GEOTECHNICAL REPORT

Arroyo Grande Creek Channel Waterway Management Program

San Luis Obispo County, California

Yeh Project No.: 218-169

February 22, 2020

Prepared for:

Cannon
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San Luis Obispo, California, 93401
Attn: Mr. John Evans

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Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

February 22, 2020 Project No. 218-169

Cannon
1050 Southwood Drive
San Luis Obispo, California, 93401

Attn: Mr. John Evans

Subject: Geotechnical Report, Arroyo Grande Creek Channel Waterway Management Program, San Luis Obispo County, California

Dear Mr. Evans:

Yeh and Associates, Inc. is pleased to submit this geotechnical report for the design of the Arroyo Grande Creek Channel Waterway Management Program in San Luis Obispo County, California. This report was prepared in accordance with our task order dated December 18, 2018. This report presents design input based on the results of our evaluation of the seepage and stability conditions relative to the proposed north levee improvements along Arroyo Grande Creek. The evaluation was based on site-specific exploration, other geotechnical studies in the site vicinity, review of published geologic information, project information provided by Cannon and the County of San Luis Obispo, and hydraulic and stream flow information provided by Waterways Consulting.

The geotechnical evaluation consisted of a program of field exploration, laboratory testing, and analysis. Field and laboratory data collected for this study, graphics showing the locations of the field explorations, and interpreted subsurface profiles are attached. A summary of geotechnical considerations for the design of the levee improvements are as follows:

- Seven cone penetration test (CPT) soundings were advanced along the north levee of Arroyo Grande Creek to depths ranging from approximately 27 to 48 feet below the ground surface in November 2019. The soundings encountered artificial fill materials overlying alluvium deposits. The artificial fill generally consisted of the existing levee fill composed of predominantly sandy soil. The alluvium was characterized as two predominant units of sandy alluvium and three predominant units of fine-grained alluvium that were encountered at various depths below the ground surface. The artificial fill upstream of Highway 1 appears to have been placed intermittently and was likely placed by adjacent landowners for flood protection and to expand adjacent residential and agricultural areas. The creek channel banks are generally composed of alluvium deposits, with discontinuous sections of overlying levee fill and artificial fill.

- Groundwater was encountered at a depth of 11 feet below the north levee crestin two of the CPT soundings. The sounding holes created by four of the CPTs caved following removal of the CPT probe at approximate depths of 8 to 19 feet. Groundwater levels and depth to the caved surfaces were encountered at approximately the same elevation as the water elevation in Arroyo Grande Creek. The water level flowing in Arroyo Grande Creek was observed to be approximately 1 to 2 feet deep during our field exploration program
- Seepage and slope stability analyses were performed to provide a basis for the recommendations of this report. The proposed levee raise will result in north levee crest elevations that will provide 3 feet of freeboard above the 10-year storm event water surface elevations. We understand based on discussions with the County that our evaluation of the potential for underseepage and through-seepage to develop based on transient seepage conditions is acceptable to the County relative to the project goal of providing protection for the relatively short-duration 10-year storm event.
- There is a low potential for underseepage or through-seepage to develop during the 10-year storm event based on our seepage analyses. The 10-year storm event water surface elevation would need to persist for at least 96 hours (4 days) for steady-state conditions to develop, based on our transient seepage analyses. The anticipated duration of elevated water surfaces during the 10-year flood event is approximately 24 hours. The County's reports regarding historical flood events with peak flows greater than the estimated 10-year storm event design flow (5,010 cfs) suggest that steady-state conditions have not developed through the north levee during those previous flood events. The County has not reported or observed evidence of through-seepage daylighting on the north levee landside slope or evidence of underseepage, such as sand boils beyond the exterior toe of the north levee during or following those events. It is our opinion that steady-state conditions would likely not develop during the design 10-year storm event on Arroyo Grande Creek based on our analyses and County reports, and that no special recommendations to mitigate seepage are needed for the design of the north levee improvements. The County plans to continue monitoring levee slopes during and following storm events and repair levee slopes, as necessary, as part of the levee operation and maintenance program.
- There is a low potential for slope instability resulting from seepage during the 10-year storm event based on our slope stability analyses. It should be anticipated that new levee slopes keyed into and supported by existing levee slopes will be susceptible to instability of the underlying existing slopes that are disturbed by rodent burrows or deep-rooted vegetation. The new levee slopes between approximately Station 123+00 and 123+40 will be susceptible to surficial instability due to the proposed 1h:1v (horizontal:vertical) inclination, and regular maintenance to repair or re-grade the slope should be anticipated. We understand the County

plans to implement a slope monitoring program to review levee slopes for evidence of instability on a regular basis.

- We observed rodent burrows and loose surface soil on the existing interior and exterior levee slopes. Burrowing animals and large buried roots of vegetation such as trees that have been removed as part of a vegetation management program can cause extensive void systems. Subsurface voids generally shorten flow paths through the levee and increase the potential for seepage-related hazards and slope instability. The slope monitoring program should also document evidence of burrowing animals and deep-rooted vegetation.
- As directed by the County, the scope of the improvements is for flood protection only, and no seismic criteria were considered in evaluating the stability of the levee slopes. We understand potential seismic hazards and repairs to the levees would be performed in response to a damaging seismic event as part of the County's operation and maintenance of the levee.

We appreciate the opportunity to be of service. Please contact Gresh Eckrich at 805-616-0399 or geckrich@yeh-eng.com if you have questions or require additional information.

Sincerely,
YEH AND ASSOCIATES, INC.

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Senior Project Manager

Reviewed by:

Jonathan D. Blanchard, G.E.
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1. Purpose and Scope of Study

Yeh and Associates was retained by Cannon to provide geotechnical recommendations for the design of levee improvements. The improvements are intended to provide 10-year flood protection as part of the Arroyo Grande Creek Waterways Management Program (AGWMP) in San Luis Obispo County, California. The study focused on the Arroyo Grande Creek north levee improvements, which will be designed to protect residential areas to the north. The south levee crest will be lower than the north levee to help direct flood overtopping at the south levee. The location of the site and approximate upstream and downstream project locations are shown on Figure 1.

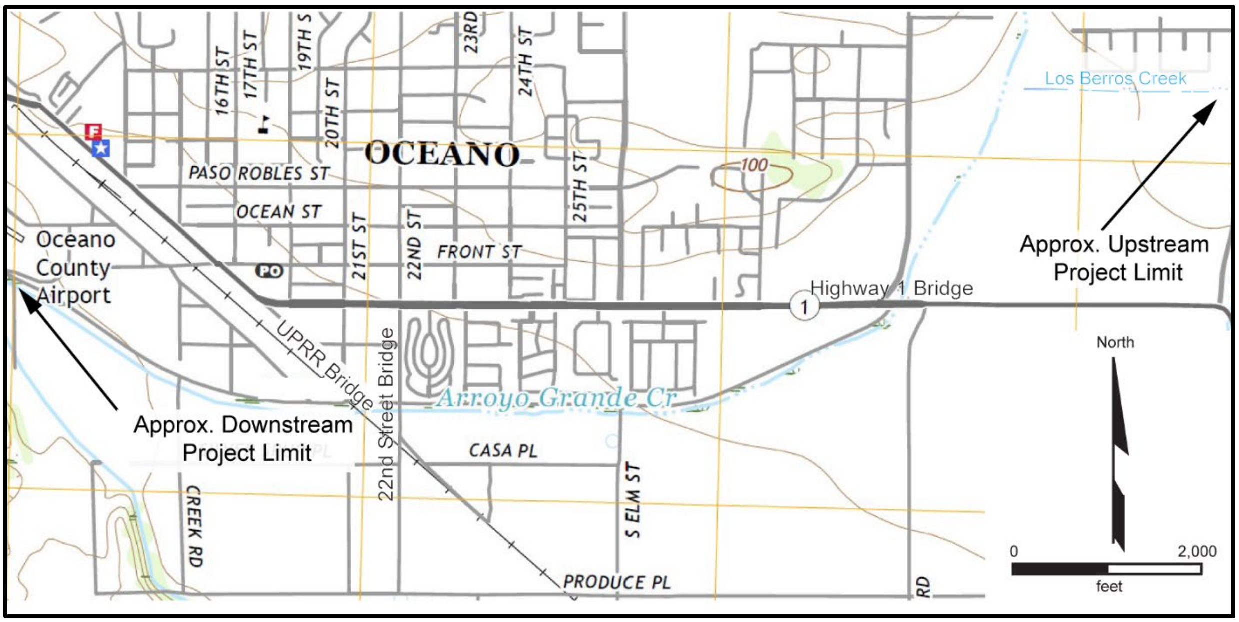


Figure 1: Vicinity Map

The geotechnical evaluation consisted of a program of project coordination, data review, field exploration, laboratory testing, and engineering analyses as a basis for providing the recommendations in this report.

2. Existing Site

The layout of the site, stationing along the centerline (thalweg) of the creek, exploration locations, and cross section locations used in seepage and stability analysis are shown on Plate 1 - Field Exploration Plan. Los Berros Creek flows west into Arroyo Grande Creek near the upstream limits of the project. Arroyo Grande Creek then flows west to the Pacific Ocean, about 3½ miles downstream of the Los Berros Creek confluence. Concrete weirs and check dams are located within the Los Berros Creek channel. Bridges span Arroyo Grande Creek at Highway 1/Cienega Street, 22nd Street, and at the Union Pacific Railroad (UPRR) crossing. The terrain in the site vicinity is generally flat with natural grades ranging from approximately 1 percent to 5 percent. Existing elevations at the invert of the creek shown on the Cannon (2019a) plans range from approximately elevation 13 feet at the downstream end of the project, to approximately elevation 60 feet at the upstream end of the project, near the city limits of Arroyo Grande.

The levees and channelized Arroyo Grande Creek were constructed in 1959 as a U.S. Department of Agriculture, Soil Conservation Service project (USDA 1956). Portions of the creek were relocated as part of the construction of the levee system. The lower portion of Los Berros Creek from the Valley Road Bridge downstream to the confluence with Arroyo Grande Creek was diverted from its pre-1960 channel, which ran along the southern edge of La Cienega Valley, to its current confluence upstream of the Highway 1 Bridge. The Arroyo Grande Creek channel was designed to carry a discharge of 10,120 cubic feet per second (cfs), which was estimated by the original design analysis to be a 100-year storm event. The capacity of the channel has decreased due to sediment accumulation and vegetation growth within the channel (Waterways 2010).

The existing levee slopes are less well defined and intermittent upstream of Highway 1, with a design height generally less than about 3 feet above adjacent grades. The levees consist of earthen berms downstream of Highway 1. The USDA (1956) design plans show the levee embankments were designed with 15-foot wide crests, exterior slope inclinations of 1½h:1v to 2h:1v (horizontal:vertical), and 3h:1v interior slope inclinations. The interior slopes were likely constructed as steep as about 2h:1v based on as-built plans (USDA 1956) and cross sections developed by Fugro (2012a). The existing channel bottom consists mostly of gravel with vegetated banks and levee slopes. The existing land use adjacent to the south levee is predominantly agricultural. The existing land use adjacent to the north levee includes the Oceano airport, South County Wastewater Treatment Plant, and residential and agricultural plots. Downstream of the project, the south levee is bordered by active sand dunes within the Oceano Vehicle Recreation Area operated by State Parks.

Topographic data collected by Waterways (2012) showed interior slope heights up to about 18 feet. The interior height of the channel slopes indicated on the plans ranged from about 11 to 14 feet. The design height of the exterior slopes was about 5 to 12 feet above the adjacent grades downstream of Highway 1. Cross sections prepared by Cannon (2019a) plans show the heights of existing exterior slopes are up to approximately 10 feet.

The Los Berros Creek Diversion Channel consists of a meandering 3- to 4-foot deep low-flow channel confined by graded cut slopes that are inclined at approximately 3h:1v or flatter. Concrete weirs and check dams are located within the low-flow channel. The height of the graded cut slopes ranges from approximately 7 to 10 feet. The County maintains access roads at the tops of the channel slopes. The agricultural fields south of the channel are approximately 1 foot below the top of the channel slope. The exterior slope to the south of the channel slopes away from the channel at approximately 2% grade or flatter and was likely graded for agricultural purposes. Existing land use north of the channel includes residential properties. The properties are at approximately the same grade as the top of the channel.

2.1 Historic Flooding

The south levee breached during a high-intensity storm event between approximately Stations 55+00 and 58+00 on March 5, 2001. The breach resulted in flooding of the adjacent agricultural land and residential properties. The north levee did not breach during that event (Waterways 2010).

The south levee was overtopped in 2015 between approximately Station 36+80 and Station 62+50, downstream of the 22nd Street and UPRR bridges. The overtopping resulted in surficial erosion of the exterior levee slope and flooding of the adjacent agricultural land. The County subsequently placed visqueen sheets and sandbags along the south levee slope as a temporary erosion mitigation measure.

2.2 Historic Streamflow

Waterways (2020) estimated the peak discharge for the design 10-year storm event is approximately 4,901 cubic feet per second (cfs). The US Geological Survey maintained a streamflow gage station on Arroyo Grande Creek in the City of Arroyo Grande between 1940 and 1986 (https://waterdata.usgs.gov/nwis/annual). The creek's base flow during this period ranged from approximately 11 to 19 cfs. Annual peak discharges during this period ranged from 11 to 5,400 cfs. We were unable to locate discharge data for the 2001 flood and the 2015 overtopping events.

The County has collected stream stage elevation data since 2006 from a gage station on the 22nd Street Bridge (https://wr.slocountywater.org/home.php). The full storm flow stage (when flood response personnel are notified) is shown as elevation (el.) 27 feet. The stream stage reached approximate el. 28.5 feet in Spring/Summer of 2015, when the south levee was overtopped downstream of the bridge.

2.3 Project Understanding

In the project area, the Arroyo Grande Creek channel is managed through Zones 1 and 1A of the San Luis Obispo County Flood Control and Water Conservation District (the District). Under the purview of the County Public Works Department, the District developed the Arroyo Grande Creek Waterways Management Program (AGWMP) to increase the creek channel capacity and provide 10-year flood protection from the southwestern city limits of Arroyo Grande and the confluence with Los Berros Creek to the western edge of the Arroyo Grande Creek lagoon at the Pacific Ocean.

The first phase of the AGWMP consisted of vegetation management, sediment removal, and grading secondary channels at 11 of 22 proposed sites along Arroyo Grande Creek, and was completed in October 2019. The Cannon (2019a) plans show improvements for the second phase of the AGWMP will extend from approximately Station 36+80 (downstream) to Station 141+00 (upstream). The second phase will consist of the following flood protection improvements along the north levee. The second phase will also include sediment and vegetation management, and grading secondary channels at the remaining 11 sites.

2.3.1 Levee Raise

Raising the levee crest approximately 2 feet or less above the existing top of levee. The levee raise will result in north levee crest elevations that will provide 3 feet of freeboard above the 10-year storm event water surface elevation. The levee raise will reduce the crest width to approximately 9 feet, and the new interior and exterior slopes will be inclined at 2h:1v. The raised levee section will be designed with sliver fills placed against the existing interior and exterior levee slopes to provide the 9-foot minimum crest width. The toe of sliver fill slopes will be up to approximately 10 feet below the crest. We understand fill will likely be derived from sediment removed from the project's proposed sediment and vegetation management sites. The top of the levee will be composed of aggregate base to support maintenance vehicles.

The raised section between approximately Station 123+00 and 123+40 will accommodate the County's right of way constraints and will consist of a 3-foot wide crest with interior and exterior slopes inclined at approximately 1h:1v. We understand the new fill at this location will consist of imported aggregate base.

2.3.2 Flood Control Wall

A flood wall is proposed north of the creek at Station 101+00, along the western boundary of the Rapp property, as shown on Plate 1. The wall alignment will be oriented roughly perpendicular to the north levee, and the length of the wall will be 295 feet. The proposed flood wall will consist of an L-shaped cantilevered cast-in-place wall. The top of wall elevation (el. 45 feet) will be one foot higher than the north levee crest elevation at Station 101+00.

2.3.3 Los Berros Creek Access Road

The Cannon (2019a) plans show the proposed flood control improvements to the north access road on Los Berros Creek will extend from approximately Station 0+00 (downstream) to 28+00 (upstream). The north access road improvements will consist of raising the channel slope by up to approximately 1.5 feet above the existing grade. The raised section will include a fill slope inclined at 2h:1v that will be placed at the top of the existing north channel slope, and sliver fills placed against the existing slope are not anticipated.

2.4 Previous Studies

Previous studies performed within the project limits are summarized below. Subsurface data presented in Fugro (2009, 2012a) were used in our interpretation of subsurface conditions and are presented in Appendix D.

2.4.1 Caltrans (1956, 1984) and San Luis Obispo County (1984)

The California Department of Transportation (Caltrans 1956, 1984) and San Luis Obispo County (SLO County 1984) prepared logs of test borings as part of geotechnical investigations for the State Route 1 Bridge and 22nd Street Bridge, respectively. The approximate locations of the bridge borings are shown on Plate 1.

2.4.2 U.S. Geological Survey (Holzer et al., 2004)

The U.S. Geological Survey (Holzer et al., 2004) previously performed a geotechnical study in the project vicinity. The study focused on evaluating liquefaction and liquefaction-induced lateral spreading that occurred in Oceano in response to the 2003 San Simeon Earthquake. As part of that study, the USGS performed three CPT soundings (SOC 036, 035 and 037) on the Arroyo Grande Creek south levee. The approximate locations of the CPT soundings performed by the USGS are shown on Plate 1. The soundings were performed in this area of the levee because the USGS observed evidence of levee instability and liquefaction adjacent to the levee. The logs of CPT soundings performed by the USGS are included with the Fugro (2009) report.

2.4.3 Fugro (2009)

Fugro (2009) performed a preliminary geotechnical investigation of the north and south levees. The investigation evaluated the potential for the site to be impacted by geologic hazards, analyzed static and seismic stability of levee slopes, and discussed geotechnical considerations for proposed levee raise alternatives. Field exploration activities consisted of advancing six (6) electric cone penetration test (CPT) soundings, collecting hand samples from the creek, and excavating a hand auger boring adjacent to the levee. The logs of the CPT soundings and hand auger boring are presented in the Fugro (2009) report, and the approximate locations of the explorations are shown on Plate 1. Subsurface profiles summarizing Fugro's interpretation of the subsurface conditions based on the study's explorations and previous logs of test borings (Caltrans 1956, 1984; SLO County 1984) along the alignment of Arroyo Grande Creek are shown in Fugro (2009). Fugro (2009) concluded that the levee could be impacted by liquefaction and slope instability in response to an earthquake.

2.4.4 Fugro (2012a)

Fugro (2012a) prepared a limited geotechnical report addressing seepage conditions along the existing north levee. The report included an evaluation of the potential for steady-state flow conditions to result in seepage through (i.e., through seepage) and under the levee (i.e., underseepage), instability of the levee slopes, the need for mitigation to address seepage conditions, and construction considerations relative to existing residences and land uses along the north levee. Field exploration activities consisted of drilling and sampling three (3) hollow-stem-auger borings. The logs of borings are presented in the Fugro (2012a) report, and the approximate locations of the explorations are shown on Plate 1.

2.4.5 Fugro (2012b)

Fugro (2012b) prepared a geotechnical report to further characterize subsurface conditions along the existing north levee and perform seepage and slope stability analyses as a basis for providing geotechnical recommendations for the design of previously proposed levee improvements. The previously proposed levee improvements consisted of raising the levee crest between about Stations 36+00 and 109+50 and between about Stations 122+00 and 130+00. Floodwalls were planned in levee sections that were constrained by limited right-of-way. Field exploration activities consisted of drilling and sampling five (5) hollow-stem-auger borings to depths ranging from approximately 21½ to 41½ feet below the existing ground surface. The logs of the borings are presented in the Fugro (2012b) report, and the approximate locations of the explorations are shown on Plate 1.

3. Geotechnical Exploration and Testing

3.1 Cone Penetration Test (CPT) Soundings

The CPT subcontractor for this project was Middle Earth Geo Testing, Inc. of Orange, California. Middle Earth advanced seven CPT soundings using a hydraulic ram mounted inside a 25-ton truck on November 19, 2019. CPT soundings were performed in general accordance with ASTM D-5778 using an electric piezocone penetrometer. The piezocone had a diameter of approximately 1.7 inches with a tip area of 15 square centimeters (cm^2) and a sleeve area of 225 cm^2. Cone tip resistance (q_c), sleeve friction (f_s), and penetration pore water pressures measured from a transducer placed behind the tip (in the u2 location) were recorded at approximately 3-centimeter intervals during penetration using an on-board computer. The friction ratio (FR, the ratio of the sleeve friction to the tip resistance in percent) was computed for each value of q_c and f_s recorded. The data and soil behavior type classifications were used in subsequent geotechnical analyses and to evaluate soil types and boundaries for analyses. Upon removal of the CPT rod, the soil generally collapsed to near the groundwater level encountered. The void above that depth was filled with bentonite chips.

The soundings were advanced to depths ranging from approximately 27 to 48 feet below the ground surface. Logs of the CPT soundings are presented in Appendix A.

4. Site Conditions

4.1 Geologic Setting

The project is located in the Arroyo Grande and Cienega Valleys and within the Coast Ranges geologic and geomorphic province. The province consists of north-northwest-trending sedimentary, volcanic, and igneous rocks extending from the Transverse ranges to the south into northern California. Rocks of the Coast Ranges province are predominantly of Jurassic and Cretaceous age; however, the range is often flanked by pre-Jurassic, Paleocene-age to recent

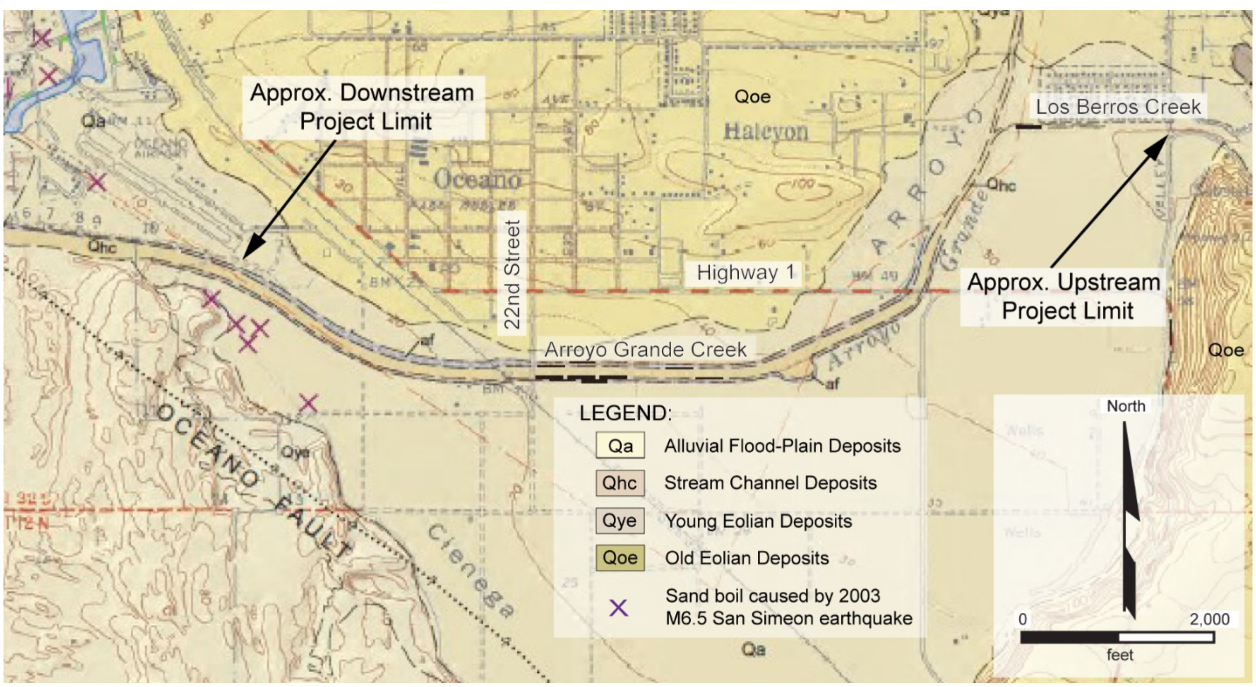


Figure 2: Geologic Map

rocks that overlie older rock formations. The surficial geology as mapped by Holland (2013) is shown on Figure 2.

The Arroyo Grande and Cienega Valleys and adjacent highlands composed of eolian (windblown) dune sand deposits are the dominant geomorphic features within the project vicinity. The valleys were formed during a period of low sea level (the Wisconsin glacial stage), as coastal streams adjusted to the drop in sea level by carving into the landscape. A subsequent rise in sea level produced a dynamic depositional environment reflected in the discontinuous and variable subsurface stratigraphy. Approximately 800 feet of interlayered and unconsolidated sediments have been deposited within the valleys (Hall 1973). The unconsolidated sediments dip gently to the west and are underlain by bedrock consisting of Tertiary-age sedimentary formations and Cretaceous- to Jurassic-age mélange of the Franciscan Complex.

The predominant surficial geologic units mapped in the study area are sediments composed of stream channel deposits (Qhc), alluvial flood-plain deposits (Qa), young eolian (dune sand) deposits (Qye), older eolian deposits (Qoe). Hall (1973) described the older dune sands as eolian deposits that have been stabilized and subsequently covered by vegetation. The alluvial deposits include floodplain, fluvial, and estuarine sediments that have been deposited along Arroyo Grande Creek and Los Berros Creek, and on the floor of the Arroyo Grande and Cienega Valleys.

Figure 2 also shows the location of sand boils caused by liquefaction during the 2003 M6.5 San Simeon earthquake and mapped by the USGS (Holzer et al. 2004), The sand boils were mapped north and south of Arroyo Grande Creek near the downstream project limits, where the USGS also observed evidence of instability on the south levee slope.

4.2 Climate

The climate in the Oceano area is Mediterranean with annual rainfall averaging approximately 18 inches. Rainfall data that the County has collected at the gage station on Arroyo Grande Creek since 2006 is available online (https://wr.slocountywater.org/home.php). Annual rainfall accumulation at the station since 2006 ranged from approximately 6 inches in rainfall year 2013-2014 to approximately 28 inches in 2016-2017.

4.3 Subsurface Conditions

Logs of the CPT soundings advanced for this investigation are presented in Appendix A. The locations of the CPT soundings are shown on Plate 1. Subsurface profiles summarizing our interpretation of subsurface conditions encountered below the north levee between approximately Station 85+00 and 140+00 are shown on Plates 2a and 2b. Our interpretation of subsurface conditions is based on the CPT correlations developed by Robertson and Campanella (1986) and is generally supplemented by logs of previous explorations (Fugro 2009, 2012a, 2012b; USGS 2004; Caltrans 1956, 1984; San Luis Obispo County, 1984).

The CPT soundings encountered artificial fill (Af) materials overlying alluvium deposits (Qal) along the north levee. The artificial fill upstream of Highway 1 appears to have been placed intermittently and was likely placed by adjacent landowners for flood protection and to expand adjacent residential and agricultural areas. The creek channel banks are generally composed of alluvium deposits, with discontinuous sections of overlying levee fill and artificial fill.

Artificial Fill (Af). Artificial fill materials were encountered in each of the CPT soundings advanced through the existing levee. The thickness of the fill ranged from approximately 1 to 7 feet below the ground surface. The artificial fill generally consisted of soil placed during construction of the existing levee, except in CPT-205, which was advanced in an existing agricultural field approximately 350 feet north of the creek centerline at approximately Station 101+00. The artificial fill materials encountered in the CPT soundings consisted predominantly of medium dense to very dense sand (SP or SW) and silty sand (SM). Relatively thin interbedded medium stiff to stiff silty clay (CL-ML), sandy clay and clay (CL or CH) were encountered in CPT-202, CPT-203, CPT-204.

We observed rodent burrows and loose surface soil on the existing interior and exterior levee slopes. Figure 3 shows evidence of rodent burrows on the interior levee slope at approximately Station 69+00. We understand the County periodically manages vegetation and rodent activity on the levee, which is common maintenance practice for hydraulic earth structures.

Figure 3: Rodent Burrows on north levee interior slope
(facing east; 22nd Street Bridge in background)

Alluvium Deposits (Qal). The alluvium encountered included undifferentiated units of floodplain, fluvial, and estuarine sediments deposited along Arroyo Grande Creek. The alluvium was encountered below the artificial fill materials in all of the CPT soundings to the maximum depth explored, approximately 27 to 48 feet below the existing ground surface. The alluvium encountered during the Fugro (2009, 2012a, 2012b) field exploration programs was characterized as two predominant units of sandy alluvium (Qal1, Qal2), and three predominant units of fine-grained alluvium that were encountered at various depths between and below the sandy alluvium units (Qal3, Qal4 and Qal5). All of those alluvium units were encountered in the CPT soundings advanced for this study, and are characterized below in a manner consistent with Fugro (2009, 2012a, 2012b).

Qal1. This unit consisted of sandy alluvium encountered below artificial levee fill to depths of approximately 8 to 13 feet below the surface. This upper sand unit consisted of loose to medium dense sand (SP), sand with silt (SP-SM), and silty sand (SM). The thickness of the unit ranged from approximately 3 to 20 feet. This unit was encountered near or just below the levee exterior toe between approximately Stations 103+00 and 135+00, and between approximately Stations 53+00 and 70+00 (Fugro 2009, 2012b). The unit was encountered by Fugro (2012b) the Qal1 unit at the ground surface between approximately Stations 135+00 and 143+00. This unit was encountered below approximately 1 to 2 feet of fill at the proposed flood wall location in CPT-205 and Fugro's (2012b) boring B-103.

Qal2. This unit consisted of sandy alluvium encountered between the Qal3, Qal4, and Qal5 units to depths of approximately 24 to 44 feet below the existing ground surface. This lower sand unit consisted of medium dense to very dense sand (SP), sand with silt (SP-SM), and silty sand (SM).

Qal3. This unit of fine-grained alluvium consisted of relatively shallow strata composed of soft to very stiff fat clay (CH) and lean clay (CL) encountered in each of the CPT soundings advanced for this study except CPT-205. The thickness of the unit ranged from approximately 2 to 23 feet. This unit was encountered near or just below the levee exterior toe between approximately Stations 70+00 and 103+00. Between approximately Stations 103+00 and 140+00, the Qal3 unit was encountered at or above the approximate elevation of the creek invert.

Qal4. This unit consisted of very stiff to hard fat clay (CH) and lean clay (CL) encountered in CPT-204 through CPT-207. The thickness of the unit ranged from approximately 1 to 7 feet.

Qal5. This unit consisted of very stiff to hard fat clay (CH) and lean clay (CL) encountered in CPT-203 and CPT-207. The thickness of the unit ranged from approximately 10 to 12 feet.

4.4 Groundwater

Groundwater was encountered at a depth of 11 feet below the north levee crest in CPT-206 and CPT-207 during the November 2019 field exploration program. A pore pressure dissipation test performed in CPT-205 estimated a groundwater depth of approximately 24 feet. The sounding holes created by CPT-201 through CPT-204 caved following removal of the CPT probe at approximate depths of 8 to 19 feet. Groundwater levels and caved surfaces were typically encountered at approximately the same elevation as the water elevation in Arroyo Grande Creek. The water in Arroyo Grande Creek was observed to be approximately 1 to 2 feet deep during our field exploration program. Variations in groundwater levels and soil moisture conditions will occur depending on changes in precipitation, runoff, tidal fluctuations, irrigation schedules, and other factors.

5. Geotechnical Evaluations

Yeh performed seepage analyses for two cross sections within the limits of the proposed improvements along the north levee. Analyses were performed using the SLIDE software developed by Rocscience (2019). The cross sections were located at Station 123+23 (creek centerline stationing) and Station 1+00 (wall stationing) of the Rapp property flood wall. Slope stability and seepage analyses were performed for the proposed levee prism at Station 123+23.

The proposed Rapp property flood wall will be sited on a relatively flat grade; therefore, that cross section was not analyzed for slope stability.

The ground surface profile of the existing levee and proposed levee raise at Station 123+23 were estimated based on the Cannon (2020) cross sections. The ground surface and dimensions of the proposed flood wall at Station 1+00 were estimated based on the Cannon (2019b) cross sections, and preliminary calculations provided by Cannon.

The subsurface conditions in our analyses were generally modeled as levee fill overlying impervious foundation material and pervious foundation material. The artificial fill was modeled as a relatively pervious uniform levee fill material for our seepage and stability analyses. We modeled the sandy alluvium units (Qal1, Qal2) as a uniform relatively pervious foundation material for seepage and stability analyses. The fine-grained alluvium units (Qal3, Qal4, Qal5) were modeled as a uniform relatively impervious foundation material. The sequence of the units does not necessarily progress from Qal1 to Qal5 with depth from the ground surface, and each unit may not be present at each location that has been explored.

Geotechnical Properties. The total unit weight, hydraulic conductivity parameters, and shear strength parameters selected for our analyses are summarized below. Yeh estimated the vertical hydraulic properties using correlations to the CPT data collected for this study, and using field and laboratory data presented in the Fugro (2012a, 2012b) reports. The horizontal to vertical hydraulic conductivity ratios were estimated using recommendations presented in the Department of Water Resources (DWR 2015) Guidance Document for Geotechnical Analyses. Drained and undrained shear strength parameters were assigned to the impervious alluvium unit for the rapid drawdown slope stability analyses. The total unit weight and shear strength parameters were estimated based on laboratory data presented in the Fugro (2012a, 2012b) reports.

Table 1: Summary of Selected Geotechnical Properties

Geologic Unit	Predominant USCS Soil Types	Total Unit Wt. (pcf)	Hydraulic Conductivity (cm/s)	Horizontal to Vertical Hydraulic Conductivity Ratio	Volumetric Water Content (ft^3/ ft^3)	Drained Strength Parameters[1]	Undrained Strength Parameters[2]
Artificial Fill (Af)	SM, SC, CL	120	5×10^{-2}	1	0.3	ϕ' = 37° c' = 0 psf	NA
Pervious Alluvium (Qal1, Qal2)	SP, SP-SM, SW-SM, SM	115	4×10^{-3} to 9×10^{-3}	4	0.2	ϕ' = 35° c' = 0 psf	NA
Impervious Alluvium (Qal3, Qal4, Qal5)	CH, CL	115	3×10^{-5} to 5×10^{-7}	8	0.4	ϕ' = 29° c' = 100 psf	ψ_{RD} = 29° d_{RD} = 510 psf
New Aggregate Base	GC/GM	120	5×10^{-2}	1	0.3	ϕ' = 38° c' = 100 psf	NA

Notes:
1. Effective Friction Angle (ϕ') and Cohesion (c')
2. Undrained strength parameters (ψ_{RD}, d_{RD}) define the isotropic consolidation envelope described in Appendix G of EM 1110-2-1902 (USACE, 2003)

Hydraulic Conductivity. The computer software Cliq V2.2.0.28 (GeoLogismiki) was used to estimate the vertical hydraulic conductivity of each unit using CPT data. Both horizontal (kh) and vertical hydraulic conductivity (kv) values are input for modeling in SLIDE. Hydraulic conductivity values are assigned by inputting the saturated permeability in the vertical direction and the ratio of horizontal to vertical permeability (kh/kv). Plots presented in Appendix B show estimates of vertical hydraulic conductivity versus depth for CPT sounding based on correlations presented by Lunne et al. (1997). The values selected for our analyses are also presented in Appendix B.

Modeling seepage through unsaturated soils requires definition of unsaturated permeability and volumetric water content variations with matric suction (volumetric water content equals volume of water divided by total volume [volume of air plus volume of water plus volume of soil]; suction equals pore air pressure minus [negative] pore water pressure, resulting in a positive suction value). SLIDE allows the user to select curves representing the variation of permeability (unsaturated permeability) versus matric suction for seepage analyses. The curves were selected based on the soil types encountered at each cross section. Volumetric water content values were estimated using the laboratory results presented in the Fugro (2012b) report and were assigned to the various subsurface units to model the initial porewater pressure conditions of the unsaturated soil.

5.1 Seepage Analyses

Seepage analyses were performed considering transient seepage conditions that consider water surface elevations and storm duration estimated by Waterways Consulting (2020) for the 10-year design storm event on Arroyo Grande Creek. The analyses consider the potential for seepage beneath the levee, referred to as underseepage, and seepage through the levee embankment, referred to as through-seepage. The seepage model dimensions and hydraulic head boundary conditions were developed following the DWR (2015) guidelines.

5.1.1 Steady-state Analyses

Steady-state seepage occurs when a sustained water surface elevation in the creek channel results in stabilized flow paths through and beneath the levee. Steady-state seepage evaluations assume that design flood elevations are maintained for a sufficient time to allow steady-state seepage flow conditions to develop through and beneath the levee system. We estimated buoyancy pressures acting at the bottom of the flood wall footing based on steady-state seepage conditions.

Performance criteria for underseepage and through-seepage are based on steady-seepage conditions, which typically develop during storm events with relatively long durations and long recurrence intervals, such as 100- to 200-year storm events. Deviations from the use of steady-state analyses for levees subjected to river stage loading for short durations are typically substantiated with information such as hydraulic data and transient seepage analyses (DWR 2015). We understand based on discussions with the County that our evaluation of the potential for underseepage and through-seepage to develop based on transient seepage conditions is acceptable to the County relative to the project goal of providing protection for the relatively short-duration 10-year storm event.

5.1.2 Transient Analyses

Transient analyses consider seepage conditions beneath or through the levee at specified time periods during the design flood event. Yeh performed transient seepage analyses of the cross sections to estimate the time to develop seepage forces and phreatic surfaces relative to the duration of the 10-year storm event. The transient analyses were used to assess the potential for steady-state seepage conditions to develop during the 10-year storm event. Waterways (2020) provided the hydrograph for the 10-year storm event depicted in Figure 4. The peak discharge for the 10-year storm event occurs over approximately 3 hours, and the full duration of the storm is approximately 24 hours.

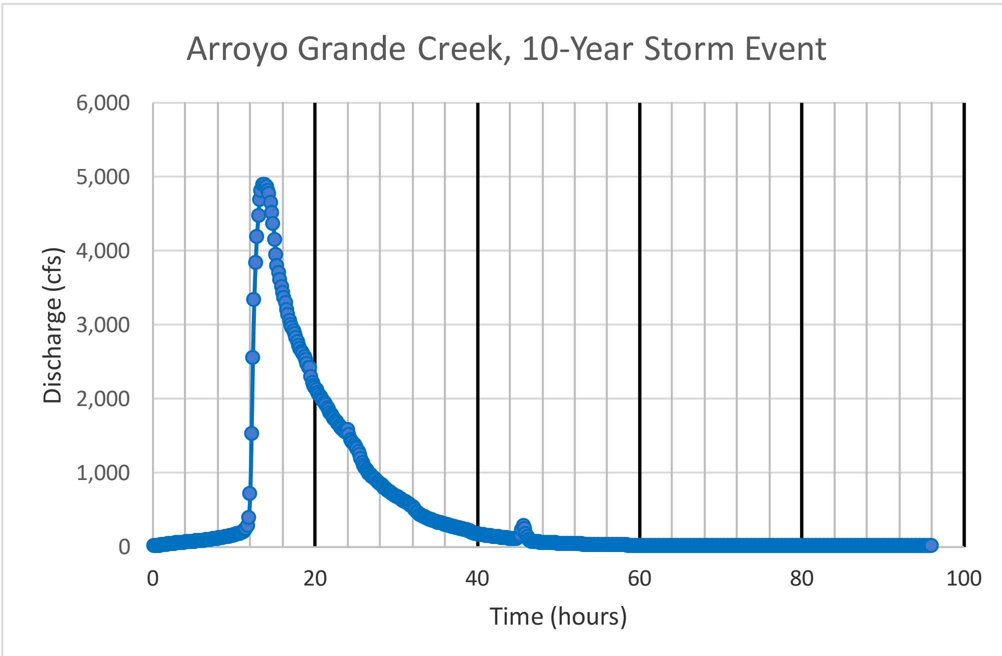


Figure 4: Hydrograph for 10-year flood event

Input parameters applied to the transient seepage models were the same as those applied to the steady-state models, except the hydraulic head boundary conditions. Initial hydraulic head boundary conditions estimated for the transient seepage analyses included the creek water surface elevations based on our field observations and groundwater level estimates based on data collected for this study. Time-dependent water surface elevations for the transient analyses were based on the change in discharge shown in Figure 4.

5.1.3 Underseepage

Foundation underseepage is hydraulic flow that occurs beneath the levee when a higher water level (high gradient) in the creek infiltrates the creek bed and flows beneath the levee or flood wall to the lower water level on the landside of the levee (low gradient).

5.1.4 Through-seepage

Through-seepage that daylights on an unconfined exterior soil slope decreases slope stability. Sustained through-seepage and erosion can lead to piping, which typically consists of a tunnellike void that forms within the embankment when uncontrolled seepage daylights on the face of the exterior levee slope.

Through-seepage that daylights on an exterior slope during a design storm event is typically not considered acceptable for design, particularly for erodible soils (DWR 2015). An example of seepage analyses results illustrating through-seepage is presented in Figure 5. SLIDE was used to estimate the phreatic surface during the design storm event and the potential for through-seepage to daylight on the exterior slope.

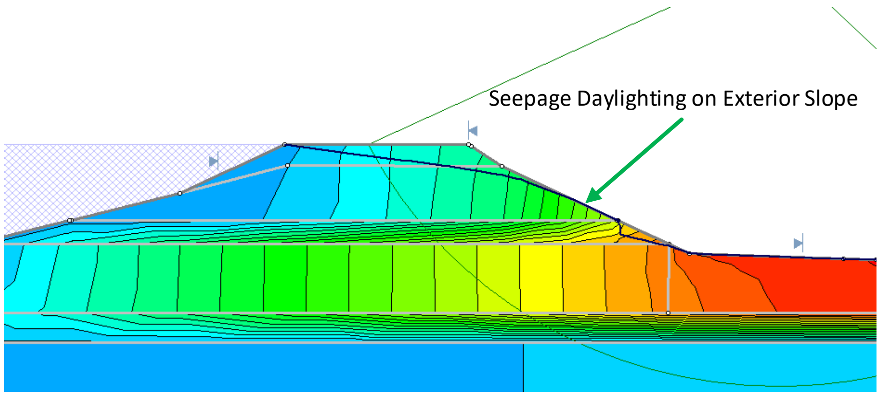


Figure 5: Through-seepage example

5.2 Slope Stability Analyses

Yeh performed slope stability analyses of the proposed exterior slope for full flood conditions, with water surface elevations corresponding to the design 10-year storm event. Additionally, we performed stability analyses of the interior slope considering rapid drawdown conditions, which could occur as flood water recedes following the design storm event. Phreatic surfaces and pore pressures modeled in our stability analyses for full flood and rapid drawdown conditions were based on the results of steady-state seepage analyses in accordance with U.S. Army Corps of Engineers guidelines (USACE 2000). Steady-state conditions are generally more adverse for slope stability than transient conditions.

Slope Stability Criteria. The San Luis Obispo County (2005) Guidelines for Engineering Geology Reports considers slopes stable when the estimated factor of safety from slope stability analyses is at least 1.5 under static loading conditions. These values are consistent with local practice and California Geologic Survey (CGS 2008) guidelines for slope stability evaluations.

It should be noted that these publications do not specifically address slope stability analyses of full flood and rapid drawdown conditions. We therefore considered a minimum factor of safety equal to 1.4, as specified by the USACE (2000) for levee slope stability under long-term, steady seepage conditions. A minimum factor of safety equal to 1.0 is specified by the USACE (2000) for rapid drawdown stability analyses.

A factor of safety of 1.0 represents the theoretical boundary below which a slope is no longer stable and experiences failure. Minimum factors of safety greater than 1.0, such as those stated above, are typically used to define the criteria for stable slope conditions in practice to help account for uncertainties in characterizing subsurface conditions and limitations of analyses used to evaluate slope stability.

6. Conclusions and Recommendations

The conditions evaluated and the results of our seepage and slope stability analyses for the two cross sections are presented in Appendix C.

6.1 Seepage

There is a low potential for underseepage or through-seepage to develop during the 10-year storm event based on our seepage analyses. The 10-year storm event water surface elevation would need to persist for at least 96 hours (4 days) for steady-state conditions to develop, based on our transient seepage analyses. The anticipated duration of elevated water surfaces during the 10-year flood event is approximately 24 hours. The County's reports regarding historical flood events with peak flows greater than the estimated 10-year storm event design flow (5,010 cfs) suggest that steady-state conditions have not developed through the north levee during those previous flood events. The County has not reported or observed evidence of through-seepage daylighting on the north levee exterior slope or evidence of underseepage, such as sand boils beyond the exterior toe of the north levee during or following those events. It is our opinion that steady-state conditions would likely not develop during the design 10-year storm event on Arroyo Grande Creek based on our analyses and County reports, and that no special recommendations to mitigate seepage are needed for the design of the north levee improvements. It should be noted that the potential for seepage-related hazards increases for storm durations exceeding the 10-year event. Storm events with longer recurrence intervals (and longer durations) have not been evaluated for this project.

Pore pressure contours estimated by the transient seepage analyses are presented in Appendix C for time periods of 0.1 hours, 1.1 hours, 3 hours, 8 hours, and 24 hours after the start of the 10-year storm event. The hydraulic boundary condition corresponding to the peak water surface elevation of the 10-year storm event was applied at 0.1 hours. Subsequent hydraulic boundary conditions are time-dependent and correspond to water surface elevation estimates based on the Waterways (2020) hydrograph depicted in Figure 4. The subsurface materials approximately 5 feet beneath the levee exterior slope and flood wall toe are estimated to remain unsaturated (i.e., negative pore pressure) during the 10-year storm event.

Fine-grained alluvium (unit Qal3) encountered at a shallow depth below the levee provides a blanket layer of relatively impervious material that limits underseepage through the foundation soil. The Qal3 unit was not encountered at a shallow depth below the proposed flood wall location or below the levee between approximately Stations 103+00 and 135+00, as shown on Plates 2a and 2b. DWR (2015) states that levees and flood walls without a blanket layer do not meet typical performance criteria for underseepage. As discussed by Fugro (2012b), the potential susceptibility of the north levee to adverse underseepage during a 50-year flood event is potentially influenced by the depth to the relatively impervious Qal3 unit (i.e., blanket layer). Exit gradients estimated by Fugro (2012b) based on steady-state conditions for the 50-year storm event did not meet performance criteria where the Qal3 unit was not present directly below the levee fill. Those analyses results show the potential vulnerability of the levee to underseepage during storm events with longer recurrence intervals than the design 10-year storm event.

6.2 Slope Stability

The results of our slope stability analyses for the section at Station 123+23 are shown in Table 2 and Appendix C. There is a low potential for slope instability resulting from seepage during the 10-year storm event based on our slope stability analyses. Slope stability results for the exterior slope during full flood conditions and the interior slope following rapid drawdown meet typical performance criteria. As noted above, steady-state seepage conditions are generally more adverse for slope stability than transient seepage conditions. Therefore, slope stability analyses based on transient conditions were considered unnecessary.

We understand that the County will address the potential for ongoing erosion or surficial instability of slopes through their normal operation and maintenance of the levee. The County plans to continue monitoring levee slopes during and following storm events and repair levee slopes, as necessary.

Table 2: Results of Slope Stability Analyses

Section	Levee Slope	Factor of Safety	
		Seepage During Full Flood Event (Exterior Slope)	Rapid Drawdown (Interior Slope)
123+23	Exterior	3.35	1.64

6.3 Grading – General

6.3.1 Clearing and Grubbing

Clearing and grubbing should be performed to remove existing vegetation and objectionable material from improvement areas that will be graded, receive fill, or serve as borrow sources. Grubbing should include removing stumps, roots and buried vegetation. Care should be taken not to injure trees, plants or existing improvements outside of the clearing limits. Soil containing pavement, debris, organics, unsuitable, loose or disturbed materials should be removed prior to placing fill. Demolition areas should be cleared of old foundations, existing fill, pavement, abandoned utilities, and soil disturbed during clearing and grubbing. Depressions or disturbed material left from the removal or demolition of materials should be replaced with compacted fill.

6.3.2 Compaction and Grading

Fill placement and grading operations should be performed according to the recommendations of this report. Table 3 provides a summary of the recommended minimum levels of compaction for locations where fill will be placed. Relative compaction should be assessed according to the latest approved edition of ASTM Standard Test Method D1557.

Table 3: Recommended Relative Compaction

Location of Fill Placement	Recommended Minimum Relative Compaction
General	90% U.O.N. [1]
Utility trench bedding, pipe zone or backfill	90% U.O.N.
Fill or backfill placed within 3 feet of finished grade in pavement areas	95%
Aggregate base, or subbase	95%

6.3.3 Fill Placement

Fill should be mechanically compacted. Jetting or ponding should not be permitted for placement or compaction of fill materials. Fill materials should be moisture conditioned and spread in lifts that are suitable for compaction with the equipment being used. Control of compaction layer thickness will be necessary to achieve compaction throughout the material being placed.

Fill should typically be spread in loose lifts of no more than 8 inches, and within approximately 2 percent of the optimum moisture content, to achieve the recommended compaction. Each layer should be spread evenly, bladed and mixed to provide relative uniformity of material within each layer, and be moisture conditioned by adding water or drying the material to provide a moisture content suitable for compaction. Soft or yielding materials should be removed and replaced with properly compacted fill material prior to placing the next layer of fill. Fill and backfill materials may need to be placed in thinner lifts to achieve the recommended compaction with the equipment being used.

Particles greater than half the compacted lift thickness can limit compactive effort. The fill should not contain rocks, gravel or other solid particles larger than 3 inches in the greatest dimension. Deleterious materials, such as concrete or pavement rubble, metal, glass or sharp objects should not be placed within the fill material being placed. Recycled or reused materials should only be used and placed within the fill when specifically permitted by the project specifications. Rocks should not be nested, and voids should be filled with compacted fill material.

[1] U.O.N. – unless otherwise noted

6.3.4 EROSION AND DRAINAGE CONSIDERATIONS

Drainage should be provided such that surface water does not run over slopes or pond on pavement. Concentrated flows and runoff should not be permitted to discharge on slopes. Down drains, solid pipes, or lined ditches should be provided where needed to carry surface water from the top of the slope to the base of the slope. Energy dissipation and erosion control devices should be provided at the outlet of drain pipes and in areas of concentrated runoff to reduce the potential for erosion. Graded slopes will be vulnerable to erosion. Landscaping and maintenance of graded slopes should be provided to assist the establishment of vegetation and reduce the potential for erosion.

6.3.5 SUGGESTED MATERIAL SPECIFICATIONS

Standard Specifications refers to the 2018 edition of the Standard Specifications published by the California Department of Transportation. The following specifications are suggested for materials recommended in this report.

Aggregate Base. Aggregate base shall consist of imported material conforming to Section 26-1.02C of the Caltrans *Standard Specifications* for Class 3 Aggregate Base.

Compacted Fill. Compacted fill material shall consist of imported or on-site material free of organics, oversize rock (greater than 3 inches), trash, debris, corrosive, and other deleterious materials. Fill and borrow sources shall be reviewed by the Engineer before being imported to the site. Fill materials shall comply with all specified material requirements for the designated placement location at the site. Fill materials used in structure locations shall not include expansive or collapsible materials. Fill placed within 3 feet of the grading plane shall have an R-value of at least 25 when tested according to California Test 301.

6.3.6 REUSE OF EXCAVATED ONSITE MATERIAL

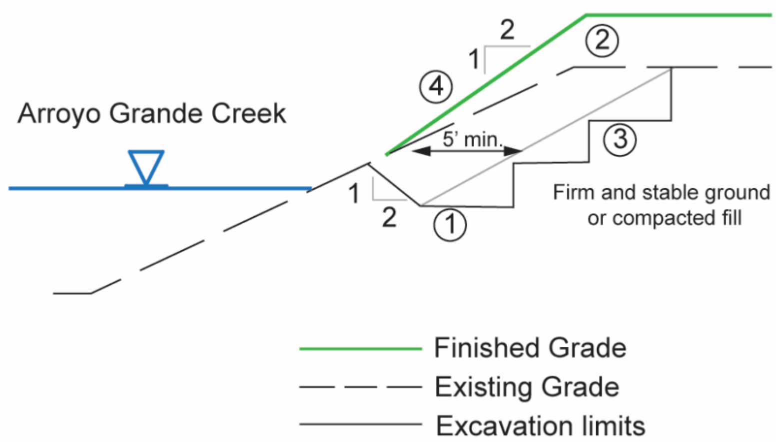
Anticipated fill materials for the project include common borrow for constructing the levee berm, and structure backfill for the proposed flood wall. The new fill will be predominantly derived from sediment removed from the project's proposed sediment and vegetation management sites. On-site creek channel and alluvial deposits that are free of debris, organics, oversized rocks, and other deleterious materials should be suitable for use as compacted fill.

Selected soil (silty sand [SM], sand with silt [SP-SM], and sand [SP]) may be suitable for use as structure backfill for flood wall construction. These materials may be interbedded with fine grained soils that are not considered suitable for structure backfill. Segregation and processing of the on-site sandy materials may be needed to make the excavated material suitable for use as structure backfill. Granular material recovered from sediment management should be stockpiled separate from other soil if the material appears suitable for reuse as structure backfill.

6.4 Grading for Levee Improvements

The existing north levee embankments will be raised approximately 2 feet above the existing levee crest elevations along most of the alignment. We understand that the typical embankment section will be approximately 9 feet wide at the top and constructed with interior and exterior slope inclinations of 2h:1v. The raised levee section will be designed with sliver fills placed against the existing interior and exterior levee slopes to provide the 9-foot minimum crest width.

Where new embankment is constructed against an existing slope, the fill materials should be keyed and benched into the existing slope. We understand the County's preference is to place sliver fills on the interior slope rather than the exterior slope, where site conditions allow, and the placement of fill will not extend to the base of the existing slopes. The recommended grading for levee improvements is summarized in Figure 6. Fill material and placement should be performed according to the recommendations of this report.



1. Excavate base key into firm and competent material at the toe of the proposed fill.
2. Place compacted fill per recommendations of the report.
3. Key and bench into existing embankment slope such that the outer 5 feet of the existing embankment is removed. Existing fill and excavated soil can be incorporated into the new fill.
4. Overbuild slope and cut back to expose compacted fill at finished grade.

Figure 6: Typical Levee Grading Detail

Keying and benching should remove the outer 5 feet of the existing levee embankment materials to improve the existing embankment slopes impacted by rodent burrows and deep-rooted vegetation. The upper 9 inches of the top of the embankment should be scarified and recompacted to at least 90 percent relative compaction.

Burrowing animals and large buried roots of vegetation such as trees that have been removed as part of a vegetation management program can cause extensive void systems. Subsurface voids generally shorten flow paths through the levee and increase the potential for seepage-related hazards and slope instability. Figure 7 illustrates the potential for seepage-related levee failure mechanism due to burrowing animals. We observed rodent burrows on the interior and exterior slopes (see Figure 3) and Fugro (2012b) reported probing the levee slopes by hand to depths of up to 4 feet. The potential for instability of loose surficial soil and seepage-related hazards during relatively long-duration storm events would be improved by removal and replacement of the outer 5 feet of the existing levee embankment.

It should be anticipated that new levee slopes keyed into and supported by existing levee slopes will be susceptible to instability of the underlying existing slopes that are disturbed by rodent burrows or deep-rooted vegetation. The new levee slopes between approximately Station 123+00 and 123+40 will be susceptible to surficial instability due to the proposed 1h:1v inclination, and regular maintenance to repair or re-grade the slope should be anticipated. We understand the County plans to implement a slope monitoring program to review levee slopes for evidence of instability on a regular basis. The slope monitoring program should also document evidence of burrowing animals and deep-rooted vegetation.

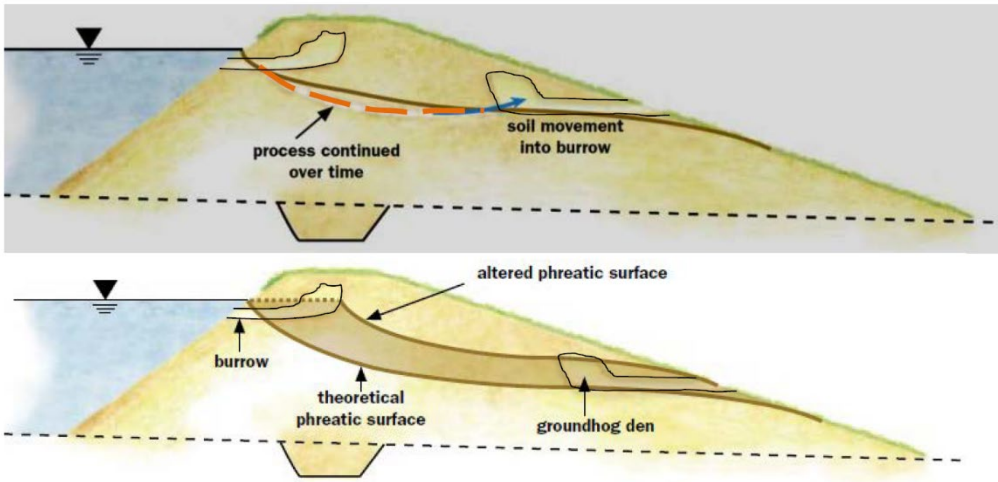


Figure 7: Seepage-related levee failure mechanism due to burrowing animals (FEMA, 2005)

We recommend that the geotechnical engineer review the limits of excavations and benching during grading operations to evaluate whether the excavation is in stable and firm material, and if the excavation should be deepened or widened to remove additional unsuitable material prior to placing fill. The project specifications should provide for variations in the limits of excavation, and for removal of additional loose or unsuitable material beyond the specified limits of keying and benching, if needed.

6.5 Flood Wall Design

The proposed flood wall will consist of an L-shaped cantilevered cast-in-place wall. The top of wall elevation (el. 45 feet) will be one foot higher than the north levee crest at approximately Station 101+00. Preliminary calculations provided by Cannon that are based on Yeh's preliminary design input show the footing will be 4.5 feet wide with a bearing elevation of el. 40 feet. The following recommendations are provided for modifications to the flood wall design, if necessary.

6.5.1 Shallow Foundation Design

Footings bearing in compacted fill material can be designed using a maximum allowable bearing pressure of 2,500 pounds per square foot (psf). The continuous wall footing should be embedded at least 1 foot below the lowest adjacent grade in front of the flood wall. The recommended bearing pressure can be increased by 600 psf and 1,600 psf for each additional foot of footing width beyond 4.5 feet and for each additional foot of embedment, respectively, to a maximum of 4,000 pounds per square foot.

The recommended allowable bearing pressure can be increased by 1/3 when considering seismic or other transient loading conditions. The toe pressure below retaining wall footings or or edge pressure below eccentrically loaded footings, can exceed the recommended bearing pressure provided the resultant force acts within the middle third of the footing and the average pressure on the footing does not exceed the maximum allowable.

Settlement. Footings should be designed to tolerate settlement and differential movement associated with static and seismic conditions. Shallow foundations should be designed to tolerate at least 1 inch of total settlement and ¾ inches of differential settlement in 30 feet along strip footings or between foundation elements. Foundations should be designed for the estimated total settlement and to assume that at least ½ of the estimated total settlement could occur differentially across the structure.

The proposed flood wall is located in an area that may also be prone to seismic settlement. Seismic settlement could exceed those settlement tolerances recommended for static loading conditions. Seismic hazards are not being considered as part of the flood wall design.

Uplift Pressures. The design of the flood wall should consider the potential for uplift forces to act on the base of the wall. Seepage analyses of the proposed wall dimensions estimate the uplift pressures acting at the heel and toe of the wall will be approximately 205 psf and 100 psf, respectively. Estimated uplift pressures can be provided for modified wall dimensions, if needed.

Resistance to Uplift. The ultimate uplift resistance can be resisted by the dead weight of the footing plus the soil overburden pressure above the footing. The unit weight of compacted soil above the footing can be estimated as 120 pounds per cubic foot total or 58 pounds per cubic foot buoyant.

Resistance to lateral loads. Resistance to lateral loading can be provided by sliding friction acting on the base of the spread footing or mat foundations combined with passive pressure acting on the sides of the foundations bearing in compacted fill. A coefficient of friction of 0.5 should be used to estimate the sliding resistance along the bottom of footings bearing in compacted fill. A net passive resistance of 250 pounds per cubic foot, equivalent fluid weight, should be used to estimate the lateral resistance acting on the sides of the footings, considering submerged foundation conditions. A 1/3 increase in the passive value can be used when considering short term wind or seismic loads. Passive resistance should not be used for the upper one foot of soil that is not constrained at the ground surface by slab-on-grade or pavement.

6.6 Levee Access Road Section

The recommended access road section is based on the Federal Highway Administration (FHWA 2010) design methods and a traffic index (TI) of 5 provided by Cannon. The subgrade conditions were characterized as "fair" and the traffic level was characterized as "low" to develop the recommended section in accordance with the FHWA guidelines for aggregate-surfaced roads. The road section should consist of a minimum of 5 inches of aggregate base placed on compacted fill. Prior to placing aggregate base, the subgrade should be scarified to a depth of 9 inches, moisture conditioned, and compacted in-place to at least 95 percent relative compaction. Aggregate base should then be placed on the prepared subgrade and compacted to at least 95 percent relative compaction.

6.7 Construction Considerations

6.7.1 Excavation

The existing embankment fill and alluvium encountered within the depth of our explorations can likely be excavated using conventional heavy construction equipment, such as backhoes, excavators or dozers. The materials that were encountered within the anticipated depths of the excavation are not anticipated to require ripping to assist with excavation.

6.7.2 Groundwater and Dewatering

Groundwater conditions are discussed in Section 4.3 of this report. The groundwater elevation was generally encountered at elevations lower than the bottom elevation of the proposed excavations, and at approximately the same elevations as the water surface in Arroyo Grande Creek. If seepage or groundwater are encountered during excavation, the groundwater level should be lowered below the base of the excavation prior to placing fill. Dewatering procedures such as gravel wells, ditches, or gravel mats with sump pumps. Dewatering systems should be designed by a qualified professional engineer or hydrogeologist registered in California, and should be properly filtered such that soil is not eroded from the foundation soil during dewatering.

6.7.3 Temporary Slopes and Shoring

In accordance with OSHA requirements, the contractor should be responsible for job site safety, reviewing the soil conditions encountered during construction, and for the design of temporary slopes and shoring systems. Within the expected depths of excavation, the subsurface conditions encountered consisted of predominantly sandy artificial fill and alluvium. There is a potential for the excavations to encounter seepage that would result in wet soil excavations. Therefore, the soil encountered within the expected depths of excavation should be considered Type D sandy soil based on Cal OSHA. Per OSHA guidelines, Type C soil should be excavated no steeper than 1.5h:1v. Slopes should not be considered stable if seepage can daylight on the slope or groundwater is expected within the planned depths of excavation. If excavations need to extend below the groundwater table, dewatering should be provided in advance of the excavation to reduce the potential for groundwater to daylight on the slope.

6.7.4 Grading Observations

The geotechnical professional should continue to evaluate the subsurface conditions and observe key steps of the construction process. The geotechnical professional should review the limits of excavations and benching during grading operations to evaluate whether the excavation is in stable and firm material, and if the excavation should be deepened or widened to remove additional unsuitable material prior to placing fill.

7. References

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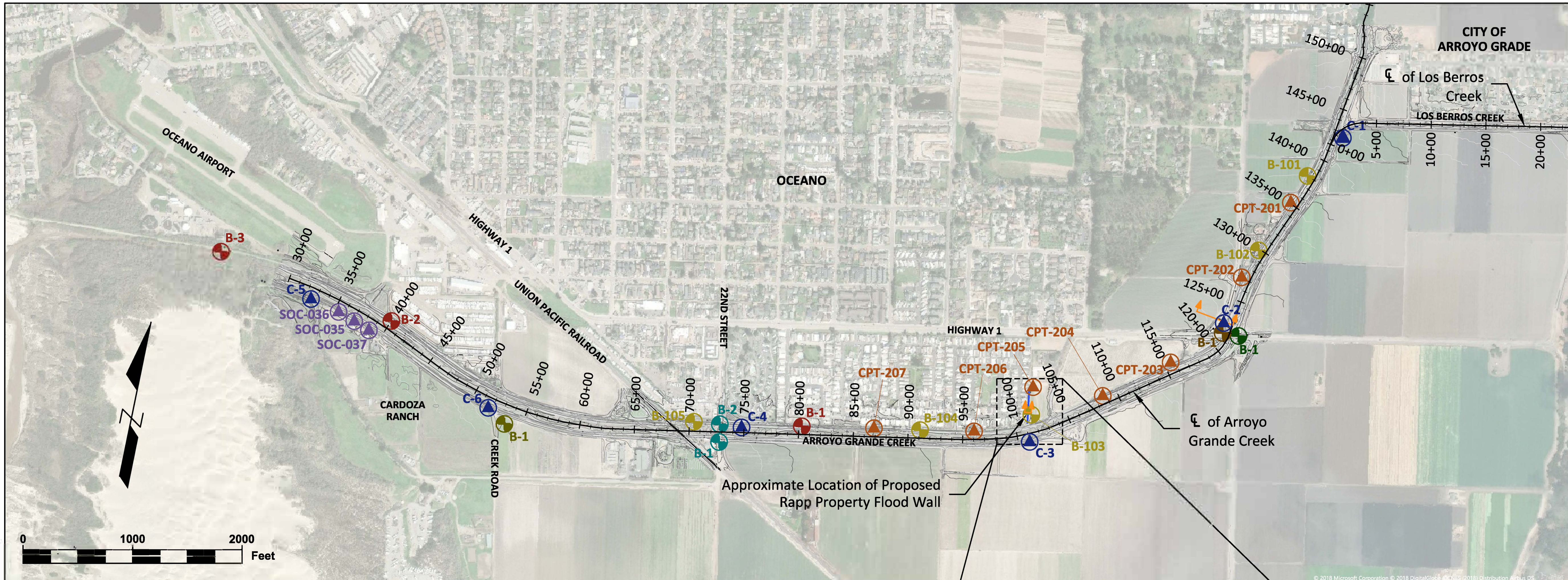

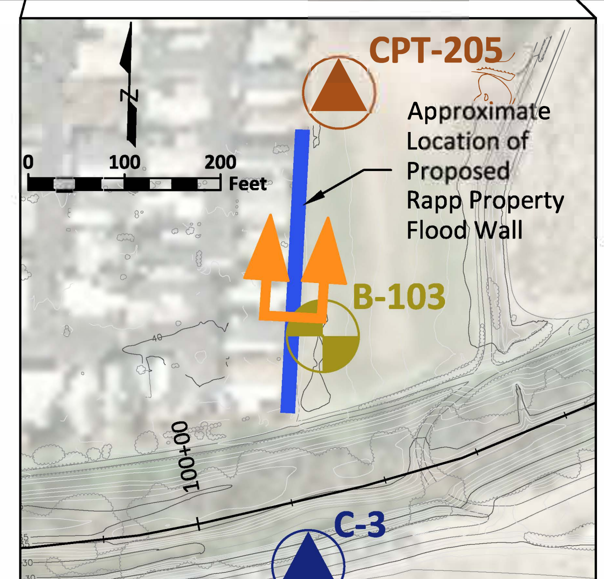

LEGEND:

- CPT-201 — CPT Location (Yeh 2019)
- B-101 — Boring Location (Fugro July 2012)
- B-1 — Boring Location (Fugro January 2012)
- C-1 — CPT Location (Fugro 2008)
- B-1 — Hand Auger Location (Fugro 2008)
- SOC-035 — SCPT Location (USGS 2003)
- B-1 — Boring Location (SLO County 1984)
- B-1 — Boring Location (Caltrans 1981)
- B-1 — Boring Location (Caltrans 1955)
- Cross Section Location for Seepage Analyses

Base Maps: Aerial image and topography per Cannon, 2019

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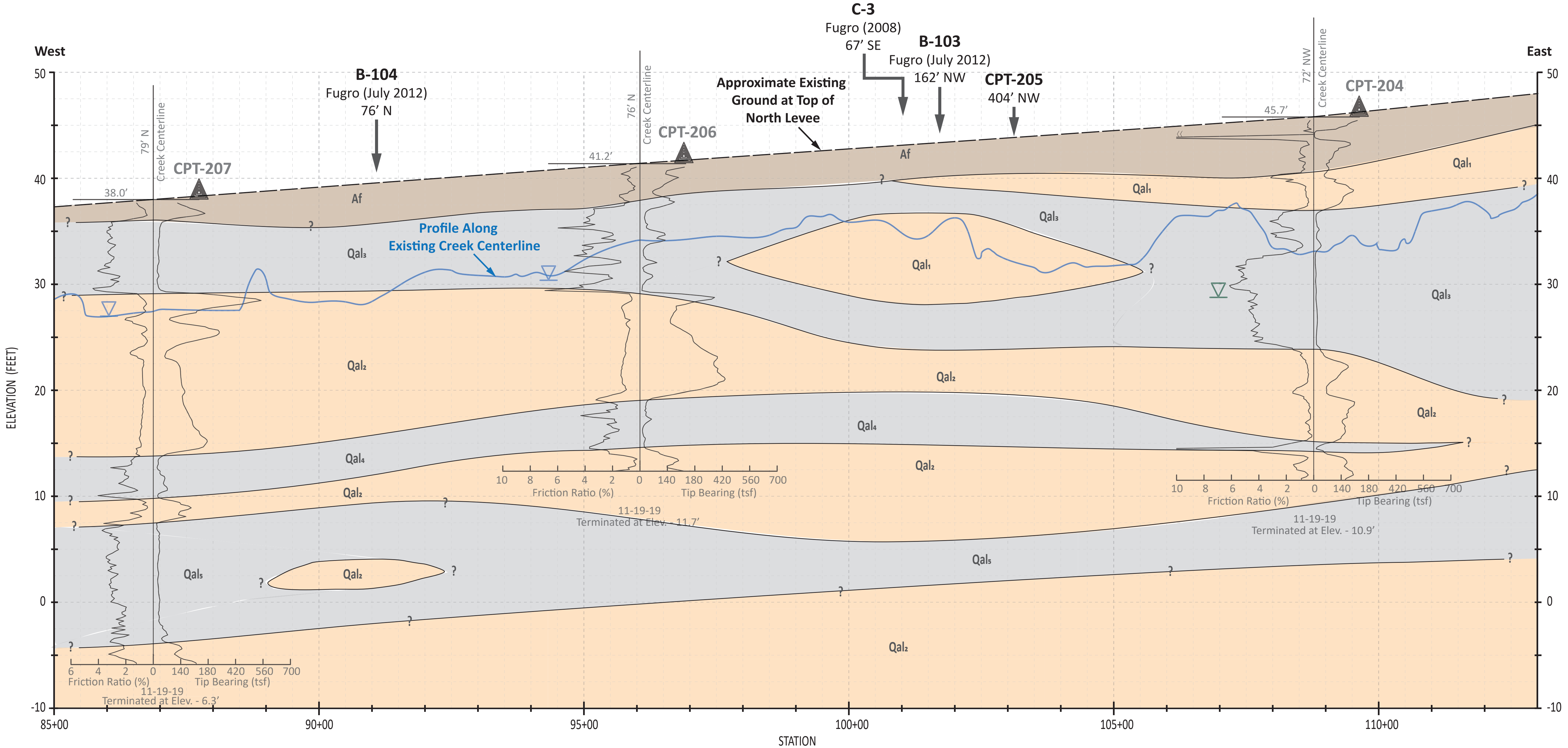
FIELD EXPLORATION PLAN

PROJECT NAME:	PLATE
ARROYO GRANDE CREEK CHANNEL WATERWAY MANAGEMENT Arroyo Grande, CA	1
PROJECT NUMBER: 218-169	REVISION DATE: 1/27/2020

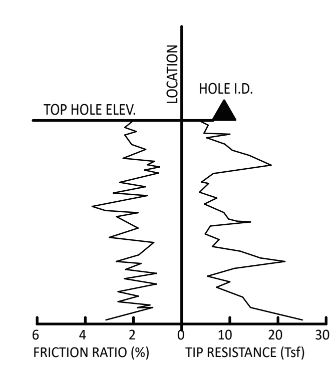


LEGEND:

— — — —	Existing ground surface	Qal	Fine-grained Alluvium
——?——	Geologic contact, queried where uncertain	▽ (blue)	Groundwater level encountered during November 2019 cone penetration testing
Af	Artificial Fill	▽ (green)	Interpreted groundwater level from caving depth encountered during November 2019 cone penetration testing
Qal	Sandy Alluvium		

See text and logs of exploration for description of subsurface conditions. All boundaries and locations are approximate.

BORING OR CPT NO.
Reference Study (If Applicable)
Offset from Creek Centerline



CONE PENETRATION TEST (CPT) DIAGRAM

PROFILE
1 in. = 10 ft. vertical
1 in. = 200 ft. horizontal

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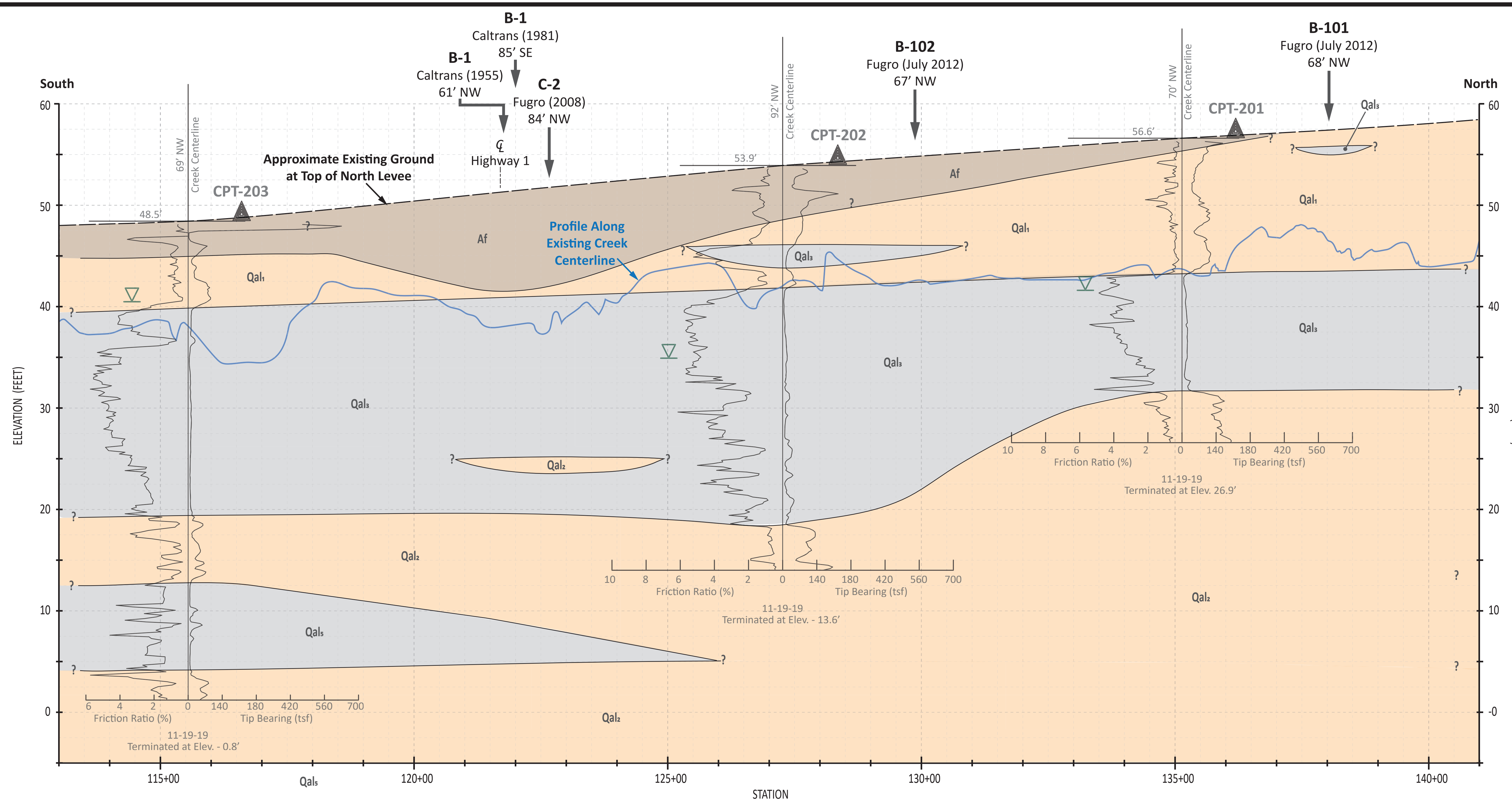
NORTH LEVEE - INTERPRETED SUBSURFACE PROFILE

PROJECT NAME:	PLATE
ARROYO GRANDE CREEK CHANNEL WATERWAY MANAGEMENT Arroyo Grande, CA	2a
PROJECT NUMBER: 218-169	REVISION DATE: 1/30/2020

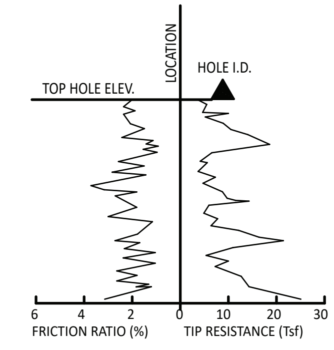


LEGEND:

— — — —	Existing ground surface
—?—	Geologic contact, queried where uncertain
Af	Artificial Fill
Qal	Sandy Alluvium
Qal	Fine-grained Alluvium
▽	Interpreted groundwater level from caving depth encountered during November 2019 cone penetration testing

See text and logs of exploration for description of subsurface conditions. All boundaries and locations are approximate.

BORING OR CPT NO.
Reference Study (If Applicable)
Offset from Creek Centerline



CONE PENETRATION TEST (CPT) DIAGRAM

PROFILE
1 in. = 10 ft. vertical
1 in. = 200 ft. horizontal

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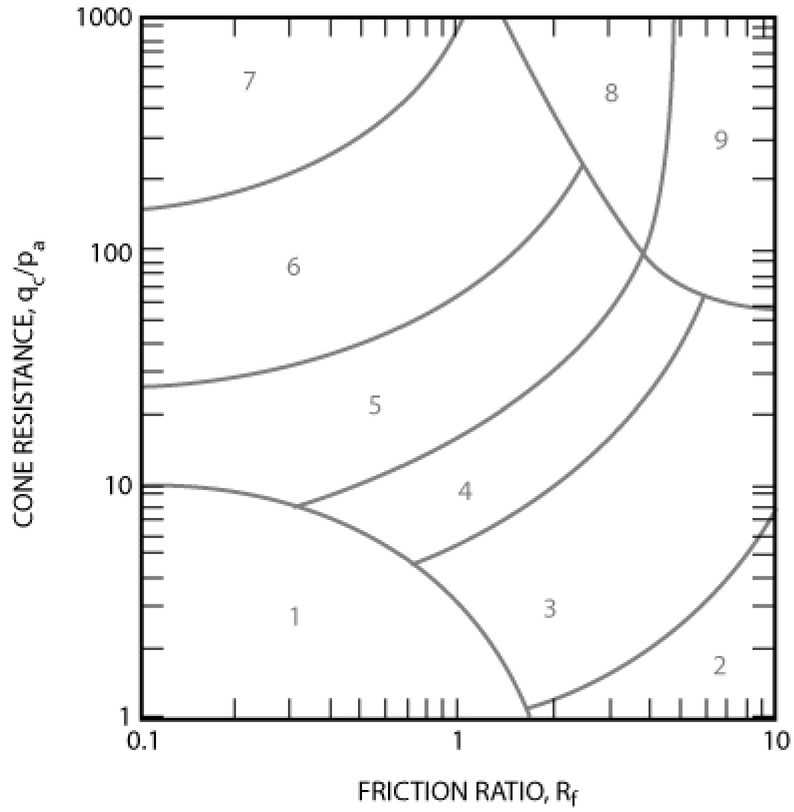
INTERPRETED SUBSURFACE PROFILE STA. 113+00 to 141+00

PROJECT NAME:	PLATE
ARROYO GRANDE CREEK CHANNEL WATERWAY MANAGEMENT Arroyo Grande, CA	2b

PROJECT NUMBER:	REVISION DATE:
218-169	1/30/2020

APPENDIX A - CONE PENETRATION TEST LOGS



Zone	Soil Behavior Type	USCS
1	Sensitive, fine grained	OL-CH
2	Organic soils - clay	OL-OH, CH
3	Clay – silty clay to clay	CL-CH
4	Silt mixtures – clayey silt to silty clay	MH-CL
5	Sand mixtures – silty sand to sandy silt	SM-ML
6	Sands – clean sand to silty sand	SW-SP
7	Gravelly sand to dense sand	SW-GW
8	Very stiff sand to clayey sand*	SC-SM
9	Very stiff fine grained*	CH-CL

* Heavily overconsolidated or cemented

P_a = atmospheric pressure = 100 kPa = 1 tsf

Non-normalized CPT Soil Behavior Type (SBT) chart
(Robertson et al., 1986, updated by Robertson, 2010).

Yeh and Associates, Inc.
Consulting Engineers & Scientists

REPORT TITLE	CPT SOIL BEHAVIOR CHART (SBT) LEGEND
PROJECT NAME	Arroyo Grande Creek Channel WMP
DATE 1/25/2020	SHEET 1 of 1

Yeh and Associates, Inc.
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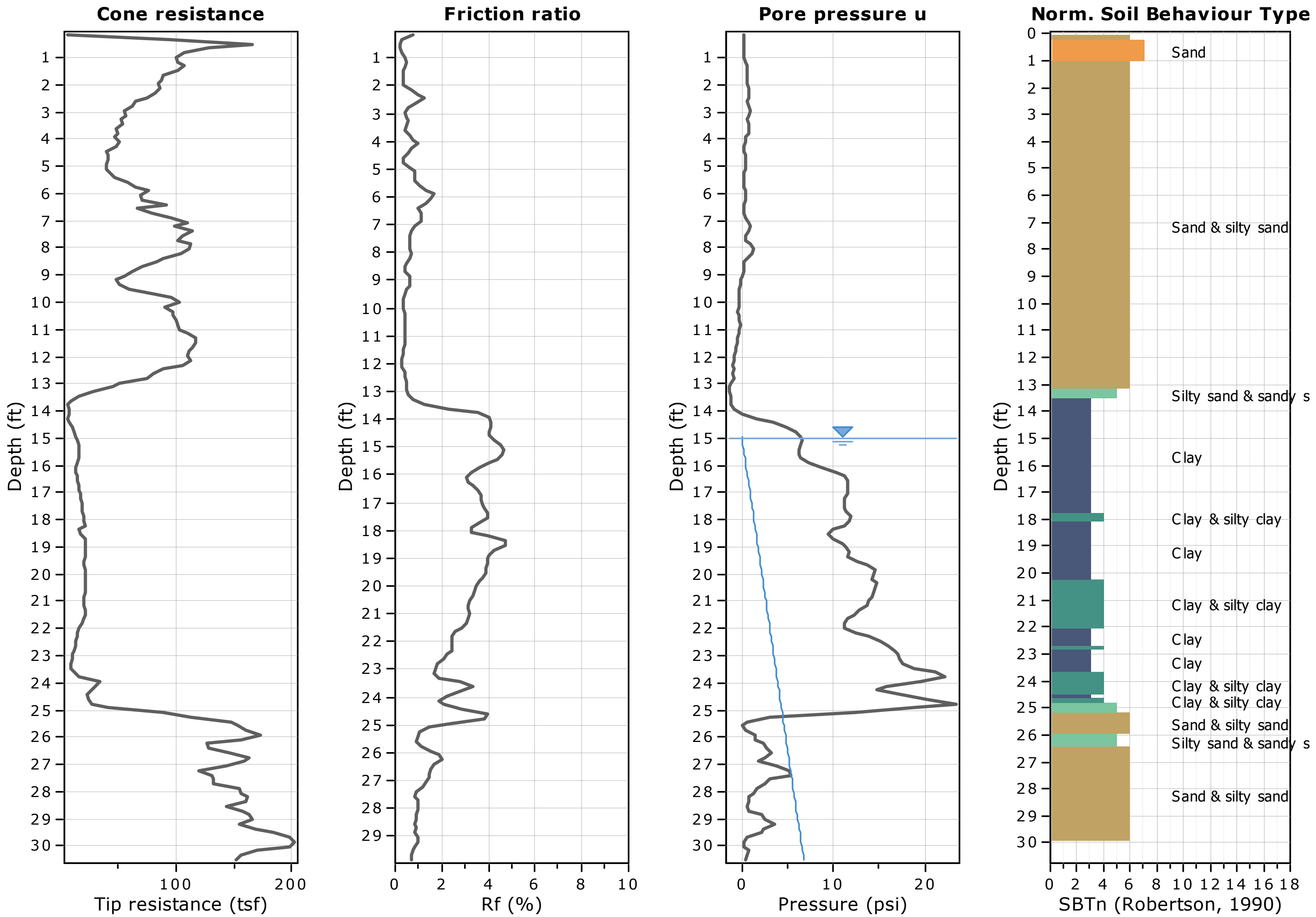
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-201
Total depth: 30.51 ft, Date: 11/27/2019
Surface Elevation: 56.60 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

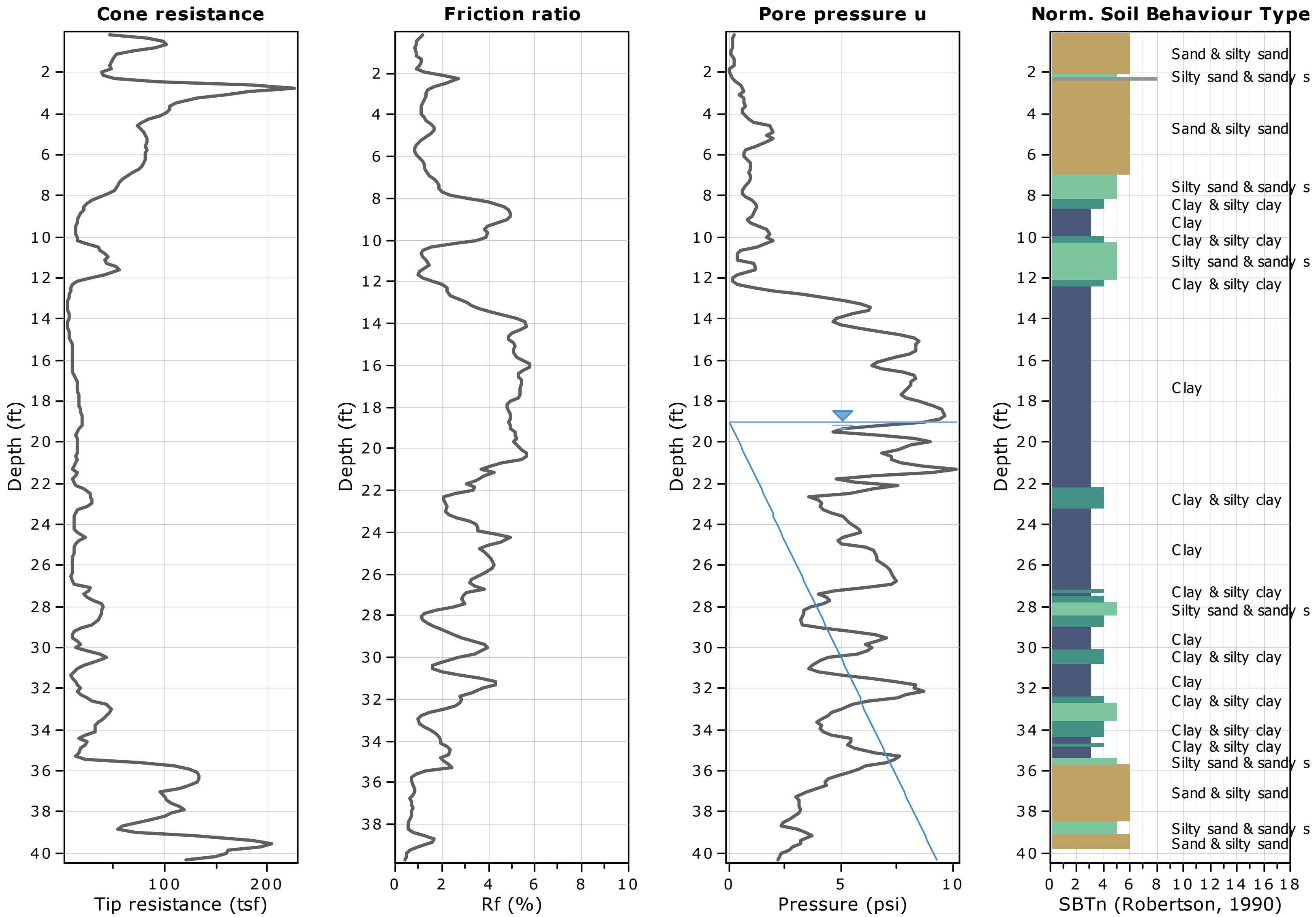
Project: Arroyo Grande Creek Waterways Management
Location: San Luis Obispo County, Ca



Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-202
Total depth: 40.35 ft, Date: 11/27/2019
Surface Elevation: 53.90 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

Project: **Arroyo Grande Creek Waterways Management**
Location: **San Luis Obispo County, Ca**



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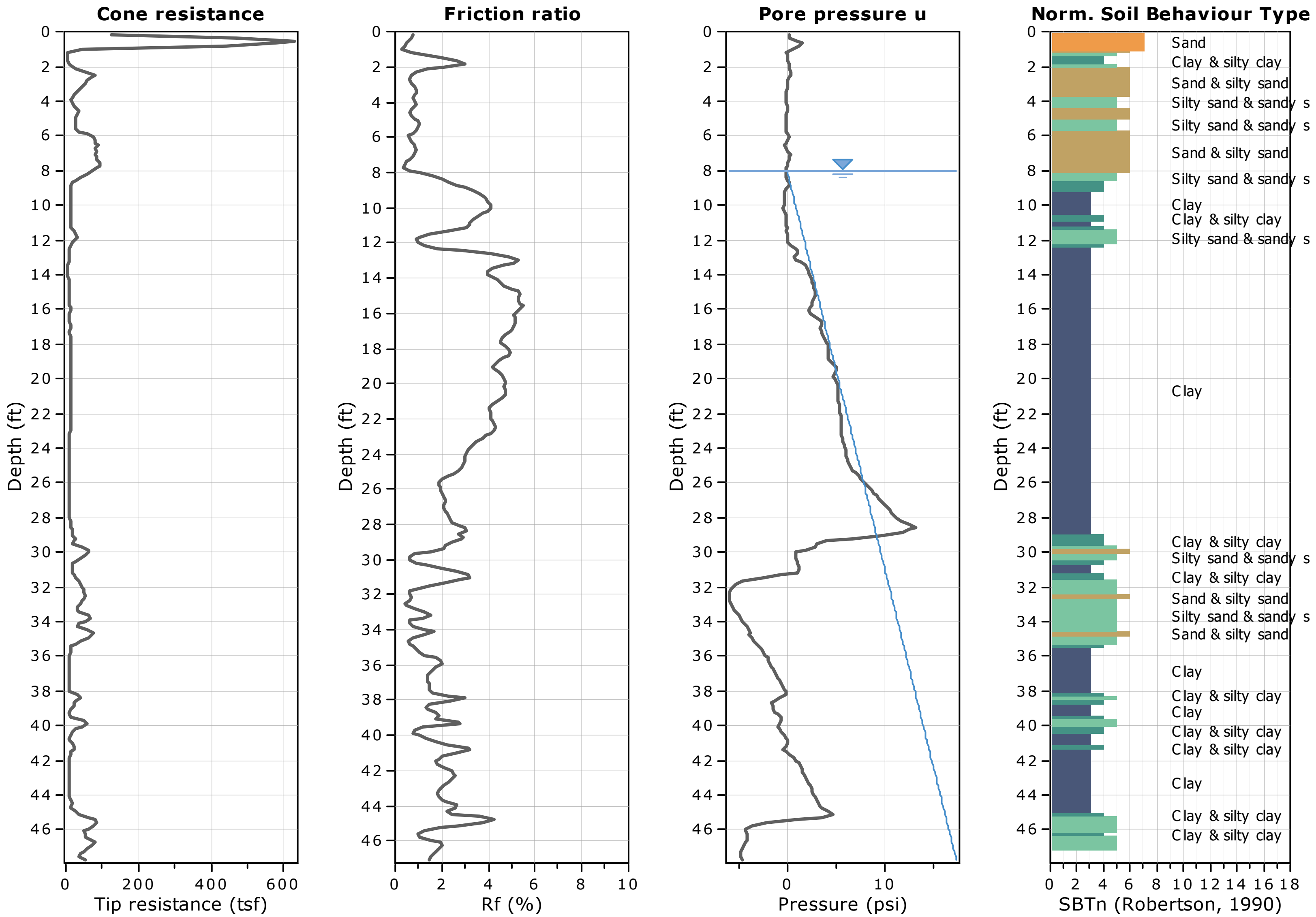
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-203
Total depth: 47.74 ft, Date: 11/27/2019
Surface Elevation: 48.50 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

Project: **Arroyo Grande Creek Waterways Management**
Location: **San Luis Obispo County, Ca**



Yeh and Associates, Inc.
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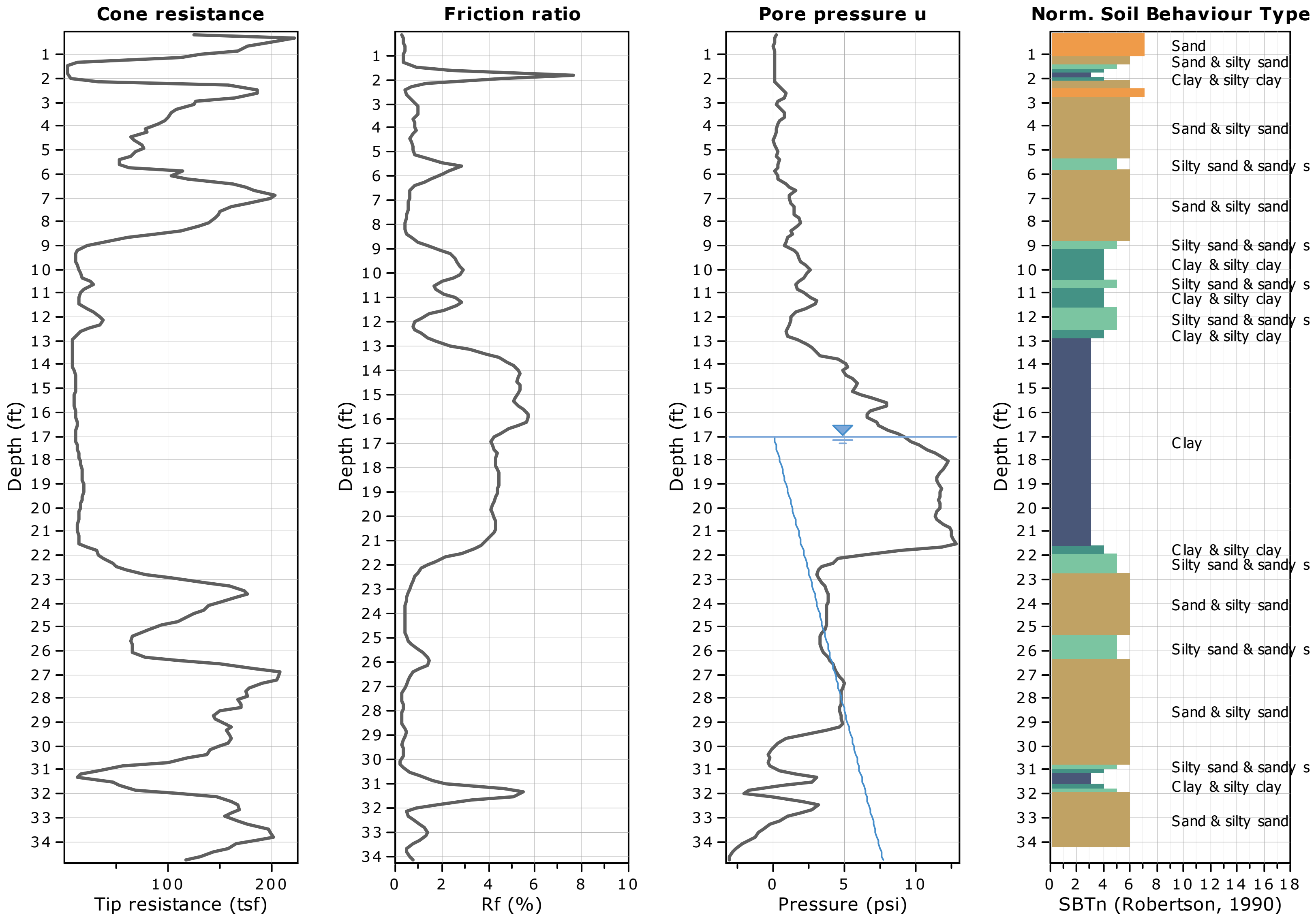
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-204
Total depth: 34.78 ft, Date: 11/27/2019
Surface Elevation: 45.70 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

Project: Arroyo Grande Creek Waterways Management
Location: San Luis Obispo County, Ca



Yeh and Associates, Inc.
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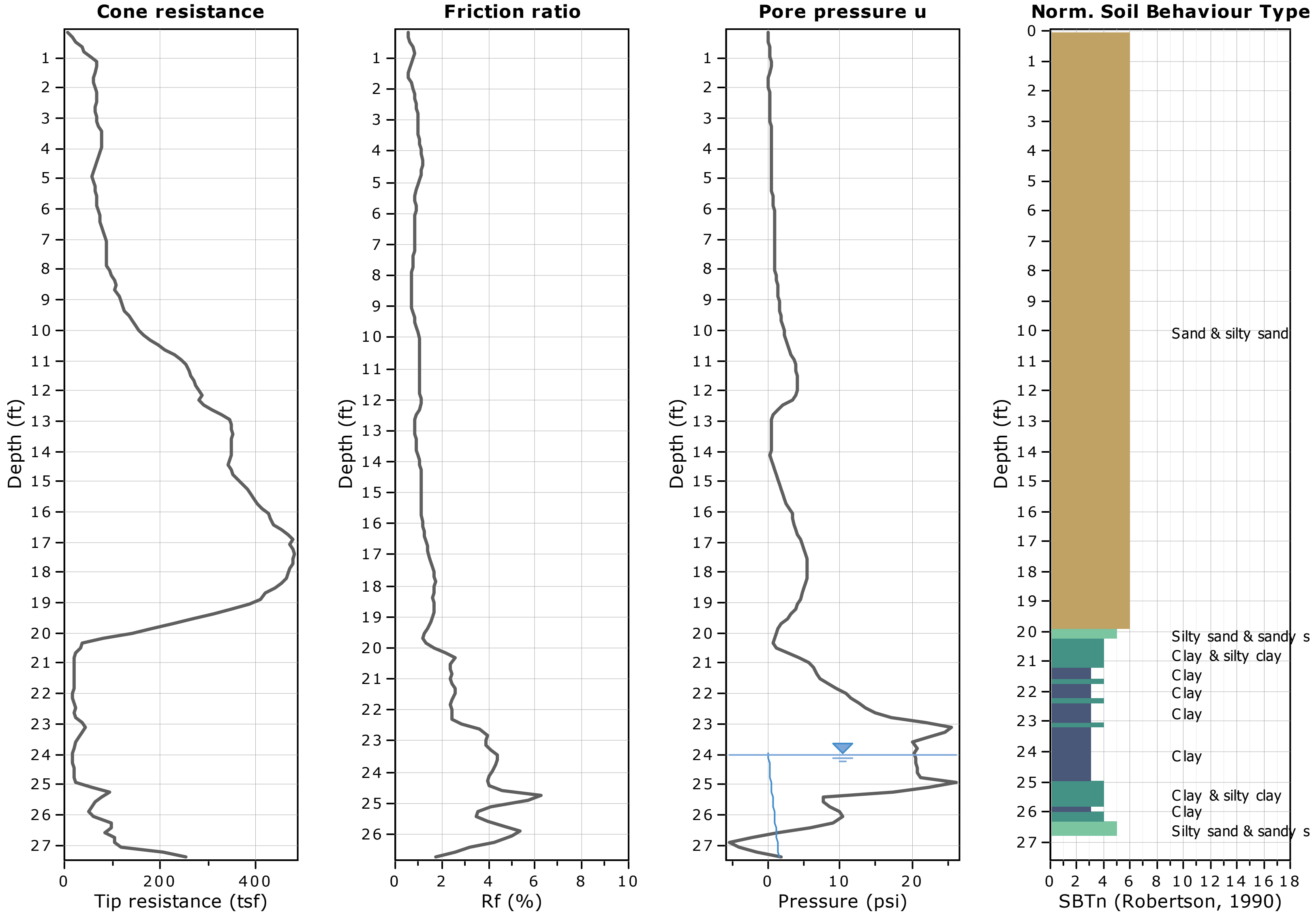
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-205
Total depth: 27.40 ft, Date: 11/27/2019
Surface Elevation: 44.00 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

Project: Arroyo Grande Creek Waterways Management
Location: San Luis Obispo County, Ca



Yeh and Associates, Inc.
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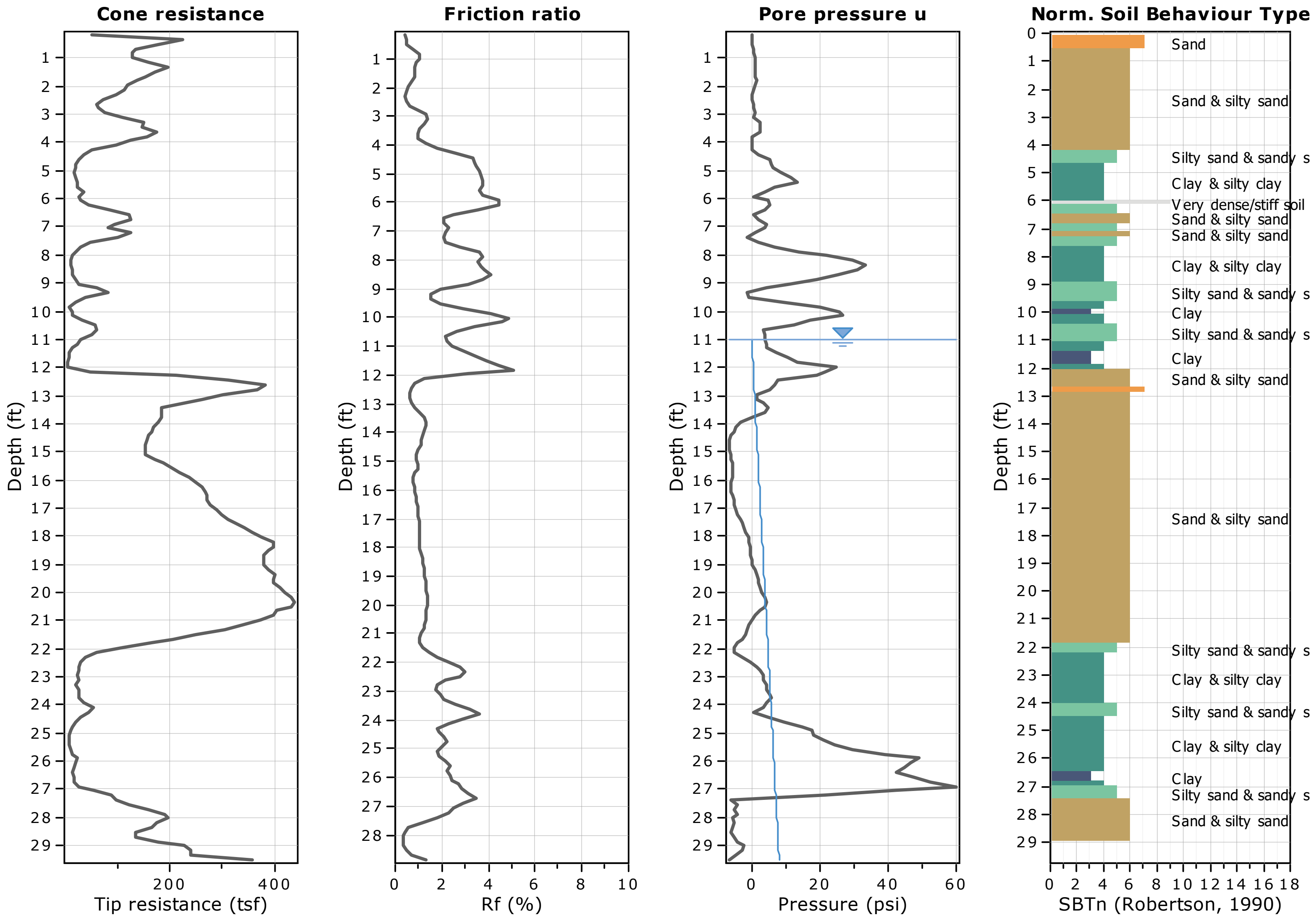
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

CPT: CPT-206
Total depth: 29.53 ft, Date: 11/27/2019
Surface Elevation: 41.20 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

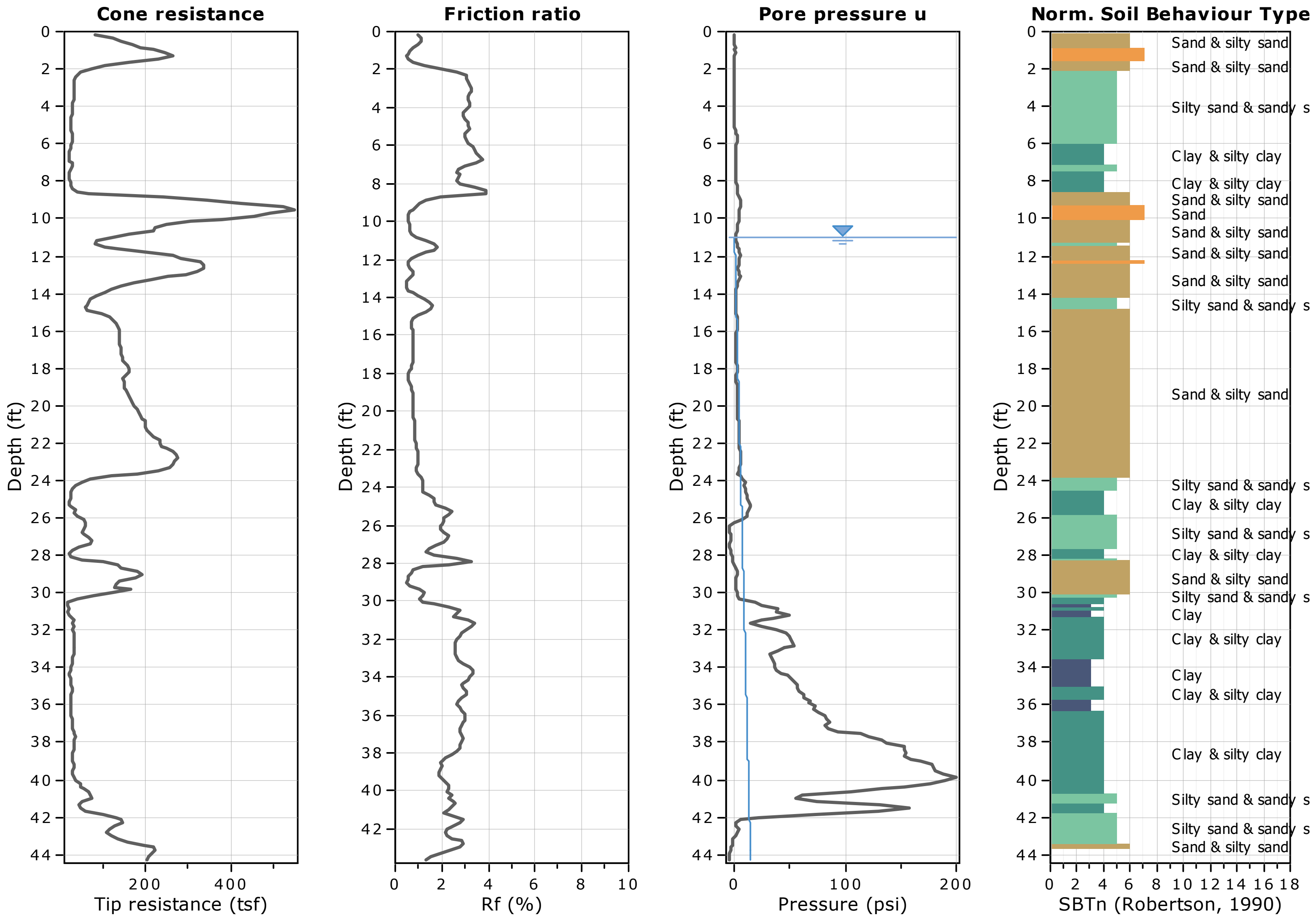
Project: Arroyo Grande Creek Waterways Management
Location: San Luis Obispo County, Ca



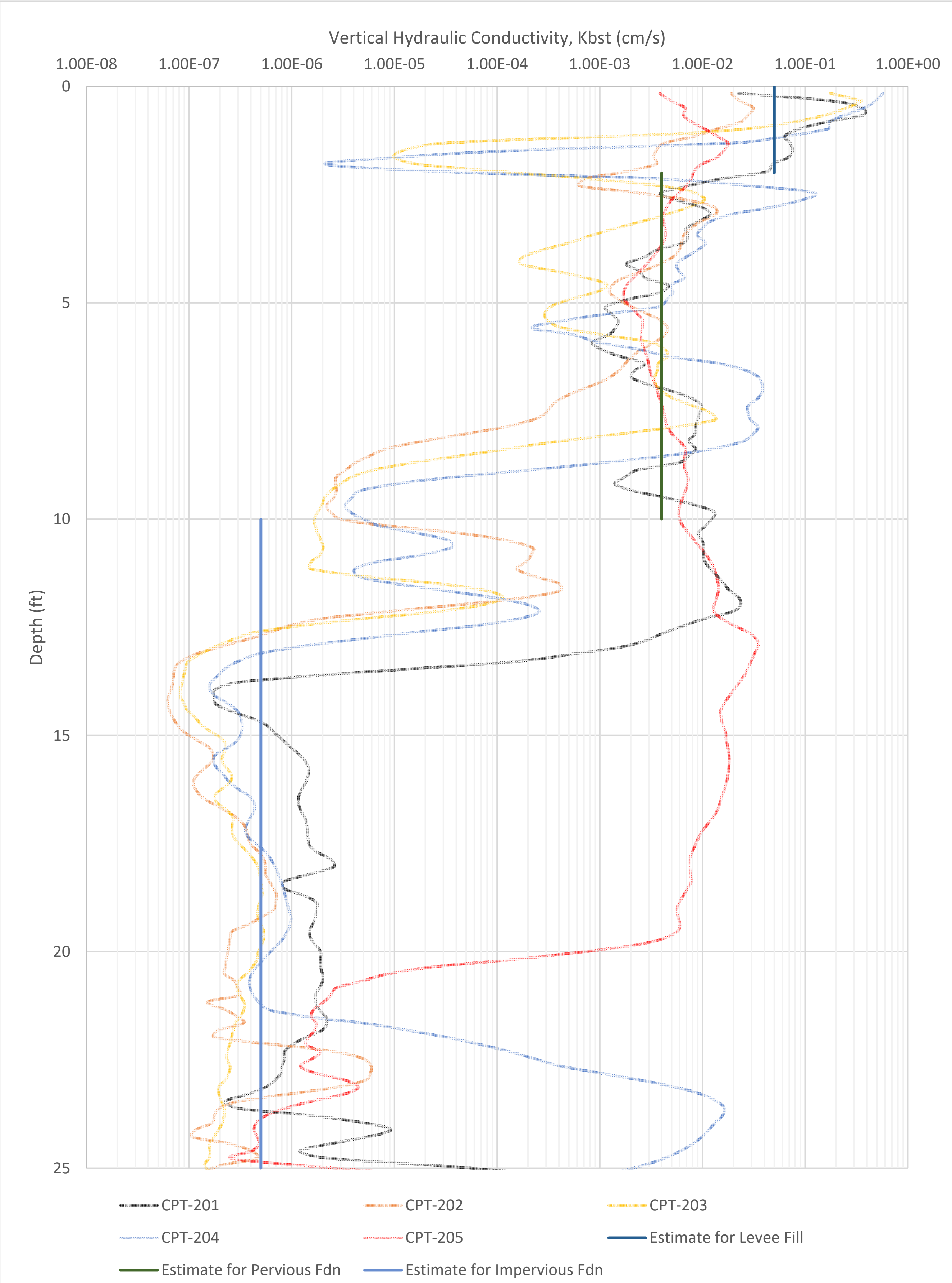
Yeh and Associates, Inc.
391 Front Street, Suite D
Grover Beach, Ca 93433

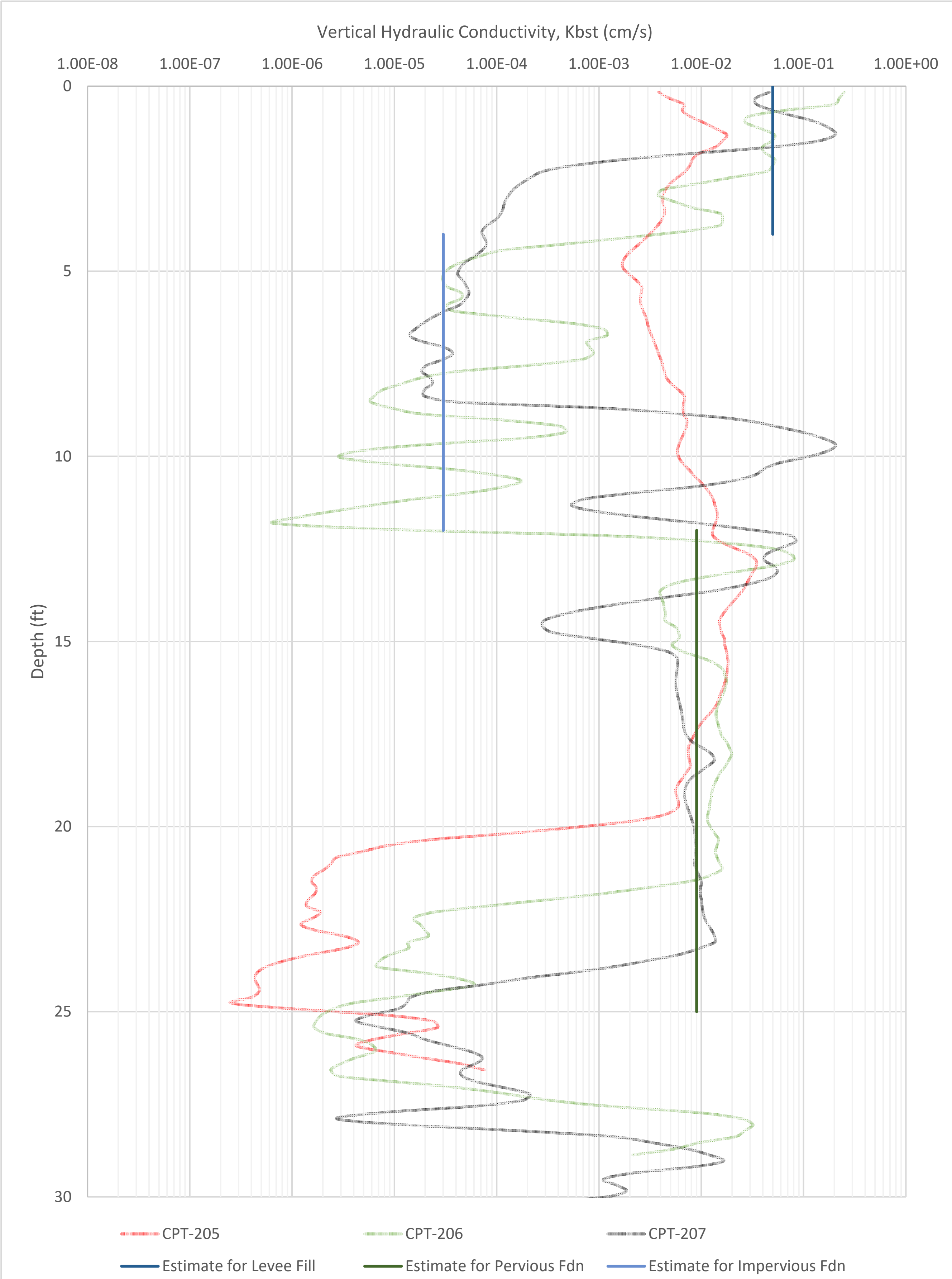
CPT: CPT-207
Total depth: 44.29 ft, Date: 11/27/2019
Surface Elevation: 38.00 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 sq. cm. Cone
Cone Operator: Middle Earth Geo Testing, Inc.

Project: Arroyo Grande Creek Waterways Management
Location: San Luis Obispo County, Ca

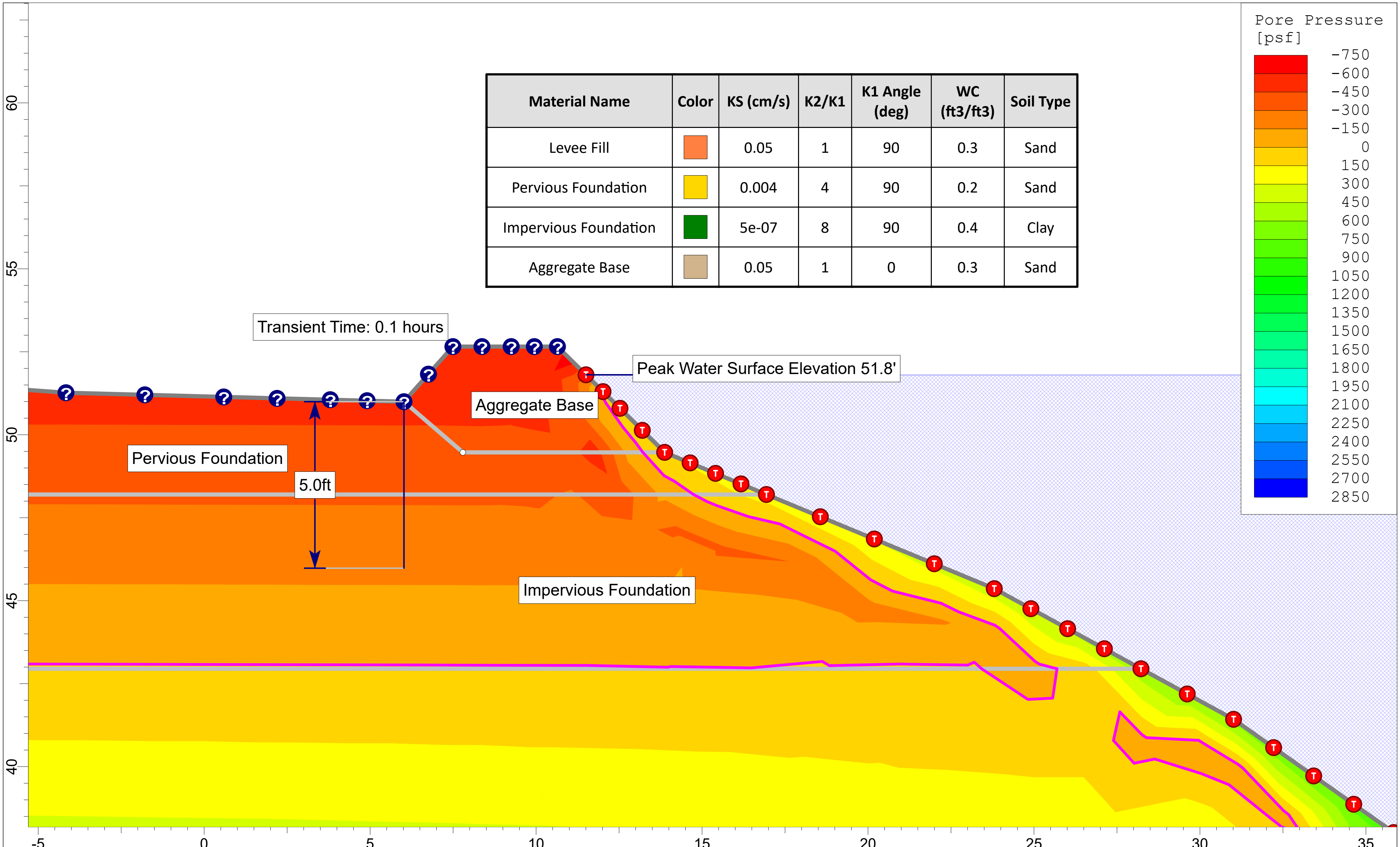


APPENDIX B - HYDRAULIC CONDUCTIVITY ESTIMATES


Vertical Hydraulic Conductivity, Kbst (cm/s)
1.00E-08
1.00E-07
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
Depth (ft)
0
5
10
15
20
25
CPT-201
CPT-202
CPT-203
CPT-204
CPT-205
Estimate for Levee Fill
Estimate for Pervious Fdn
Estimate for Impervious Fdn


Vertical Hydraulic Conductivity, Kbst (cm/s)
1.00E-08
1.00E-07
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
0
5
10
15
20
25
30
Depth (ft)
CPT-205
CPT-206
CPT-207
Estimate for Levee Fill
Estimate for Pervious Fdn
Estimate for Impervious Fdn

Appendix C - Seepage and Slope Stability Results

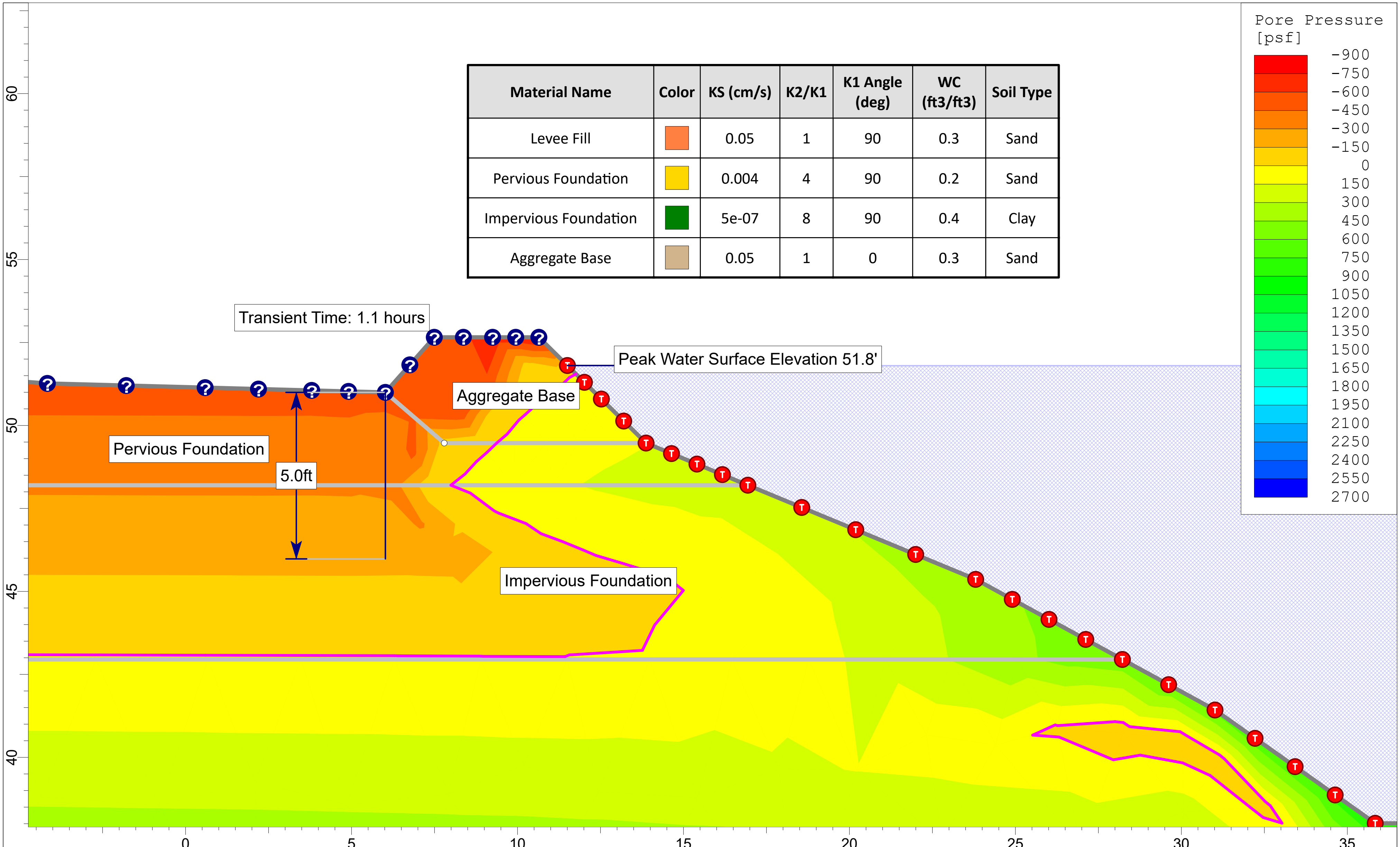


Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.004	4	90	0.2	Sand
Impervious Foundation		5e-07	8	90	0.4	Clay
Aggregate Base		0.05	1	0	0.3	Sand

rocscience

Project	Arroyo Grande Creek Levee Improvements
Analysis Description	STA 123+23 Proposed Levee_Transient
Drawn By	GDE
Scale	1:48
Company	Yeh and Associates
Date	December, 2019
File Name	sta 123+23_n levee_proposed_transient.slim

SLIDEINTERPRET 8.029



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.004	4	90	0.2	Sand
Impervious Foundation		5e-07	8	90	0.4	Clay
Aggregate Base		0.05	1	0	0.3	Sand

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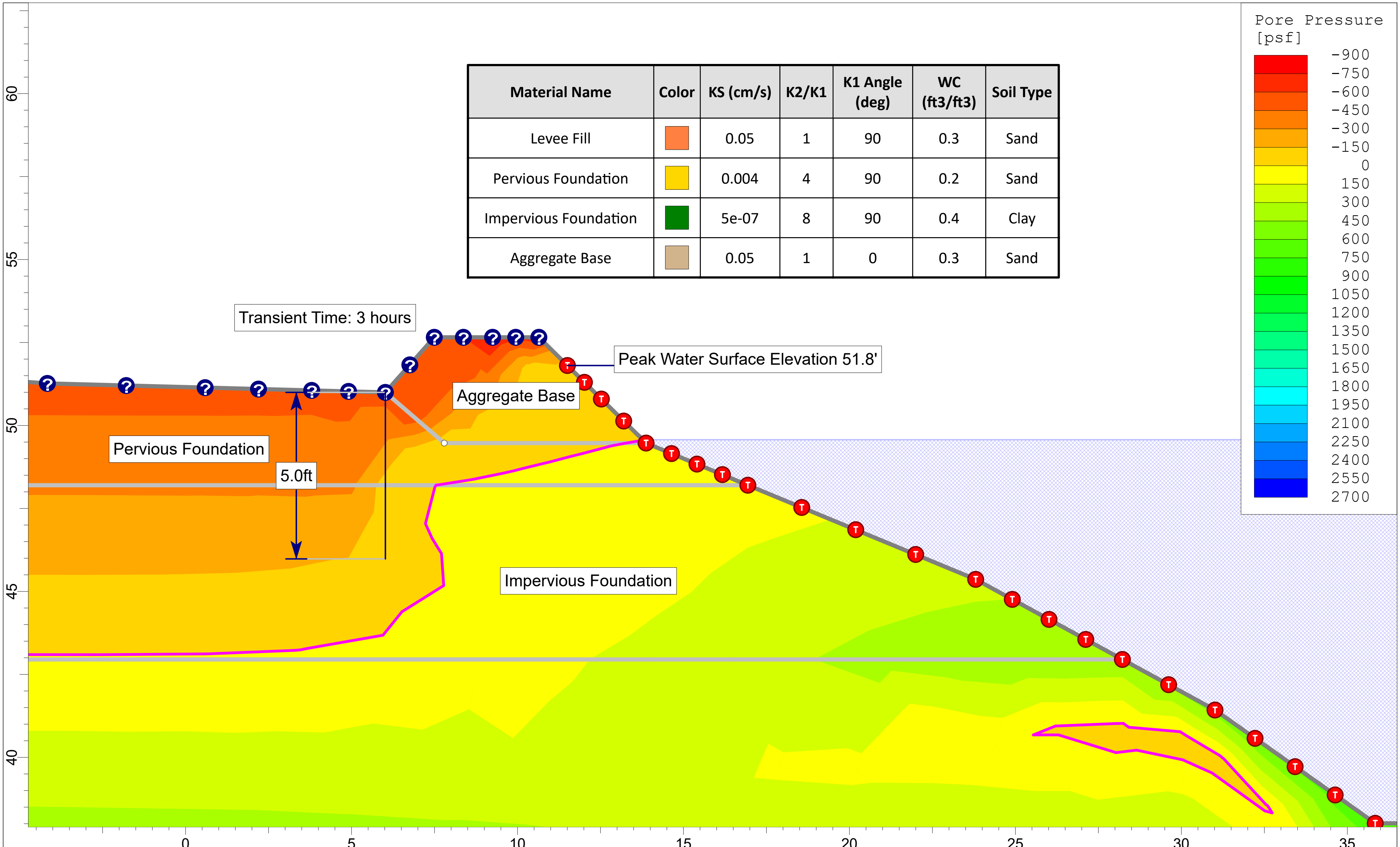
Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 123+23 Proposed Levee_Transient		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date December, 2019		*File Name*	sta 123+23_n levee_proposed_transient.slim



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
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Impervious Foundation		5e-07	8	90	0.4	Clay
Aggregate Base		0.05	1	0	0.3	Sand

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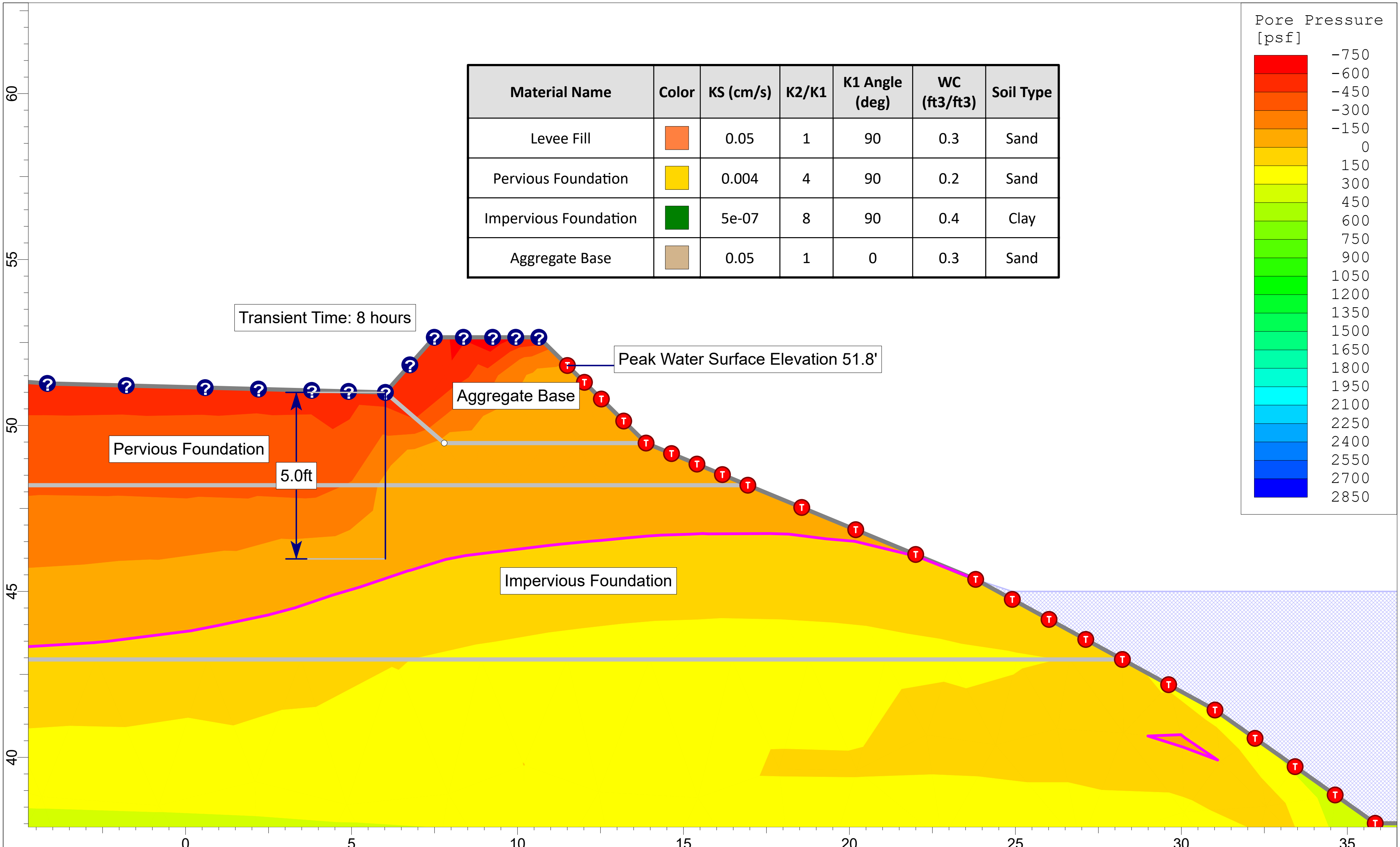
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements
Analysis Description	STA 123+23 Proposed Levee_Transient
Drawn By	GDE
Scale	1:48
Company	Yeh and Associates
Date	December, 2019
File Name	sta 123+23_n levee_proposed_transient.slim



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.004	4	90	0.2	Sand
Impervious Foundation		5e-07	8	90	0.4	Clay
Aggregate Base		0.05	1	0	0.3	Sand

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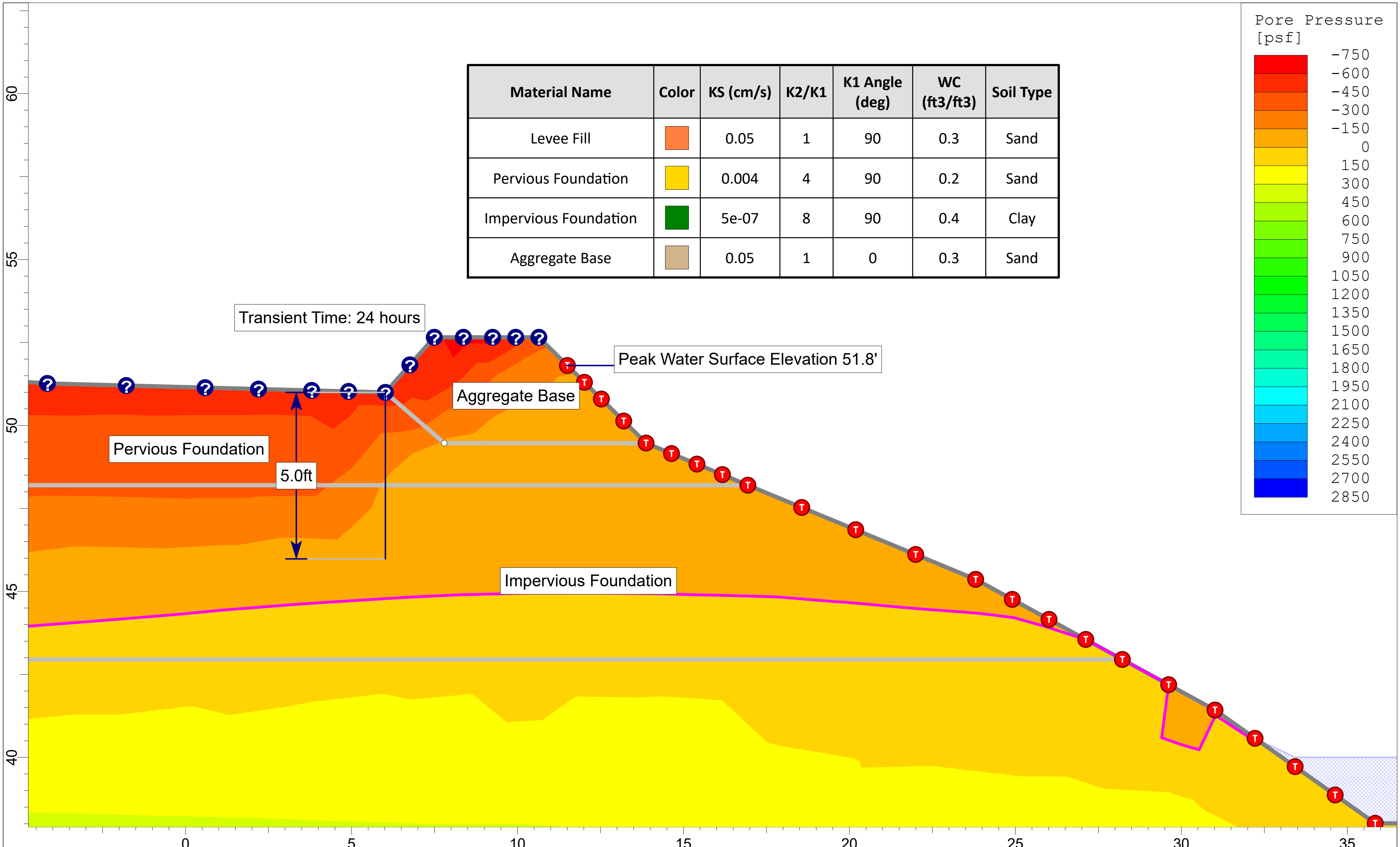
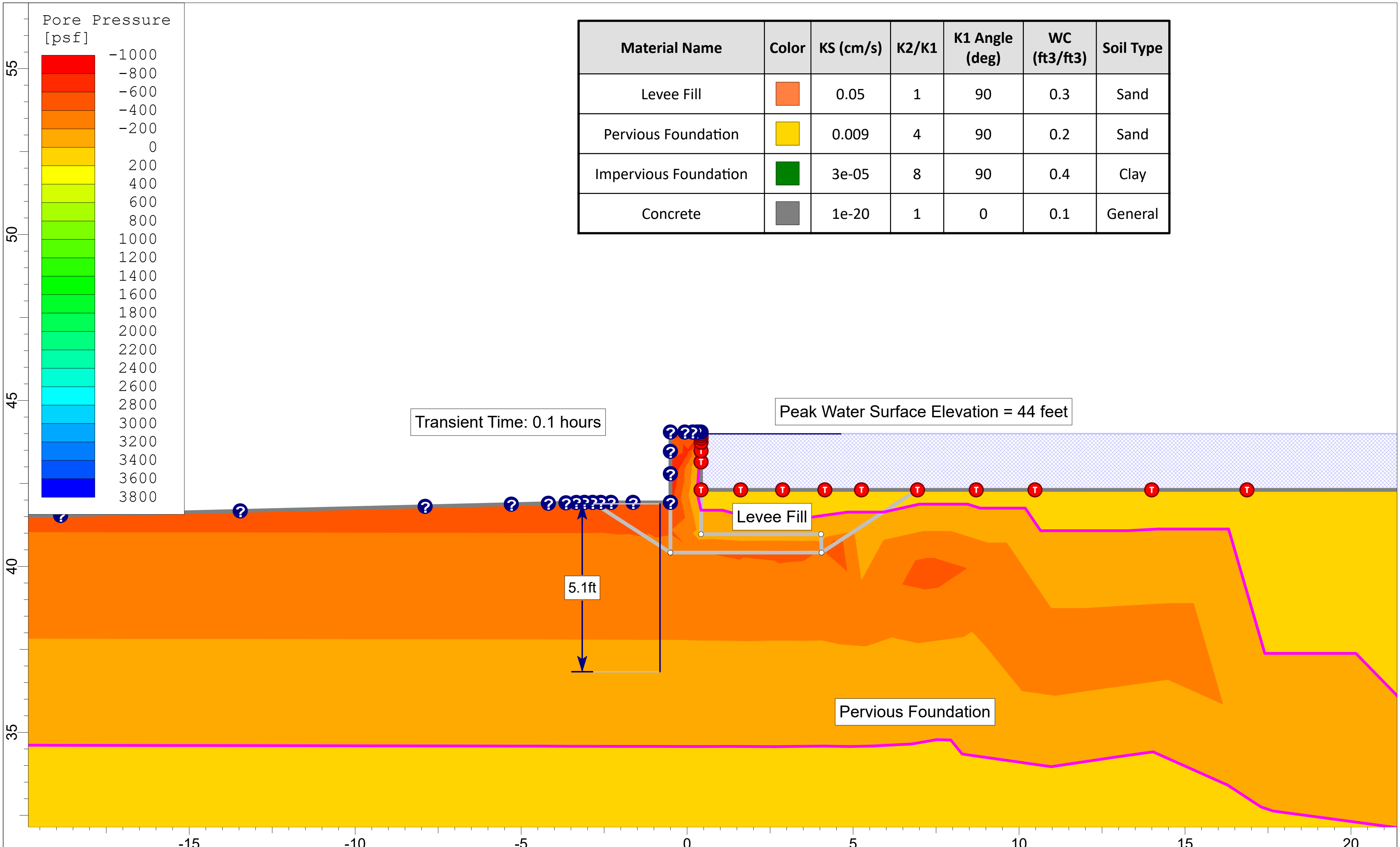
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 123+23 Proposed Levee_Transient		
Drawn By	GDE	Scale	1:48
Company	Yeh and Associates		
Date	December, 2019	File Name	sta 123+23_n levee_proposed_transient.slim



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.004	4	90	0.2	Sand
Impervious Foundation		5e-07	8	90	0.4	Clay
Aggregate Base		0.05	1	0	0.3	Sand

rocscience	*Project* Arroyo Grande Creek Levee Improvements		
	Analysis Description STA 123+23 Proposed Levee_Transient		
	Drawn By GDE	*Scale* 1:48	*Company* Yeh and Associates
SLIDEINTERPRET 8.029	*Date* December, 2019		*File Name* sta 123+23_n levee_proposed_transient.slim



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.009	4	90	0.2	Sand
Impervious Foundation		3e-05	8	90	0.4	Clay
Concrete		1e-20	1	0	0.1	General

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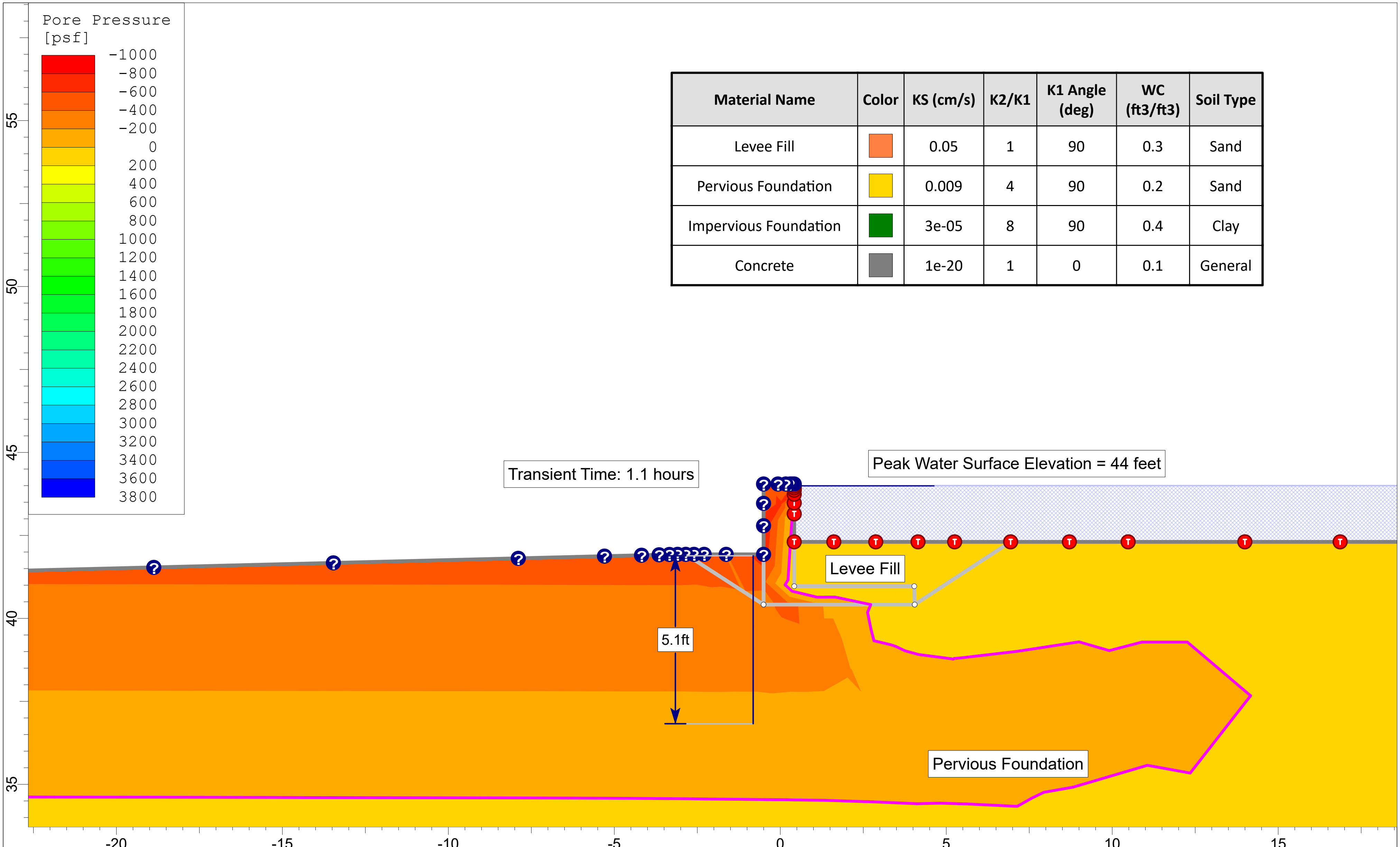
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 1+00 (Rapp Wall) Transient Seepage		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date	December 2019	*File Name*	rapp sta 1+00_floodwall_transient.slmd



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.009	4	90	0.2	Sand
Impervious Foundation		3e-05	8	90	0.4	Clay
Concrete		1e-20	1	0	0.1	General

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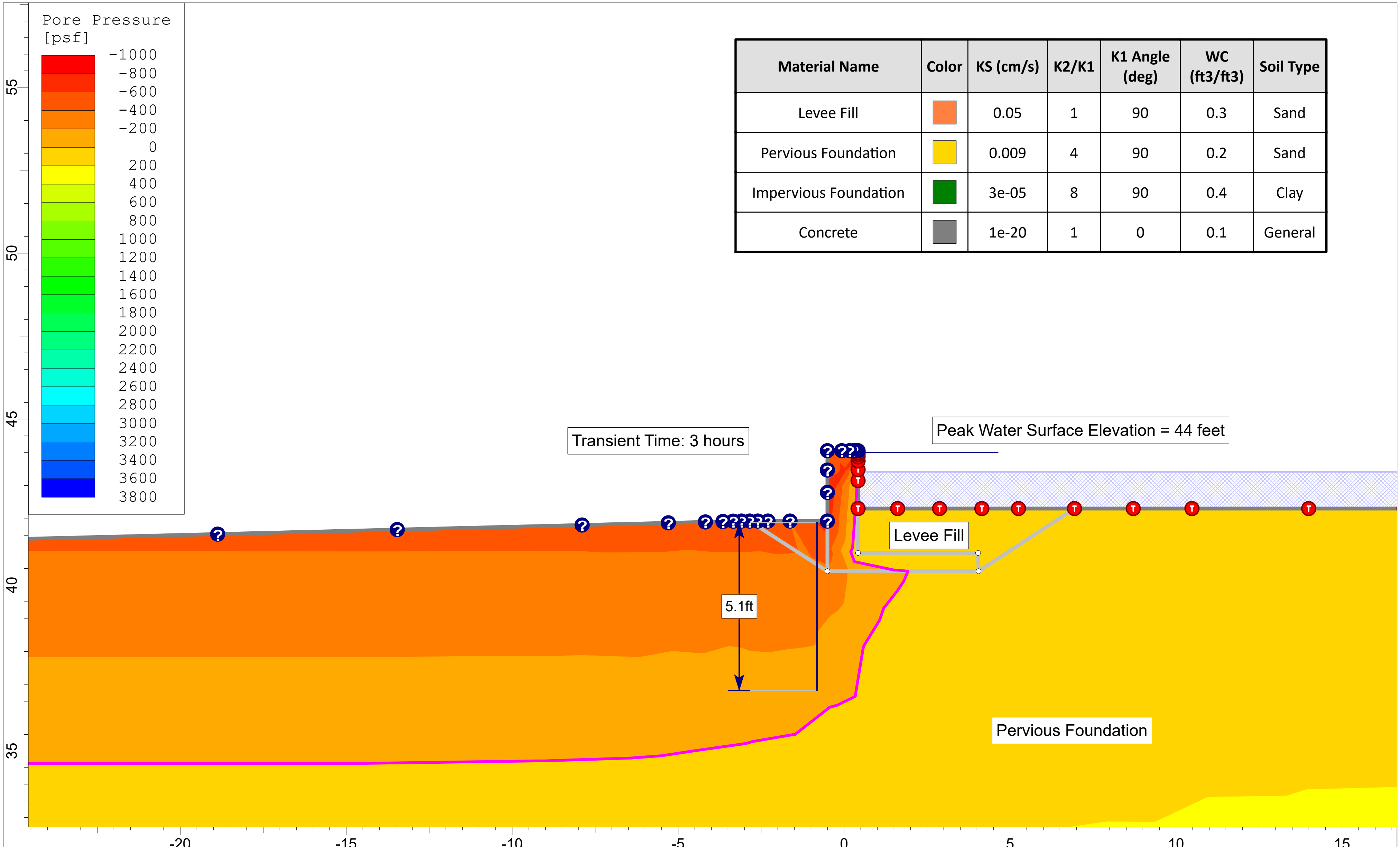
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 1+00 (Rapp Wall) Transient Seepage		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date	December 2019	*File Name*	rapp sta 1+00_floodwall_transient.slmd



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.009	4	90	0.2	Sand
Impervious Foundation		3e-05	8	90	0.4	Clay
Concrete		1e-20	1	0	0.1	General

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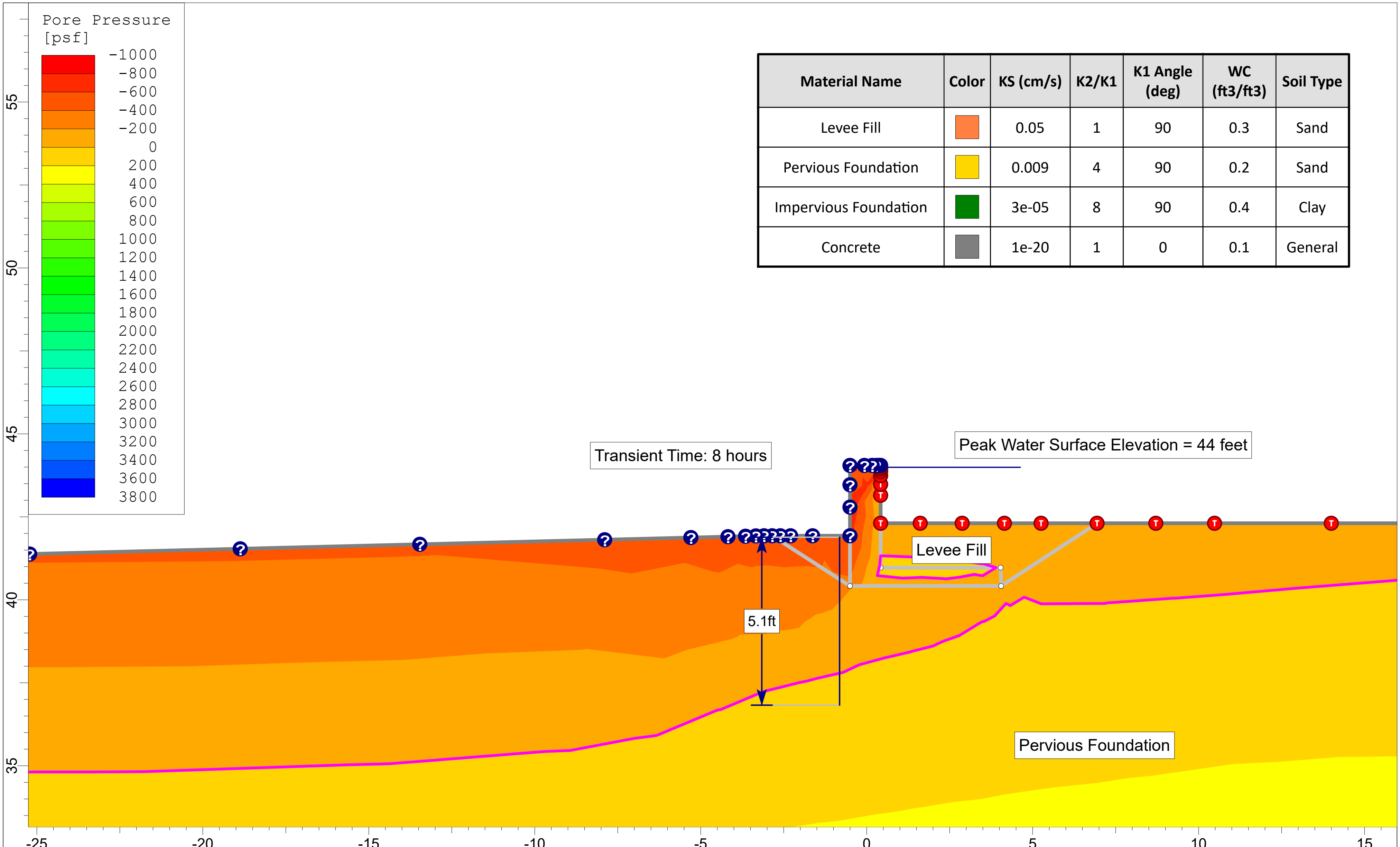
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 1+00 (Rapp Wall) Transient Seepage		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date	December 2019	*File Name*	rapp sta 1+00_floodwall_transient.slmd



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.009	4	90	0.2	Sand
Impervious Foundation		3e-05	8	90	0.4	Clay
Concrete		1e-20	1	0	0.1	General

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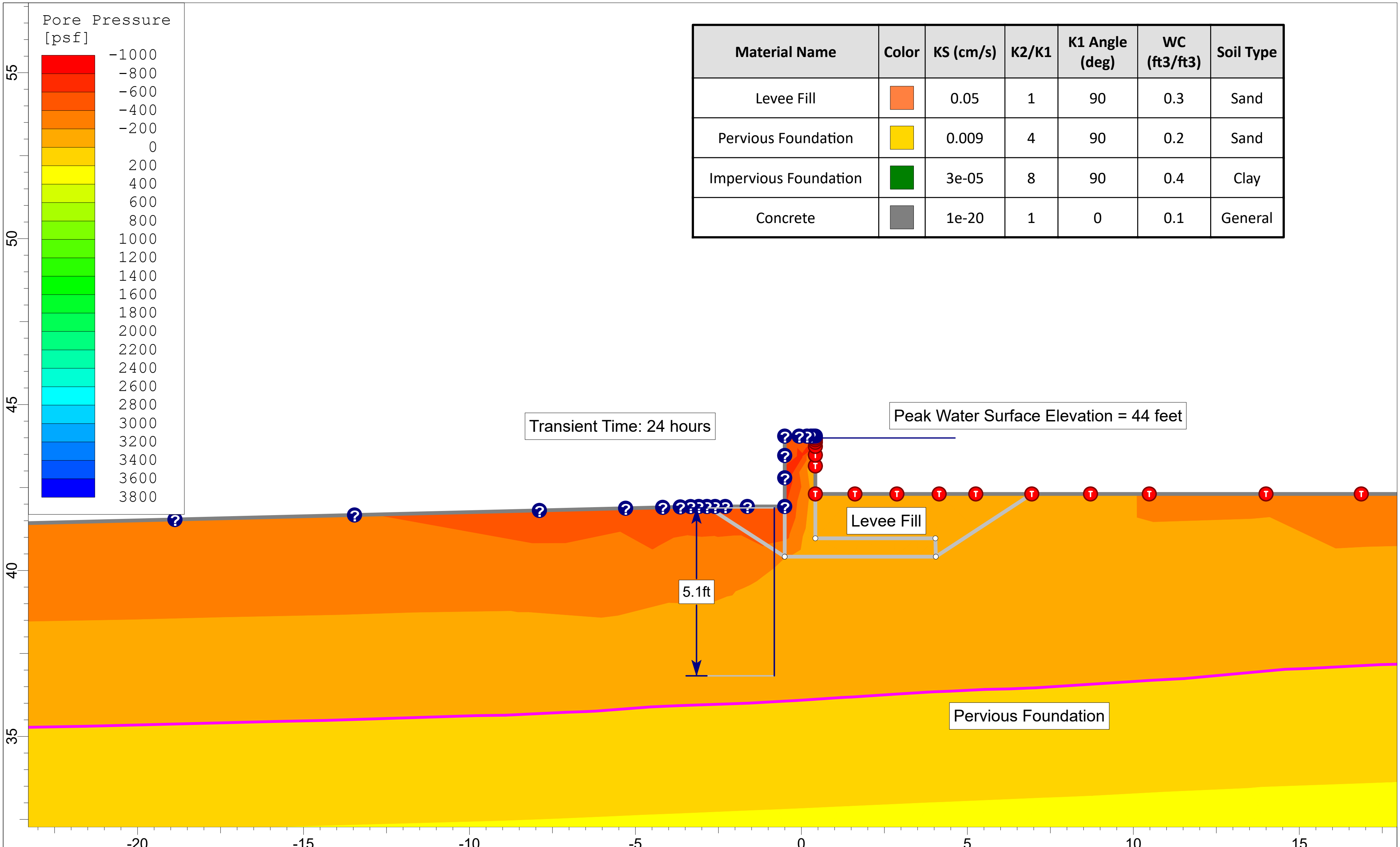
SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 1+00 (Rapp Wall) Transient Seepage		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date	December 2019	*File Name*	rapp sta 1+00_floodwall_transient.slmd



Material Name	Color	KS (cm/s)	K2/K1	K1 Angle (deg)	WC (ft3/ft3)	Soil Type
Levee Fill		0.05	1	90	0.3	Sand
Pervious Foundation		0.009	4	90	0.2	Sand
Impervious Foundation		3e-05	8	90	0.4	Clay
Concrete		1e-20	1	0	0.1	General

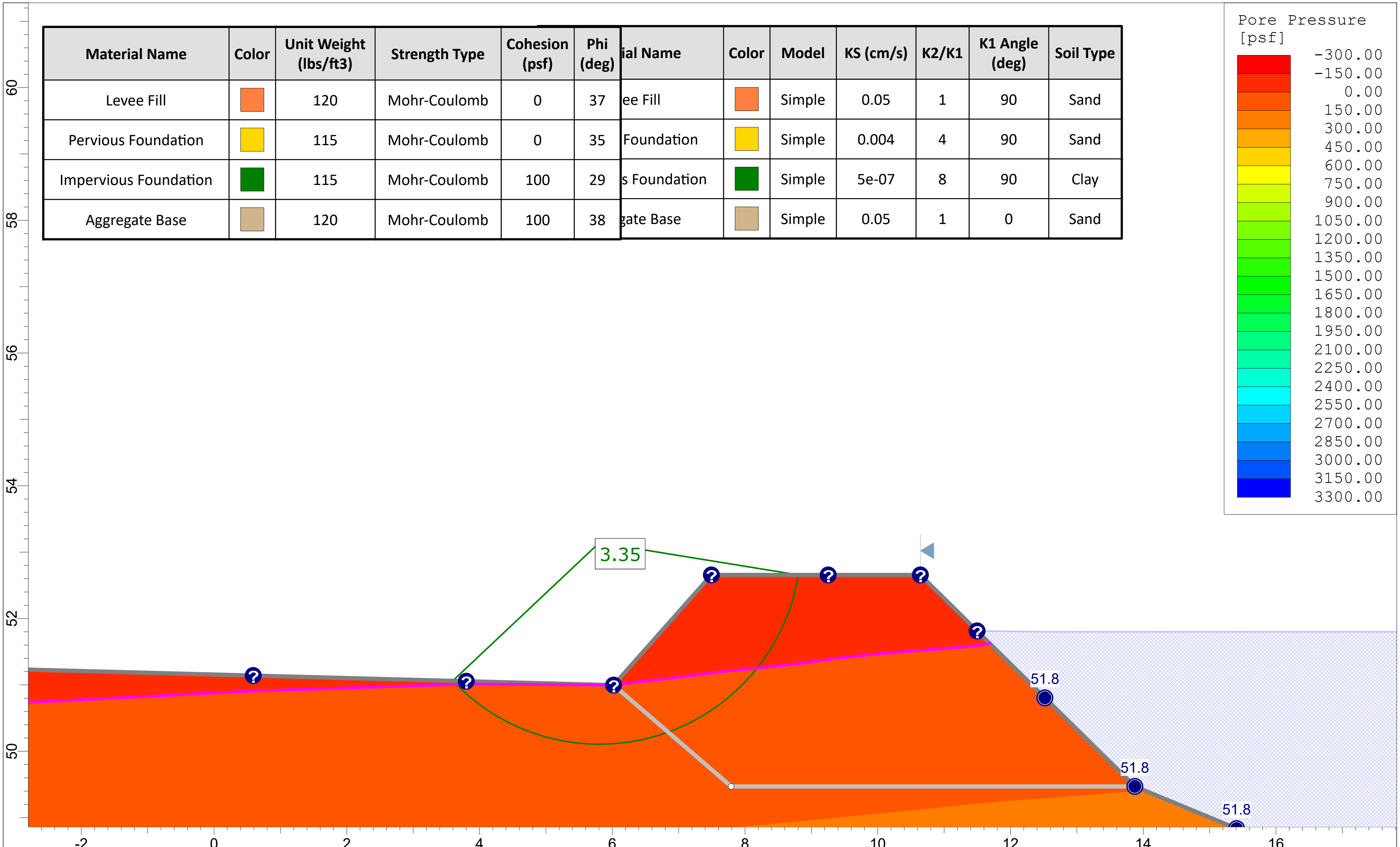
rocscience

SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 1+00 (Rapp Wall) Transient Seepage		
Drawn By GDE	*Scale* 1:48	*Company*	Yeh and Associates
Date	December 2019	*File Name*	rapp sta 1+00_floodwall_transient.slmd

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Levee Fill		120	Mohr-Coulomb	0	37
Pervious Foundation		115	Mohr-Coulomb	0	35
Impervious Foundation		115	Mohr-Coulomb	100	29
Aggregate Base		120	Mohr-Coulomb	100	38

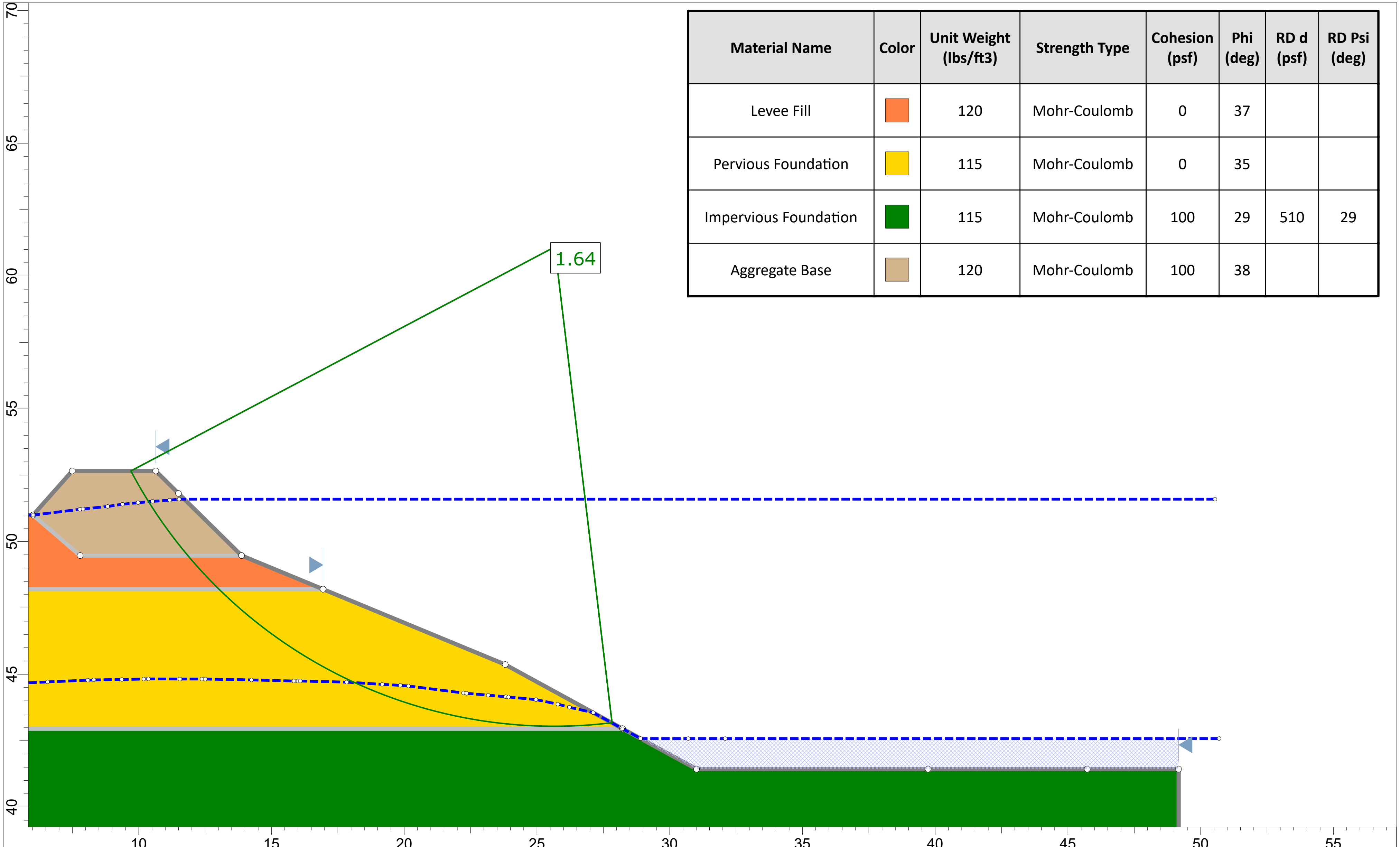
ial Name	Color	Model	KS (cm/s)	K2/K1	K1 Angle (deg)	Soil Type
ee Fill		Simple	0.05	1	90	Sand
Foundation		Simple	0.004	4	90	Sand
s Foundation		Simple	5e-07	8	90	Clay
gate Base		Simple	0.05	1	0	Sand



rocscience

SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements
Analysis Description	STA 123+23 Steady State Exterior Slope
Drawn By	GDE
Scale	1:24
Company	Yeh and Associates
Date	December 2019
File Name	sta 123+23_n levee_proposed_steady state.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	RD d (psf)	RD Psi (deg)
Levee Fill		120	Mohr-Coulomb	0	37		
Pervious Foundation		115	Mohr-Coulomb	0	35		
Impervious Foundation		115	Mohr-Coulomb	100	29	510	29
Aggregate Base		120	Mohr-Coulomb	100	38		

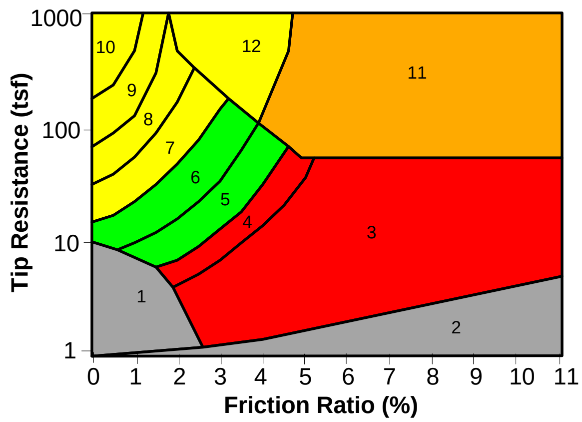
rocscience

SLIDEINTERPRET 8.029

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 123+23 Rapid Drawdown - Interior Slope		
Drawn By GDE	*Scale* 1:60	*Company*	Yeh and Associates
Date	December 2019	*File Name*	sta 123+23_n levee_proposed_RD_steady-state_v2.slim

APPENDIX D - PERTINENT DATA FROM PREVIOUS STUDIES

COLOR LEGEND FOR FRICTION RATIO TRACES



Zone	Soil Behavior Type	U.S.C.S.
1	Sensitive Fine-grained	OL-CH
2	Organic Material	OL-OH
3	Clay	CH
4	Silty Clay to Clay	CL-CH
5	Clayey Silt to Silty Clay	MH-CL
6	Sandy Silt to Clayey Silt	ML-MH
7	Silty Sand to Sandy Silt	SM-ML
8	Sand to Silty Sand	SM-SP
9	Sand	SW-SP
10	Gravelly Sand to Sand	SW-GW
11	Very Stiff Fine-grained *	CH-CL
12	Sand to Clayey Sand *	SC-SM

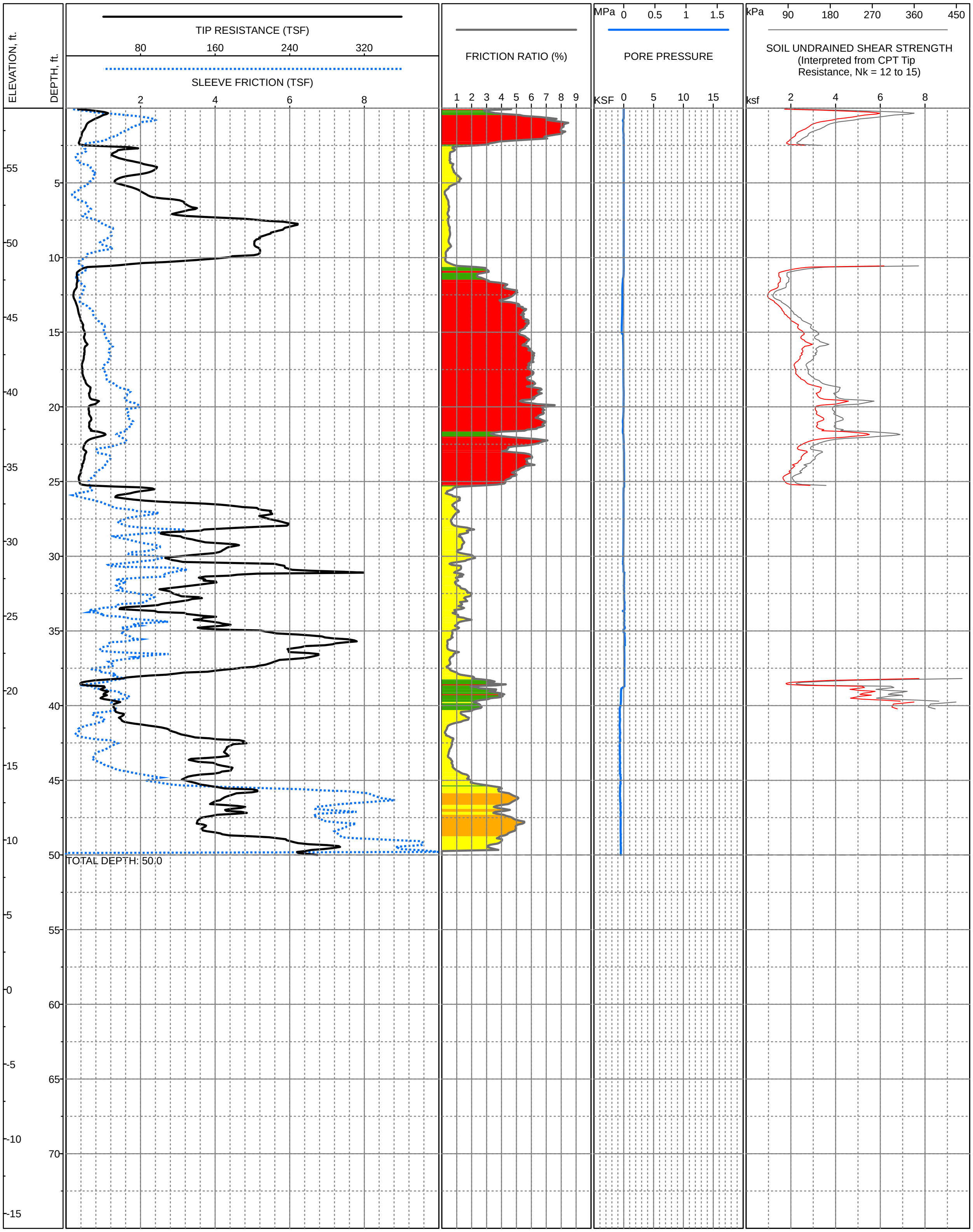
*overconsolidated or cemented

CPT CORRELATION CHART
(Robertson and Campanella, 1984)

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Su_2008_08_13\MXD\PlateA-3_CPTKey.mxd, 08/29/08, ksheil

KEY TO CPT LOGS
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

PLATE A-3



COORDINATES: 2,233,857.20N 5,787,490.08W
SURFACE EL: 59.0ft +/- (MSL)
COMPLETION DEPTH: 50.0ft
TESTDATE: 7/22/2008

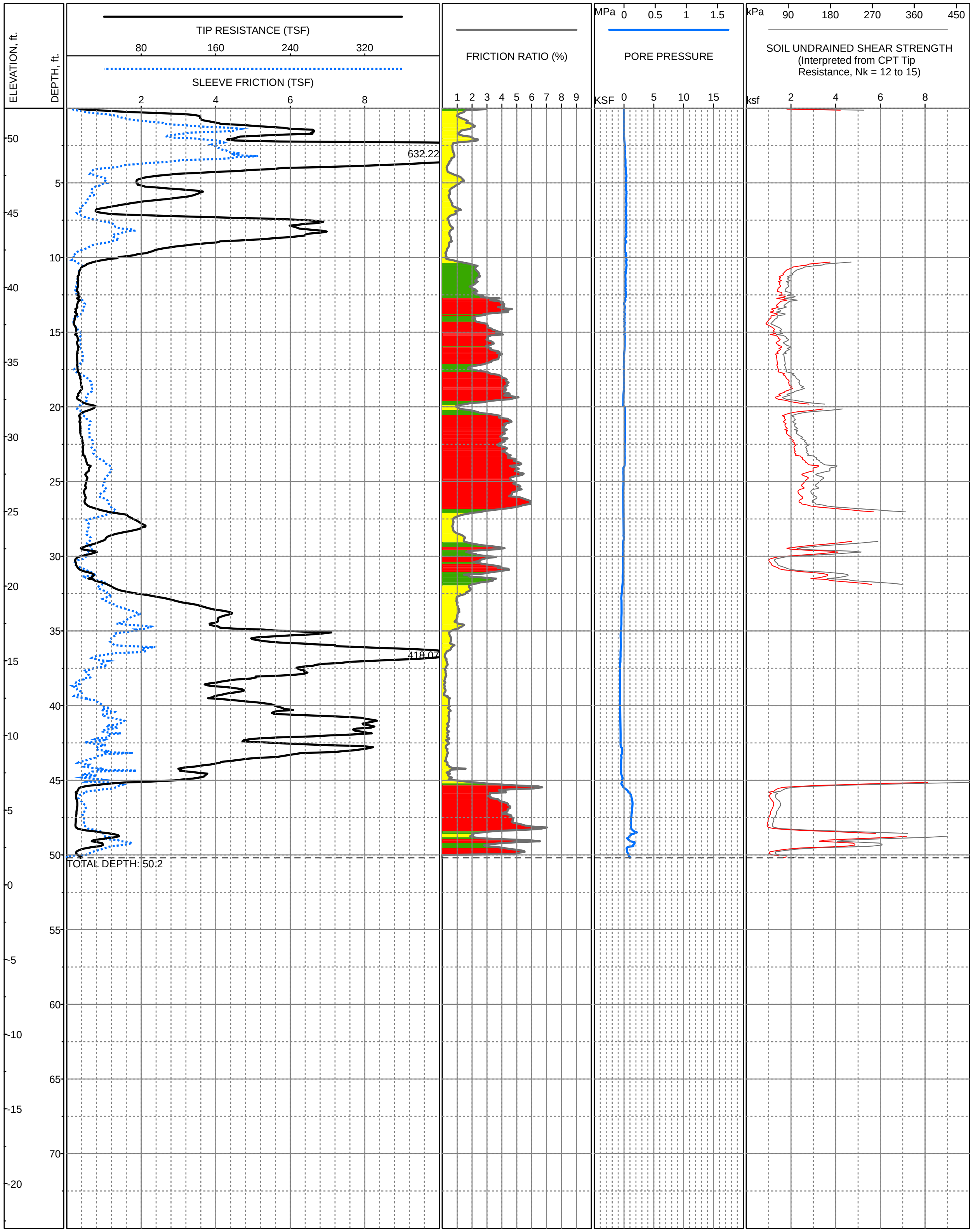
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J.Blanchard

LOG OF C-1

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Su_2008_08_13\MXD\CPTLog_Su.mxd,08/29/2008,ksheil

PLATE A-4



COORDINATES: 2,232,173.97N 5,786,405.43W
SURFACE EL: 52.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

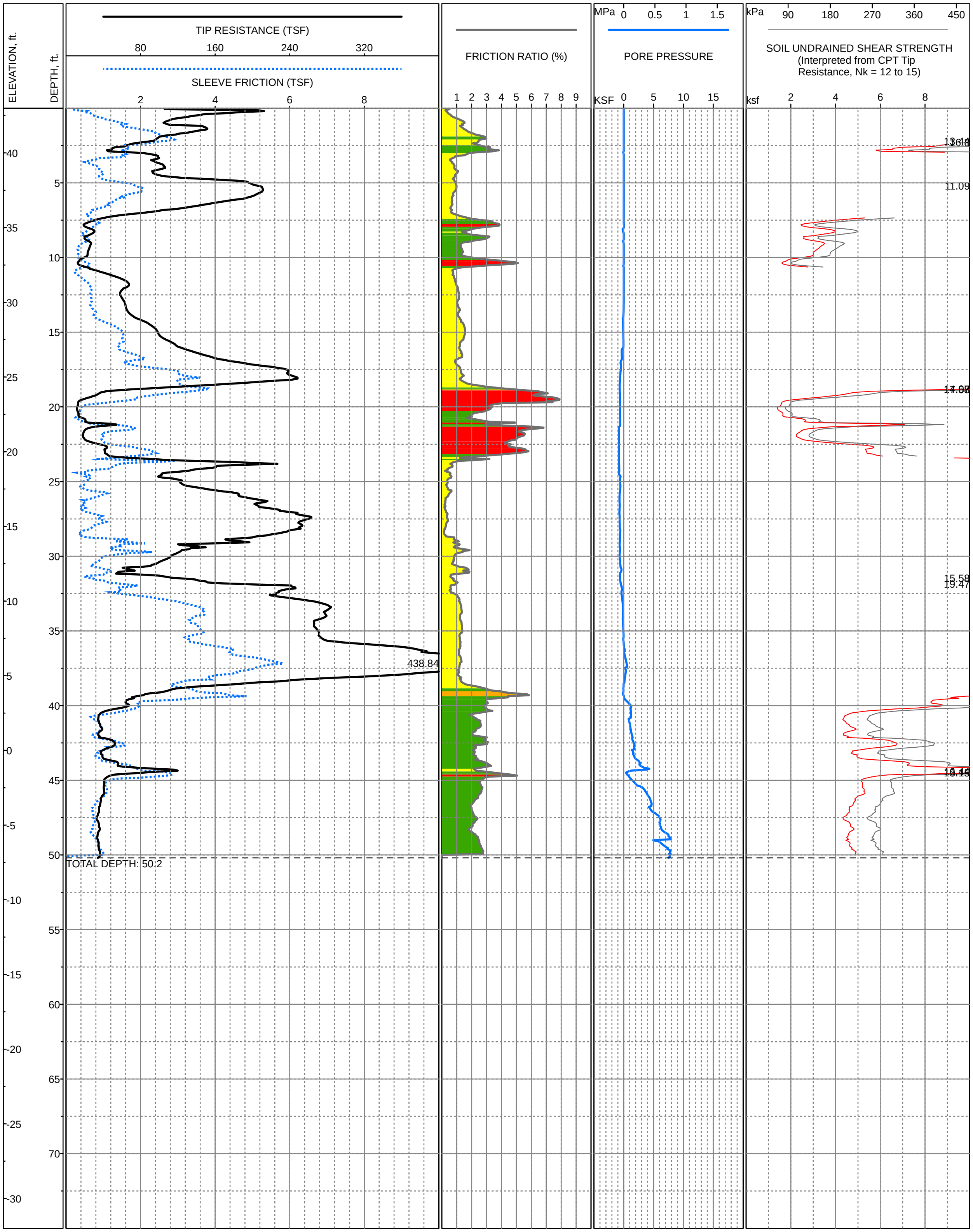
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J.Blanchard

LOG OF C-2

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Su_2008_08_13\MXD\CPTLog_Su.mxd,08/29/2008,ksheil

PLATE A-5



COORDINATES: 2,231,087.37N 5,784,635.85W
SURFACE EL: 43.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J.Blanchard

LOG OF C-3

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Su_2008_08_13\MXD\CPTLog_Su.mxd,08/29/2008,ksheil

PLATE A-6

FUGRO

ELEVATION, ft	DEPTH, ft
-12	2
-14	4
-16	6
-18	8
-20	10
-22	12
-24	14
-26	16
-28	18
-30	20
-32	22
-34	24
-36	26
-38	28
-40	30
-42	32
-44	34
-46	36
-48	38

SAMPLE NO.	BLOW COUNT / REC"/DRIVE"
1	25
2	(25)
3	(25)
4	(25)
5	18"/ 30"
6	
7	
8	20"/ 24"
9	(25)
10	30"/ 30"
11	20"/ 24"
12	
13	

LOCATION: The drill hole location referencing local landmarks or coordinates

SURFACE EL: Using local, MSL, MLLW or other datum

MATERIAL DESCRIPTION	
Well graded GRAVEL (GW)	COARSE GRAINED
Poorly graded GRAVEL (GP)	COARSE GRAINED
Well graded SAND (SW)	COARSE GRAINED
Poorly graded SAND (SP)	COARSE GRAINED
Silty SAND (SM)	COARSE GRAINED
Clayey SAND (SC)	COARSE GRAINED
Silty, Clayey SAND (SC-SM)	COARSE GRAINED
Elastic SILT (MH)	FINE GRAINED
SILT (ML)	FINE GRAINED
Silty CLAY (CL-ML)	FINE GRAINED
Fat CLAY (CH)	FINE GRAINED
Lean CLAY (CL)	FINE GRAINED
CONGLOMERATE	ROCK
SANDSTONE	ROCK
SILTSTONE	ROCK
MUDSTONE	ROCK
CLAYSTONE	ROCK
BASALT	ROCK
ANDESITE BRECCIA	ROCK
Paving and/or Base Materials	

General Notes

Soil Texture Symbol

Sloped line in symbol column indicates transitional boundary

Samplers and sampler dimensions
(unless otherwise noted in report text) are as follows:

Symbol for:	
1	SPT Sampler, driven 1-3/8" ID, 2" OD
2	CA Liner Sampler, driven 2-3/8" ID, 3" OD
3	CA Liner Sampler, disturbed 2-3/8" ID, 3" OD
4	Thin-walled Tube, pushed 2-7/8" ID, 3" OD
5	Bulk Bag Sample (from cuttings)
6	CA Liner Sampler, Bagged
7	Hand Auger Sample
8	CME Core Sample
9	Pitcher Sample
10	Lexan Sample
11	Vibracore Sample
12	No Sample Recovered
13	Sonic Soil Core Sample

Sampler Driving Resistance
Number of blows with 140 lb. hammer, falling 30" to drive sampler 1 ft. after seating sampler 6"; for example,

Blows/ft	Description
25	25 blows drove sampler 12" after initial 6" of seating
86/11"	After driving sampler the initial 6" of seating, 36 blows drove sampler through the second 6" interval, and 50 blows drove the sampler 5" into the third interval
50/6"	50 blows drove sampler 6" after initial 6" of seating
Ref/3"	50 blows drove sampler 3" during initial 6" seating interval

Blow counts for California Liner Sampler shown in ( )

Length of sample symbol approximates recovery length

Classification of Soils per ASTM D2487 or D2488

Geologic Formation noted in bold font at the top of interpreted interval

Strength Legend
- Q = Unconfined Compression
- u = Unconsolidated Undrained Triaxial
- t = Torvane
- p = Pocket Penetrometer
- m = Miniature Vane

Water Level Symbols
- Initial or perched water level
- Final ground water level
- Seepages encountered

Rock Quality Designation (RQD) is the sum of recovered core pieces greater than 4 inches divided by the length of the cored interval.

KEY TO TERMS & SYMBOLS USED ON LOGS

PLATE A-1

LOCATION: Approximately 900' northeast of B-102, Station 138+50

SURFACE EL: 58.5 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
58.5	0	A		**ALLUVIUM (Qal_1)** Poorly graded SAND with silt (SP-SM): very loose, light grayish brown, moist							
		1	(4)								
56.5	2.3	2	7	**Qal_3** Lean CLAY with sand (CL): soft, dark brown, moist, trace fine sand	118	94	14 26	10			
				Qal_1 Silty SAND (SM): loose, light brown, moist, fine sand							
		3A	(11)	Poorly graded SAND with silt (SP-SM): loose, light brown, moist, medium to coarse sand							
		3B			97	87	13	8			
52.5	6	4	4	Silty SAND (SM): very loose, light brown, moist, lenses of silty CLAY (CL-ML) with oxidation staining, trace gravel				24			
49.5	9	5	(6)	**Qal_3** Fat CLAY (CH): soft to stiff, black, moist	111	80	39		64	44	p 1.5
		6	(17)	- stiff to hard							p 4.0
40.5	18	7	(16)	Lean CLAY (CL): stiff to hard, light brown, moist, oxidation mottling							p 3.0
37.5	21										

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: Not Encountered
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-101

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-2

LOCATION: Approximately 760' north of and 160' east of westerly intersection of SR-1 and Halcyon Road, Station 130+00

SURFACE EL: 54.5 ft +/- (rel. NAVD88 datum)

SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
A		**ARTIFICIAL FILL (af)** Lean CLAY with sand (CL): soft, very dark brown to black, moist, scattered subangular to angular gravel up to 1"				57			
1	(4)		88	68	29	79			
2	2								
3A	(8)	**ALLUVIUM (Qal_3)** Lean CLAY (CL): medium stiff to hard, brownish gray, moist, trace fine sand							p 1.8
3B			115	89	29		45	27	p 3.0
4A	4	**Qal_1** Silty SAND (SM): very loose, light gray, moist							
4B									
5	(11)	**Qal_3** Lean CLAY (CL): soft to very stiff, gray, moist							p 2.0 p 1.8
6	5	**Qal_1** Silty SAND (SM): loose, light gray, moist							
		Qal_3 Fat CLAY (CH): soft to very stiff, black, moist							p 1.3 p 1.8
7		Sandy lean CLAY (CL): very dark grayish brown, moist	114	91	25		44	29	
8	(23)	Lean CLAY (CL): very stiff, brownish gray, moist, oxidation mottling							p 3.3

Elevation scale (ft): 54, 52, 50, 48, 46, 44, 42, 40, 38, 36, 34, 32, 30, 28
Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: Not Encountered
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-102

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-3

LOCATION: Approximately 1200' east of B-104, approximately 75' north of Arroyo Grande Creek Levee, Station 101+00

SURFACE EL: 43 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
43–41	0–2	A		**ARTIFICIAL FILL (af)** Silty SAND with gravel (SM): reddish brown, dry, subangular gravel up to approximately 1"							
41–38.5	2–4.5	1	(8)	**ALLUVIUM (Qal_1)** Poorly graded SAND with silt (SP-SM): loose, black, moist, abundant organics	104	96	9	10			
		2	7								
38.5–33.5	4.5–9.5	3A	(11)	Silty SAND (SM): loose, reddish brown, moist, fine sand							
		3B			99	91	10	20			
		4	9	- light brown, trace rounded gravel up to 1"							
33.5–29	9.5–14	5	(21)	Silty SAND with gravel (SM): medium dense, light brown, moist, fine to coarse sand, subangular to well-rounded gravel							
29–22	14–21	6A	(47)	Silty SAND (SM): dense, yellowish brown to reddish yellow, wet, abundant oxidation staining							
		6B									
		7	(50)								

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: 11.5 ft
BACKFILLED WITH: Native cuttings
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-103
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-4

FUGRO

LOCATION: Approximately 1840' east of 22nd Street Bridge, Station 91+40

SURFACE EL: 39.8 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
		A		**ARTIFICIAL FILL (af)** approximately 2.5" base material							
				Clayey SAND with gravel (SC): dense, brown to light brown, dry, subrounded to well-rounded gravel up to approximately 1"							
38	2	1	(47)								
					119	109	9	19			
		2	15	- medium dense							
36	4			**ALLUVIUM (Qal_3)** Sandy Fat CLAY (CH): stiff to hard, dark brown to black, dry, trace oxidation staining, fine to medium sand, subrounded gravel							p 4.5+
34	6	3									
					116	91	27		54	35	
		4	(19)								
32	8										p 4.5
30	10	5	(17)								p 2.8
28	12			**Qal_1** Poorly graded SAND with silt (SP-SM): dense, reddish orange, wet							
26	14	6A	(52)					7			
		6B		Silty SAND (SM): dense, reddish orange, wet	128	106	21				
24	16										
22	18										
20	20	7A	(50/6")								
		7B		- yellowish brown, very dense							
18	22										
16	24	8	(25)								
14	26			- medium dense, trace subangular gravel up to ½"							

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 41.0 ft
DEPTH TO WATER: 13.5 ft
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-104

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-5a