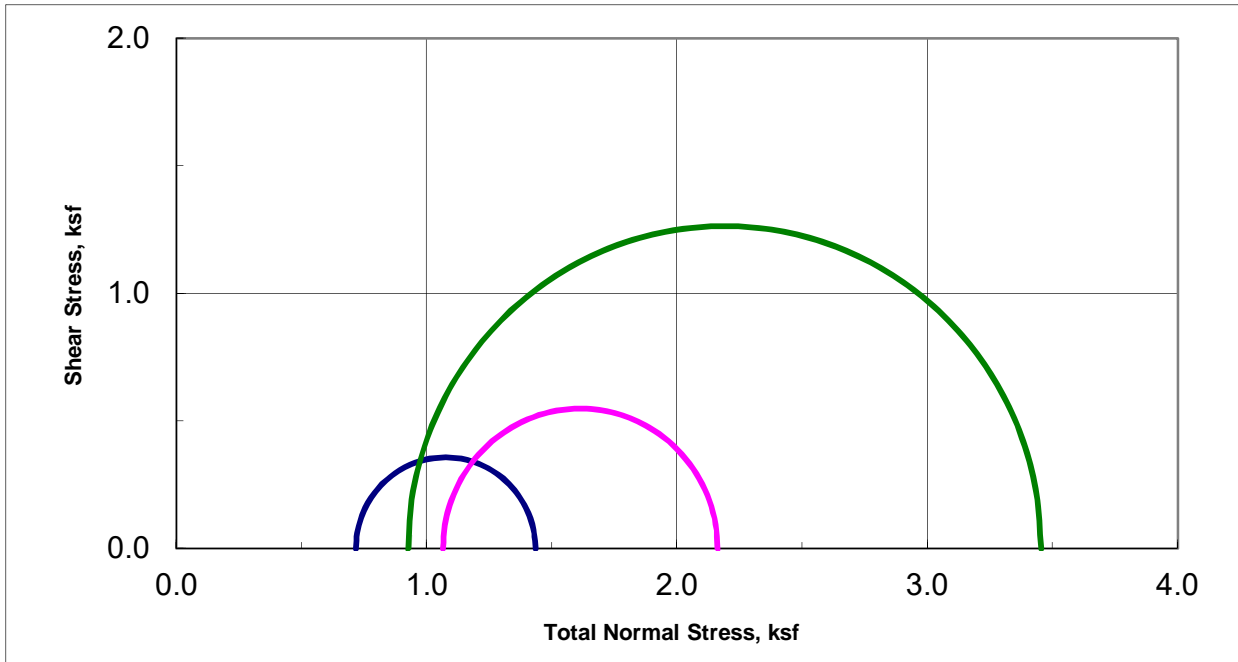


Sample Data				
	1	2	3	4
Moisture %	74.3	51.2	86.4	21.4
Dry Den,pcf	55.7	69.6	50.0	106.1
Void Ratio	2.027	1.422	2.370	0.588
Saturation %	99.0	97.3	98.4	98.2
Height in	6.07	6.08	5.99	6.08
Diameter in	2.87	2.87	2.87	2.87
Cell psi	8.3	3.1	7.1	12.3
Strain %	3.64	15.00	3.84	15.00
Deviator, ksf	1.403	1.153	0.989	2.759
Rate %/min	1.00	1.00	1.00	0.99
in/min	0.061	0.061	0.060	0.060
Job No.:	855-012b			
Client:	HDR Engineering, Inc.			
Project:	028-243911			
Boring:	B-08	B-09	B-09	B-09
Sample:	L12	L2	L6	L13
Depth ft:	25-27.5(Tip-4.5")	5-7.5(Tip-9")	20-22.5(Tip-5")	40-42.5(Tip-1")
Visual Soil Description				
Sample #	1 Dark Gray Elastic SILT (Bay Mud)			
	2 Greenish Gray Mottled Dark Gray Elastic SILT (Bay Mud)			
	3 Greenish Gray Elastic SILT (Bay Mud)			
	4 Olive Lean Clayey SAND			
Remarks:				

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.



Unconsolidated-Undrained Triaxial Test ASTM D2850



Sample Data				
	1	2	3	4
Moisture %	68.3	77.9	25.5	
Dry Den,pcf	58.9	54.2	99.7	
Void Ratio	1.863	2.109	0.690	
Saturation %	98.9	99.7	99.8	
Height in	6.00	5.95	6.04	
Diameter in	2.85	2.86	2.89	
Cell psi	5.0	7.4	6.4	
Strain %	15.00	6.30	15.00	
Deviator, ksf	0.717	1.098	2.529	
Rate %/min	1.00	1.00	0.99	
in/min	0.060	0.059	0.060	
Job No.:	855-012c			
Client:	HDR Engineering, Inc.			
Project:	028-243911			
Boring:	B-10	B-10	B-11	
Sample:	L7	L10	L6	
Depth ft:	10-12.5(Tip-5")	20-22.5(Top-1")	15-17	
Visual Soil Description				
Sample #	1 Dark Greenish Gray Elastic SILT w/ organics (Bay Mud)			
	2 Very Dark Bluish Gray CLAY (Bay Mud)			
	3 Greenish Gray Sandy Fat CLAY w/ soil nodules			
	4			
Remarks:				

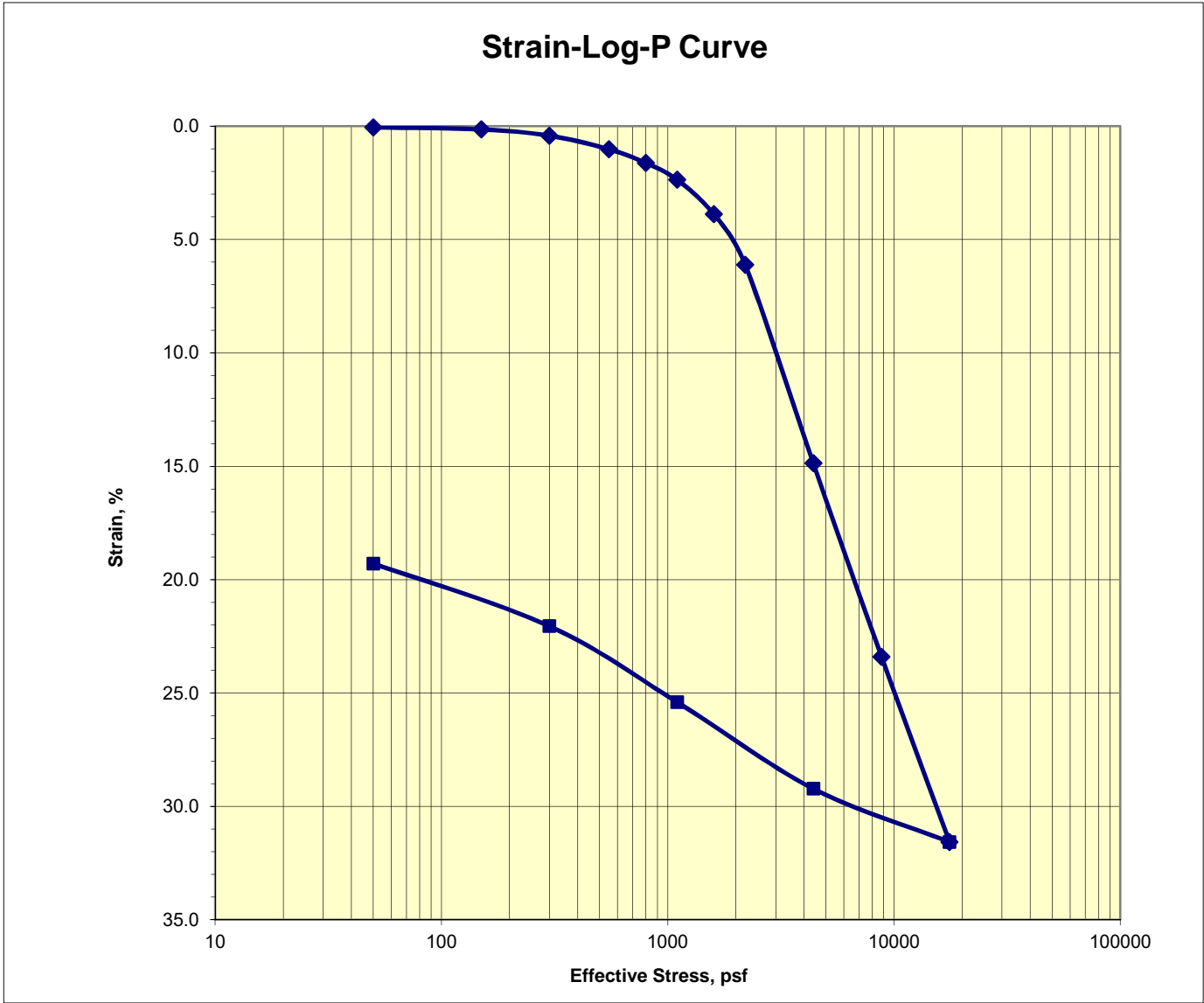
Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.



Consolidation Test

ASTM D2435

Job No.: 855-012	Boring: B-07	Run By: MD
Client: HDR Engineering, Inc.	Sample: L6	Reduced: PJ
Project: 028-243911	Depth, ft.: 15-17.5(Tip-3")	Checked: PJ/DC
Soil Type: Dark Greenish Gray Fat CLAY (Bay Mud)		Date: 3/2/2016



Assumed Gs	2.75	Initial	Final
Moisture %:		81.7	59.6
Dry Density, pcf:		52.4	65.1
Void Ratio:		2.275	1.638
% Saturation:		98.7	100.0

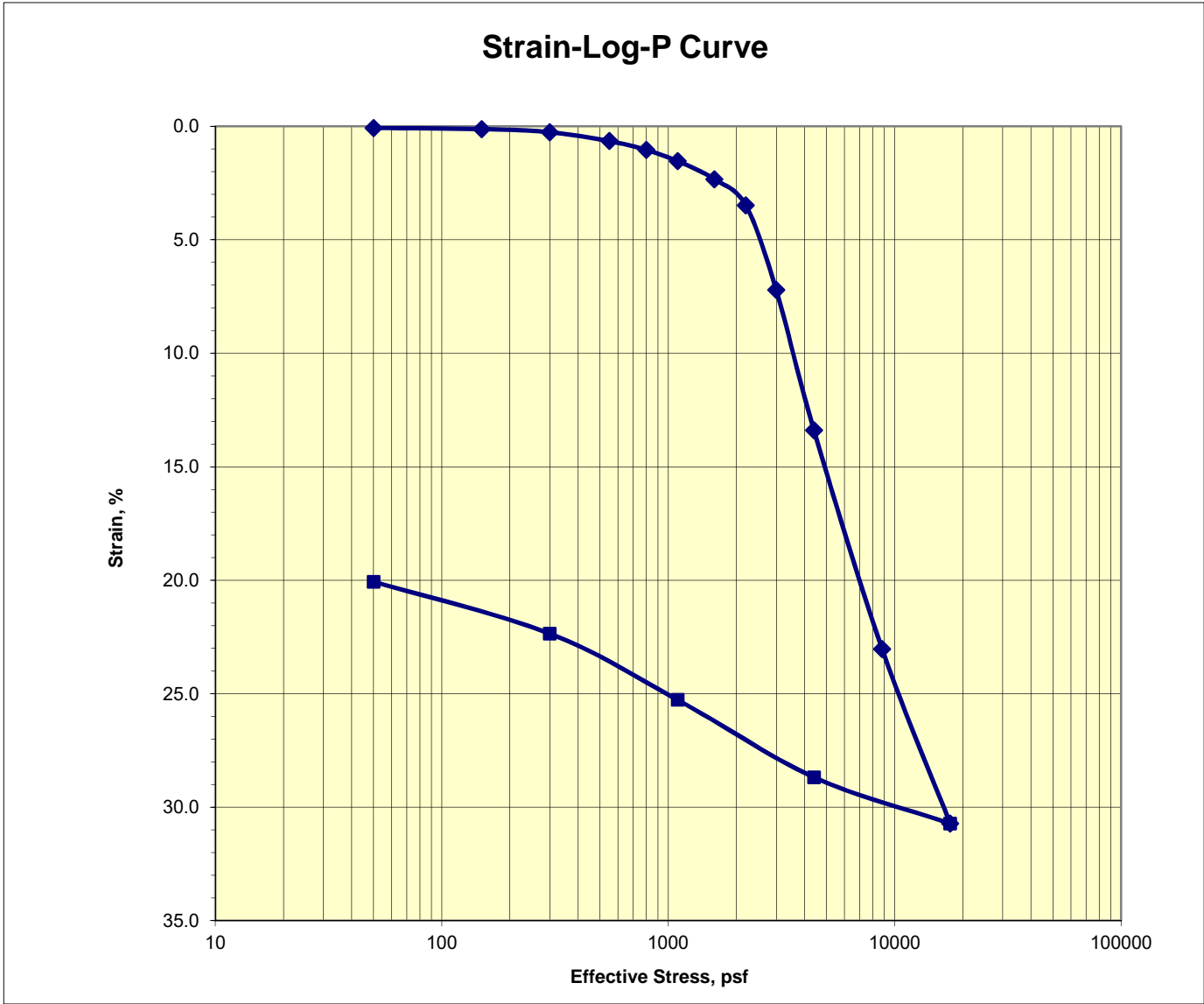
Remarks:



Consolidation Test

ASTM D2435

Job No.: 855-012	Boring: B-08	Run By: MD
Client: HDR Engineering, Inc.	Sample: L12	Reduced: PJ
Project: 028-243911	Depth, ft.: 25-27.5(Tip-4")	Checked: PJ/DC
Soil Type: Dark Gray Elastic SILT (Bay Mud)		Date: 3/4/2016



Assumed Gs	2.7	Initial	Final
Moisture %:		77.8	54.9
Dry Density, pcf:		53.8	67.9
Void Ratio:		2.133	1.482
% Saturation:		98.5	100.0

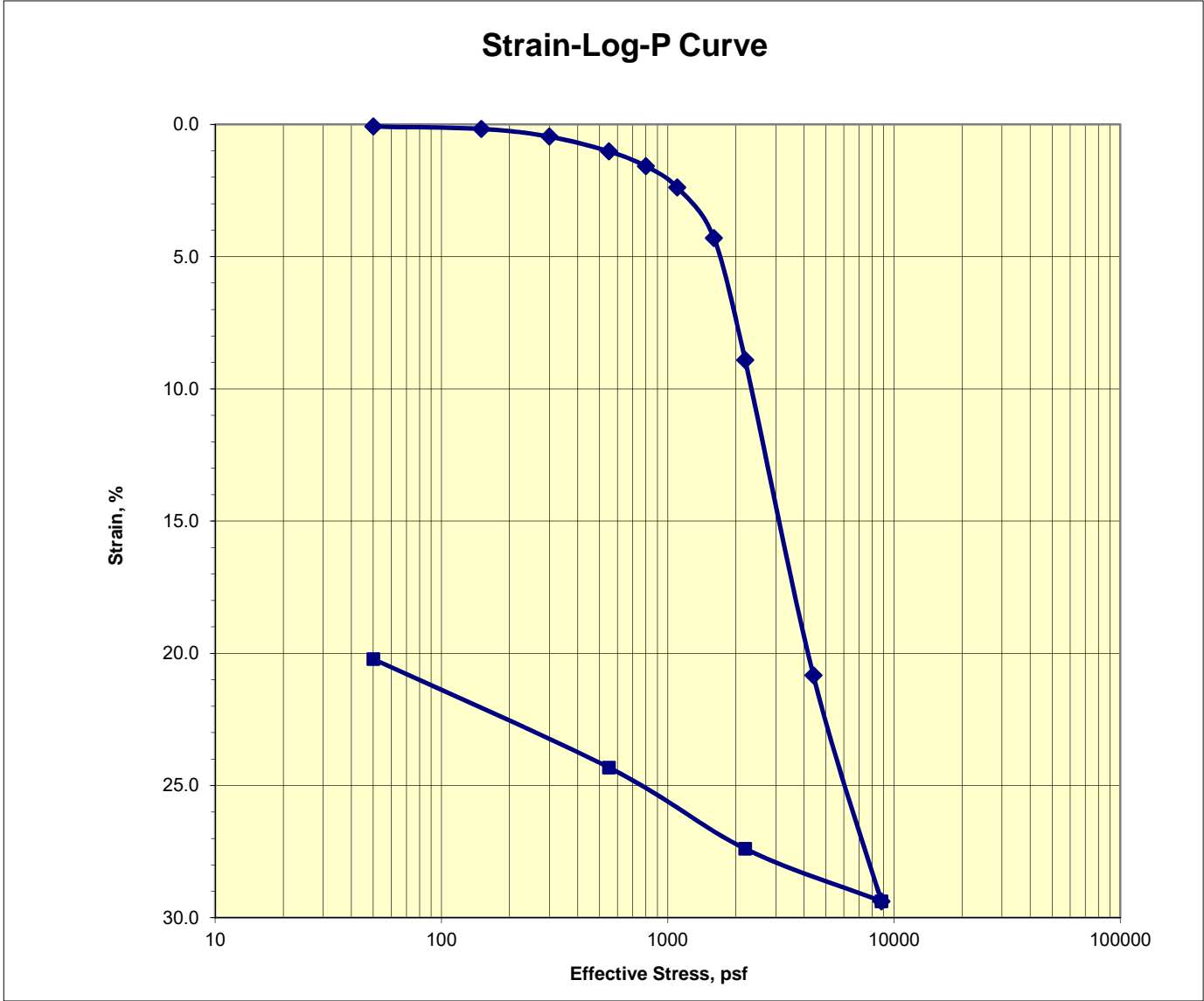
Remarks:



Consolidation Test

ASTM D2435

Job No.: 855-012	Boring: B-09	Run By: MD
Client: HDR Engineering, Inc.	Sample: L6	Reduced: PJ
Project: 028-243911	Depth, ft.: 20-22.5(Tip-4")	Checked: PJ/DC
Soil Type: Greenish Gray Elastic SILT (Bay Mud)		Date: 3/2/2016



Assumed Gs	2.75	Initial	Final
Moisture %:	92.6	66.9	
Dry Density, pcf:	48.0	60.5	
Void Ratio:	2.574	1.840	
% Saturation:	98.9	100.0	

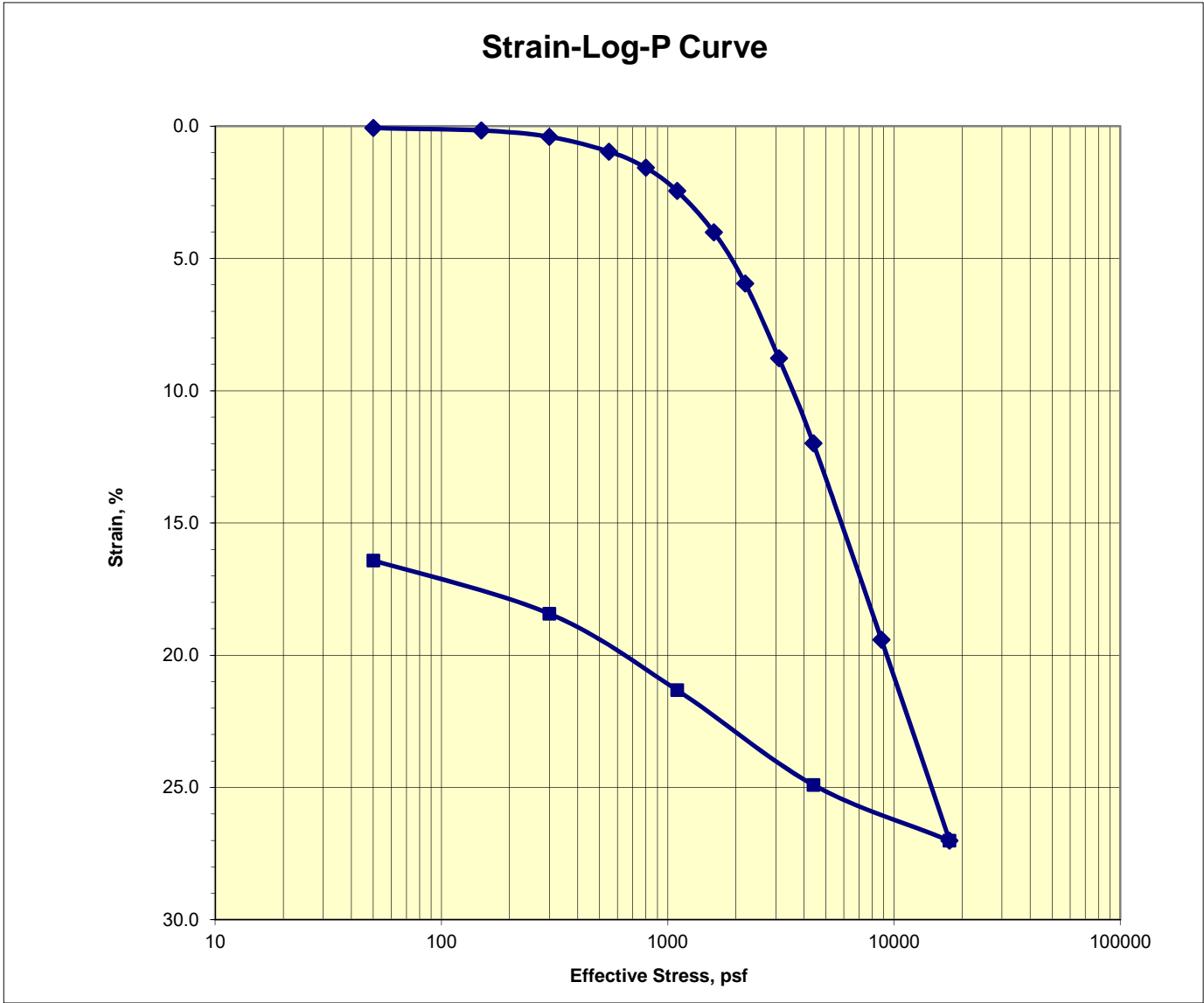
Remarks:



Consolidation Test

ASTM D2435

Job No.: 855-012	Boring: B-10	Run By: MD
Client: HDR Engineering, Inc.	Sample: L7	Reduced: PJ
Project: 028-243911	Depth, ft.: 10-12.5(Tip-3")	Checked: PJ/DC
Soil Type: Dark Greenish Gray Elastic SILT (Bay Mud)		Date: 3/4/2016



Assumed Gs	2.7	Initial	Final
Moisture %:		73.8	56.2
Dry Density, pcf:		55.9	67.0
Void Ratio:		2.013	1.518
% Saturation:		99.0	100.0

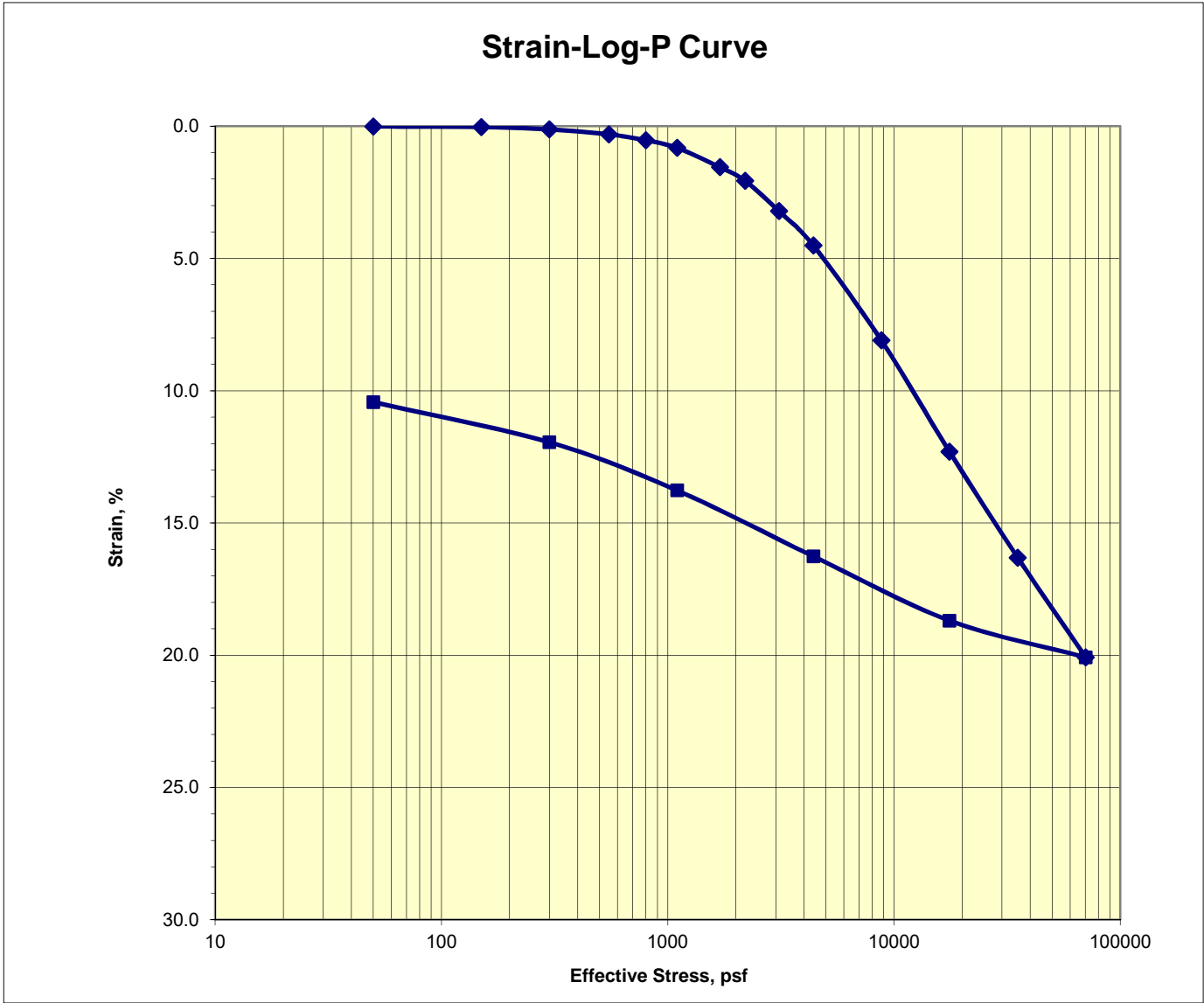
Remarks: The 3000psf point was adjusted to 3100psf to smooth the curve. The pneumatic air regulators can drift over a 24 hour period by as much as 100 psf. Consult lab for uncorrected data.



Consolidation Test

ASTM D2435

Job No.: 855-012	Boring: B-11	Run By: MD
Client: HDR Engineering, Inc.	Sample: L6	Reduced: PJ
Project: 028-243911	Depth, ft.: 15-17 (top-16")	Checked: PJ/DC
Soil Type: Greenish Gray Sandy Fat CLAY w/ soil nodules		Date: 3/7/2016



Assumed Gs	2.75	Initial	Final
Moisture %:		28.6	24.0
Dry Density, pcf:		92.5	103.4
Void Ratio:		0.856	0.660
% Saturation:		92.1	100.0

Remarks: Adjusted the 1600 and 3000 psf points by 100 psf to smooth the curve. Pneumatic air regulators can drift as much as 100 psf during a 24 hour loading cycle.



This page intentionally left blank.



Appendix C Stability Analyses Results



This page intentionally left blank.



Appendix C contains the following:

Figures C-1 through C-4: Cross Section G9 – Located within Reach 10, and represents the segment along the east side and southern end of the Palo Alto Airport runway (both Options 1 and 2).

Figures C-5 through C-8: Cross section G10 – Located within Reach 10, and represents the segment of Reach 10 (both Options 1 and 2) from the southern end of the Palo Alto Airport runway, and along the Palo Alto WWTP to just before the Byxbee Park landfill.

Figures C-9 through C-15: Cross section G11 – Located within Reach 11, Option 1, and represents the northern segment of Reach 11, Option 1.

Figures C-16 through C-22: Cross section G12 – Located within Reach 11, Option 1, and represents the southern segment of Reach 11, Option 1.

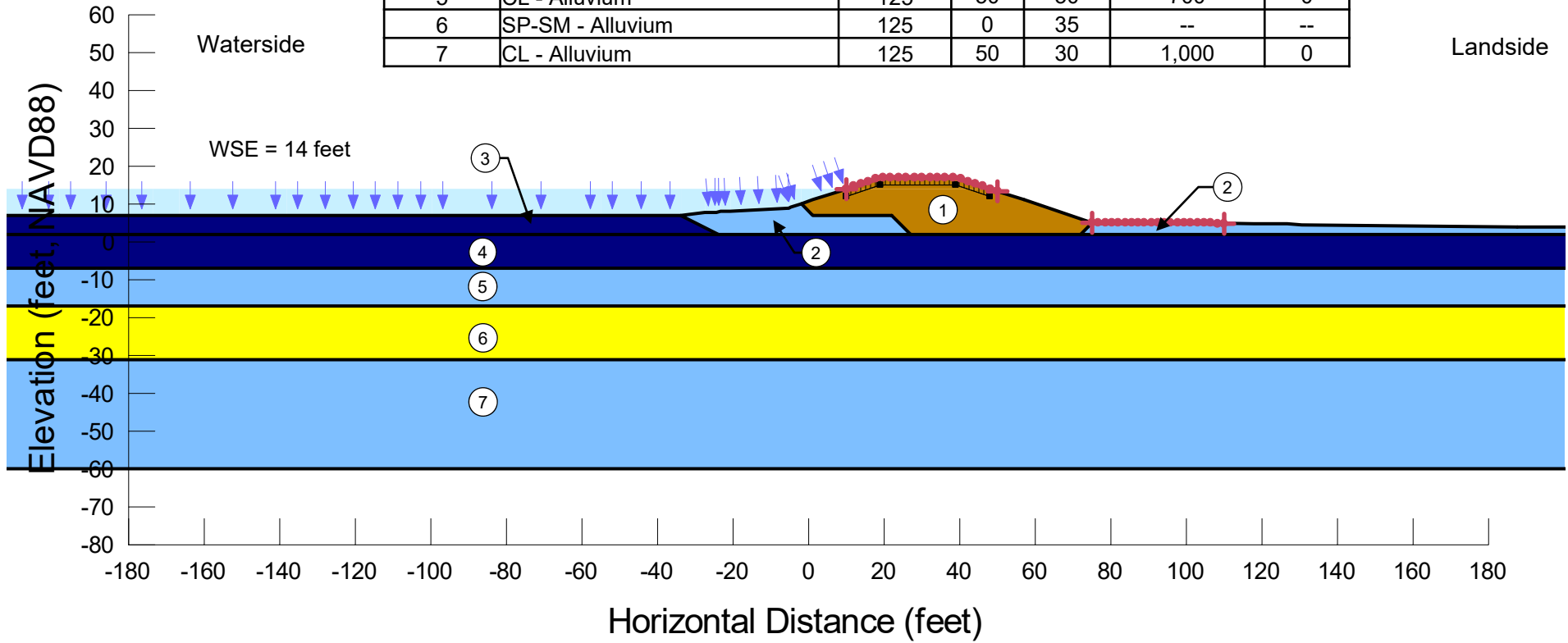
Figures C-23 through C-26: Cross section G13 – Located within Reach 11, Option 2, and represents the segment of this reach and option that is situated along Adobe Creek, between the southern end of Charleston Slough and Highway 101.

Figures C-27 through C-30: Cross section G14 – Located within Reach 11, Option 2, and represents the segment of this reach and option that is situated along East Bayshore Road and the south and east sides of the Palo Alto Operations and Maintenance Facility.

Figures C-31 through C-37: Cross section G16 – Located within Reach 11, Option 2a, and represents the segments of Reach 10 along the north side of the Byxbee Park landfill, Reach 11, Option 2a along the east side of the Byxbee Park landfill, and Reach 11, Option 2, between the landfill and the northern end of the Palo Alto Operations and Maintenance Facility.

Figures C-38 through C-44: Cross section G17 – Cross section G17 – Located within Reach 11, Option 3, and represents this reach and option across the Palo Alto flood control basin.

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	CL - Existing Levee / Fill	115	75	30	500	0
3	MH/CH - YBM Fill (Desiccated)	95	0	29	300	0
4	MH/CH - YBM	95	0	29	300	0
5	CL - Alluvium	125	50	30	700	0
6	SP-SM - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	1,000	0



SAFER Bay Project, Task Order No. 2

Palo Alto, California

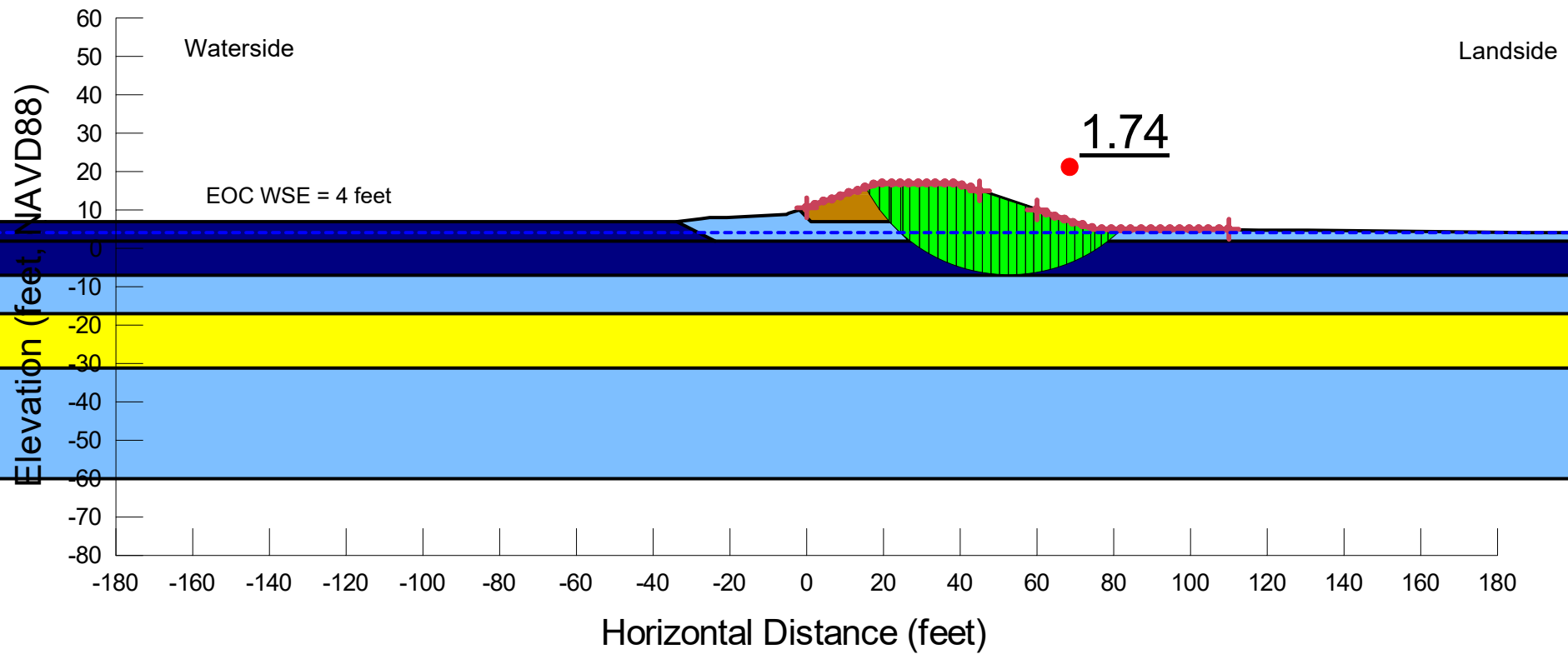


Cross Section G9

Stability Model

July 2016

Figure C-1



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

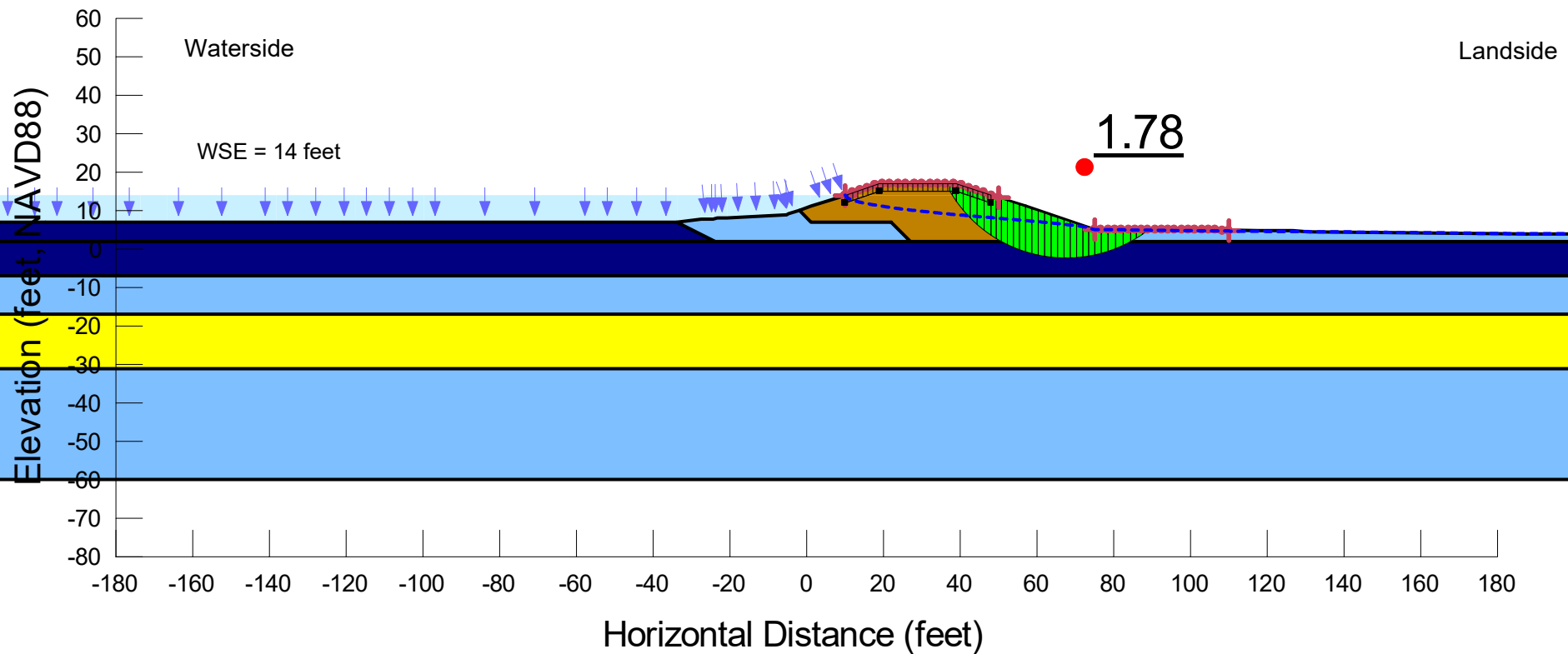


Cross Section G9

End-of-Construction
Full Levee

July 2016

Figure C-2



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

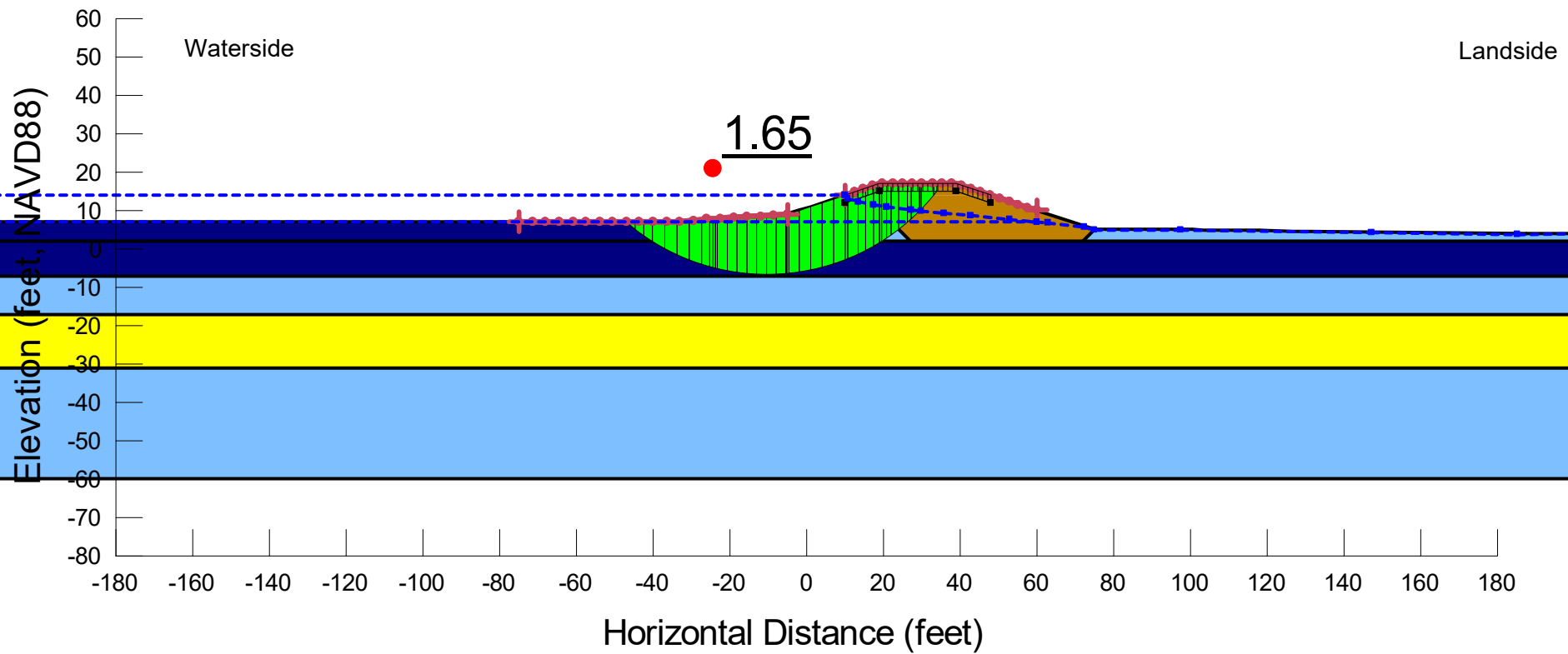


Cross Section G9

Steady-State Stability

July 2016

Figure C-3



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



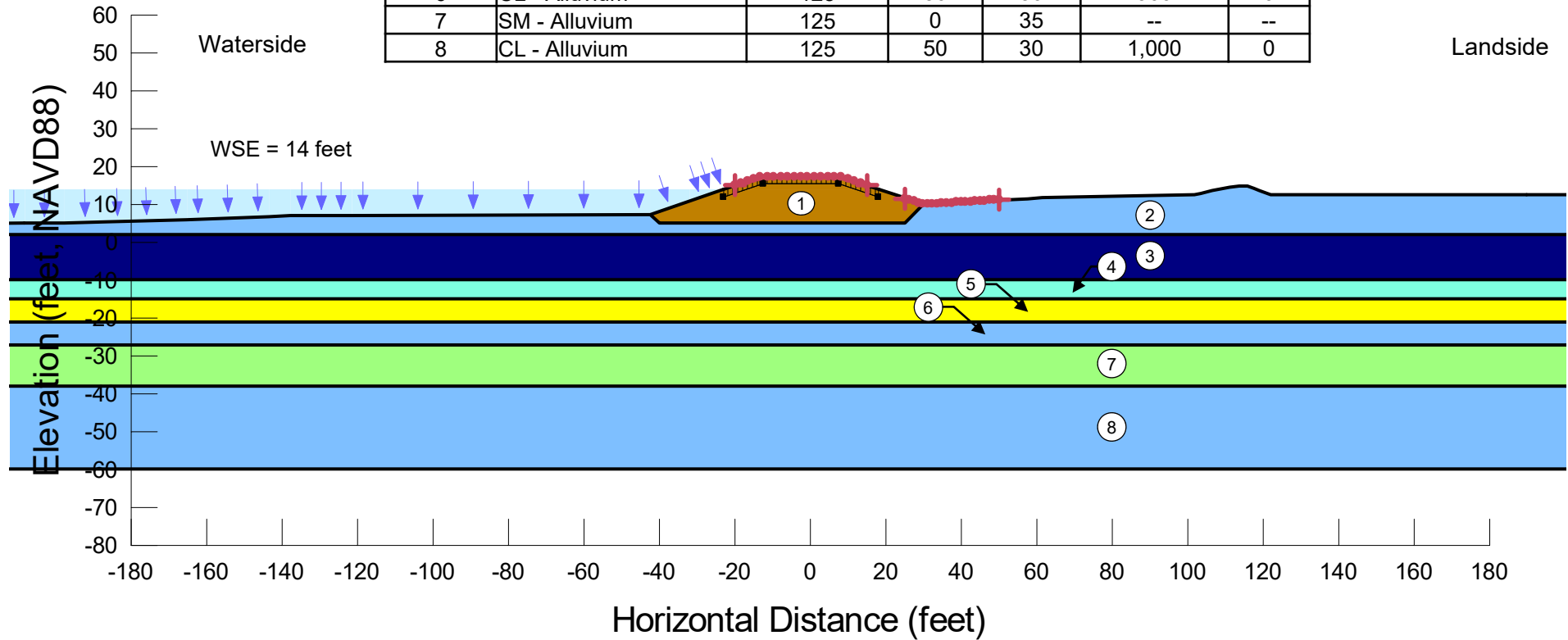
Cross Section G9

Waterside Rapid Drawdown

July 2016

Figure C-4

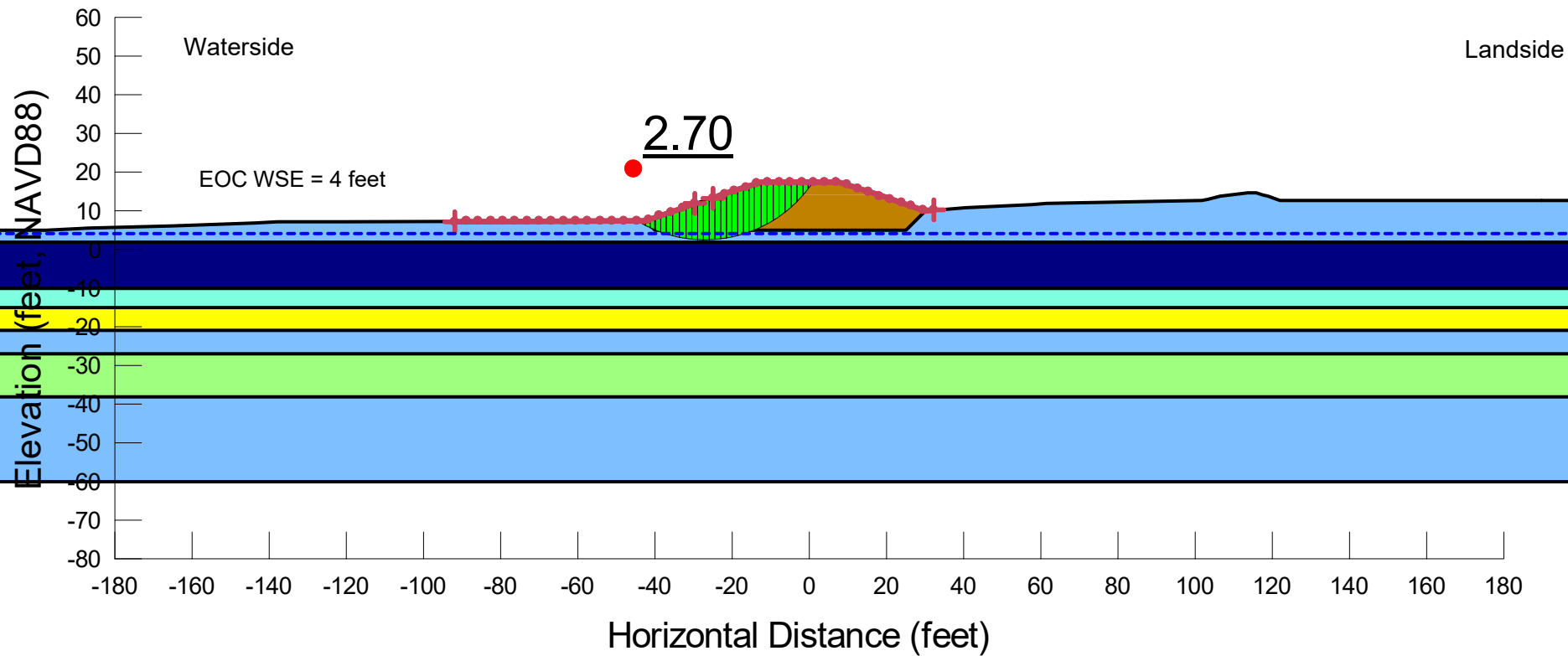
Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	MH/CL/SC - Fill	115	0	29	300	0
3	CH/MH - YBM	95	0	29	300	0
4	SC/CL - Alluvium	125	50	30	800	0
5	SP-SM - Alluvium	125	0	35	--	--
6	CL - Alluvium	125	50	30	900	0
7	SM - Alluvium	125 </td <td>0</td> <td>35</td> <td>--</td> <td>--</td>	0	35	--	--
8	CL - Alluvium	125	50	30	1,000	0



SAFER Bay Project, Task Order No. 2
Palo Alto, California



Cross Section G10
Stability Model
July 2016 Figure C-5



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

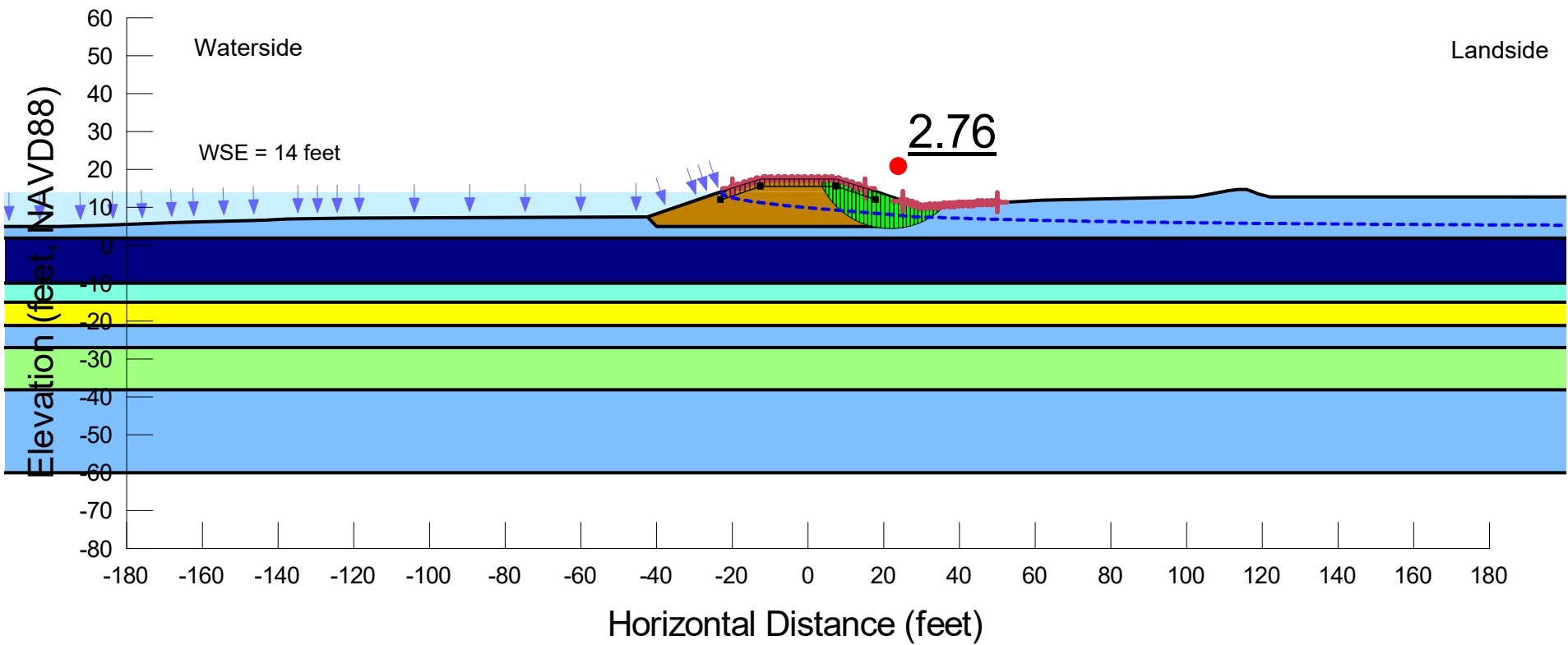


Cross Section G10

End-of-Construction
Full Levee

July 2016

Figure C-6



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

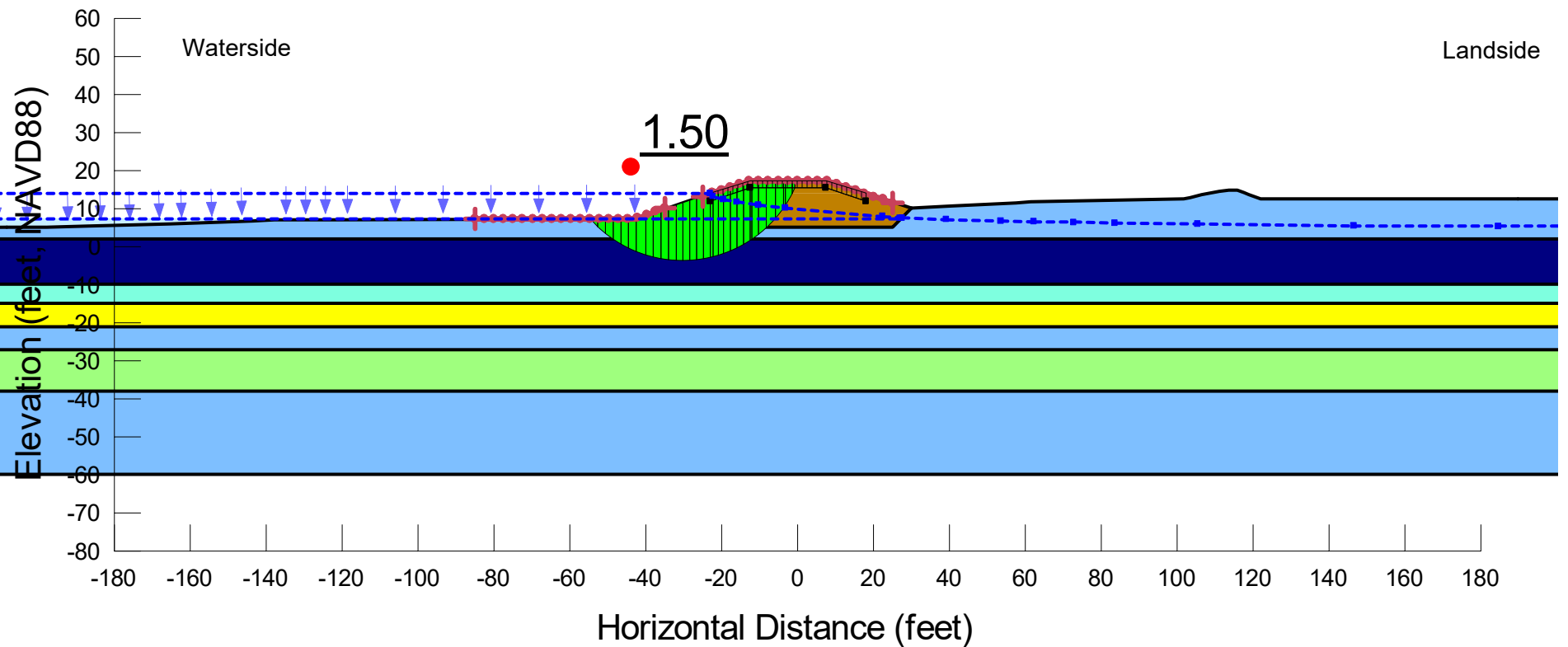


Cross Section G10

Steady-State Stability

July 2016

Figure C-7



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



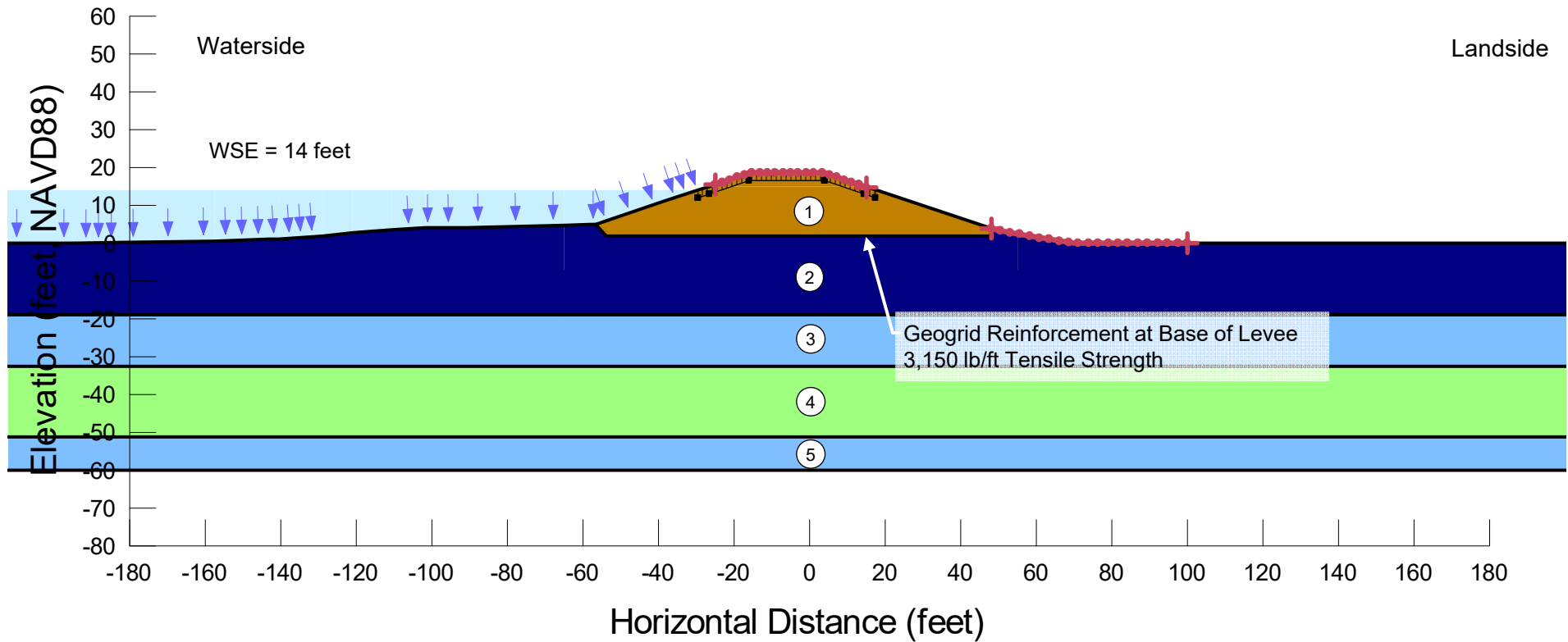
Cross Section G10

Waterside Rapid Drawdown

July 2016

Figure C-8

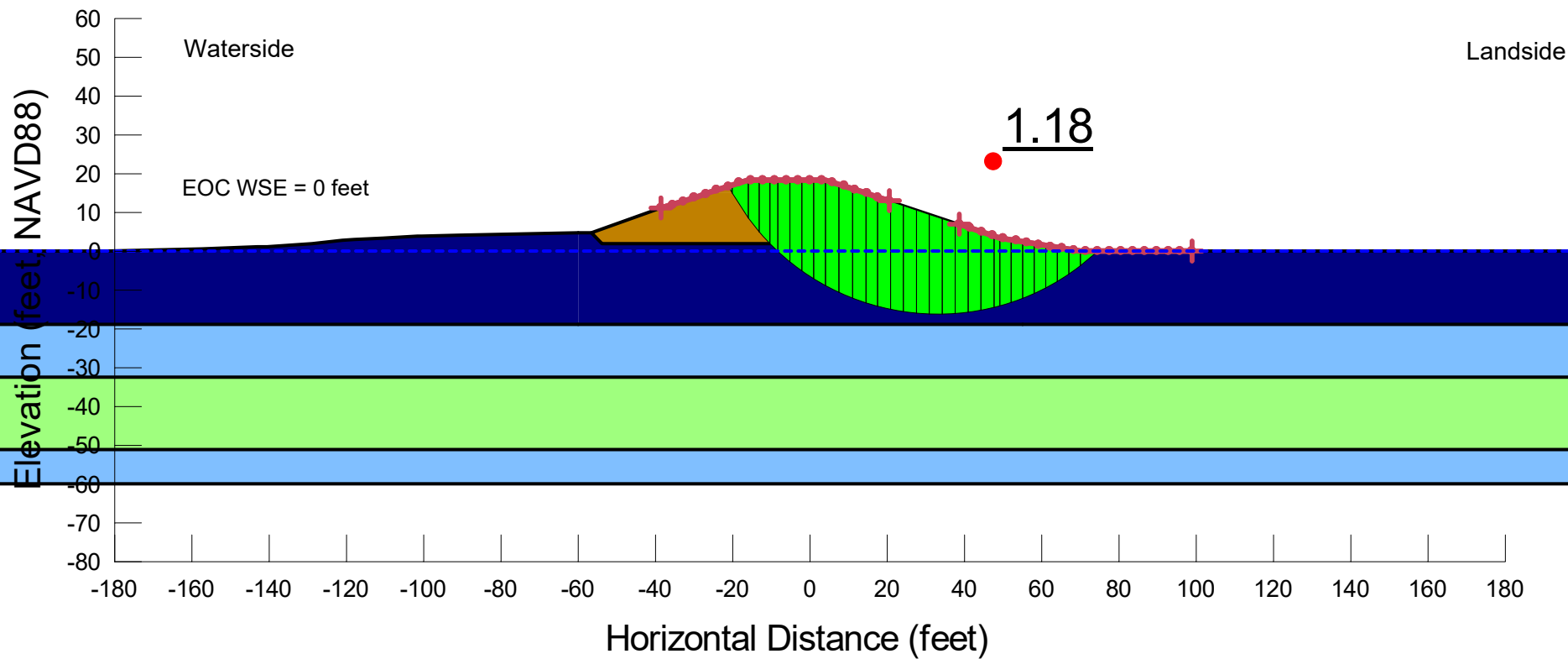
Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee	125	75	30	750	0
2	MH/CH - YBM	98	0	29	225 - 300	0
3	CL - Alluvium	125	50	30	900	0
4	SW-SC - Alluvium	125	0	35	--	--
5	CL - Alluvium	125	50	30	1,200	0



SAFER Bay Project, Task Order No. 2
Palo Alto, California



Cross Section G11
Stability Model
July 2016 Figure C-9



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

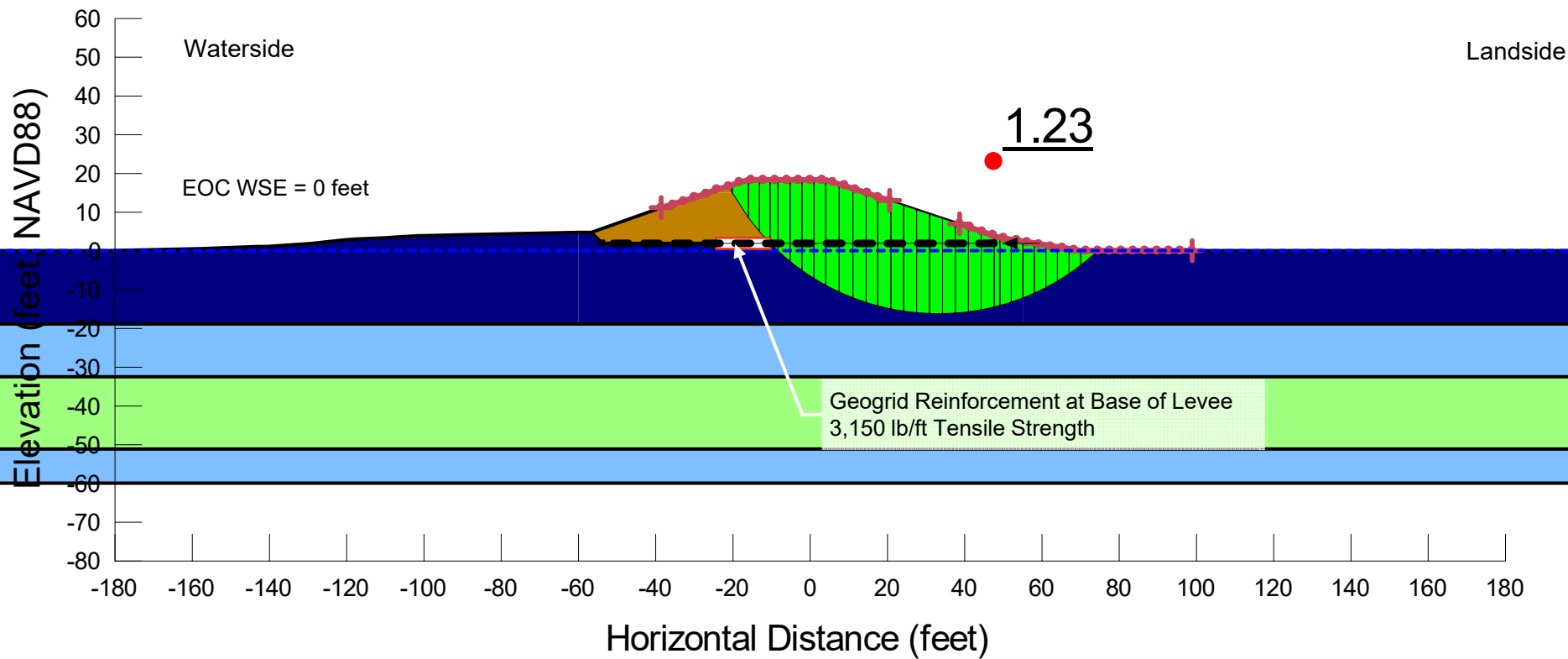


Cross Section G11

End-of-Construction
Full Levee without Geogrid

July 2016

Figure C-10



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

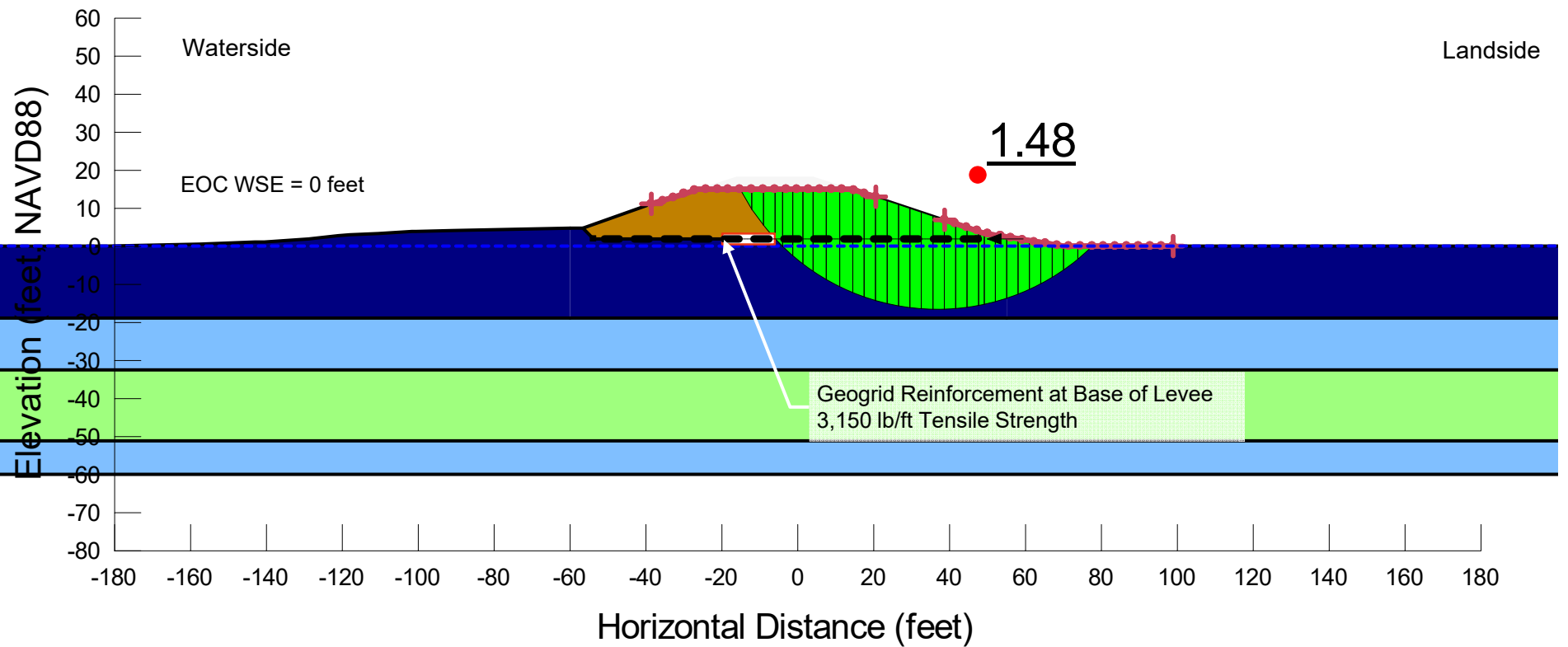


Cross Section G11

End-of-Construction
Full Levee with Geogrid

July 2016

Figure C-11



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

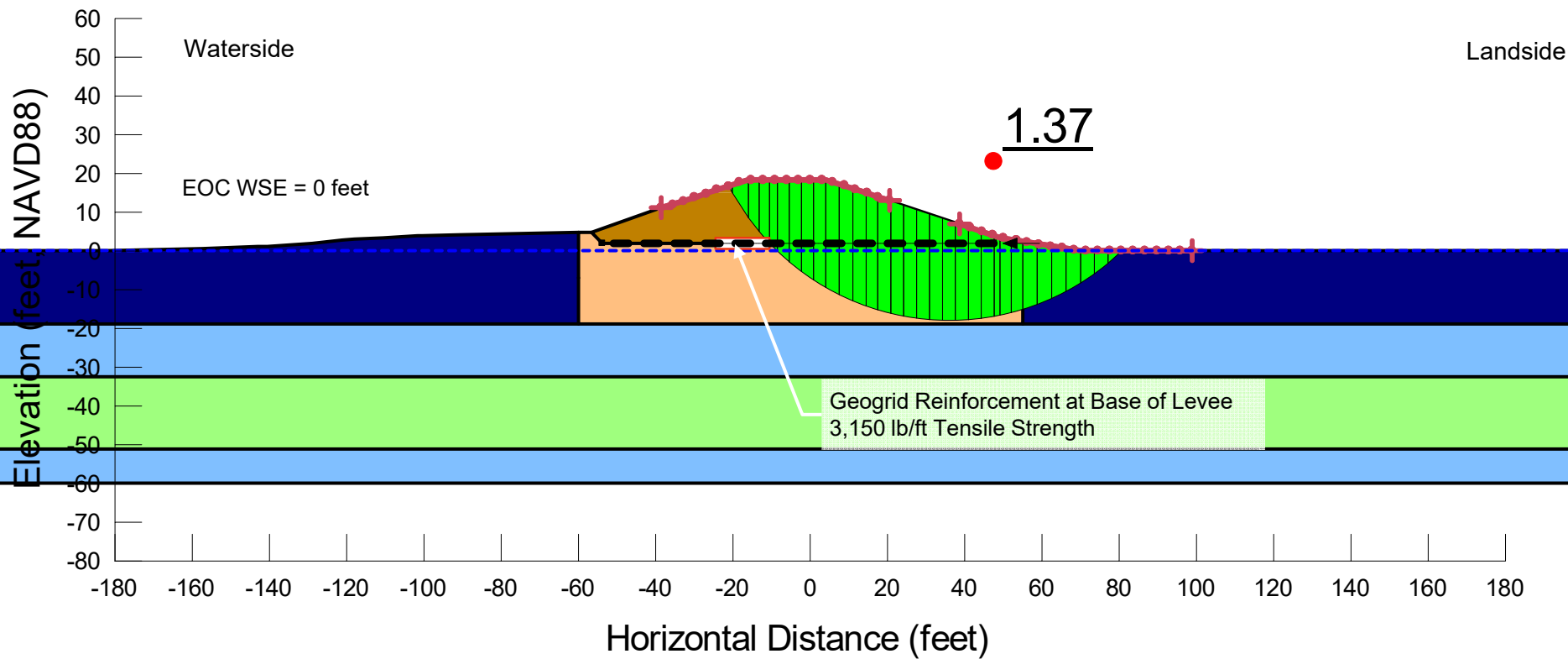


Cross Section G11

End-of-Construction
Stage 1 Levee with Geogrid

July 2016

Figure C-12



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

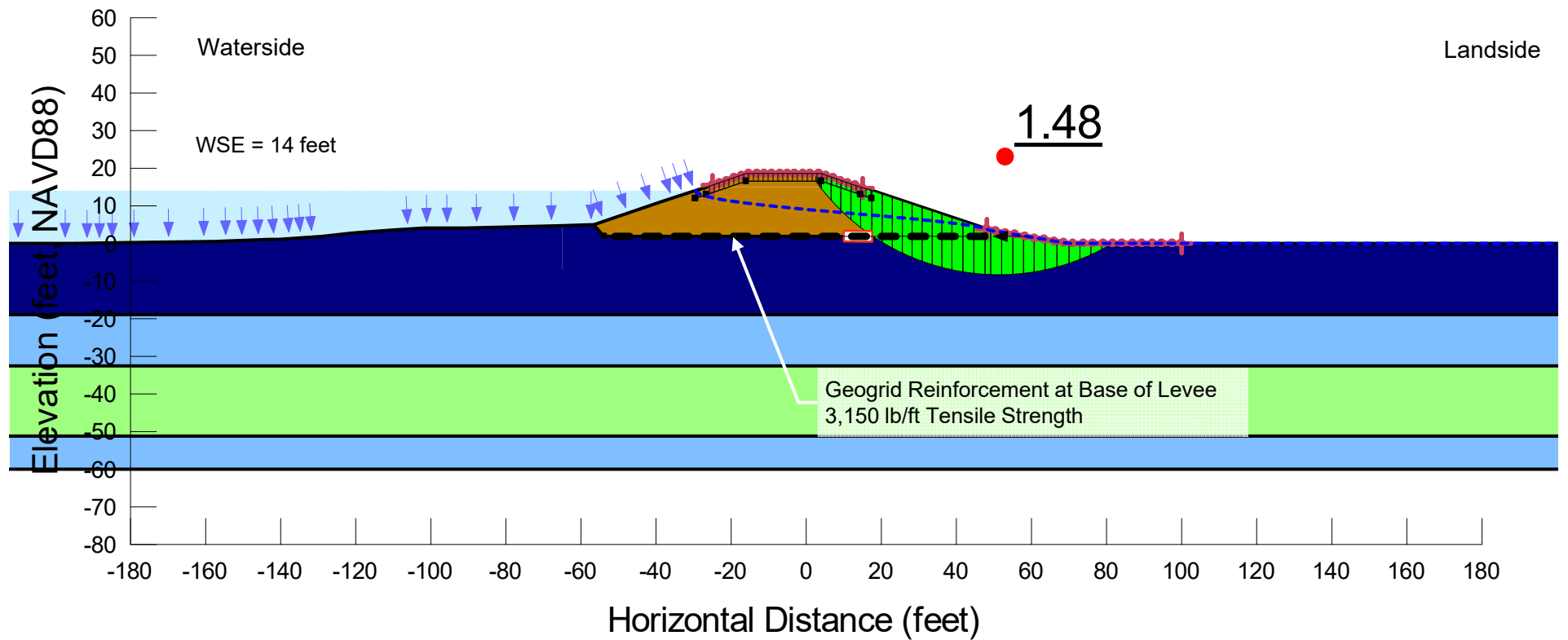


Cross Section G11

End-of-Construction
Stage 2 Levee with Geogrid

July 2016

Figure C-13



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

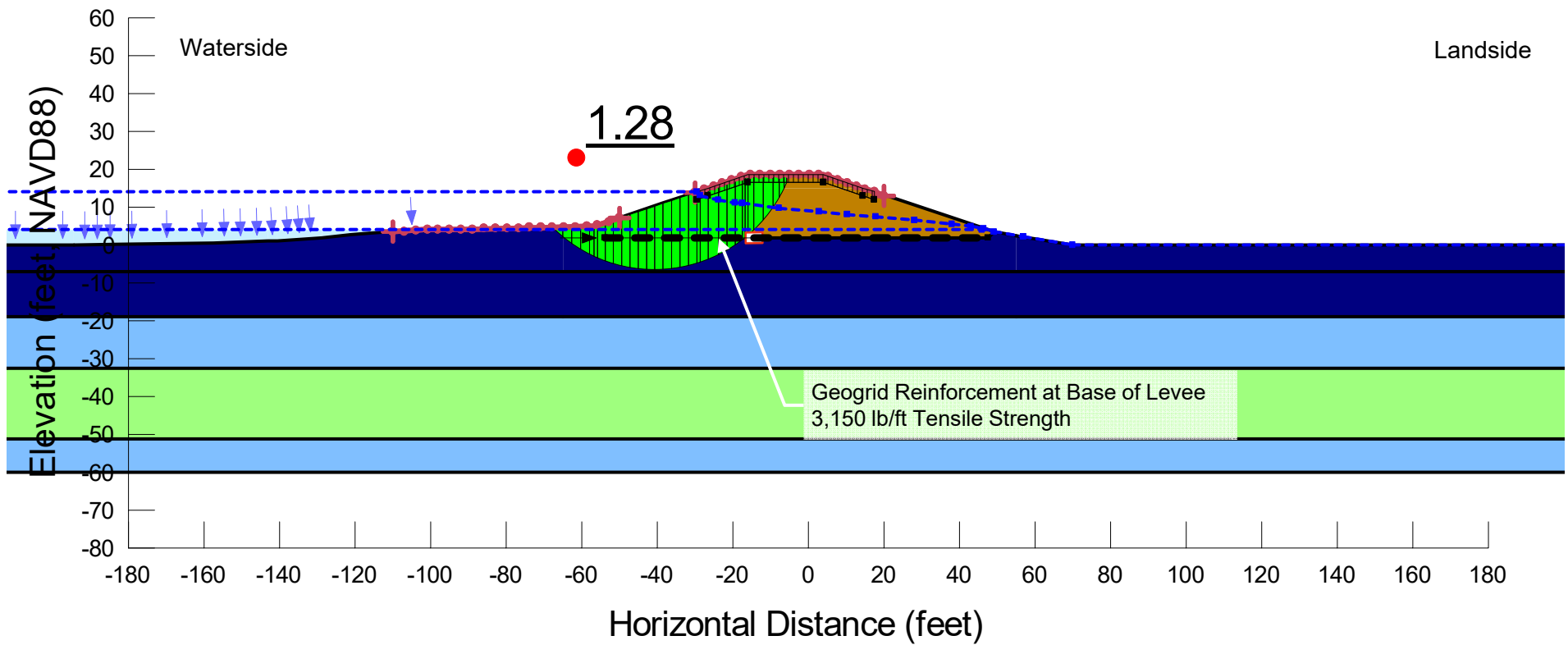


Cross Section G11

Steady-State Stability with Geogrid

July 2016

Figure C-14



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



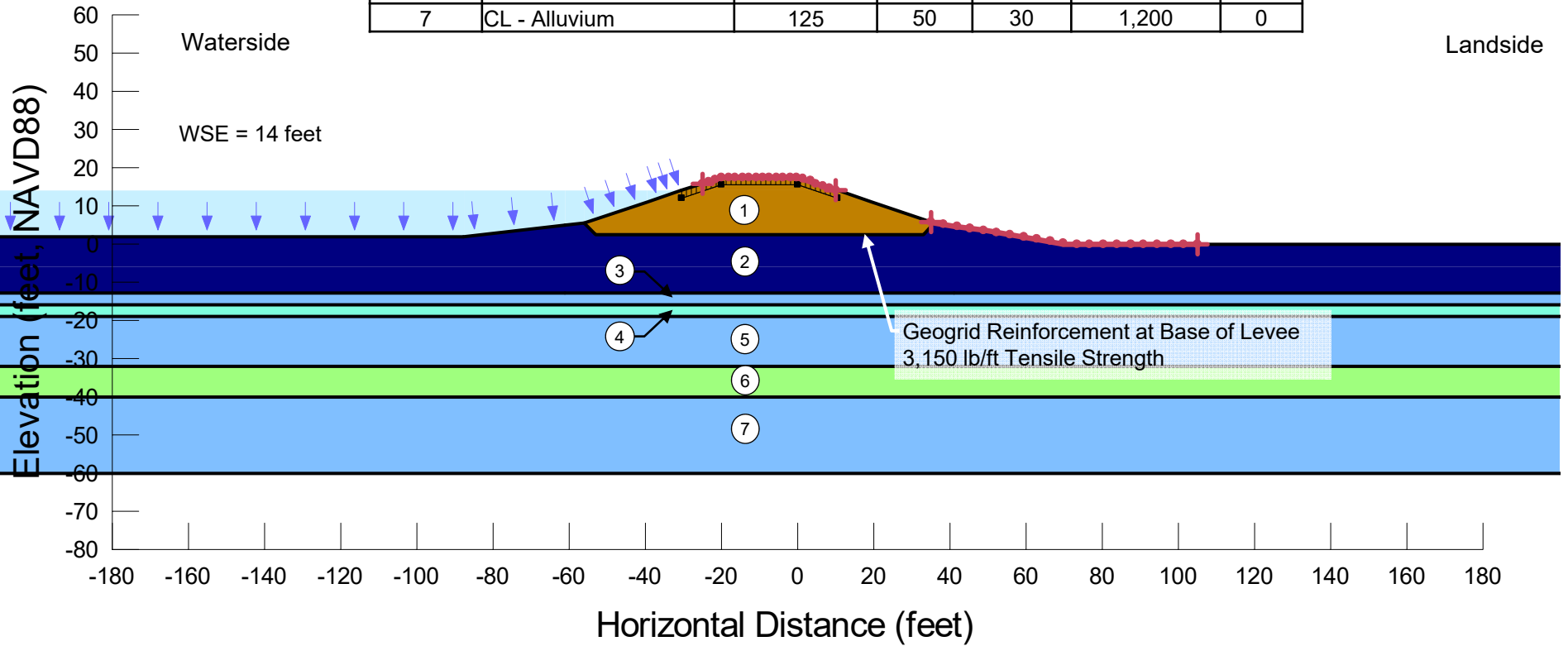
Cross Section G11

Waterside Rapid Drawdown
with Geogrid

July 2016

Figure C-15

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	MH/CH - YBM	98	0	29	225-300	0
3	CL - Alluvium	125	50	30	700	0
4	SC - Alluvium	125	0	35	--	--
5	CL - Alluvium	125	50	30	900	0
6	SW-SC - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	1,200	0



SAFER Bay Project, Task Order No. 2

Palo Alto, California

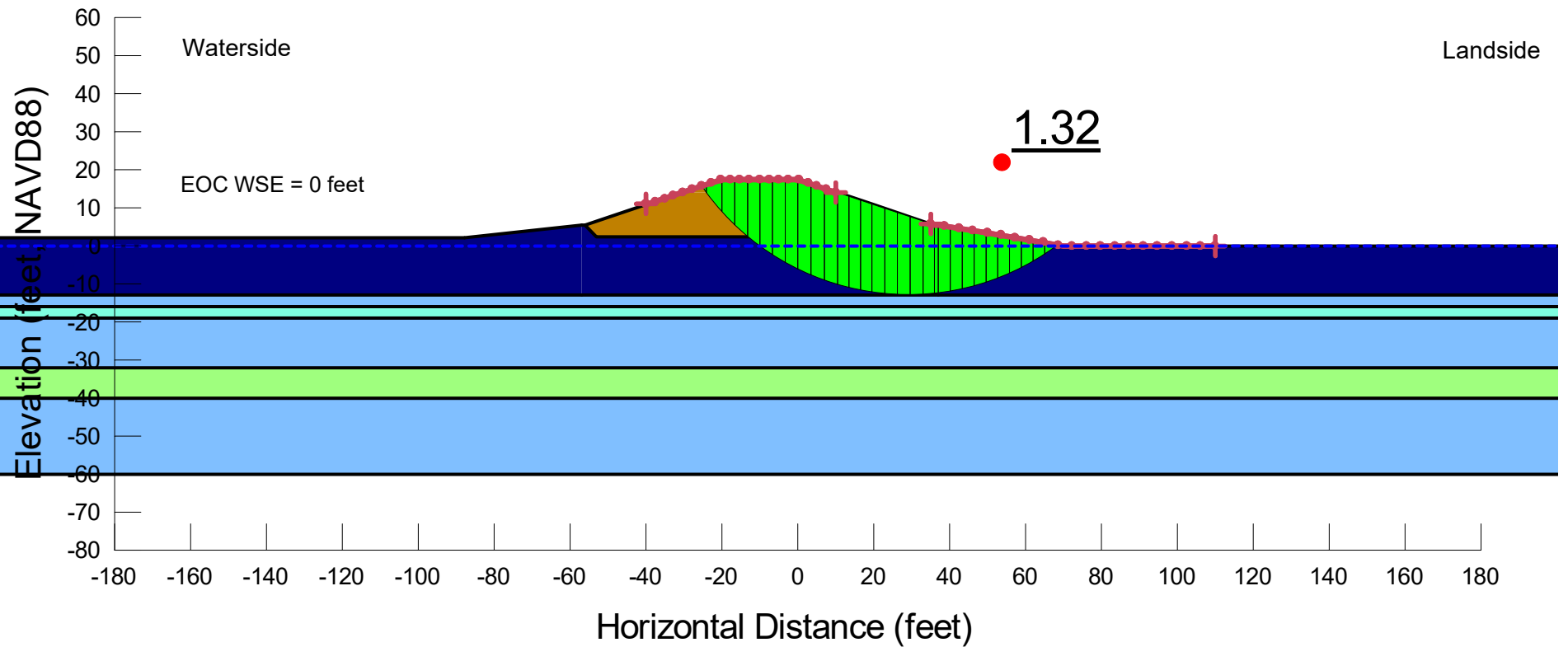


Cross Section G12

Stability Model

July 2016

Figure C-16



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

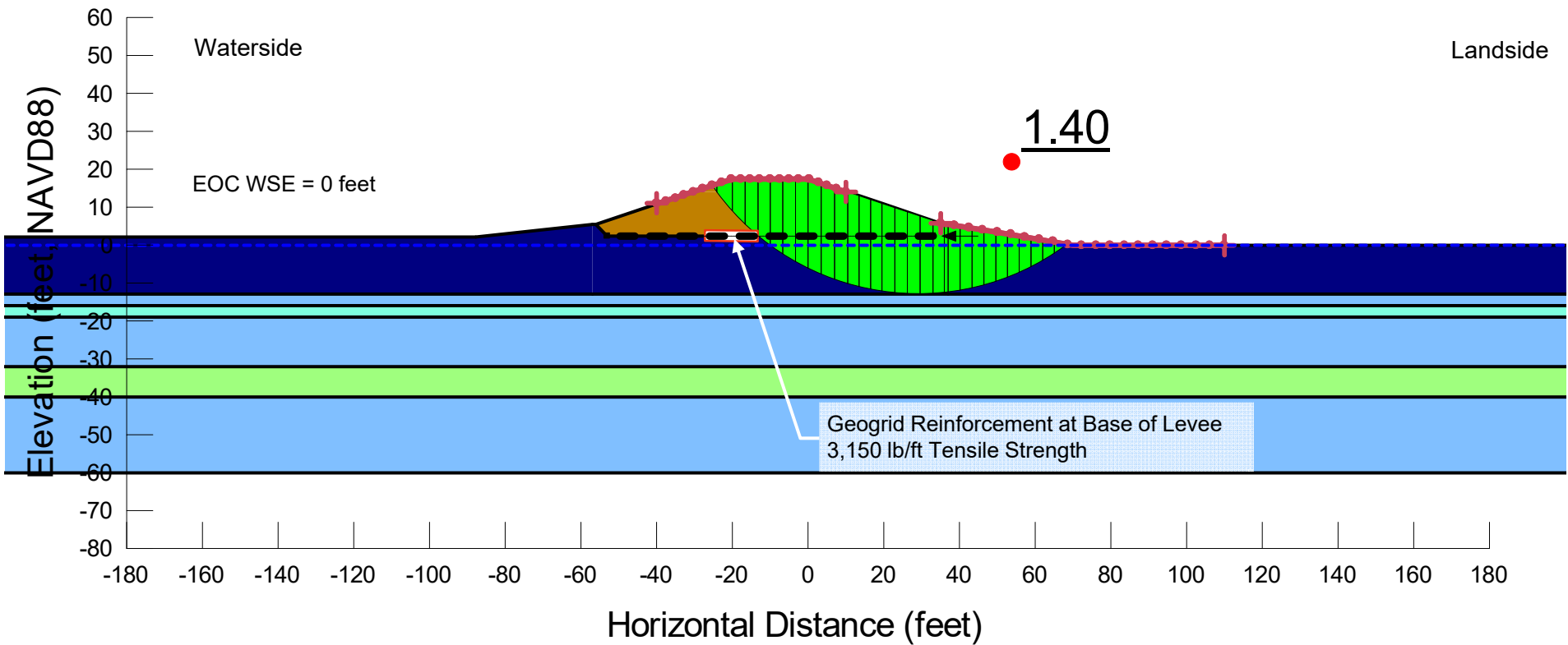


Cross Section G12

End-of-Construction
Full Levee without Geogrid

July 2016

Figure C-17



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

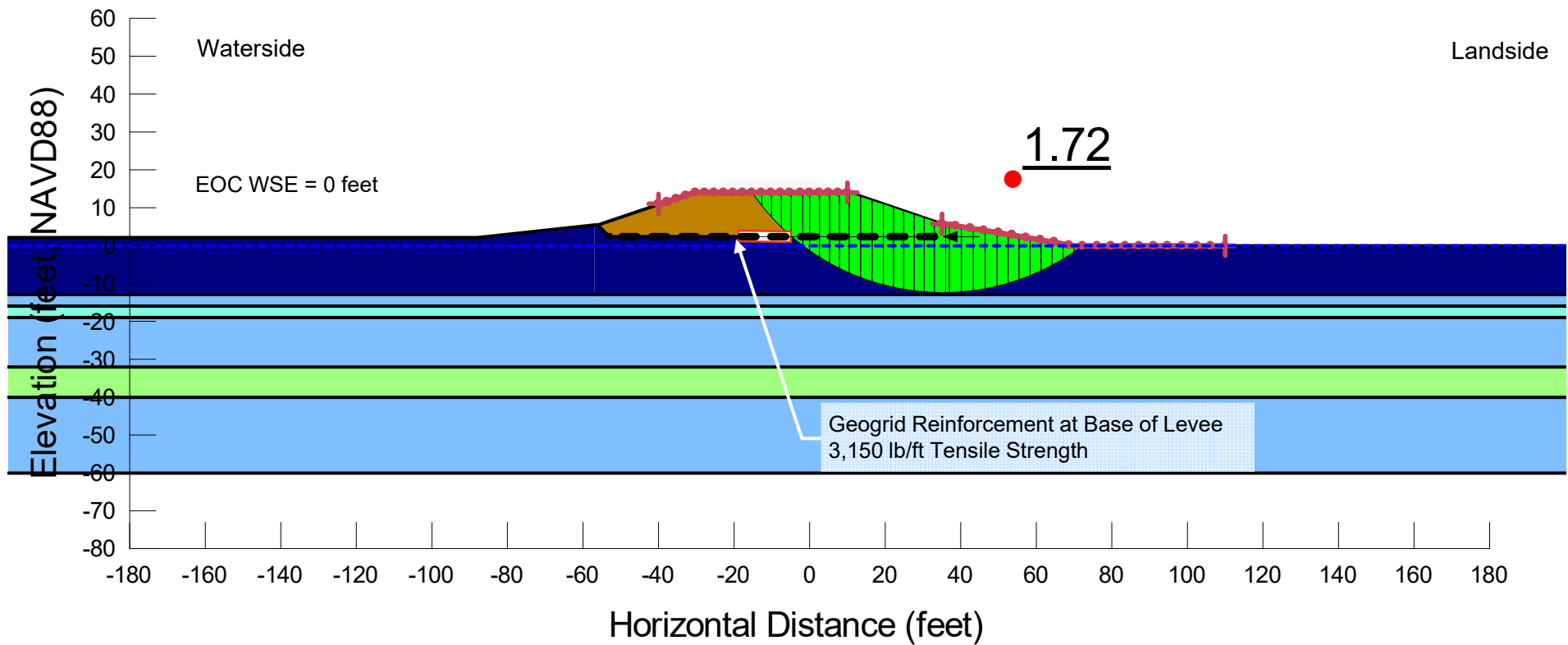


Cross Section G12

End-of-Construction
Full Levee with Geogrid

July 2016

Figure C-18



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

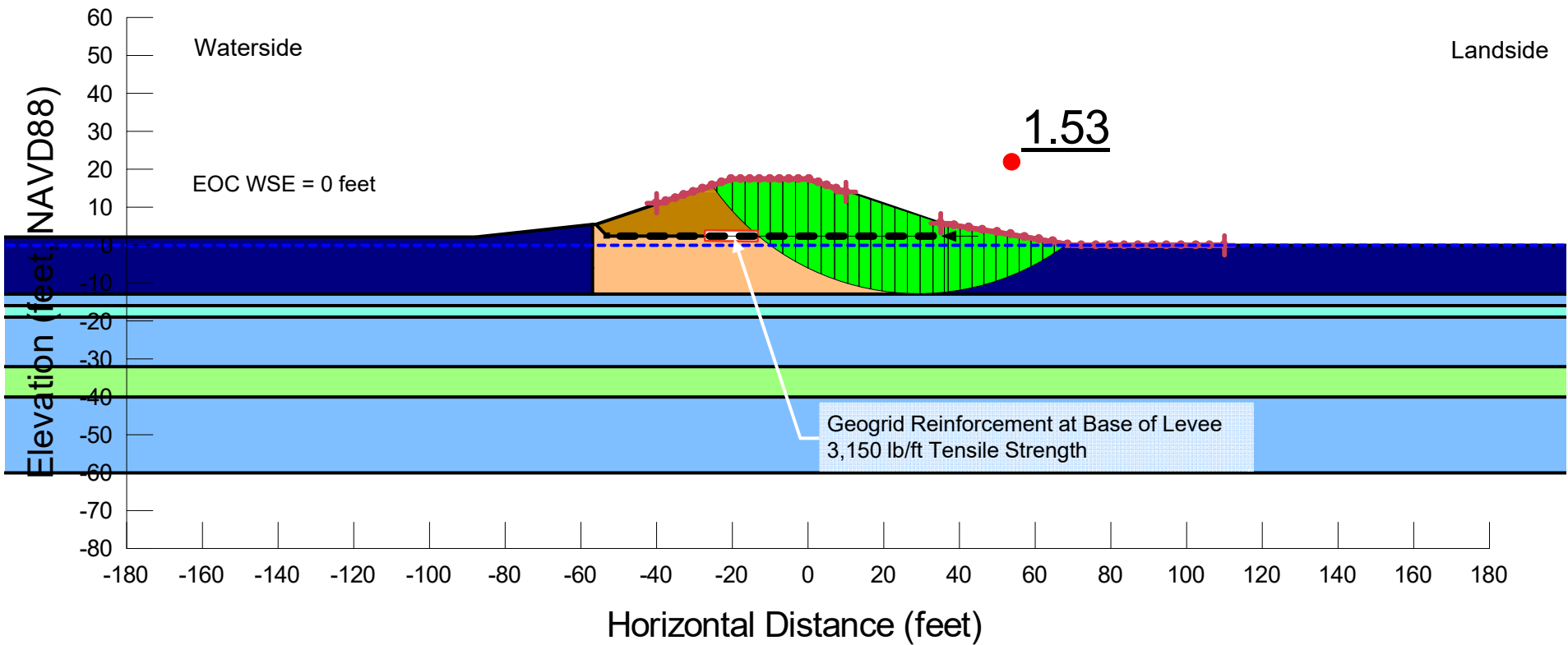


Cross Section G12

End-of-Construction
Stage 1 Levee with Geogrid

July 2016

Figure C-19



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

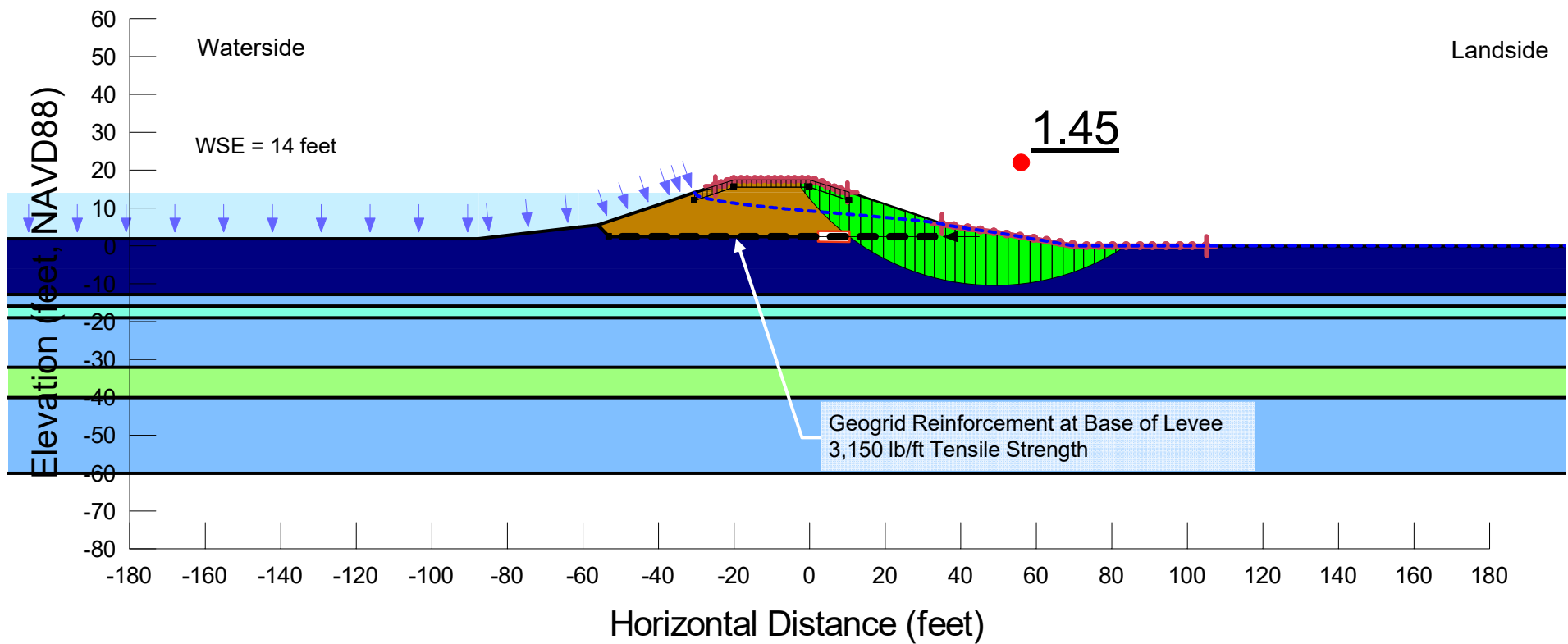


Cross Section G12

End-of-Construction
Stage 2 Levee with Geogrid

July 2016

Figure C-20



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

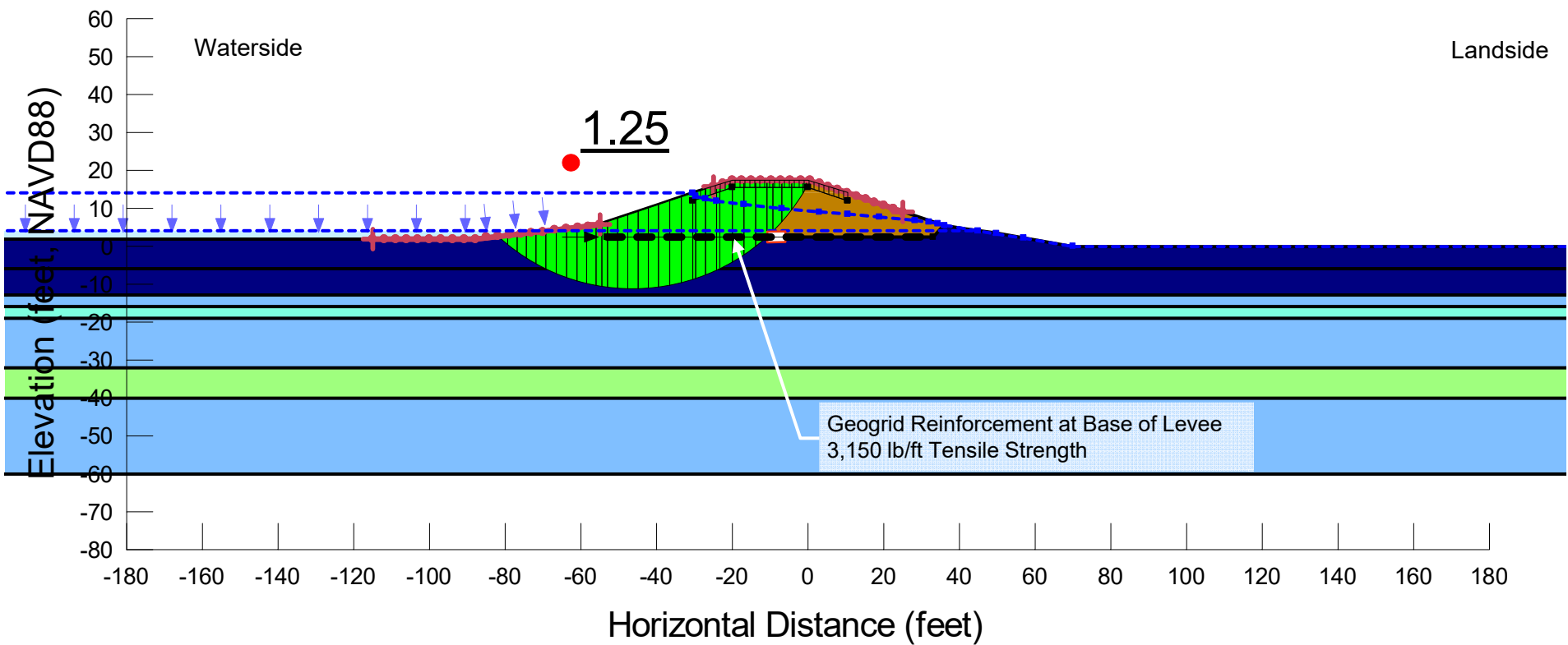


Cross Section G12

Steady-State Stability
with Geogrid

July 2016

Figure C-21



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



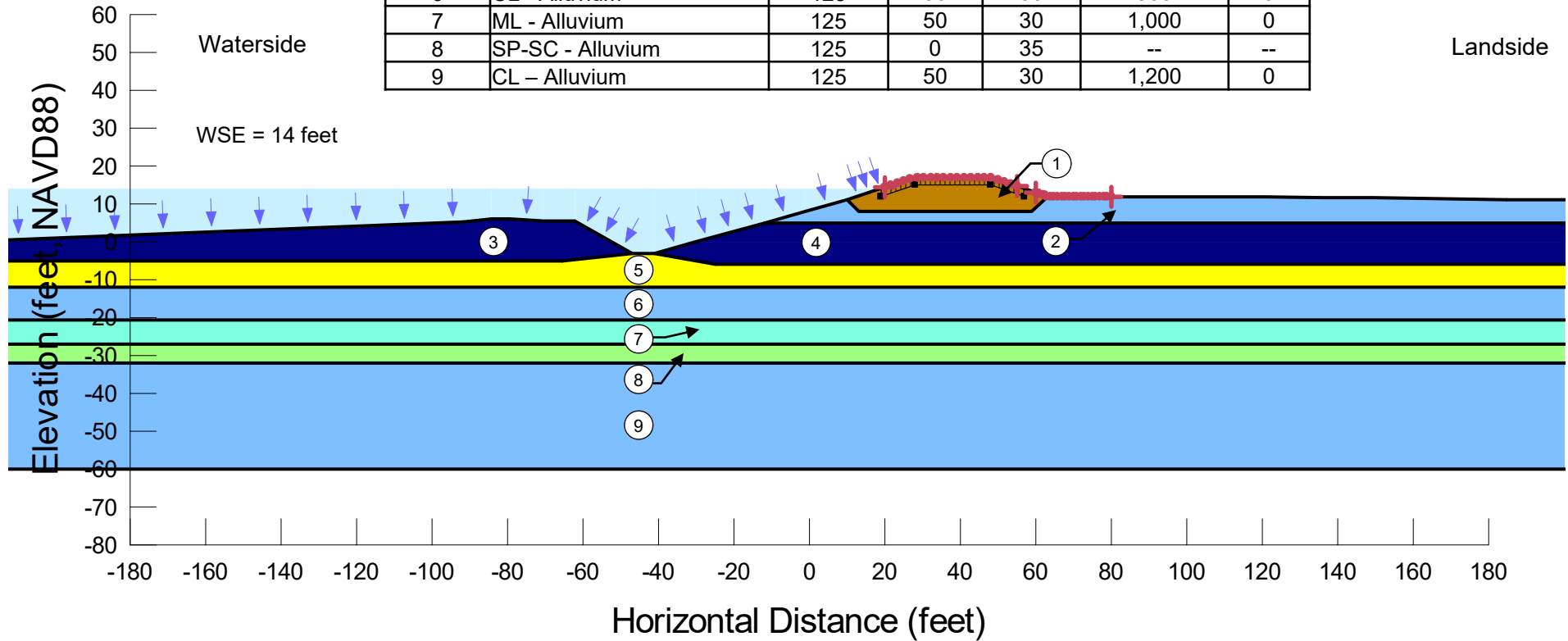
Cross Section G12

Waterside Rapid Drawdown
with Geogrid

July 2016

Figure C-22

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	CL - Fill	125	75	30	500	0
3	MH/CH - YBM (Desiccated)	110	0	29	350	0
4	MH/CH - YBM	110	0	29	350	0
5	SW-SM - Alluvium	125	0	35	--	--
6	CL - Alluvium	125	50	30	900	0
7	ML - Alluvium	125	50	30	1,000	0
8	SP-SC - Alluvium	125	0	35	--	--
9	CL - Alluvium	125	50	30	1,200	0



SAFER Bay Project, Task Order No. 2

Palo Alto, California

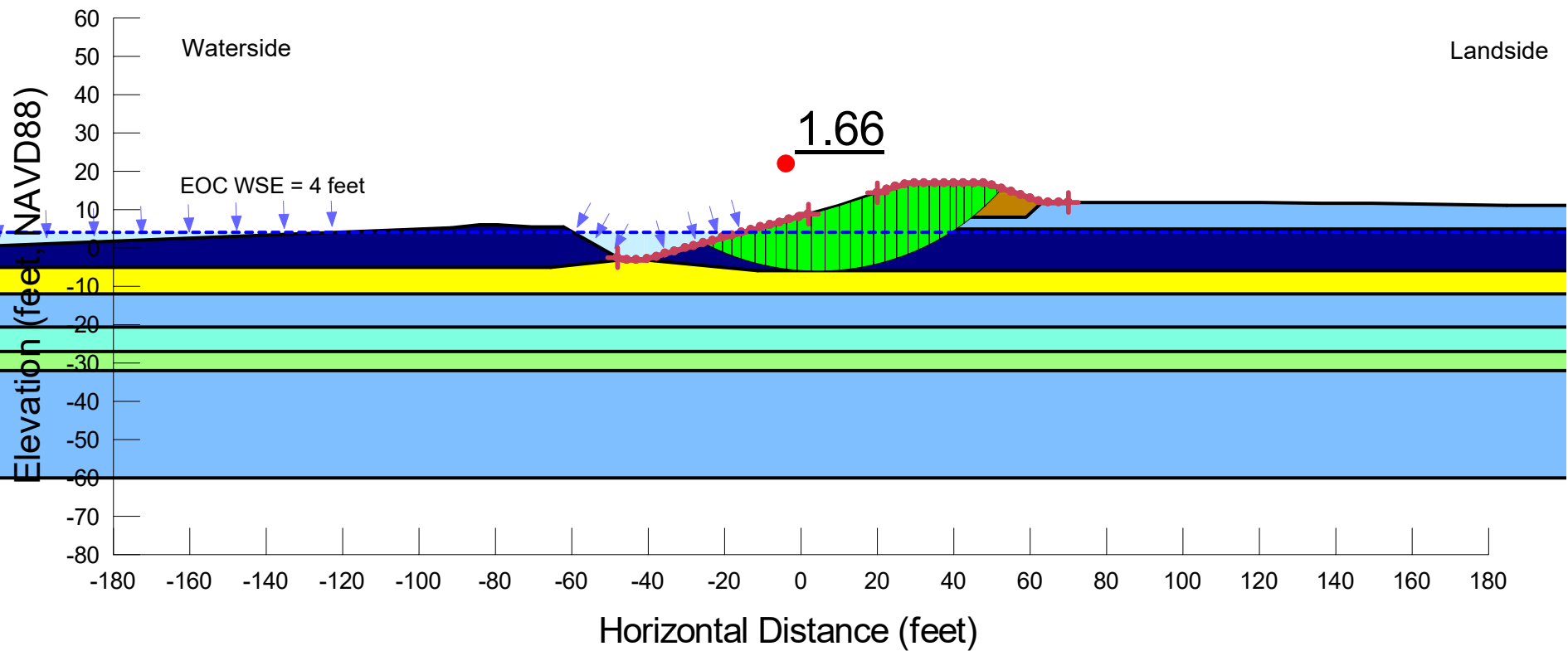


Cross Section G13

Stability Model

July 2016

Figure C-23



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

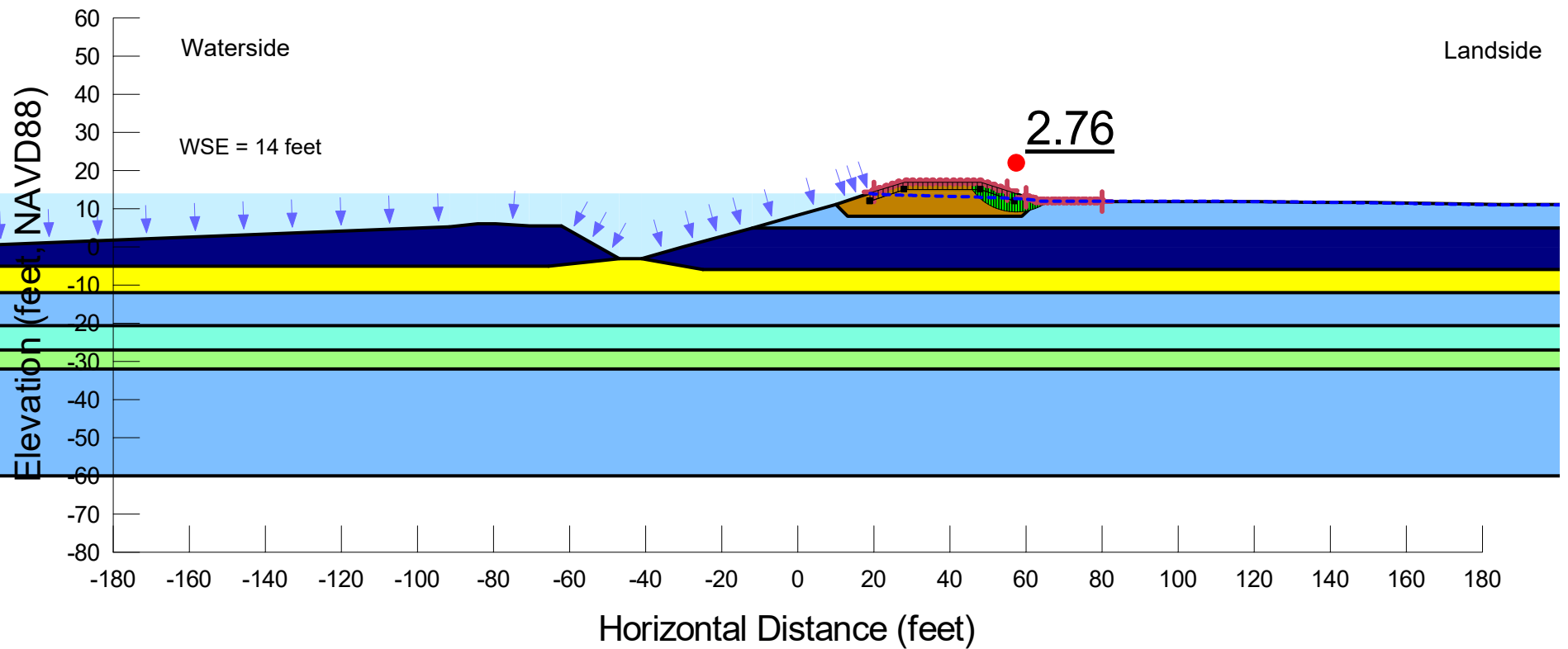


Cross Section G13

End-of-Construction
Full Levee

July 2016

Figure C-24



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

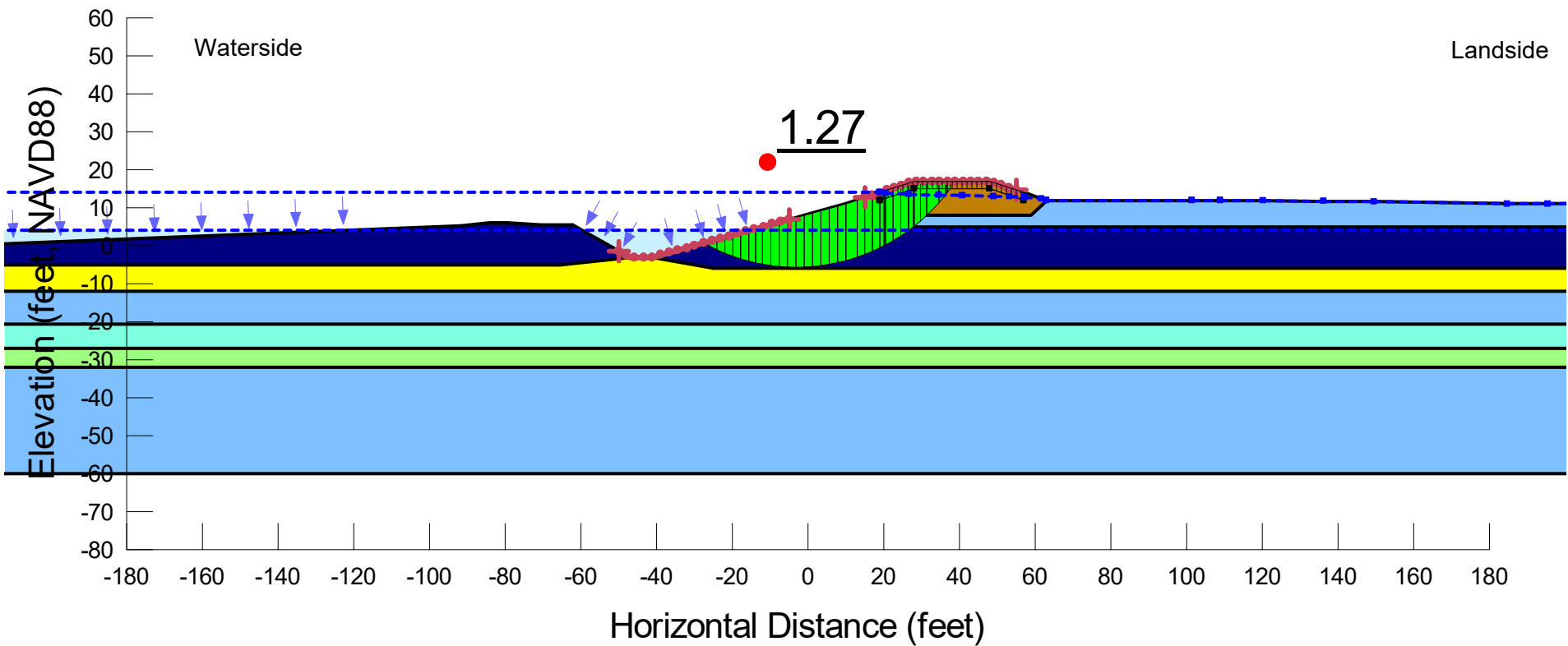


Cross Section G13

Steady-State Stability

July 2016

Figure C-25



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



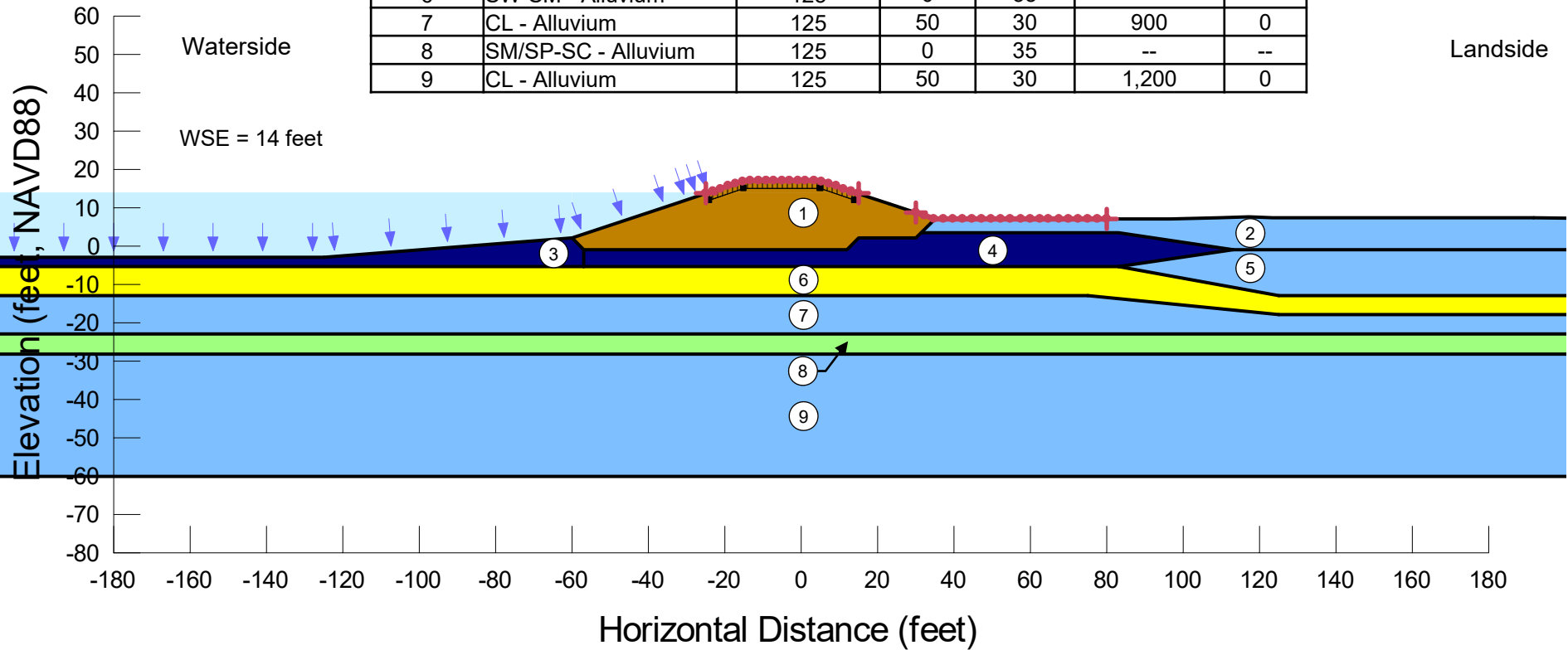
Cross Section G13

Waterside Rapid Drawdown

July 2016

Figure C-26

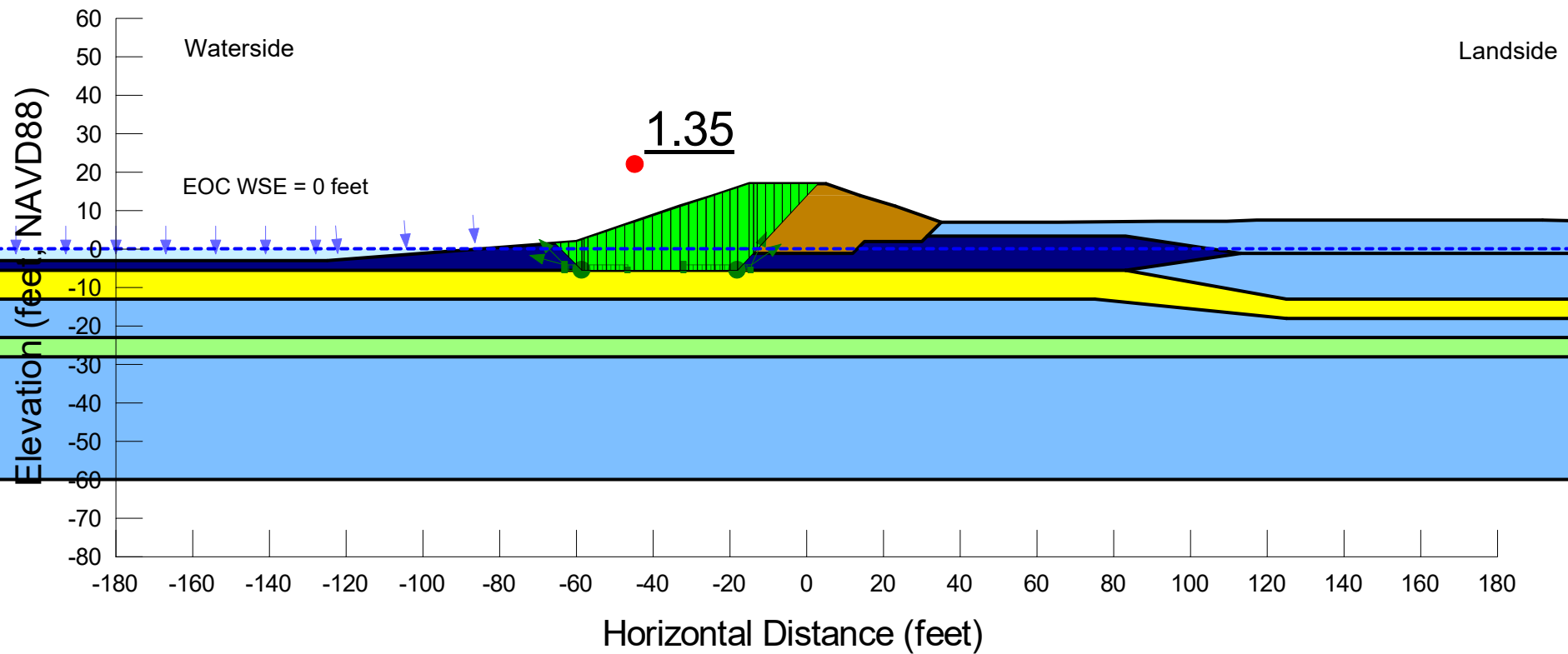
Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	CL - Fill	120	75	30	500	0
3	CH - YBM (Desiccated)	98	0	29	250	0
4	CH - YBM	98	0	29	250	0
5	CL - Alluvium	125	50	30	500	0
6	SW-SM - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	900	0
8	SM/SP-SC - Alluvium	125	0	35	--	--
9	CL - Alluvium	125	50	30	1,200	0



SAFER Bay Project, Task Order No. 2
Palo Alto, California



Cross Section G14
Stability Model
July 2016 Figure C-27



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee.
3. A block-type failure surface was assumed due to the presence of a thin weak YBM layer (Layer 4) overlying stiffer alluvium (Layer 5).

SAFER Bay Project, Task Order No. 2

Palo Alto, California

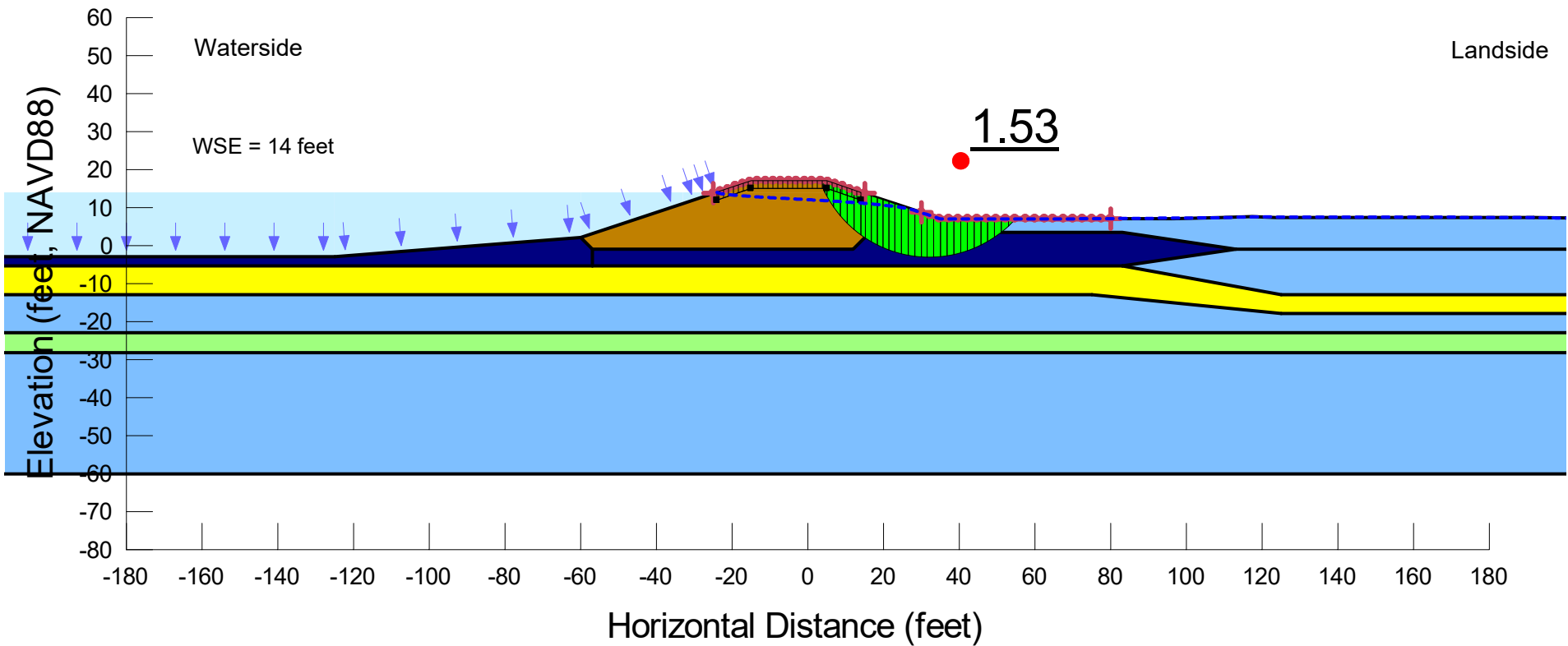


Cross Section G14

End-of-Construction
Full Levee

July 2016

Figure C-28



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

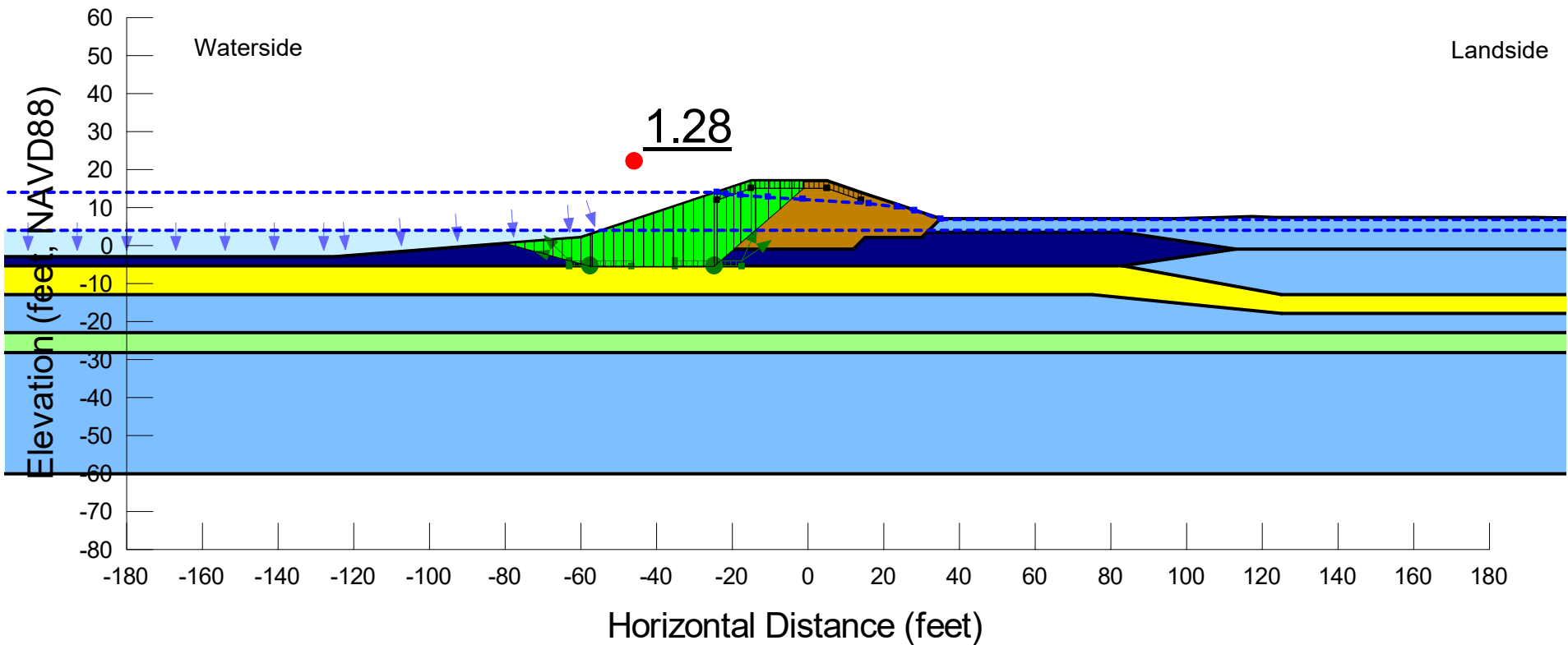


Cross Section G14

Steady-State Stability


July 2016

Figure C-29

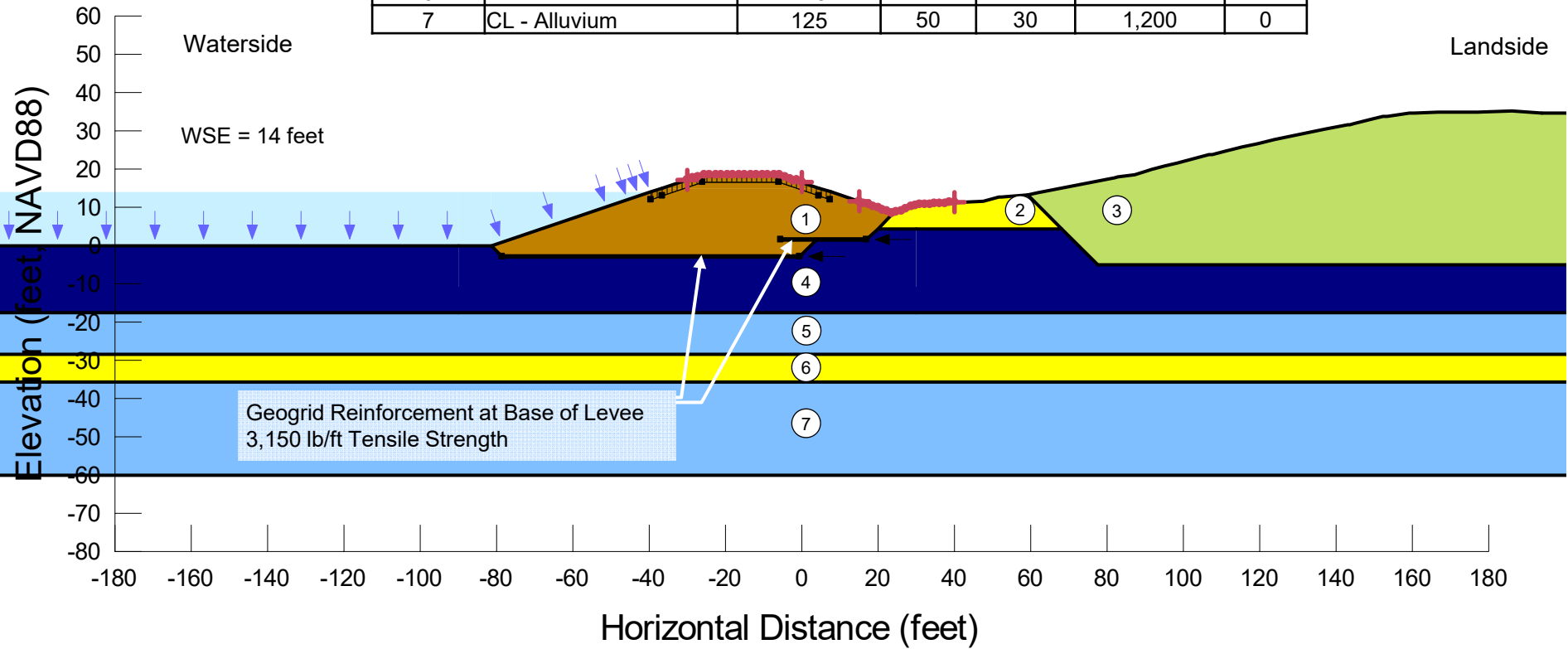


Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.
3. A block-type failure surface was assumed due to the presence of a thin weak YBM layer (Layer 4) overlying stiffer alluvium (Layer 5).

SAFER Bay Project, Task Order No. 2		Cross Section G14 Waterside Rapid Drawdown
Palo Alto, California		July 2016

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	SP-SM - Fill	120	0	35	--	--
3	Refuse - Landfill	100	0	29	--	--
4	MH/CH - YBM	98	0	29	200-325	0
5	CL - Alluvium	125	50	30	800	0
6	SP-SM - Alluvium	125	0	35	--	--
7	CL - Alluvium	125	50	30	1,200	0



SAFER Bay Project, Task Order No. 2

Palo Alto, California

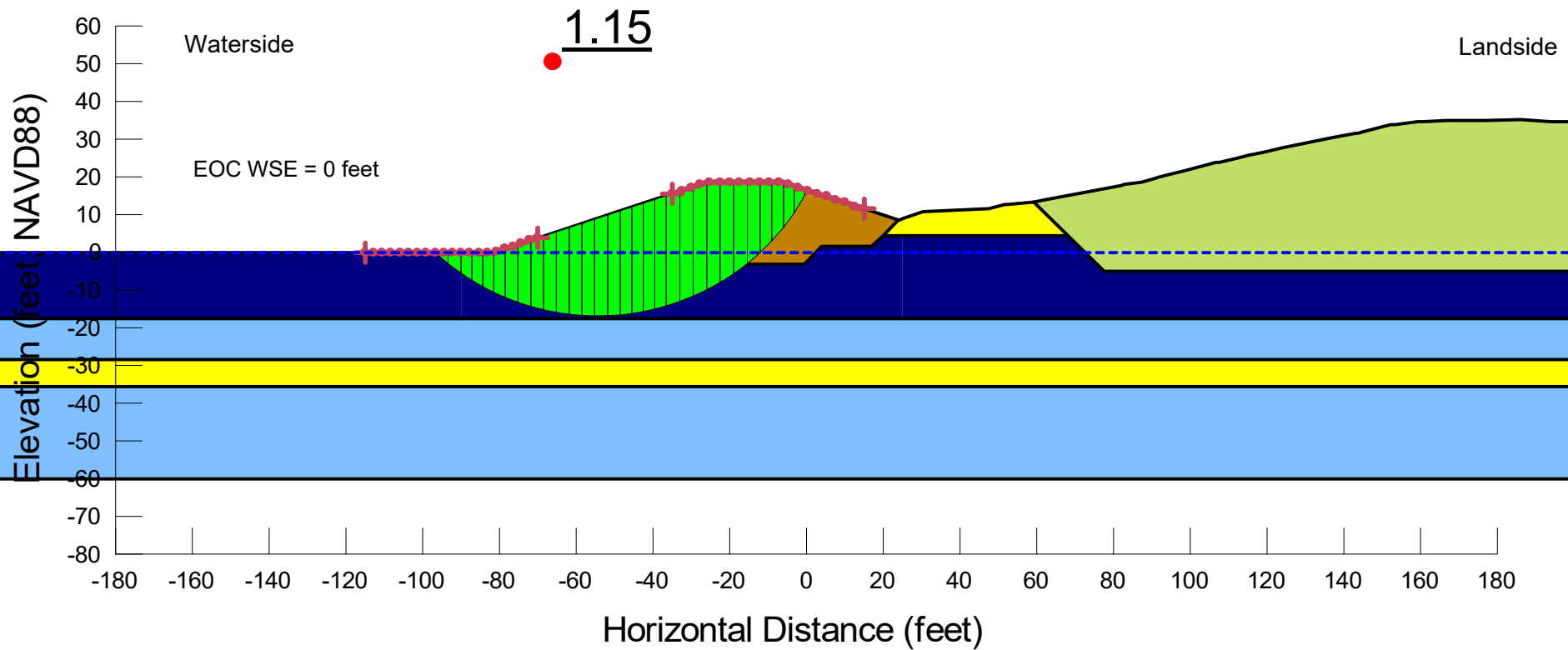


Cross Section G16

Stability Model

July 2016

Figure C-31



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

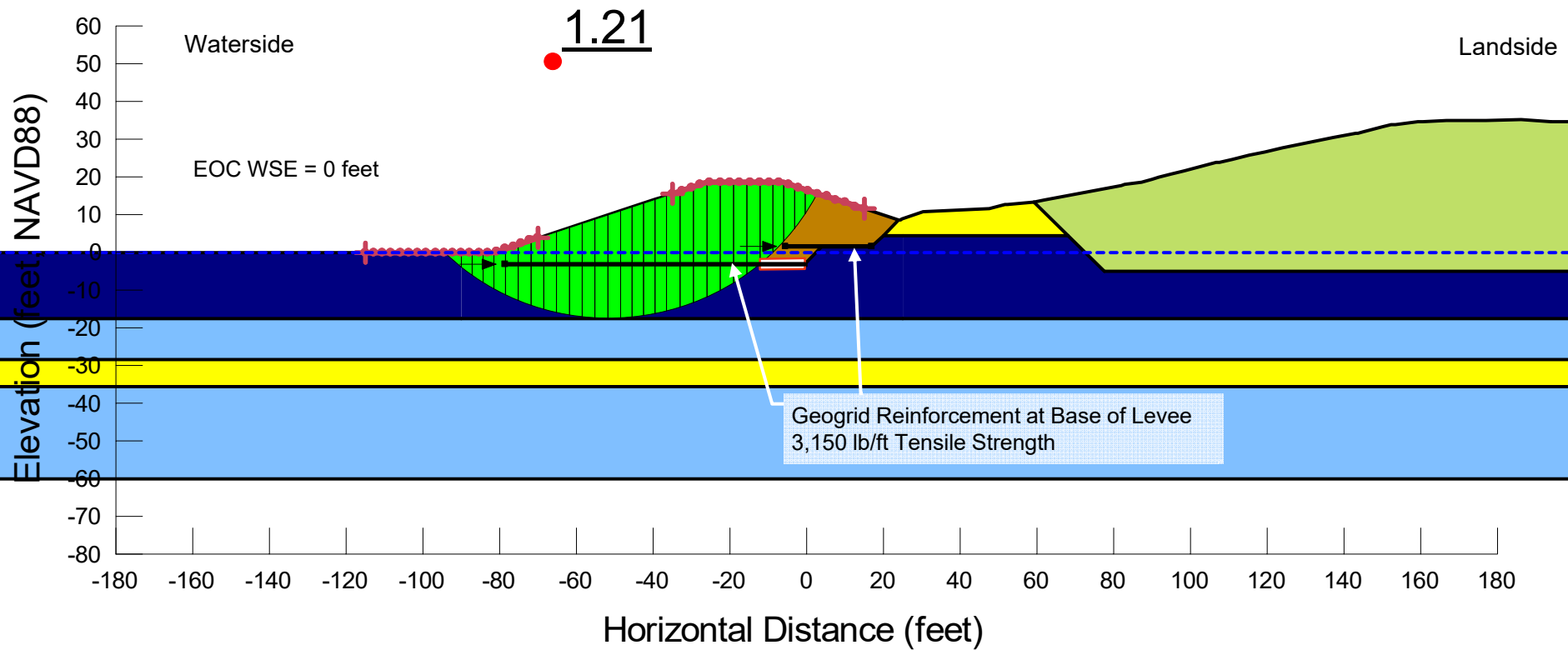


Cross Section G16

End-of-Construction
Full Levee without Geogrid

July 2016

Figure C-32



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

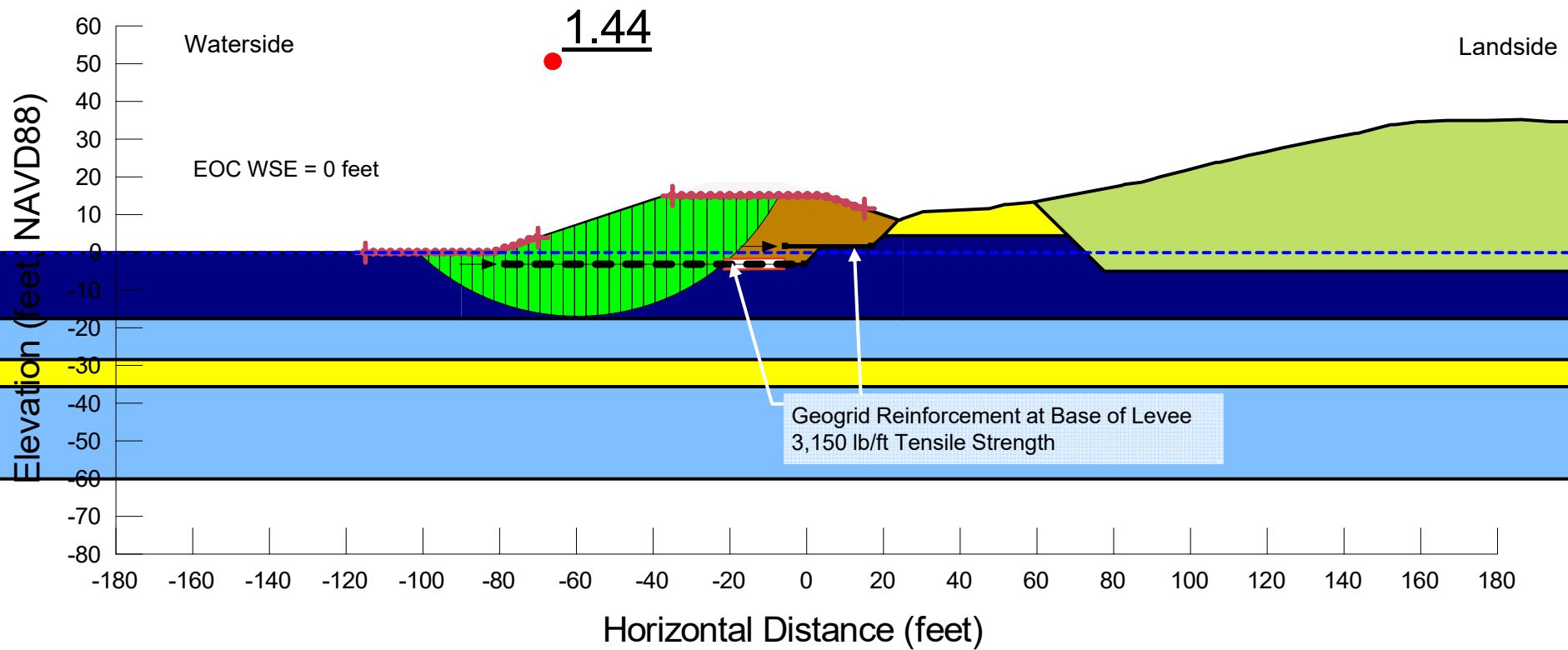
SAFER Bay Project, Task Order No. 2

Palo Alto, California



Cross Section G16
End-of-Construction
Full Levee with Geogrid

July 2016 Figure C-33



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

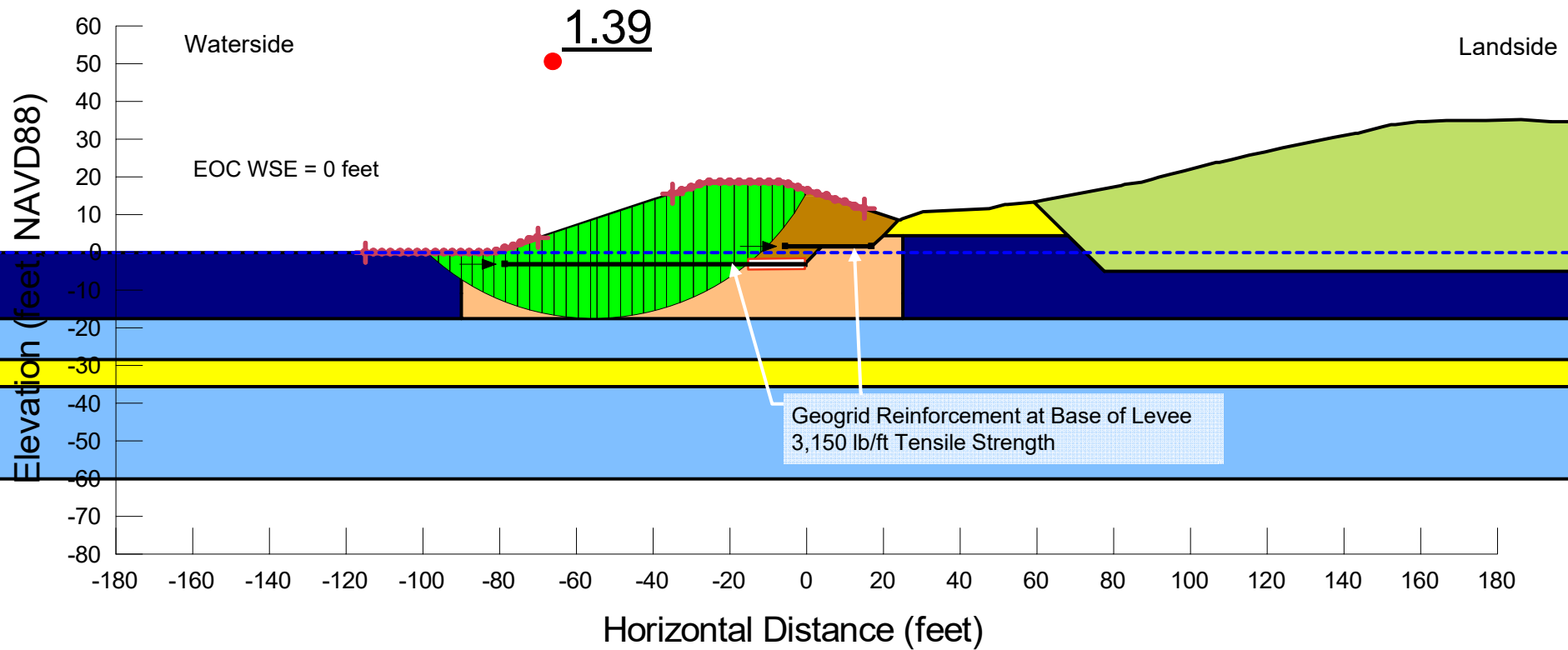
SAFER Bay Project, Task Order No. 2

Palo Alto, California



Cross Section G16
 End-of-Construction
 Stage 1 Levee with Geogrid

July 2016 Figure C-34



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

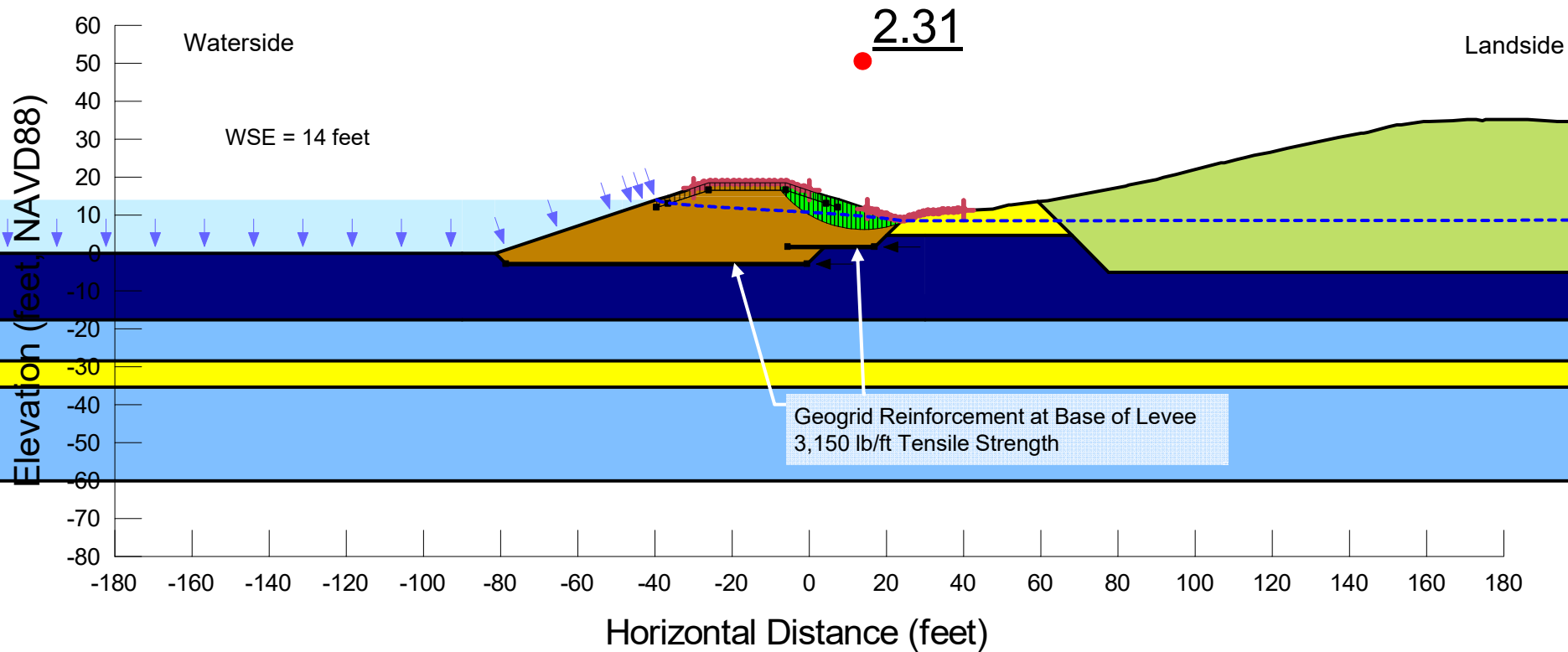
SAFER Bay Project, Task Order No. 2

Palo Alto, California



Cross Section G16
 End-of-Construction
 Stage 2 Levee with Geogrid

July 2016 Figure C-35



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

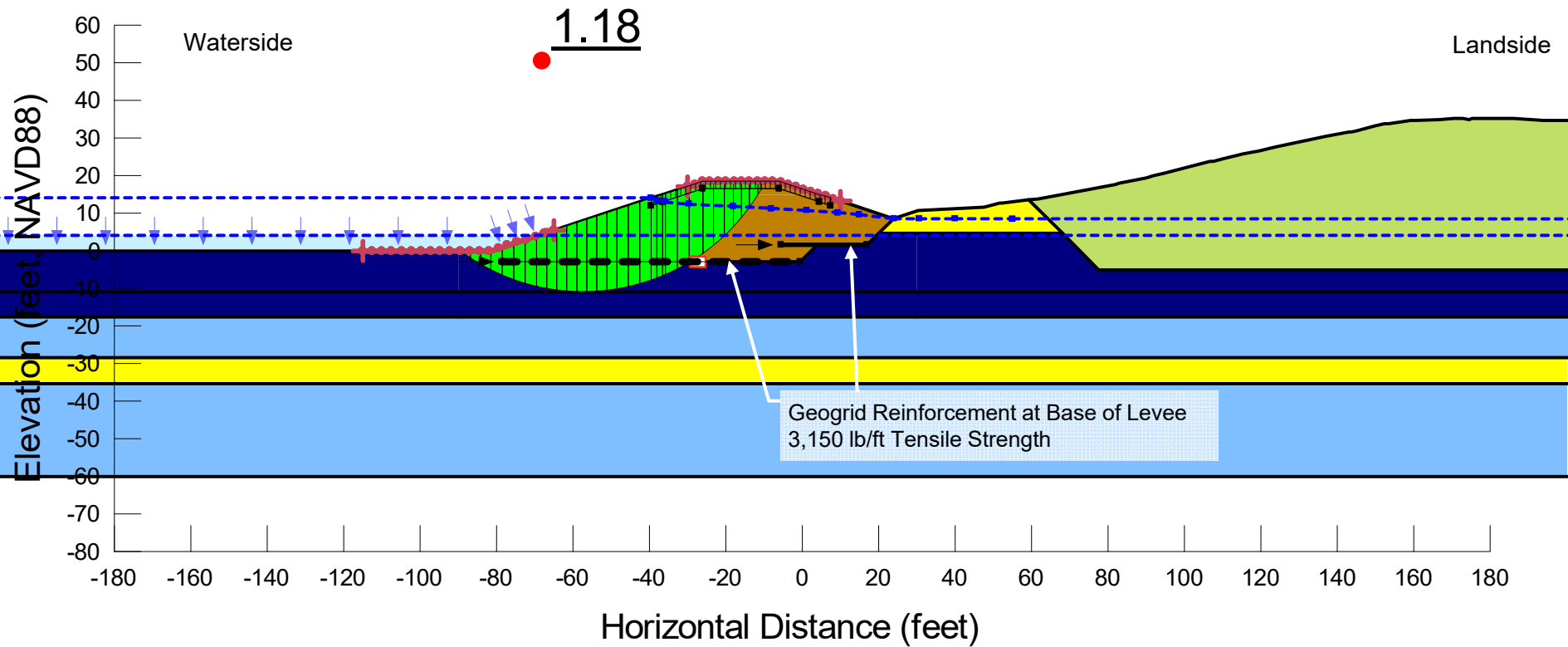


Cross Section G16

Steady-State Stability
with Geogrid

July 2016

Figure C-36



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



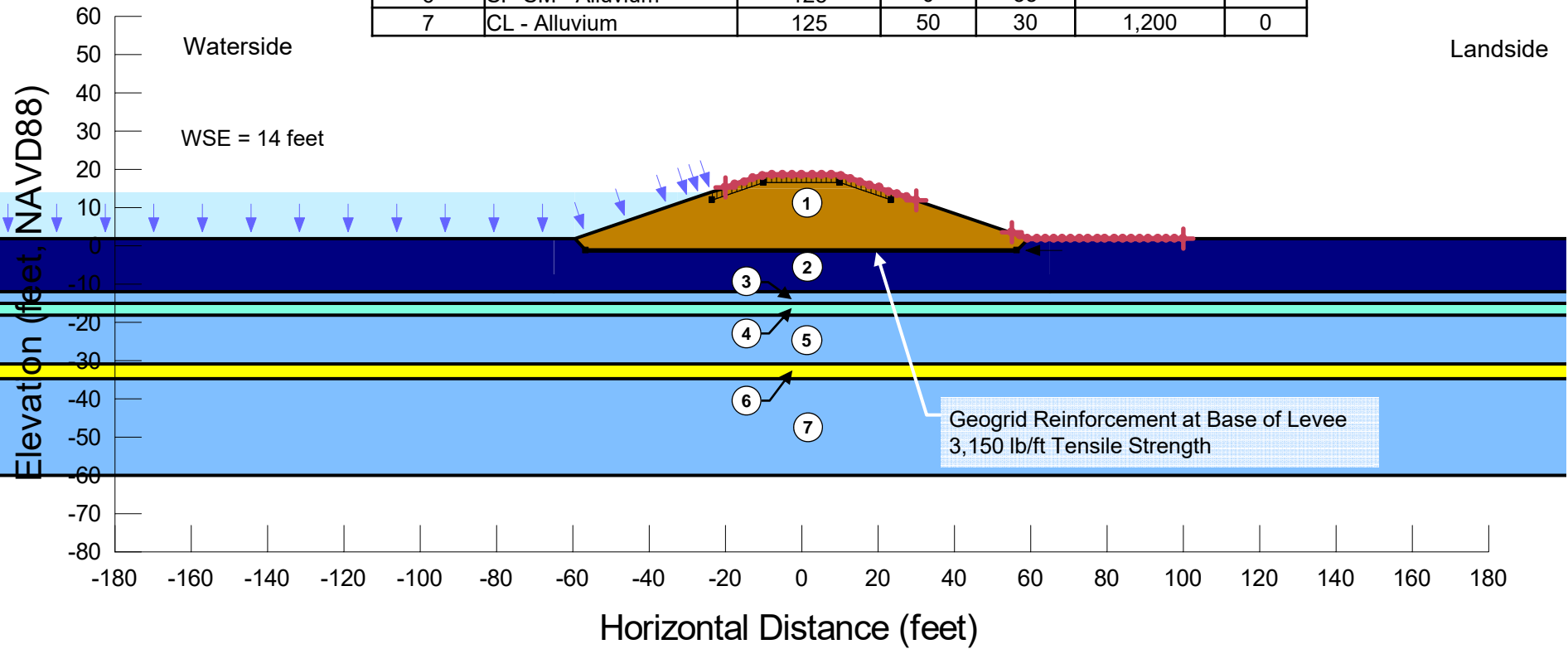
Cross Section G16

Waterside Rapid Drawdown
with Geogrid

July 2016

Figure C-37

Layer Number	Layer Name	Saturated Unit Weight (pcf)	Drained Parameters		Undrained Parameters	
			c' (psf)	ϕ' (deg.)	c (psf)	ϕ (deg.)
1	CL - Levee Fill	125	75	30	750	0
2	MH/CH - YBM	98	0	29	200-275	0
3	CL - Alluvium	125	50	30	700	0
4	SC - Alluvium	125	0	35	--	--
5	CL - Alluvium	125	50	30	1,000	0
6	SP-SM - Alluvium	125	0	35	--	--
7	CL - Alluvium	125 </td <td>50</td> <td>30</td> <td>1,200</td> <td>0</td>	50	30	1,200	0



SAFER Bay Project, Task Order No. 2

Palo Alto, California

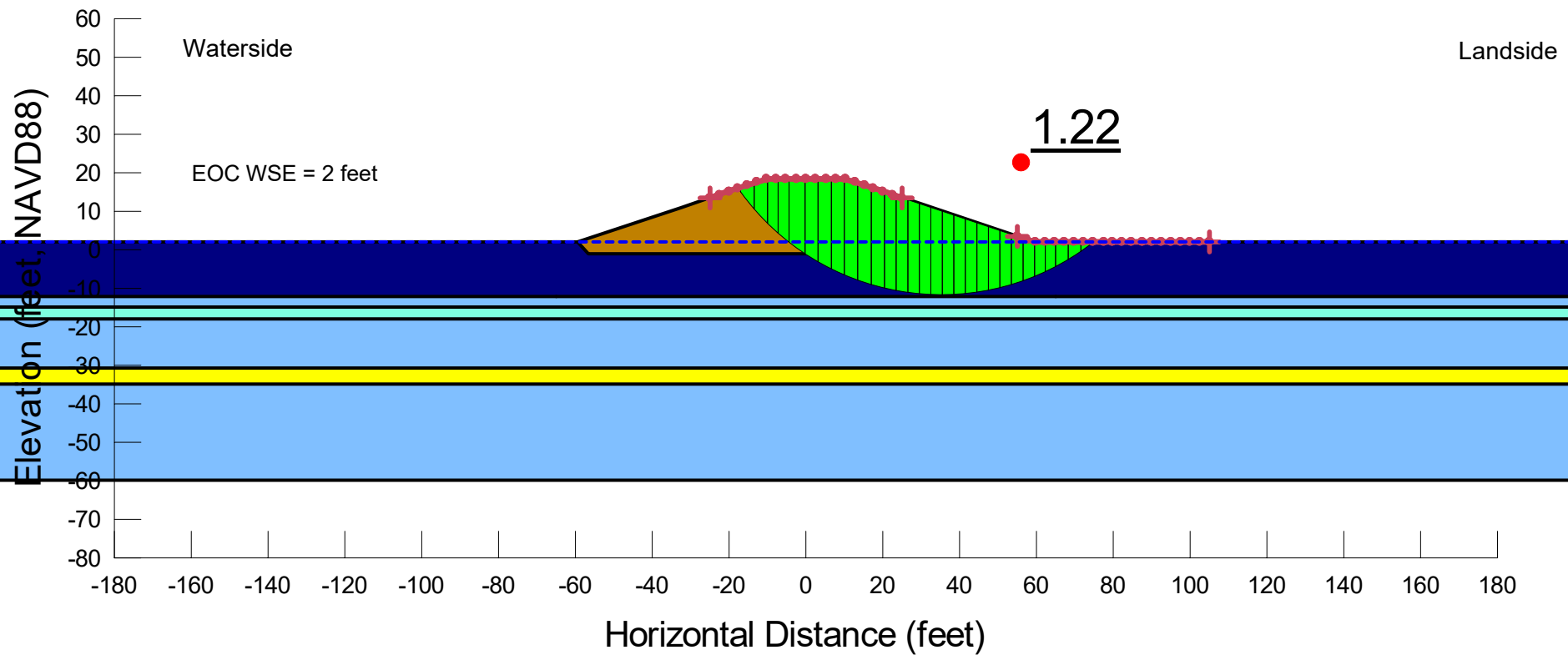


Cross Section G17

Stability Model

July 2016

Figure C-38



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

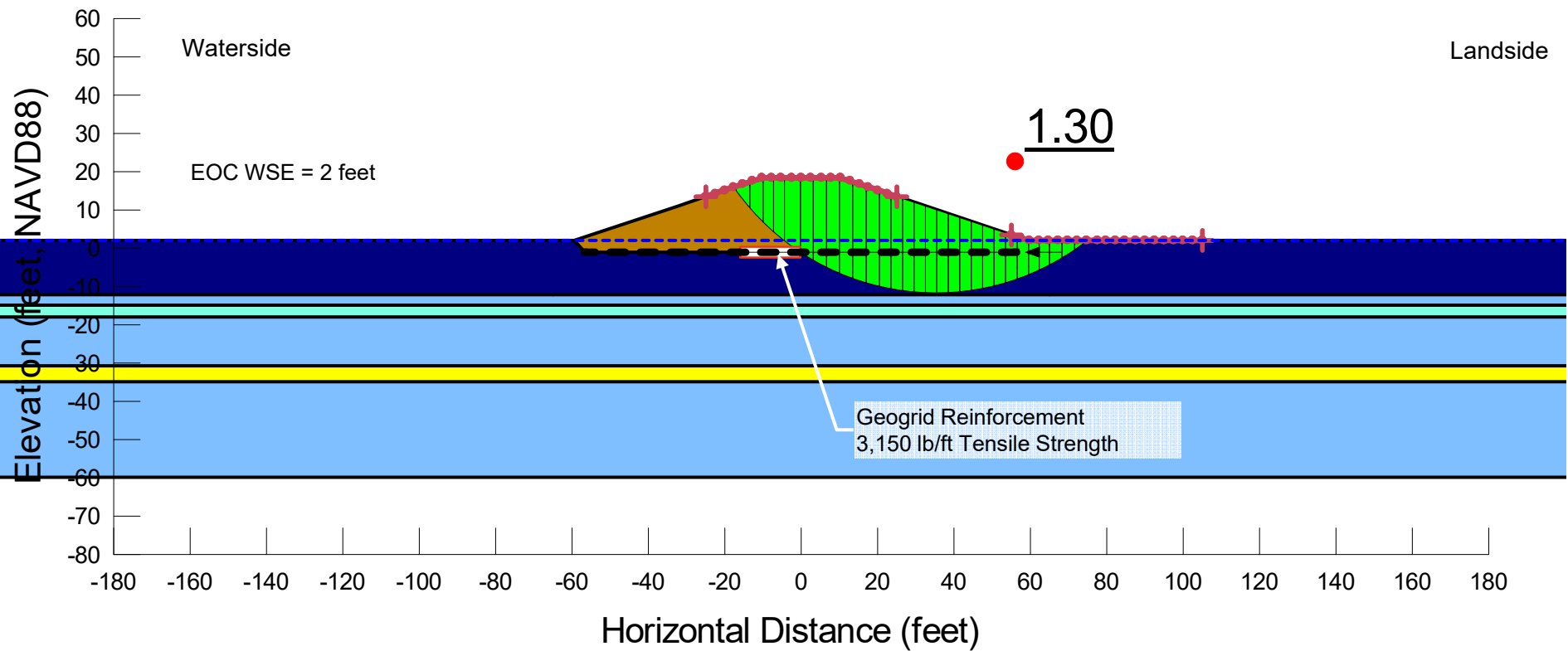


Cross Section G17

End-of-Construction
Full Levee without Geogrid

July 2016

Figure C-39



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

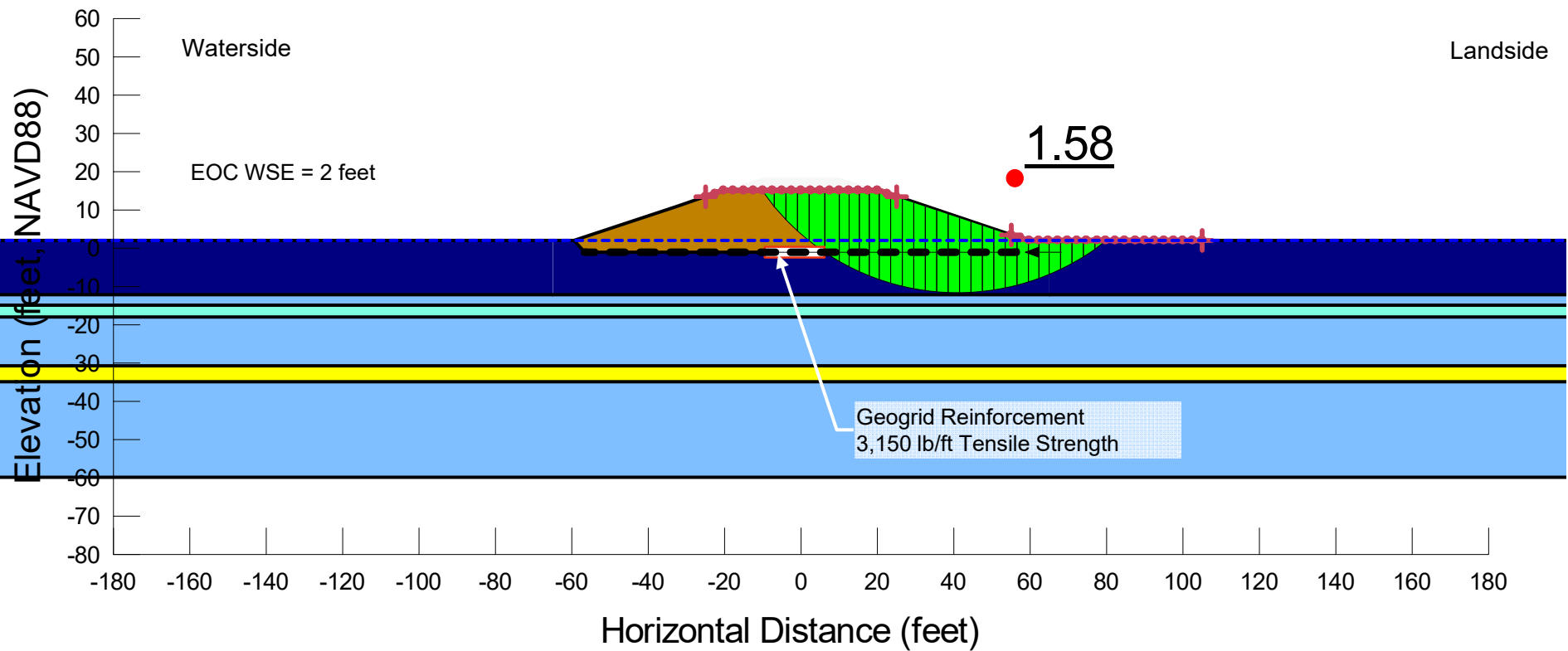
Palo Alto, California



Cross Section G17
End-of-Construction
Full Levee with Geogrid

July 2016

Figure C-40



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

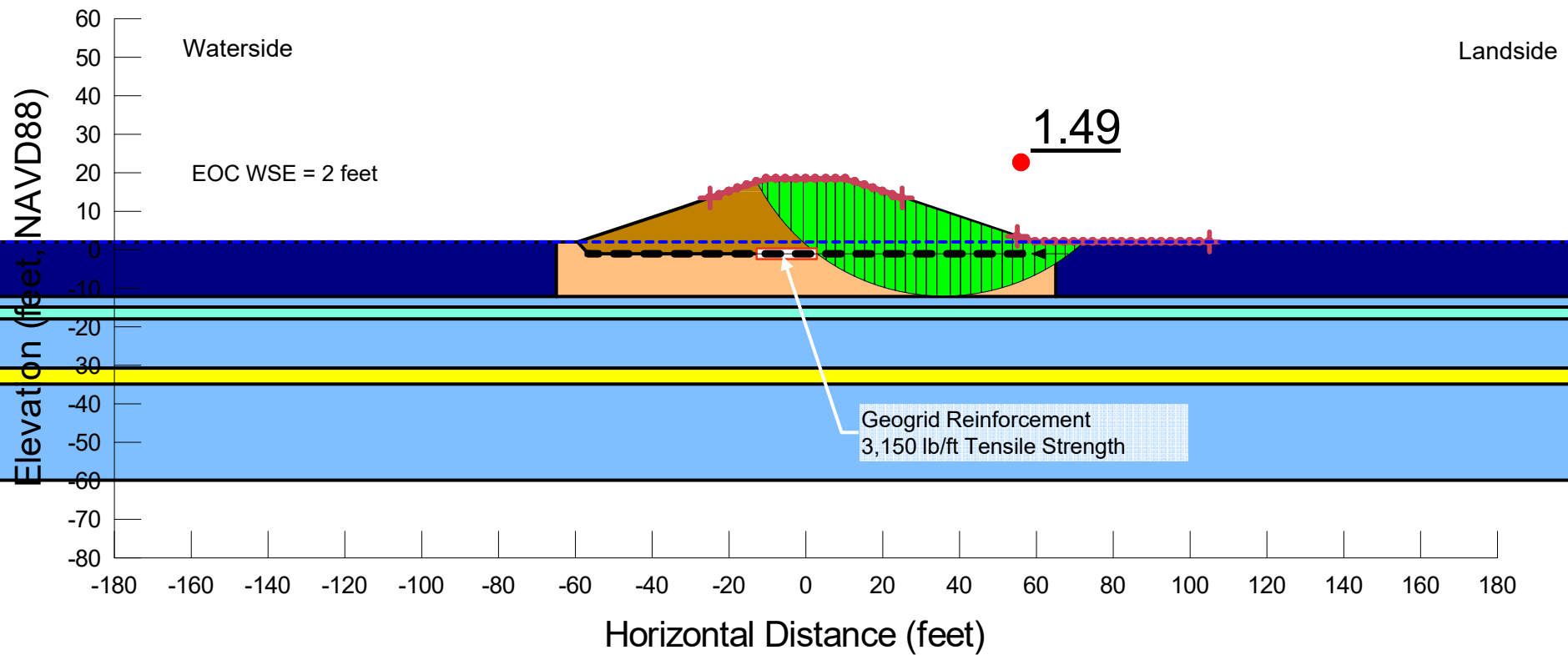


Cross Section G17

End-of-Construction
Stage 1 Levee with Geogrid

July 2016

Figure C-41



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. End-of-construction stability is shown only on the more critical side of the levee

SAFER Bay Project, Task Order No. 2

Palo Alto, California

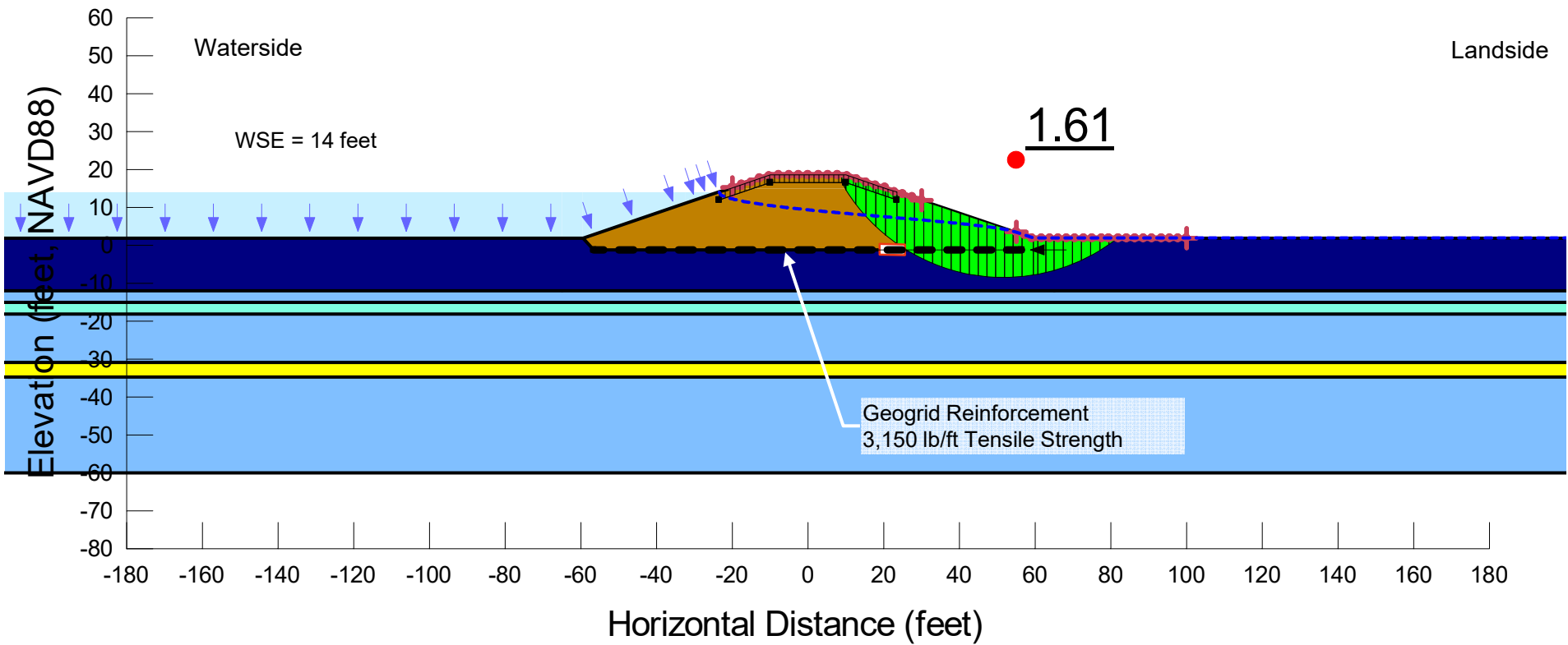


Cross Section G17

End-of-Construction
Stage 2 Levee with Geogrid

July 2016

Figure C-42



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. Pore pressures are calculated from the steady-state seepage model with WSE = 14 feet.
3. 2' deep tension cracks filled with water are assumed for landside steady-state stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California

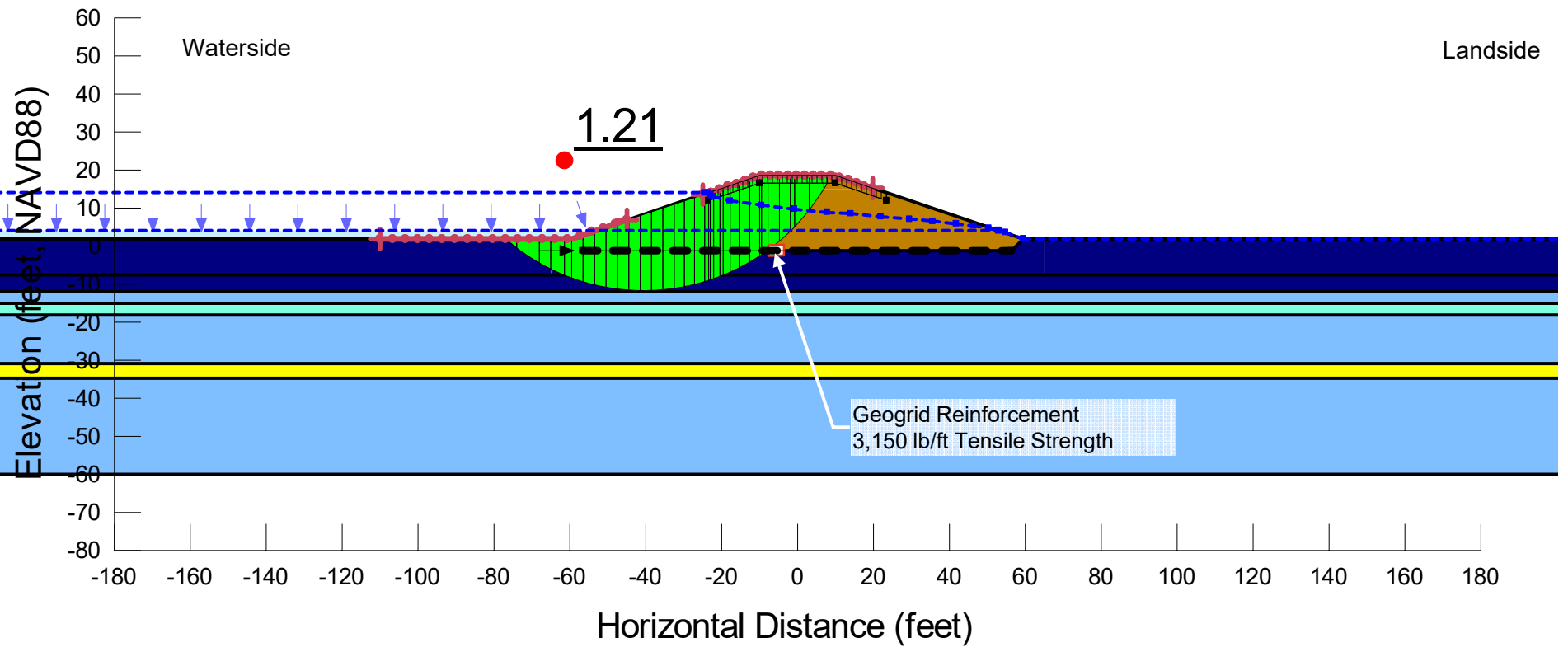


Cross Section G17

Steady-State Stability
with Geogrid

July 2016

Figure C-43



Notes:

1. The Factor of Safety (FS) value shown is for the critical failure surface.
2. 2' deep tension cracks filled with water are assumed for waterside rapid drawdown stability calculations.

SAFER Bay Project, Task Order No. 2

Palo Alto, California



Cross Section G17


Waterside Rapid Drawdown
with Geogrid

July 2016

Figure C-44



This page intentionally left blank.



Appendix D Seepage Analyses Results



This page intentionally left blank.



Appendix D contains the following:

Figures D-1 and D-2: Cross Section G9 – Located within Reach 10, and represents the segment along the east side and southern end of the Palo Alto Airport runway (both Options 1 and 2).

Figures D-3 and D-4: Cross section G10 – Located within Reach 10, and represents the segment of Reach 10 (both Options 1 and 2) from the southern end of the Palo Alto Airport runway, and along the Palo Alto WWTP to just before the Byxbee Park landfill.

Figures D-5 and D-6: Cross section G11 – Located within Reach 11, Option 1, and represents the northern segment of Reach 11, Option 1.

Figures D-7 and D-8: Cross section G12 – Located within Reach 11, Option 1, and represents the southern segment of Reach 11, Option 1.

Figures D-9 and D-10: Cross section G13 – Located within Reach 11, Option 2, and represents the segment of this reach and option that is situated along Adobe Creek, between the southern end of Charleston Slough and Highway 101.

Figures D-11 and D-12: Cross section G14 – Located within Reach 11, Option 2, and represents the segment of this reach and option that is situated along East Bayshore Road and the south and east sides of the Palo Alto Operations and Maintenance Facility.

Figures D-13 and D-14: Cross section G15 – Located within Reach 11, Option 2, and represents the segment of this reach that is situated along Matadero Creek west of the Palo Alto Operations and Maintenance Facility.

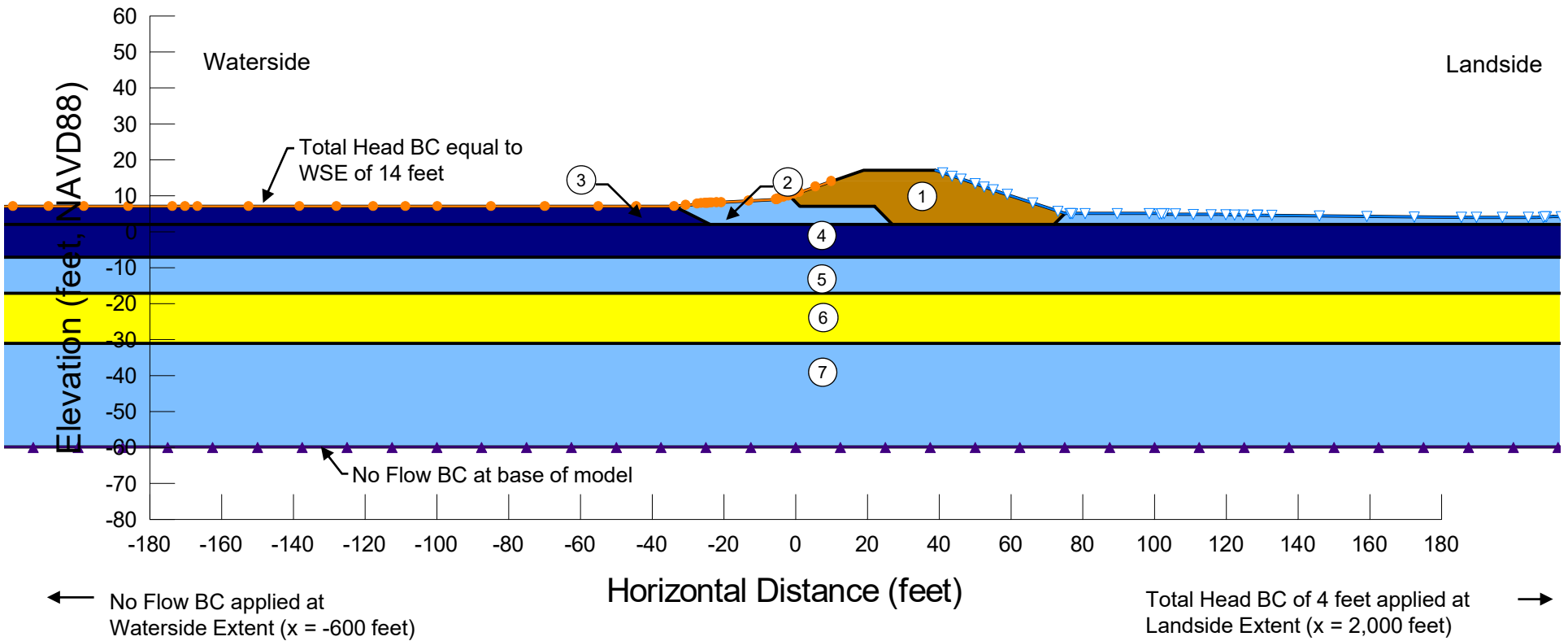
Figures D-15 and D-16: Cross section G16 – Located within Reach 11, Option 2a, and represents the segments of Reach 10 along the north side of the Byxbee Park landfill, Reach 11, Option 2a along the east side of the Byxbee Park landfill, and Reach 11, Option 2, between the landfill and the northern end of the Palo Alto Operations and Maintenance Facility.

Figures D-17 and D-18: Cross section G17 – Cross section G17 – Located within Reach 11, Option 3, and represents this reach and option across the Palo Alto flood control basin.



This page intentionally left blank.

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	CL - Existing Levee	1.0E-06	2.5E-07	4
3	MH/CH - YBM (Desiccated)	4.0E-06	1.0E-06	4
4	MH/CH - YBM	4.0E-07	1.0E-07	4
5	CL - Alluvium	1.0E-06	2.5E-07	4
6	SP-SM - Alluvium	1.0E-02	2.5E-03	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

Palo Alto, California

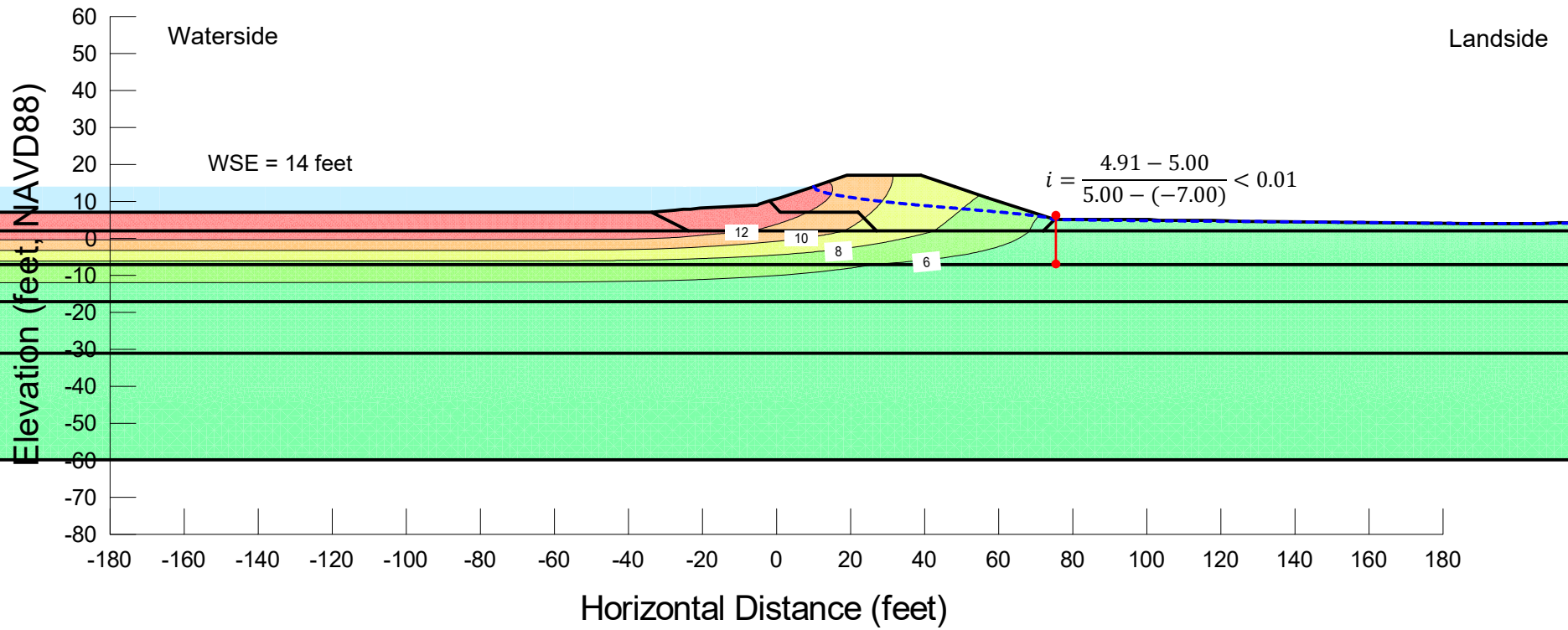


Cross Section G9

Steady-State Seepage Model

July 2016

Figure D-1



SAFER Bay Project, Task Order No. 2

Palo Alto, California



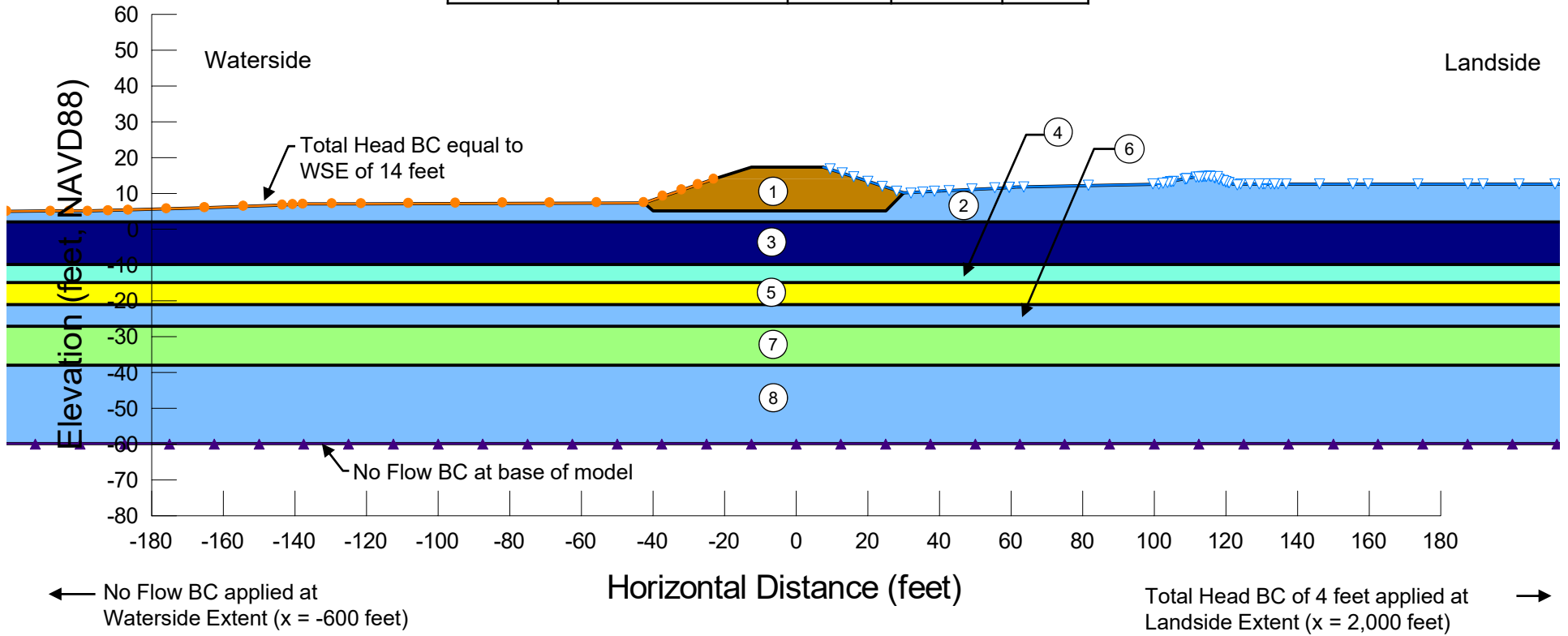
Cross Section G9

Steady-State Seepage Results

July 2016

Figure D-2

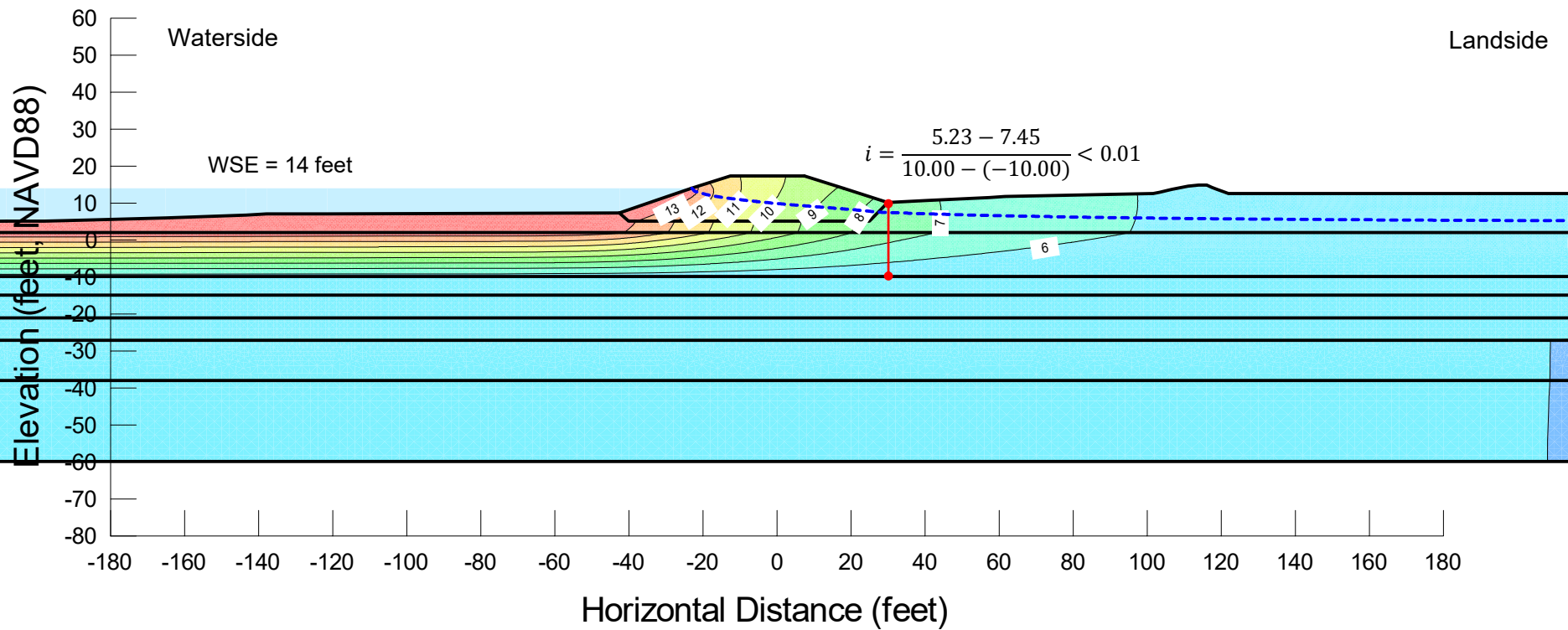
Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	MH/CL/SC – Fill	4.0E-06	1.0E-06	4
3	CH/MH – YBM	4.0E-07	1.0E-07	4
4	SC/CL – Alluvium	1.0E-05	2.5E-06	4
5	SP-SM – Alluvium	1.0E-02	2.5E-03	4
6	CL – Alluvium	1.0E-06	2.5E-07	4
7	SM – Alluvium	1.0E-03	2.5E-04	4
8	CL – Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2
 Palo Alto, California



Cross Section G10
 Steady-State Seepage Model
 July 2016 Figure D-3



SAFER Bay Project, Task Order No. 2

Palo Alto, California



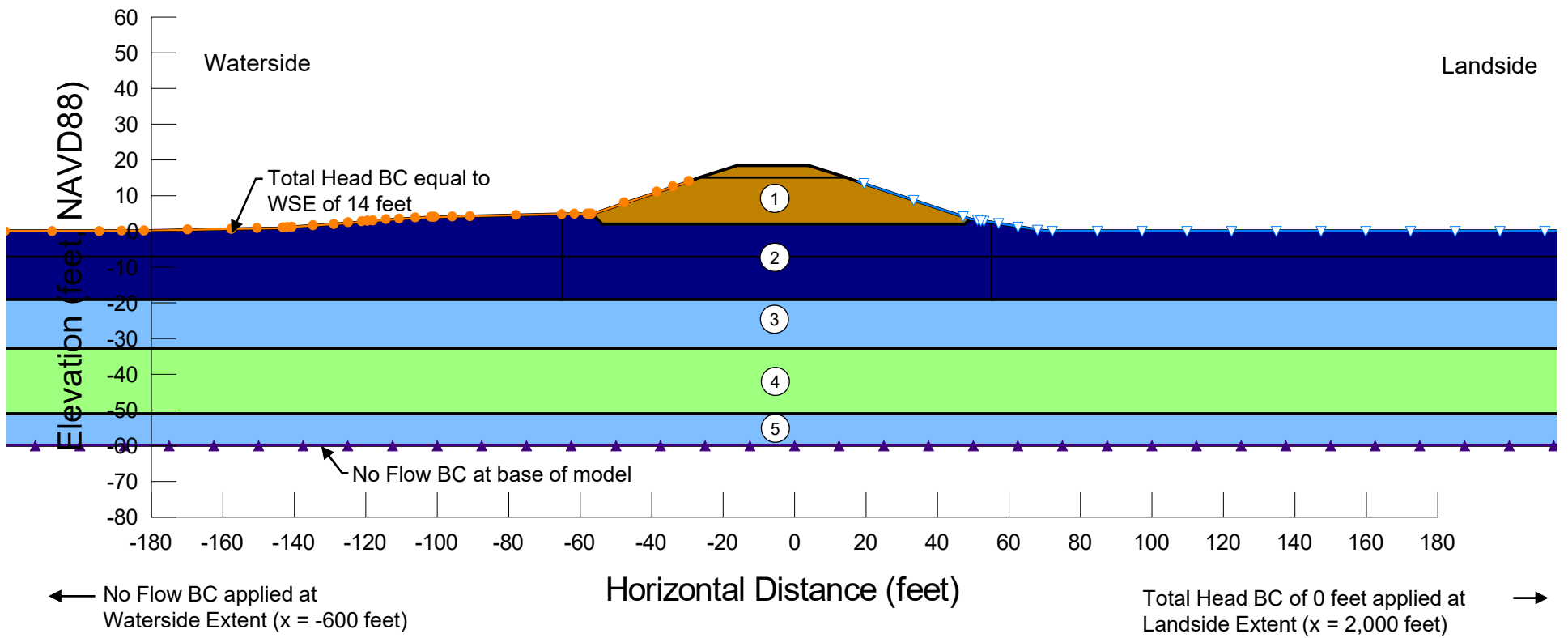
Cross Section G10

Steady-State Seepage Results

July 2016

Figure D-4

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL - Levee Fill	1.0E-06	2.5E-07	4
2	ML/CH -YBM	4.0E-07	1.0E-07	4
3	CL - Alluvium	1.0E-06	2.5E-07	4
4	SW-SC - Alluvium	1.0E-03	2.5E-04	4
5	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

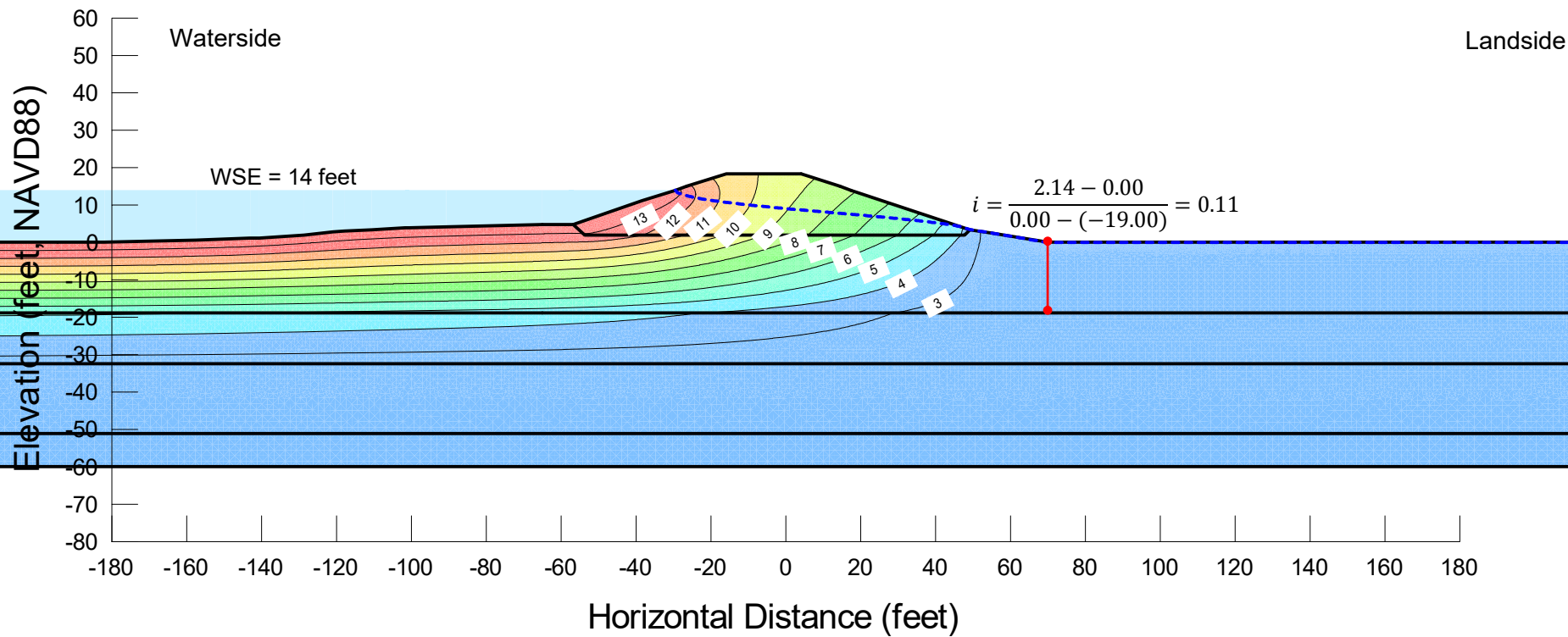
Palo Alto, California



Cross Section G11
Steady-State Seepage Model

July 2016

Figure D-5



SAFER Bay Project, Task Order No. 2

Palo Alto, California



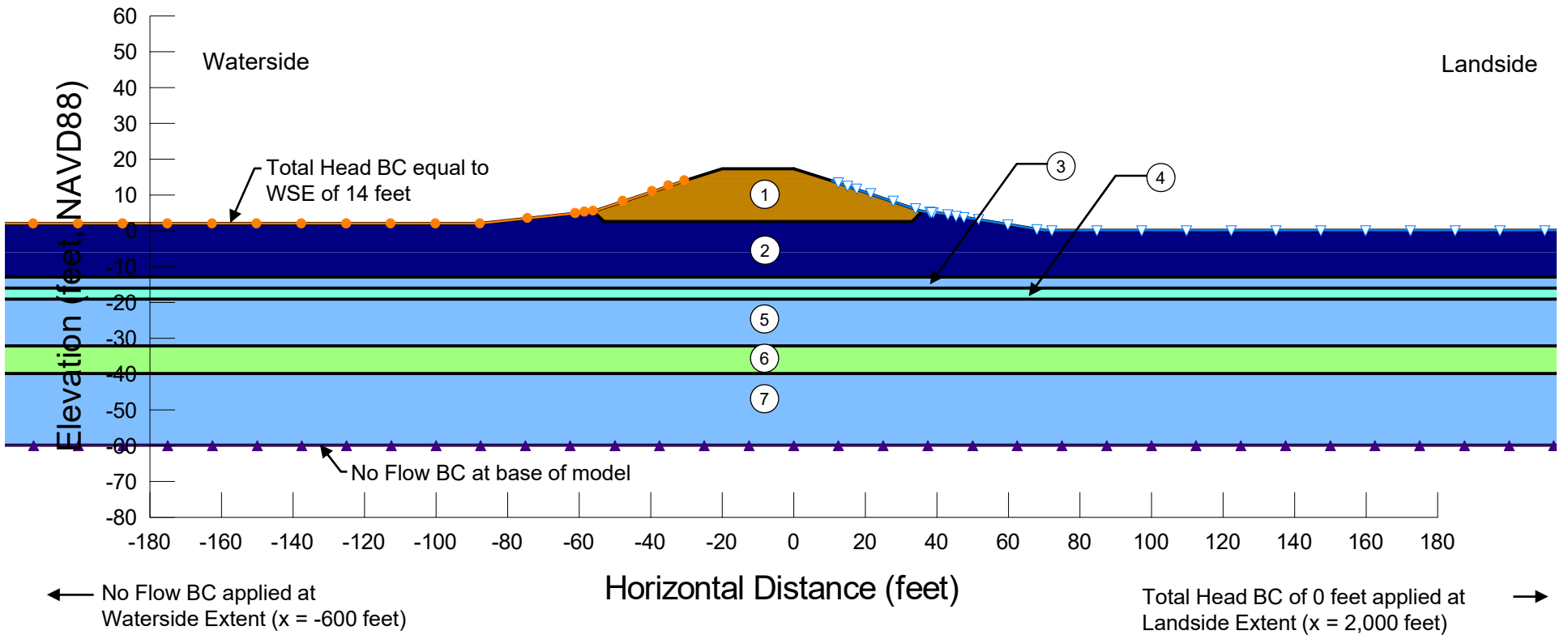
Cross Section G11

Steady-State Seepage Results

July 2016

Figure D-6

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	ML/CH – YBM	4.0E-07	1.0E-07	4
3	CL – Alluvium	1.0E-06	2.5E-07	4
4	SC – Alluvium	1.0E-04	2.5E-05	4
5	CL – Alluvium	1.0E-06	2.5E-07	4
6	SW-SC – Alluvium	1.0E-03	2.5E-04	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

Palo Alto, California

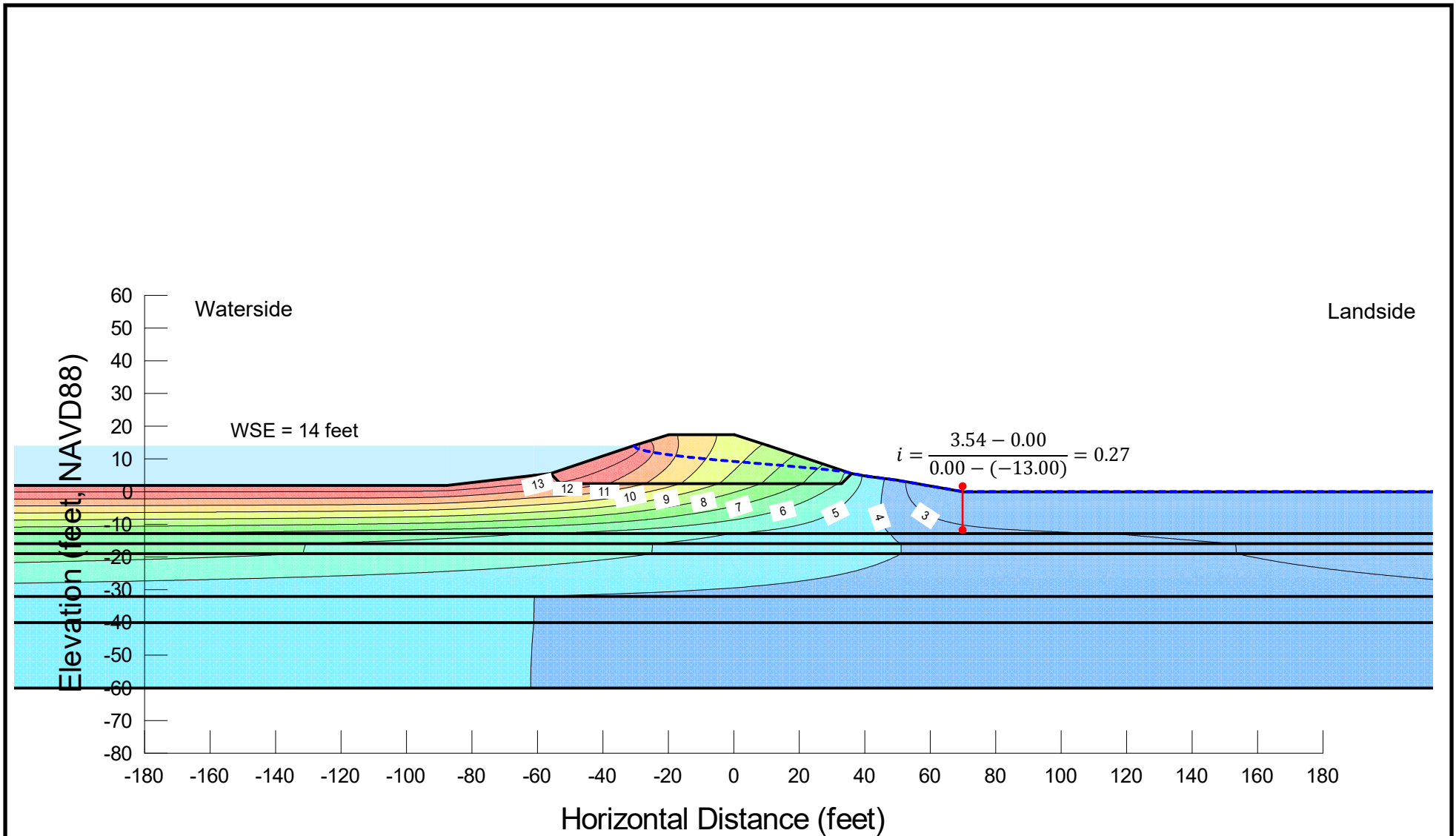


Cross Section G12

Steady-State Seepage Model

July 2016

Figure D-7



SAFER Bay Project, Task Order No. 2

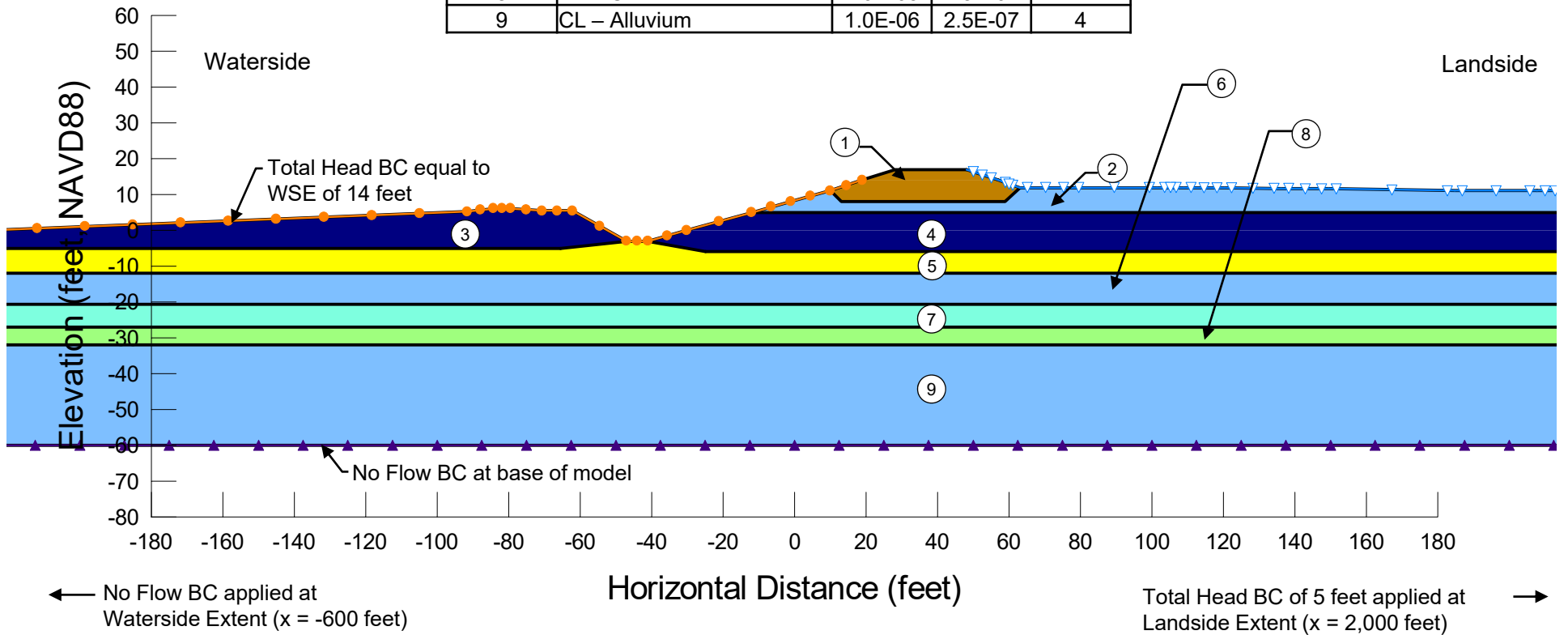
Palo Alto, California



Cross Section G12
Steady-State Seepage Results

July 2016 Figure D-8

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	CL – Fill	1.0E-06	2.5E-07	4
3	MH/CH – YBM	4.0E-06	1.0E-06	4
4	MH/CH – YBM (Desiccated)	4.0E-07	1.0E-07	4
5	SW-SC – Alluvium	1.0E-02	2.5E-03	4
6	CL – Alluvium	1.0E-06	2.5E-07	4
7	ML – Alluvium	1.0E-04	2.5E-05	4
8	SP-SC – Alluvium	1.0E-03	2.5E-04	4
9	CL – Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

Palo Alto, California

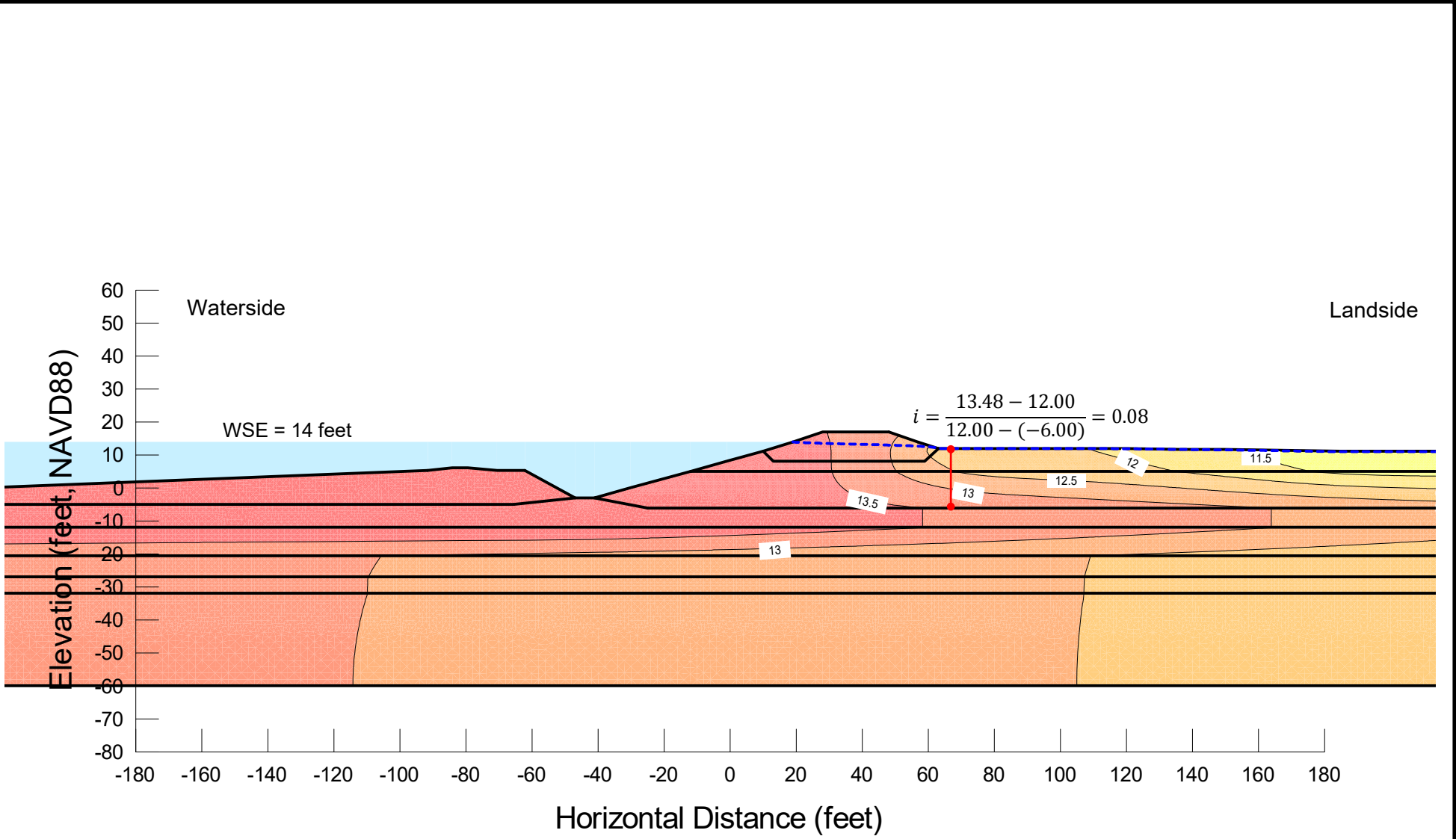


Cross Section G13

Steady-State Seepage Model

July 2016

Figure D-9



SAFER Bay Project, Task Order No. 2

Palo Alto, California

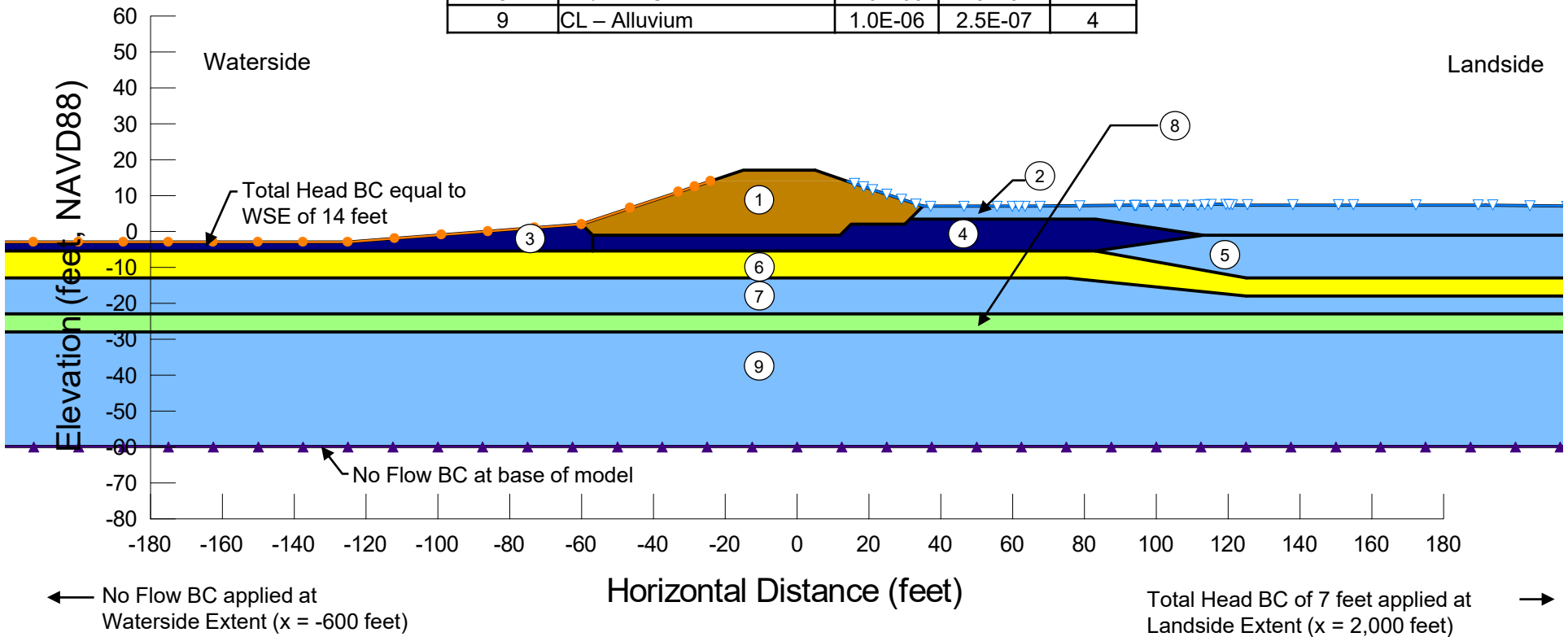


Cross Section G13
Steady-State Seepage Results

July 2016

Figure D-10

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee Fill	1.0E-06	2.5E-07	4
2	CL – Existing Levee	1.0E-06	2.5E-07	4
3	CH – YBM (Desiccated)	4.0E-06	1.0E-06	4
4	CH – YBM	4.0E-07	1.0E-07	4
5	CL – Alluvium	1.0E-06	2.5E-07	4
6	SW-SM – Alluvium	1.0E-02	2.5E-03	4
7	CL – Alluvium	1.0E-06	2.5E-07	4
8	SM/SP-SC – Alluvium	1.0E-03	2.5E-04	4
9	CL – Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

Palo Alto, California

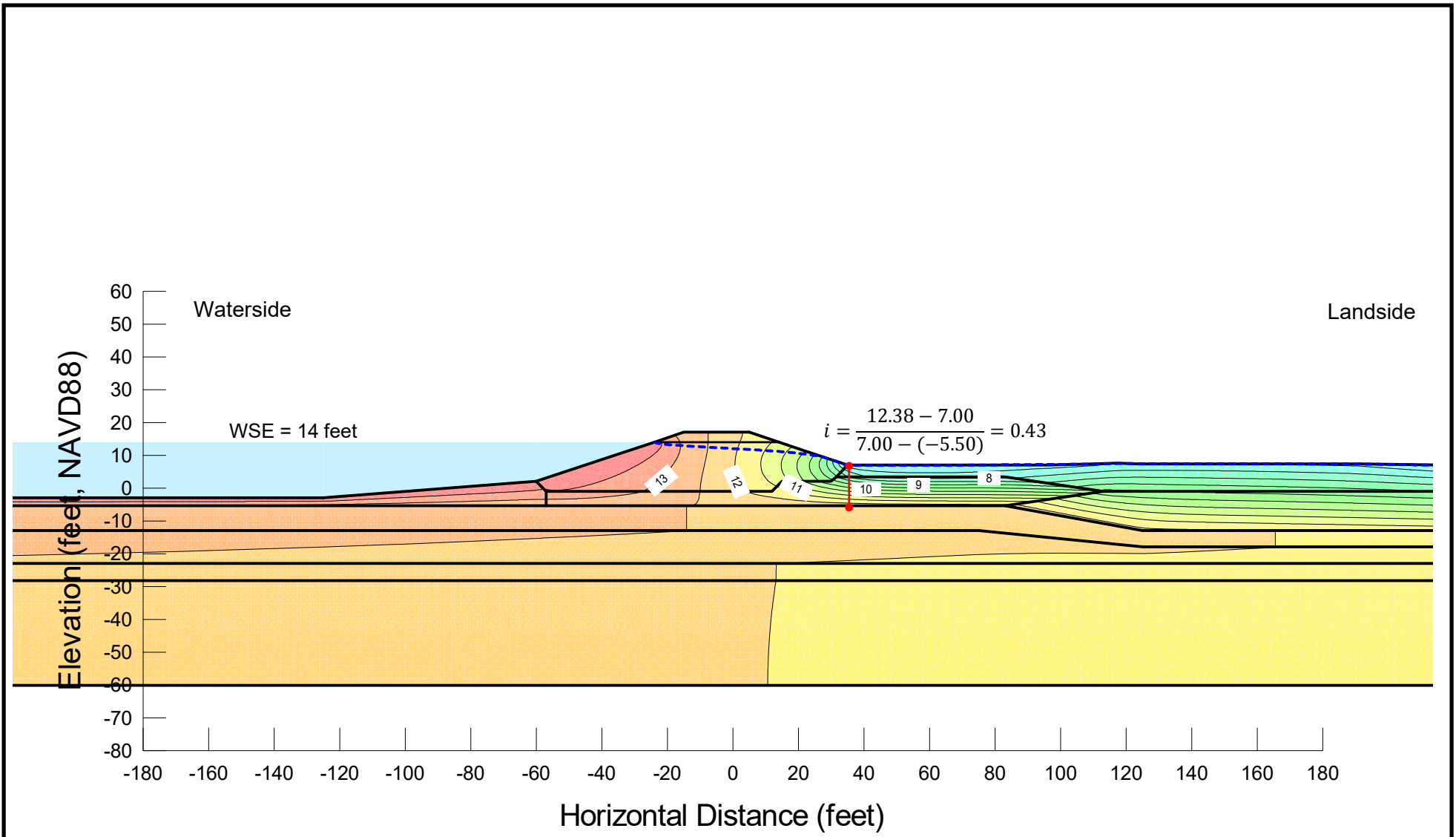


Cross Section G14

Steady-State Seepage Model

July 2016

Figure D-11



SAFER Bay Project, Task Order No. 2

Palo Alto, California

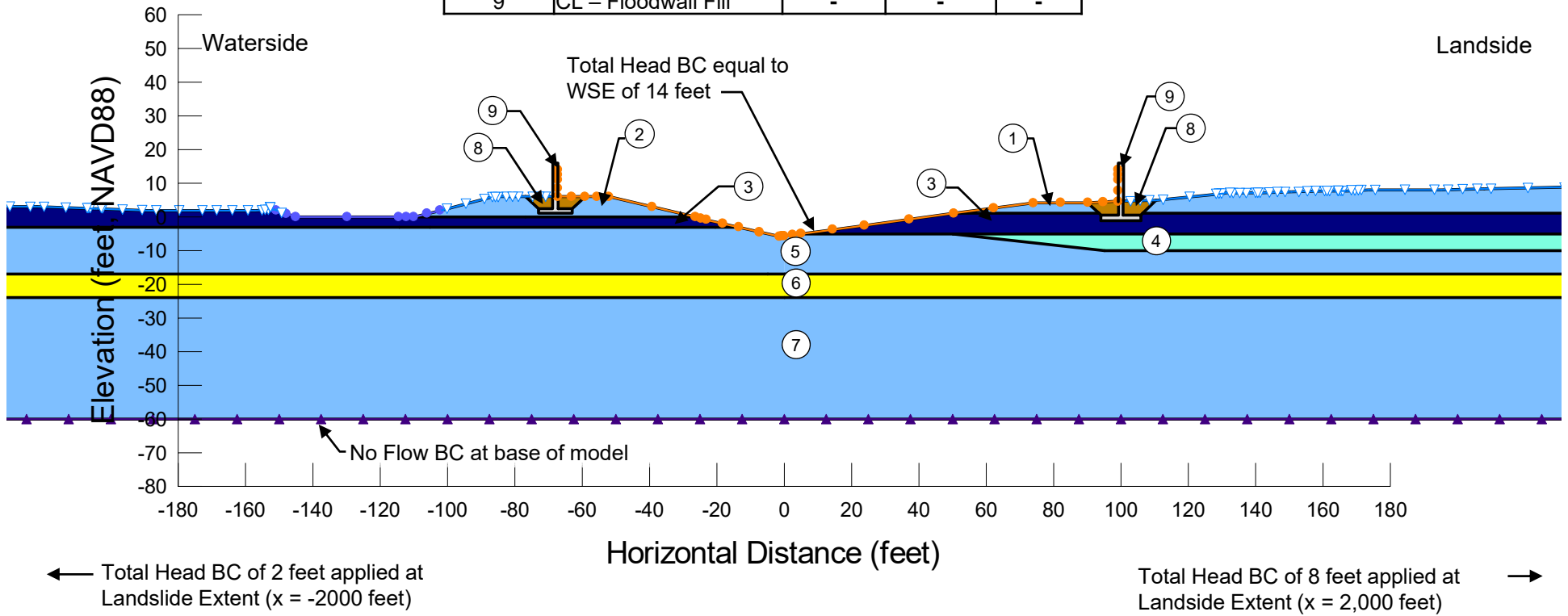


Cross Section G14
Steady-State Seepage Results

July 2016

Figure D-12

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CH – Fill	1.0E-06	2.5E-07	4
2	CL – Existing Levee	1.0E-06	2.5E-07	4
3	CH – YBM	4.0E-07	1.0E-07	4
4	SC – Alluvium	1.0E-05	2.5E-06	4
5	CL – Alluvium	1.0E-06	2.5E-07	4
6	SP-SM – Alluvium	1.0E-02	2.5E-03	4
7	CL – Alluvium	1.0E-06	2.5E-07	4
8	CL – Floodwall Fill	1.0E-06	2.5E-07	4
9	CL – Floodwall Fill	-	-	-



SAFER Bay Project, Task Order No. 2

Palo Alto, California

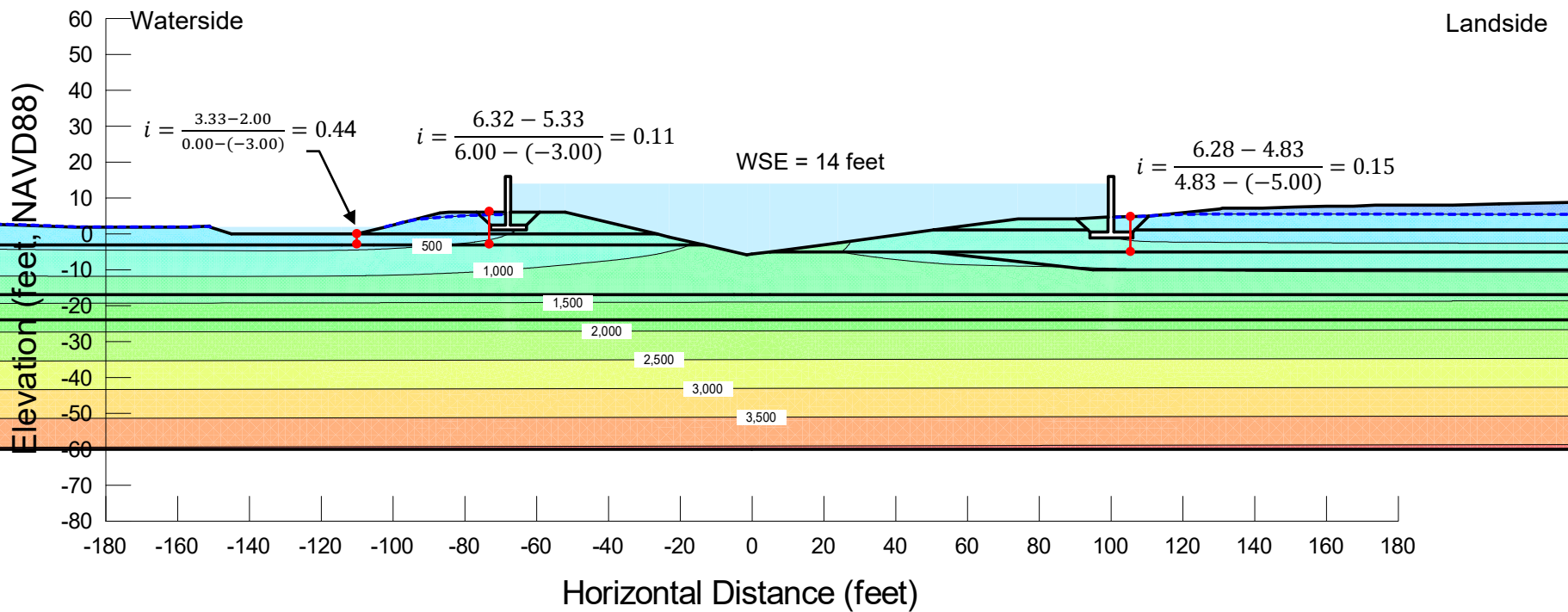


Cross Section G15

Steady-State Seepage Model

July 2016

Figure D-13



SAFER Bay Project, Task Order No. 2

Palo Alto, California



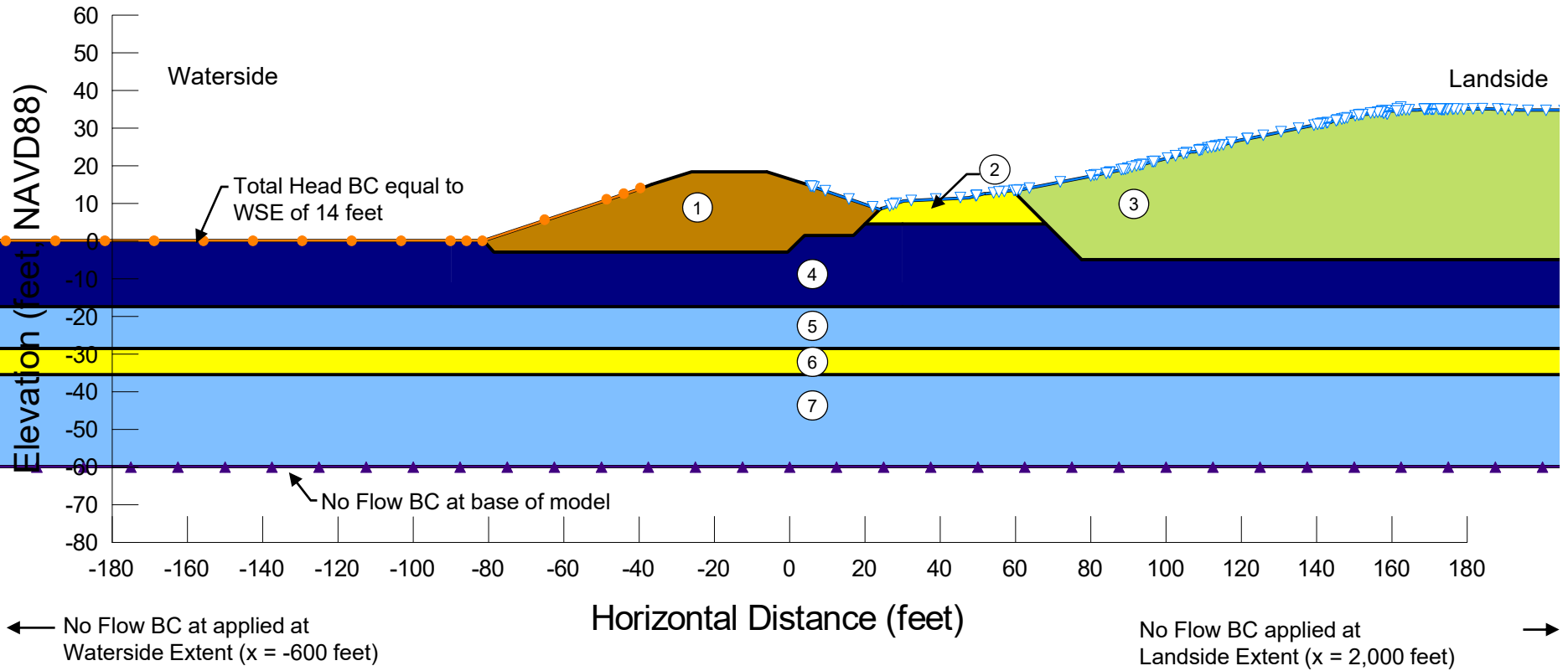
Cross Section G15

Steady-State Seepage Results

July 2016

Figure D-14

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee	1.0E-06	2.5E-07	4
2	SP-SM – Fill	1.0E-02	2.5E-03	4
3	Refuse – Landfill	4.0E-04	1.0E-04	4
4	MH/CH – YBM	4.0E-07	1.0E-07	4
5	CL – Alluvium	1.0E-06	2.5E-07	4
6	SP-SM – Alluvium	1.0E-02	2.5E-03	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

Palo Alto, California

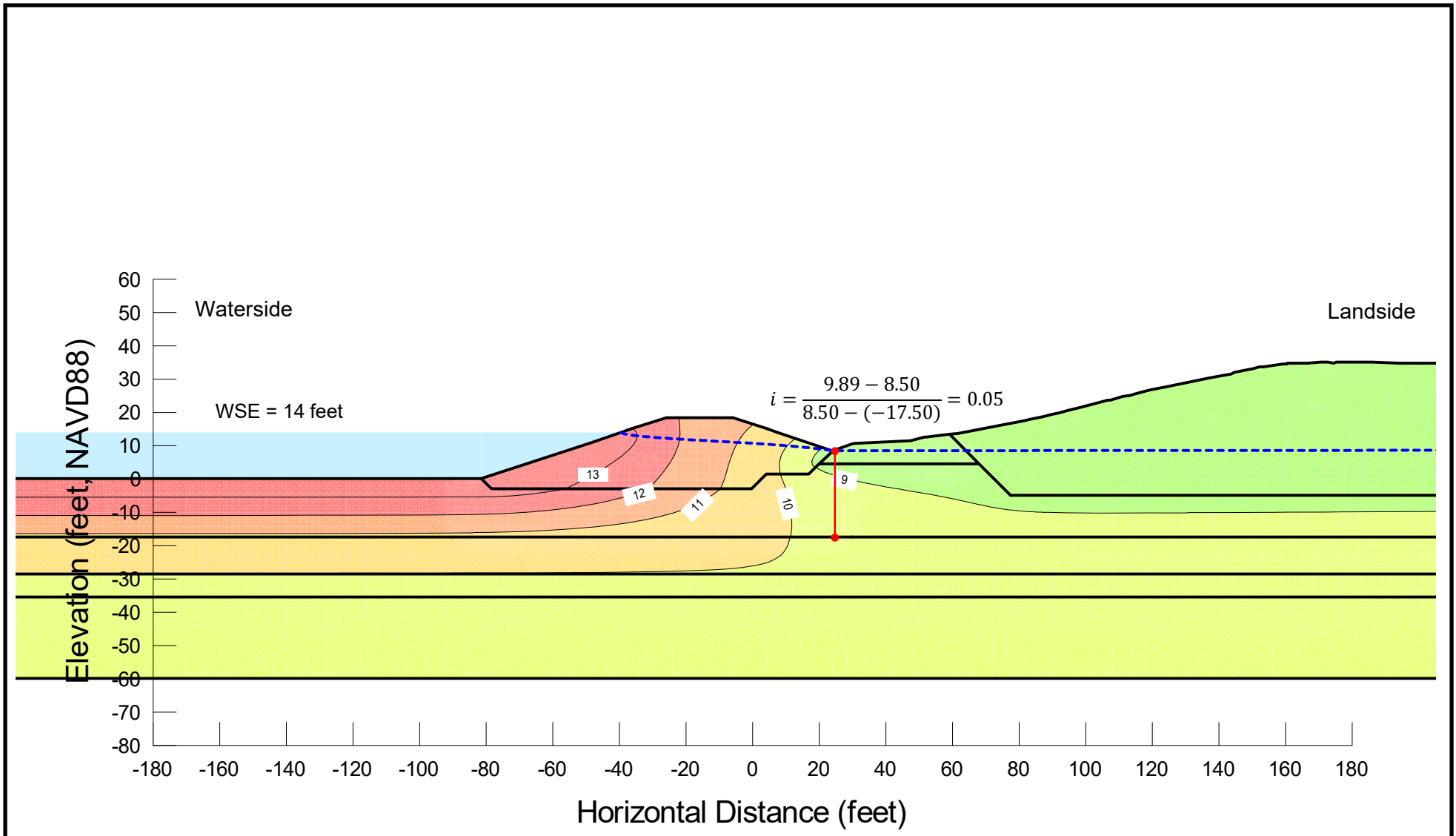


Cross Section G16

Steady-State Seepage Model

July 2016

Figure D-15



SAFER Bay Project, Task Order No. 2

Palo Alto, California

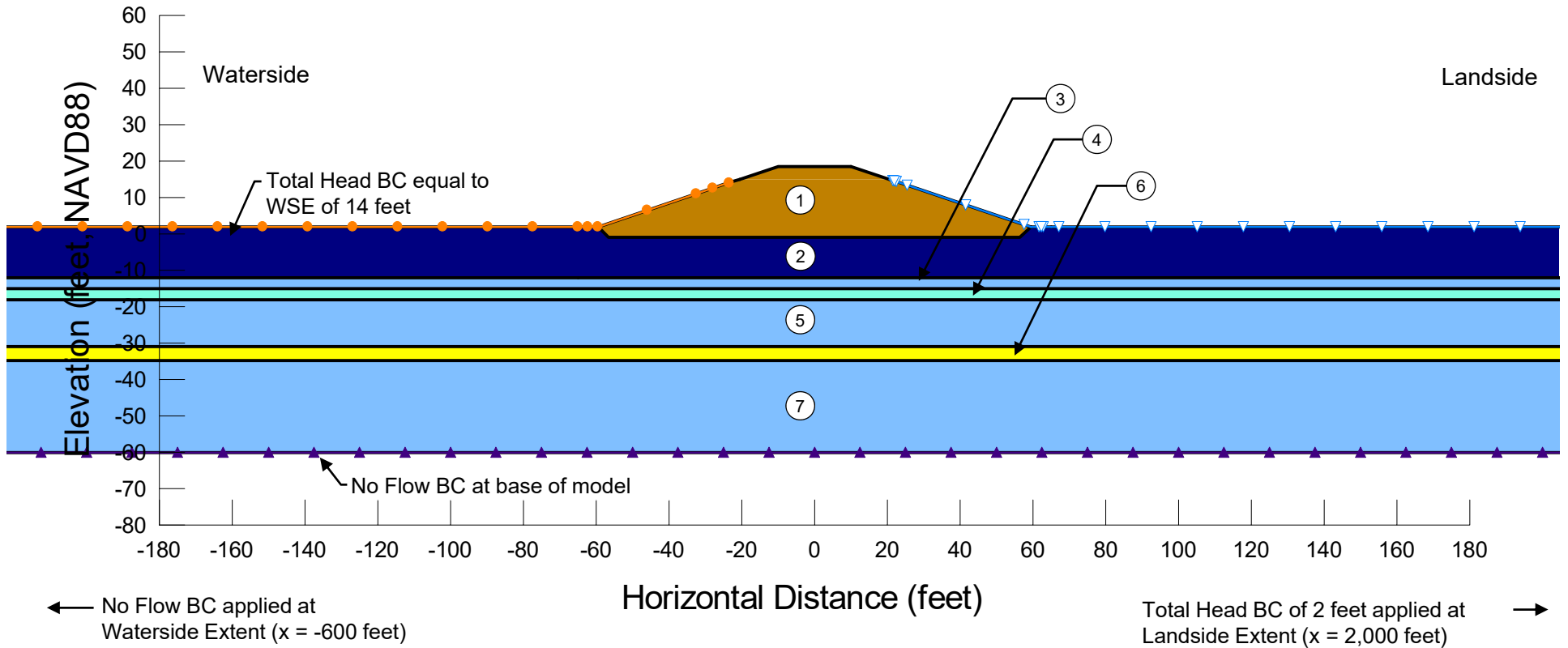


Cross Section G16
Steady-State Seepage Results

July 2016

Figure D-16

Layer Number	Layer Name	k_h	k_v	k_h/k_v
		(cm/sec)	(cm/sec)	(-)
1	CL – Levee	1.0E-06	2.5E-07	4
2	ML/CH – YBM	4.0E-07	1.0E-07	4
3	CL – Alluvium	1.0E-06	2.5E-07	4
4	SC – Alluvium	1.0E-04	2.5E-05	4
5	CL – Alluvium	1.0E-06	2.5E-07	4
6	SP-SM – Alluvium	1.0E-02	2.5E-03	4
7	CL - Alluvium	1.0E-06	2.5E-07	4



SAFER Bay Project, Task Order No. 2

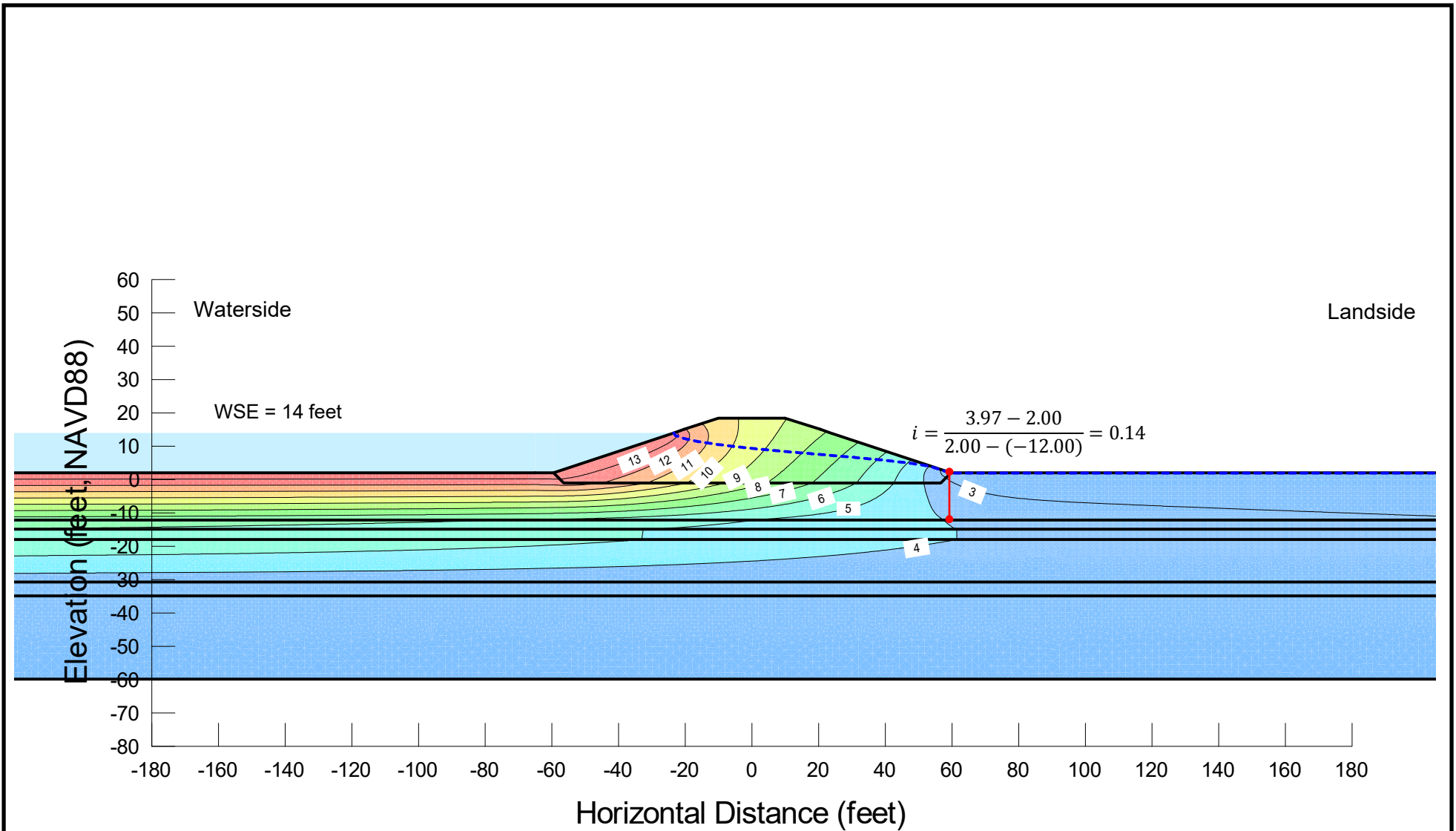
Palo Alto, California



Cross Section G17
Steady-State Seepage Model

July 2016

Figure D-17



SAFER Bay Project, Task Order No. 2

Palo Alto, California



Cross Section G17
Steady-State Seepage Results

July 2016 Figure D-18

Appendix C - Individual Reach Feasibility Evaluation Factors and Consideration Scoring Metrics

Construction Cost and Constructability

Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	\$ 27,271,000	4	\$ 28,698,000	4	\$ 26,301,000	4
Reach 11	\$ 90,372,000	2	\$ 258,497,000	1	\$ 80,672,000	2

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3 \$ 106,973,000	6
2, Restoration Alternative	3 \$ 287,195,000	5
3, Recreation Alternative	3 \$ 117,643,000	6

Lifecycle Cost

Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Minor Difficulty	4	Moderate Difficulty	3	Moderate Difficulty	3
Reach 11	Some Difficulty	2	Moderate Difficulty	3	Most Difficulty	1

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	2	4
2, Restoration Alternative	3	6
3, Recreation Alternative	3	6

Construction Schedule

Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	1 Season	4	1 Season	4	1 Season	4
Reach 11	3 Seasons	2	3 Seasons	2	3+ Seasons	1

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	5
2, Restoration Alternative	3	6
3, Recreation Alternative	3	6

Construction Considerations

Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Minor Difficulty	4	Some Difficulty	2	Minor Difficulty	4
Reach 11	Moderate Difficulty	3	Most Difficulty	1	Some Difficulty	2

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	6
2, Restoration Alternative	2	3
3, Recreation Alternative	4	7

Real Estate and Access

Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Moderate Impacts	3	Severe Impacts	2	Most Impacts	1
Reach 11	Modest Impacts	4	Most Impacts	1	Moderate Impacts	3

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	2	5
2, Restoration Alternative	2	3
3, Recreation Alternative	4	7

Operation and Maintenance						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Minor Difficulty	4	Moderate Difficulty	3	Minor Difficulty	4
Reach 11	Most Difficulty	1	Some Difficulty	2	Most Difficulty	1

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	5
2, Restoration Alternativ	3	5
3, Recreation Alternative	3	5

Debris and Sediment Management						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Easiest	5	Easiest	5	Easiest	5
Reach 11	Most Difficulty	1	Easiest	5	Most Difficulty	1

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	6
2, Restoration Alternativ	5	10
3, Recreation Alternative	3	6

Passive / Active						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Passive & Active	3	Mostly Active	2	Passive & Active	3
Reach 11	Mostly Active	2	Passive	5	Mostly Active	2

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	5
2, Restoration Alternativ	4	7
3, Recreation Alternative	3	5

Flood Fighting Accessibility						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Moderate	3	Moderate	3	Moderate	3
Reach 11	Very Poor	1	Poor	2	Poor	2

	<u>Average</u>	<u>Sum</u>
1, Low Cost Alternative	3	5
2, Restoration Alternativ	3	5
3, Recreation Alternative	2	4

Restoration						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	87	2	174	3	154	3
Reach 11	0	1	679	5	347	4
	<u>Average</u>		<u>Sum</u>			
1, Low Cost Alternative		4		7		
2, Restoration Alternativ		4		8		
3, Recreation Alternative		2		3		

Interagency Coordination						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Poor	2	Very Poor	1	Moderate	3
Reach 11	Moderate	3	Very Poor	1	Moderate	3
	<u>Average</u>		<u>Sum</u>			
1, Low Cost Alternative		3		6		
2, Restoration Alternativ		1		2		
3, Recreation Alternative		3		5		

Environmental - Potential Impacts / Migitation Requirements						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Most Impacts	1	Modest Impacts	4	Moderate Impacts	3
Reach 11	Most Impacts	1	Severe Impacts	2	Moderate Impacts	3
	<u>Average</u>		<u>Sum</u>			
1, Low Cost Alternative		3		6		
2, Restoration Alternativ		3		6		
3, Recreation Alternative		1		2		

Recreation, Bay Trail						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Good	4	Moderate	3	Good	4
Reach 11	Excellent	5	Poor	2	Moderate	3
	<u>Average</u>			<u>Sum</u>		
1, Low Cost Alternative		4		7		
2, Restoration Alternative		3		5		
3, Recreation Alternative		5		9		

Interpretive / Viewing						
Reaches	Option 1	Points	Option 2	Points	Option 3	Points
Reach 10	Moderate Impacts	3	Moderate Impacts	3	Moderate Impacts	3
Reach 11	No Impacts	5	Most Impacts	1	Moderate Impacts	3
	<u>Average</u>			<u>Sum</u>		
1, Low Cost Alternative		3		6		
2, Restoration Alternative		2		4		
3, Recreation Alternative		4		8		

Appendix D - Individual Reach Feasibility Level Cost Estimates



Project SAFER BAY TO 2 Job No : 10022067 Computed: LJ - DEC 2018

Subject SAFER BAY Feasibility Cost Analysis Checked: NG - DEC 2018

REACH 10 OPTION 1

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition	-	-	-	-	-	21.9	AC	\$0.00	\$0
A2	Mobilization/Demobilization	-	-	-	-	-	1	LS	\$904,800	\$904,800
A3	Traffic Control	-	-	-	-	-	1	LS	\$181,000	\$181,000
A4	Erosion Control	-	-	-	-	-	1	LS	\$181,000	\$181,000
A5	Tree Removal	-	-	-	-	-	60	EA	\$5,000	\$300,000
A6	Clearing and Grubbing	1,820	117	-	G8	-	21.9	AC	\$5,000	\$109,600
		3,168	97	-	G9	-				
		4,706	92	-	G10	-				
A7	Demolition - Existing Bike Path - Aggregate	4,663	8	-	G8 & G9	-	4,145	SY	\$12	\$49,800
A8	Excavation	1,820	-	-	G8	204	83,040	CY	\$20	\$1,660,800
		3,168	-	-	G9	248				
		4,706	-	-	G10	231				
A9	Relocate Sanitary Sewer	1,795	-	-	-	-	1,795	LF	\$537	\$963,758
A10	Levee Embankment - Above Water	1,820	-	-	G8	405	154,899	CY	\$45	\$6,970,500
		3,168	-	-	G9	415				
		4,706	-	-	G10	453				
A10	Levee Embankment - Below Water	1,820	-	-	G8	217	85,894	CY	\$60	\$5,153,700
		3,168	-	-	G9	309				
		4,706	-	-	G10	201				
A11	Geogrid Reinforcement	1,820	70	-	G8	-	74,372	SY	\$6	\$446,300
		3,168	76	-	G9	-				
		4,706	64	-	G10	-				
A12	Asphalt Concrete Pavement	9,694	20	0.5		10	3,590	CY	\$266	\$955,100
A13	Hydroseeding	1,820	119	-	G8	-	22	AC	\$3,000	\$67,400
		3,168	100	-	G9	-				
		4,706	95	-	G10	-				
A14	Flood Gate at Runway 13						1	EA	\$1,012,500	\$1,012,500
A14	Flood Gate at Embarcadero Rd						1	EA	\$405,000	\$405,000

SubTotal	\$19,361,258
Contingency (30%)	\$5,808,377
Escalation (10.85%)	\$2,100,696
GRAND TOTAL =	\$27,271,000



Project	SAFER BAY TO 2	Job No :	10022067	Computed:	LJ - DEC 2018
Subject	SAFER BAY Feasibility Cost Analysis			Checked:	NG - DEC 2018

REACH 10 OPTION 2

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition	-	-	-	-	-	21.7	AC	\$0.00	\$0
A2	Mobilization/Demobilization	-	-	-	-	-	1	LS	\$952,100	\$952,100
A3	Traffic Control	-	-	-	-	-	1	LS	\$190,500	\$190,500
A4	Erosion Control	-	-	-	-	-	1	LS	\$190,500	\$190,500
A5	Tree Removal	-	-	-	-	-	60	EA	\$5,000	\$300,000
A6	Clearing and Grubbing	1,598	117	-	G8	-	21.7	AC	\$5,000	\$108,800
		3,004	97	-	G9	-				
		5,084	92	-	G10	-				
A7	Demolition - Existing Bike Path - Aggregate	1,598	8	-	-	-	1,420	SY	\$12	\$17,100
A8	Excavation	1,598	-	-	G8	204	83,089	CY	\$20	\$1,661,800
		3,004	-	-	G9	248				
		5,084	-	-	G10	231				
A9	Relocate Sanitary Sewer	1,795	-	-	-	-	1,795	LF	\$537	\$963,758
A10	Levee Embankment - Above Water	1,598	-	-	G8	405	155,388	CY	\$45	\$6,992,500
		3,004	-	-	G9	415				
		5,084	-	-	G10	453				
A10	Levee Embankment - Below Water	1,598	-	-	G8	217	85,045	CY	\$60	\$5,102,800
		3,004	-	-	G9	309				
		5,084	-	-	G10	201				
A11	Geogrid Reinforcement	1,598	70	-	G8	-	73,949	SY	\$6	\$443,700
		3,004	76	-	G9	-				
		5,084	64	-	G10	-				
A12	Asphalt Concrete Pavement	9,686	20	0.5	-	10	3,587	CY	\$266	\$954,300
A13	Hydroseeding	1,598	119	-	G8	-	22	AC	\$3,000	\$66,900
		3,004	100	-	G9	-				
		5,084	95	-	G10	-				
A14	Floodgate at Runway 13	-	-	-	-	-	1	EA	\$1,012,500	\$1,012,500
A14	Floodgate at Runway 31	-	-	-	-	-	1	EA	\$1,012,500	\$1,012,500
A14	3 Flood Gates at Embarcadero Rd	-	-	-	-	-	1	EA	\$405,000	\$405,000

SubTotal	\$20,374,758
Contingency (30%)	\$6,112,427
Escalation (10.85%)	\$2,210,661
GRAND TOTAL =	\$28,698,000



Project SAFER BAY TO 2 Job No : 10022067 Computed: LJ - DEC 2018

Subject SAFER BAY Feasibility Cost Analysis Checked: NG - DEC 2018

REACH 10 OPTION 3

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition	-	-	-	-	-	20.9	AC	\$0.00	\$0
A2	Mobilization/Demobilization	-	-	-	-	-	1	LS	\$872,600	\$872,600
A3	Traffic Control	-	-	-	-	-	1	LS	\$174,600	\$174,600
A4	Erosion Control	-	-	-	-	-	1	LS	\$174,600	\$174,600
A5	Tree Removal	-	-	-	-	-	60	EA	\$5,000	\$300,000
A6	Clearing and Grubbing	1,598	117	-	G8	-	20.9	AC	\$5,000	\$104,800
		3,004	97	-	G9	-				
		4,706	92	-	G10	-				
A7	Demolition - Existing Bike Path - Aggregate	1,598	8	-	-	-	1,420	SY	\$12	\$17,100
A8	Excavation	1,598	-	-	G8	204	79,858	CY	\$20	\$1,597,200
		3,004	-	-	G9	248				
		4,706	-	-	G10	231				
A9	Relocate Sanitary Sewer	1,795	-	-	-	-	1,795	LF	\$537	\$963,758
A10	Levee Embankment - Above Water	1,598	-	-	G8	405	149,049	CY	\$45	\$6,707,300
		3,004	-	-	G9	415				
		4,706	-	-	G10	453				
A10	Levee Embankment - Below Water	1,598	-	-	G8	217	82,233	CY	\$60	\$4,934,000
		3,004	-	-	G9	309				
		4,706	-	-	G10	201				
A11	Geogrid Reinforcement	1,598	70	-	G8	-	71,261	SY	\$6	\$427,600
		3,004	76	-	G9	-				
		4,706	64	-	G10	-				
A12	Asphalt Concrete Pavement	9,308	20	0.5	-	10	3,447	CY	\$266	\$917,100
A13	Hydroseeding	1,598	119	-	G8	-	21	AC	\$3,000	\$64,500
		3,004	100	-	G9	-				
		4,706	95	-	G10	-				
A14	Flood Gate at Runway 13	-	-	-	-	-	1	EA	\$1,012,500	\$1,012,500
A14	Flood Gate at Embarcadero Rd	-	-	-	-	-	1	EA	\$405,000	\$405,000
									SubTotal	\$18,672,658
									Contingency (30%)	\$5,601,797
									Escalation (10.85%)	\$2,025,983
									GRAND TOTAL =	\$26,301,000

Project		SAFER BAY TO2		Job No : 10022067		Computed: LJ - DEC 2018				
Subject		SAFER BAY Feasibility Cost Analysis		Checked: NG - DEC 2018						
REACH 11 OPTION 1										
Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition						0	AC	\$0	\$0
A2	Mobilization/Demobilization	-	-	-		-	1	LS	\$2,998,300	\$2,998,300
A3	Traffic Control	-	-	-		-	1	LS	\$599,700	\$599,700
A4	Erosion Control	-	-	-		-	1	LS	\$599,700	\$599,700
A5	Tree Removal	-	-	-	-	-	30	EA	\$5,000	\$150,000
A6	Clearing and Grubbing	6,172	127	-	G11	-	33	AC	\$5,000	\$163,900
		5,675	114	-	G12	-				
A7	Demolition - Existing Bike Path - Aggregate	6,172	14	-	G11	-	9,600.9	SY	\$12	\$115,300
A8	Excavation	6,172	-	-	G11	534	243,350	CY	\$20	\$4,867,000
		5,675	-	-	G12	578				
A10	Levee Embankment Fill - North Levee Above Water	6,172	-	-	G11	541	228,704	CY	\$45	\$10,291,700
		5,675	-	-	G12	500				
A10	Levee Embankment Fill - North Levee Wet Below Water	6,172	-	-	G11	589	256,088	CY	\$60	\$15,365,300
		6,172	-	-	G12	531				
A11	Geogrid Reinforcement	6,172	101	-	G11	-	123,702	SY	\$6	\$742,300
		5,675	86	-	G12	-				
A12	Asphalt Concrete Pavement	11,847	20	0.5		10	4,388	CY	\$266.00	\$1,167,200
A13	Hydroseeding	6,172	131	-	G11	-	34	AC	\$3,000	\$101,400
		5,675	117	-	G12	-				
A16	Tide Gate Structure - 16 Gates Total						1	EA	\$5,000,000	\$5,000,000
A17	Stormwater Pump Station	-	-	-		-	1	EA	\$22,000,000	\$22,000,000
SubTotal										\$64,161,800
Contingency (30%)										\$19,248,540
Escalation (10.85%)										\$6,961,555
GRAND TOTAL =										\$90,372,000

Project SAFER BAY TO2 Job No : 10022067 Computed: LJ - DEC 2018

Subject SAFER BAY Feasibility Cost Analysis Checked: NG - DEC 2018

REACH 11 OPTION 2

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition	-	-	-	-	-	38	AC	\$0	\$0
A2	Mobilization/Demobilization	-	-	-	-	-	1	LS	\$8,576,000	\$8,576,000
A3	Traffic Control	-	-	-	-	-	1	LS	\$1,715,200	\$1,715,200
A4	Erosion Control	-	-	-	-	-	1	LS	\$1,715,200	\$1,715,200
A5	Tree Removal	-	-	-	-	-	50	EA	\$5,000	\$250,000
A6	Clearing and Grubbing	2,261	73		G13	-	38	AC	\$5,000	\$188,400
		3,898	122		G14	-				
		1,660	40		G15	-				
		7,582	123		G16	-				
A7	Demolition - Existing Bike Path - Aggregate	8,442	12	-	G15 Partial, G16	-	11,256	SY	\$12	\$135,100
A7.1	Demolition - Existing Bike Path - AC	6,959	10		G13, G14, G15 Partial		7,732	SY	\$15	\$116,000
A7.2	Demolition - Remove Ex. Floodwall	36,005			G15		36,005	LF	\$200	\$7,201,000
A8	Excavation	2,261	-	-	G13	173	166,198	CY	\$20	\$3,324,000
		3,898	-	-	G14	329				
		1,660	-	-	G15	80				
		7,582			G16	354				
A10	Levee Embankment Fill - Above Water	2,261			G13	373.0	232,711	CY	\$45	\$10,472,100
		3,898	-	-	G14	423				
		7,582	-	-	G16	500				
A10	Levee Embankment Fill - Below Water	7,582			G13	0.0	1,460,102	CY	\$60	\$87,606,200
		8,442	-	-	G14	874				
		36,005	-	-	G16	890				
A11	Geogrid Reinforcement	2,261	46	-	G13	-	137,620	SY	\$6	\$825,800
		3,898	99	-	G14	-				
		7,582	99	-	G16	-				
A12	Asphalt Concrete Pavement	15,401	20	0.5	G13, G14, G16	10	5,704	CY	\$266	\$1,517,300
A13	Hydroseeding	2,261	75		G13	-	37	AC	\$3,000	\$111,600
		3,898	125	-	G14	-				
		7,582	127	-	G16	-				
A14	Floodwall	37,665	-	-	G15	-	37,665	LF	\$1,500	\$56,497,500
A15	HeadWalls	1,310	-	-	G15	-	1,310	LF	\$2,500	\$3,275,000
SubTotal										\$183,526,400
Contingency (30%)										\$55,057,920
Escalation (10.85%)										\$19,912,614
GRAND TOTAL =										\$258,497,000



Project	SAFER BAY TO2	Job No :	10022067	Computed:	LJ - DEC 2018
Subject	SAFER BAY Feasibility Cost Analysis			Checked:	NG - DEC 2018

REACH 11 OPTION 3

Line Item	Bid Item	Length (ft)	Width (ft)	Depth (ft)	X-SEC #	X-SEC AREA (ft ²)	Quantity	Unit	Unit Price	Total Price
A1	Property Acquisition	-	-	-	-	-	21.4	AC	\$0	\$0
A2	Mobilization/Demobilization	-	-	-	-	-	1	LS	\$2,651,600	\$2,651,600
A3	Traffic Control	-	-	-	-	-	1	LS	\$530,400	\$530,400
A4	Erosion Control	-	-	-	-	-	1	LS	\$1,060,800	\$1,060,800
A5	Tree Removal	-	-	-	-	-	60	EA	\$5,000	\$300,000
A6	Clearing and Grubbing	4,262	123	-	G16	-	21.4	AC	\$5,000	\$107,000
		2,755	148	-	G18	-				
A7	Demolition - Remove Bike Path - Aggregate	4,262	15	-	-	-	7,103	SY	\$12	\$85,300
A8	Excavation	4,262	-	-	G16	354	94,143	CY	\$20	\$1,882,900
		2,755	-	-	G18	375				
A10	Levee Embankment Fill - Above Water	4,262	-	-	G16	500	129,944	CY	\$45	\$5,847,500
		2,755	-	-	G18	500				
A10	Levee Embankment - Below Water	4,262	-	-	G16	890	263,647	CY	\$60	\$15,818,900
		2,755	-	-	G18	1,207				
A11	Geogrid Reinforcement	4,262	99	-	G16	-	83,991	SY	\$6	\$503,945
		2,755	122	-	G18	-				
A12	Asphalt Concrete Pavement	4,262	20	0.5	G16, G18	10	1,579	CY	\$266	\$419,900
A13	Hydroseeding	4,262	127	-	G16	-	22	AC	\$3,000	\$66,500
		2,755	154	-	G18	-				
A16	Tide Gate Structure - 8 Gates	-	-	-	-	-	2	EA	\$3,000,000	\$6,000,000
A17	Pump Station	-	-	-	-	-	1	EA	\$22,000,000	\$22,000,000

Total	\$57,274,745
Contingency (30%)	\$17,182,423
Escalation (10.85%)	\$6,214,310
GRAND TOTAL =	\$80,672,000