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Geotechnical
Environmental and
Water Resources
Engineering

San Francisquito Creek Flood Protection Project

Geotechnical Evaluation Report

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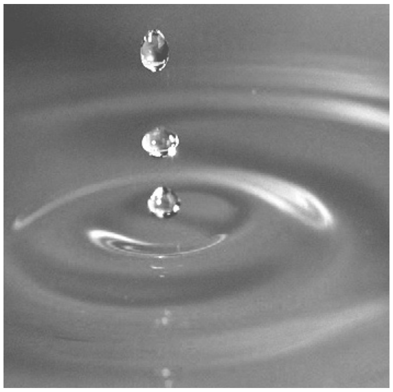

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1. Introduction

1.1 Project Description

GEI Consultants, under contract to HDR Engineering, Inc. (HDR), performed geotechnical engineering services in support of the design for the San Francisquito Creek Flood Protection Project. The Project consists of flood control improvements along San Francisquito Creek, downstream of Highway 101/East Bayshore Road in San Mateo and Santa Clara Counties. The Project sponsor is the San Francisquito Creek Joint Powers Authority (SFCJPA).

San Francisquito Creek has been the source of several significant flood events in the areas near Palo Alto, East Palo Alto, and Menlo Park over the past several decades. The purpose of the San Francisquito Creek Flood Protection Project is to provide elements needed to protect homes, businesses, and other facilities in the cities Palo Alto and East Palo Alto downstream of Highway 101/East Bayshore Road. The intent of the Project is to provide conveyance of the design flood flow through the area of consideration from the downstream face of East Bayshore Road to San Francisco Bay. HDR has determined the design flood flow and associated water surface elevations for the project, which is discussed below:

At the direction of the SFCJPA, the following hydraulic design criteria apply to the San Francisquito Creek Flood Protection Project from Highway 101 to the San Francisco Bay. The design water surface is equivalent to that produced by a 100-year fluvial event (9,400 cfs) coincident with the 100-year tide (10.35 feet NAVD 88), plus anticipated sea level rise (26 inches), for a starting water surface elevation of 12.5 feet NAVD 88. Following discussion between the HDR design team and the SFCJPA, one additional foot was added to the modeled design water surface, for GEI's use in analysis. This value is expected to be conservative, and was added to account for any future variability in levee alignment based on right-of-way issues not yet resolved, the minor water surface elevation fluctuations to be expected as the issue of the degraded levee downstream of Friendship Bridge is finalized, and minor future changes brought about by information provided in the pending Shoreline Study. These water surface elevations are discussed in *Section 4.1* below and provided in **Table 1** for reference.

In general, this project involves widening the creek channel by constructing new retaining walls, floodwalls and new levees, degrading existing levees, and abandoning small levees at the downstream reach of San Francisquito Creek to allow flood flows into the adjacent Faber Tract to the north. Reconfiguration of portions of the Palo Alto Municipal Golf Course is also planned, as some of the flood control elements include new levees that encroach on to the golf course.

HDR prepared a Design Criteria and Considerations Technical Memorandum (HDR, 2010) for the project. The memorandum indicates that the planned levees will be designed to meet the criteria set by the Code of Federal Regulations (CFR), Title 44, Volume 1, Chapter I, Section 65.10 and the California Code of Regulations (CCR) Title 23. HDR further indicates that the most recent USACE published documents will be the basis for the design criteria. In performing this study, GEI has followed guidance provided by the HDR Technical Design Memorandum and the USACE documents shown in the References.

The planned levee design provides a minimum levee crown width of 16 feet, a levee landside slope of 2 horizontal to 1 vertical (2H:1V) or flatter, and a levee waterside slope of 3H:1V or flatter. Based on the preliminary 60% design layout provided by HDR, new levees will be up to 13 feet high (measured from the landside toe). Design top of levee and floodwall elevations range from El. 16.1 to 21.3[1].

Floodwalls are also planned in areas that full levee prisms cannot be constructed due to space and right-of-way limitations. The floodwalls will tie in to the existing San Francisquito Creek pump station just downstream of Highway 101/East Bayshore Road. The pump station building itself will be the flood control feature for about 100 feet of length. (The pump station consists of a wet well, discharge box, pump house and control building, and is supported on mat type foundation).

The Project also includes modification of the structure (culvert) that crosses below Highway 101/East Bayshore Road, although the design of that feature is not included in the scope of our geotechnical study.

1.2 Purpose and Scope

The purpose of our geotechnical engineering study was to obtain information on subsurface conditions at the site, evaluate the geotechnical aspects of the project, and develop geotechnical recommendations and criteria for design of levees and .

The scope of our services was detailed in the proposal from GEI to HDR, dated November 23, 2009 and revised in Amendment No. 1, dated November, 2011. In general, our scope includes:

- Compiling and reviewing available geotechnical and geologic data contained in reports prepared previously for projects within the project vicinity;
- Conducting a field exploration and laboratory-testing program to supplement the available information on subsurface conditions;
- Performing engineering analyses for new levees and floodwalls including seepage, stability and settlement evaluations; and

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[1] Unless otherwise stated, elevations noted in this report refer to the North American Vertical Datum of 1988 (NAVD 88).

- Preparing this geotechnical report presenting the results of our geotechnical field exploration and laboratory-testing programs, discussing the geotechnical issues affecting design, and providing geotechnical recommendations and design criteria.

1.3 Previous Studies

Numerous geotechnical investigations, studies, and designs have been performed for various projects in the site vicinity. A review of available information, as provided by HDR, was performed by GEI and summarized in a Technical Memorandum, submitted to HDR in January, 2010. Information from this review was used to supplement and/or confirm project data when it was found to be relevant to the project. Typically, relevant information included project site construction history, geologic history and setting, and previous geotechnical investigations that provided subsurface data (boring logs) and laboratory test results. Documents providing pertinent project information are listed below and are included in *Section 7*. Logs of relevant previous borings by others are included in **Appendix A.**

- USACE 2009, Geotechnical Appendix and Reliability Analysis, San Francisquito Creek
- TRC Lowney, 2006, Geotechnical Investigation, San Francisquito Creek Pump Station
- Lowney Associates, 2002, Geotechnical Report, San Francisquito Creek Levee Project
- Earth Systems Consultants, 1983, Geotechnical Report, Baylands Bike Trail.

GEI reviewed and commented on the HDR Design Criteria and Considerations Technical Memorandum (HDR, 2010) that provided levee, structural and hydraulic design information for the project. GEI followed the technical memorandum and used pertinent information provided therein in performing our geotechnical evaluations.

1.4 Project Personnel

The geotechnical studies described in this report were coordinated with the following individuals from HDR:

- Amy Gilleran, Project Manager
- Chris Trumbull, Project Geotechnical Engineer

Key GEI personnel who participated in this project include:

- Mark Freitas, Principal Geotechnical Engineer
- Len Sansone, Project Manager/Principal Geotechnical Engineer
- Matt Powers, Staff Engineer
- Tim Haynes, Staff Engineer

We also appreciate the assistance of Kevin Murray of the San Francisquito Creek Joint Powers Authority, Bill Springer of the Santa Clara County Water District, Jay Farr of East Palo Alto Public Works, Joe Teresi of the City of Palo Alto and Palo Alto Baylands Park Ranger Darren Anderson in facilitating access to the project site.

2. Site Description and Project Information

2.1 Site Location and Description

The San Francisquito Creek Flood Control Project area is located along San Francisquito Creek, downstream (east) of Highway 101/East Bayshore Road, along the border of Santa Clara and San Mateo Counties, as well as the cities of Palo Alto and East Palo Alto, California. The project extends approximately 5,000 feet along the existing creek alignment, and about 180 to 300 feet from the creek centerline (including its adjacent levee system). East Bayshore Road borders the site to the west, the creek outlet to San Francisco Bay to the east, East Palo Alto to the north, and the Palo Alto Municipal Golf Course to the south. Within the project area, San Francisquito Creek flows generally from the west to the east, discharging into San Francisco Bay north of the Palo Alto Municipal Airport.

The Sand Francisquito Creek pump station is located at the upstream end of the project and the O’Conner pump station is located near the midpoint of the project. **Figure 1** shows the San Francisquito Creek Project Area and relevant landmarks.

Surrounding ground elevations, away from the existing levees, and adjacent to San Francisquito Creek vary from about El. 16 feet in the vicinity of Highway 101 to approximately El. 1 feet in areas within the golf course. Existing levee crest elevations range from approximately El. 13 to 15 feet.

Along the south bank of the creek, adjacent to Palo Alto Municipal Golf Course between Friendship Bridge and the Baylands Athletic Center, the levee crown is capped with asphalt concrete pavement. East of Friendship Bridge, extending to the Bay and west of the Baylands Athletic Center to East Bayshore Road, the levee crown is surfaced with gravel. The width of the levee crown ranges from approximately 10 to 15 feet. The levee crown along the north (East Palo Alto) side of the creek is surfaced with gravel, and ranges in with from approximately 8 to 20 feet.

2.2 Geologic Setting

2.2.1 Regional Geology

The San Francisco Bay Area is located at the boundary between the Pacific and North American plates, two large crustal plates that are separated by the north-northwest trending San Andreas Fault, within the California Coast Ranges Geomorphic Province. The geomorphology of the region includes parts of three prominent, northwest trending geologic/geomorphic features, which include from west to east; the Santa Cruz Mountains, Santa Clara Valley, and the Diablo Range. Santa Clara Valley forms part of an elongated structural block (the San Francisco Bay block) within the central Coast Ranges that contains San Francisco Bay and its surrounding alluvial margins (Page, 1989). This structural block is fault bounded by the San Andreas Fault to the southwest and the Hayward-Calaveras fault zone to the northeast.

The oldest rocks in the region belong to the Franciscan Complex of Jurassic to Cretaceous age (205 to 65 million years before present [Ma]). These rocks are intensely deformed (i.e. folded, faulted, and fractured) due to ancient tectonic processes and, to a lesser extent, from more recent tectonic processes associated with the San Andreas fault system. Franciscan rocks generally comprise the basement of the Coast Ranges northeast of the San Andreas Fault; Cretaceous granitic rocks, known as the Salinian block, comprise the basement of the ranges located to the southwest of the San Andreas Fault. A sequence of Tertiary (65 to 1.8 Ma) marine and non-marine sedimentary rocks unconformably overlies, and locally is in fault contact with the granitic and Franciscan basement rocks in the region.

Quaternary (1.6 Ma to present) surficial deposits are concentrated in the Santa Clara Valley and locally over lie the complexly deformed cretaceous rocks and Tertiary strata in the adjacent hills. During the Plio-Pleistocene (5 Ma to 11,000 [11 ka] years ago) epochs, sediments eroded from the uplifting Diablo Range and the Santa Cruz Mountains formed broad alluvial fan complexes along the margins of the Santa Clara Valley. The 5 Ma to 300,000-year-old (Plio-Pleistocene) Santa Clara Formation, which consists of a sequence of fluvial and lacustrine sediments, was deposited unconformably on the older Tertiary and Franciscan rocks along the margins of Santa Clara Valley during this time and subsequently has been folded, faulted, and eroded. The Santa Clara Formation is unconformably overlain by younger Quaternary and Holocene (11 ka to present) alluvial and fluvial deposits (stream channel, overbank, and flood basin environments), which interfinger to the north with estuarine muds of San Francisco Bay (Helley et al., 1979). The youngest Holocene Bay Muds underlie almost all of the original San Francisco Bay (Atwater et al., 1977; Helley et. al., 1979; CDMG, 1969); including portions of the San Francisquito Creek levee Project Area (USACE, 2009). Depth to bedrock in the site vicinity is likely greater than 300 feet (CDMG, 1969).

2.2.2 Local Geology

Figure 2 shows a geologic map of the San Francisquito Creek Project area. The ground surface adjacent to the creek channel downstream of Highway 101/East Bayshore Road is mapped as levee fills (alf) and general artificial fill (af). According to geologic mapping and descriptions by the United States Geological Survey (USGS), these man-made deposits are composed of various materials of various ages. Some are compacted and quite firm, but fills placed before 1965 are generally not well compacted and consist of dumped materials. The artificial fill appears to overlay Holocene flood plain (Qhfp), flood basin (Qhb), and young bay deposits (Qhbm) referred to locally as Bay Mud. Flood plain deposits are generally described as stiff sandy to silty clay, with some locations having lenses of coarse material. The basin deposits are generally described as fine silty clay to clay. Bay Mud is an estuarine mud deposited during the post-Wisconsin glacial period rise in sea-level (12 ka to present) and is comprised of saturated clay and silty clay, with local lenses of fine sand and silt, shelly layers (oysters) and peat (USGS, 2000).

2.2.3 Faulting and Seismic Considerations

A regional fault map showing known faults within the region is shown on **Figure 3**. The site is not located within a state designated Alquist-Priolo Earthquake Fault Zone, or a Santa Clara County fault rupture hazard zone. No known surface expression of active faults is believed to cross the project site, and therefore surface fault rupture is not anticipated for the project.

The San Francisco Bay Area is one of the most seismically active regions in the United States. Significant earthquakes that occur in the Bay Area are generally associated with crustal movement along well-defined, active fault zones of the San Andreas Fault system, which regionally trend in a northwesterly direction. The San Andreas Fault, which generated the great San Francisco earthquake of 1906, is located approximately 5 miles southwest of the project. Other major Holocene active faults in the area include the San Gregorio Fault, the Monte-Vista Shannon fault, and the Hayward Fault.

The USGS 2007 Working Group on California earthquakes (WG07) has reported that it is a near certainty (93 percent chance) that at least one magnitude 6.7 or greater earthquake will occur within Northern California within the next 30 years, with a 63 percent chance of occurrence within the Bay Area. The Hayward Fault is the most likely source, having a more than 30 percent chance of at least one magnitude 6.7 earthquake or larger within the next 30 years. Design Ground Motions for Liquefaction Analysis are discussed in *Section 4.5*.

2.2.4 Liquefaction Considerations

Soil liquefaction results from loss of strength during cyclic loading that could occur due to earthquake ground shaking. Soils most susceptible to liquefaction are clean, loose saturated, fine-grained sands and silts. The State of California has mapped the San Francisquito Creek Project area as having potential for seismically induced liquefaction (CGS, 2006). **Figure 4** shows the Project area where historical occurrences of liquefaction occurred, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements (shaded green). Further discussion and more detailed analyses of liquefaction and seismic considerations are provided in *Section 4.5* of this report.

2.3 San Francisquito Creek Alignment History

The San Francisquito Creek Levee Project area is mostly located within a historic tidal estuary. The course of historic San Francisquito Creek did not follow its present day course, but instead flowed downstream from present day Highway 101/East Bayshore Road eastwards to its mouth, where it entered the historic estuary (tidal marsh) at its western extent (see **Figure 5**). The location of the mouth of San Francisquito Creek has varied over time in response to sediment load within the channel and, later, as a result of man-made alterations.

Beginning around 1900-1920, levees were constructed within areas of the historic estuary to remove tidal action and create farmable lands. Nearby tidal channels were dredged to improve navigation (particularly Wilson's Landing and Clarke's Landing), with the dredging spoils used for fill in these new farmlands levee construction. There is some evidence of continued alluvial deposition within the estuary during this period in the Project area, which may have been the result, in part, of local efforts to direct stream sediments in order to raise the marsh surface level for agricultural use.

Major re-routing of San Francisquito Creek took place in the late 1920's. Flow was controlled by levees on both sides of the excavated channel downstream of present day Highway 101/East Bayshore Road. The channel was turned sharply north near the site of its former mouth and ran north for approximately half a mile before turning to the northeast out to the bay. This re-routed channel alignment is, for the most part, the present day alignment (see **Figure 5**). It is assumed that these early levees were built of non-engineered fill from locally sourced earth materials (channel dredging, alluvial over bank deposits, etc.) and may have been built up over time as needed to control flood flows within the channel. A more comprehensive review of historic ecology and landscape evolution of San Francisquito Creek within the Project Area is provided by the San Francisco Estuary Institute (Hermstadt, D. et. Al., 2009) in a Technical Memorandum titled "*Historical Ecology of Lower San Francisquito Creek*", and is included for reference in **Appendix B**.

The Federal government first authorized the study of San Francisquito Creek in 1941 in response to flooding that occurred several times in the first half of the 19th Century. Major levee improvements, along with slight alignment alterations, were constructed downstream of present day Highway 101/East Bayshore Road in 1958 by the Santa Clara County Flood Control and Water Conservation District. In general, the creek channel was widened and slightly deepened by excavating previous non-engineered levee fills and constructing engineered levees setback from the channel. The channel alignment was smoothed and levee height increased to accommodate the projects' design flood flow. In 2004, the downstream levees were raised approximately 0.5 to 2.6 feet by the San Francisquito Creek Joint Powers Authority, in a maintenance operation to restore the levees to the 1958 design elevation. Levee crest elevations in many locations were found to be lower than the 1958 design, due to settlement, land subsistence, and erosion. Other improvements, including areas of levee slope armoring, and recreational trail and pump station construction have also been completed in more recently within the Project Area (USACE, 2009; SCVWD, 2004, 2002; SCCFCWCD, 1958).

2.4 Proposed Flood Control Features

The SFCJPA has selected San Francisquito Creek flood control features that generally follow the Alternative 2 concept, as detailed in the Alternatives Analysis conducted by Philip Williams & Associates (PWA), in July 2009. Alternative 2 consists of setback floodwalls which tie into the existing San Francisquito Creek pump station structure in the upper reach, setback levees in the middle reach, an overflow terrace near Friendship Bridge, and a degrade of the north levee between the Faber Tract and San Francisquito Creek, downstream of Friendship Bridge. The upper reach extends from East Bayshore Road to the Palo Alto Municipal Golf Course, the middle reach extends from the golf course to Friendship Bridge and the lower reach extends from Friendship Bridge to the San Francisco Bay. The conceptual layout and cross sections of Alternative 2 are shown in the PWA report.

HDR refined the Alternative 2 alignment concepts in their 30% design. **Figures 6a through 6e** show the HDR planned alignment of new flood control improvements with stationing extending from 76+00 at East Bayshore Road to approximately 23+00 where the new improvements coincide with the existing levees adjacent to the Palo Alto Municipal Golf Course. Floodwalls will extend from approximately Station 76+00 to 53+50 along the East Palo Alto side and Station 76+00 to 50+00 along the Palo Alto side of the creek. New levees will extend downstream from the floodwall locations. Preliminary design documents indicate right levee and left levee of San Francisquito Creek and are based on an upstream view. Thus, right levee protects East Palo Alto and left levee protects Palo Alto.

New levees will be about 10 to 13 feet high (above the landside ground surface elevation) with a crown width of 16 feet, waterside slopes of 3 horizontal to 1 vertical (3H:1V) and landside slopes of 2H:1V. The floodwall design consists of sheetpiles embedded in competent soils. In general, sheet piles will be installed along the creek channel, extending about 10 to 13 feet vertically above the creek bottom. These floodwalls will retain a berm or high ground with a trail on the landside, such that the vertical wall height on the landside is not excessive.

The existing San Francisquito Creek pump station situated just downstream of Highway 101/East Bayshore Road along the Palo Alto side of the creek, will be part of the flood control system for San Franciquito Creek. In the vicinity of the pump station (approximate Station 76+00 to 68+70), the floodwall alignment will be set back from the creek and will tie into the pump station structure. The floodwalls in this area will extend approximately 4 to 5 feet above existing ground surface. Based on the preliminary 60% design plans (HDR, December 2011), the building itself will be the flood control feature between approximately stations 71+00 and 72+00.

The design water surface for the San Francisquito Creek study area was provided by HDR (see **Table 1**). As discussed in *Section 1.1*, the design water surface is equivalent to that produced by a 100-year fluvial event coincident with the 100-year tide, plus anticipated sea level rise for San Francisquito Creek between Stations 0+00 to 77+00. This design flood scenario is herein referred to as the HDR Design Water Surface.

3. Field Exploration and Laboratory Testing

3.1 Field Explorations

A subsurface exploration program was performed to evaluate and characterize the subsurface conditions at the site. The exploration program was developed based on the results of review of available geologic and geomorphic information, existing site conditions assessed during site reconnaissance, and proposed levee and floodwall alignments. The field exploration program was completed in two phases at the site using cone penetration tests (CPT) and rotary wash, hollow-stem, and solid-flight auger borings along the crest of the levee and at several landside locations. The approximate locations of the explorations are shown in **Figures 6a through 6e**.

Phase 1 was performed from January 28 through February 8, 2010, using both rotary wash and auger exploratory borings and cone penetration tests (CPT) along the levee crest and landside areas. The Phase 1 rotary-wash borings and CPT soundings were performed to characterize foundation conditions beneath the proposed levee and floodwall alignments. Auger borings were performed to characterize the soil conditions within the existing levees, obtain bulk samples of levee fill, and to assess groundwater conditions at the time of drilling.

Seven CPTs were performed within the Project area on January 28 and 29, 2010; four on the landside of the existing East Palo Alto levee, one on the crown of the existing East Palo Alto Levee, and two on the landside of the existing Palo Alto levee, within the Palo Alto Municipal Golf Course. CPTs were advanced from 42 to 100 feet below existing ground surface. Based on an initial review of the CPT results, final locations and soil sampling intervals were established for the planned borings.

Nine borings were performed within the Project area between February 1 and February 8, 2010 including six rotary wash borings and three auger borings. Two rotary wash borings were performed on the landside of the existing Palo Alto levee within the Palo Alto Municipal Golf Course, using track mounted equipment to minimize damage to the golf course playing surface and cart paths. Two rotary-wash borings were performed on the crown and one on the landside of the existing Palo Alto levee using conventional truck-mounted equipment. One final rotary-wash boring was performed on the landside of the existing East Palo Alto Levee using conventional truck-mounted equipment. Rotary-wash borings were advanced between 48.5 and 53.5 feet below existing ground surface. Two borings were drilled adjacent to CPTs to correlate the CPT stratigraphy with the borings and obtain samples of select materials. Three auger borings were performed on the crown of the existing levees, two on the East Palo Alto levee and one on the Palo Alto levee, using truck-mounted equipment. Auger borings were advanced from 16 to 22.5 feet below existing ground surface.

Phase 2 was performed on October 11 and 12, 2011, using hollow-stem and solid-flight auger borings along the levee crest and landside areas in the vicinity of the San Francisquito Creek pump station. The Phase 2 hollow-stem and solid-flight auger borings were performed to characterize foundation conditions in the vicinity of the San Francisquito Creek pump station in support of the design of the floodwall realignment that occurred following completion of the Phase 1 explorations.

Two hollow-stem auger borings were performed within the Project area on October 11 and advanced to 55 feet below existing ground surface using truck-mounted equipment. Two solid-flight auger borings were performed within the Project area on October 12 and advanced from 25 to 30 feet below existing ground surface using limited access drilling equipment.

3.2 Exploration Methods and Details

CPTs were performed by Gregg Drilling, Inc., of Martinez, California, using a 20-ton push capacity, track-mounted rig which incorporates Cone Penetration Testing tools that meet the ASTM D5778 Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils. The cones have 10 cm^2 tips and 150 cm^2 friction sleeves and include a porous filter and pressure sensor. The cone and porous filter are saturated under vacuum with glycerin to promote rapid equilibration with in-situ pore pressures. Cones are advanced at the ASTM standard rate of two cm/sec. Baseline readings are performed both before and after each push to measure temperature and load cell drift. The cone measures bearing, sleeve friction, and dynamic pore pressure at two centimeter intervals and this data is plotted in real time and recorded on a laptop computer adjacent to the push platform. Plots of soil behavior type (SBT), SPT N_{60} energy ratio, undrained shear strength, and unit weights are calculated and/or interpreted by CPT-Pro software based on algorithms presented in Robertson et al. (1986), Robertson (1990), and Lunne et al. (1997). The CPT data files were provided to GEI and used in project analyses.

Phase 1 rotary wash borings were performed by Pitcher Drilling Company, of East Palo Alto, California, using a track-mounted Fraste Multidrill XL drill rig equipped with a 4.5-inch-diameter rotary wash drill. Auger borings in Phase 1 were also performed by Pitcher Drilling Company using a Failing 1500 truck-mounted drill rig equipped with a 6-inch-diameter auger.

The Phase 2 auger borings, B-7 and B-10, were performed by Exploration Geoservices, of San Jose, CA, using a mobile truck-mounted drill rig equipped with an 8-inch-diameter hollow-stem auger. Borings B-8 and B-9 were performed by Access Soil Drilling Inc., of

San Mateo, California, used a tripod-mounted limited access ‘minute-man’ drilling set-up equipped with a 4-inch-diameter solid-flight auger.

During the Phase 1 and Phase 2 drilling operations, soil samples were obtained using one of the following sampling methods:

- California Modified (CM) Sampler; 3.0-inch outer diameter (O.D.), 2.5-inch inner diameter (I.D.)
- Standard Penetration Test (SPT) Split Spoon Sampler; 2.0-inch O.D, 1.375-inch I.D.
- Thin-walled Shelby Tube; 3.0-inch O.D.

For the Phase 1 borings, the CM and SPT samplers were driven 18 inches (unless otherwise noted) into undisturbed soil using a 30-inch drop of a 140-pound hammer using an automatic trip system (automatic hammer) The hammer energy was not measured specifically for this project..

For the Phase 2 borings, specifically Borings B-7 and B-10 the CM and SPT samplers were driven 18 inches (unless otherwise noted) into undisturbed soil using a 30-inch drop of a 140-pound downhole hammer. For Borings B-8 and B-9, the limited access hand-portable rig was equipped with a rope-and-cathead system and the samplers were driven into the undisturbed soil using a 30-inch drop of a 140-pound hammer.

The number of blows required to drive the SPT and CM sampler 6 inches was recorded for each sample and included on the boring logs. The Shelby Tube sampler was either pushed with the drill rig kelly bar or advanced hydraulically into the underlying soil to within a few inches of the tube length (generally 36 inches) in order to obtain a relatively undisturbed sample. Some sampling runs were terminated when resistance from the soil was sufficient to reach a limiting hydraulic pressure selected by the driller to avoid damage to the tube and/or sampler. The required pressure to push the Shelby Tube was recorded on the field logs. Soil samples obtained from the borings were packaged and sealed in the field to reduce moisture loss and disturbance and transported to the GEI Oakland office for temporary storage prior to review and laboratory testing.

GEI field representatives were on site during all subsurface exploration activities to coordinate and direct the investigations, log the borings in general accordance with ASTM D2488, and collect and recover representative soil samples of the subsurface materials. Soil cuttings from the exploration borings were temporarily stockpiled at a pre-approved location at the landside levee toe, adjacent to the Baylands Athletic Center. Following completion of the explorations, soil cuttings were removed by City of Palo Alto Maintenance staff for proper disposal. All exploration boreholes were grouted to the surface with cement grout upon completion of the investigation, in accordance with both Santa Clara Valley Water District and San Mateo County Environmental Health Department guidelines. Additional details regarding the field exploration program and the logs of the boring and CPT explorations are included in **Appendix C**.

3.3 Laboratory Testing

Laboratory tests were performed on selected samples to aid in classification of the soils encountered at the site and to obtain parameters and material properties for use in our engineering analyses. The tests include moisture content and unit weight determinations, Atterberg limits, grain size distribution, fines content, consolidation, and unconfined compression and triaxial unconsolidated undrained strength tests. In addition, a suite of corrosion testing was performed, at the request of HDR, for use in assessment of corrosion potential by others. No evaluation of corrosion potential was performed by GEI as part of this study.

Geotechnical laboratory tests were performed on soil samples collected during the subsurface field investigation, by Cooper Testing Lab, Inc., in Palo Alto. The type and quantity of tests are summarized below:

Geotechnical Laboratory Test Summary			
Test Type	**ASTM**	**Quantity**	**Purpose**
Classification and Strength Tests			
Moisture Content	D2216	11	In-place moisture content
Moisture-Density	D2937	9	In-place moisture content and density
Atterberg Limits	D4318, Method B	16	Evaluate sample liquid and plastic limits
Grain Size Distribution	D422	7	Determine gravel, sand, and fines content
-200 Wash (% passing #200 sieve)	D1140	9	Determine fines content
Unconfined Compression	D2166	18	Estimate soil strength parameters
Consolidation	D4767	2	Estimate consolidation settlement parameters
Triaxial Unconsolidated Undrained	D2850	2	Estimate undrained shear strength

Corrosion Tests			
Resistivity (100% Saturated)	G57	7	Evaluate corrosion potential
pH	G51		
Sulfate	Caltrans 417		
Sulfide	Qualitative		
Chloride	Caltrans 422		
Redox Potential	Standard Methods 2580B		

Results of laboratory testing were used to develop material properties for use in stability, seepage, and settlement analyses and modeling of proposed levee and floodwall designs. Laboratory testing results are provided in **Appendix D**.

3.4 Surveys

In April, 2010, a project site survey was performed by Towill Inc., of Concord, California to develop topographical profiles and sections for project use, as well as to identify existing infrastructure that may have influence on project design and construction. Information from this survey was used to estimate existing ground surface elevations of the geotechnical investigation locations, as well as to develop ground surface profiles for use in stability, seepage, and settlement calculations and analyses.

4. Engineering Analyses

4.1 Introduction

GEI performed stability, seepage, and settlement analyses and evaluated lateral earth pressures and liquefaction for the proposed flood control features. The HDR Design Water Surface, provided by HDR, was used in the analyses (Refer to **Table 1**) Levee geometry criteria were established by the HDR Design Criteria and Considerations Technical Memorandum (HDR, 2010). GEI also evaluated the planned tie-in of the floodwall to the existing San Francisquito Creek Pump Station in Palo Alto and foundations for a planned boardwalk extension on the east (Palo Alto) side of Friendship Bridge.

The soils at the site are generally comprised of estuarine, alluvial, and artificial fill deposits. The natural estuarine and alluvial deposits result from a complex erosional and depositional environment. Artificial fills (levees and golf course fills) result from recent man-made alterations of the surface and near-surface soils. Some variation in subsurface stratigraphy was observed in the subsurface explorations performed along the alignment, but the thickness of estuarine deposits (Bay Mud), particularly along the proposed new embankment alignments on both the East Palo Alto and Palo Alto sides, was fairly consistent (approximately 8 feet in thickness).

Based on site geology and results of the subsurface explorations, estimated profiles were developed along the levee and floodwall alignments, and four cross sections were established for engineering analyses. Analytical cross sections were evaluated at the following locations and based on existing topography, site observations, and planned design features:

Station 51+00; Right East Palo Alto side - New setback levee location
Station 46+50; Left Palo Alto side - New setback levee location
Station 70+00; Left Palo Alto side - New floodwall location
Station 71+00; Right East Palo Alto side - New floodwall location

The analytical sections are located in areas that are judged to be representative of the planned alignment and geometry of flood control features, and subsurface conditions at the site, including areas with soft underlying Bay Mud material, and areas with thicker pervious soil strata underlying thinner alluvial near surface soils. Analyses were performed to evaluate both levee and flood wall structures and at least one section was analyzed on each side of the creek.

4.2 Seepage Analysis

4.2.1 Analytical Approach

Seepage analyses were conducted for planned new levees within the San Francisquito Creek Project area. Analyses were performed in general accordance with the HDR Technical Design Memorandum (HDR, 2010) and the referenced USACE Engineer Manual EM 1110-2-1913, *Design and Construction of Levees*. The seepage analyses results were compared to established USACE criteria. The design criteria considered a maximum allowable exit gradient estimated at the landside levee toe of 0.5.

The objectives for the seepage analyses included:

- Assessing seepage flow mechanisms and characteristics for selected cross-sections.
- Estimating seepage exit gradients in landside levee slope and toe areas.
- Estimating phreatic surfaces within the levee prism.
- Estimating pressure distributions within the levee prism and foundation.

A similar approach was used for flood walls with the flood wall modeled as an impervious barrier. The seepage evaluations were performed using finite element analyses using 2007 SEEP/W software, developed by GEO-SLOPE International, Ltd. Total head estimates from SEEP/W analyses were used to estimate average vertical exit gradients at landside levee and flood wall toe areas and the phreatic surface within the levee prism or adjacent to floodwall structures. Pore pressure distributions from SEEP/W were used in slope stability analyses as described in *Section 4.3* of this report.

Seepage models extended from the center of the channel to at least 100-feet past the landside toe of the proposed levee or flood wall. A no-flow boundary condition was assumed along the lower boundary of the model. A constant-head boundary condition set to the HDR design water surface elevation was modeled along the vertical waterside boundary at the center of the creek channel.

For levee cross-sections, the channel bottom and the waterside slope of the levee was model with a constant head boundary condition set at the HDR design water surface elevation. The landside portion of the model along the levee and landside ground surface was modeled as a potential seepage surface. A constant-head boundary condition set to the ground surface elevation was modeled at the vertical landside boundary of the model.

For flood wall cross-sections, the channel bottom and the waterside ground surface was model with a constant head boundary condition set at the HDR design water surface elevation. The landside portion of the model beyond the flood wall was modeled as a potential seepage surface. A constant-head boundary condition set to the ground surface elevation was modeled at the vertical landside boundary of the model.

4.2.2 Design Hydraulic Conductivity Parameters

Values for saturated hydraulic conductivity were selected using stratigraphic and visual material classification, index tests and subsequent classification, and gradation analyses. Typical published hydraulic conductivity values for field and laboratory classified materials were compared to values stated by USACE in Appendix C of their San Francisquito Creek report (USACE, 2009), to select permeability values for seepage analyses. The actual values for hydraulic conductivity, including anisotropy ratios were selected for different soil layers in the analyzed sections are based on or experience and the DWR Urban Levee Evaluation (ULE) guidance document (DWR, 2010). These values are presented in **Table 2**. In some cases an interlayered soil zone was modeled as a single layer with hydraulic conductivity values selected to representatively describe the different soils in the layer.

4.2.3 Seepage Evaluation and Results

Levee Cross Section (Left Station 46+50; Palo Alto, Right Station 51+00; East Palo Alto): For levee seepage analyses, the project team evaluated the estimated phreatic surface within the levee fill and average vertical exit gradients at the landside toe of the levee. The results from seepage analyses indicate that exit gradients estimated at the landside levee toe are less than the maximum allowable exit gradient of 0.5 (i.e. acceptable), as prescribed in EM 1110-2-1913. No areas of potential through seepage were identified during analyses as estimated phreatic surfaces exited at or very near the landside levee toe. Since the levee fill material specified for use in construction is expected to have low permeability and moderate to high cohesion, the piping potential through the levee prism is expected to be low.

Floodwall Cross Section (Left Station 70+00; Palo Alto, Right Station 71+00; East Palo Alto): The results from seepage analyses indicate that exit gradients estimated at the landside floodwall toe exceed the maximum allowable exit gradient of 0.5 for a floodwall constructed with a shallow foundation. In the vicinity of the San Francisquito Creek Pump Station, a shallow and pervious soil unit was encountered between approximate Elevation 10 to -5, underlying a relatively thin blanket layer. Extending the floodwall structure to cut off seepage flow through this unit reduces the estimated exit gradient to an acceptable value, below maximum allowable exit gradient of 0.5 (i.e. acceptable), as prescribed in EM 1110-2-1913.

Seepage analyses results are presented in **Table 3** and presented graphically in **Appendix E**. Tabular results include the exit gradients estimated at the landside levee or floodwall toe. Graphical results show total head contour variations throughout the model, material properties assumed for each layer, analysis section details, and estimated exit gradients.

4.3 Levee Stability Analysis

4.3.1 Analytical Approach

Analyses were performed in general accordance with the HDR Technical Design Memorandum (HDR, 2010) and the referenced USACE EM 1110-2-1913, and USACE Engineer Manual EM 1110-2-1902, *Slope Stability.* The seepage analyses results were compared to established USACE criteria. Levee stability was evaluated for three analysis cases:

- **Case 1** – End-of-Construction
- **Case 2** – Steady State Seepage
- **Case 3** – Rapid Drawdown

The stability evaluations were performed using finite element analyses using 2007 SLOPE/W software, developed by GEO-SLOPE International, Ltd. Levee stability for each case was evaluated using the appropriate piezometric conditions and corresponding soil strength properties. Stability was evaluated using the Morgenstern and Price analysis method, which satisfies both moment and force equilibrium. Slip surfaces were defined using the grid and radius method, assuming a 5-foot minimum thickness for each failure. The approach for each case is summarized in the sections below.

Case 1: End-of-Construction (Short Term Condition)

This case represents the condition during and immediately after levee construction. Seepage analyses were conducted using SEEP/W to estimate the phreatic surface and pore water pressures in the embankment for use in end-of-construction stability evaluations. Seepage analyses assumed that the levee foundation was subjected to Mean Higher High Water (MHHW; Elev. 7.1, provided by HDR) in the creek channel. Undrained strengths were assumed for impervious levee embankments and foundation soils as these low permeability soils do not have sufficient time to drain once the load is placed. Drained strengths were assumed for coarse-grained soils. Both the waterside and landside slopes were evaluated. As specified in EM 1110-2-1913, the required minimum factor of safety for this condition is 1.3.

Case 2: Steady State Seepage Conditions

This case represents the levee embankment under the design flood condition. The analysis assumes the duration of the design flood (HDR design water surface) is long enough to establish steady-state seepage conditions through the levee embankment. The phreatic surface and pore water pressures estimated within the embankment and levee foundation during steady-state seepage analyses (see *Section 4.2* above) were used in this stability evaluation. Shear strengths of the soils were defined using estimated drained strengths. As specified in EM 1110-2-1902, the required minimum factor of safety for the steady state seepage condition is 1.4 for the landside levee slope.

Case 3: Rapid Drawdown Conditions

This case represents a three-stage rapid drawdown analysis approach (Duncan and Wright, 2005). The levee is assumed to have been saturated long enough under the design flood (HDR design water surface) to develop steady state seepage conditions within the embankment, and the flood recedes too quickly for the embankment and foundation pore pressures to dissipate. The first phreatic surface in this case represents the HDR design water surface and was estimated from the seepage analyses discussed in *Section 4.2* above. The second phreatic surface represents the post-drawdown water surface elevation, a conservative estimate of low-flow conditions within the channel (one foot above the channel bottom), and an assumed ground water elevation in the vicinity of the levee prism based on observations during field explorations.

For the three-stage rapid drawdown analysis, a separate slope stability computation is performed at each stage as follows, and the lowest computed factor of safety is reported:

- For low-permeability materials; (1) effective stresses (drained strengths) are used with the first phreatic surface before drawdown, (2) total stresses (undrained strengths) are used for the second phreatic surface after drawdown (3) the lower of the two strengths (drained or undrained) is used with the second phreatic surface
- For free draining materials, effective stresses (drained conditions) are used for all three stages

Shear strengths for the levee material and upper, fine-grained foundation layer were defined with drained and undrained strengths, in accordance with the procedure outlined in Duncan and Wright, 2005. Shear strengths for lower foundation soils, below potential drawdown failure surfaces, were modeled using drained strengths. As specified in EM 1110-2-1902, the required minimum factor of safety for the rapid drawdown condition is 1.0 for the waterside levee slope following a relatively short duration flood stage, which is considered appropriate for this analysis.

4.3.2 Strength Parameters Used for Analyses

The general approach used to evaluate shear strengths for the embankment and foundation soils is summarized below. Input parameters such as unit weights, cohesion and friction angle are presented in **Table 2**. Specific shear strength information used for analysis for all materials is presented below.

Existing and New Embankment Fills

The drained shear strength for the existing and new embankment materials were selected from a range of appropriate values provided by USACE in Appendix C of their San Francisquito Creek report (USACE, 2009). Effective cohesion and effective friction angle are used for drained shear strength. The undrained shear strength for the new embankment material was estimated from a laboratory Consolidated Undrained (CU) triaxial test from the USACE in Appendix C of their San Francisquito Creek report (USACE, 2009). Undrained strengths of the embankment soil were estimated using total strength parameters (cohesion and friction angle). The undrained strength of the embankment material for the end of construction condition was reduced due to the presence of the underlying weaker Bay Mud layer (soft material) based on correlations from Duncan et. al., 1989.

Undrained Shear Strengths - Foundation Soils

Undrained shear strengths for foundations soils were estimated by correlating CPT determined shear strength with shear strength values from unconfined compression tests and triaxial unconsolidated undrained tests. The empirical cone factor, N_{kt}, was adjusted so the CPT data correlated with the laboratory data. An N_{kt}, value of 15 was used in for correlation.

Coarse-grained foundation soils were assumed to drain reasonably rapidly and not generate excess pore water pressure; therefore, the shear strengths for coarse-grained foundation soils were assumed to be the same for undrained and drained conditions.

Drained Shear Strengths - Foundation Soils

The drained shear strength for the foundation materials were selected from a range of appropriate values developed for soils in the Central Valley as part of the DWR ULE program. This program included triaxial tests, direct simple shear tests and direct shear tests for a variety of alluvial soils and softer, normally consolidated clays, similar to the soil conditions at the San Francisquito Creek site.

4.3.3 Levee Stability Evaluation and Results

The results of the levee stability evaluations for the three analyses cases are discussed below. The results are also presented in **Table 3** and in **Appendix F**. Tabular results include Factors of Safety estimated for the three applicable analyses cases. Graphical results show critical slip surface geometries, material properties assumed for each layer, analysis section details and geometry, and estimated Factors of Safety.

Case 1: End-of-Construction Stability Evaluation

The initial analyses for the end of construction condition included a new levee about 13 feet high (top of levee elevation 18.6’), placed on a Bay Mud foundation with the undrained shear strength of the Bay Mud materials equal to 150 psf. An additional assumption is that there is no strength gain in the normally consolidated Bay Mud material due to rapid placement of the levee fill (i.e. fill placement would occur before the Bay Mud could begin to dissipate pore pressures). The end of construction stability factor of safety for a full height levee is less than the required value of 1.3.

Additional stability evaluations of the planned levees were performed assuming the embankment fill was placed in stages to allow for strength gain in the Bay Mud. The staged construction assumptions and approach consists of construction of the levee to one-half its height in approximately one month, followed by a one and a half month (45 day) waiting period to allow for Bay Mud consolidation, dissipation of pore pressures and strength gain. After this period the levee would be constructed to full-height. The waiting period allows excess pore pressures in the foundation material to dissipate, resulting in a partially consolidated condition, and higher undrained strengths under the levee prism. An undrained shear strength value of 300 psf was selected for Bay Mud materials under this staged construction condition. The partial dissipation of pore pressure and increase in Bay Mud shear strengths beneath the levee from 150 psf to 300 psf is based on the following assumptions:

- The coefficient of consolidation (C_v) of the Bay Mud is estimated to be 20 ft^2 per year.
- A non-linear strain stain profile was applied to estimate the pore pressure dissipation in the Bay Mud, based on an approach by J.M. Duncan, 1991. This approach is based on the concept that strains in the Bay Mud layer will be non-uniform, and will be greater near the surface of layer and will decrease with depth.
- There is a minimum 45 day wait time at the end of the first stage construction (i.e. fill placement to half the levee height) and the beginning of the second stage construction (i.e. continuation of fill placement to the levee design grade).

The factor of safety is improved with staged construction as compared with full height construction of the levee. However, with staged construction, stability results of the representative sections indicated factors of safety of less the minimum design requirement of 1.3.

In order to improve the factor of safety to meet criteria, additional reinforcement of the levee foundation will be required, in addition to staged construction. Foundation reinforcement was modeled as a reinforcement “load”. The necessary reinforcement “load” can be achieve by placing a high strength, biaxial polyester geogrid product (Huesker Fortrac Geogrid 80 MP, or equivalent) within the embankment. By incorporating two layers of geogrid, the factors of safety for the design sections were approximately equal to, or greater than the design limit of 1.3. The stability results shown in the table below are for the end of construction condition using staged construction, for both landside and waterside slopes of the levee, with and without geogrid reinforcement.

End-of-Construction Levee Stability; Geogrid Comparison		
Station	**Factor of Safety Staged Construction Without Geogrid Layers**	**Factor of Safety Staged Construction With Geogrid Layers**
46+50 Palo Alto Waterside	1.2	1.6
46+50 Palo Alto Landside	1.0	1.3
51+00 East Palo Alto Waterside	1.5	1.7
51+00 East Palo Alto Landside	1.1	1.5

It is noted that the geogrid will provide a stabilizing layer for construction of the initial lifts of the levee embankment fill. Further discussions are provided in *Section 5*.

Case 2: Steady State Stability Evaluation
The results of steady-state stability evaluations for the applicable analysis cross-sections indicate that the estimated factor of safety is equal to or greater than the minimum design requirement of 1.4.

Case 3: Rapid Drawdown Stability Evaluation
The results of rapid drawdown stability evaluations for the applicable analysis cross-sections indicate that the estimated factor of safety is equal to or greater than the minimum design requirement of 1.0.

4.4 Settlement Analysis

The new levees will be located on areas underlain by soft compressible Bay Mud that will consolidate under the weight of the new embankment fill. Laboratory consolidation tests were performed on the Bay Mud to evaluate its compressibility. Soil parameters evaluated include compression ratio ($C_{\varepsilon c}$), recompression ratio ($C_{\varepsilon r}$), coefficient of consolidation (C_v), maximum past pressure, and secondary compression ratio ($C_{\varepsilon\alpha}$). These properties are used in analyses to estimate levee settlement, and are included in **Table 2**.

4.4.1 Primary Consolidation Settlement Estimates

The computer program SetCalc Version 1.0, developed by Virginia Polytechnic Institute and State University, was used to estimate total primary consolidation settlement for an analysis section. As stated in the SetCalc user's manual, "SetCalc can be used to compute primary consolidation settlement or rebounds caused by foundation and fill loads, reduction in stress due to excavation, and increase or decrease in effective stress due to changes in water table elevation."

In SetCalc, the embankment load is modeled as layers of rectangular loads. The load is widest at the base of the embankment and narrowest at the crest of the embankment. The embankment was assumed to have a length of 1,000 feet to ensure the accuracy of the settlement at the center of the levee. For all the analysis sections, the geometry of the strip fill for the embankment was developed assuming a 3H:1V waterside slope, a 2H:1V landside slope, and a 16-foot wide crest. The height of the levee at each analysis section was taken as the difference between the surveyed ground surface elevation and the design crest elevation.

The embankment properties, subsurface profiles, and soil parameters were developed for Station 46+50 Palo Alto area (golf course) along the planned embankment centerline. The settlement of the coarse-grained soils along the alignment (especially post-construction) are relatively small compared to those of the fine-grained soils, so settlement of the coarse grained soils was approximated by assigning equivalent fine-grained consolidation properties to the coarse-grained soils. For the analysis section, the subsurface profile data, assumed maximum past pressure distribution, and embankment loading were all input into the SetCalc program; and the total primary consolidation settlement was estimated to be about 18 inches, for the full levee prism, over a period of 23 months.

4.4.2 Secondary Compression

Long term secondary compression is assumed to begin at the end of primary consolidation and is assumed to continue indefinitely. However, for practicality, the end of secondary compression is assumed to occur in 50 years. Theoretically, the end of primary consolidation occurs after all excess pore pressures are dissipated due to application of loading. However, 100% pore pressure dissipation can require a long period of time, and secondary compression (rearrangement of soil particles due to applied stress) usually begins before 100% pore pressure dissipation is completed. For settlement evaluation, the beginning of secondary compression is assumed to occur after 90% pore pressure dissipation.

Secondary compression was estimated for the planned levee at Station 46+50 (Palo Alto Side) and Station 51+00 (East Palo Alto side) at the time corresponding to 50 years after the start of construction. Coarse-grained and overconsolidated strata are not expected to undergo significant secondary compression, so secondary compression was only estimated for Bay Mud strata. Estimated secondary compression of the Bay Mud under the planned levee prism loads is approximately 2 to 4 inches.

4.4.3 Post-Construction Settlements

Due to the need to construct the planned levees in a staged fashion, simplifying assumptions were made to divide total settlement into during construction and post- construction settlements. For analyses purposes we assumed that construction of the initial stage (lower 6 feet) of the levee section would be completed within a 60 day period (2 months), followed by a 45 day waiting period to allow for some strength gain in the Bay Mud material (refer to Section 4.3.4), and consolidation settlement. Post initial-stage-construction- plus-waiting-period settlements are estimated to range from 12 to 14 inches, which includes primary consolidation and secondary compression.

4.4.4 Differential Settlements

Variations in foundation conditions over relatively short horizontal distances should be expected where the levee alignment crosses between the Bay mud deposits in the new levee alignment areas and the less compressible Holocene flood plain and flood basin deposits. Soil deposits in the floodwall areas will also experience relatively small increases in net loading, reducing the settlement potential of the soils in these areas, compared with new levee fills over Bay Mud deposits.

Differential settlements at transitions between floodwalls and new levee fills should be expected. Differential settlements, if concentrated over a short horizontal distance, could cause transverse cracking of the new embankment areas, particularly for embankments built of relatively stiff cohesive materials. Such cracking could permit through seepage and potentially cause internal erosion during periods of high water levels in the creek. Based on the assumption that a post-construction differential settlement of 8 inches could occur over a 100 foot distance, we do not anticipate that transverse cracking of the new embankment will occur.

4.5 Seismic Analyses

An evaluation of seismic hazards that could potentially impact site improvements, such as liquefaction and liquefaction-induced settlement, was performed using data and information from the subsurface exploration program and review of relevant geologic references. Details of this evaluation are discussed below.

4.5.1 Liquefaction

As shown on **Figure 4**, the site is located within a Seismic Hazard Zone for liquefaction (CGS, 2006). The term liquefaction has been used to describe the seismic behavior of saturated soils. The phenomenon is generally characterized as loss of strength and stiffness during and following seismic shaking. Soils most susceptible to liquefaction are loose, clean, poorly graded, saturated sands and silts. A liquefaction analysis was performed following the procedures recommended by Idriss and Boulanger (2008) based on CPT data collected during the subsurface exploration program. The analysis considered a design ground water depth of 2 feet.

Design Ground Motion for Liquefaction Analysis

Liquefaction assessment requires consideration of both peak ground acceleration (PGA) and earthquake magnitude. Special Publication 117 - Guidelines for Evaluating and Mitigating Seismic Hazards in California (CGS, 2008) specifies "characterization of the ground motion at the site in terms of PGA with a 10% probability of exceedance in 50 years." For this analysis, seismic loading conditions were developed for a 20% probability of exceedance in 50 years (224-year return period), as this closely represents the criteria given in the DWR ULE guidance document (200-year return period). This results in a PGA of approximately 0.4g at the site. The majority of the hazard is associated with a magnitude 8.0 event on the San Andreas Fault. The effect of earthquake magnitude is incorporated into liquefaction analysis using a Magnitude Scaling Factor (MSF), which was estimated at 0.85.

Liquefaction Triggering Analysis

The liquefaction analysis was based on the 2008 Idriss and Boulanger Method, which is an update to the NCEER 1997 Method (Youd and Idriss, 2001). Visual classification and laboratory test results from the borings were used for site-specific correlation of CPT data. The analysis indicates that some of the sand layers may liquefy during a large seismic event. Potentially liquefiable layers, that will not be removed, are below a depth of 10 feet and are generally less than 1½ feet thick.

4.5.2 Consequences of Liquefaction

Soil liquefaction can result in ground surface rupture, bearing failure, lateral spreading, and settlement at the ground surface. Due to the presence of a stiff, non-liquefiable capping layer and the depth and discontinuous nature of the potentially liquefiable layers, ground surface rupture and bearing failure are not anticipated.

Lateral spreading refers to horizontal displacement of relatively flat-lying alluvial material toward an open or "free" face such as an open body of water, channel, or excavation. Since there is no free face within an appropriate distance from the site, the probability of lateral spreading occurring is considered to be low. Sand layers encountered during geotechnical explorations were found to be deeper than the channel bottom.

Post-liquefaction volumetric strain and settlement were estimated using the procedure by Idriss and Boulanger (2008). Post-liquefaction settlement was considered only for soil layers where the liquefaction triggering factor of safety was less than 1.1. Estimated liquefaction settlements generally ranged from ½-inch to ¾-inch.

4.5.3 Seismically-Induced Settlement

Strong ground shaking can also cause settlement of unsaturated soils above the groundwater table. Soils considered susceptible to seismically-induced settlement are generally loose, cohesionless soils and poorly compacted fills. The surficial soils encountered in our borings and CPTs above the groundwater table were cohesive and relatively stiff or the cohesionless soils will be removed beneath the levee; therefore, seismically-induced settlement of the near-surface soils is not anticipated at the site.

5. Conclusions and Recommendations

HDR prepared a Design Criteria and Considerations Technical Memorandum (HDR, 2010) that provided levee, structural and hydraulic design information. The geotechnical recommendations and design information presented herein are based on that design criteria and supplement the HDR memorandum.

Along much of the alignment, the planned levees will be supported on soft Bay Mud that underlies the project area. The geotechnical recommendations provided herein account for the relatively low strength and high compressibility of the Bay Mud. The Bay Mud materials will be soft and unstable, and these conditions will place limitations on the maximum depth of excavation and levels of compaction that are achievable in levee foundation areas. The depths of the exploration trenches for the proposed new setback levee alignment will need to be relatively shallow, and the initial lifts of fill may need to be constructed with reduced compaction criteria.

As discussed in *Section 4*, the slope stability factor of safety for the end of construction condition will be less than the minimum required criterion of 1.3 unless the levee fill is placed using staged construction techniques and the base of the levee fill (i.e. top of the foundation) is reinforced with geogrid materials. The staged levee construction will allow for partial consolidation and strength gain of the Bay Mud materials, so that the stability of the levee is improved when the remaining levee fill is placed to design grades. The strength improvement with staged construction will need to be supplemented with the geogrid layers that will provide additional tensile reinforcement and strength resistance against levee slope driving force, improving stability factor of safety values for end of construction conditions to the minimum design criterion of 1.3.

Also, as discussed in *Section 4*, the long term (steady-state) seepage and slope stability factors of safety meet design criteria based on modeled levee geometries, design water surfaces, and subsurface conditions. The waterside levee slopes meet the minimum factor of safety criteria for rapid drawdown. We do not expect that design mitigation measures will be necessary for steady state and rapid drawdown conditions.

The potential magnitudes of levee settlements (primary, secondary and liquefaction based) should be taken into account in levee crest grade design.

The remainder of this section presents recommendations for new levee geometries, levee earthwork, and staged construction of levee fill and geogrid placement, penetrations, and encroachments.

5.1 New Levee Geometry

HDR Design Criteria and Considerations Technical Memorandum (HDR, 2010) indicated a levee cross section with the waterside slopes inclined at 3 horizontal to 1 vertical (3H: 1V) and the landside slopes inclined at 2H: 1V. The levee crown width should be a minimum of 16 feet with 2% slopes for drainage purposes. This geometry provides levees that meet the requirements in USACE EM 1110-2-1913.

The levees should be over-built to accommodate up to 12 inches of post construction settlement, including primary, secondary and liquefaction related settlements. The proposed profile will be adequate to accommodate estimated settlements as discussed earlier in the report.

5.2 Levee Earthwork

5.2.1 Foundation Preparation and Geogrid Placement

In general, the foundation soils and younger Bay Mud deposits discussed previously that surround and underlie the planned levee are soft and of relatively low strength, particularly when the soils are saturated. Care is required to minimize disturbance of the levee foundation soils while preparing the foundation for the new levee. Bay Mud is expected to be exposed when excavating an exploration trench below along the planned levee alignment.

Based on our experience and understanding of young Bay Mud behavior and the results of the geotechnical investigations at the site, it is our opinion that the Bay Mud foundation soils are not trafficable by heavy equipment and will be significantly disturbed by conventional heavy equipment.

To the extent practicable, heavy equipment should not be allowed to travel over the levee foundation soils, unless a platform has been built up to enable equipment access. If operation of heavy equipment cannot be avoided on foundation soils the equipment should be track-mounted, low ground pressure equipment, with a maximum operating ground pressure equal or less than that of a Caterpillar D-4 dozer with wide tracks, and operation of the equipment on the foundation will be minimized to the maximum extent practicable. Placement and spreading of fill for construction of the foundation treatment should be performed using track-mounted, low ground pressure equipment, with a maximum operating ground pressure equal to or less than 4.2 pounds per square inch (psi).

The exploration trench for the levee should be excavated to a depth of 3 feet below the existing ground surface within the planned levee footprint, and should extend across the entire width of the proposed levee. The exploration trench will also function as a keyway for placement of the levee fill. A layer of geogrid, consisting of Fortrac 80 or equivalent, should be installed at the base of the exploration trench for purposes of stabilizing the subgrade and further improving the stability of the overlying levee fill during construction. The recommended levee configuration including exploration trench and geogrid placement is shown in **Figure 7**. The foundation preparation including the excavating the exploration trench and geogrid placement should consist of the following steps:

- The exploration trench should be excavated in the existing fill materials located above the Bay Mud layer to expose any detritus materials and unsuitable soil within the levee foundation. The trench should be excavated to a depth of 3 feet below the stripped and spoiled foundation surface with the base width extending to the toe of the existing levee as shown on **Figure 7**. Excavation slopes for the exploration trench should have a maximum inclination of 1 horizontal to 1 vertical.

- The trench should be inspected by a Geotechnical Engineer prior to geogrid placement and backfilling to ensure the proper removal of unsuitable materials and to identify any potential seepage paths. Unsuitable materials are considered as soils having high organic contents, or very soft soils with high moisture contents that could inhibit proper placement of the bottom geogrid layer.

- Unsuitable material should be carefully removed from the levee foundation to provide a relatively smooth, even surface across the width of the foundation, and a geogrid consisting of Fortrac 80 or equivalent, should be placed across the entire base width of the exploration trench, as shown in **Figure 7**.

- Levee fill should be used to backfill the exploration trench area. Levee fill material should be spread in uniform lifts not exceeding 8-inches in uncompacted thickness and moisture conditioned to optimum moisture or above as determined by ASTM D 1557. Due to the soft nature of the underlying Bay Mud it may not be possible for the contractor to compact the initial lifts of backfill to the same relative compaction as the levee embankment fill soils above the foundation. For the initial 16 inches (two lifts) of fill placed in the exploration trench/keyway, the minimum relative compaction requirement can be reduced to 90 percent based on ASTM D 1557.

- For subsequent lifts of levee fill within the exploration trench, the compaction requirement should be increased to 92 percent based on ASTM D 1557. All fill materials placed in the exploration trench should be moisture conditioned to optimum or above.

- The second geogrid layer should be placed over the exploration trench fill, three feet above the initial geogrid layer (and base of exploration trench) as shown in **Figure 7**. The second geogrid layer is for purposes of improving the static factor of safety of the landside levee slope under end of construction conditions, and should have a minimum reinforcement length of 40-feet as shown on Figure 7.

- All remaining levee fill above the second geogrid layer should be moisture conditioned to optimum or above and compacted to a relative compaction of 92 percent based on ASTM D 1557.

5.2.2 Additional Considerations for Foundation Preparation

Regardless of the care taken to minimize disturbance of the foundation soils and methods used to treat the foundation, very soft and sensitive zones may be encountered at the planned foundation levels for the levee that cannot be treated as planned. Careful observation of the foundation preparation will be required in the field, and modifications to the foundation preparation procedures or removal and replacement of foundation soils may be required.

If, in the opinion of the geotechnical engineer in the field, very soft soils at the base of the exploration trench area are too soft, the excavation may need to be taken deeper than planned. Additional foundation subgrade stabilization requirements may be necessary, such as additional layers of geogrid reinforcement, and /or admixture soil treatment.

In some cases, the foundation soils may appear suitable for foundation preparation, but efforts to treat the foundation may result in shear failure of the foundation soil. If shear failures occur, the disturbed soil will need to be removed and additional treatment or over-excavation of the foundation soils may be required to develop a more suitable foundation.

Trees or heavy brush vegetation encountered in the foundation area should have their root systems removed. Roots greater than 1.5 inches in diameter should be removed from areas of the proposed levee raise. The voids created by the removal of trees should be backfilled with low-permeability soil and compacted to at least the density of the adjacent, firm, undisturbed material.

5.2.3 Levee Fill

The new levees fill should meet the criteria established in the Design Criteria and Considerations Technical Memorandum (HDR, 2010). Levee fill material should be a soil or soil-rock mixture free from organic material or other deleterious substance. The material should have a plasticity index of at least 8% and less than 40%, a liquid limit less than 45%, and 100 percent of the material passing the 2-inch sieve, and at least 20 percent passing the number 200 sieve.

Levee fill material should be spread in uniform lifts not exceeding 8-inches in uncompacted thickness and moisture conditioned to optimum moisture or above as determined by ASTM D 1557. The fill should be compacted to a minimum dry density of 92% of the maximum laboratory dry density determined by ASTM Method D 1557, unless otherwise noted in this report.

5.3 Floodwalls

5.3.1 General

Both interlocking steel sheetpile cantilever walls and concrete T-type concrete walls were considered for floodwall design. During the subsurface exploration program, shallow, pervious soil units and soft Bay deposits were encountered below relatively thin blankets of low permeability soils along the proposed floodwall alignments. As discussed in *Section 4*, the results of SEEP/W analyses indicate that flood walls should include a cut off to penetrate the pervious foundation soils in order to meet the minimum acceptance criteria for underseepage gradients. In addition, flood wall cut offs should fully penetrate the soft bay deposits and tip in competent material below.

Shallow supported concrete T-type walls would likely have a wide foundation and be embedded 3 to 5 feet below the ground surface, and include a cutoff at the heel. Construction of this type of floodwall would require significant excavation, and a large construction footprint. Sheetpile walls could be constructed in a more limited construction zone with fewer disturbances to adjacent areas. Based on these considerations, we recommend that the flood walls consist of interlocking sheet piles walls.

Steel sheetpiles can be installed by either driving or vibrating individual sheet sections into place along the floodwall alignment. Steel sheets are typically interlocking using a ball and socket connection to link adjacent sections. It is critical that the individual sheetpiles remain interlocked during and after installation. We recommend continuous installation of the sheetpiles for the full depth of the flood wall. Excavation of the levee fill in front of the flood wall should commence only after the sheets have been installed to the design depth.

The installation of sheetpiles in hard or dense soils, or soils with gravel, may require pre-drilling around the perimeter of the shaft to loosen the soils and allow them to be driven or vibrated to full depth. If pre-drilling is used for pile installation, drilling voids remaining around and behind the members should be backfilled with coarse sand, gravel, or grout.

Installation of sheetpiling by driving may cause settlement of loose sands and softer silts and clays, depending on location relative to driving.

5.3.2 Design Parameters for Sheetpiles

Recommended lateral earth pressures for use in design of the sheetpile floodwalls are shown in **Figure 8** for cantilever wall conditions. These pressure diagrams include active and passive earth pressure values above and below the groundwater table, and also ground surcharge loading conditions. **Figure 8** includes earth pressures for static and seismic loading conditions. The seismic loading condition is based on the assumption that the cantilever sheetpile walls could be subjected to peak horizontal ground acceleration (PGHA) of 0.40 g during the design life of the structure. This PGHA value is approximately equal to a design earthquake with a return period of 224 years (i.e. a 20% probability of occurrence in 50 years).

The active earth pressures presented in **Figure 8** are based on the assumption that cantilever sheet pile elements are allowed to rotate outward towards the creek a small amount. Because of this rotation, settlement behind the shoring should be expected as high as 1 inch. This settlement is in addition to any settlement caused by construction vibrations, liquefaction related settlements, or consolidation settlements of new fill placed behind the sheetpile walls in areas underlain by Bay Mud.

We understand that HDR will be designing the flood walls based on applicable USACE standards and guidelines. For sheetpile floodwall design, USACE EM 1110-2-2504, (Table 5-1) indicates the required stability criteria for each design case based upon both the “unconsolidated undrained” and the “consolidated drained” shear strengths. **Table 4** provides soil parameters for use in the USACE design procedures for retaining, flood wall or sheetpile walls.

Minimum tip elevations are necessary to provided cutoff for seepage and a penetration into stiff soils below soft Bay Mud. We recommend a minimum embedment of 8 feet below the estimated bottom of young Bay Mud. Based on the estimated stratigraphy, the sheetpiles should be embedded to the following minimum tip elevation (i.e. no shallower than the elevations shown).

- Right Bank, East Palo Alto, Station 76+50 to 54+00: Elevation -15
- Left Bank, Palo Alto, Station 76+00 to 67+00: Elevation -10
- Left Bank, Palo Alto, Station 67+00 to 49+00: Elevation -15

Actual embedment could be deeper depending on the structural design.

5.4 Differential Settlements

In order to mitigate the potential for differential settlement at the transition between the floodwall and the new levee fill, the floodwall section should be extended into the new levee fill section (i.e. sheetpiles driven through the new levee crest), with a minimum overlap distance of 150 feet. This overlap will provide additional protection against levee through seepage if differential settlement and cracking of the levee fill should occur.

5.5 San Francisquito Creek Pump Station

The existing San Francisquito Creek pump station consists of a wet well, discharge box, pump house and control building, and is supported on mat type foundation. The bottom of the mat foundation varies within the structure. Based on the preliminary 60% design plans (HDR, December 2011), the building itself will be the flood control feature between approximately stations 71+00 and 72+00. The planned sheetpile floodwalls will tie into the pump station structure.

As built constructions documents were reviewed to evaluate the floodwall – pump station tie in. The documents provided by the JPA indicate that the backfill around the pump station is clayey sand with about 40% fines. The backfill is low permeability material and seepage around the building should not be an issue provided the flood wall is attached to the pump station.

We understand that the pump station was constructed in a deep shored excavation and that some of the soil encountered at subgrade level was overexcavated and replaced with well compacted fill. The pump station mat foundation extended several feet beyond the perimeter walls, resulting in a "lip" with backfill placed above the lip. The pump station will be subject to uplift pressures and buoyancy due to the flood levels. The HDR design flood level (approximately elevation 17) should be used to evaluate the uplift forces on the base of the pump station.

Resistance to uplift forces included the weight of the pump station and the weight of the soil above the foundation "lip". We recommend a buoyant weight of soil equal to 63 pcf be used above the lip. Additional resistance will be provided by the shearing resistance of the soil or the soil/structure contact. Based on an average foundation depth of 20 feet, a value of 200 psf over the length and depth of the below grade structure may be used to estimate the soil shearing resistance contribution to the overall uplift resistance. A minimum factor of safety of 1.2 should be provided against uplift.

5.6 Friendship Bridge Boardwalk Foundations

The foundation conditions at the planned boardwalk from Friendship bridge to the new Bay Trail are expected to consist of several feet of fill underlain by about 10 feet of soft, compressible young Bay Mud. The bottom of Bay Mud is at approximately elevation -10. The boardwalk should be supported on deep foundations deriving support in the stiff clays below the Bay Mud. Driven concrete piles may be designed on the basis of friction/adhesion between the pile and the surrounding soil below elevation -10. For design purposes, an allowable adhesion value of 500 psf is recommended for design for dead plus live loads. This value may be increased by 50% for all loads including wind or seismic. Based on this value a 12-inch square concrete pile driven to a tip elevation of -25 feet, would have an allowable capacity of 30 kips.

5.7 Levee Penetrations

There may be several locations where existing pipes and conduits located beneath the levee prism or within 10 feet of the toe of the levee will need to be removed and relocated above the HDR design water surface, or abandoned. If there are pipes or utilities beneath the levee footprint that need to relocated or abandoned, this activity should be carried out during the foundation preparation phase of the project. The pipe and surrounding backfill should be completely removed and the void left by the pipe should be backfilled with material meeting the requirements of levee fill, as discussed in *Section 5.2.3*. In areas where compaction of levee fill will be difficult (e.g. utilities extending into Bay Mud), a controlled low strength material may be used as an alternate. Controlled strength material should have a minimum compressive strength of 50 psi.

If removal of the pipe is not practical, then the pipe should be sealed, preferably by completely filling with concrete. However, seepage control measures such as landside toe drains may be necessary to collect water that maybe conveyed through the backfill surrounding the sealed pipe.

5.8 Levee Vegetation and Embankment Protection

Criteria for maximum permissible water velocities are presented in the USACE guidelines for the design of flood control channels (EM-1110-2-1601). These guidelines show maximum permissible mean flood channel velocities for bare earth channels ranging from 2 feet per second (fps) for fine sand to 6 fps for clay. For grass lined channels, maximum permissible velocities range from 5 fps to 8 fps depending on the type of soil and grass cover. If the mean velocities for the design flow in the channel are less than 5 fps, then the combination of silty and clayey soils to be used for the levee embankment construction and a well established vegetated cover on the levee slopes should provide adequate erosion protection. The erosion cover should be a non-woody ground cover in order to meet the USACE Guidelines for Landscape Planting and Vegetation Management as presented in the HDR Design Criteria and Considerations Technical Memorandum. If the design flow in the channel is greater than 5 fps, then additional erosion protection measures such as rock riprap, or permanent turf reinforcement mats (i.e. permanent geosynthetic erosion control blankets) may be necessary.

6. Limitations

This report was prepared for the use of HDR and the San Francisquito Creek Joint Powers Authority, exclusively. Our recommendations are based on the project information provided to us at the time of this report and may require modification if there are any changes in the nature, design, or location of the proposed flood protection improvements. We cannot accept responsibility for designs based on our recommendations unless we are engaged to review the final plans and specifications to determine whether any changes in the project affect the validity of our recommendations and whether our recommendations have been properly implemented in the design.

The recommendations in this report are based in part on the data obtained from the subsurface explorations. The nature and extent of variations between explorations may not become evident until construction. If variations from the anticipated conditions are encountered, it may be necessary to revise the recommendations in this report. We, therefore, recommend that GEI be engaged to make site visits during construction to: a) check that the subsurface conditions exposed during construction are in general conformance with our design assumptions and b) ascertain that, in general, the work is being performed in compliance with the contract documents.

Our professional services for this project have been performed in accordance with generally accepted engineering practices; no warranty, express or implied, is made.

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Figures

Figure 1 – San Francisquito Creek Flood Control Project Area Map

Figure 2 – Project Area Geologic Map

Figure 3 – Regional Fault Map

Figure 4 –State of California Seismically Induced Liquefaction Hazard Map

Figure 5 – Historic Estuary and Creek Channel Extents

Figure 6 – Site and Field Exploration Plan

Figure 7 – Typical Levee Schematic

Figure 8 – Lateral Earth Pressures

Figure 1 – San Francisquito Creek Flood Control Project Area

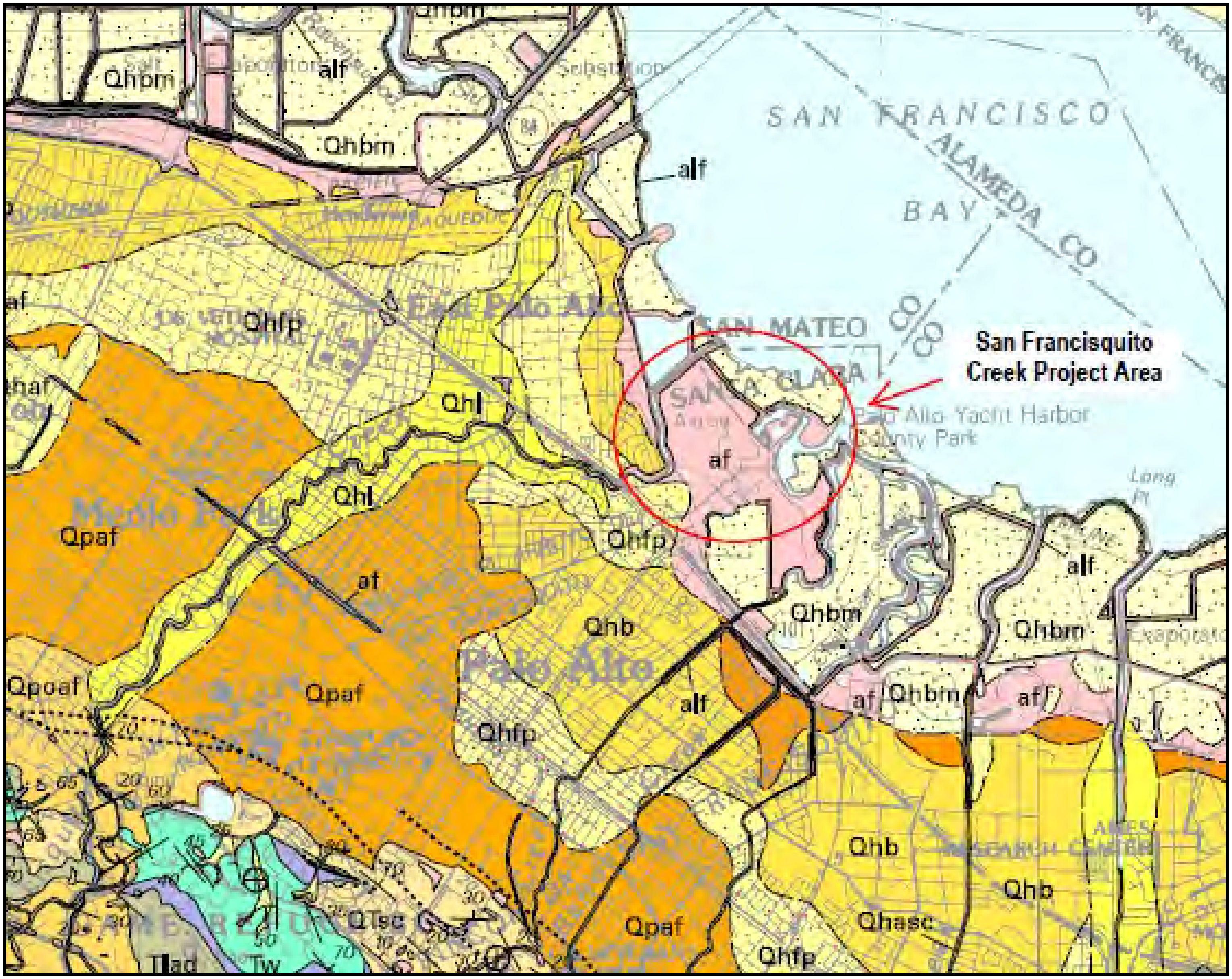


Figure 2 - Project Area Geologic Map (USGS, 2000)

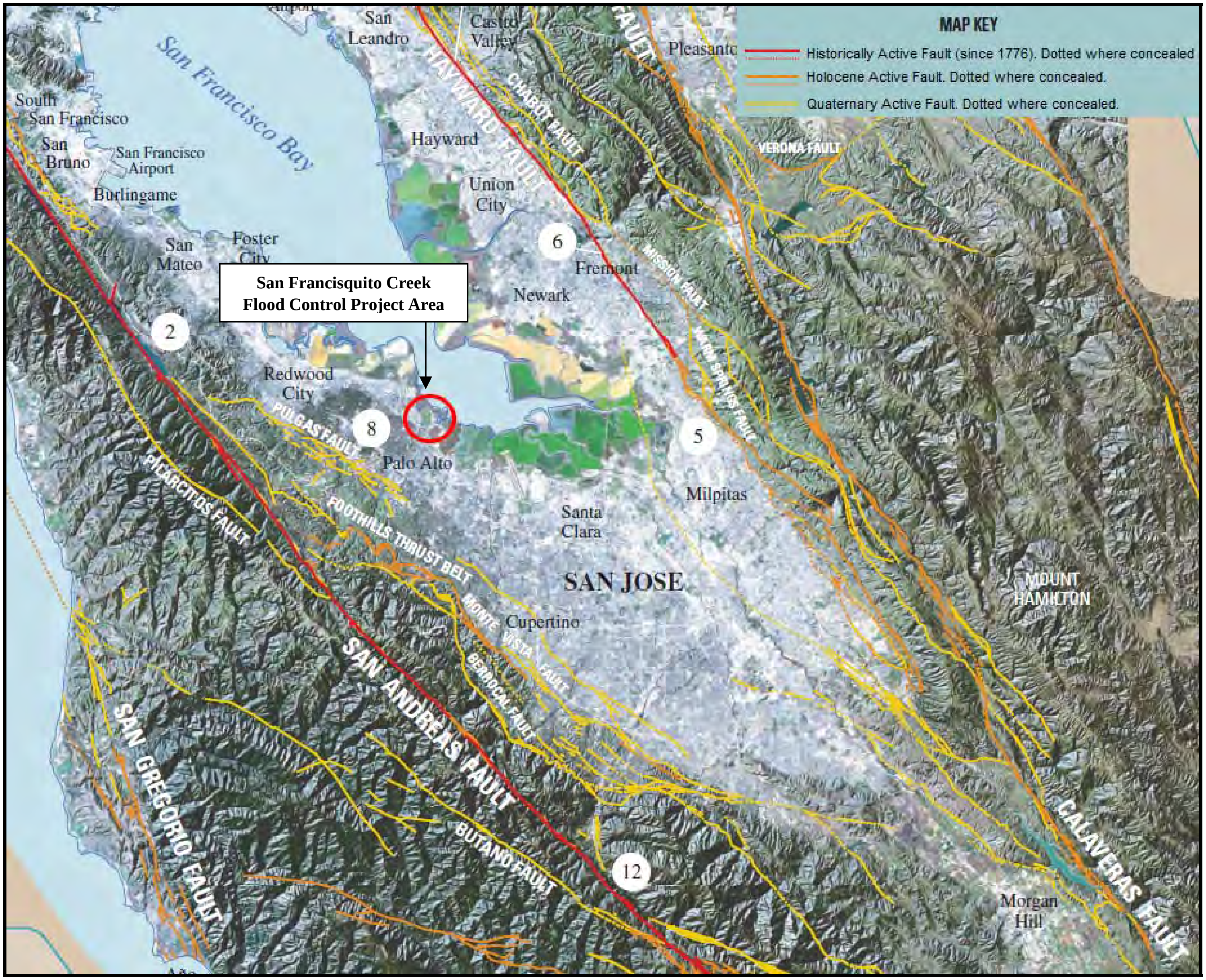


Figure 3 – Regional Fault Map (USGS, 2008)

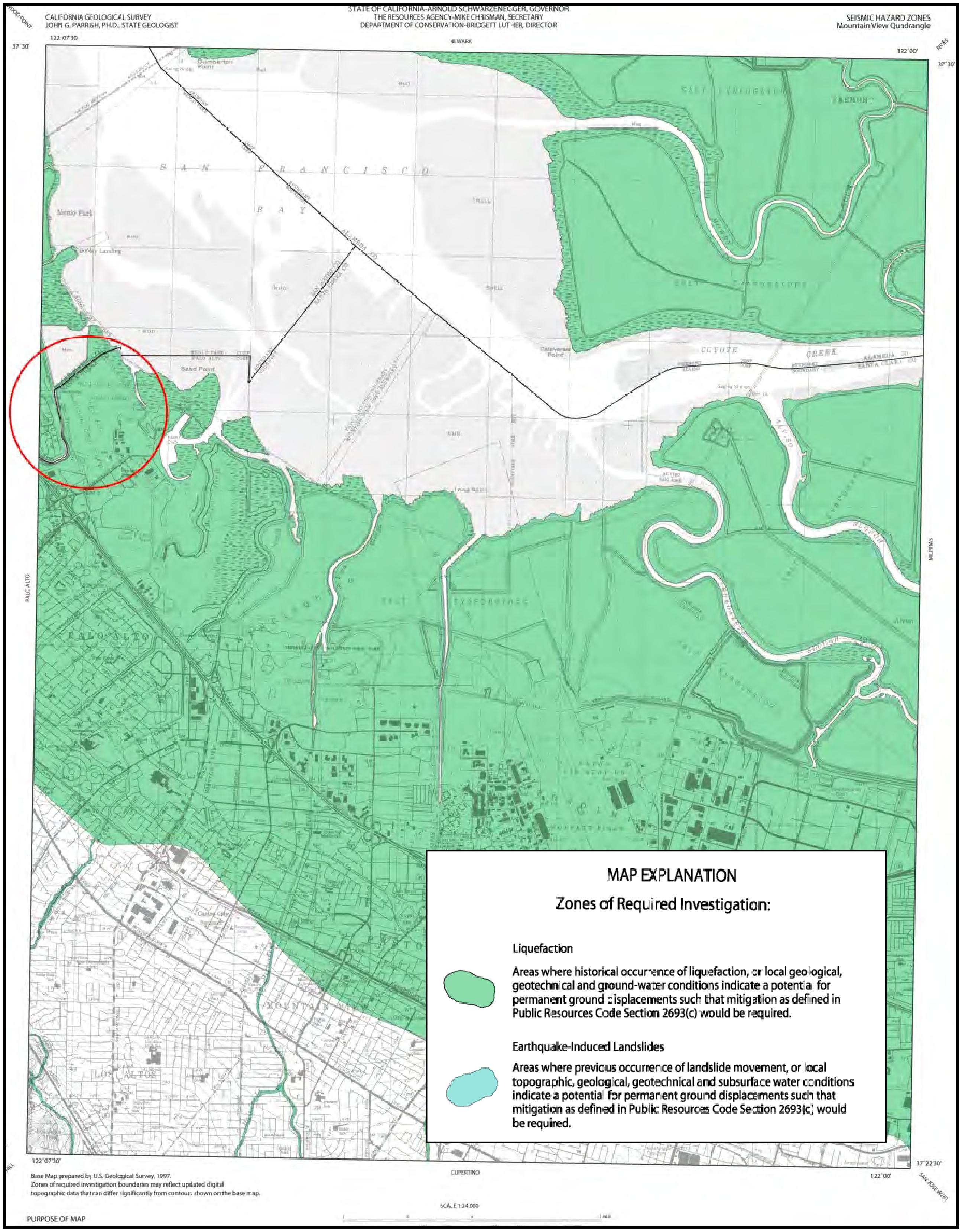


Figure 4 – State of California Seismically Induced Liquefaction Hazard Map; Mountain View Quadrangle (CGS, 2006)

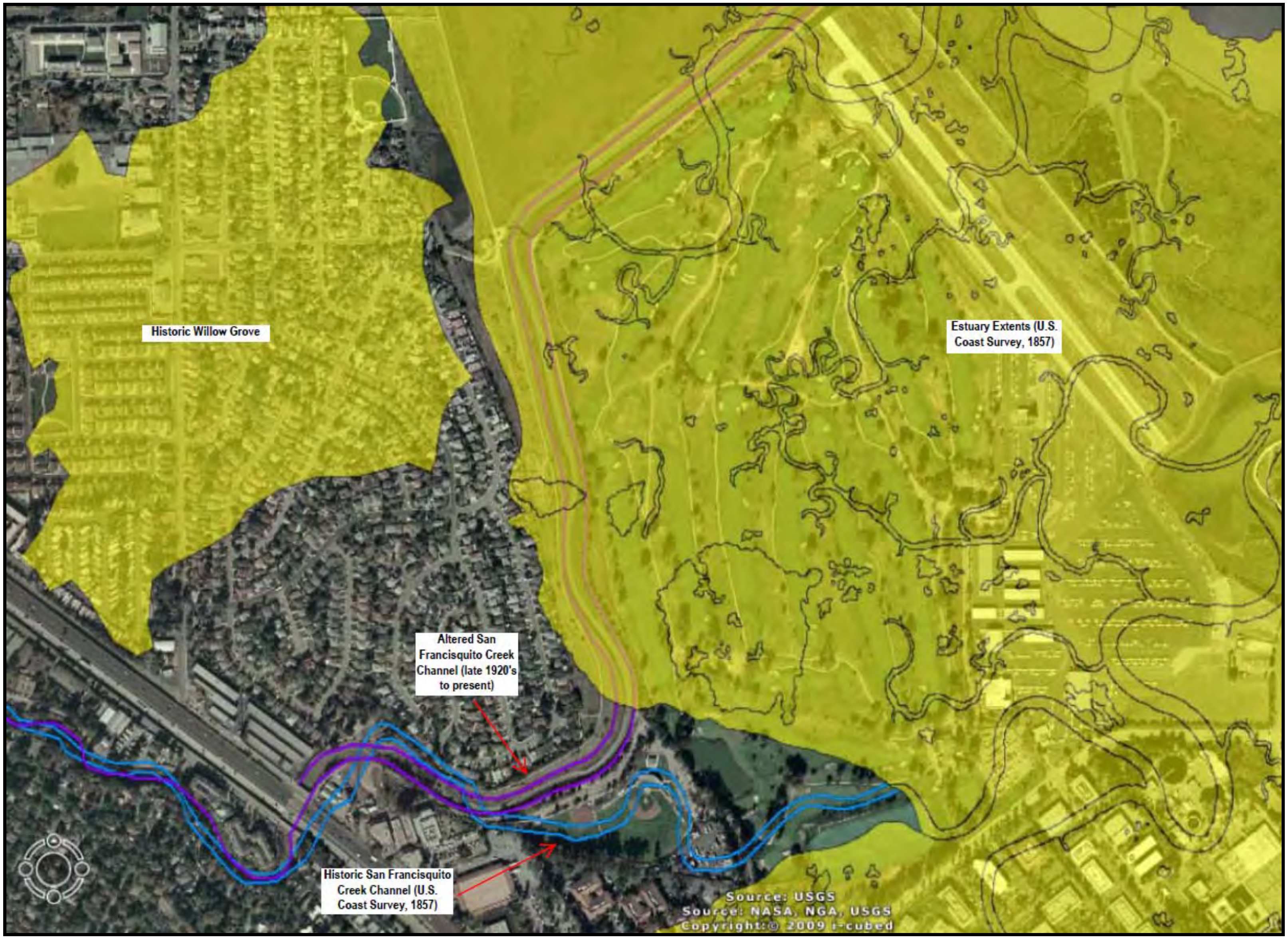
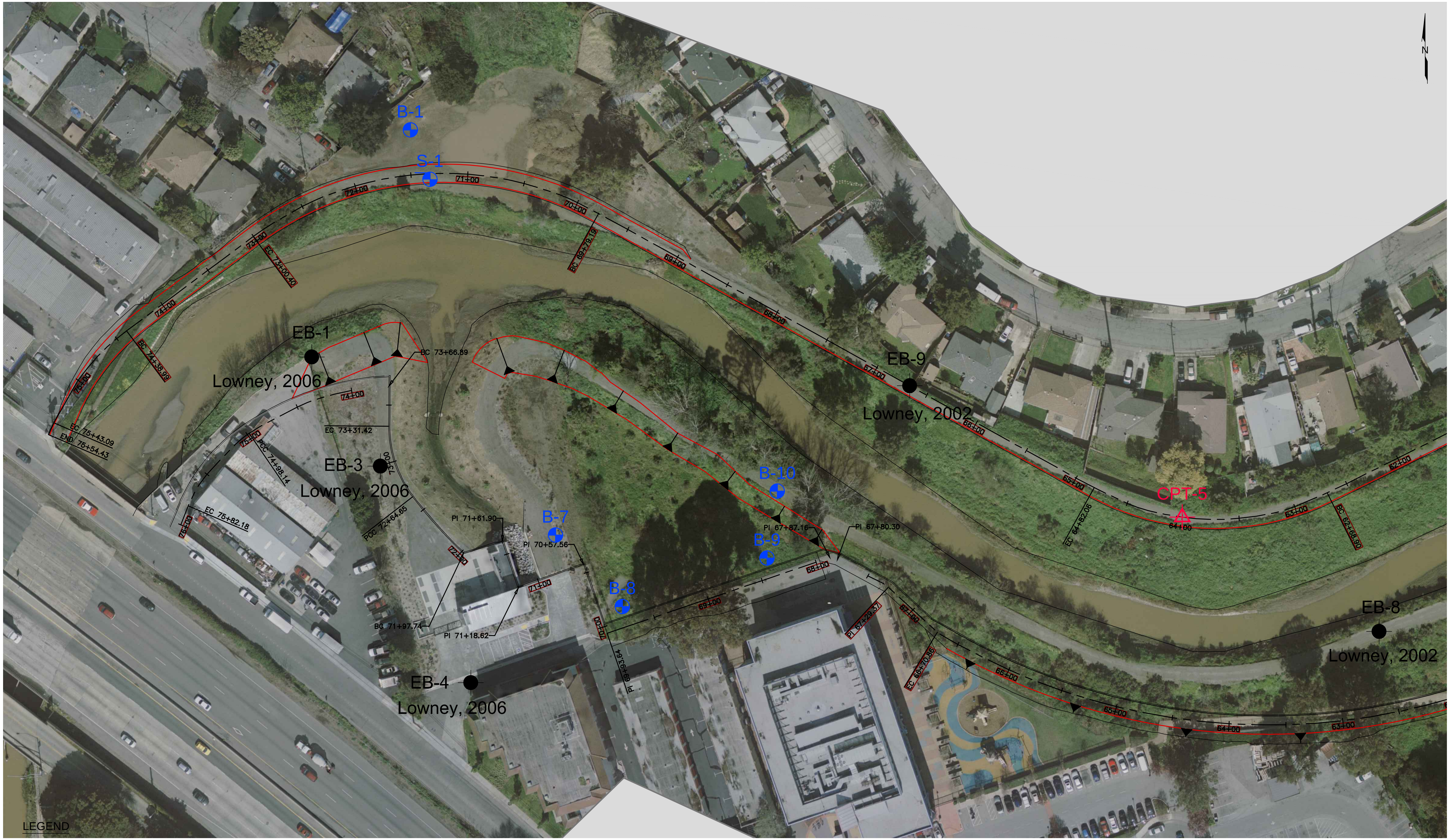


Figure 5 – Historic Estuary Extents and Historic and Re-Routed San Francisquito Creek Channel (SFEI, 2009)



LEGEND

⊕ APPROXIMATE LOCATION OF EXPLORATORY BORING

△ APPROXIMATE LOCATION OF CONE PENETRATION TEST

● APPROXIMATE LOCATION OF EXPLORATION BY OTHERS

0 80' 160'

SCALE, FEET

Oakland
California
GEI Consultants

San Francisquito Creek
Flood Protection Capitol Project
Highway 101 to S.F. Bay

GEI Project 092850

San Francisquito Creek
Joint Powers Authority

SITE AND FIELD EXPLORATION
PLAN
(sheet 1 of 5)

12/20/11

FIGURE
6a

Figure 6a 12/20/11 PYM

LEGEND

- 🌕 APPROXIMATE LOCATION OF EXPLORATORY BORING
- △ APPROXIMATE LOCATION OF CONE PENETRATION TEST
- ● APPROXIMATE LOCATION OF EXPLORATION BY OTHERS

0 80' 160'

SCALE, FEET

Oakland
California
GEI Consultants

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Flood Protection Capitol Project
Highway 101 to S.F. Bay

GEI Project 092850

San Francisquito Creek
Joint Powers Authority

SITE AND FIELD EXPLORATION
PLAN
(sheet 2 of 5)

12/20/11

FIGURE
6b

Figure 6b 12/20/11 PYM

LEGEND

◐ APPROXIMATE LOCATION OF EXPLORATORY BORING

△ APPROXIMATE LOCATION OF CONE PENETRATION TEST

● APPROXIMATE LOCATION OF EXPLORATION BY OTHERS

0 80' 160'

SCALE, FEET

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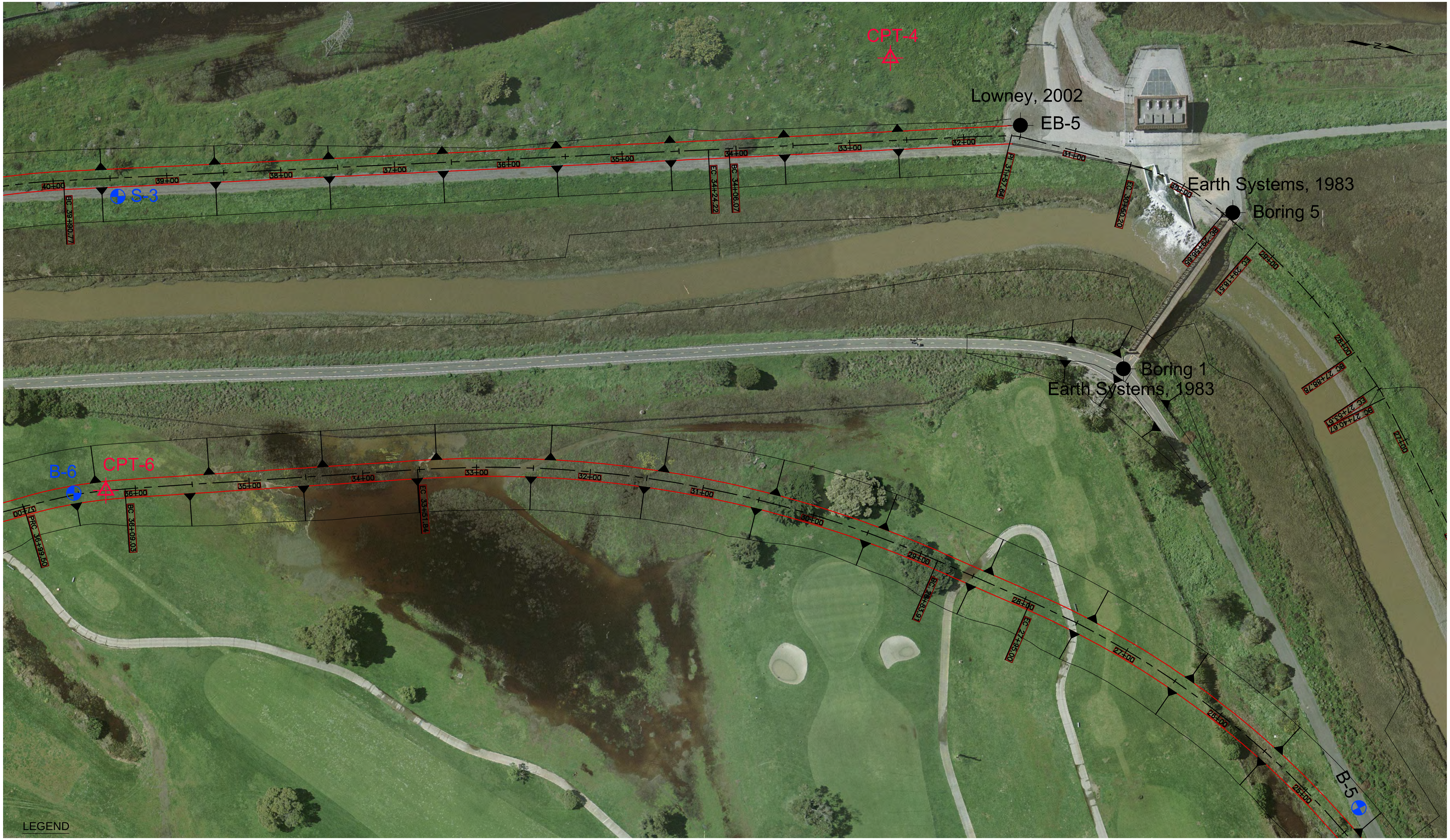
SITE AND FIELD EXPLORATION
PLAN
(sheet 3 of 5)

12/20/11

FIGURE
6c

Figure 6c 12/20/11 PYM



APPROXIMATE LOCATION OF EXPLORATORY BORING

APPROXIMATE LOCATION OF CONE PENETRATION TEST

APPROXIMATE LOCATION OF EXPLORATION BY OTHERS

0 80' 160'

SCALE, FEET

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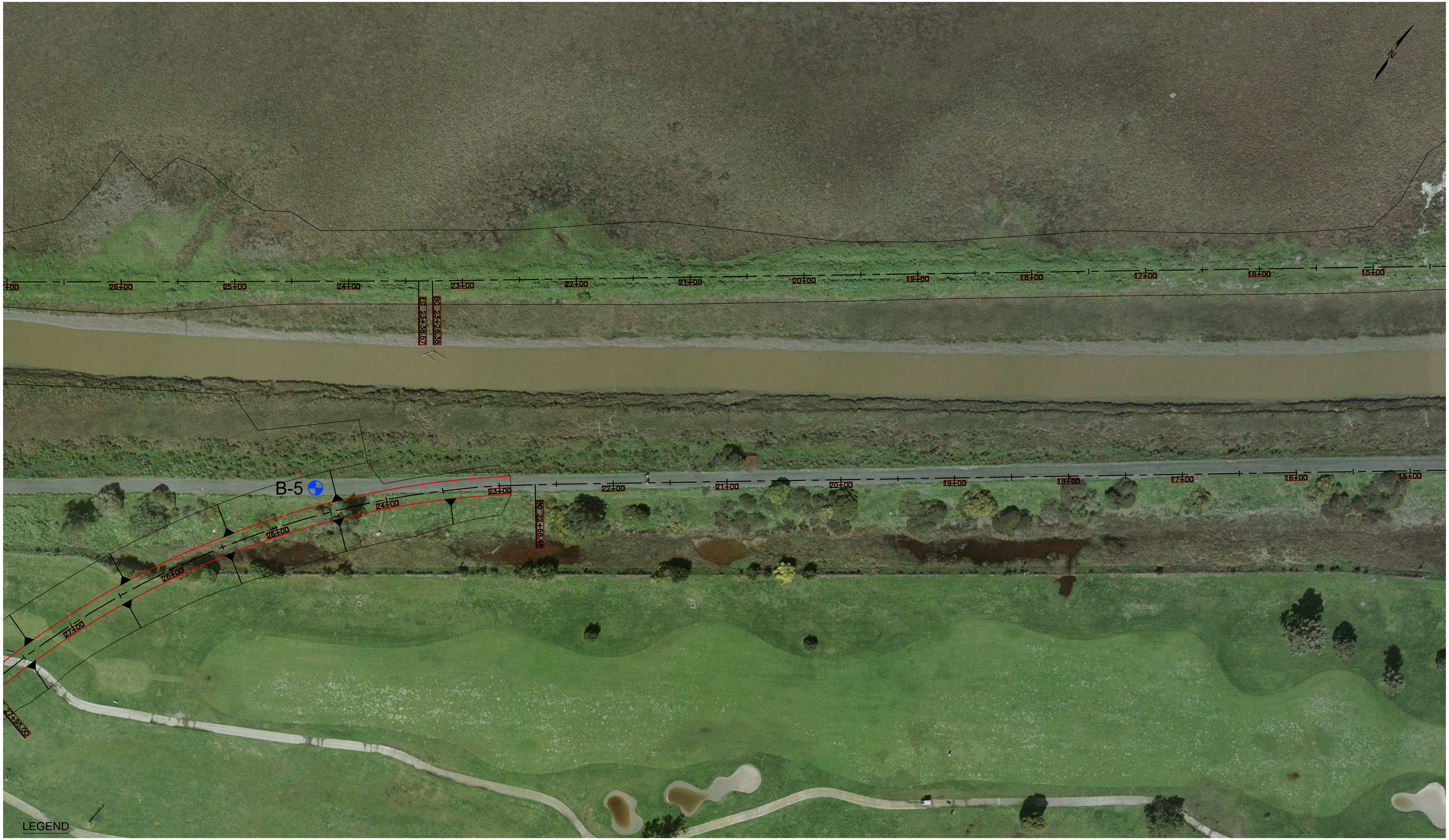
Joint Powers Authority

SITE AND FIELD EXPLORATION PLAN
(sheet 4 of 5)

12/20/11

FIGURE
6d

Figure 6d 12/20/11 PYM



LEGEND

● APPROXIMATE LOCATION OF EXPLORATORY BORING

△ APPROXIMATE LOCATION OF CONE PENETRATION TEST

● APPROXIMATE LOCATION OF EXPLORATION BY OTHERS

0 80' 160'

SCALE, FEET

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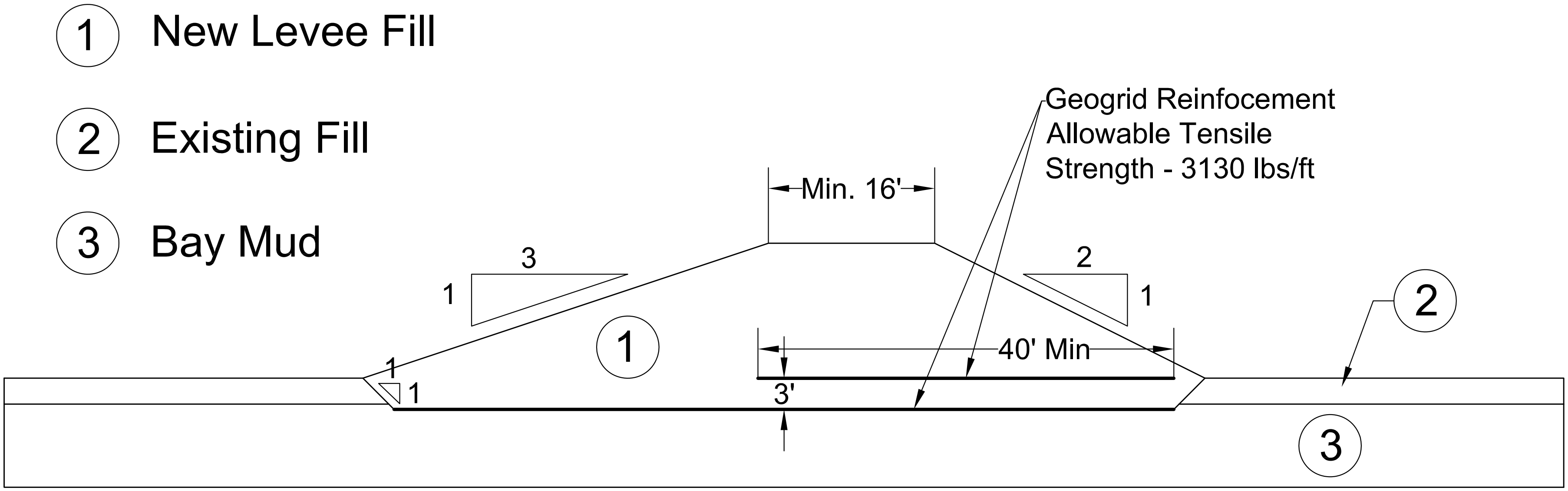
SITE AND FIELD EXPLORATION
PLAN
(sheet 5 of 5)

12/20/11

FIGURE
6e

Figure 6e 12/20/11 PYM



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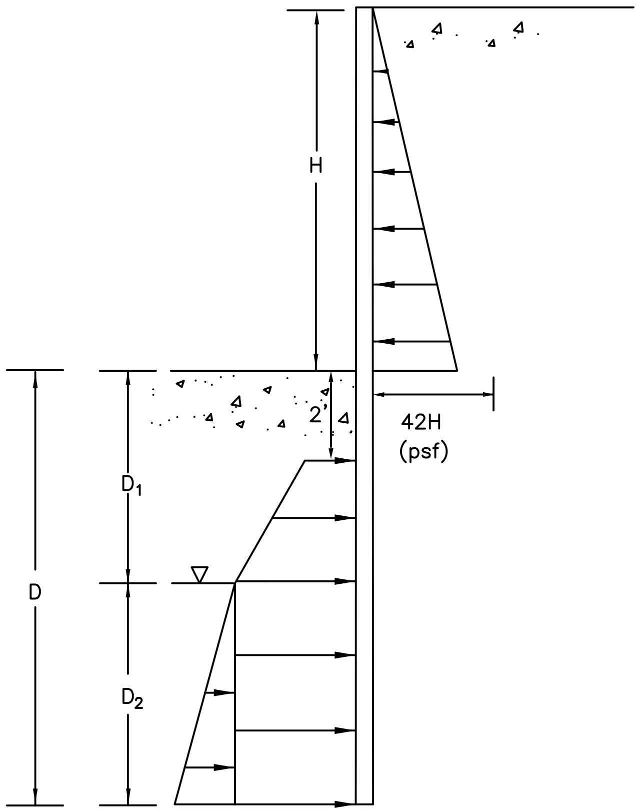
Flood Protection Project
San Mateo & Santa Clara
Counties, California

GEI Project 09285-0

Typical Levee Schematic

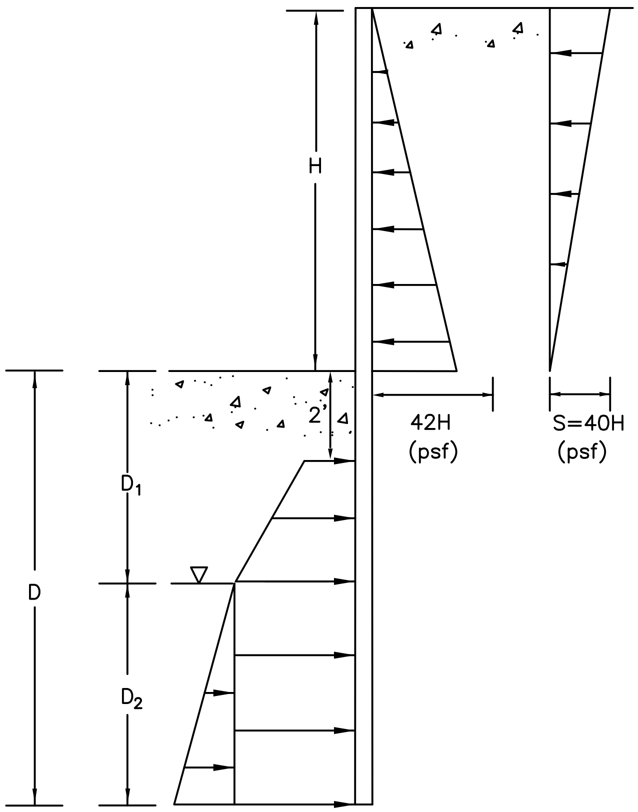
FIGURE
7

STATIC



ABOVE GROUNDWATER: 350 D_1 (psf)
BELOW GROUNDWATER: 350 D_1 + 200 D_2 (psf)

DYNAMIC



ABOVE GROUNDWATER: 400 D_1 (psf)
BELOW GROUNDWATER: 400 D_1 + 200 D_2 (psf)

LEGEND

H = HEIGHT OF THE WALL ABOVE THE BOTTOM OF THE CHANNEL EXCAVATION (FEET)

D = DEPTH OF THE WALL BELOW THE BASE OF THE CHANNEL EXCAVATION (FEET)

D_1 = DEPTH OF THE WALL ABOVE THE DESIGN WATER LEVEL (FEET)

D_2 = DEPTH OF THE WALL BELOW THE DESIGN WATER LEVEL (FEET)

S = SEISMIC PRESSURE

NOTE:
1. IGNORE PASSIVE RESISTANCE IN UPPER 2 FEET BELOW CHANNEL EXCAVATION.
2. IF THE WALL IS SUBJECTED TO ADJACENT VEHICULAR LOAD, THE WALL SHOULD BE DESIGNED FOR A UNIFORM PRESSURE OF 100 PSF FOR THE UPPER 10 FEET OF THE WALL.

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Counties, California

GEI Project 09285-0

Lateral Earth Pressures

FIGURE
8

Tables

Table 1 – HDR Project Design water Surface Elevations

Table 2 – Geotechnical Material Properties

Table 3 – Geotechnical Analyses Results

Table 4 – Flood and Retaining Wall Design Parameters

TABLE 1

Design Water Surface Elevations

Source:

Job No. 130806-241
No.

HDR Engineering, Inc.

Project	San Francisquito Creek	Computed	AQ	Date	07/13/10
Subject	Design Water Surface Profiles	Checked		Date	
Task	Profile for Geotechnical Analyses				

Station	7/13/10 HDR High WSE
0+00	13.5
1+00	13.5
2+00	13.5
3+00	13.5
4+00	13.5
5+00	13.5
6+00	13.5
7+00	13.5
8+00	13.5
9+00	13.6
10+00	13.6
11+00	13.6
12+00	13.6
13+00	13.6
14+00	13.6
15+00	13.6
16+00	13.6
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18+00	13.6
19+00	13.6
20+00	13.6
21+00	13.6
22+00	13.6
23+00	13.6
24+00	13.6
25+00	13.6
26+00	13.6
27+00	13.7
28+00	13.7
29+00	13.5
30+00	13.8
31+00	13.9
32+00	14.0
33+00	14.1
34+00	14.1
35+00	14.2
36+00	14.2
37+00	14.4
38+00	14.6
39+00	14.8
40+00	15.0
41+00	15.1
42+00	15.2
43+00	15.4
44+00	15.5
45+00	15.6
46+00	15.7
47+00	15.8
48+00	15.9
49+00	16.0
50+00	16.1
51+00	16.2
52+00	16.3
53+00	16.4
54+00	16.4
55+00	16.5
56+00	16.6
57+00	16.7
58+00	16.7
59+00	16.8
60+00	16.9
61+00	17.0
62+00	17.0
63+00	17.1
64+00	17.2
65+00	17.2
66+00	17.2
67+00	17.2
68+00	17.3
69+00	17.4
70+00	17.5
71+00	17.9
72+00	18.1
73+00	18.2
74+00	18.3
75+00	18.3
76+00	18.2
77+00	18.2

Table 2 - Geotechnical Material Properties
San Francisquito Creek Flood Protection Project
San Mateo and Santa Clara Counties, California

GEI Consultants

Soil Type		Dry Density (pcf)	Moisture Content (%)	Total Density (pcf)	Φ' (degrees)	C' (psf)	K_h (cm/sec) (ft/day)	K_v (cm/sec) (ft/day)	Kh/Kv	S_u/p	S_u (psf)	OCR	C_{ec}	C_{er}	C_v (ft^2/yr)	$C_{\varepsilon\alpha}$
1a	Existing Levee Fill (CL)	100	20	120	30	75	1.00E-04 2.83E-01	2.50E-05 7.09E-02	4	---	750	---	0.16	0.16	---	---
1b	New Levee Fill (CL)	100	20	120	30	75	1.00E-06 2.83E-03	2.50E-07 7.09E-04	4	---	750	---	---	---	---	---
1c	Golf Course Fill (SC)	100	20	120	30	75	1.00E-04 2.83E-01	2.50E-05 7.09E-02	4	---	750	---	0.012	0.0012	---	---
2a	Bay Deposits (CH)	65	65	107	29	0	5.00E-07 1.42E-03	1.00E-07 2.83E-04	5	0.23	---	1-1.5	0.28	0.028	20	0.014
2b	Bay Deposits; Desiccated (CH)	65	65	107	29	0	5.00E-06 1.42E-02	1.00E-06 2.83E-03	5	0.23	---	2	0.28	0.028	20	0.014
3a	Older Alluvial Deposits; Fine (CL)	95	25	119	30	50	1.00E-06 2.83E-03	2.50E-07 7.09E-04	4	---	1500	---	0.18	0.018	---	---
3b	Older Alluvial Deposits; Coarse (SP-SM)	110	15	127	33	0	1.00E-02 2.83E+01	2.50E-03 7.09E+00	4	---	---	---	---	---	---	---
4a	Recent Alluvial Deposits; Fine (CL)	90	30	117	30	50	1.00E-05 2.83E-02	2.50E-06 7.09E-03	4	---	1500	---	---	---	---	---
4b	Recent Alluvial Deposits; Coarse (SP-SM)	105	15	121	33	0	1.00E-03 2.83E+00	2.50E-04 7.09E-01	4	---	---	---	---	---	---	---

Table 3 - Geotechnical Analyses Results
San Francisquito Creek Flood Protection Project
San Mateo and Santa Clara Counties, California

GEI Consultants

		Analysis Section				
		Station 46+50	Station 51+00	Station 70+00	Station 70+00	Station 71+00
		Palo Alto	East Palo Alto	Palo Alto	Palo Alto	East Palo Alto
				Shallow Foundation	Cutoff Wall	Cutoff Wall
Seepage Analysis	Steady State Seepage Exit Gradient	0.40	0.23	0.66	0.30	0.03
Stability Analysis	End of Construction Waterside	1.6	1.7			
	End of Construction Landside	1.3	1.5			
	100 Year Flood Steady State Seepage	1.7	1.6			
	Rapid Drawdown	2.3	2.2			
Primary Settlement	Levee Center (feet)	1.57	1.27			
	1/3 Slope from Waterside Toe (feet)	0.83	0.62			

Table 4 - Flood and Retaining Wall Design Parameters
San Francisquito Creek Flood Protection Project
San Mateo and Santa Clara Counties, California

Right Bank - East Palo Alto

*Station		Elevation		Soil Type	Total Density	Q (undrained strength)		S (drained strength)	
From	To	Top	Bottom		(pcf)	c (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)
76+50	67+00	16	12	Existing Fill	125	750	0	0	30
		12	-5	Recent Alluvium	121	500	0	0	30
		-5	-10	Bay Deposits	107	300	0	0	28
		-10	Depth	Older Alluvium	127	1500	0	0	33
67+00	54+00	16	5	Existing Levee Fill	125	750	0	0	30
		5	-5	Bay Deposits	107	300	0	0	28
		-5	Depth	Older Alluvium	127	1500	0	0	33
30+50	31+50	EGS	2	Existing Fill	125	750	0	0	30
		2	-8	Bay Deposits	107	300	0	0	28
		-8	Depth	Older Alluvium	127	1000	0	0	33

Left Bank - Palo Alto

*Station		Elevation		Soil Type	Total Density	Q (undrained strength)		S (drained strength)	
From	To	Top	Bottom		(pcf)	c (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)
76+00	72+00	16	12	Existing Fill	125	750	0	0	30
		12	4	Recent Alluvium	121	500	0	0	30
		4	-1	Bay Deposits	107	300	0	0	28
		-1	Depth	Older Alluvium	127	1500	0	0	33
72+00	71+00	15	-12	San Francisquito Creek Pumpstation Structure					
71+00	67+00	15	10	Existing Fill	125	750	0	0	30
		10	5	Recent Alluvium	121	500	0	0	30
		5	0	Bay Deposits	107	300	0	0	28
		0	Depth	Older Alluvium	127	1500	0	0	33
67+00	53+00	Varies	EGS	New Fill	130	750	0	0	30
		EGS	0	Landfill/ Disposal (Exact Extent Unknown)	100	500	0	0	28
		0	-5	Bay Deposits	107	300	0	0	28
		-5	Depth	Older Alluvium	127	1500	0	0	33
53+00	49+00	Varies	EGS	New Fill	130	750	0	0	30
		EGS	1	Recent Alluvium	121	500	0	0	30
		1	-10	Bay Deposits	107	300	0	0	28
		-10	Depth	Older Alluvium	127	1500	0	0	33

EGS: Existing Ground Surface Elevation

* Stationing extents based on HDR 60% design plan for layout of flood control features, provided by HDR December 2011.

Appendix A

Pertinent Exploration Logs by Others

1372

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Geotechnical Investigation

San Francisquito Creek Pump Station
Palo Alto, California

Report No. 1453-17 has been prepared for:

Schaaf & Wheeler
100 N. Winchester Boulevard Suite 200

Santa Clara, California

July 14, 2006

for:
Alberto Cortez
Staff Engineer

Brian Hubel, P.E.
Project Engineer

Scott E. Fitinghoff, P.E., G.E.
Principal Engineer
Quality Assurance Reviewer

REGISTERED PROFESSIONAL ENGINEER
BRIAN A. HUBEL
No. 064367
Exp. 6/30/07
CIVIL
STATE OF CALIFORNIA

PRIMARY DIVISIONS			SOIL TYPE		SECONDARY DIVISIONS
COARSE GRAINED SOILS MORE THAN HALF OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVELS MORE THAN HALF OF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (Less than 5% Fines)	GW		Well graded gravels, gravel-sand mixtures, little or no fines
			GP		Poorly graded gravels or gravel-sand mixtures, little or no fines
		GRAVEL WITH FINES	GM		Silty gravels, gravel-sand-silt mixtures, plastic fines
			GC		Clayey gravels, gravel-sand-clay mixtures, plastic fines
	SANDS MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (Less than 5% Fines)	SW		Well graded sands, gravelly sands, little or no fines
			SP		Poorly graded sands or gravelly sands, little or no fines
		SANDS WITH FINES	SM		Silty sands, sand-silt-mixtures, non-plastic fines
			SC		Clayey sands, sand-clay mixtures, plastic fines
FINE GRAINED SOILS MORE THAN HALF OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS LIQUID LIMIT IS LESS THAN 50 %		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL		Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS LIQUID LIMIT IS GREATER THAN 50 %		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH		Inorganic clays of high plasticity, fat clays
			OH		Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT		Peat and other highly organic soils

DEFINITION OF TERMS

U.S. STANDARD SIEVE SIZE — 200 — 40 — 10 — 4

CLEAR SQUARE SIEVE OPENINGS — 3/4" — 3" — 12"

SILTS AND CLAY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

0.08 — 0.4 — 2 — 5 — 19 — 76mm

GRAIN SIZES

☒	TERZAGHI SPLIT SPOON STANDARD PENETRATION
⧗	MODIFIED CALIFORNIA
▯	ROCK CORE
■	PITCHER TUBE
○	NO RECOVERY

SAMPLERS

SAND AND GRAVEL	BLOWS/FOOT*
VERY LOOSE	0-4
LOOSE	4-10
MEDIUM DENSE	10-30
DENSE	30-50
VERY DENSE	OVER 50

RELATIVE DENSITY

SILTS AND CLAYS	STRENGTH+	BLOWS/FOOT*
VERY SOFT	0-1/4	0-2
SOFT	1/4-1/2	2-4
MEDIUM STIFF	1/2-1	4-8
STIFF	1-2	8-16
VERY STIFF	2-4	16-32
HARD	OVER 4	OVER 32

CONSISTENCY

*Number of blows of 140 pound hammer falling 30 inches to drive a 2-inch O.D. (1-3/8 inch I.D.) split spoon (ASTM D-1586).
+Unconfined compressive strength in tons/sq.ft. as determined by laboratory testing or approximated by the standard penetration test (ASTM D-1586), pocket penetrometer, torvane, or visual observation.

KEY TO EXPLORATORY BORING LOGS

Unified Soil Classification System (ASTM D-2487)

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FIGURE A-1

EXPLORATORY BORING: EB-1

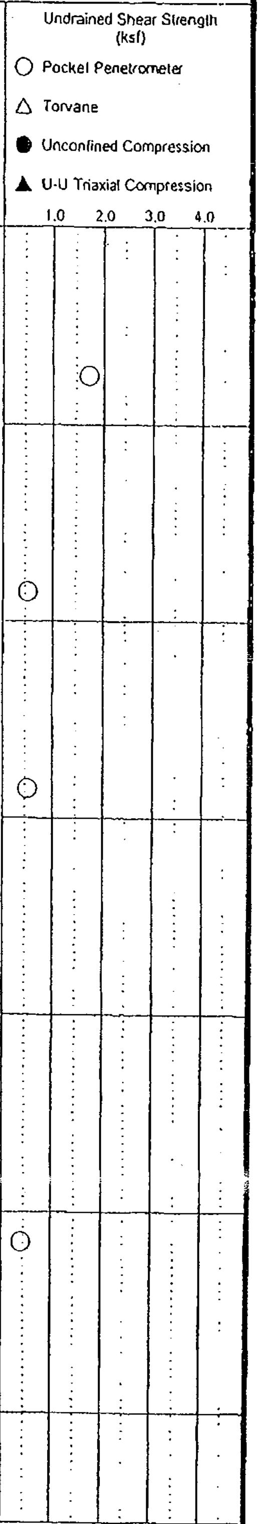
Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: AC
START DATE: 3-1-06 FINISH DATE: 3-1-06

PROJECT NO: 1453-17
PROJECT: SAN FRANCISQUITO CREEK PUMP STATION
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 60.0 FT.

This log is a part of a report by TRC Lowney, and should not be used as a stand-alone document. This description applies only to the location of the exploration at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with time. The description presented is a simplification of actual conditions encountered. Transitions between soil types may be gradual.

ELEVATION (FT)	DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
		SURFACE ELEVATION: 14 FT. (+/-)					
14.0	0						
13.8		**POORLY GRADED GRAVEL (GP)**	GP, FILL				
		CLAYEY SAND (SC) [FILL] dense, moist, brown, fine sand, some medium to coarse sand, trace fine subrounded gravel	SC, FILL	33	13	109	
11.3		**SANDY LEAN CLAY (CL) [FILL]** stiff, moist, brown, fine sand, low plasticity Plasticity Index = 8, Liquid Limit = 27	CL, FILL	19	14	103	
9.3	5	**CLAYEY SAND (SC) [FILL]** dense, moist, brown, fine sand, some medium to coarse sand	SC, FILL	6	17		33
7.5		**SANDY LEAN CLAY (CL) [Native]** medium stiff, moist, brown, fine sand, low plasticity	CL	7	27	84	52
	10						
-0.5				10	31	92	
	15	**LEAN CLAY (CL) [Bay Mud]** soft, wet, gray with brown mottles, some fine sand, moderate plasticity	CL	100-250p			
-3.0		**POORLY GRADED SAND WITH CLAY (SP-SC)** dense, wet, brown, fine to coarse sand, some fine subrounded gravel	SP-SC	31	14		8
	20						
		medium dense		21			
-10.0	25	**SANDY LEAN CLAY (CL)** medium stiff, wet, gray, fine to medium sand, some fine subrounded gravel, low plasticity	CL	4	22		
				200psi			
-15.5	30	**POORLY GRADED SAND WITH CLAY (SP-SC)** medium dense, moist, brown, fine to coarse sand, some to coarse subangular gravel	SP-SC	20			
-17.5		*Continued Next Page*					



GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH CIRCULATION

TRC Lowney

EXPLORATORY BORING: EB-1 Cont'd

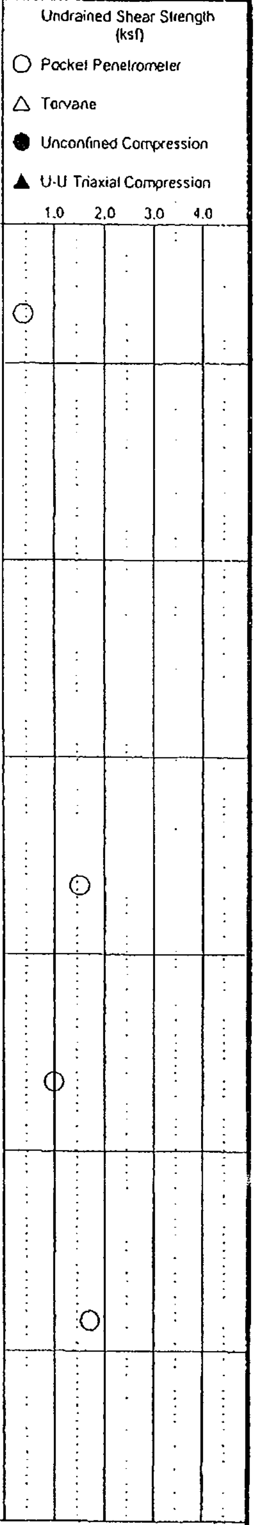
Sheet 2 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: AC
START DATE: 3-1-06 FINISH DATE: 3-1-06

PROJECT NO: 1453-17
PROJECT: SAN FRANCISQUITO CREEK PUMP STATION
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 60.0 FT.

This log is a part of a report by TRC Lowney, and should not be used as a stand-alone document. This description applies only to the location of the exploration at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with time. The description presented is a simplification of actual conditions encountered. Transitions between soil types may be gradual.

ELEVATION (FT)	DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
-17.5							
-18.0		**LEAN CLAY (CL)** medium stiff, wet, dark brown, some fine sand, trace fine to coarse subangular gravel, low plasticity	CL	6	28		
	35						
-22.0		**POORLY GRADED SAND WITH CLAY (SP-SC)** dense, wet, brown, fine to coarse sand, some to coarse subangular gravel					
				30			
	40		SP-SC				
				51			
	45						
-32.0		**LEAN CLAY WITH SAND (CL)** stiff, moist, gray, fine to medium sand, moderate plasticity		36	27	98	
		some coarse subrounded gravel					
	50						
			CL	24	28	92	
	55						
					26	95	
-46.0	60	Bottom of Boring at 60 feet					



GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH CIRCULATION

LA CORP.GDT 6/13/06 MV' FLL

TRC Lowney

EXPLORATORY BORING: EB-3

Sheet 1 of 1

DRILL RIG: MOBILE B-53
BORING TYPE: 8 INCH HOLLOW-STEM AUGER
LOGGED BY: AC
START DATE: 3-9-06 FINISH DATE: 3-9-06

PROJECT NO: 1453-17
PROJECT: SAN FRANCISQUITO CREEK PUMP STATION
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 29.5 FT.

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Undrained Shear Strength (ksf)
○ Pocket Penetrometer
△ Torvane
● Unconfined Compression
▲ U-U Triaxial Compression
1.0 2.0 3.0 4.0

ELEVATION (FT)	DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS SURFACE ELEVATION: 13 FT. (+/-)	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
13.0	0	**CLAYEY SAND (SC) [FILL]** very dense, moist, brown, fine to coarse sand, some fine to coarse subangular gravel	SC, FILL	50/6"	6		
10.5		**POORLY GRADED SAND WITH CLAY (SP-SC) [Native]** loose, moist, brown, fine to medium sand, some fine subangular to subrounded gravel		13	6		
	∇ 5			7	5		
			SP-SC	8	6		
	10	wet		11			
1.0		**FAT CLAY WITH SAND (CH) [Bay Mud]** soft, moist, dark gray, trace fine to coarse sand, trace fine subangular gravel, moderate to high plasticity	CH	4	40	80	
	15						
-3.5		**CLAYEY SAND (SC)** medium dense, moist, gray and olive brown mottled, fine to coarse sand, trace fine subangular gravel	SC	25	17	116	
	20						
-9.0		**POORLY GRADED SAND WITH CLAY (SP-SC)** medium dense to dense, wet, brown, fine to coarse sand, some fine subangular to subrounded gravel		24	20		5
	25		SP-SC	33			
		very dense		50/6"			
-16.5	30	Bottom of Boring at 29½ feet					

GROUND WATER OBSERVATIONS:
∇: FREE GROUND WATER MEASURED DURING DRILLING AT 5.0 FEET

LA CORP.GDT 6/13/06 MV* FLL

TRC Lowney

EXPLORATORY BORING: EB-4

Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: AC
START DATE: 3-1-06 FINISH DATE: 3-1-06

PROJECT NO: 1453-17
PROJECT: SAN FRANCISQUITO CREEK PUMP STATION
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 60.0 FT.

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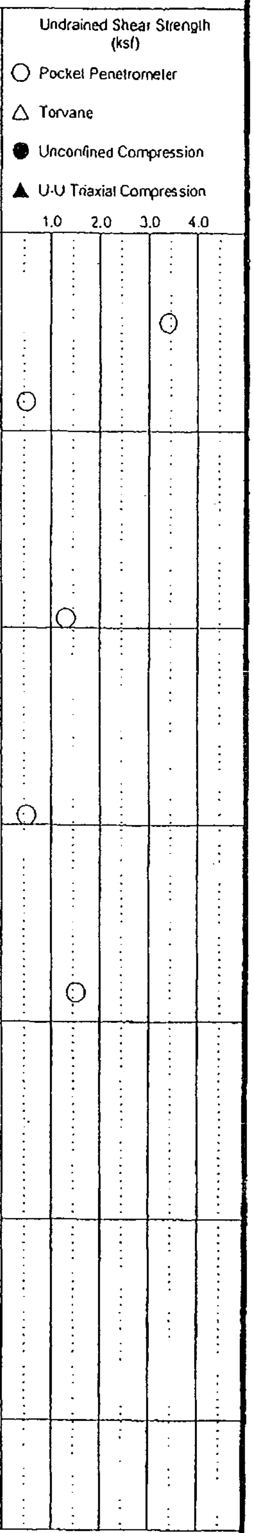
SURFACE ELEVATION: 13 FT. (+/-)

ELEVATION (FT)	DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
12.5	0	7 inches asphalt concrete					
11.9		**SANDY LEAN CLAY (CL) [FILL]** very stiff, moist, brown, fine to coarse sand, some fine subangular gravel, low plasticity	CL, FILL	00-300p			
8.8		**SANDY LEAN CLAY (CL) [FILL]** medium stiff, moist, brown, fine sand, low plasticity	CL, FILL	8	27	89	
7.8	5	**POORLY GRADED SAND WITH CLAY (SP-SC) [Native]** medium dense, wet, brown, fine to coarse sand, some fine subrounded gravel	SP-SC	15	10		
4.5	10	**LEAN CLAY (CL)** stiff, wet, dark gray, trace fine to coarse sand, trace fine to coarse subangular gravel, low to moderate plasticity	CL	100psi			
1.5		**FAT CLAY (CH) [Bay Mud]** medium stiff, dark gray to black, trace fine sand, moderate to high plasticity	CH				
-2.0	15	**LEAN CLAY (CL)** stiff, yellow, trace fine sand, low plasticity	CL	75psi			
-5.5	20	**LEAN CLAY (CL)** stiff, moist, gray with brown mottles, fine sand, low plasticity	CL	16	27	98	
-8.5	25	**POORLY GRADED SAND WITH CLAY (SP-SC)** dense, wet, brown, fine to coarse sand, some fine to coarse subrounded gravel	SP-SC	39	17		8
	30	very dense		51	14		
-19.0							



Continued Next Page

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH CIRCULATION

EXPLORATORY BORING: EB-4 Cont'd

Sheet 2 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: AC
START DATE: 3-1-06 FINISH DATE: 3-1-06

PROJECT NO: 1453-17
PROJECT: SAN FRANCISQUITO CREEK PUMP STATION
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 60.0 FT.

This log is a part of a report by TRC Lowney, and should not be used as a stand-alone document. This description applies only to the location of the exploration at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with time. The description presented is a simplification of actual conditions encountered. Transitions between soil types may be gradual.

Undrained Shear Strength (ksf)
○ Pocket Penetrometer
△ Torvane
● Unconfined Compression
▲ U-U Triaxial Compression

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	SAMPLER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE	Undrained Shear Strength (ksf) 1.0 2.0 3.0 4.0
-19.0			**POORLY GRADED SAND WITH CLAY (SP-SC)** dense, wet, brown, fine to coarse sand, some fine to coarse subrounded gravel							
	35		very dense	SP-SC	76	☒				
			very dense		55	☒	13			
-24.5			**LEAN CLAY (CL)** soft, moist, brown, trace fine to medium sand, moderate plasticity	CL						
-27.5	40				6	☒	33			○
			Bottom of Boring at 40 feet							
	45									
	50									
	55									
	60									

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH CIRCULATION

LA CORP.GDT 6/13/06 MV* FLL

TRC Lowney

LOWNEY ASSOCIATES
Environmental/Geotechnical/Engineering Services

29

Geotechnical Report

San Francisquito Creek Levee Project
Palo Alto and East Palo Alto, California

Report No. 109-17B has been prepared for:

Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, California 95118

July 12, 2002

DRAFT

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P.O. Box 1388 Mountain View, CA 94042-1388 E-mail: mail@lowney.com

PRIMARY DIVISIONS			SOIL TYPE		SECONDARY DIVISIONS
COARSE GRAINED SOILS MORE THAN HALF OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVELS MORE THAN HALF OF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (Less than 5% Fines)	GW	●	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	○	Poorly graded gravels or gravel-sand mixtures, little or no fines
		GRAVEL WITH FINES	GM	○	Silty gravels, gravel-sand-silt mixtures, plastic fines
			GC	▨	Clayey gravels, gravel-sand-clay mixtures, plastic fines
	SANDS MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (Less than 5% Fines)	SW	⁘	Well graded sands, gravelly sands, little or no fines
			SP	⁘	Poorly graded sands or gravelly sands, little or no fines
		SANDS WITH FINES	SM	▥	Silty sands, sand-silt-mixtures, non-plastic fines
			SC	▨	Clayey sands, sand-clay mixtures, plastic fines
FINE GRAINED SOILS MORE THAN HALF OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS LIQUID LIMIT IS LESS THAN 50 %		ML	▥	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	☰	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS LIQUID LIMIT IS GREATER THAN 50 %		MH	▥	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH	▨	Inorganic clays of high plasticity, fat clays
			OH	≋	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	⁂	Peat and other highly organic soils

DEFINITION OF TERMS

U.S. STANDARD SIEVE SIZE: 200 40 10 4

CLEAR SQUARE SIEVE OPENINGS: 3/4" 3" 12"

SILTS AND CLAY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

0.08 0.4 2 5 19 76mm

GRAIN SIZES

☒ TERZAGHI SPLIT SPOON STANDARD PENETRATION

⧗ MODIFIED CALIFORNIA

▯ D&M UNDERWATER SAMPLER

■ SHELBY TUBE

○ NO RECOVERY

SAMPLERS

SAND AND GRAVEL	BLOWS/FOOT*
VERY LOOSE	0-4
LOOSE	4-10
MEDIUM DENSE	10-30
DENSE	30-50
VERY DENSE	OVER 50

RELATIVE DENSITY

SILTS AND CLAYS	STRENGTH+	BLOWS/FOOT*
VERY SOFT	0-1/4	0-2
SOFT	1/4-1/2	2-4
MEDIUM STIFF	1/2-1	4-8
STIFF	1-2	8-16
VERY STIFF	2-4	16-32
HARD	OVER 4	OVER 32

CONSISTENCY

*Number of blows of 140 pound hammer falling 30 inches to drive a 2-inch O.D. (1-3/8 inch I.D.) split spoon (ASTM D-1586).
+Unconfined compressive strength in tons/sq.ft. as determined by laboratory testing or approximated by the standard penetration test (ASTM D-1586), pocket penetrometer, torvane, or visual observation.

KEY TO EXPLORATORY BORING LOGS

Unified Soil Classification System (ASTM D-2487)

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FIGURE A-1

EXPLORATORY BORING: EB-5

Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-20-02 FINISH DATE: 2-20-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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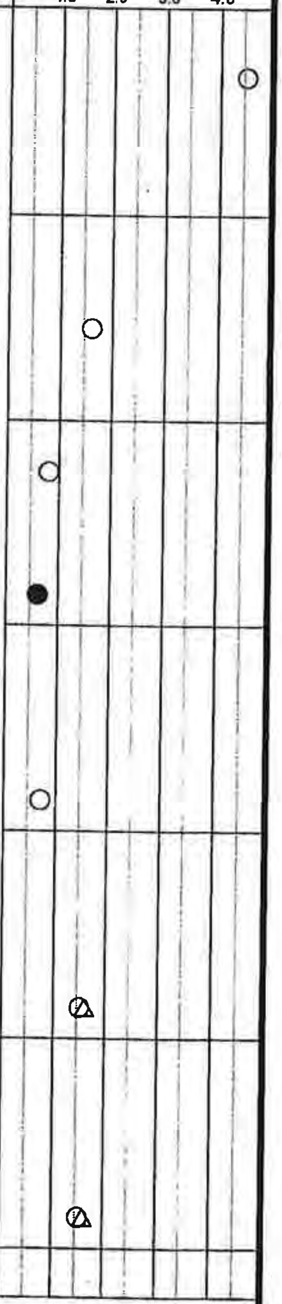
SURFACE ELEVATION:

MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
SANDY LEAN CLAY (CL) [FILL] hard, moist, brown, fine to medium sand, some fine to coarse gravel, low plasticity	CL, FILL	50/4"	12	114	
very stiff					
FAT CLAY (CH) [BAY MUD] medium stiff, moist, dark gray, trace organics, high plasticity	CH	18	34	86	
		15	50	75	
LEAN CLAY (CL) medium stiff to stiff, moist to wet, bluish gray, some fine gravel, low to moderate plasticity	CL	10	23	104	
color changes to brown with orange motttles		17	31	93	
		17	38	84	

Undrained Shear Strength (ksf)



Continued Next Page

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA_CORP.GDT 7/2/02 MV* FLL

LOWNEYASSOCIATES
Environmental/Geotechnical/Engineering Services

EXPLORATORY BORING: EB-5 Cont'd

Sheet 2 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-20-02 FINISH DATE: 2-20-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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Undrained Shear Strength (ksf)
○ Pocket Penetrometer
△ Torvane
● Unconfined Compression
▲ U-U Triaxial Compression
1.0 2.0 3.0 4.0

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	SAMPLER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE	Undrained Shear Strength (ksf)
	30	▨	**LEAN CLAY (CL)** medium stiff to stiff, moist to wet, bluish gray, some fine gravel, low to moderate plasticity	CL						
					42	☒				
	35	▨	**CLAYEY SAND WITH GRAVEL (SC)** dense, moist, brown, fine to coarse sand, fine gravel	SC	46	☒	15		23	
					54	☒				
	40		Bottom of Boring at 40 feet							
	45									
	50									
	55									
	60									

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA_CORP.GDT 7/2/02 MV* FLL

LOWNEYASSOCIATES
Environmental/Geotechnical/Engineering Services

EXPLORATORY BORING: EB-6

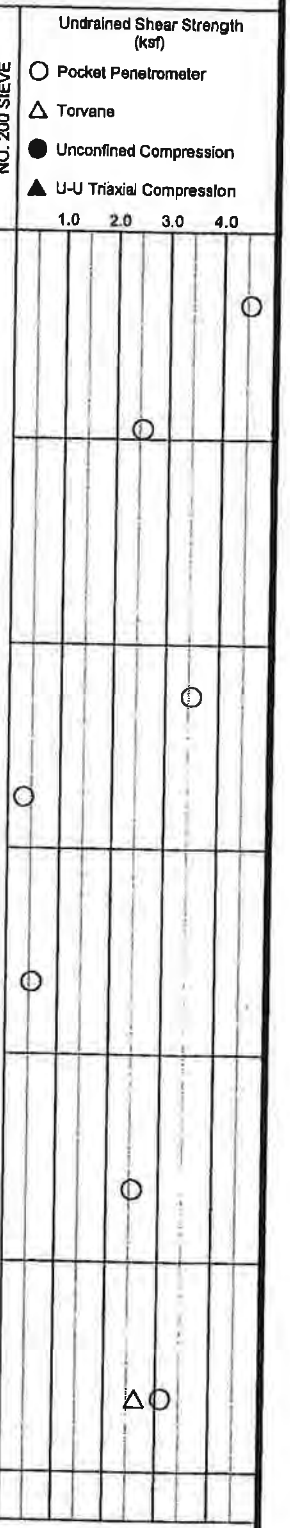
Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-21-02 FINISH DATE: 2-21-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

SURFACE ELEVATION:

ELEVATION (FT)	DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
	0	1½ inches asphalt concrete					
		LEAN CLAY WITH SAND (CL) [FILL] hard, moist, brown, fine to coarse sand, trace fine gravel, low plasticity	CL, FILL	43	18	106	
		very stiff					
	5						
		increasing sand					
	10			31	22	103	
		FAT CLAY (CH) [BAY MUD] soft to medium stiff to stiff, moist, dark gray, high plasticity	CH				
	15						
				7	37	83	
		LEAN CLAY (CL) very stiff, moist, gray with orange mottles, some coarse sand, some fine gravel, low plasticity	CL				
	20						
				32	29	95	
	25						
				43	21	108	
	30	*Continued Next Page*					



GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

EXPLORATORY BORING: EB-7

Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-20-02 FINISH DATE: 2-20-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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Undrained Shear Strength (ksf)
○ Pocket Penetrometer
△ Torvane
● Unconfined Compression
▲ U-U Triaxial Compression
1.0 2.0 3.0 4.0

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	SAMPLER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE	Undrained Shear Strength (ksf)
			SURFACE ELEVATION:							
	0		**FAT CLAY (CH) [FILL]**	CH, FILL						
			SILTY SAND (SM) [FILL] medium dense, moist, brown, fine to medium sand, some coarse sand	SM, FILL	18 13		9		35	
	5 10		**SANDY LEAN CLAY (CL) [FILL]** stiff, wet, brown, fine sand, trace fine gravel, low plasticity	CL, FILL	8		28	92		○
	15		**LEAN SANDY CLAY (CL) [FILL]** medium stiff, moist, gray with orange mottles, fine sand, low to moderate plasticity	CL, FILL	13		43	76		○
	20		**FAT CLAY (CH) [BAY MUD]** medium stiff, moist, bluish gray, high plasticity	CH						
	25 30		**LEAN CLAY WITH SAND (CL)** medium stiff to stiff, moist, gray with orange mottles, fine sand, some fine gravel, low to moderate plasticity	CL	10 16		26 31	98 91		○ △○

Continued Next Page

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA_CORP.GDT 7/2/02 MV* FLL

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EXPLORATORY BORING: EB-7 Cont'd

Sheet 2 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-20-02 FINISH DATE: 2-20-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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Undrained Shear Strength (ksf): ○ Pocket Penetrometer; △ Torvane; ● Unconfined Compression; ▲ U-U Triaxial Compression (scale 1.0, 2.0, 3.0, 4.0)

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	SAMPLER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE	Undrained Shear Strength (ksf)
	30	▨	**LEAN CLAY WITH SAND (CL)** medium stiff to stiff, moist, gray with orange mottles, fine sand, some fine gravel, low to moderate plasticity	CL						
			POORLY GRADED SAND WITH SILT (SP-SM) dense, wet, gray-brown, medium to coarse sand, some fine sand, trace fine gravel	SP-SM	47	☒	17		7	
	35	▨	**LEAN CLAY (CL)** medium stiff, wet, brown, some fine sand, low plasticity	CL	15	⧗	27	100		○△
	40		Bottom of Boring at 40 feet							
	45									
	50									
	55									
	60									

GROUND WATER OBSERVATIONS:

NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA CORP.GDT 7/2/02 MV* FLL

LOWNEYASSOCIATES
Environmental/Geotechnical/Engineering Services

EXPLORATORY BORING: EB-8

Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-22-02 FINISH DATE: 2-22-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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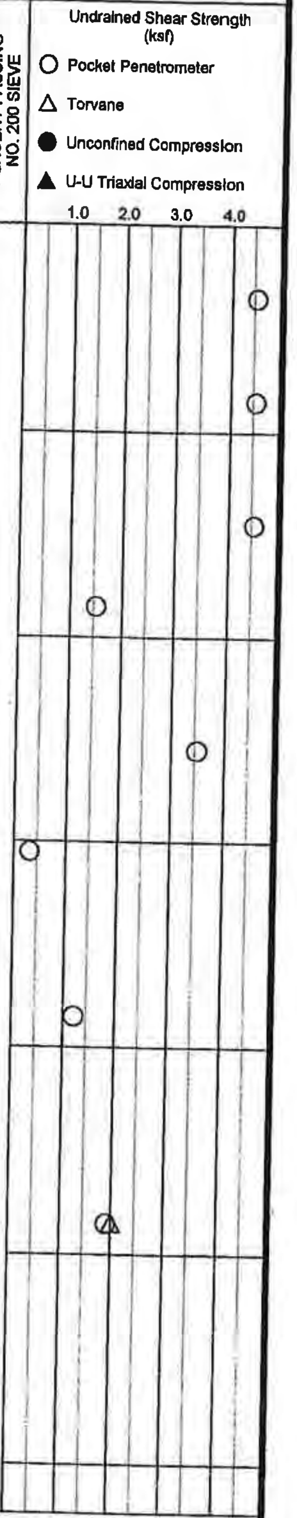
MATERIAL DESCRIPTION AND REMARKS

SURFACE ELEVATION:

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE
	0	▩	**LEAN CLAY WITH SAND (CL) [FILL]** hard, moist, brown, fine to coarse sand, trace fine gravel, low plasticity	CL, FILL
	10	▩	**SANDY LEAN CLAY (CL) [FILL]** stiff, wet, gray, fine to medium sand, low plasticity	CL, FILL
		▨	**FAT CLAY (CH) [BAY MUD]** soft, moist, dark bluish gray, high plasticity	CH
		▨	**LEAN CLAY (CL)** stiff, moist, brown with orange mottles, some coarse sand, some fine gravel, low plasticity	CL
		▨	**CLAYEY SAND WITH GRAVEL (SC)** dense, wet, gray and brown with orange mottles, fine to coarse sand, fine gravel	SC

PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
40	12	118	
61	15	117	
26	20	108	
22	22	106	
28	27	96	
36			



Continued Next Page

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA CORP.GDT 7/2/02 MV* FLL

LOWNEYASSOCIATES
Environmental/Geotechnical/Engineering Services

EXPLORATORY BORING: EB-9

Sheet 1 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-21-02 FINISH DATE: 2-21-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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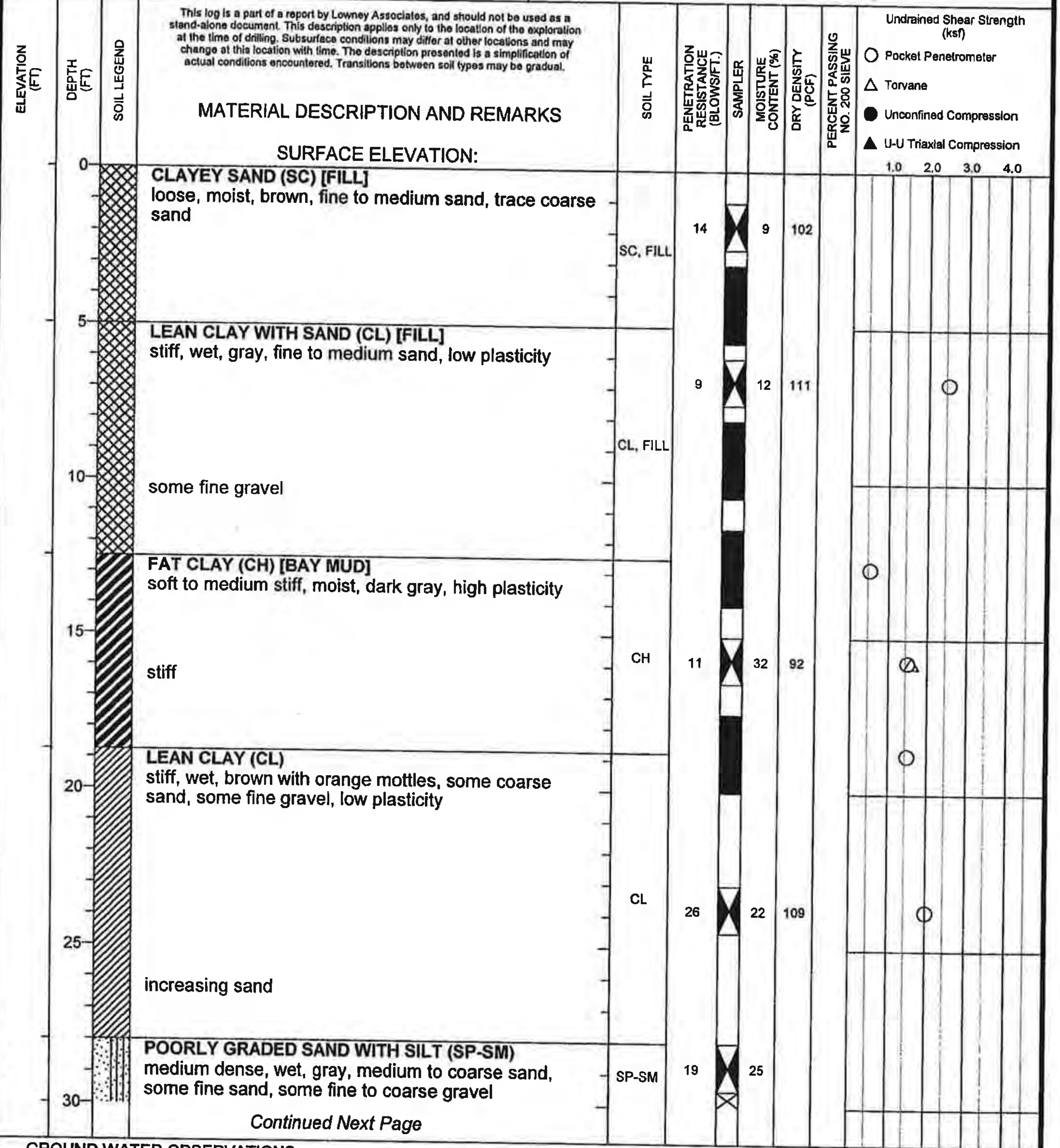

SURFACE ELEVATION:

DEPTH (FT)	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE
0	**CLAYEY SAND (SC) [FILL]** loose, moist, brown, fine to medium sand, trace coarse sand					
			14	9	102	
		SC, FILL				
5	**LEAN CLAY WITH SAND (CL) [FILL]** stiff, wet, gray, fine to medium sand, low plasticity					
			9	12	111	
		CL, FILL				
10	some fine gravel					
	FAT CLAY (CH) [BAY MUD] soft to medium stiff, moist, dark gray, high plasticity					
15	stiff	CH	11	32	92	
	LEAN CLAY (CL) stiff, wet, brown with orange mottles, some coarse sand, some fine gravel, low plasticity					
20						
		CL	26	22	109	
25	increasing sand					
	POORLY GRADED SAND WITH SILT (SP-SM) medium dense, wet, gray, medium to coarse sand, some fine sand, some fine to coarse gravel	SP-SM	19	25		
30						

Continued Next Page

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

LA CORP.GDT 7/2/02 MV* FLL

EXPLORATORY BORING: EB-9 Cont'd

Sheet 2 of 2

DRILL RIG: FAILING 1500
BORING TYPE: ROTARY WASH
LOGGED BY: BAH
START DATE: 2-21-02 FINISH DATE: 2-21-02

PROJECT NO: 109-17
PROJECT: SAN FRANCISQUITO CREEK LEVEE
LOCATION: PALO ALTO, CA
COMPLETION DEPTH: 40.0 FT.

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Undrained Shear Strength (ksf)
○ Pocket Penetrometer
△ Torvane
● Unconfined Compression
▲ U-U Triaxial Compression

ELEVATION (FT)	DEPTH (FT)	SOIL LEGEND	MATERIAL DESCRIPTION AND REMARKS	SOIL TYPE	PENETRATION RESISTANCE (BLOWS/FT.)	SAMPLER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PERCENT PASSING NO. 200 SIEVE	Undrained Shear Strength (ksf) 1.0 2.0 3.0 4.0
	30		**POORLY GRADED SAND WITH SILT (SP-SM)** medium dense, wet, gray, medium to coarse sand, some fine sand, some fine to coarse gravel	SP-SM	29	☒	15			
					30	☒	17			
	35									
			LEAN CLAY (CL) stiff, moist, bluish gray, some fine sand, low plasticity	CL						
					17	⧓	26			○
	40		Bottom of Boring at 40 feet							
	45									
	50									
	55									
	60									

GROUND WATER OBSERVATIONS:
NOT APPLICABLE DUE TO ROTARY WASH DRILLING METHOD

GEOTECHNICAL REPORT
BAYLANDS BIKE TRAIL CIP 82-31
Palo Alto and East Palo Alto, California

Prepared for

CITY OF PALO ALTO

Palo Alto, California

By

EARTH SYSTEMS CONSULTANTS
1900 Embarcadero Road
Palo Alto, California

NOVEMBER 1983

KEY TO LOGS OF BORINGS

◫	3" O.D. Modified California Sampler
○	Pocket Penetrometer Test Result (in t.s.f.)
⧄	Standard Penetration Test
☒	Bulk Sample
⊠	Disturbed Sample
▽	Groundwater at time of Drilling
	Elevation 100 equals Mean Sea Level

No. C3-1284-C1

DEPTH IN FEET	SAMPLE NO	LOG & LOCATION OF SAMPLE	Penetration Resistance Blows/ft	DESCRIPTION		IN-PLACE	
						DRY DENSITY pcf	MOISTURE CONTENT % dry wt
				Boring 1 - Elevation 110±			
0				FILL: Light brown silty CLAY with occasional gravel, slightly damp, hard (CL)			
	1-1-1 1-1-2		45	-brown sandy silt (ML)	4.5+ ○	98 108	10.5 15.0
5				-medium stiff			
	1-2-1 1-2-2 1-2-3		4	-medium orange-brown clayey SILT, saturated, soft (ML)	∇ ○ 0.25	87 91 84	33.0 31.2 36.5
10				NATURAL GROUND: Dark to medium grey organic silty CLAY with peat, medium stiff (OH) (BAY MUD)	○ 0.85		
					0.75 ○	74	45.4
	1-3		9				
15							
	1-4-1 1-4-2		27	Greenish-grey sandy CLAY with caliche, stiff (CL) -very stiff	1.75 ○	108	20.3
20				Greenish-brown (mottled) sandy CLAY, very stiff (CL)	3.0 ○	126	16.2
25							
				-very stiff to hard			
	1-5-1 1-5-2		19	Orange-brown clayey SAND to silty SAND, medium dense (SC-SM)		107 103	21.5 23.6
30							
	1-6	☒		Orange-brown sandy CLAY, stiff (CL)			
	1-7-1			Medium dark orange-brown sandy CLAY with fine gravel, very stiff (CL)		121	11.7
	1-7-2		51	Orange-brown sandy GRAVEL, dense (GP)		121	12.8

continued...

DEPTH IN FEET	SAMPLE NO.	LOG & LOCATION OF SAMPLE	Penetration Resistance Blows/ft	DESCRIPTION	IN-PLACE DRY DENSITY p.c.f.	IN-PLACE MOISTURE CONTENT % dry wt.
				Boring 1 - continued		
35				Orange-brown sandy GRAVEL (¼ - 1") with varying clay binder, saturated, dense (GP-GC)		
40						
	1-8		60	-with trace clay binder	115	12.1
45				Boring terminated at 44½ feet. Drilled on September 19, 1983.		
50						

No. C3-1284-C1

DEPTH IN FEET	SAMPLE NO	LOG & LOCATION OF SAMPLE	Penetration Resistance Blows/ft	DESCRIPTION	IN-PLACE DRY DENSITY p.c.f.	IN-PLACE MOISTURE CONTENT % dry wt
0				Boring 5 - Elevation 112±		
				FILL: Brown sandy SILT to silty SAND and black silty CLAY, moist, stiff (ML)		
				1.5 ○		
5	5-1		13		97	21.8
				-dark brown sandy SILT with minor black silty clay, moist, medium stiff (ML)		
10	5-2		8		100	24.6
				-saturated ∇		
				0.75 ○		
15	5-3-1 5-3-2		9	NATURAL GROUND: Medium to dark grey silty CLAY with minor organics, medium stiff (OH) (BAY MUD)	61 66	61.2 53.0
				1.5 ○		
20	5-4		12	0.75 ○ Greenish-grey silty CLAY with fine sand, moist to medium stiff to stiff (CL)	91	31.3
				Orange-brown silty CLAY with caliche, very stiff (CL)		
25	5-5-1 5-5-2		17	1.0 ○ Mottled brown alternating sandy SILT and sandy CLAY, stiff (ML-CL)	100 99	25.0 25.7
30	5-6		27	2.0 ○ Mottled grey-brown sandy CLAY with caliche, very stiff (CL)	99	25.6
				Brown clayey GRAVEL, dense (GC)		
				Mottled brown sandy CLAY (CL)		

continued...

Appendix B

Historical Ecology of Lower San Francisquito Creek

HISTORICAL ECOLOGY PROGRAM
CONTRIBUTION NO. 579 • APR 09

Historical Ecology of Lower San Francisquito Creek

Phase 1

Technical memorandum accompanying project GIS data

Prepared for the San Francisquito Creek Joint Powers Authority

By the San Francisco Estuary Institute
Dan Hermstad
Kristen Cayce
Robin Grossinger

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This report should be cited as:

Hermstad, D., Cayce, K. and Grossinger, R. (2009). Historical Ecology of Lower San Francisquito Creek, Phase 1. Technical memorandum accompanying project GIS Data, Contribution No. 579. Historical Ecology Program, San Francisco Estuary Institute, Oakland, California.

Introduction

This memo is intended to accompany the GIS layers developed by SFEI to document historical changes in habitat and hydrology on lower San Francisquito Creek. Information about the timing, extent, and character of major landscape changes can be an important part of the technical foundation for the selection and design of flood protection alternatives. Historical landscape information can provide rationale for flood protection decisions in a number of ways. Some of the applications suggested by the data discovered in this project include the following.

- Stream routes documented over time show former stream positions, significant changes, and long-term tendencies
- Alluvial fill areas indicate large amounts of sediment deposition from the upper watershed
- Connections to tidal channels and tidal marsh show how marsh and secondary channels were used to disperse flood waters
- Large willow patches along the creek channel served as natural flood retention basins
- Shoreline erosion trends indicate the need for sediment deposition and marsh plain development to maintain buffer marshes, especially given projected sea-level rise.

The primary goal of this phase was to produce GIS layers and georeferenced imagery for use by the planning and engineering team of the San Francisquito Creek Joint Powers Authority. The memo serves as metadata for the GIS, helping explain the interpretation of original historical documents.

Phase 1 was also intended to explore the potential value of historical ecology in a broader social context, towards developing community understanding of the history of changes to the watershed, and the challenges and opportunities this history presents. Accordingly, we carried out some limited initial data collection efforts as part of this phase, but much more local information remains to be collected. We present here a very brief summary of information collected to-date.

The complex stream and floodplain changes over the past 150 years are relevant to contemporary management. The timeseries mapping presented here documents the natural location of floodplain elements such as willow groves, tidal marsh, and tidal channels. Elements of these features might be considered for natural flood storage capacity and ecosystem benefits. Of interest may also be the history of sedimentation in the lower stream reaches, where sediment aggradation has tended to exceed the stream's ability to maintain a channel. Apparent management of this sediment by local farmers to raise marsh levels may be a practice of contemporary relevance, given concerns about shoreline erosion and limited sediment supply. Rates of shoreline change, which have been dynamic and variable along the shore (with a recent erosive trend), are also an area of potential further exploration.

Landscape Changes on Lower San Francisquito Creek, 1857-2004

In the last 150 years, lower San Francisquito Creek has undergone dramatic modification. This history is illustrated by a series of exceptional early maps and aerial photographs.

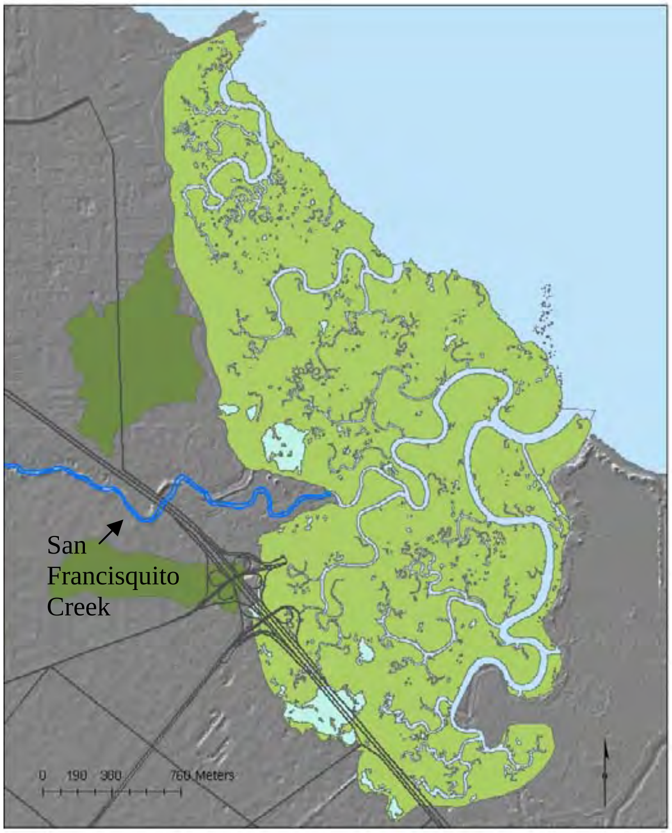
In 1857, the US Coast Survey (USCS), a federal mapping agency renowned for its accuracy, surveyed the lower stream reaches and surrounding baylands (Figure 1A). At this time, tidal marsh habitat covered 1142 acres. The tidal marshes were dotted with small pannes and larger, salt-producing salinas. Also surveyed on this T-sheet are two large (63 and 118 acres) willow groves adjacent to the tidal marsh associated with high groundwater tables and seasonal flooding. San Francisquito Creek maintained a sinuous stream course with several major meanders in the reach between current day Highway 101 and the backshore extent of historical tidal marsh. The depiction of the shoreline on the 1857 T-sheet indicates that tidal marsh is accreting, developing a chain of small marsh patches out into the Estuary.

By the 1897 resurvey of the area around San Francisquito Creek (carried out by same agency, now called the US Coast and Geodetic Survey), the creek mouth was mapped much further inland, at the present day Highway 101 crossing (Figure 1B). High sediment load apparently caused the creek to fill its channel, creating a distributary system about a half mile from the former tidal mouth. Since 1857, the willow groves have changed size, shape and position due to changes in land use and characteristics of San Francisquito Creek. In 1897, there have been only limited modifications to the broad tidal marsh area. While some levees are visible, they were generally not successful (Westdahl 1897). Wilson’s Landing and Clarke’s Landing are clearly visible by 1897, apparently creating small areas of landfill. However, tidal marsh habitat acreage remains roughly the same as in 1857 at 1109 acres (1142 acres in 1857). Interestingly, loss of tidal marsh can be seen along the backshore boundary as San Francisquito Creek appears to have deposited significant amounts of sediment over the marsh surface. We referred to this process as "alluvial fill." Over the same period -- presumably due to large sediment supply -- the shoreline continued to build out north of the San Francisquito tidal slough, offsetting the loss in the upland transition.

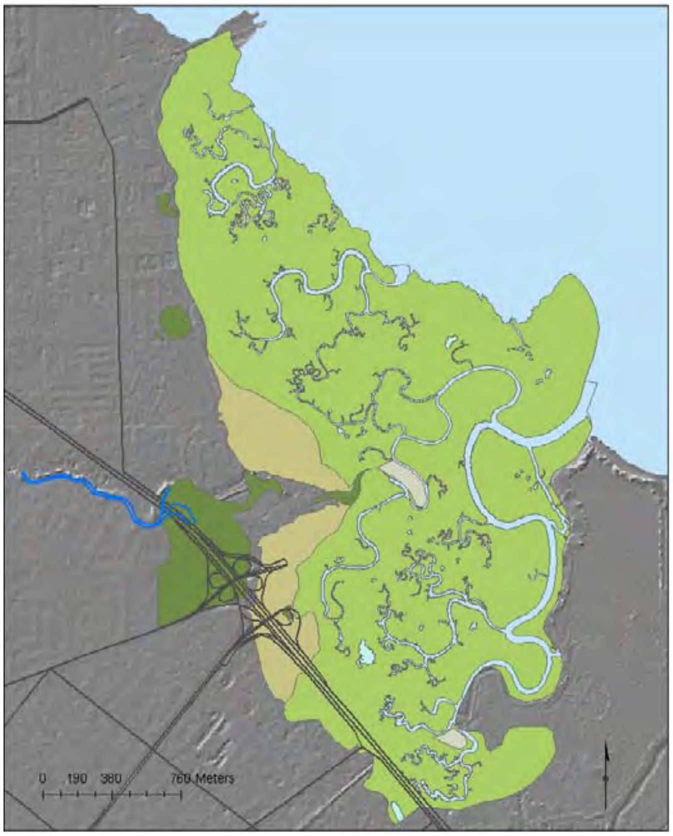
Much more rapid human modification of marshlands occurred during 1900-1920. By this time, extensive levees have removed tidal action from much of the former marshland, extending the backshore further east (Figure 1C). Diked bayland becomes a significant portion of the study area, encompassing approximately 574 acres while tidal marshes have shrunk by over 60% to 428 acres. Numerous tidal flats and channels have been cut off, changed course, or otherwise altered during this time period. The first significant dredging of tidal channels begins at this time and dredged materials can be seen filling areas of former marshland. The dredged channels are notably widened; discarded bay fill begins to cover surrounding tidal marsh areas. In the 1921 view, as in the 1897 picture, San Francisquito Creek does not maintain a well-defined channel through the baylands, but rather appears to spread broadly. There is evidence of continued alluvial deposition over the baylands, in the form of distinct splay deposits. This may have been the result, in part or in full, of local efforts to increase the marsh surface level for agricultural use by directing stream sediments (Clark 1924). Shoreline erosion is evident by this time.

Major re-routing of the San Francisquito Creek takes place in the late 1920’s (Applequist 1931, Silberling 1971) and can be seen in the 1960 image (Figure 1D). Controlled by two levees each side of the channel, the creek now has a well-defined, excavated channel. It turns sharply north near the site of its former mouth, runs north for a length of approximately half a mile, turns to the northeast and exits to the bay through areas of former tidal marsh and diked bayland. Areas of fill have grown substantially, subsuming areas of former tidal marsh, diked bayland and alluvial fill. Filled areas allowed development such as a golf course and the Palo Alto Airport. Total area composed of fill, including bay fill and alluvial fill, is 370 acres. By this time, the Palo Alto Harbor has been fully excavated from surrounding marshlands and includes a back pool, (24 acres in size) that was formerly tidal marsh, tidal flat, and channel. Tidal marsh extent has been reduced to 270 acres. The shoreline continues to erode south of the creek outlet to the Estuary.

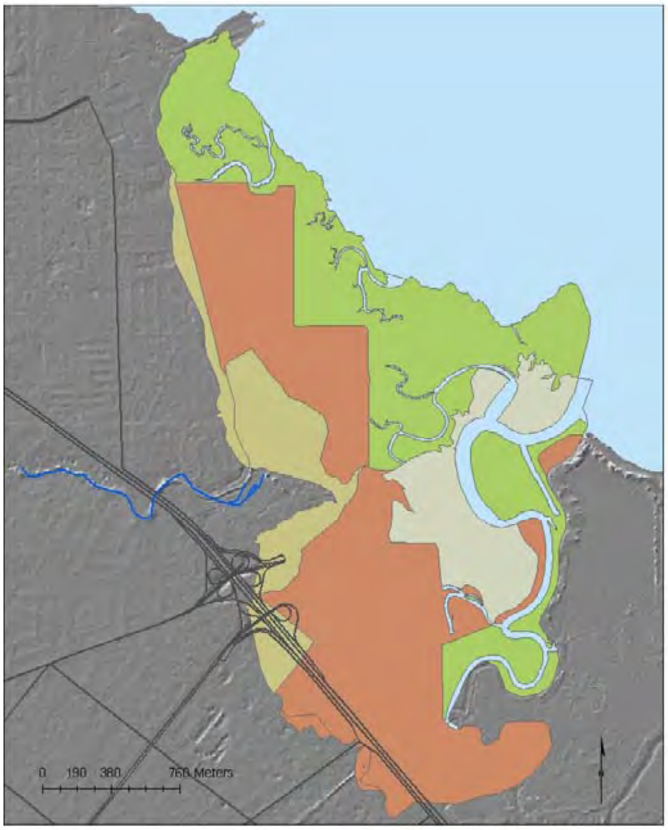
Landscape alterations continue in 2004 (Figure 1E). The imagery shows more extensive fill but there is also an increase in tidal marsh area since 1960. Total tidal marsh habitat contains 352 acres. This increase has resulted from a restoration project south of Cooley’s Landing, where a breached levee opened up tidal action to diked bayland. Fill now encompasses 685 acres of the study area. At the same time, a larger area of fill is now evident in an eastern portion of the study area where Mayfield Slough formerly passed. The creek channel remains in its re-routed position.



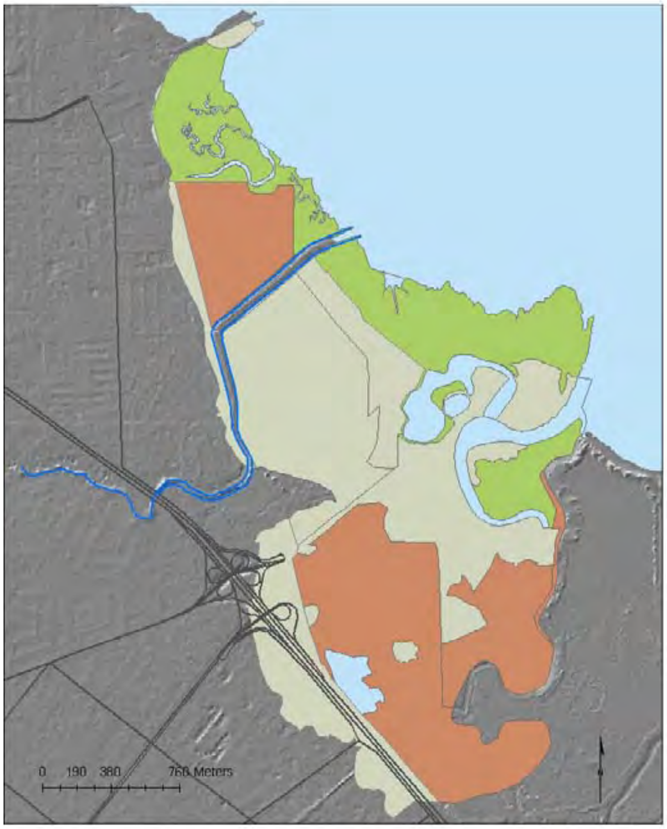
A: 1857



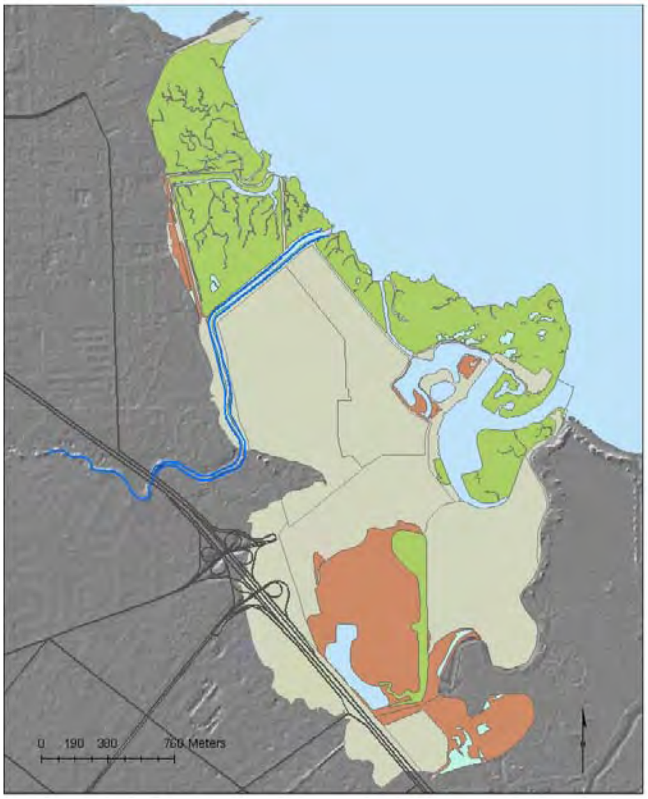
B: 1897



C: 1921



D: 1960



E: 2004

Figure 1: Changes in lower San Francisquito Creek habitats and hydrology, 1857-2004.

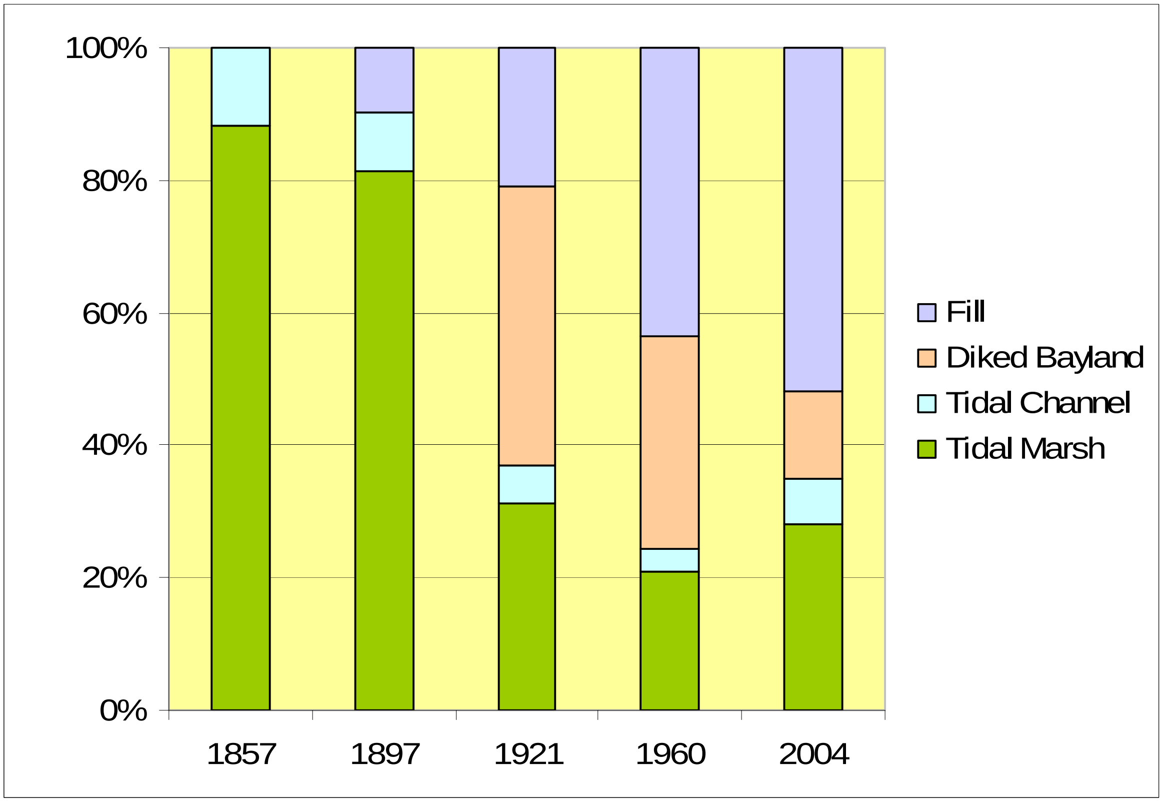


Figure 2: Shifts in landscape functions in lower San Francisquito Creek. Total area approximately 1300 acres.

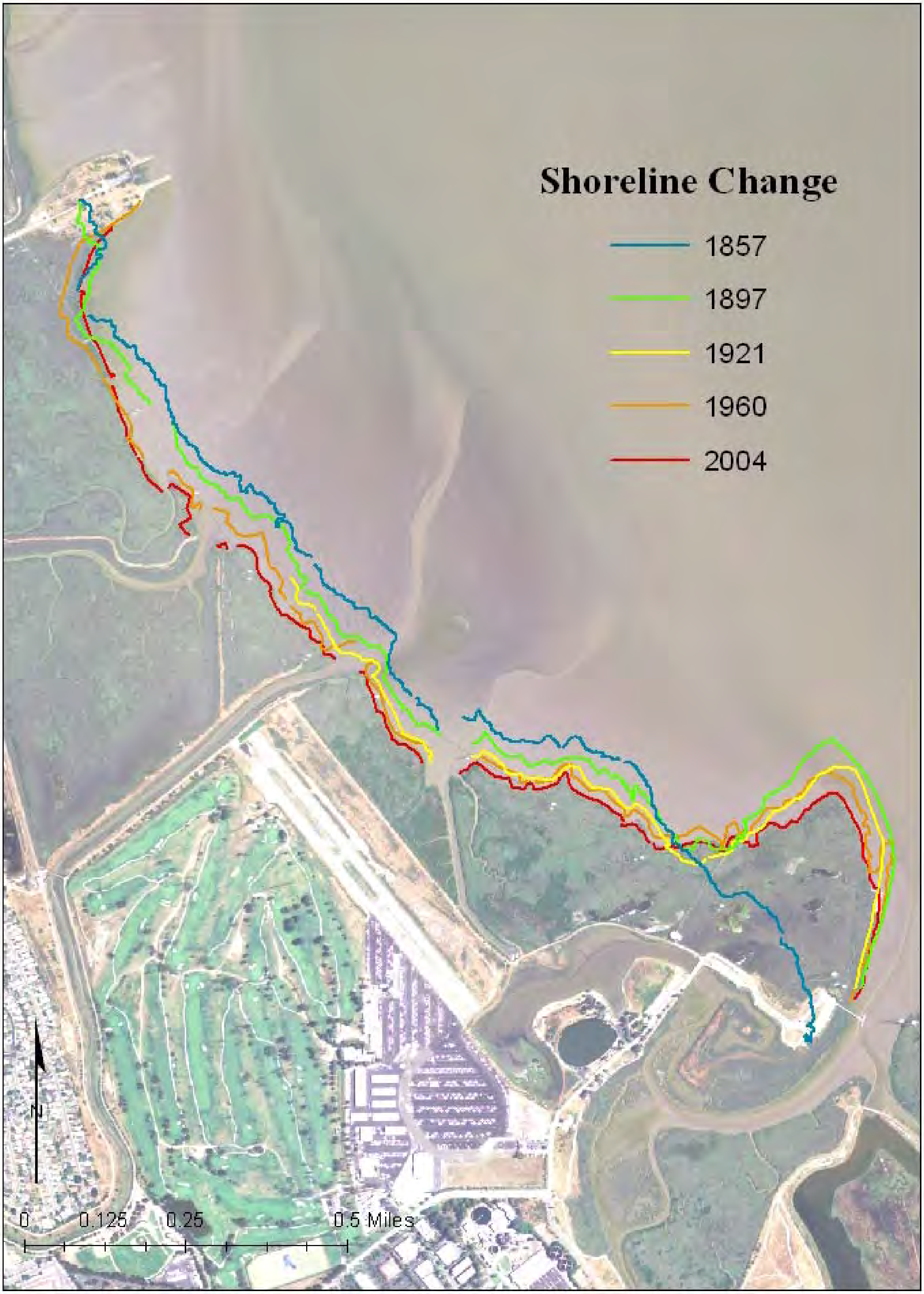


Figure 3: Change in Shoreline Position, 1857--2004 (background image true-color 2005 NAIP imagery)

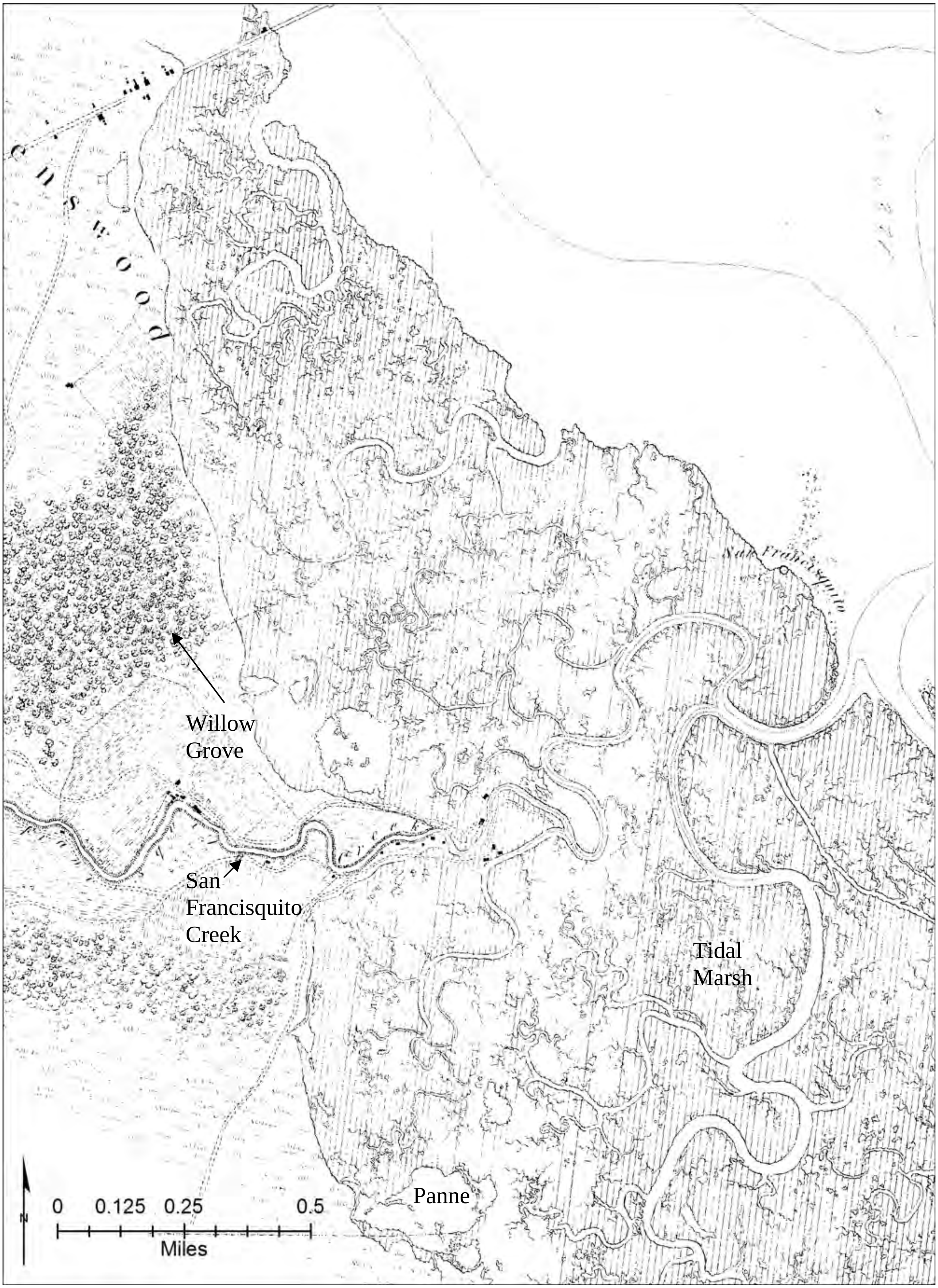
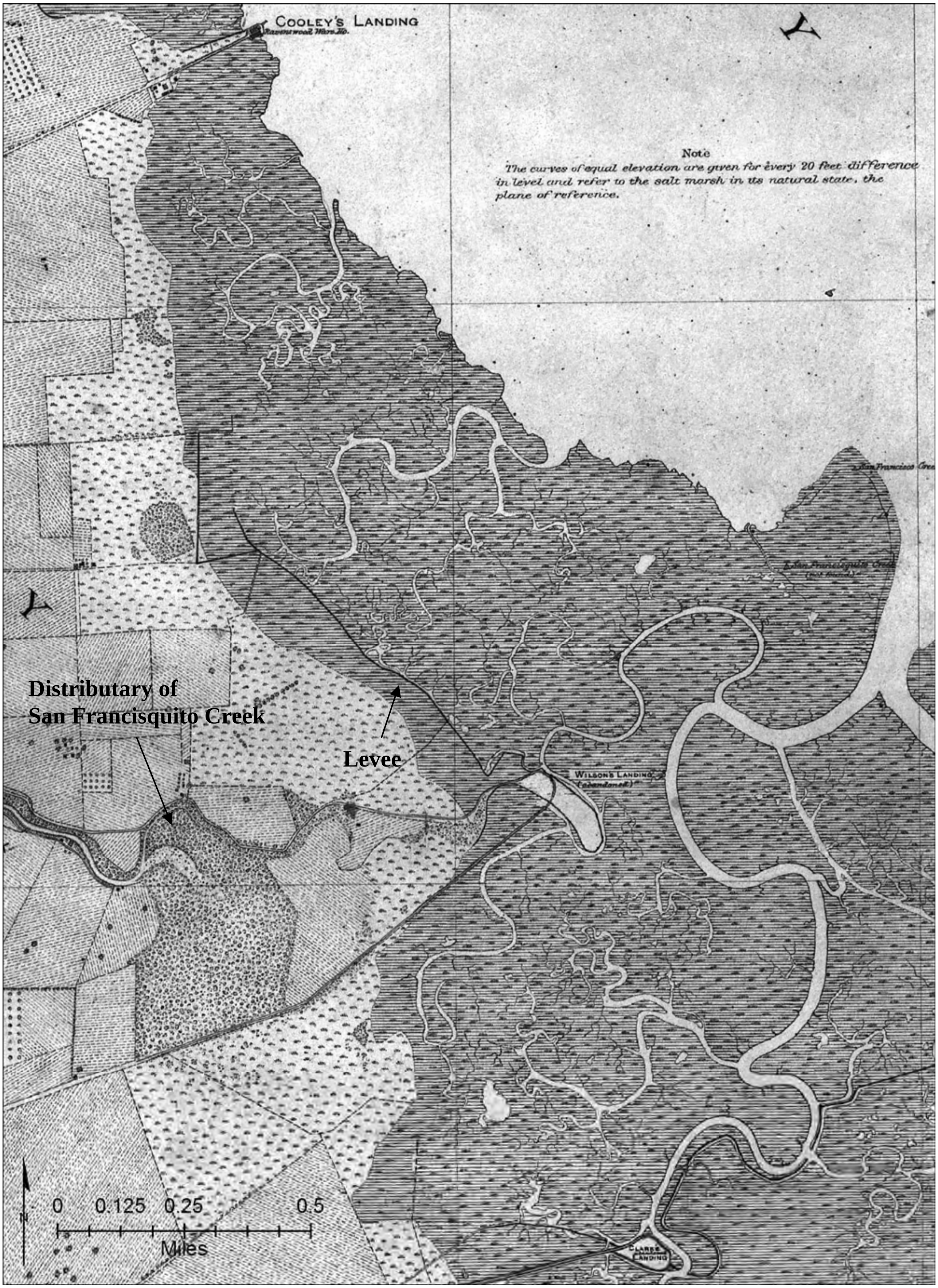


Figure 4: US Coast Survey T-sheet 676, 1857 (courtesy NOAA)



Note
The curves of equal elevation are given for every 20 feet difference in level and refer to the salt marsh in its natural state, the plane of reference.

Figure 5: US Coast Survey T-sheet 2312, 1897 (courtesy NOAA)

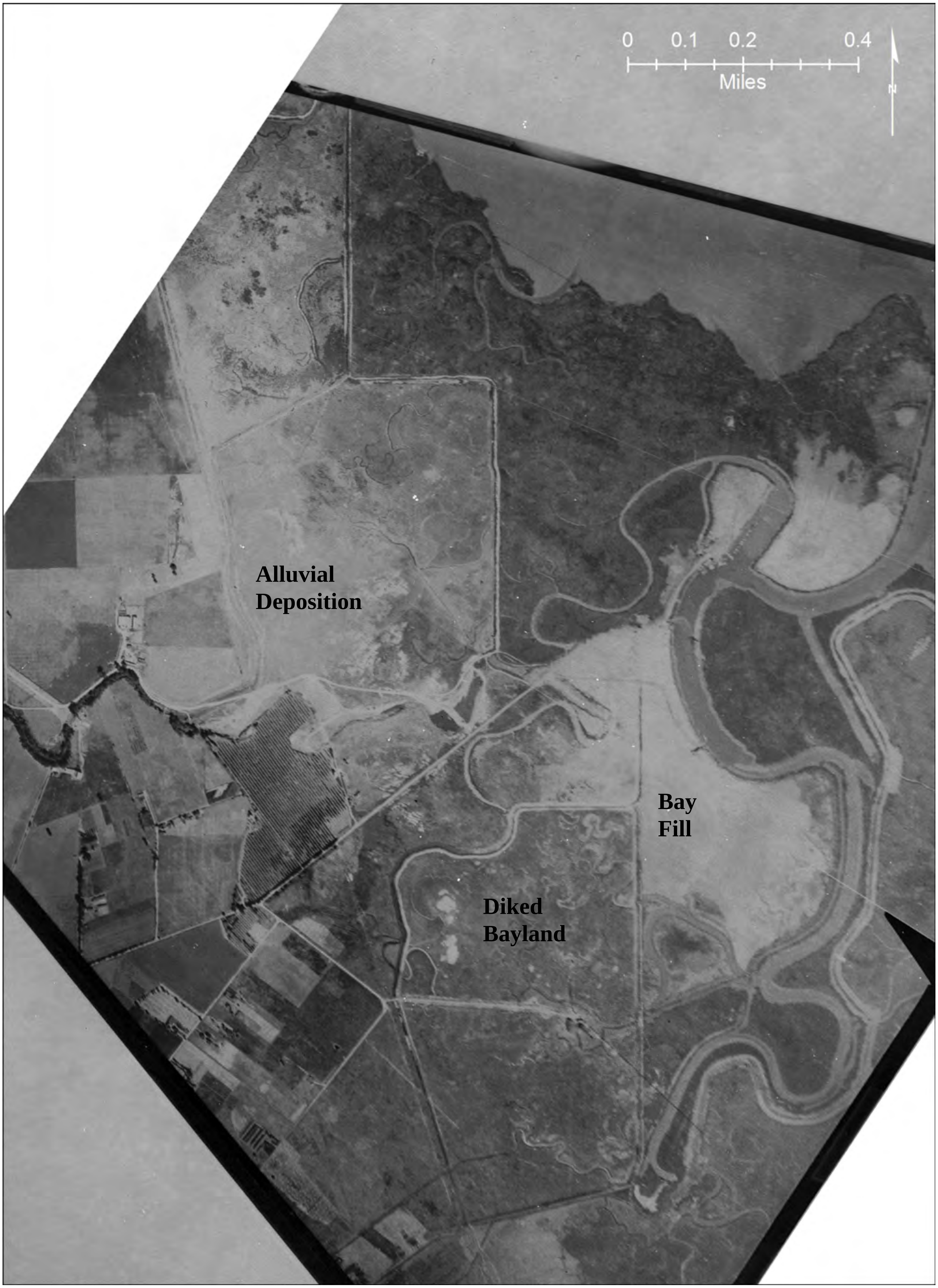


Figure 6: National Ocean Survey Photograph, 1921 (courtesy Alan K. Brown)

Figure 7: US Air Force Photograph, 1960 (courtesy UC Berkeley Earth Sciences and Map Library)

Figure 8: Color Infrared IKONOS Satellite Imagery, 2004 (courtesy City of San Jose)

APPENDIX: Methods

Data Sources

Habitat and land use figures were generated from a variety of sources collected for this project. 1857 and 1897 data were digitized into a GIS from the USCS/USCGS Topographic Sheets (T-sheets). These maps were surveyed using the most sophisticated geographic methods of the time, etched onto printing plates and printed on woven paper. Aerial photography was used to map 1921 and 1960 features. 2004 data were mapped from IKONOS color infrared satellite imagery. We obtained electronic copies of each dataset, accurately tied them to points on the ground during the georectification process, and vectorized into a Geographic Information System.

Data Source Details

1857 and 1897

These years were mapped based on the T-sheets. Variations in detail exist between the two years. It appears that the earlier T-sheet shows pannes in the tidal marshes with much greater detail and accuracy. The 1897 T-sheet shows very few pannes despite few other major changes. It is possible, but unlikely that such a large number of pannes disappeared in that time period. For this reason, it is important to note that the number of pannes in the 1897 view is likely to be greater than that depicted.

1921

The map of 1921 habitats was produced based on unusually early aerial imagery obtained by Alan K. Brown from the National Ocean Survey, and provided to SFEI. This imagery contains a gap in the far northern portion of the study area. This lack of information occurs in an area of tidal marsh that has remained undisturbed throughout our analysis. For this reason, we have retained tidal channels from the previous era and assumed no significant change when surrounding areas also showed no significant change. Pannes and salinas were not mapped due to difficulties in distinguishing these features from aerial imagery, but these features likely existed on the ground.

1960

Data and maps were generated based on aerial imagery of this year, flown by the US Air Force and obtained from UC Berkeley. A single image covered the extent of the study area and presented few difficulties for mapping. Like 1921, pannes and salinas were not mapped from the aerial imagery. This habitat is excluded in the mapping, but believed to exist on the ground.

2004

IKONOS color infrared satellite imagery was used for this year. A greater level of detail was mapped for the tidal marshes so that levees are distinct as areas of fill. Pannes were included in this view as they were readily apparent, visible in the imagery, and indicate a recent configuration for tidal wetlands.

Georectification

Before digitization of habitats, the T-sheets and imagery required georectification, or tying points on the map or image to points on the ground. Georectification was completed in ArcGIS 9.2 using standard Arc toolsets. Persistent features such as street crossings and large trees were preferred. However, because of the small size of the study site and lack of such features in early coastal maps, points on small tidal channels (especially confluences) that are believed to be fairly spatially stable were used to geo-reference parts of some images and maps. Where the study area required two images for complete coverage, the adjoining photo was georectfied to the first image of the same year. Care was taken to ensure consistency among the data sets. Overall accuracy for the images is believed to be approximately within 15 meters.

Classification

Habitat and land use classifications were determined based on map symbology, feature shape and relationship to other landscape features. Pixel values, or color signature, were also used for classifying from aerial and satellite imagery. Accommodations were made to address the differences between maps and images. For example, tidal channels were not altered from earlier mapped sources if they showed a similar shape, width, curvature and length, and met the 15 meter accuracy standard in the image being mapped. This is due to the difficulty of relating visible features (as in a photograph) to drawn historical features. As a result, greater change in channel width and alignment occurred in some places than is shown in the GIS. If of interest, these details can be examined in the original sources.

Feature Definition

Tidal Marsh	Habitat characterized by tidal wetland vegetation that was not impounded or otherwise enclosed by levees, dikes, ditches or any other restriction that prevented tidal inundation.
Tidal Channel/Flat	Linear and sinuous water courses in and around tidal marsh through which waters of the San Francisco Bay Estuary pass freely with the natural action of the tides. We included associated mudflats in this class as the datasets represented different tidal stages, making identification of the lower tidal flat boundary (MLLW) difficult. The size and shape of these channels were not altered if they appeared to retain a similar shape to the previously mapped year.
Bay Fill	Bay sediments manually dredged from tidal channels to allow for boat passage. This material was placed on surrounding baylands.
Alluvial Fill	Creek sediment deposited by San Francisquito Creek over historic baylands since 1857. The shape of the feature in 1897 has a distinct fan shape, as inferred from landscape shapes and characteristic striation patterns evident in imagery. Alluvial Fill can include agriculture but was not classified as such once development took place. The southern boundary of the fan feature was not clearly evident.
Fill	Deposited material of unknown origin. All developments were assumed to have been built on Fill.
Diked Bayland	Areas of former tidal marsh that no longer receive tidal action, usually due to a barrier such as a levee or dike. A functioning dike or levee had to be present and visible for this classification.
Panne	Natural, shallow ponds within tidal marsh habitat that fill and recede with high tidal waters. Pannes contain little to no vegetation. Very detailed pannes were mapped for the 1857 T-sheet.
Salina	Elongated, panne-like features that develop parallel to the marsh backshore and are inundated infrequently by very, very high tides. Salinas can have varying salinity levels due to micro-topography and freshwater influence.

References

Applequist H.C. 1931. Topographic sheet number 4606. U.S. Coast and Geodetic Survey.

Clark, W. O. 1924. Ground water in Santa Clara valley, California. Prepared in cooperation with the Department of Engineering of the State of California. U.S. Government Printing Office, Washington, D.C.

Silberling, Barbara. 1971. Historical Summary of Dredging in the Palo Alto Yacht Harbor.

Westdahl, F. 1897. Descriptive Report for Topographic sheet number 2312. U.S. Coast and Geodetic Survey.

Appendix C

Field Exploration Logs

SOIL CLASSIFICATION CHART
UNIFIED SOIL CLASSIFICATION SYSTEM

GRAPHIC SYMBOL	LETTER	DESCRIPTION OF SYMBOLS USED IN BORING LOGS	MAJOR DIVISIONS		
⬭	GW	WIDELY GRADED GRAVELS	CLEAN GRAVELS (LITTLE OR NO FINES)	GRAVELS MORE THAN HALF OF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	COARSE GRAIN SOILS MORE THAN HALF OF MATERIAL IS LARGER THAN NO. 200 SIEVE
⁘	GP	NARROWLY GRADED GRAVELS			
▥	GM	SILTY GRAVELS	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		
▨	GC	CLAYEY GRAVELS			
⁘	SW	WIDELY GRADED SANDS	CLEAN SANDS (LITTLE OR NO FINES)	SANDS MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE	
⁘	SP	NARROWLY GRADED SANDS			
▥	SM	SILTY SANDS	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		
▨	SC	CLAYEY SANDS			
▥	ML	SILTS	SILTS & CLAYS LIQUID LIMIT LESS THAN 50		FINE GRAIN SOILS MORE THAN HALF OF MATERIAL IS SMALLER THAN NO. 200 SIEVE
▨	CL	LEAN CLAYS			
▥	OL	ORGANIC SILTS/ORGANIC CLAYS			
▥	MH	ELASTIC SILTS	SILTS & CLAYS LIQUID LIMIT GREATER THAN 50		
▨	CH	FAT CLAYS			
▨	OH	ORGANIC CLAYS/ORGANIC SILTS			
◠	PT	PEATS	HIGHLY ORGANIC SOILS		

SOIL SAMPLER SYMBOLS

☒ MODIFIED CALIFORNIA SAMPLER

■ SHELBY TUBE

◩ STANDARD PENETRATION SAMPLER

FIELD TEST

250 PSI = GAUGE PRESSURE TO ADVANCE THE SHELBY TUBE SAMPLER

NOTES

1. For driven sampler, sampling resistance is the number of hammer blows required to advance the sampler 12-inches, after an initial 6-inches seating penetration. Liners were not used in the SPT sampler.
2. Description of the hammer used to drive the samplers are presented in the text.
3. Description of the drilling method and bit used are presented in the logs.

SAN FRANCISQUITO CREEK
FLOOD CONTROL PROJECT

Oakland
California
GEI Consultants

KEY TO BORING
LOGS

Project 092850

July 2010

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 15
LOCATION: ~25' N of Landside Toe, near end of Verbena Drive, East Palo Alto

BORING

B-1

PAGE 1 of 2

Drilling Information

DATE START / END: 2/3/10 - 2/4/10 **TOTAL DEPTH (FT):** 53.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden **LOGGED BY:** M. Powers
EQUIPMENT: Truck Mounted Failing 1500 **BORING METHOD:** Solid Stem Auger/Mud Rotary
AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): Water level not observed during rotary wash exploration
GENERAL NOTES:

ABBREVIATIONS:

ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Clayey GRAVEL (GC) mixed with concrete debris [FILL]							
			S1	18/16	5 3 3	Q_P=3.5		Sandy Silty CLAY (CL-ML); medium stiff; dark brown (10YR 3/3); moist; 70% low plasticity fines; 30% fine sand.							
10	5														
			S2	18/9	3 3 4	Q_P=2.5		Clayey SAND (SC); loose; dark brown (10YR 3/3); moist; trace organics (roots).			45				
			S3	18/11	2 4 4	Q_P=1.5									
5	10		S4	18/12	3 3 5			Poorly Graded Silty SAND (SM); loose; dark brown (10YR 3/3); wet; fine to medium sand; low plasticity fines.							
			S5	18/10	3 2 3						19				
0	15							Organics (wood) at 15.0', fine to coarse sand in cuttings from 15.0 to 16.5'.							
			S6	18/8	10 17 17			Well Graded SAND with Silt and Gravel (SW-SM); dense; dark olive gray (5Y 3/2); 75% fine to coarse sand; 15% fine gravel; 10% low plasticity fines. Coarse sand and fine gravel in cuttings from 18.0 to 20.5'.							
-5	20														
			S7	25/25	350 psi	Q_P=1.0 S_U=0.8		Sandy fat CLAY (CH); soft to medium stiff; dark greenish gray (GLEY1 4/1); high plasticity fines. Dark gray clay in cuttings from 20.5 to 21.0'.	70	59					
-10	25							Well graded SAND with Silt and Gravel (SW-SM); meduim dense; dark greenish gray (GLEY1 4/1); 65% fine to coarse gravel; 20% fine to coarse sand; 15% low plasticity fines.							
			S8	18/8	6 9 12										

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location
NORTHING: ________ **EASTING:** ________ **STATION:** ________ **OFFSET:** ________
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ________
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 15
LOCATION: ~25' N of Landside Toe, near end of Verbena Drive, East Palo Alto

BORING

B-1

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		☒	S9	18/9	10 10 17			55% fine to coarse gravel, 30% fine to coarse sand, 15% low plasticity fines from 31.0 to 42.0'.			8				
-20	35														
		⧗	S10	18/0	7 5 6			Clay with sand lens at 36.0'.							
		☒	S11	18/9	15 14 15										
-25	40														
		☒	S12	18/7	19 18 12			Poorly Graded SAND with Clay (SP-SC); medium dense to dense; olive (5Y 5/3); 90% medium to coarse sand; 10% low plasticity fines; trace fine gravel.							
-30	45														
								Fat CLAY (CH); stiff; olive (5Y 5/3); medium to high plasticity.							
		⧗	S13	18/11	8 10 13	Q_P=3.0 S_U=1.75			31	91				Q_u=2.92 ksf	
-35	50														
		⧗	S14	18/14	10 11 12	Q_P=3.0 S_U=1.75		Silty CLAY (CL-ML); stiff; olive (5Y 5/3) mottled with greenish gray (GLEY1 6/1); low to medium plasticity fines; less than 5% fine sand.							
								End of Boring at 53.5 feet							
-40	55														
-45	60														
-50	65														

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GEI Consultants

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

BORING

B-2

PAGE 1 of 2

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 13
LOCATION: ~25' S of Landside Toe, near Athletic Complex, Palo Alto

Drilling Information

DATE START / END: 2/2/10 - 2/3/10
TOTAL DEPTH (FT): 48.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden
LOGGED BY: M. Powers
EQUIPMENT: Truck Mounted Failing 1500
BORING METHOD: Solid Stem Auger/Mud Rotary
AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140
HAMMER DROP (inch): 30
WATER LEVEL DEPTHS (ft): Water level not observed during rotary wash exploration
GENERAL NOTES: ______

ABBREVIATIONS:

ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
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U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
	0							Poorly Graded GRAVEL with Sand (GP); road base, compacted [FILL].							
		✋	S1	12/12				Sandy Lean CLAY with Gravel (CL); hard; dark grayish brown; moist; 70% low plasticity fines, no dilatency, high toughness; 20% fine to coarse sand; 10% fine gravel [FILL].							
10		⧗	S2	18/14	10 11 11	Q_P=8.0									
								Fat CLAY (CL); stiff; black; 80% low plasticity fines; 20% fine sand; trace organics (wood debris); organic scent; glass shard recovered [FILL].							
	5	⧗	S3	18/10	4 5 7	Q_P=3.0									
								Obstructions/debris encountered from 7.0 to 13.0'.							
5		⧗	S4	18/8	8 4 3			Trace fine gravel from 8.0 to 13.0'.	53	56					
	10							Rubber pieces at 11.0'. ~7" diameter concrete chunk at 11.5'.							
0		⧗	S5	18/0	3 10 11			Lean CLAY (CL); stiff; greenish gray (GLEY1 6/1); 90% medium to high plasticity fines; 10% fine sand.							
	15	⧗	S6	18/12	3 5 6	Q_P=2.0 S_U=1.25		Wood debris in cuttings at 15.0'	28	95		48	32	Q_u=2.57 ksf	
-5								Poorly Graded SAND with Silt and Gravel (SP-SM); medium dense; olive brown (2.5Y 4/3); fine to coarse sand; fine to coarse gravel; no to low plasticity fines. Driller's Note: cuttings changed to sand and change in drill rate at 18.5'.							
	20	⧖	S7	18/11	10 10 12						8				
-10															
	25	⧖	S8	18/11	9 8 10										
-15								Silty CLAY with Sand (CL-ML); medium stiff to stiff; olive brown (2.5Y 4/3); 75% low plasticity fines, slow dilatency, medium toughness.							

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

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CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location
NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 13
LOCATION: ~25' S of Landside Toe, near Athletic Complex, Palo Alto

BORING

B-2

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
			S9	18/15	5 6 7	Q_P=1.5 S_U=1.75		Driller's Note: cuttings change to clay and change in drill rate at 28.0'	27	96				Q_u=2.22 ksf	
			S10	30/30	175 psi 300 psi			INTERBEDDED LENSES OF SILTY CLAY AND SILT SAND FROM 28.0 TO 48.5'.							
-20								Silty SAND (SM); light olive brown (2.5Y 5/4); 75% fine sand; 25% no to low plasticity fines.							
	35		S11	18/15	3 4 8			Silty CLAY (CL-ML); light olive brown (2.5Y 5/4); 90% low to medium plasticity fines; 10% fine sand.							
								Silty SAND (SM); light olive brown (2.5Y 5/4); 75% fine sand; 25% no to low plasticity fines.							
-25															
	40		S12	18/15	4 7 22	S_U=0.8		Silty CLAY (CL-ML); medium stiff; light olive brown (2.5Y 5/4); 95% low to medium plasticity fines, slow dilatency; 5% fine sand.							
			S13	18/11	9 11 10			Silty SAND with Gravel (SM); medium dense; olive brown (2.5Y 4/3); 55% fine to coarse sand; 25% no to low plasticity fines; 20% fine gravel.							
-30								Silty CLAY (CL-ML); medium stiff to stiff; light olive brown (2.5Y 5/4); 95% medium plasticity fines, slow dilatency; 5% fine sand.							
	45														
			S14	18/14	7 7 9	Q_P=1.0 S_U=1.0		with 15% fine sand from 47.0 to 47.6'.							
-35								SILT with Sand (ML); medium stiff to stiff; light olive brown (2.5Y 5/4); 85% no to low plasticity fines; 15% fine sand.							
	50							End of Boring at 48.5 feet							
-40															
	55														
-45															
	60														
-50															
	65														
-55															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: **EASTING:** **STATION:** **OFFSET:**
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:**
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 15
LOCATION: On Levee Crown, near Baylands Trailhead by Athletic Complex Parking Lot, Palo Alto

BORING

B-3

PAGE 1 of 2

Drilling Information

DATE START / END: 2/3/10
TOTAL DEPTH (FT): 51.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden
LOGGED BY: M. Powers
EQUIPMENT: Truck Mounted Failing 1500
BORING METHOD: Solid Stem Auger/Mud Rotary
AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): Water level not observed during rotary wash exploration
GENERAL NOTES:

ABBREVIATIONS:
ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
S = Split Spoon
DP = Direct Push Sample
U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
		✋	S1	6/6				Clayey GRAVEL with Sand (GC); dry; 65% fine gravel; 20% medium sand; 15% low plasticity fines; compacted [FILL].							
		✋	S2	6/6				Gravelly CLAY (CL); very stiff; dark olive brown; moist; 60% low plasticity fines; 30% fine gravel; 10% sand [FILL].							
		⧗	S3	18/15	9 9 12	Q_P=6.0		Plastic mesh debris at 4.0'.	15	114		35	16		
10	5														
		✋	S4	6/6				Sandy CLAY with Gravel (CL); dark olive brown; moist; 65% low plasticity fines; 25% medium to coarse sand; 10% fine gravel [FILL].							
		⧗	S5	18/17	7 8 12	Q_P=2.5 S_U=2.5		Lean CLAY (CL); very stiff; dark yellowish brown (10YR 4/4) mottled with olive gray and reddish brown; moist; low to medium plasticity fines [FILL].	24	99					
5	10	■	S6	12/12	200 psi 400 psi	Q_P=8.0		Sandy CLAY (CL); very stiff to hard; dark gray (2.5Y 4/1); 70% low plasticity fines; 30% fine to medium sand [FILL].							
		⧗	S7	18/11	15 15 12	Q_P=7.5		Clayey SAND (SC); medium dense; dark gray (2.5Y 4/1); 60% fine sand; 40% low plasticity fines [FILL].							
0	15	■	S8	30/30	150 psi 200 psi	Q_P=4.0 S_U=2.0		Fat CLAY/Elastic SILT (CH/MH); very stiff; dark gray (2.5Y 4/1); high plasticity fines.	43	77		71	35	Q_u=2.15 ksf	
-5	20	⧗	S9	18/10	4 7 10	Q_P=3.0 S_U=2.25			26	98				Q_u=3.14 ksf	
								Color change to greenish gray (GLEY1 6/1) at 21.0'.							
-10	25	■	S10	30/30	175 psi 225 psi	Q_P=1.0 S_U=1.0		Silty CLAY with Sand (CL-ML); medium stiff; yellowish brown (10YR 4/4); 75% low plasticity fines, slow dilatancy; 25% fine sand.							
		⧗	S11	18/14	3 4	Q_P=2.0		Lean CLAY with Sand (CL); medium stiff to stiff; dark							

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: ____ **EASTING:** ____ **STATION:** ____ **OFFSET:** ____

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ____

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 15

LOCATION: On Levee Crown, near Baylands Trailhead by Athletic Complex Parking Lot, Palo Alto

BORING

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PAGE 2 of 2

Elev. (ft)	Depth (ft)	Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
					5	S_U=1.2		yellowish brown; 75% low plasticity fines; 25% fine sand.							
-20	35		S12	18/12	10 9 12	Q_P=6.0 S_U=3.0		Sandy Lean CLAY (CL); dark yellowish brown; very stiff; 70% low plasticity fines; 30% fine to medium sand.	22	104					
-25	40		S13	18/16	10 3 6	Q_P=1.5		Poorly Graded SAND with Silt (SP-SM); dark brown; 95% fine to coarse sand; 5% no to low plasticity fines. Sandy Lean CLAY (CL); dark yellowish brown; medium stiff; 55% low plasticity fines; 45% fine to coarse sand. Driller's Note: drilling advanced quickly and sand in cuttings from 42.0 to 43.0'.	30	94					
-30	45		S14	18/18	WOH 7 10	Q_P=1.5 S_U=0.9		Silty CLAY (CL-ML); dark yellowish brown; medium stiff; 95% low plasticity fines; 5% fine sand.							
			S15	18/11	4 5 10			Silty SAND (SM); medium dense; dark yellowish brown; 70% fine sand; 30% low plasticity fines.							
-35	50		S16	18/12	10 11 12	Q_P=2.0 S_U=1.0 Q_P=1.5		Lean CLAY with Sand (CL); stiff; yellowish brown (10YR 5/4); 80% low plasticity fines, slow dilatency; 20% fine sand. 3-inch fat clay seam, medium stiff, medium to high plasticity fines at 50.0' End of Boring at 51.5 feet							
-40	55														
-45	60														
-50	65														

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CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: **EASTING:** **STATION:** **OFFSET:**
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:**
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 5
LOCATION: ~100' E of Landside Toe, on Golf Course, ~1800' S of Friendship Bridge, Palo Alto

BORING

B-4

PAGE 1 of 2

Drilling Information

DATE START / END: 2/1/10 **TOTAL DEPTH (FT):** 48.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden **LOGGED BY:** M. Powers
EQUIPMENT: Fraste Multidrill XL **BORING METHOD:** Solid Stem Auger/Mud Rotary
AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): Water level not recorded during rotary wash exploration
GENERAL NOTES: Fraste Mobile Track Rig

ABBREVIATIONS:					
	ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
	OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
	Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
	Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Golf Course Turf and Grass							
		✋	S1	12/12				Clayey SAND (SC); olive gray (5Y 4/2); 60% fine to medium sand; 40% fines [FILL].							
		■	S2	30/30	0 psi 200 psi			Fat CLAY (CH); olive gray mottled with reddish brown; 95% high plasticity fines; 5% fine sand.							
0	5							Silty SAND (SM); olive gray; 80% fine sand; 20% no to low plasticity fines.	59	65				Q_u=0.39 ksf	
								Fat CLAY (CH); medium stiff; dark bluish gray (GLEY2 4/1); 95% high plasticity fines, low toughness fines; 5% fine sand.							
		■	S3	30/30	100 psi 300 psi	Q_P=2.0 S_U=0.7									
-5	10								36	84					
								Color change to bluish gray from 11.0' to 13.0'.							
		⧗	S4	18/12	4 4 5	Q_P=2.0 S_U=0.7		Lean CLAY (CL); stiff; light greenish gray (GLEY 2 7/1); medium plasticity, slow dilatancy fines; trace fine sand and gravel.							
-10	15														
		■	S5	30/28	300 psi 600 psi	Q_P=2.5 S_U=1.5		Color change to greenish gray (GLEY1 6/1) from 18.0' to 23.0'.							
-15	20								29	97		46	26	Q_u=1.18 ksf	
		■	S6	30/30	300 psi 500 psi	Q_P=2.0 S_U=1.0		Sandy Lean CLAY (CL); medium stiff to stiff; 65% medium plasticity, medium toughness, slow dilatancy fines; 35% fine to coarse sand; trace fine gravel.							
-20	25														
		⧗	S7	18/14	3 3 6	Q_P=2.0 S_U=1.0		Sandy Silty CLAY (CL); medium stiff to stiff; greenish gray with brownish yellow; 70% medium plasticity fines; 30% fine sand. Sand content increased to 40%							

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: **EASTING:** **STATION:** **OFFSET:**
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:**
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 5
LOCATION: ~100' E of Landside Toe, on Golf Course, ~1800' S of Friendship Bridge, Palo Alto

BORING

B-4

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
								in sample shoe.							
		⧖	S8	18/14	9 9 6			Well Graded SAND with Silt and Gravel (SW-SM); medium dense; 70% medium to coarse sand; 20% fine gravel; 10% no to low plasticity fines. SAMPLE SHOE: Clayey SILT (ML); olive brown; 90% low plasticity fines; 10% fine sand. Interbedded coarse/fine grained layers from 34.5 to 35.5'.							
-30	35														
		■	S9	30/30	200 psi 550 psi	Q_P=4.0 S_U=1.75		Lean CLAY (CL); stiff; dark greenish gray (GLEY2 4/1); medium plasticity, no to slow dilatancy, medium toughness.							
-35	40														
		⧓	S10	18/16	6 9 11	Q_P=2.5 S_U=1.0		Sandy Lean CLAY (CL); medium stiff to stiff; 70% medium plasticity fines; 30% fine to medium sand; trace fine gravel.							
-40	45														
		⧓	S11	18/12	7 7 9	Q_P=2.5 S_U=1.0		Lean CLAY (CL); stiff; greenish gray; 95% low plasticity, no dilatancy fines; 5% coarse sand; trace fine gravel.							
								End of Boring at 48.5 feet							
-45	50														
-50	55														
-55	60														
-60	65														

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CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 14

LOCATION: On Levee Crown, ~300' E of Frienship Bridge, Palo Alto

BORING

B-5

PAGE 1 of 2

Drilling Information

DATE START / END: 2/8/10 **TOTAL DEPTH (FT):** 51.5

CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Will **LOGGED BY:** T. Haynes

EQUIPMENT: Fraste Multidrill XL Rubber Track **BORING METHOD:** Solid Stem Auger/Mud Rotary

AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A

HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30

WATER LEVEL DEPTHS (ft): Water level not observed during rotary wash exploration

GENERAL NOTES: Fraste Multidrill XL Rubber Track Rig

ABBREVIATIONS:

ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
S = Split Spoon
DP = Direct Push Sample
U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Lean CLAY (CL); very stiff; very dark gray (10YR 3/1); moist; medium plasticity fines; fine to coarse gravel at ground surface [FILL].							
			S1	18/12	4 4 7	Q_P=5.0 S_U=2.5			35	76				Q_u=2.60 ksf	
10	5		S2	18/8	3 5 5			~2-inch sandy silt seam at 3.3'. trace fine sand from 3.5 to 7.0'.							
								Sandy Lean CLAY (CL); dark grayish brown (10YR 4.2); moist; 70% low to medium plasticity fines; 30% fine sand [FILL]. Driller's Note: sand mixed with clay in cuttings at 7.0'.							
5			S3	18/14	3 3 4	Q_P=1.5 S_U=1.0			45	71					
	10		S4	18/11	1 2 2			Lean CLAY (CL); medium stiff; dark gray (2.5Y 4/1) mottled with brown (7.5YR 4/3); moist; medium plasticity fines; trace organics (plant fibers) [FILL].							
								Elastic Silt (MH); soft; very dark greenish gray (5G 3/1); moist to wet; medium to high plasticity fines.							
0	15		S5	30/29	0 psi	S_U=0.5			86	51		96	52	S_u=0.58 ksf Consol	
-5	20		S6	30/30	240 psi	Q_P=3.5 S_U=2.25									
								Lean CLAY (CL); stiff to very stiff; dark greenish gray (10Y 4/1); moist; medium to high plasticity fines.	30	93					
-10	25		S7	18/14	5 6 8	Q_P=3.0 S_U=2.25		olive gray (5Y 5/2); medium plasticity fines.	25						
-15			S8	30/24	200 psi	Q_P=2.5 S_U=1.0		Color change to gray (5Y 5/1) mottled with strong brown (7.5YR 4/6); medium stiff to stiff from 28.0 to 31.0'.							

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location
NORTHING: ____________ **EASTING:** ____________ **STATION:** __________ **OFFSET:** __________
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ____________
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 14
LOCATION: On Levee Crown, ~300' E of Frienship Bridge, Palo Alto

BORING

B-5

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)								
		■						33	88					
							Poorly Graded SAND with Gravel (SP); medium dense to dense; dark brown (10YR 3/3); moist to wet; 80% fine to coarse sand; 20% fine gravel. Driller's Note: loss of water in mud tub at 31.0'.							
-20		⧗	S9	18/14	22 23 24									
	35	☒	S10	18/6	2 4 13									
-25														
	40	☒	S11	18/8	10 15 18		65% fine to coarse sand; 35% fine gravel from 40.0 to 45.0'.							
-30														
	45	☒	S12	18/18	3 5 5		Lean CLAY (CL); stiff; yellowish brown (10YR 5/4); medium plasticity fines; trace fine sand.							
-35														
	50	⧗	S13	18/15	5 10 11	Q_P=2.0 S_U=1.2	Color change to dark greenish gray (10YR 4/1) from 50.0 to 51.5'.							
							End of Boring at 51.5 feet							
-40	55													
-45	60													
-50	65													

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 6
LOCATION: ~75' E of Landside Toe, on Golf Course, ~850' S of Friendship Bridge, Palo Alto

BORING

B-6

PAGE 1 of 2

Drilling Information

DATE START / END: 2/1/10 - 2/2/10
TOTAL DEPTH (FT): 48.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden
LOGGED BY: M. Powers
EQUIPMENT: Fraste Multidrill XL
BORING METHOD: Solid Stem Auger/Mud Rotary
AUGER ID/OD: N/A / 5 in, 2.625 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): Water level not recorded during rotary wash exploration
GENERAL NOTES: Fraste Mobile Track Rig

ABBREVIATIONS:

ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Grass turf; sandy subgrade.							
5		✋	S1	12/12				Clayey SAND (SC); dark grayish brown (2.5Y 4/2); 70% fine to medium sand; 30% medium plasticity fines; trace organics (root fibers) [FILL].							
		⧗	S2	18/13	3 3 5	Q_P=2.0 S_U=0.75		Silty CLAY (CL); medium stiff; grayish brown (2.5Y 5/2); 95% medium plasticity fines; 5% fine sand.							
0	5	■	S3	30/30	175 psi	Q_P=0.5 S_U=0.4		Fat CLAY with Sand (CH); soft; dark greenish gray (GLEY2 4/1); 85% medium to high plasticity, medium dilatancy, low toughness fines; 15% fine sand; trace organics.	44	76				Q_u=0.83 ksf	
-5	10	■	S4	30/30	275 psi	Q_P=0.5 S_U=0.4		Fat CLAY (CH); soft; dark greenish gray; 95% high plasticity fines, slow dilatancy, low toughness fines; 5% fine sand; organic scent; shell fragments.	79	54		78	43	S_u=0.36 ksf Consol	
								Lean CLAY (CL); stiff; greenish gray (GLEY2 5/1) mottled with brownish yellow; 95% low to medium plasticity fines; 5% fine sand; with calcified nodules. Driller's Note: change in cuttings color at 14.0'.							
-10	15	⧗	S5	18/11	4 7 7	Q_P=3.0 S_U=1.25			31	91					
-15	20	⧗	S6	18/12	5 6 7	Q_P=3.5 S_U=1.25		Trace shell fragments at 20.0'.	23	104					
-20	25	■	S7	30/30	800 psi 900 psi	Q_P=5.5 S_U=1.25			26						

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CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 6

LOCATION: ~75' E of Landside Toe, on Golf Course, ~850' S of Friendship Bridge, Palo Alto

BORING

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PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
-25		⧓	S8	18/13	3 6 10	Q_P=2.5 S_U=0.625	▨	Silty CLAY with Sand and Gravel (CL); medium sitff; 75% low to medium plasticity fines; 15% fine to coarse sand; 10% fine gravel.							
		⊠	S9	18/18	10 10 12		∴	Silty SAND with Gravel (SM); medium dense; olive gray (5Y 4/2); 50% medium to coarse sand; 30% fine gravel; 20% no to low plasticity fines.							
	35														
-30															
		⊠	S10	18/11	8 8 6		∴	Well Graded SAND with Silt and Gravel (SW-SM); medium dense; dark olive gray (5Y 3/2); 60% medium to coarse sand; 30% fine gravel; 10% no to low plasticity fines.							
	40														
-35							▨	Lean CLAY with Sand (CL); medium stiff to stiff; greenish gray; 80% low to medium plasticity, slow dilatancy fines; 20% fine sand.							
		⧓	S11	18/3	4 5 9	Q_P=4.0 S_U=0.75									
	45														
-40															
		⧓	S12	18/12	5 6 8	Q_P=2.0 S_U=1.0	▨	Silty CLAY (CL); medium stiff to stiff; greenish gray mottled with brownish yellow; 95% low to medium plasticity, slow dilatancy, medium toughness fines; 5% fine sand.							
	50							End of Boring at 48.5 feet							
-45															
	55														
-50															
	60														
-55															
	65														
-60															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 16.0
LOCATION: On Levee Crown, ~50' E of Pump Station

BORING

B-7

PAGE 1 of 2

Drilling Information

DATE START / END: 10/11/2011 - 10/11/2011
TOTAL DEPTH (FT): 55.0
CONTRACTOR: Exploration Geoservices Inc. **DRILLER:** Lauren
LOGGED BY: T. Haynes
EQUIPMENT: Mobile B-53
BORING METHOD: Hollow Stem Auger
AUGER ID/OD: OD - 8 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Down Hole Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): ∇ 12.0 10/11/2011
GENERAL NOTES:

ABBREVIATIONS:
ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
S = Split Spoon
DP = Direct Push Sample
U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
15								Silty SAND (SM) with Gravel; very dense; dark yellowish brown (10YR 3/4); moist; 60% fine to medium sand; 20% fine, sub rounded to sub angular gravel; 20% low plasticity fines [FILL] Color change to light brown below 2.0'							
		⧓	1	5/5	50/5"										
	5	◣	2	18/12	4 4 3			Sandy Lean CLAY (CL); dark yellowish brown (10YR 3/4) with mottling; moist; 65-70% medium plasticity fines; 30-35% fine sand	13						
10															
		⧓	3A, 3B	18/18	7 5 3			Poorly Graded SAND with Gravel (SP); loose; dark yellowish brown (10YR 4/4); moist; fine to coarse sand; fine gravel	4		3 75				
	10	◣	4	18/16	1 2 2			Lean Clay with SAND (CL); loose; brown (10YR 4/3); moist; medium plasticity fines; fine sand; trace gravel							
5	∇														
		⧓	5	18/18	3 3 3			Lean CLAY (CL/ML); dark yellowish brown (10YR 3/4); low plasticity	38	84					
	15	◣	6	18/18	2 1 3			Elastic SILT (MH); black (GLEY1 2.5/N); high plasticity; low toughness; trace coarse sand [BAY MUD]	34						
0															
		⧓	7	18/18	3 3 4			Sandy Lean CLAY (CL); soft; pale yellow (2.5Y 8/2); 70% fines; 30% fine sand	32	89		36	19	Q_u=0.28 ksf	
	20	◣	8	18/18	3 4 3										
-5															
	25	⧓	9	18/18	5 8 15										
-10								Clayey SAND (SC); dark yellowish brown (10YR 4/4); medium dense; 80% fine to medium sand; 20% fines							
		◣	10	18/12	10 17 34			Poorly Graded SAND with Silt and Gravel (SP-SM); dark yellowish brown (10YR 3/4); very dense; medium	14		7				

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Avenue
Oakland, CA 94612
(510) 350-2900

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 16.0

LOCATION: On Levee Crown, ~50' E of Pump Station

BORING

B-7

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
-15								to coarse sand; fine, sub rounded gravel							
	35	◣	11	18/16	15 34 41										
-20															
	40	◣	12	18/18	5 7 20			medium dense below 38.5' 6" sandy lean clay, dark grayish brown (2.5Y 4/2) seam at 39.5'							
-25															
	45	⧓	13	18/18	8 11 16										
-30															
	50	⧓	14	18/12	7 9 14			Lean CLAY (CL); dark yellowish brown (10YR 3/4); medium plasticity; medium toughness sandy lean clay transition from 48.5 to 49.0'							
-35															
	55	⧓	15	18/16	7 10 12										
-40								End of Boring at 55 feet							
	60														
-45															
	65														
-50															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 14.0
LOCATION: ~100' E of Pump Station

BORING

B-8

PAGE 1 of 1

Drilling Information

DATE START / END: 10/12/2011 - 10/12/2011 **TOTAL DEPTH (FT):** 25.0
CONTRACTOR: Access Soil Drilling **DRILLER:** Jose **LOGGED BY:** T. Haynes
EQUIPMENT: Minuteman **BORING METHOD:** Solid Stem Auger
AUGER ID/OD: OD - 4 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Rope and Cathead **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): ▽ 10.5 10/12/2011
GENERAL NOTES:

ABBREVIATIONS:
ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
S = Split Spoon
DP = Direct Push Sample
U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
			1	18/12	15 14 16	Q_P=0.5		Sandy Lean CLAY (CL); soft to medium stiff; light yellowish brown (2.5Y 6/4); dry to moist; 60% medium plasticity, medium toughness fines; 40% fine to medium sand; trace roots and fine gravel [FILL]							
			2	18/12	6 5 6										
10			3	18/11	9 12 15	Q_P=4.5+			11	105				Q_u=5.42 ksf	
	5		4	18/13	5 6 5			Poorly Graded SAND with Silt and Gravel (SP-SM); loose to medium dense; yellowish brown (10YR 5/4); dry to moist; fine to coarse sand; fine, sub angular to sub rounded gravel	3		5				
			5	18/16	8 12 8										
			6	18/11	3 1 3			Lean CLAY (CL); soft; dark yellowish brown (10YR 4/4); moist; medium plasticity, medium toughness fines; trace roots and organics							
5	▽10		7A, 7B	18/18	3 4 5	Q_P=0.5			39	82		51	23	Q_u=0.68 ksf	
			8	18/18	2 2 2			Elastic SILT (MH/CH); black (GLEY1 2.5N/); high plasticity, low toughness fines trace organics [BAY MUD]							
			9	18/6	1 2 3				41						
0			10	18/18	2 3 4			Lean CLAY (CL); pale yellow (2.5Y 8/3); medium plasticity, medium to high toughness fines	31						
	15							Color change to light greenish gray below 15.0'							
-5			11	18/9	4 5 8	Q_P=2.0		Lean CLAY with Sand (CL); stiff to very stiff; light yellowish brown (2.5Y 6/3) with yellowish brown (10YR 5/6) mottling; 80% medium plasticity, medium toughness fines; 20% fine sand							
	20														
-10			12	18/15	10 12 13			Poorly Graded SAND with Silt and Gravel (SP-SM); medium dense; dark yellowish brown (10YR 3/6); fine to medium sand; fine, sub rounded to sub angular gravel			9				
	25							End of Boring at 25 feet							
-15															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Avenue
Oakland, CA 94612
(510) 350-2900

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 13.0
LOCATION: ~200' E of Pump Station

BORING

B-9

Drilling Information

DATE START / END: 10/12/2011 - 10/12/2011 **TOTAL DEPTH (FT):** 30.0
CONTRACTOR: Access Soil Drilling **DRILLER:** Jose **LOGGED BY:** T. Haynes
EQUIPMENT: Minuteman **BORING METHOD:** Solid Stem Auger
AUGER ID/OD: OD - 4 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Rope and Cathead **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): ▽ 9.0 10/12/2011
GENERAL NOTES:

ABBREVIATIONS:

ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
			1A, 1B	18/12	11 22 20	Q_P=0.5		Sandy Lean CLAY (CL); hard; dark olive brown (2.5Y 3/3); dry to moist; 65-70% low to medium plasticity, medium toughness fines; 30-35% fine sand; trace roots [FILL]							
			2	18/12	22 20 14			Clayey SAND (SC); dense; brown (10YR 4/3); moist; 60% fine sand; 40% low to medium plasticity, medium toughness fines; trace fine gravel [FILL]							
10			3	18/12	18 20 18										
	5		4	18/15	4 3 2			Silty SAND (SM); medium dense; brown (10YR 4/3); moist; fine sand; trace gravel [FILL TO 4.5'] loose below 4.5'							
			5	18/11	4 5 6				15	111	43				
5			6	18/18	1 2 2			Lean CLAY (CL); medium stiff to stiff; grayish brown (10YR 5/2); moist; low to medium plasticity, medium toughness fines; trace organics							
	▽ 10		7A, 7B	18/12	3 4 3	Q_P=1.0			38	83					
			8	18/18	2 1 2			Elastic SILT (MH); stiff; black (GLEY1 2.5/N); high plasticity, low toughness fines [BAY MUD]							
0			9	18/12	2 4 6	Q_P=1.3		Sandy Lean CLAY (CL); medium stiff; pale yellow (2.5Y 8/3); 70% medium to high plasticity, medium to high toughness fines; 30% fine sand							
	15		10	18/16	2 2 3	Q_P=2.0									
-5															
	20		11	18/14	4 8 9	Q_P=0.8		Color change to light yellowish brown mottled with yellowish brown	27	97				Q_u=1.42 ksf	
-10															
	25		12	18/5	5 6 7			Lean CLAY with Sand (CL); light yellowish brown (2.5Y 6/3) mottled with yellowish brown (10YR 5/6); 80% medium to high plasticity, medium to high toughness fines; 20% fine sand							
-15															
			13	18/18	3 4 5			Sandy Lean Clay (CL); light olive brown (2.5Y 5/4);	27		61				

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 13.0

LOCATION: ~200' E of Pump Station

BORING

B-9

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								medium plasticity fines; fine sand; trace fine gravel							
								End of Boring at 30 feet							
-20															
	35														
-25															
	40														
-30															
	45														
-35															
	50														
-40															
	55														
-45															
	60														
-50															
	65														
-55															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.

PROJECT NAME: San Francisquito Creek Flood Control

CITY/STATE: Palo Alto/East Palo Alto, California

GEI PROJECT NUMBER: 092850

GEI Consultants

GEI Consultants
180 Grand Avenue
Oakland, CA 94612
(510) 350-2900

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 17.0
LOCATION: On Levee Crown, ~250' E of Pump Station

BORING

B-10

PAGE 1 of 2

Drilling Information

DATE START / END: 10/11/2011 - 10/11/2011 **TOTAL DEPTH (FT):** 55.0
CONTRACTOR: Exploration Geoservices Inc. **DRILLER:** Lauren **LOGGED BY:** T. Haynes
EQUIPMENT: Mobile B-53 **BORING METHOD:** Hollow Stem Auger
AUGER ID/OD: OD - 8 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Down Hole Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): ▽ 12.0 10/11/2011
GENERAL NOTES:

ABBREVIATIONS:

ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	 Sample No.	 Pen./ Rec. (in)	 Blow Count or RQD	 Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Poorly Graded GRAVEL with Clay and SAND (GP-GC); dark grayish brown (2.5Y 4/2); moist; 50% fine, sub angular to sub rounded gravel; 40% medium to coarse, sub rounded sand; 10% fines; trace organics [FILL]							
15			1A, 1B	18/16	5 8 11	Q_P=2.5		Fat CLAY (CH/CL); black (7.5YR 2.5/1); moist; medium to high plasticity, high toughness fines [FILL]	20	100					
			2	18/12	5 6 11			Sandy Lean CLAY (CL); very stiff; brown (10YR 4/3); moist; 70% low to medium plasticity fines; 30% fine sand; trace roots [FILL TO 5.0']							
	5														
10			3	18/12	6 9 11			Clayey SAND (SC); medium dense; brown (10YR 4/3); moist; fine to medium sand; medium plasticity fines; trace roots	8	99	40			Q_u=2.91 ksf	
			4	18/13	4 5 6										
	10														
5	▽		5A, 5B	18/12	3 3 5	Q_P=0.5-		Fat CLAY (CH); soft to medium stiff; dark grayish brown (10YR 4/2) [BAY MUD]	40	80				Q_u=0.98 ksf	
			6	18/18	2 1 2			Color change to black below 14.5'							
	15		7A, 7B	18/18	3 3 4				37	83		55	33	Q_u=0.92 ksf	
0						Q_P=0.5									
			8	18/18	3 4 5			Sandy Lean CLAY (CL); light gray (2.5YR 7/2); medium to high plasticity, medium toughness fines			49				
	20														
-5															
			9A, 9B	18/16	7 9 10	Q_P=1.5		Lean CLAY with Sand (CL); medium stiff to stiff; yellowish brown (10YR 5/8); 80% medium plasticity, medium toughness fines; 20% fine sand; trace roots at 23.5'							
	25														
-10															
			10	18/18	4 5 5			Trace fine gravel at 28.5'							

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
GEI Consultants
180 Grand Avenue
Oakland, CA 94612
(510) 350-2900

Boring Location

NORTHING: - **EASTING:** **STATION:** - **OFFSET (FT):** -

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** -

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 17.0

LOCATION: On Levee Crown, ~250' E of Pump Station

BORING

B-10

PAGE 2 of 2

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
						Q_P=1.0									
-15															
		⧗	11	18/12	6 7 7			Sandy lean clay lens at 33.5'							
	35														
-20															
		◣	12	18/18	3 4 5			Color change to dark greenish gray below 38.5'							
	40														
-25															
		⧗	13	18/15	5 7 10			Sandy Lean CLAY (CL) to Clayey SAND (SC); 45-55% medium plasticity, medium toughness fines; 45-55% fine sand							
	45														
-30															
		⧗	14	18/15	5 7 10	Q_P=1.5		Lean CLAY (CL); medium stiff; dark greenish gray (GLEY1 4/4); low to medium plasticity, medium toughness fines							
	50														
-35															
		⧗	15	18/18	5 9 9										
	55					Q_P=0.8									
								End of Boring at 55 feet							
-40															
	60														
-45															
	65														
-50															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Creek Flood Control
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants

GEI Consultants
180 Grand Avenue
Oakland, CA 94612
(510) 350-2900

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 16

LOCATION: On Levee Crown, near end of Verbena Dr., East Palo Alto

BORING

S-1

PAGE 1 of 1

Drilling Information

DATE START / END: 2/4/10 **TOTAL DEPTH (FT):** 16.0

CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden **LOGGED BY:** M. Powers

EQUIPMENT: Truck Mounted Failing 1500 **BORING METHOD:** Solid Stem Auger

AUGER ID/OD: N/A / 4 in **CASING ID/OD:** N/A / N/A

HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30

WATER LEVEL DEPTHS (ft): ▼ 12.5 2/4/2010 1:30 pm

GENERAL NOTES:

ABBREVIATIONS:

ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION					GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
		Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)									
15								Clayey GRAVEL with Sand (GC); medium dense; dark yellowish brown (10YR 4/4); dry; 50% fine gravel; 30% low plasticity fines; 20% fine to medium sand; moist below 1.0' [FILL].							
		✋	S1	12/12											
		⧗	S2	18/17	14 13 11										
								Clayey SAND (SC); dark yellowish brown (10YR 4/4); fine to medium sand; low plasticity fines; trace fine gravel [FILL].	12		41				
	5														
10															
		✋	S3	12/12				Sandy Lean CLAY (CL); very stiff to hard; dark gray (5Y 4/1); 70% low plasticity fines; 30 % fine sand [FILL].							
		⧗	S4	18/15	11 14 15										
								~3-inch root at 8.5'. Trace fine gravel at 9.0'.							
	10														
5															
	▼	✋	S5	12/12				Silty SAND (SM); loose; dark gray; moist to wet; 70% fine sand; 30% low plasticity fines.							
		⧗	S6	18/8	4 3 4										
	15	✋	S7	12/12				Wet; medium sand at 15.0'.							
0								End of Boring at 16 feet							
	20														
-5															
	25														
-10															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.

PROJECT NAME: San Francisquito Flood Control Project

CITY/STATE: Palo Alto/East Palo Alto, California

GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______

HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______

VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 14

LOCATION: On Levee Crown, ~1300' S of Pump Station, East Palo Alto

BORING

S-3

PAGE 1 of 1

Drilling Information

DATE START / END: 2/4/10

TOTAL DEPTH (FT): 15.5

CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Eden

LOGGED BY: M. Powers

EQUIPMENT: Truck Mounted Failing 1500

BORING METHOD: Solid Stem Auger

AUGER ID/OD: N/A / 4 in **CASING ID/OD:** N/A / N/A

HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30

WATER LEVEL DEPTHS (ft): ⊻ 11.0 2/4/2010 3:15 pm

GENERAL NOTES:

ABBREVIATIONS:				
ID = Inside Diameter	bpf = Blows per Foot	U = Undistrubed Tube Sample	WOR = Weight of Rods	Q_P = Pocket Penetrometer Strength
OD = Outside Diameter	mpf = Minute per Foot	C = Rock Core	WOH = Weight of Hammer	S_v = Pocket Torvane Shear Strength
Pen. = Penetration Length	S = Split Spoon	V = Field Vane Shear	RQD = Rock Quality Designation	F_v = Field Vane Shear Strength
Rec. = Recovery Length	DP = Direct Push Sample	SC = Sonic Core	OVM = Organic Vapor Meter	NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
							▨	Clayey GRAVEL (GC); dry.							
							▨	Clayey SAND with Gravel (GC); yellowish brown; 60% fine to medium sand; 30% low plasticity fines; 10% fine gravel [FILL].							
		✋	S1	12/12			▨								
		⧗	S2	18/12	3 4 4	Q_P=1.5	▨	Sandy Lean CLAY (CL); dark brown (10YR 3/3); moist; 70% low plasticity fines; 30% fine sand [FILL].							
10							▥	SILT with Sand (ML); medium stiff; dark grayish brown (10YR 4/2) mottled with reddish brown (5YR 4/4); no to low plasticity fines; fine sand [FILL].	30	91	75				
	5														
		✋	S3	12/12			▨	Lean CLAY (CL); medium stiff; dark grayish brown (10YR 4/2) mottled with reddish brown (5YR 4/4); low plasticity fines [FILL].							
5		⧗	S4	18/18	1 2 3	Q_P=1.0 S_U=0.8	▨		33	86				Q_u=0.74 ksf	
	10														
	⊻	✋	S5	12/12			▨	Sandy Lean CLAY (CL); dark grayish brown (10YR 4/2); 70% low to medium plasticity fines; 30% fine sand [FILL].							
		⧖	S6	18/18	WOH WOH WOH	Q_P=1.0	▨	Fat CLAY (CH); soft; dark gray; 95% medium to high plasticity fines; 5% fine sand.							
0		▮	S7	30/30	100 psi 200 psi		▥	Poorly Graded SAND with Silt (SP-SM); greenish gray (GLEY2 5/1) mottled with reddish brown (5YR 4/4); 95% fine sand; 5% low plasticity fines.							
	15														
								End of Boring at 15.5 feet							
-5															
	20														
-10															
	25														
-15															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

Boring Location

NORTHING: ______ **EASTING:** ______ **STATION:** ______ **OFFSET:** ______
HORIZONTAL DATUM: NAD 83 **STATION CENTERLINE:** ______
VERTICAL DATUM: NAVD 88 **GROUND SURFACE ELEVATION (FT):** 14
LOCATION: On Levee Crown, ~1100' S of Frienship Bridge, Palo Alto

BORING

S-6

PAGE 1 of 1

Drilling Information

DATE START / END: 2/8/10
TOTAL DEPTH (FT): 22.5
CONTRACTOR: Pitcher Drilling Co. **DRILLER:** Will
LOGGED BY: T. Haynes
EQUIPMENT: Fraste Multidrill XL Rubber Track
BORING METHOD: Solid Stem Auger
AUGER ID/OD: N/A / 4 in **CASING ID/OD:** N/A / N/A
HAMMER TYPE: Automatic Hammer **HAMMER WEIGHT (lbs):** 140 **HAMMER DROP (inch):** 30
WATER LEVEL DEPTHS (ft): ▼ 15.8 2/8/2010 4:30 pm
GENERAL NOTES: Fraste Multidrill XL Rubber Track Rig

ABBREVIATIONS:
ID = Inside Diameter
OD = Outside Diameter
Pen. = Penetration Length
Rec. = Recovery Length
bpf = Blows per Foot
mpf = Minute per Foot
S = Split Spoon
DP = Direct Push Sample
U = Undistrubed Tube Sample
C = Rock Core
V = Field Vane Shear
SC = Sonic Core
WOR = Weight of Rods
WOH = Weight of Hammer
RQD = Rock Quality Designation
OVM = Organic Vapor Meter
Q_P = Pocket Penetrometer Strength
S_v = Pocket Torvane Shear Strength
F_v = Field Vane Shear Strength
NA, NM = Not Applicable, Not Measured

Elev. (ft)	Depth (ft)	SAMPLE INFORMATION Type	Sample No.	Pen./ Rec. (in)	Blow Count or RQD	Field Test Data (ksf)	GRAPHIC LOG	Sample Description & Classification	Moisture Content (%)	Dry Density (pcf)	Fines % <#200	LL	PI	Other Tests	Remarks
								Clayey GRAVEL with Sand (GC); dark grayish brown (10YR 4/2); dry; 60% fine to coarse gravel; 25% fine to coarse sand; 15% low plasticity fines [FILL].							
		✋	S1	6/6											
10		☒	S2	18/12	6 12 12										
	5														
								Lean CLAY with Sand (CL); medium stiff; very dark grayish brown (2.5Y 3/2); moist; 85% medium plasticity fines; 15% fine to medium sand [FILL].							
		✋	S3	6/6											
		⧓	S4	18/18	6 6 8	Q_P=1.5									
5								Clayey SAND (SC); very dark greenish gray (5GY 3/1); moist; fine sand; low to medium plasticity fines [FILL].			46				
	10														
0		⧓	S5	18/18	3 8 12										
								Poorly Graded SAND (SP) very dark greenish gray (5GY 3/1); moist; fine to coarse sand.							
	15 ▼														
-5		☒	S6	18/12	2 2 3										
								Fat CLAY (CH); medium stiff; dark greenish gray (5GY 4/1); moist to wet; high plasticity fines.							
	20	■	S7	30/24	100 psi	S_U=0.7			75	54				Q_u=0.53 ksf	
								End of Boring at 22.5 feet							
-10															
	25														
-15															

Strata lines represent the approximate boundaries between soil types. Actual transitions may be gradual. Water level readings have been made at times stated. Water levels may be different at other times.

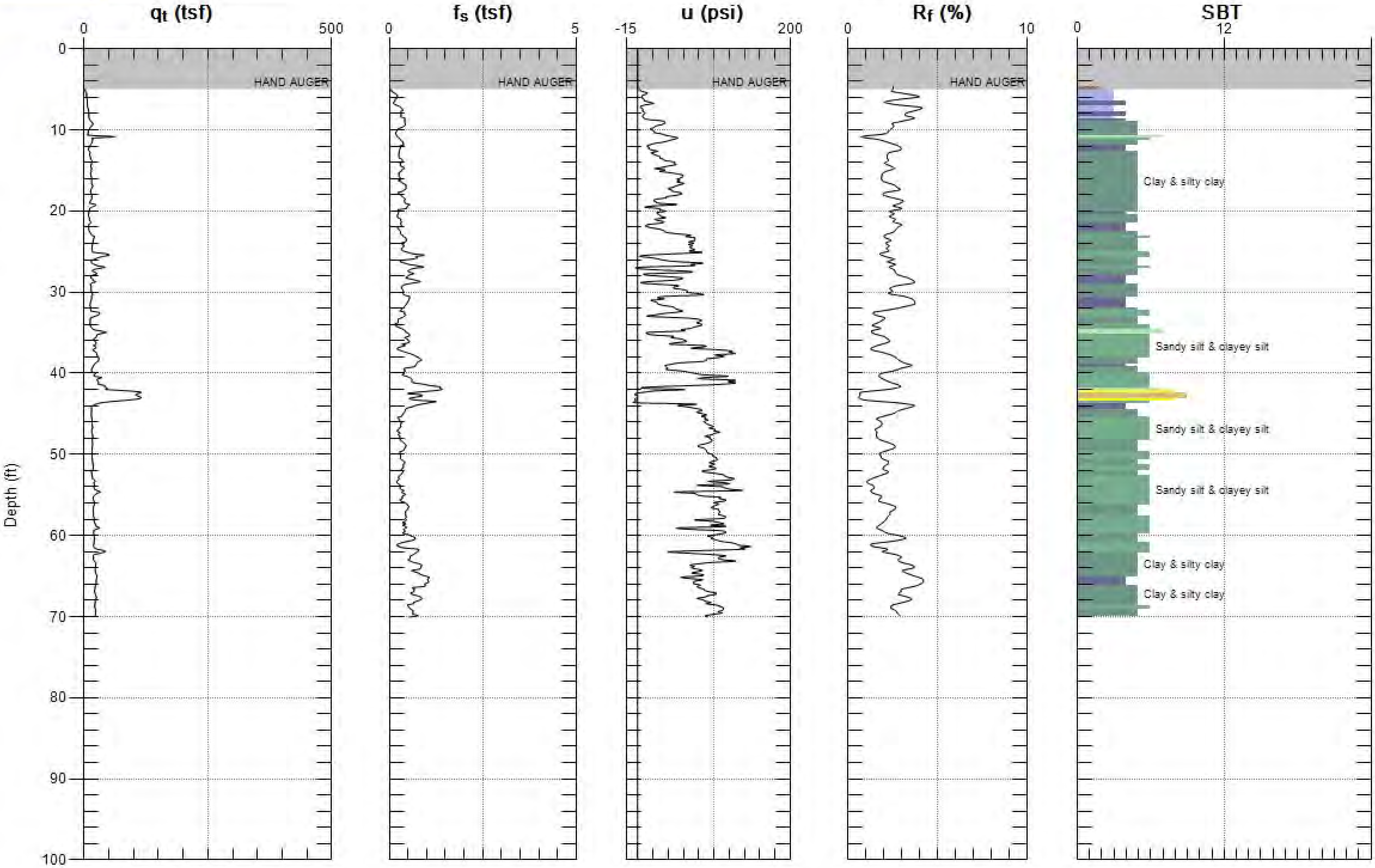
CLIENT: HDR Engineering, Inc.
PROJECT NAME: San Francisquito Flood Control Project
CITY/STATE: Palo Alto/East Palo Alto, California
GEI PROJECT NUMBER: 092850

GEI Consultants
180 Grand Ave
Oakland Ca 94611
510-350-2900

GEI

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-01 **Date: 2010-01-28 11:31**



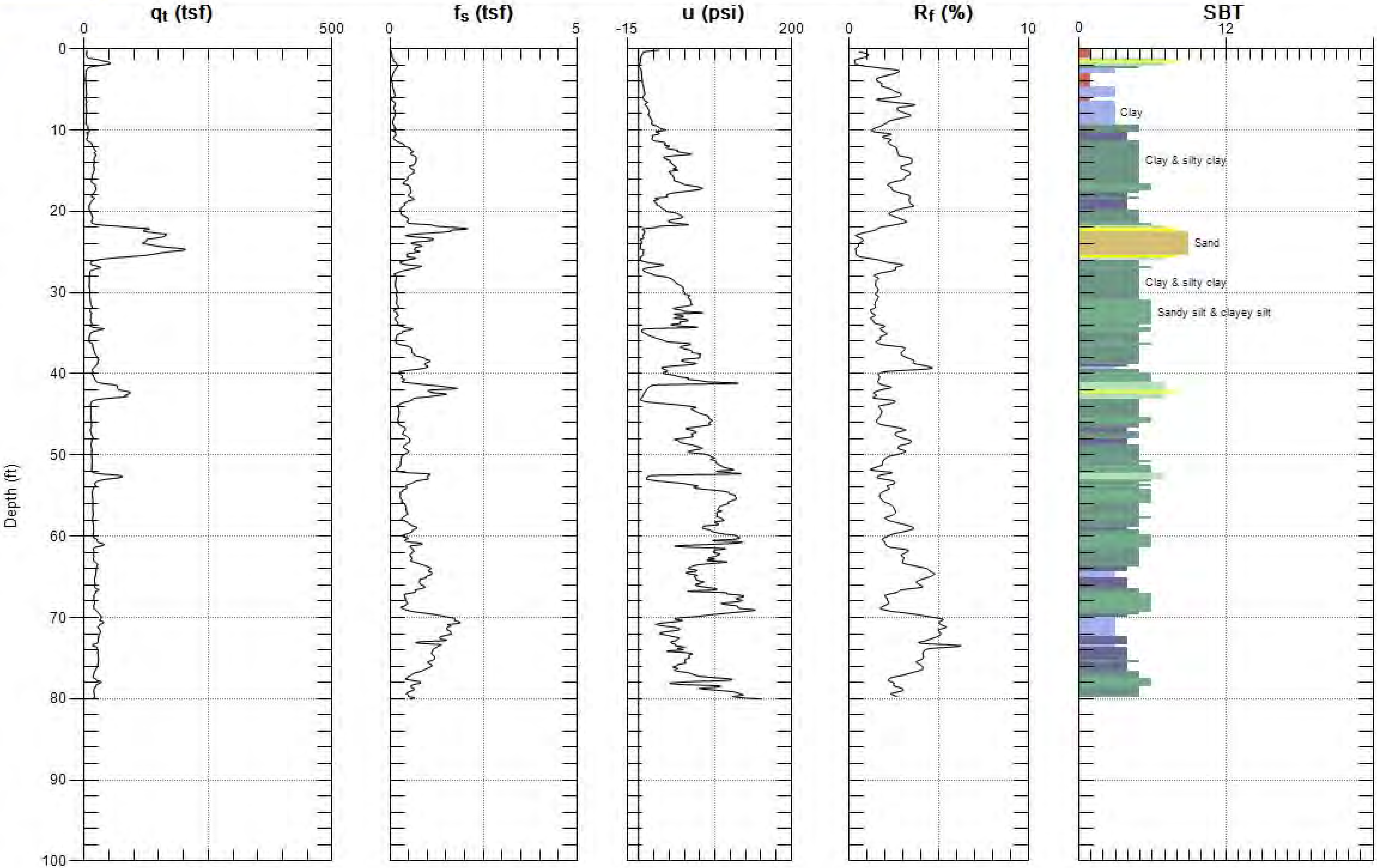
Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **GEI**

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-02 **Date: 2010-01-28 12:41**



Max. Depth: 80.052 (ft)
Avg. Interval: 0.328 (ft)

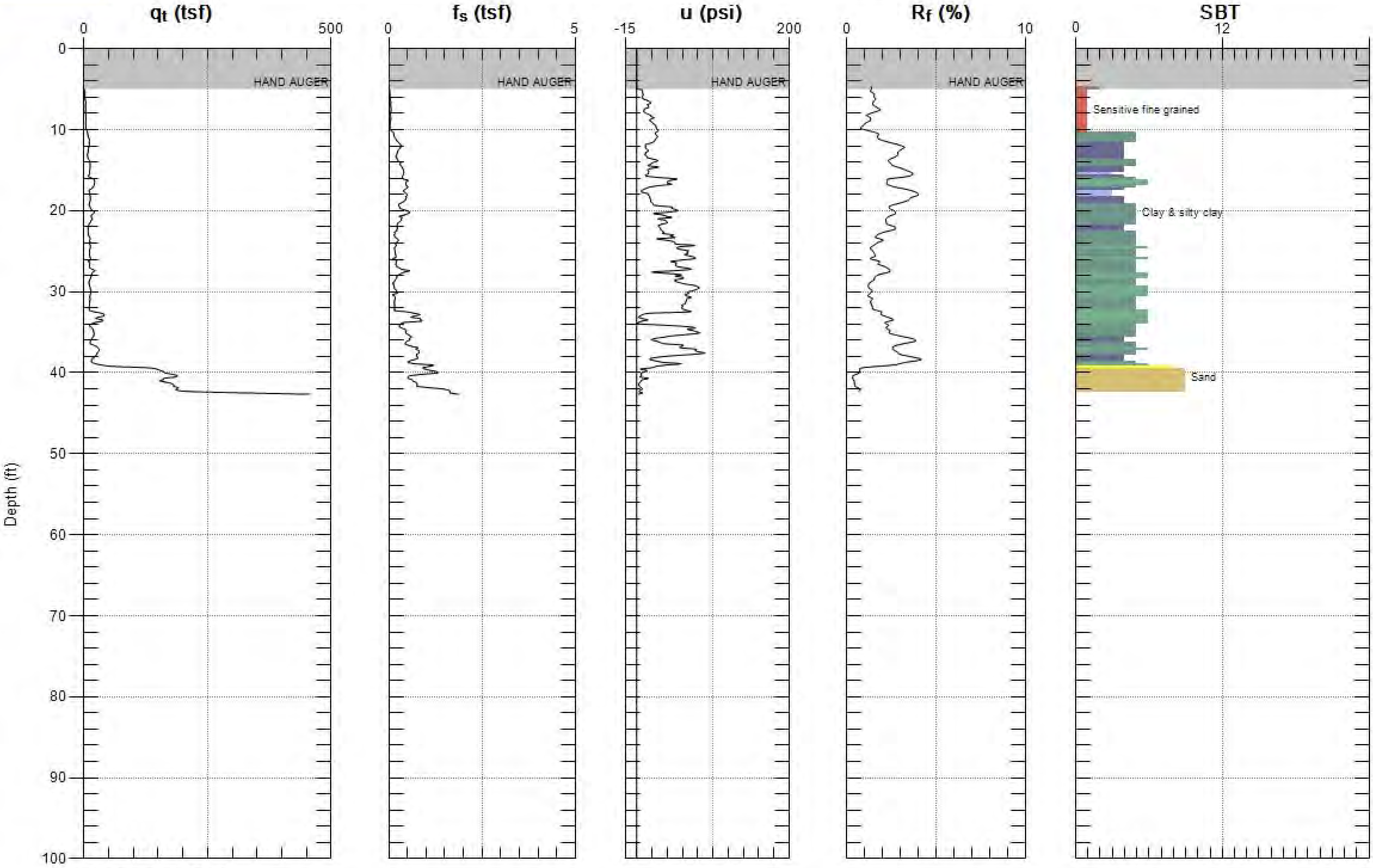
SBT: Soil Behavior Type (Robertson 1990)

GREGG

GEI

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-03 **Date: 2010-01-28 10:17**



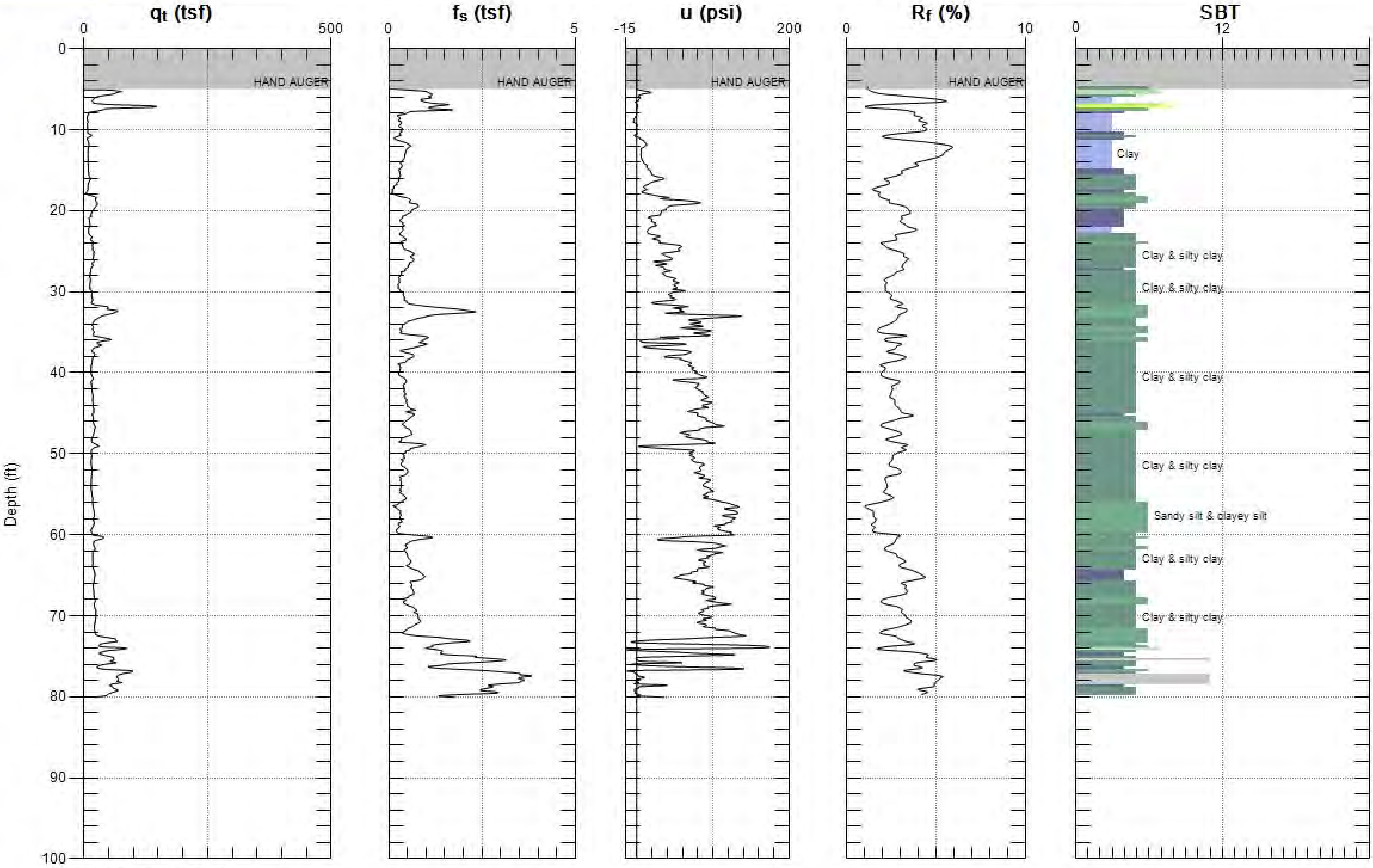
Max. Depth: 42.651 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GEI

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-04 **Date: 2010-01-28 08:10**



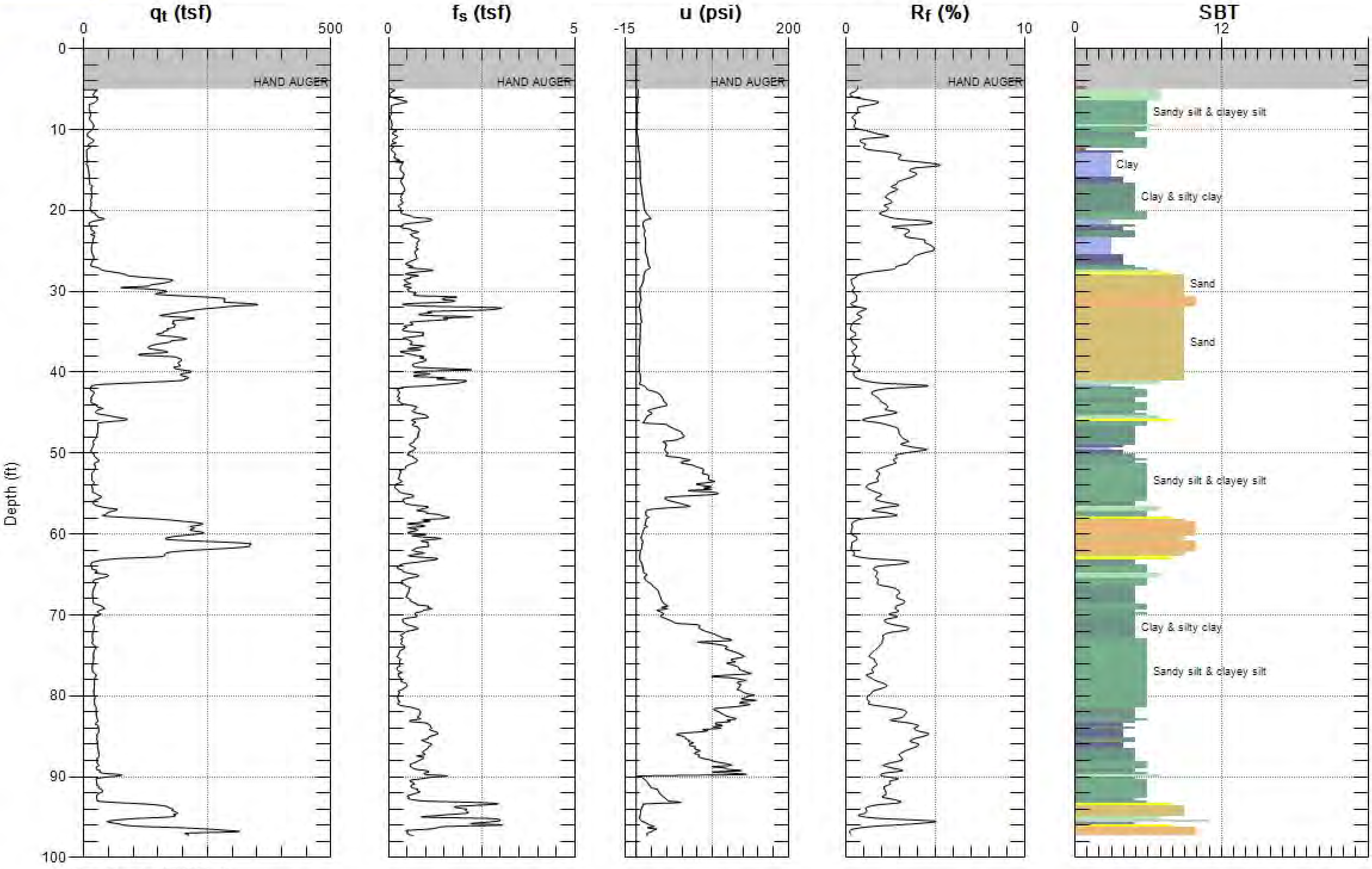
Max. Depth: 80.052 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GEI

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-05 **Date: 2010-01-28 02:13**



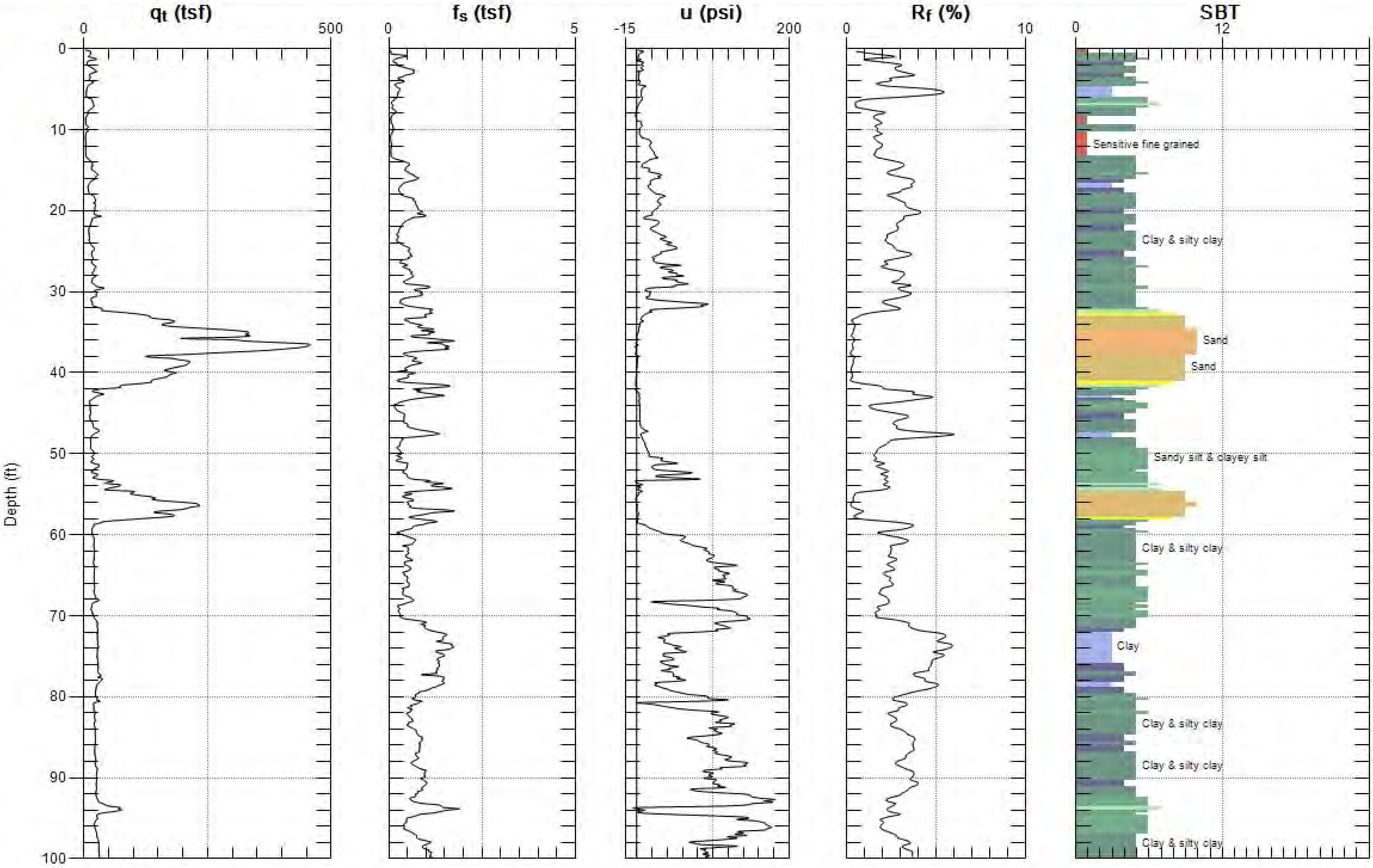
Max. Depth: 97.277 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **GEI**

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-06 **Date: 2010-01-29 10:04**



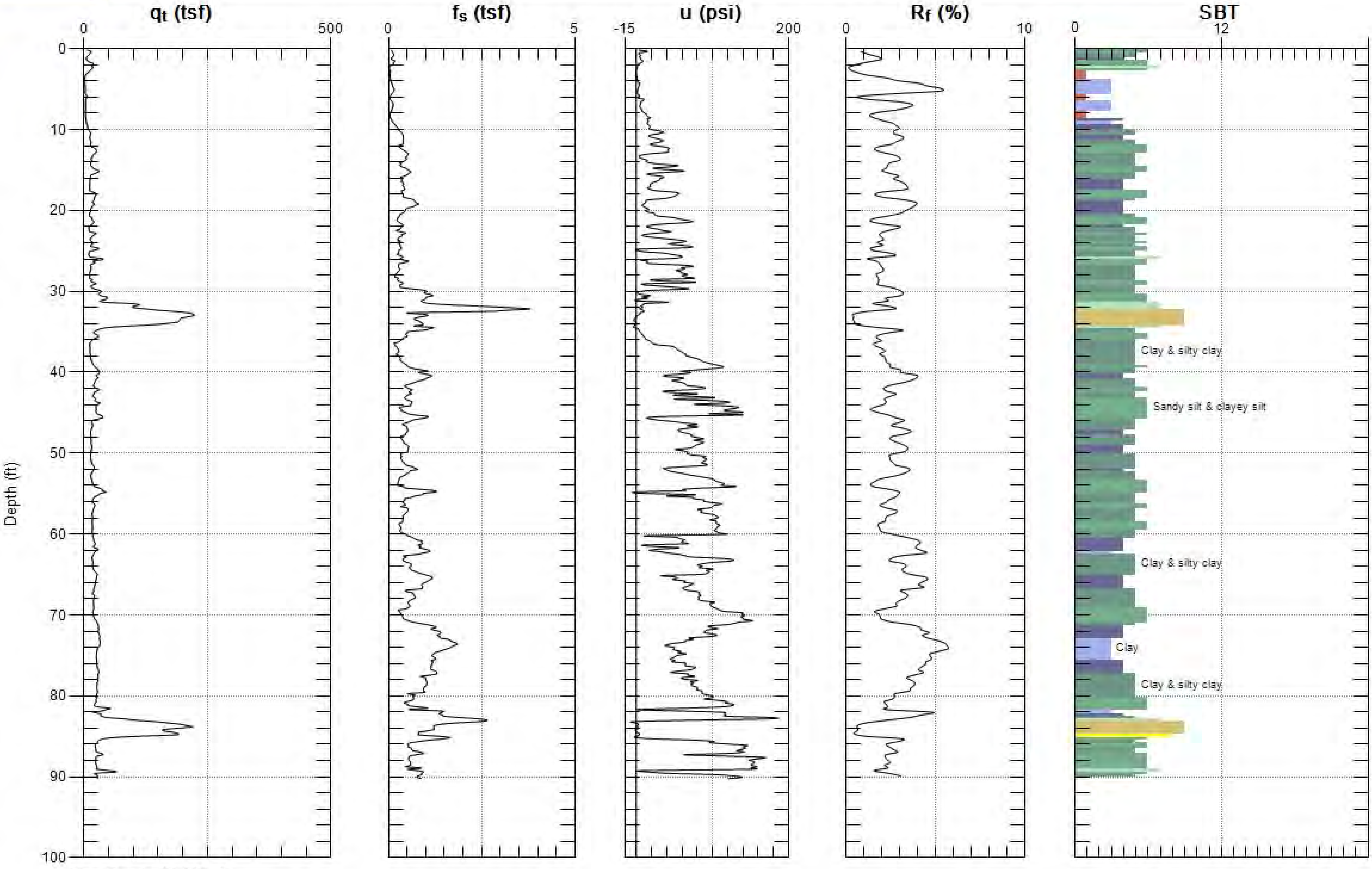
Max. Depth: 100.066 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GEI

Site: SAN FRANCISQUITO CREEK **Engineer: M.POWERS**

Sounding: CPT-07 **Date: 2010-01-29 08:16**



Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Appendix D

Geotechnical Laboratory Testing Results

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D 2937)

Job No: 432-036b
Date: 03/01/10
Client: GEI Consultants
By: RU
Project: San Farncisquito Creek Flood Protection Project - 092850

Boring:	B-5	B-5	B-5	B-6	B-6	B-6	S-1	S-3
Sample:	S6	S7-3	S8	S5-3	S6-3	S7	S2-3	S2-3
Depth, ft:	20.0	24.0	30.0	16.0	20.5	27.0	4.0	4.0
Visual Description:	Gray CLAY w/ Sand & nodules	Brown CLAY w/ Sand & nodules	Brown & Gray Silty CLAY	Gray & Brown CLAY w/ Sand	Gray Clayey SAND w/ Gravel	Brown & Gray Silty CLAY w/ Sand & nodules	Brown Silty SAND	Brown CLAY w/ Sand
Actual G_s								
Assumed G_s	2.70		2.70	2.70	2.70			2.70
Total Vol cc	309.6		309.6	151.1	150.9			443.1
Vol Solids,cc	170.1		161.9	81.8	93.2			237.8
Vol Voids,cc	139.5		147.7	69.3	57.7			205.3
Moisture, %	30.0	25.2	33.4	30.8	22.7	25.8	11.6	29.6
Wet Unit wt, pcf	120.5		117.7	119.4	127.8			117.3
Dry Unit wt, pcf	92.7		88.2	91.3	104.2			90.5
Saturation, %	98.9		98.8	98.1	99.1			92.5
Porosity, %	45.1		47.7	45.9	38.3			46.3
Air filled Poros.,%	0.5		0.6	0.9	0.3			3.5
Water filled Poros.,%	44.5		47.1	45.0	37.9			42.9
Void Ratio	0.82		0.91	0.85	0.62			0.86
Series	1	2	3	4	5	6	7	8

Note: If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

The Zero Air-Voids curves represent the dry density at 100% saturation for each value of specific gravity

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D 2937)

CTL Job No: 250-048a
Project No. 09285-0
By: RU
Client: GEI Consultants
Date: 10/24/11
Project Name: San Francisquito Creek
Remarks:

Boring:	B-7	B-7	B-7	B-7	B-7	B-8	B-8	B-8
Sample:	S-2	S-2	S-2	S-6	S-6	S-6	S-9	S-9
Depth, ft:	3.5	8	13	14.5	29.5	4.5	12	13.5
Visual Description:	Dark Brown Clayey SAND	Dark Oilve Brown GRAVEL w/ Silt and Sand	Dark Olive Brown CLAY	Black Lean Clayey SAND/ near Sandy Lean CLAY	Dark Olive Brown SAND w/ Silt and Gravel	Dark Brown GRAVEL w/ Silt and Sand	Black Sandy CLAY	Light Grayish Brown CLAY with Sand
Actual G_s								
Assumed G_s			2.70					
Moisture, %	12.8	4.3	37.7	33.8	14.1	3.1	40.6	31.2
Wet Unit wt, pcf			115.0					
Dry Unit wt, pcf			83.6					
Dry Bulk Dens.pb, (g/cc)			1.34					
Saturation, %			99.9					
Total Porosity, %			50.5					
Volumetric Water Cont,Θw			50.4					
Volumetric Air Cont., Θa			0.1					
Void Ratio			1.02					
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 (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

The Zero Air-Voids curves represent the dry density at 100% saturation for each value of specific gravity

Moisture-Density-Porosity Report

Cooper Testing Labs, Inc. (ASTM D 2937)

CTL Job No: 250-048b
Project No. 09285-0
By: RU
Client: GEI Consultants
Date: 10/24/11
Project Name: San Francisquito Creek
Remarks:

Boring:	B-9	B-9	B-9	B-10				
Sample:								
Depth, ft:	6.4	9.5	29.5	2.8				
Visual Description:	Olive Brown Clayey SAND	Dark Olive Brown CLAY	Olive Sandy CLAY	Dark Olive Brown Sandy CLAY				
Actual G_s								
Assumed G_s	2.70	2.70		2.70				
Moisture, %	15.4	38.3	26.6	20.4				
Wet Unit wt, pcf	128.5	114.4		120.0				
Dry Unit wt, pcf	111.4	82.7		99.7				
Dry Bulk Dens.pb, (g/cc)	1.78	1.33		1.60				
Saturation, %	80.8	99.6		79.6				
Total Porosity, %	34.0	51.0		40.9				
Volumetric Water Cont,Θw	27.5	50.8		32.6				
Volumetric Air Cont., Θa	6.5	0.2		8.3				
Void Ratio	0.51	1.04		0.69				
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 (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

The Zero Air-Voids curves represent the dry density at 100% saturation for each value of specific gravity

GEI Consultants
180 Grand Avenue
Oakland, CA 94612

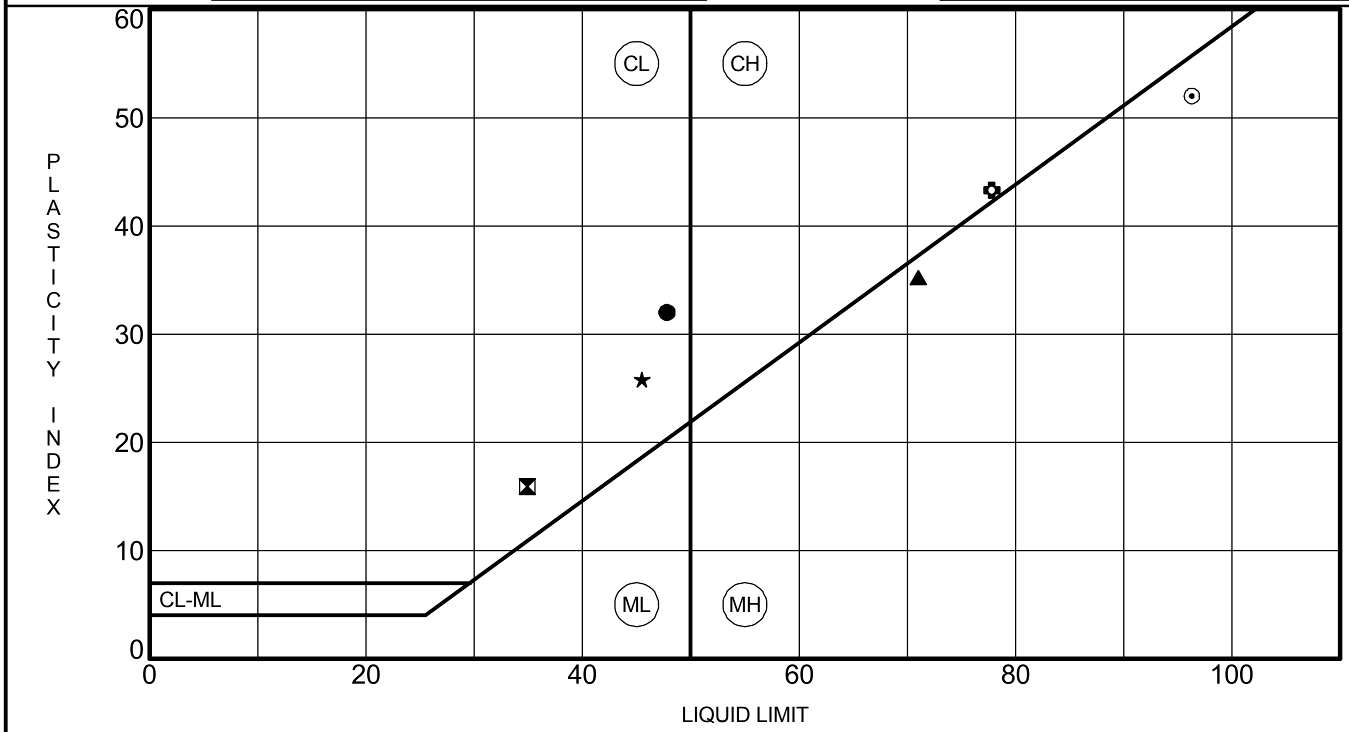
ATTERBERG LIMITS' RESULTS

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

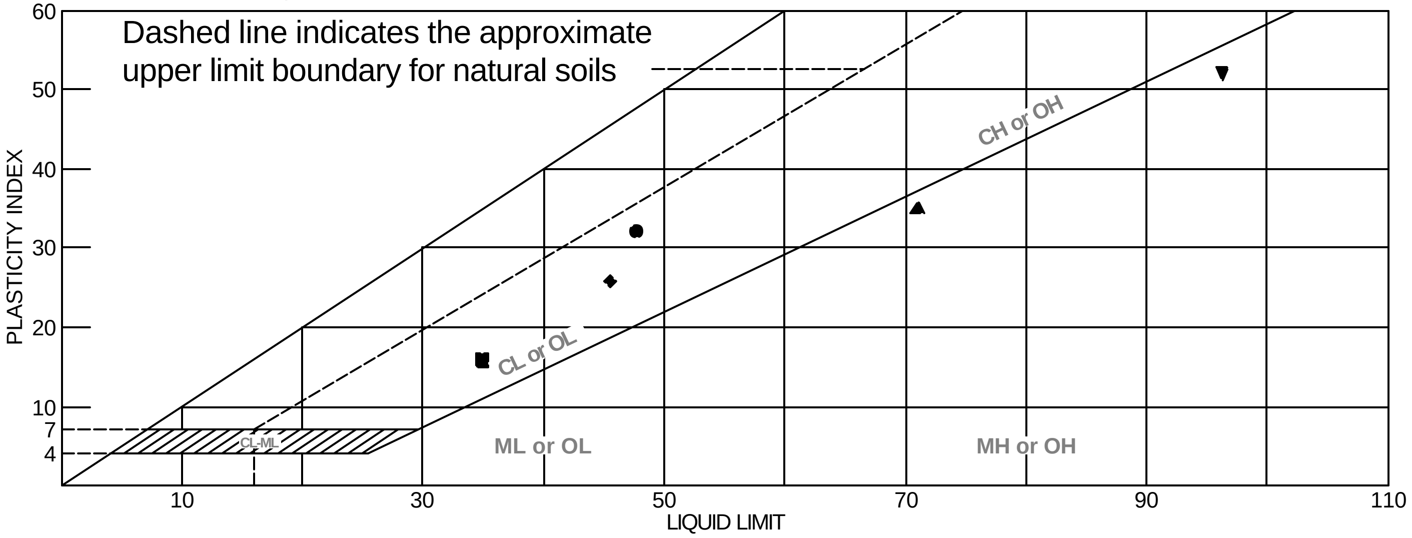
PROJECT NUMBER 092850

PROJECT LOCATION Palo Alto/East Palo Alto, California



	Boring and Depth		LL	PL	PI	Fines	Classification
●	**B-2**	15.5 ft	48	16	32		Lean CLAY (CL)
⧗	**B-3**	3.5 ft	35	19	16		Gravelly Lean CLAY (CL)
▲	**B-3**	15.5 ft	71	36	35		Elastic SILT (MH)
★	**B-4**	19.5 ft	46	20	26		Lean CLAY (CL)
⊙	**B-5**	14.0 ft	96	44	52		Elastic SILT (MH)
✿	**B-6**	11.0 ft	78	35	44		Fat CLAY (CH)

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Light Greenish Gray Lean CLAY grading to Gray Lean CLAY w/ Sand	47.8	15.8	32.0			
■	Brown Lean Clayey SAND w/ Gravel	34.9	19.0	15.9			
▲	Gray Elastic SILT w/ organics	71.0	35.8	35.2			
◆	Pale Green Lean CLAY w/ Gravel, trace Sand	45.5	19.7	25.8			
▼	Gray Elastic SILT (Bay Mud/Bay Clay)	96.3	44.3	52.0			

Project No. 432-036 **Client:** GEI Consultants

Project: San Francisquito Creek Flood Protection Project - 092850

● **Source:** B-2 **Sample No.:** 6-2 **Elev./Depth:** 15.5'
■ **Source:** B-3 **Sample No.:** S3-2 **Elev./Depth:** 3.5'
▲ **Source:** B-3 **Sample No.:** S8 **Elev./Depth:** 14-16.5 (Tip-12")
◆ **Source:** B-4 **Sample No.:** S5 **Elev./Depth:** 18-20.5 (Tip-12")
▼ **Source:** B-5 **Sample No.:** 5 **Elev./Depth:** 13-15.5' (Tip)

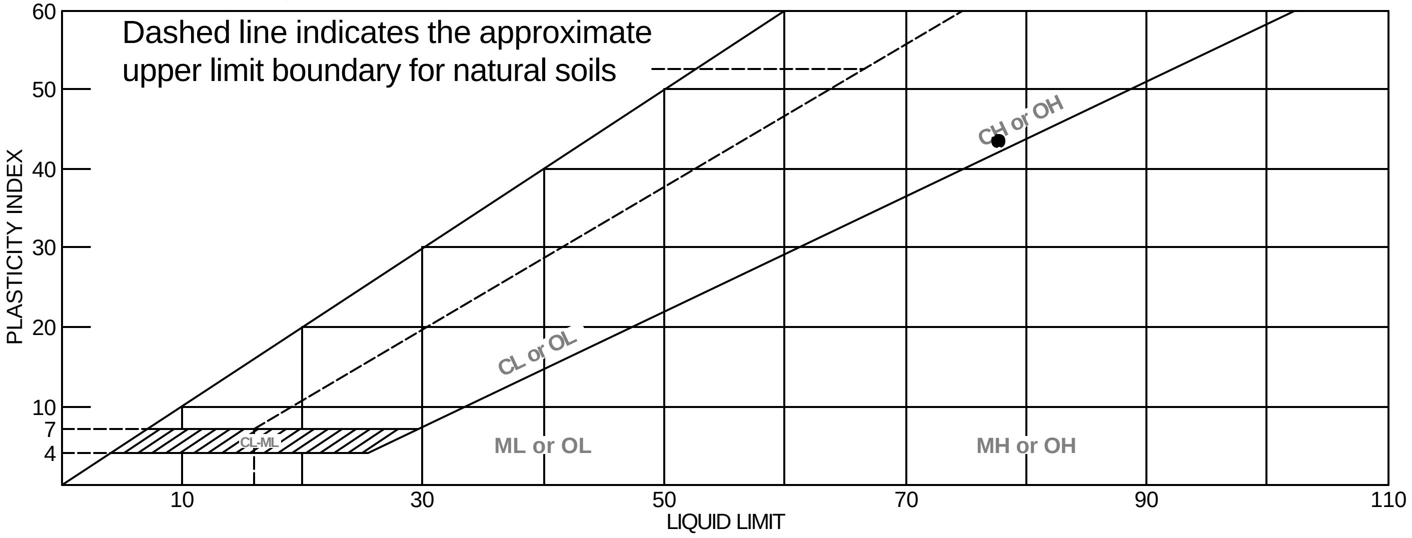
Remarks:
●
■
▲
◆
▼

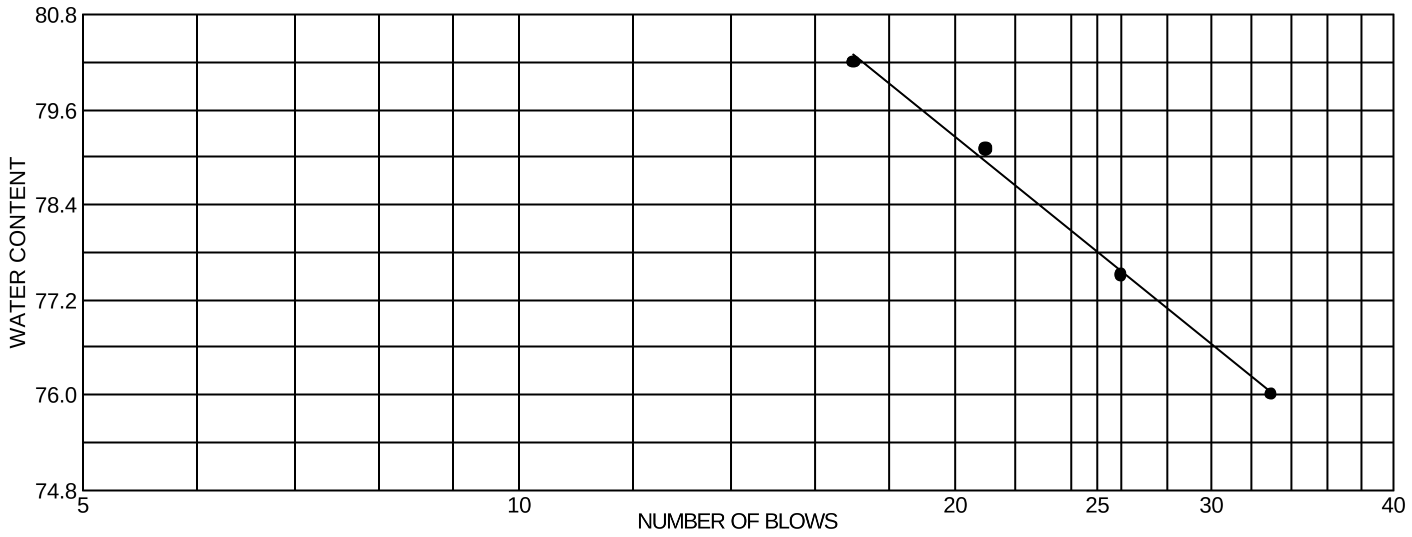
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Gray Fat CLAY	77.8	34.5	43.3			

Project No. 432-036 **Client:** GEI Consultants

Project: San Francisquito Creek Flood Protection Project - 092850

● **Source:** B-6 **Elev./Depth:** 10-12.5' (Tip-1)

Remarks:

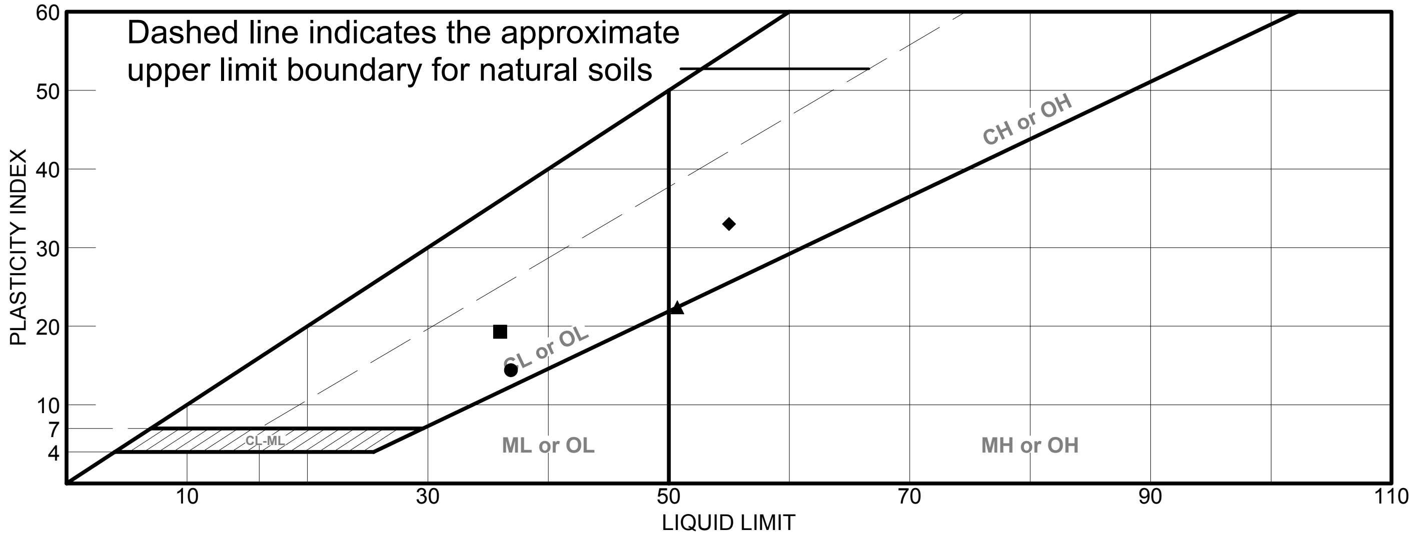
●

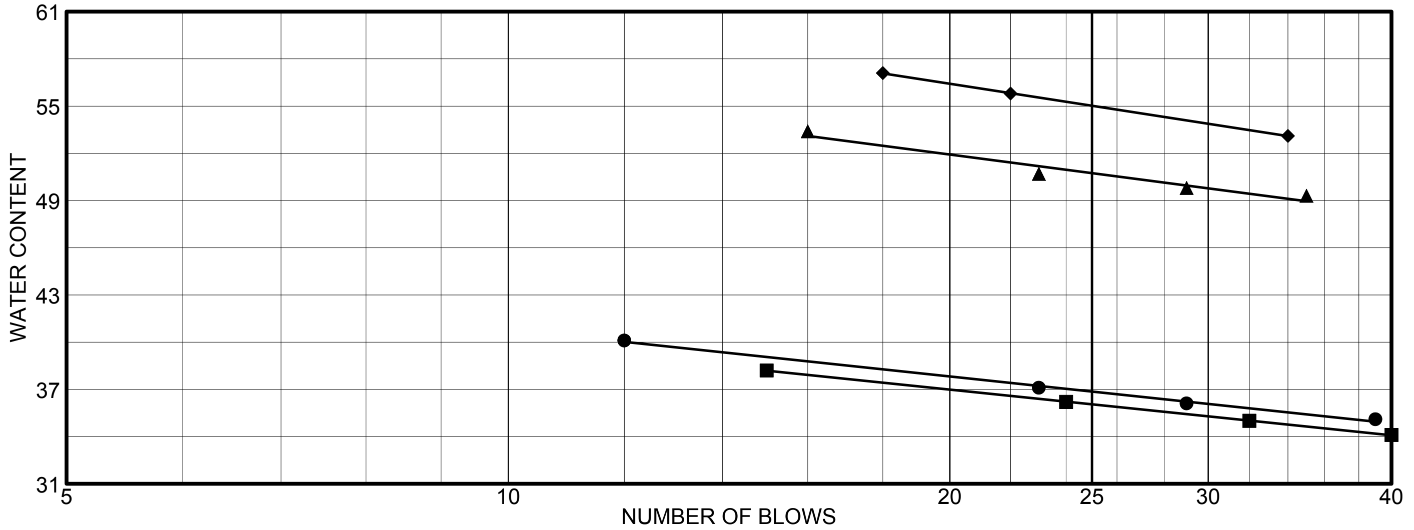
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Black Lean Clayey SAND/ near Sandy Lean CLAY	36.9	22.5	14.4			
■	Greenish Gray Sandy Lean CLAY	36.0	16.7	19.3			
▲	Dark Brown Elastic SILT	50.7	28.3	22.4			
◆	Black Fat CLAY w/ Sand	55.0	22.0	33.0			

Project No. 250-048 **Client:** GEI Consultants

Project: San Francisquito Creek - 09285-0

● **Source:** B-7 **Sample No.:** S-6 **Elev./Depth:** 14.5'
■ **Source:** B-7 **Sample No.:** S-7 **Elev./Depth:** 18'
▲ **Source:** B-8 **Sample No.:** S-7B **Elev./Depth:** 10'
◆ **Source:** B-10 **Sample No.:** S-7B **Elev./Depth:** 16'

Remarks:
●
■
▲
◆

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

GEI Consultants
180 Grand Avenue
Oakland, CA 94612

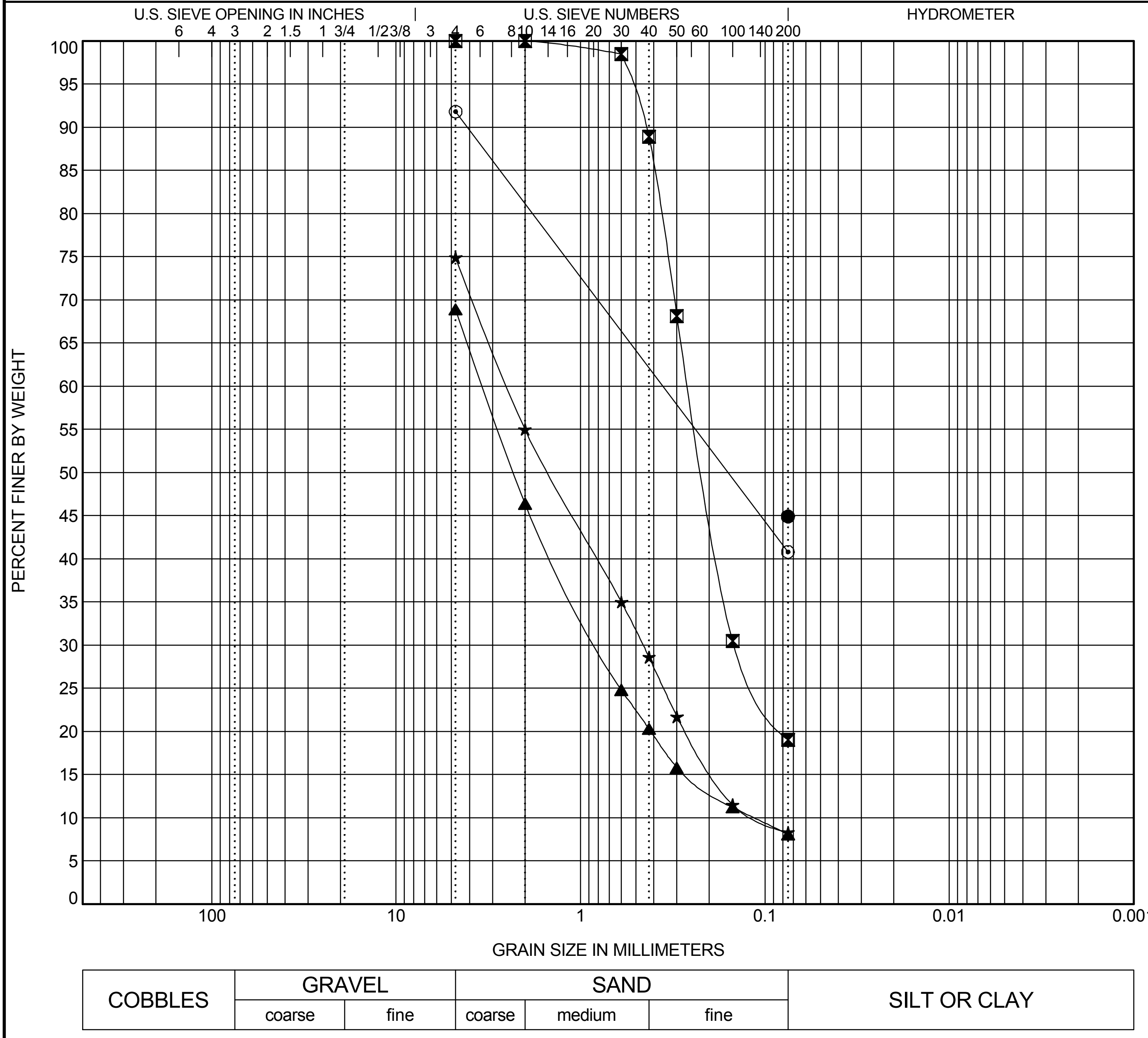
GRAIN SIZE DISTRIBUTION

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

PROJECT NUMBER 092850

PROJECT LOCATION Palo Alto/East Palo Alto, California



	Boring and Depth		Classification	LL	PL	PI	Cc	Cu
●	**B-1**	7.0 ft	**Clayey SAND (SC)**					
⊠	**B-1**	13.0 ft	**Silty SAND (SM)**					
▲	**B-1**	31.0 ft	**Well Graded SAND with Silt and Gravel (SW-SM)**				1.66	29.41
★	**B-2**	20.0 ft	**Poorly Graded SAND with Silt and Gravel (SP-SM)**				0.78	22.93
⊙	**S-1**	4.0 ft	**Clayey SAND (SC)**					

	Boring and Depth		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-1	7.0 ft	0.075						44.9	
⊠	B-1	13.0 ft	4.75	0.258	0.146		0.0	81.0	19.0	
▲	B-1	31.0 ft	4.75	3.374	0.802	0.115	31.1	60.8	8.1	
★	B-2	20.0 ft	4.75	2.486	0.458	0.108	25.1	66.6	8.3	
⊙	S-1	4.0 ft	4.75	0.358			8.2	51.0	40.8	

GEI Consultants
180 Grand Avenue
Oakland, CA 94612

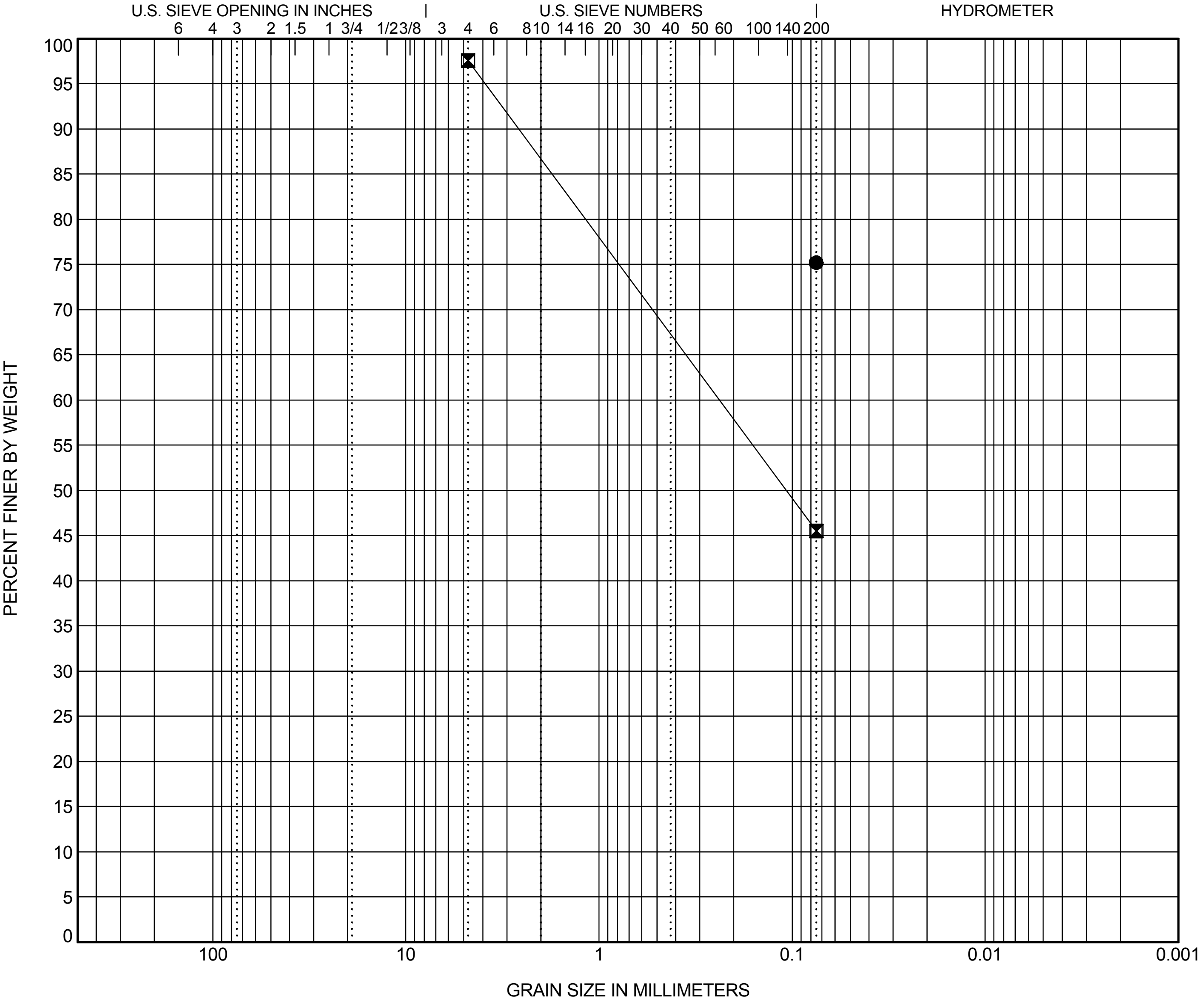
GRAIN SIZE DISTRIBUTION

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

PROJECT NUMBER 092850

PROJECT LOCATION Palo Alto/East Palo Alto, California

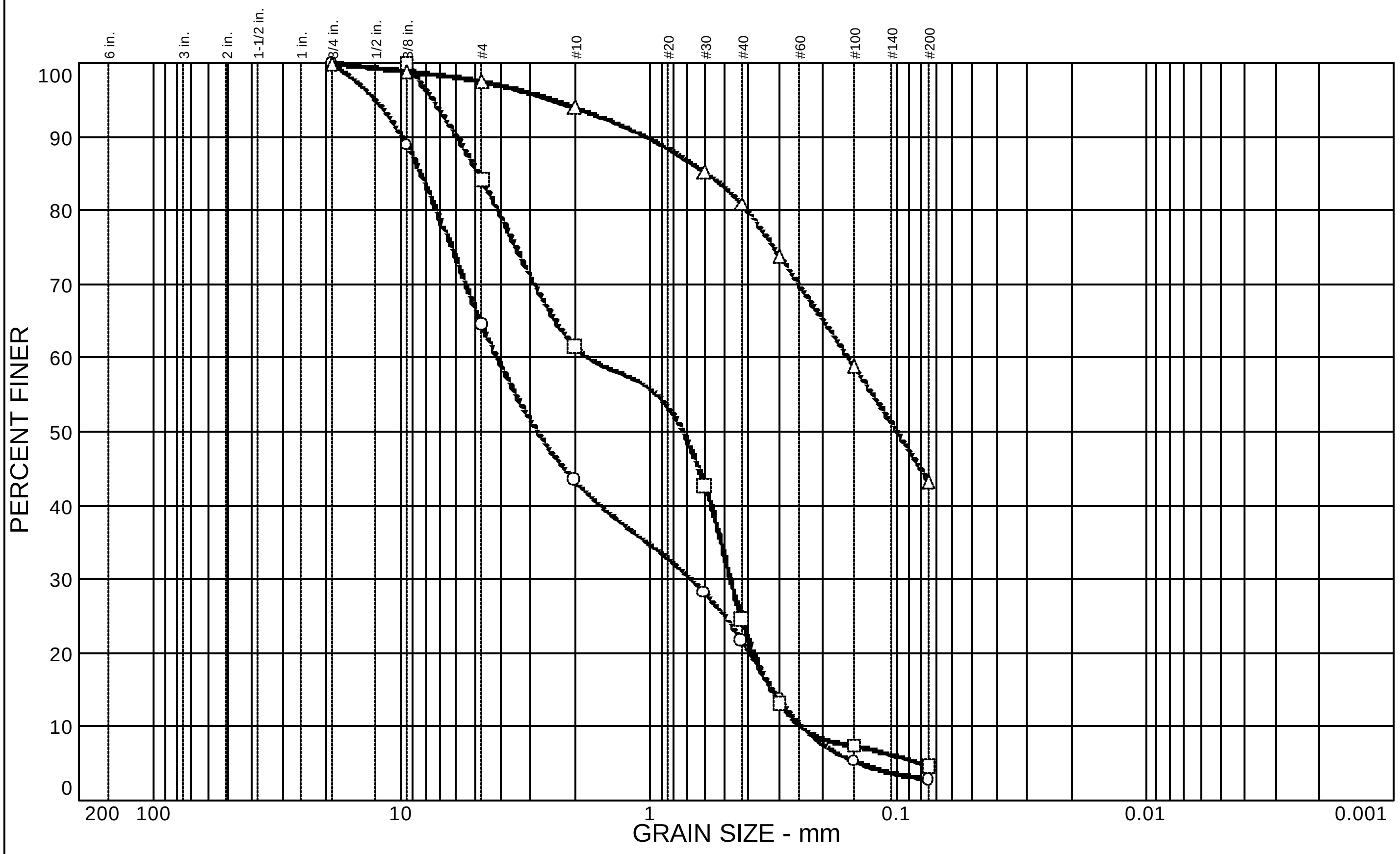


COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring and Depth		Classification	LL	PL	PI	Cc	Cu
●	**S-3**	4.0 ft	**SILT with Sand (ML)**					
☒	**S-6**	8.8 ft	**Clayey SAND (SC)**					

	Boring and Depth		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	S-3	4.0 ft	0.075						75.2	
☒	S-6	8.8 ft	4.75	0.238			2.4	52.1	45.5	

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		35.4	61.8	2.8					
□		15.8	79.5	4.7					
△		2.5	54.2	43.3					

SIEVE inches size	PERCENT FINER ○	□	△
3/4"	100.0		100.0
3/8"	88.9	100.0	98.9
	GRAIN SIZE		
D_{60}	4.12	1.76	0.158
D_{30}	0.677	0.472	
D_{10}	0.243	0.245	
	COEFFICIENTS		
C_c	0.46	0.52	
C_u	16.99	7.18	

SIEVE number size	PERCENT FINER ○	□	△
#4	64.6	84.2	97.5
#10	43.4	61.6	94.0
#30	28.2	42.6	85.3
#40	21.7	24.6	80.9
#50	13.7	13.2	73.9
#100	5.3	7.4	58.9
#200	2.8	4.7	43.3

SOIL DESCRIPTION

○ Dark Olive Brown GRAVEL w/ Silt and Sand

□ Dark Brown GRAVEL w/ Silt and Sand

△ Olive Brown Clayey SAND

REMARKS:

○

□

△

○ Source: B-7	Elev./Depth: 8'
□ Source: B-8	Elev./Depth: 4.5'
△ Source: B-9	Elev./Depth: 6.4'

COOPER TESTING LABORATORY

Client: GEI Consultants

Project: San Francisquito Creek - 09285-0

Project No.: 250-048

Figure

COOPER TESTING LABORATORY

#200 Sieve Wash Analysis

ASTM D 1140

Job No.: 250-048
Project No.: 09285-0
Run By: JC
Client: GEI Consultants
Date: 10/25/2011
Checked By: DC
Project: San Francisquito Creek

Boring:	B-7	B-7	B-8	B-9	B-10	B-10		
Sample:	S-4	S-10	S-12		S-3			
Depth, ft.:	8.5	29.5	23.5	29.5	7.5	18.5		
Soil Type:	Dark Brown CLAY w/ Sand (Silty)	Dark Olive Brown SAND w/ Silt and Gravel	Dark Olive Brown SAND w/ Silt and Gravel	Olive Sandy CLAY	Dark Brown Clayey SAND	Light Brown Clayey SAND		
Wt of Dish & Dry Soil, gm	357.7	741.8	636.8	431.1	680.9	668.7		
Weight of Dish, gm	165.8	318.2	299.6	178.2	311.8	336.6		
Weight of Dry Soil, gm	191.9	423.6	337.2	252.9	369.1	332.1		
Wt. Ret. on #4 Sieve, gm	3.6	129.7	102.4	20.5	0.0	38.1		
Wt. Ret. on #200 Sieve, gm	48.1	392.3	308.6	99.4	223.3	168.8		
% Gravel	**1.9**	**30.6**	**30.4**	**8.1**	**0.0**	**11.5**		
% Sand	**23.2**	**62.0**	**61.2**	**31.2**	**60.5**	**39.4**		
% Silt & Clay	**74.9**	**7.4**	**8.5**	**60.7**	**39.5**	**49.2**		

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).

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180 Grand Avenue
Oakland, CA 94612

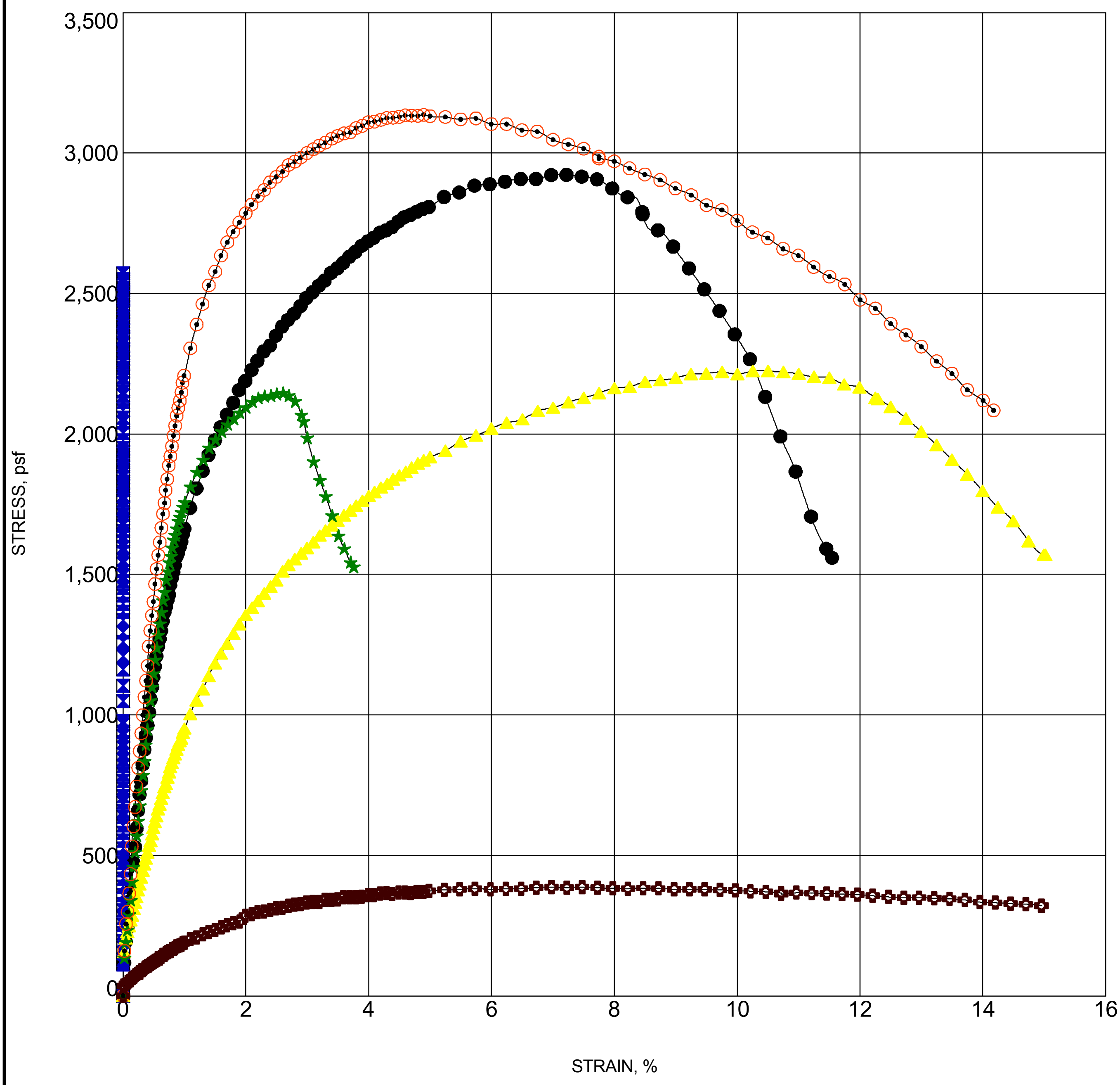
UNCONFINED COMPRESSION TEST

CLIENT HDR Engineering, Inc.

PROJECT NUMBER 092850

PROJECT NAME San Francisquito Flood Control Project

PROJECT LOCATION Palo Alto/East Palo Alto, California



Boring and Depth			Classification	γ_d (pcf)	MC%
●	B-1	48.0 ft	Lean CLAY (CL)	91.1	31.4
⧗	B-2	15.5 ft	Lean CLAY (CL)	95.2	27.9
▲	B-2	30.5 ft	Silty CLAY with Sand (CL-ML)	96.4	27.4
★	B-3	15.5 ft	Elastic SILT (MH)	77.0	43.0
⦿	B-3	20.0 ft	()	97.9	26.3
✿	B-4	4.5 ft	Fat CLAY (CH)	65.1	58.7

GEI Consultants
180 Grand Avenue
Oakland, CA 94612

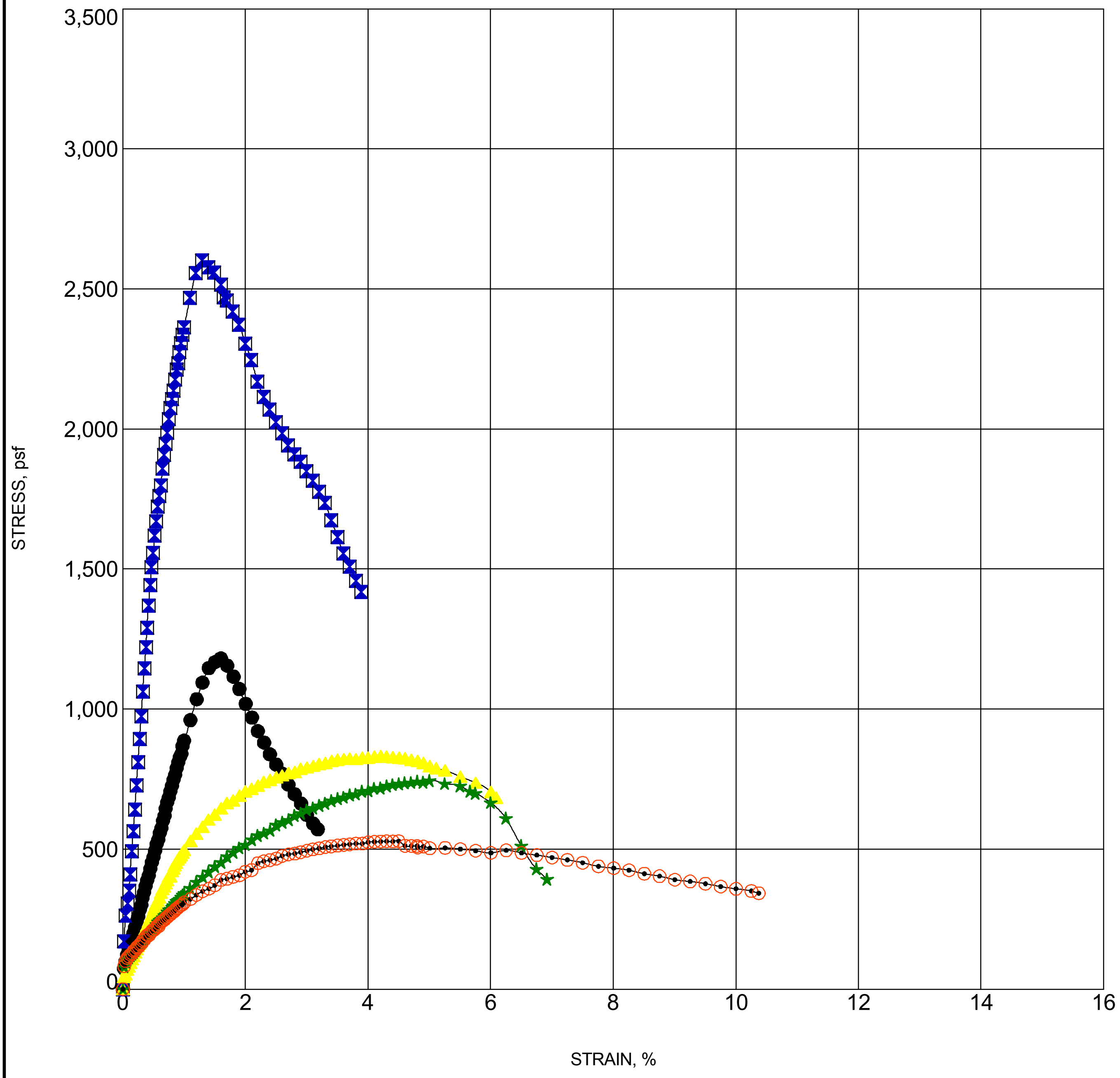
UNCONFINED COMPRESSION TEST

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

PROJECT NUMBER 092850

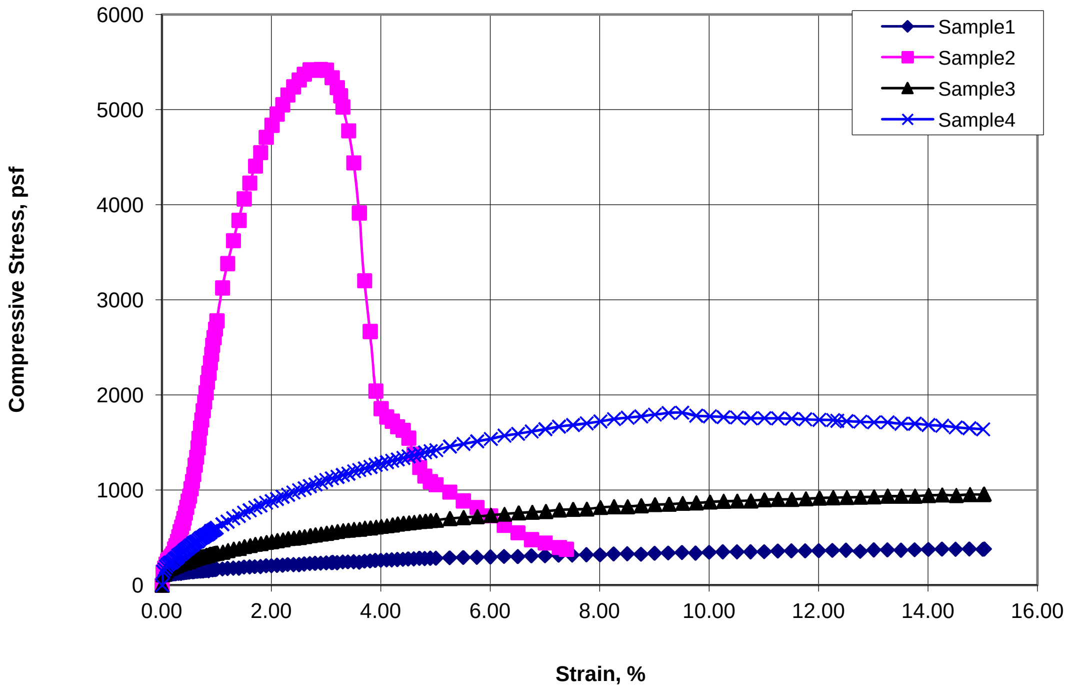
PROJECT LOCATION Palo Alto/East Palo Alto, California



	Boring and Depth		Classification	γ_d (pcf)	MC%
●	B-4	19.5 ft	Lean CLAY (CL)	97.3	29.1
☒	B-5	2.5 ft	Lean CLAY (CL)	75.7	35.3
▲	B-6	6.5 ft	Fat CLAY with Sand (CH)	76.0	43.6
★	S-3	9.0 ft	Lean CLAY (CL)	85.9	32.8
⊙	S-6	22.0 ft	Fat CLAY (CH)	53.8	75.1

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	381	5424	960	1815	
Unconfined Compressive Strength, psi	2.6	37.7	6.7	12.6	
Undrained Shear Strength, psf	190	2712	480	907	
Failure Strain, %	14.7	2.9	15.0	15.0	
Strain Rate, % per minute	1.0	1.0	1.0	1.0	
Strain Rate, inches/minute	0.05	0.05	0.05	0.05	
Moisture Content, %	31.8	10.8	39.3	27.2	
Dry Density, pcf	89.4	104.7	81.7	97.2	
Saturation, %	97.1	47.8	99.9	100.0	
Void Ratio	0.886	0.610	1.063	0.734	
Specimen Diameter, inches	2.410	2.402	2.402	2.415	
Specimen Height, inches	5.01	5.06	5.01	5.01	
Height to Diameter Ratio	2.1	2.1	2.1	2.1	
Assumed Specific Gravity	2.70	2.70	2.70	2.70	

Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-7	S-7	18	Greenish Gray Sandy Lean CLAY
2	B-8	S-3	3.4	Dark Brown Clayey SAND (Silty)
3	B-8	S-7B	10	Dark Brown Elastic SILT
4	B-9	S-11	18.7	Olive CLAY w/ Sand

Job No.: 250-048a

Type of Sample Undisturbed

Client: GEI Consultants

Project: San Francisquito Creek - 09285-0

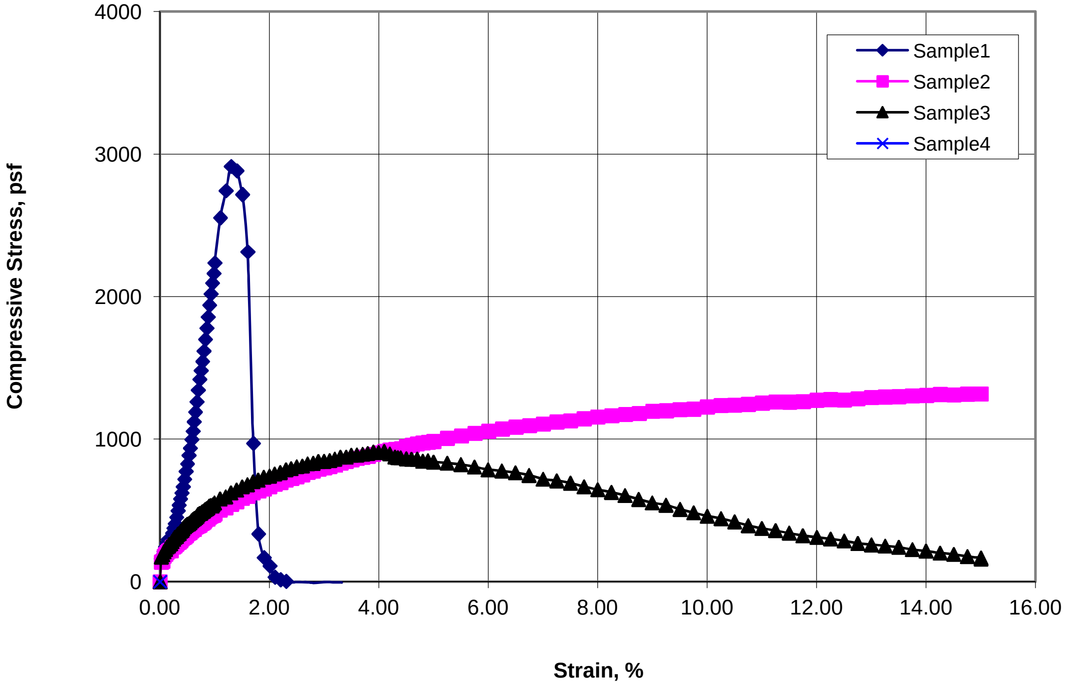
Date: 10/20/2011 **By:** MD/RU

Remarks:

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	2914	1318	915		
Unconfined Compressive Strength, psi	20.2	9.2	6.4		
Undrained Shear Strength, psf	1457	659	458		
Failure Strain, %	1.3	15.0	4.1		
Strain Rate, % per minute	1.0	1.0	1.0		
Strain Rate, inches/minute	0.05	0.05	0.05		
Moisture Content, %	7.7	40.5	37.1		
Dry Density, pcf	99.0	79.8	83.1		
Saturation, %	29.8	98.3	97.5		
Void Ratio	0.703	1.112	1.027		
Specimen Diameter, inches	2.396	2.405	2.415		
Specimen Height, inches	4.99	5.02	5.00		
Height to Diameter Ratio	2.1	2.1	2.1		
Assumed Specific Gravity	2.70	2.70	2.70		

	Sample Location			
	Boring	Sample	Depth, ft.	Soil Description
1	B-10	S-3	7.5	Dark Brown Clayey SAND
2	B-10	S-5B	12.5	Dark Brown CLAY w/ Sand
3	B-10	S-7B	16	Black Fat CLAY w/ Sand
4				

Job No.: 250-048b

Type of Sample Undisturbed

Client: GEI Consultants

Project: San Francisquito Creek - 09285-0

Date: 10/20/2011 **By:** MD/RU

Remarks:

COOPER TESTING LABORATORY

GEI Consultants
180 Grand Avenue
Oakland, CA 94612

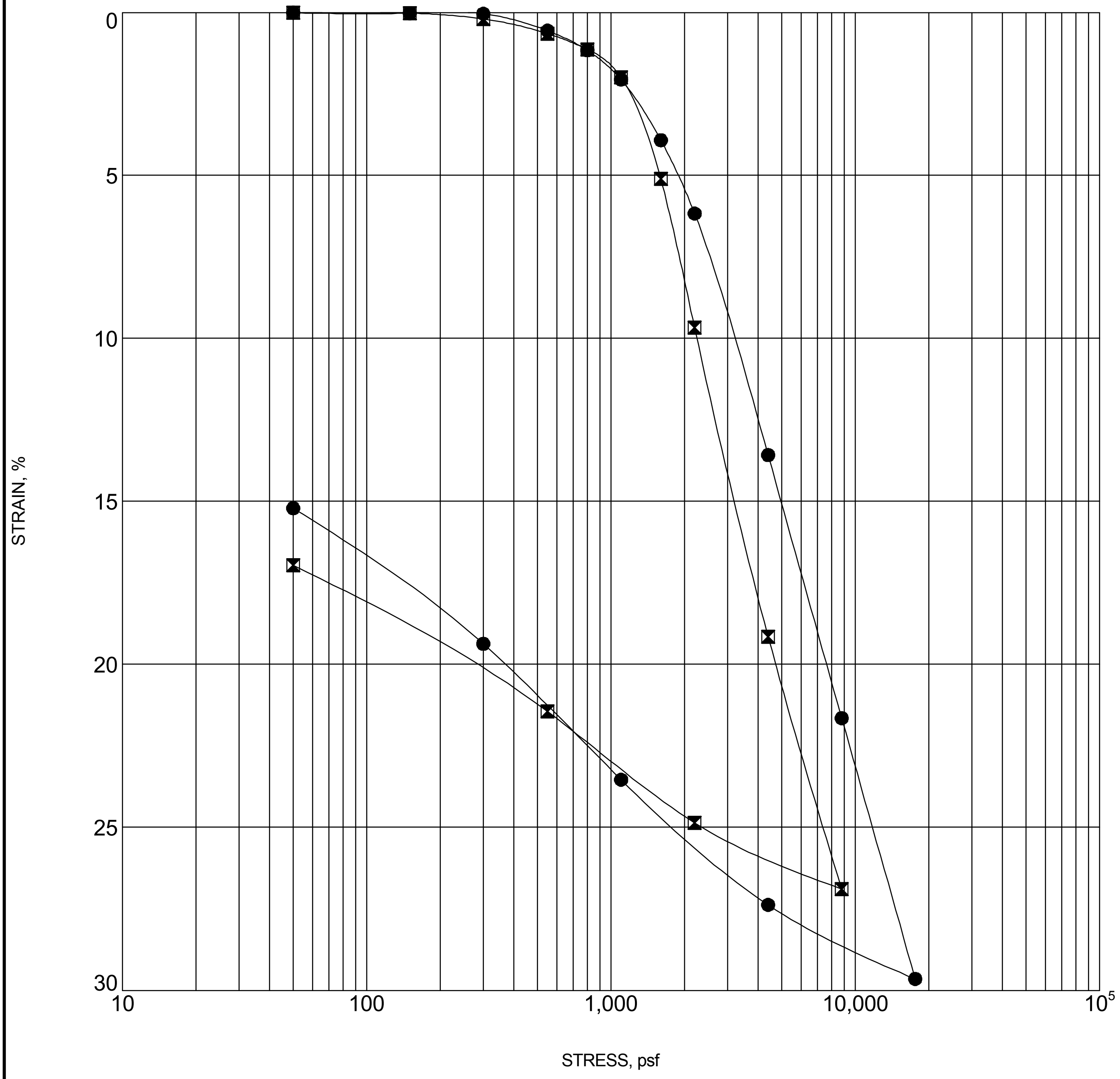
CONSOLIDATION TEST

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

PROJECT NUMBER 092850

PROJECT LOCATION Palo Alto/East Palo Alto, California



Boring and Depth			Classification	γ_d (pcf)	MC%
●	B-5	14.0 ft	Elastic SILT (MH)	**50.8**	**85.8**
☒	B-6	11.0 ft	Fat CLAY (CH)	**53.7**	**78.9**

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180 Grand Avenue
Oakland, CA 94612

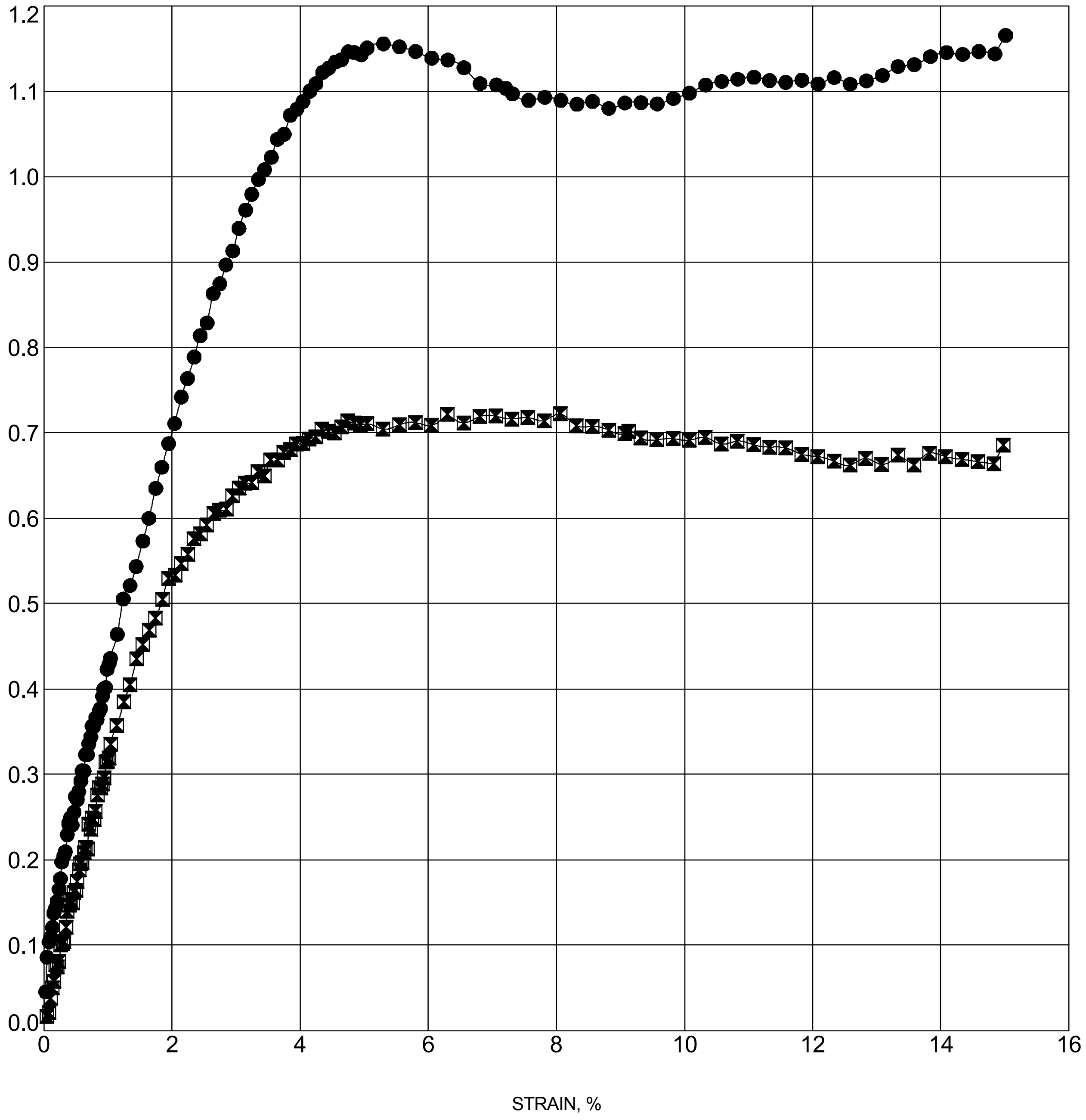
TRIAXIAL UNCONSOLIDATED UNDRAINED TEST

CLIENT HDR Engineering, Inc.

PROJECT NAME San Francisquito Flood Control Project

PROJECT NUMBER 092850

PROJECT LOCATION Palo Alto/East Palo Alto, California



Boring and Depth			Classification	γ_d (pcf)	MC%
●	B-5	14.0 ft	Elastic SILT (MH)	**50.8**	**85.8**
⧗	B-6	11.0 ft	Fat CLAY (CH)	**53.7**	**78.9**

Corrosivity Test Summary

CTL # 250-042 **Date:** 10/4/2010 **Tested By:** PJ **Checked:** PJ

Client: GEI Consultants **Project:** San Francisquito Creek Flood Control Project **Proj. No:** 092850

Remarks:

Sample Location or ID			**Resistivity @ 15.5 ^{o}C (Ohm-cm)**			**Chloride**	**Sulfate-(water soluble)**		**pH**	**ORP**	**Sulfide**	**Moisture**	**Soil Visual Description**
Boring	**Sample, No.**	**Depth, ft.**	**As Rec.**	**Minimum**	**Saturated**	**mg/kg**	**mg/kg**	**%**		(Redox)	Qualitative	%	
						Dry Wt.	Dry Wt.	Dry Wt.		mv	by Lead	At Test	
			ASTM G57	Cal 643	ASTM G57	Cal 422-mod.	Cal 417-mod.	Cal 417-mod.	ASTM G51	SM 2580B	Acetate Paper	ASTM D2216	
B-1	S1	3.5-4.0	-	-	1,580	16	<5	<0.0005	7.5	255	Negative	11.5	Brown Silty SAND
B-2	S6	16.0-16.5	-	-	801	262	161	0.0161	7.8	231	Negative	19.7	Olive Gray Clayey SAND
B-3	S11	29.5-30.0	-	-	299	1,401	252	0.0252	8.1	252	Negative	23.2	Olive Brown Clayey SAND
B-3	S8	14.0	-	-	227	2,861	79	0.0079	7.5	5	Positive	44.3	Mottled Dark Olive Brown CLAY
S-1	S4	6.5-7.0	-	-	572	84	975	0.0975	7.4	212	Negative	16.9	Brown Clayey SAND
B-5	S4	9.5-11.0	-	-	189	3,112	731	0.0731	6.8	277	Negative	33.2	Brown CLAY
B-6	S4	11	-	-	109	6,865	928	0.0928	7.9	-56	Positive	77.0	Dark Gray CLAY (Bay Mud)

NOTE: The reported sulfate level in samples B-3 @ 14' and B-6 @ 11' may be slightly low due to loss of H2S prior to the sulfate test. Also these two samples have been stored for 7 months prior to testing.

Appendix E

Seepage Analyses Plates

Station 46+50 Palo Alto Steady State Seepage

Soil Type 1A - Existing Levee Fill
K-Sat: 0.283 ft/days
Kh/Kv: 4

Soil Type 1B - New Levee Fill
K-Sat: 0.00283 ft/days
Kh/Kv: 4

Soil Type 1C - Golf Course Fill
K-Sat: 0.283 ft/sec
Kh/Kv: 4

Soil Type 2A - Bay Deposits
K-Sat: 0.00142 ft/days
Kh/Kv: 5

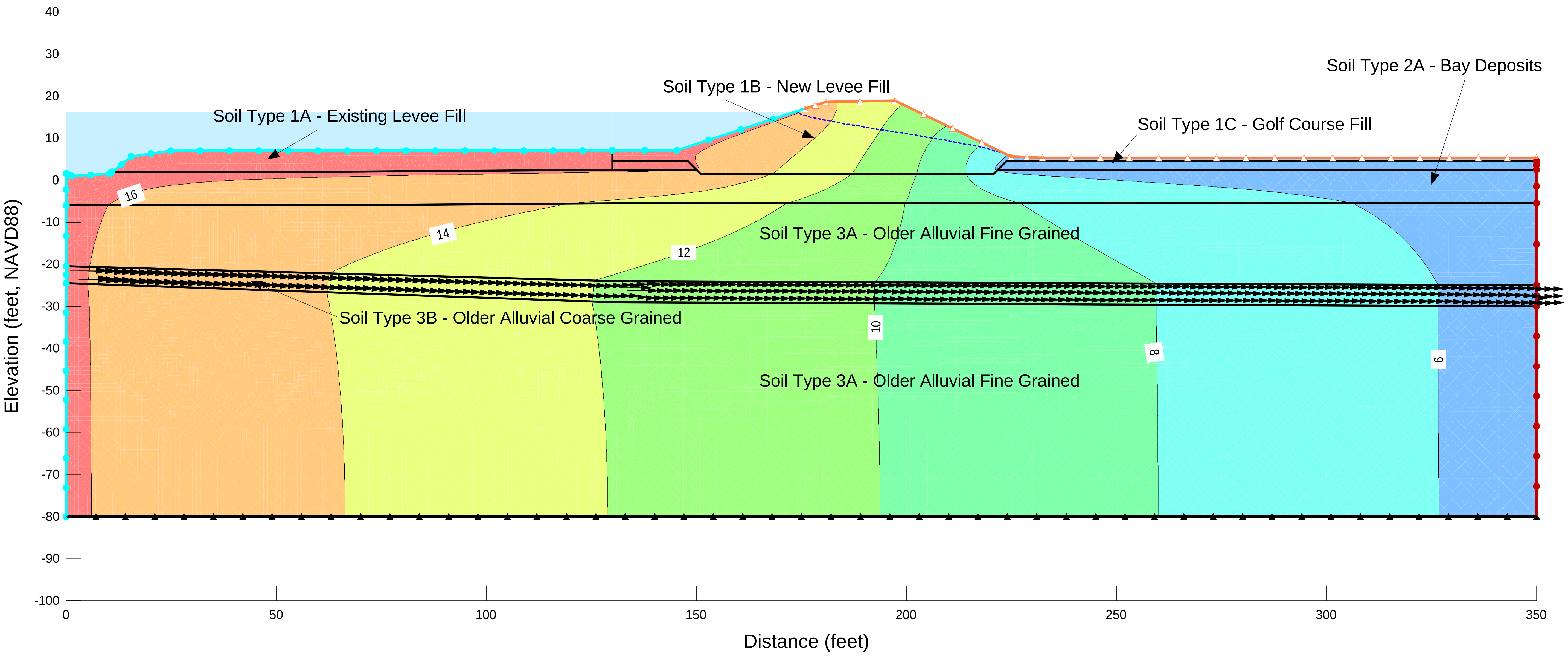
Soil Type 3A - Older Alluvial Fine Grained
K-Sat: 0.00283 ft/days
Kh/Kv: 4

Soil Type 3B - Older Alluvial Coarse Grained
K-Sat: 28.3 ft/days
Kh/Kv: 4

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V

Results:
Exit Gradient at Landside Toe: 0.23



Station 51+00 East Palo Alto Steady State Seepage

Soil Type 1A - Existing Levee Fill
K-Sat: 0.283 ft/days
Kh/Kv: 4

Soil Type 1B - New Levee Fill
K-Sat: 0.00283 ft/days
Kh/Kv: 4

Soil Type 2A - Bay Deposits
K-Sat: 0.00142 ft/days
Kh/Kv: 5

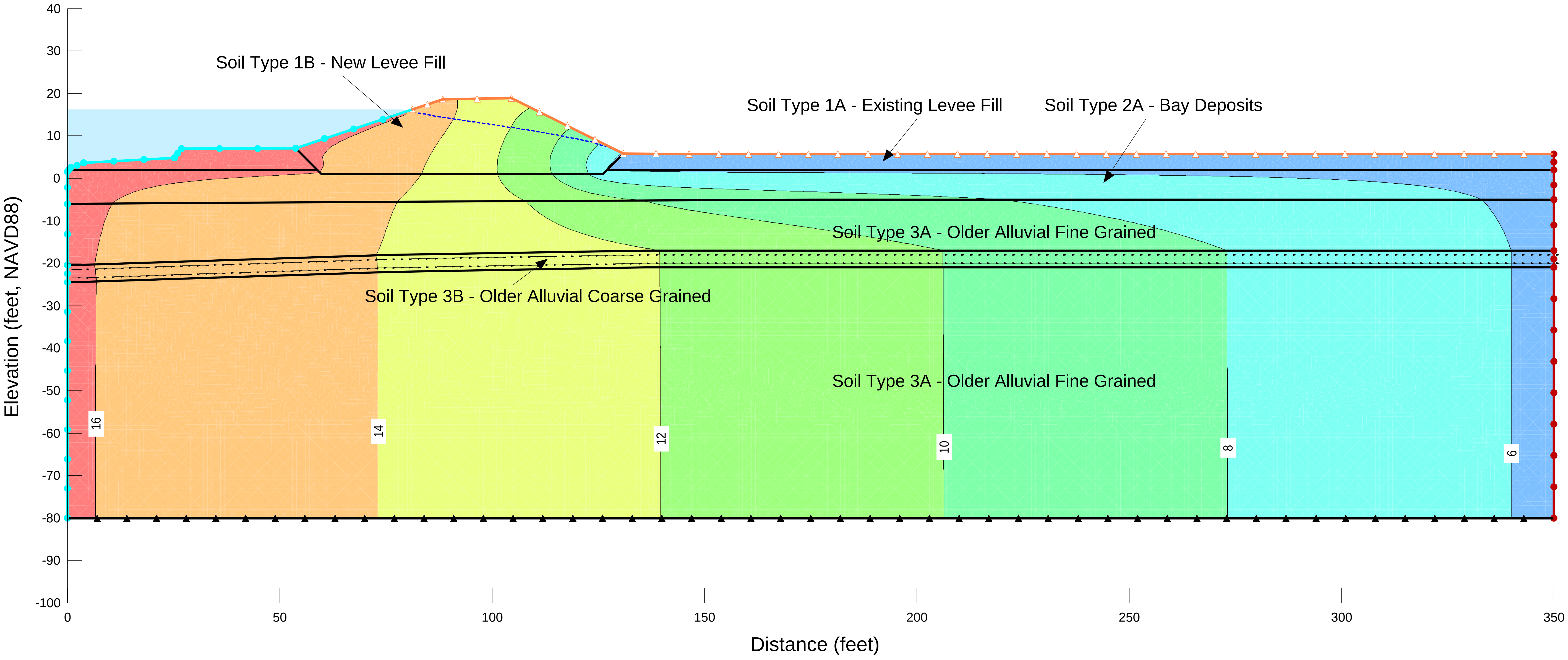
Soil Type 3A - Older Alluvial Fine Grained
K-Sat: 0.00283 ft/days
Kh/Kv: 4

Soil Type 3B - Older Alluvial Coarse Grained
K-Sat: 28.3 ft/days
Kh/Kv: 4

Analysis Section Details

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V

Results:
Exit Gradient at Landside Toe: 0.40



Station 70+00 Palo Alto Steady State Seepage (Floodwall; Shallow Foundation)

Soil Type 1A - Existing Levee Fill
K-Sat: 0.28 ft/days
Kh/kv: 4

Soil Type 2A - Bay Deposits
K-Sat: 0.0014 ft/days
Kh/kv: 5

Soil Type 3A - Older Alluvial Fine Grained
K-Sat: 0.0028 ft/days
Kh/kv: 4

Soil Type 3B - Older Alluvial Coarse Grained
K-Sat: 28 ft/days
Kh/kv: 4

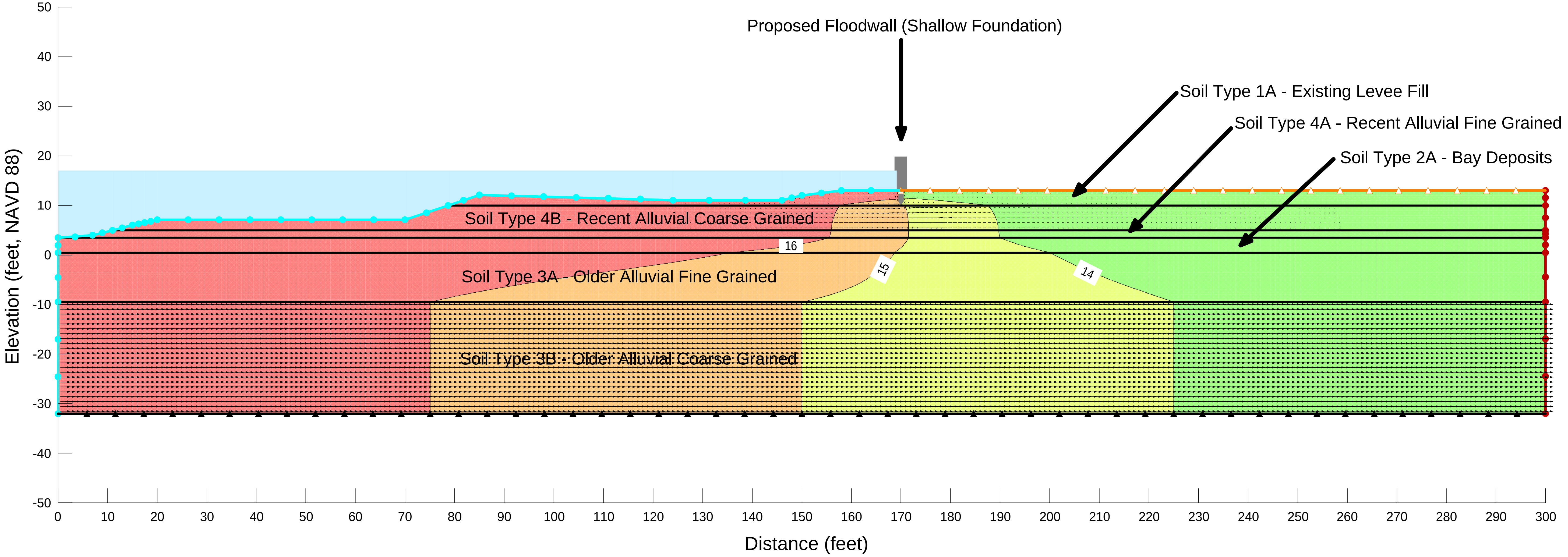
Soil Type 4A - Recent Alluvial Fine Grained
K-Sat: 0.028 ft/days
Kh/Kv: 4

Soil Type 4B - Recent Alluvial Coarse Grained
K-Sat: 2.8 ft/days
Kh/Kv: 4

Analysis Section Details:

Top of Floodwall Elevation: 20 ft
Design WSE: 17 ft
Ground Elevation at Wall: 13 ft
Bottom of Wall Elevation: 10 ft

Results:
Exit Gradient Behind Wall: 0.66



Station 70+00 Palo Alto Steady State Seepage (Floodwall; Cutoff Wall)

Soil Type 1A - Existing Levee Fill
K-Sat: 0.28 ft/days
Kh/kv: 4

Soil Type 2A - Bay Deposits
K-Sat: 0.0014 ft/days
Kh/kv: 5

Soil Type 3A - Older Alluvial Fine Grained
K-Sat: 0.0028 ft/days
Kh/kv: 4

Soil Type 3B - Older Alluvial Coarse Grained
K-Sat: 28 ft/days
Kh/kv: 4

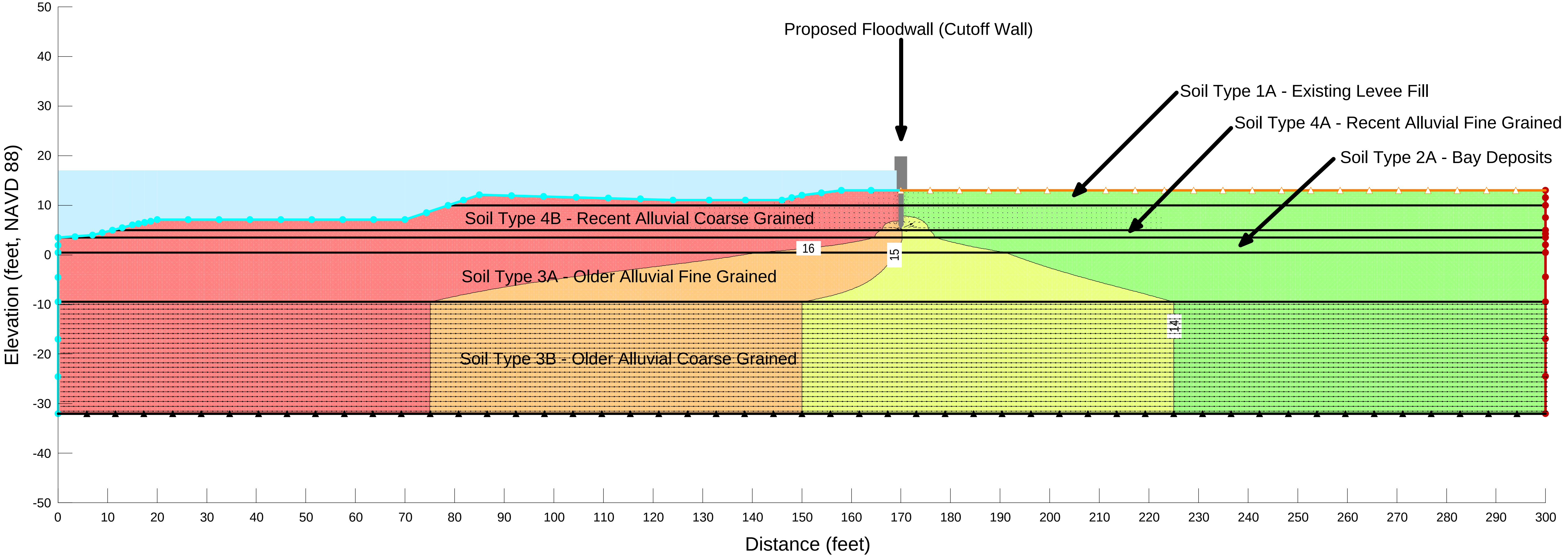
Soil Type 4A - Recent Alluvial Fine Grained
K-Sat: 0.028 ft/days
Kh/Kv: 4

Soil Type 4B - Recent Alluvial Coarse Grained
K-Sat: 2.8 ft/days
Kh/Kv: 4

Analysis Section Details:

Top of Floodwall Elevation: 20 ft
Design WSE: 17 ft
Ground Elevation at Wall: 13 ft
Bottom of Wall Elevation: 5 ft

Results:
Exit Gradient Behind Wall: 0.30



Station 71+00 East Palo Alto Steady State Seepage

Soil Type 1A - Existing Levee Fill
K-Sat: 0.283 ft/days
Kh/Kv: 4

Soil Type 2A - Bay Deposits
K-Sat: 0.00142 ft/days
Kh/Kv: 5

Soil Type 3A - Older Alluvial Fine Grained
K-Sat: 0.00283 ft/days
Kh/Kv: 4

Soil Type 4A - Recent Alluvial Fine Grained
K-Sat: 0.0283 ft/days
Kh/Kv: 4

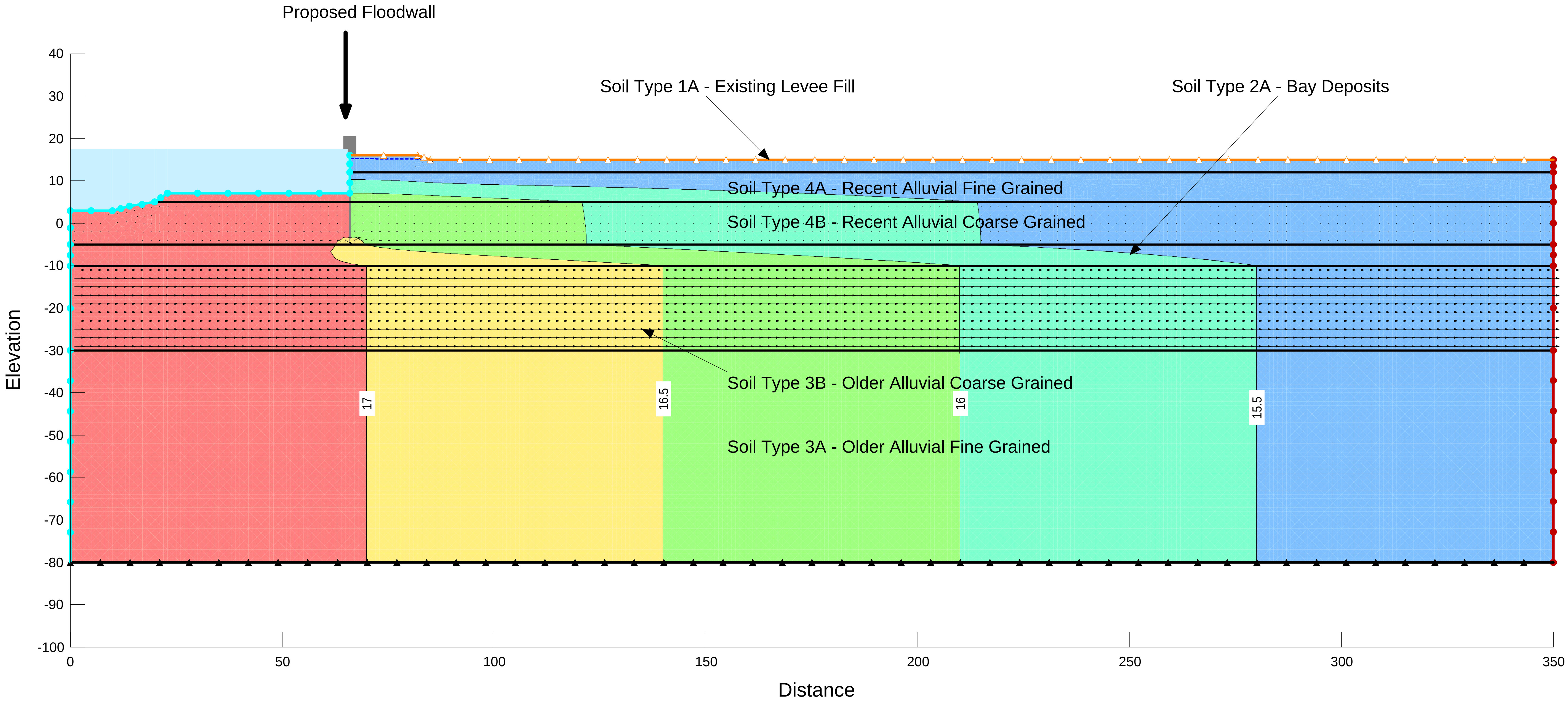
Soil Type 3B - Older Alluvial Coarse Grained
K-Sat: 28.3 ft/days
Kh/Kv: 4

Soil Type 4B - Recent Alluvial Coarse Grained
K-Sat: 2.83 ft/days
Kh/Kv: 4

Analysis Section Details

Top of Floodwall Elevation: 20.5 ft
Design WSE: 17.5 ft
Ground Elevation at Wall: 16 ft
Bottom of Wall Elevation: -5 ft

Results:
Exit Gradient Behind Wall: 0.03



Appendix F

Stability Analyses Plates

Station 46+50 Palo Alto End of Construction Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Cohesion: 750 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Cohesion: 120 psf
Phi: 20 °

Soil Type 1C - Golf Course Fill
Unit Weight: 120 pcf
Cohesion: 75 psf
Phi: 30 °

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Cohesion: 150 psf
Cohesion Under Levee: 300 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Cohesion: 1500 psf

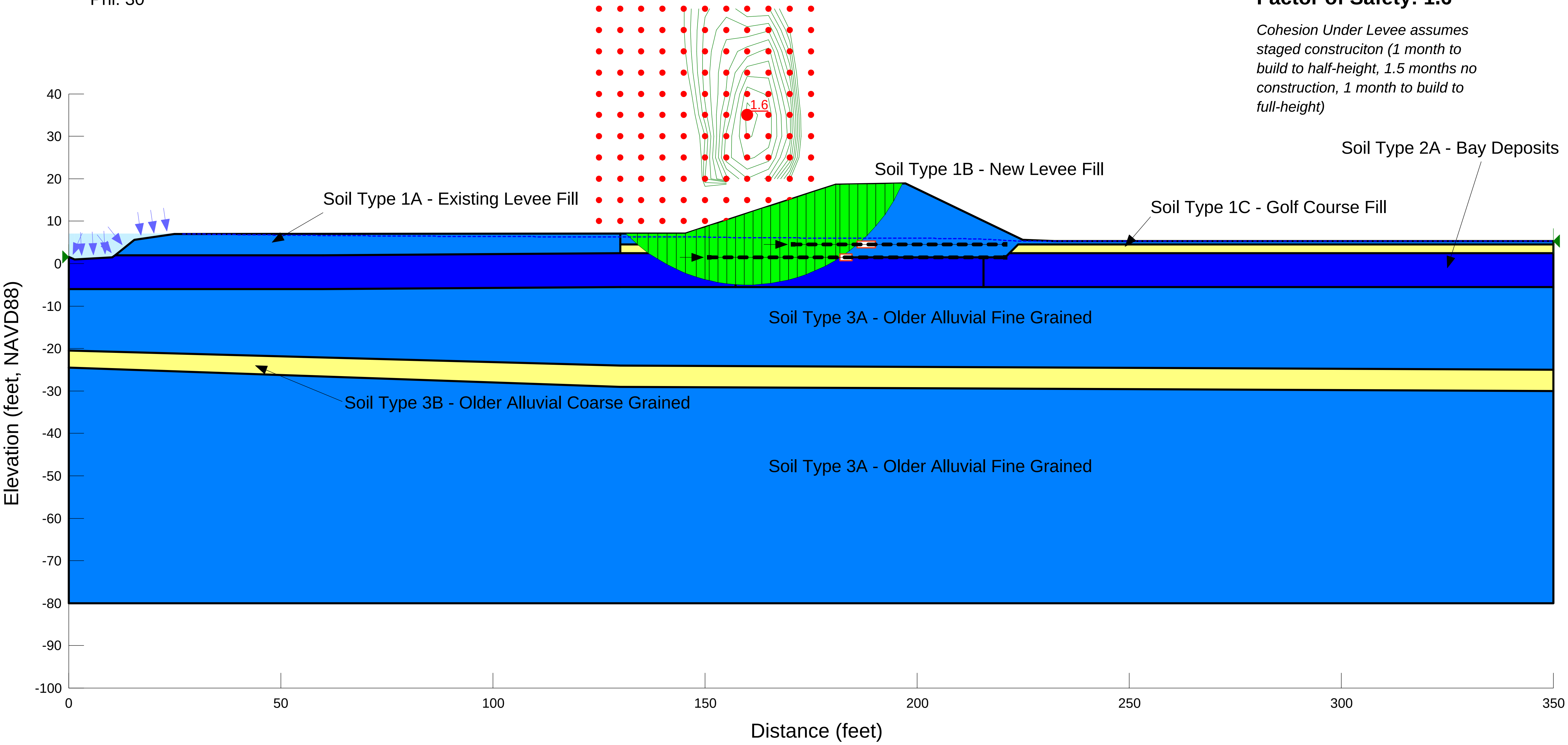
Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Cohesion: 0 psf
Phi: 33 °

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 7.1 ft (MHHW)
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.6

Cohesion Under Levee assumes staged construciton (1 month to build to half-height, 1.5 months no construction, 1 month to build to full-height)



Station 46+50 Palo Alto End of Construction Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Cohesion: 750 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Cohesion: 120 psf
Phi: 20 °

Soil Type 1C - Golf Course Fill
Unit Weight: 120 pcf
Cohesion: 75 psf
Phi: 30 °

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Cohesion: 150 psf
Cohesion Under Levee: 300 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Cohesion: 1500 psf

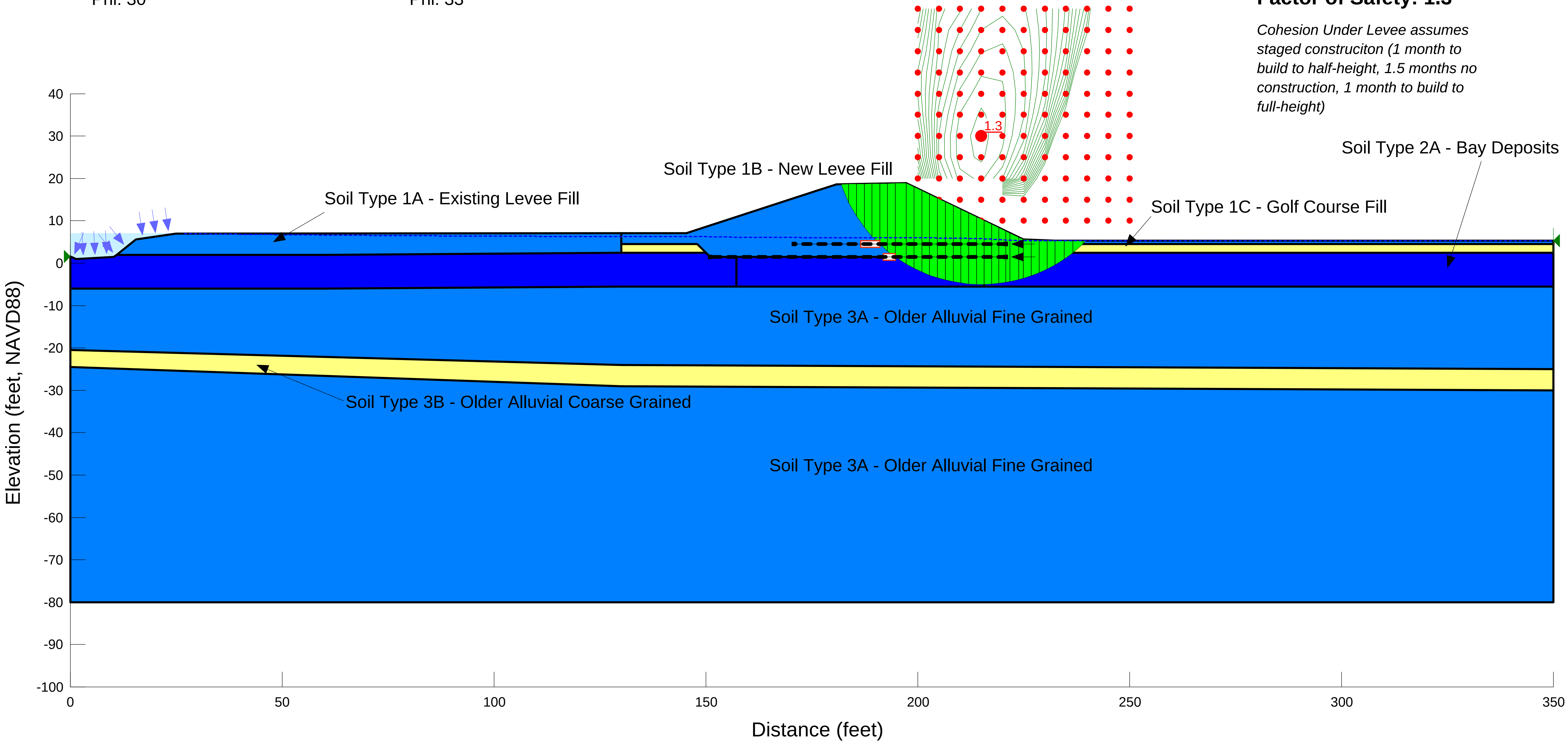
Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Cohesion: 0 psf
Phi: 33 °

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 7.1 ft (MHHW)
Landside Toe Elevation: 6 Ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.3

Cohesion Under Levee assumes staged construciton (1 month to build to half-height, 1.5 months no construction, 1 month to build to full-height)



Station 46+50 Palo Alto Steady State Seepage Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 1C - Golf Course Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Phi: 29 °
Cohesion: 0 psf

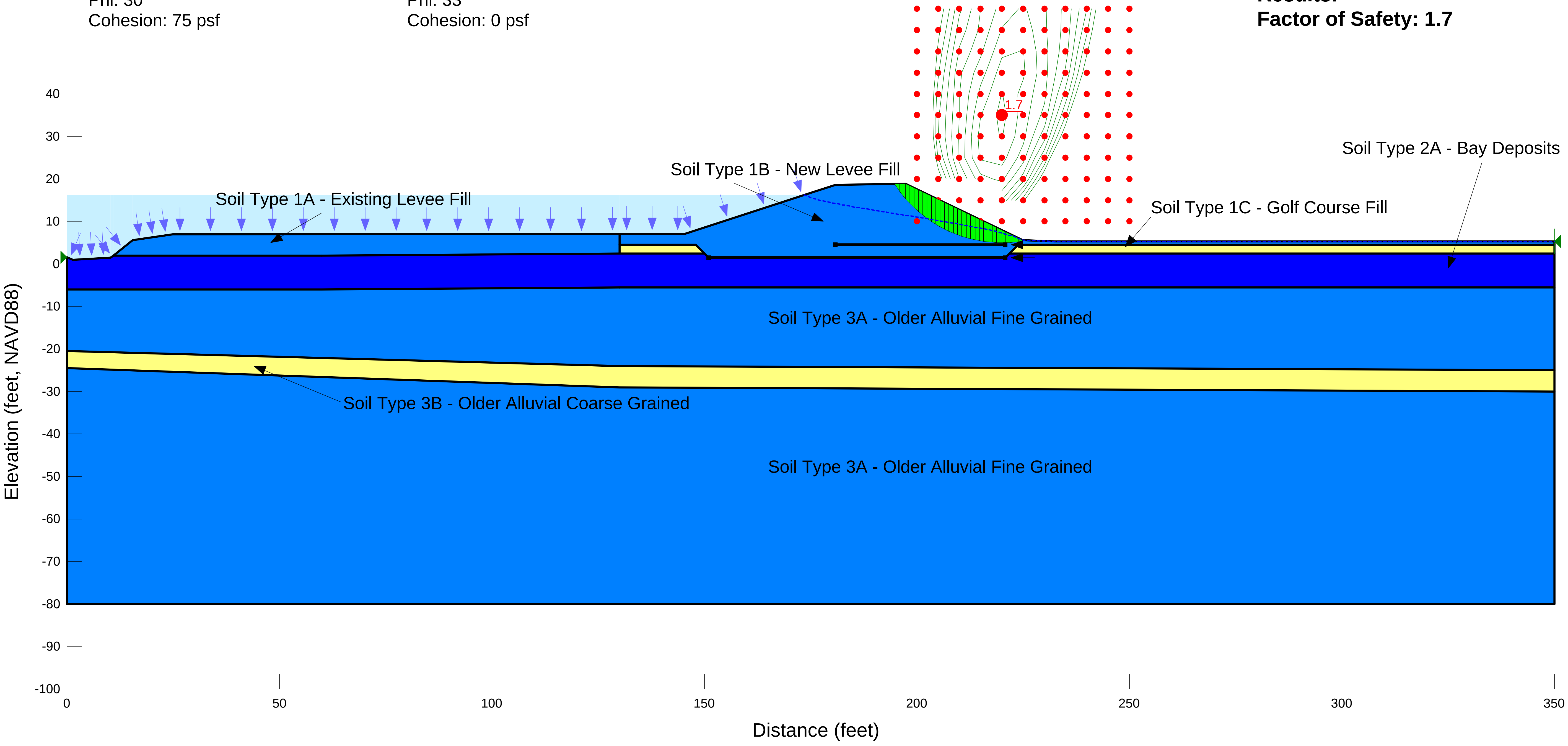
Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Phi: 30 °
Cohesion: 50 psf

Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.7



Station 46+50 Palo Alto Rapid Drawdown Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 1C - Golf Course Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Phi: 30 °
Cohesion: 50 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf
Drawdown Total Phi: 25 °
Drawdown Total Cohesion: 150 psf

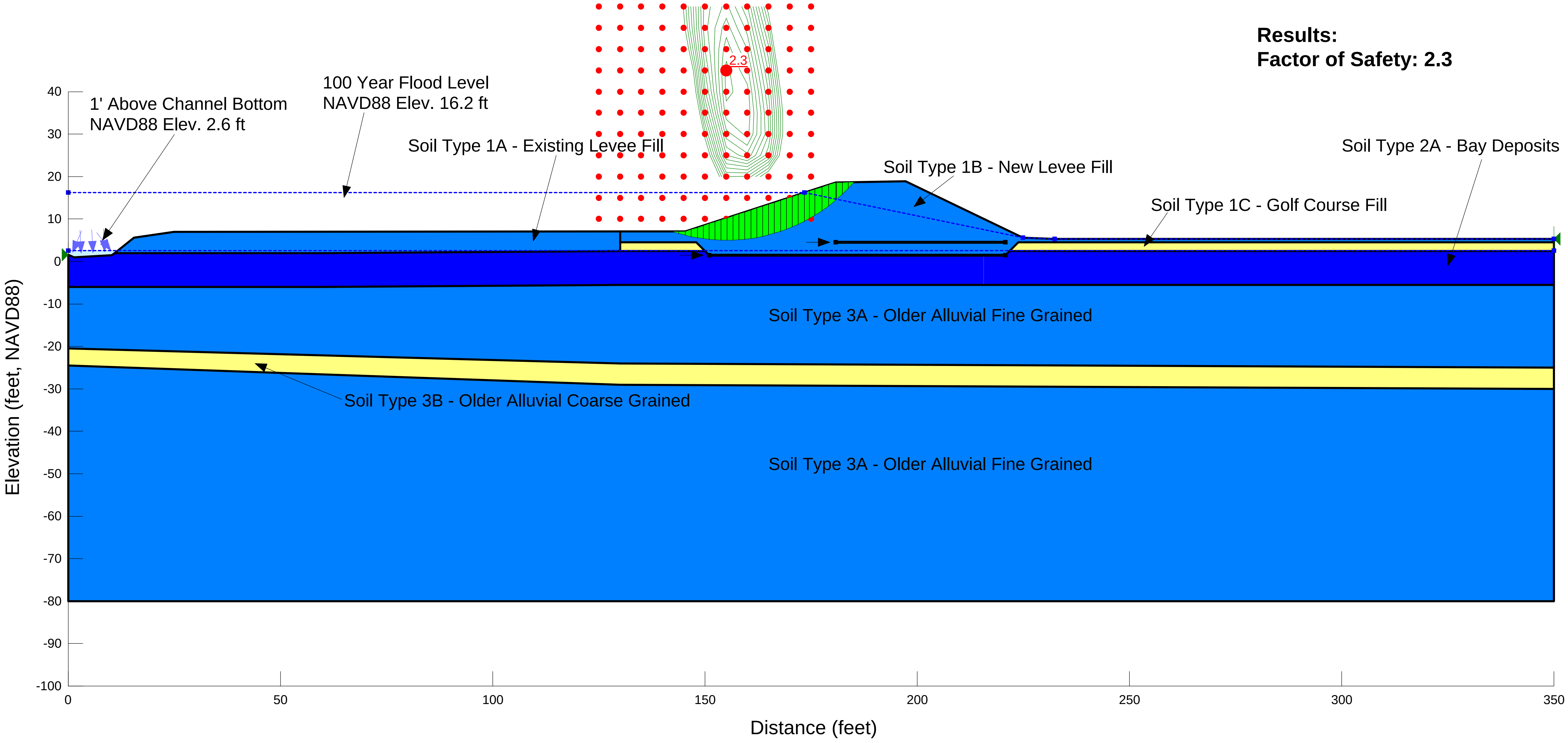
Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Phi: 29 °
Cohesion: 0 psf

Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Drawdown WSE: 2.6 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 2.3



Station 51+00 East Palo Alto End of Construction Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Cohesion: 750 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 20 °
Cohesion: 120 psf

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Cohesion: 150 psf
Cohesion Under Levee: 300 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Cohesion: 1500 psf

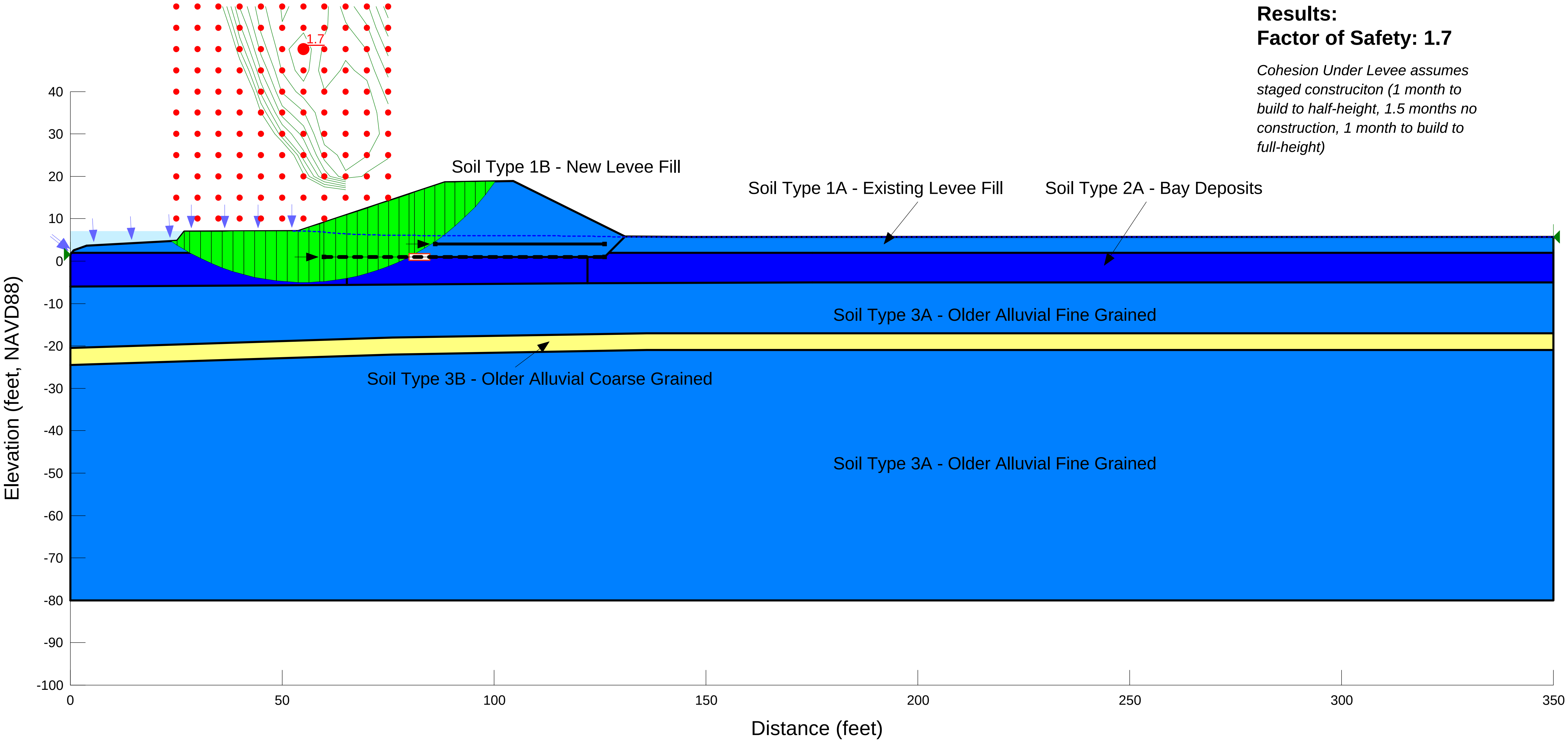
Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 7.1 ft (MHHW)
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.7

Cohesion Under Levee assumes staged construciton (1 month to build to half-height, 1.5 months no construction, 1 month to build to full-height)



Station 51+00 East Palo Alto End of Construction Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Cohesion: 750 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 20 °
Cohesion: 120 psf

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Cohesion: 150 psf
Cohesion Under Levee: 300 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Cohesion: 1500 psf

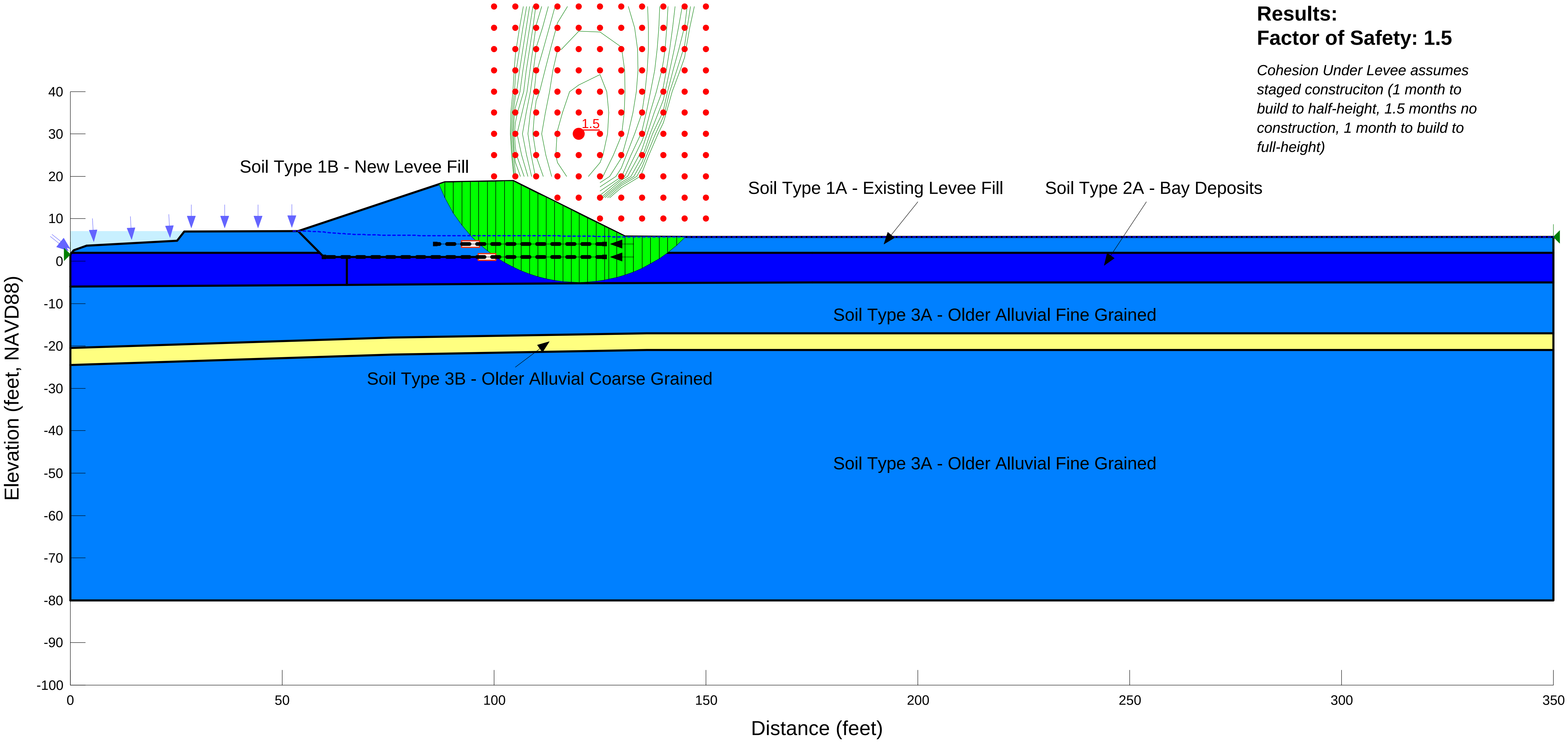
Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 7.1 ft (MHHW)
Landside Toe Elevation: 6ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.5

Cohesion Under Levee assumes staged construciton (1 month to build to half-height, 1.5 months no construction, 1 month to build to full-height)



Station 51+00 East Palo Alto Steady State Seepage

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Phi: 29 °
Cohesion: 0 psf

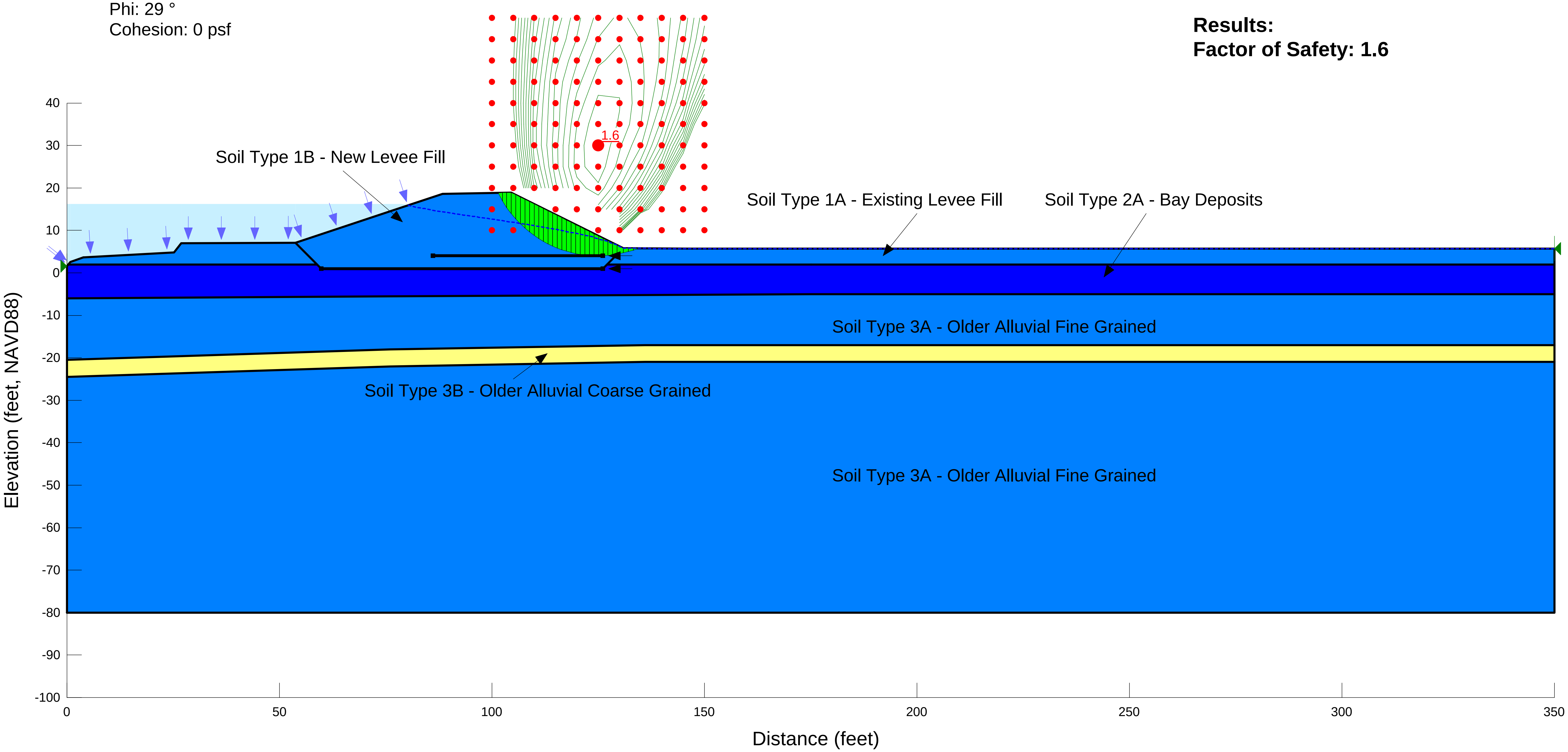
Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Phi: 30 °
Cohesion: 50 psf

Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 1.6



Station 51+00 East Palo Alto Rapid Drawdown Stability

Soil Type 1A - Existing Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf

Soil Type 1B - New Levee Fill
Unit Weight: 120 pcf
Phi: 30 °
Cohesion: 75 psf
Drawdown Total Phi: 25 °
Drawdown Total Cohesion: 150 psf

Soil Type 2A - Bay Deposits
Unit Weight: 107 pcf
Phi: 29 °
Cohesion: 0 psf

Soil Type 3A - Older Alluvial Fine Grained
Unit Weight: 119 pcf
Phi: 30 °
Cohesion: 50 psf

Soil Type 3B - Older Alluvial Coarse Grained
Unit Weight: 127 pcf
Phi: 33 °
Cohesion: 0 psf

Analysis Section Details:

Top of Levee Elevation: 18.6 ft
Design WSE: 16.2 ft
Drawdown WSE: 2.6 ft
Landside Toe Elevation: 6 ft
Waterside Toe Elevation: 7.1 ft
Waterside Slope: 3H:1V
Landside Slope: 2H:1V
Fabric Capacity: 3130 lbs

Results:
Factor of Safety: 2.2