FUGRO WEST, INC.

PRELIMINARY GEOTECHNICAL REPORT
ARROYO GRANDE CREEK WATERWAYS MANAGEMENT PLAN
LOS BERROS CREEK TO NEAR OCEANO AIRPORT
SAN LUIS OBISPO COUNTY, CALIFORNIA

Prepared for:
County of San Luis Obispo
Department of Public Works

April 22, 2009

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April 22, 2009
Project No. 3014.029

County of San Luis Obispo
Public Works Department, Utilities Administration
County Government Center, Room 107
San Luis Obispo, California 93401

Attention: Ms. Jill Ogren

Subject: Preliminary Geotechnical Report, Arroyo Grande Creek Waterways Management Plan, Los Berros Creek to near Oceano Airport, San Luis Obispo County, California

Dear Ms. Ogren:

Fugro is pleased to submit this Preliminary Geotechnical Report for the Arroyo Grande Creek Waterways Management Plan in San Luis Obispo County, California. This report was prepared in accordance with our proposal dated April 3, 2008. The proposal was authorized under County Purchase Order No. 25004312, dated April 29, 2008.

This report presents the results of a preliminary geotechnical evaluation of alternatives to raise the levees along a portion of Arroyo Grande Creek. Site-specific exploration, previous geotechnical studies, published geologic information, and project information provided by the County of San Luis Obispo, Swanson Hydrology + Geomorphology, Cannon Associates, and the Morro Group were used as a basis for preparing this report.

The purpose of this report is twofold: to provide input to the Environmental Impact Report and study being prepared by the Morro Group; and to provide geotechnical alternatives for improving the levee along Arroyo Grande Creek. Preliminary design of the improvements is being prepared by Swanson Hydrology + Geomorphology (SH +G). This report summarizes geologic hazards and geotechnical considerations that are likely to impact the design and construction of the project, and discusses mitigation measures that may be needed to address these items.

We appreciate the opportunity to provide our services on this project. Please contact the undersigned if you have questions regarding this report, or require additional information.

Sincerely,

FUGRO WEST, INC.

Jonathan D. Blanchard, GE 2312
Principal Geotechnical Engineer

Gresham D. Eckrich
Staff Engineer/Geologist

Reviewed by:

Lori E. Prentice, C.E.G. 2312
Principal Engineering Geologist

Copies: 4 – Addressee (1 – pdf on CD ROM)

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1. SITE AND PROJECT DESCRIPTION

The project will generally consist of raising an existing levee from the city limits of Arroyo Grande and the confluence with Los Berros Creek to approximately 2,500 feet downstream of Creek Road, near the Oceano Airport. The location of the site and project limits is shown on Plate 1 - Site Map. The proposed levee improvements will extend along the lower approximately 3½ miles of Arroyo Grande Creek and the lower approximately 1,700 feet of Los Berros Creek (a total of about 7 miles of levee). Arroyo Grande Creek is mainly confined by levees west of Highway 1, and intermittently confined by levees east of Highway 1.

1.1 EXISTING SITE

Los Berros Creek flows west into Arroyo Grande Creek at the eastern terminus of the project. Arroyo Grande Creek then flows westerly to the Pacific Ocean, about 3½ miles downstream of Los Berros Creek. Based on site observations, concrete weirs and check dams are located within the Los Berros Creek channel, and rip-rap boulders associated with construction and maintenance of existing levees were observed along sections of variable length within the Arroyo Grande Creek channel. Bridges span Arroyo Grande Creek at Highway 1/Cienega Street, 22nd Street, and the Union Pacific Railroad (UPRR).

Existing site grades range from approximately elevation 11 feet (SH+G, 2008), at the west end of the project reach, to approximately elevation 63 feet, near the city limits of Arroyo Grande. The existing channel bottom consists mostly of gravel with vegetated banks and levee slopes. Sand and gravel bars have built up within the channel between the slopes of the levees. The existing land use adjacent to the southern levee is predominantly agricultural land planted in irrigated row crops. There is also the Cardoza (horse) Ranch west of Creek Road. The existing land use adjacent to the northern levee is a combination of the Oceano airport, and residential and agricultural plots. Beyond the down stream limits of the project, the south levee is bordered by active sand dunes within the Oceano Vehicle Recreation Area operated by State Parks.

The levees and channelized Arroyo Grande Creek were constructed in the late 1950s 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. Downstream of Highway 1, the levees consist of earthen berms. Review of the USDA (1956) plans show the levee embankments designed with 15-foot wide crests, with 1½h :1v to 2h:1v exterior slope inclinations, and 3h:1v interior slope inclinations. As-built plans provided by the County, and cross sections developed from recent topo, show that the interior slopes were constructed as steep as about 2h:1v. The interior height of the channel slopes indicated on the plans ranges from about 11 to 14 feet. The exterior slope height appears to have been designed about 5 to 12 feet above the adjacent grades downstream of Highway 1. However, upstream of Highway 1, the existing levee is less pronounced and more intermittent, with a design height generally less than about 3 feet above adjacent grades. The existing stream channel upstream of Highway 1 is increasingly incised to the east, with localized areas of near vertical creek banks, likely from bank erosion.

As part of the levee construction (USDA 1956), the alignment of Los Berros Creek was altered. Prior to 1956, Los Berros Creek appears to have merged with Arroyo Grande Creek downstream of their current confluence, closer to the western limits of the project and along the southwestern edge of Cienega Valley. The approximate pre-1956 Los Berros Creek alignment is shown on Plate 2. This channel appears to serve as a seasonal drainage path.

The levee was damaged by the 2003 San Simeon Earthquake. Damage to the southern levee, as evidenced by cracking and settlement of the berm, was observed by the County near Creek Road following the earthquake. Based on reports discussed by the U.S. Geologic Survey (Holzer et al. 2004), the damage was likely related to liquefaction and settlement of the foundation support soil in response to the earthquake. The County subsequently repaired the levee by regrading areas where the cracking was observed. We understand that the County performs periodic tree trimming and vegetation management of the channel as part of the maintenance of the levee system. Levee maintenance was being performed at the time of our field work in the summer of 2008.

1.2 FLOOD CONTROL IMPROVEMENTS

In the project area, Arroyo Grande Creek receives storm water runoff from the Arroyo Grande Flood Control Channel, referred to as Zones 1 and 1A of the San Luis Obispo County Flood Control and Water Conservation District (Morro Group, 2008). The project will involve flood control improvements along the northern and southern banks of the Arroyo Grande and Los Berros Creeks. The project is intended to provide increased flood control benefits and riparian enhancement through vegetation management and sediment control within Arroyo Grande Creek channel. The preliminary designs under consideration for the project are described as Alternatives 3a, 3b and 3c in a memorandum prepared by Swanson Hydrology + Geomorphology (SH+G, 2008).

Alternative 3c is the main alternative evaluated for this study. The geotechnical aspects of the proposed flood control improvements for Alternative 3c include raising the height of the levees by approximately 3 to 6 feet along roughly 3 miles of the creek. Raising the levees will increase the channel capacity and elevate the levees above the 20-year water surface with 2 feet of freeboard. Alternative 3c involves placement of the greatest quantity and lineal extent of imported or native fill relative to Alternatives 3a and 3b.

2. WORK PERFORMED

2.1 PURPOSE

The purpose of this report is to provide a preliminary engineering evaluation regarding the geotechnical feasibility of raising the levee along Arroyo Grande Creek for the preliminary design and as input to the Environmental Impact Report. The main geotechnical considerations that we have evaluated for this project are:

- Potential for the levee to be impacted by geologic hazards;

- Characterization of the soil and groundwater conditions along the alignment of the levee relative to foundation design, constructability, and seismic vulnerability; and
- A preliminary evaluation of the stability of planned levee improvements relative to slope stability, erosion, seepage, and feasibility for design.

2.2 SCOPE

To evaluate the geotechnical considerations for the project, we have executed the following scope of work:

- Meeting and consulting with members of the design team regarding our approach to providing geotechnical services for the project, and to review the project objectives;
- Reviewing selected published geologic maps and reports, previous geotechnical studies performed along the levee and for bridges that span the creek channel, and as-built plans for the existing levee;
- Performing site visits to observe the general site conditions, coordinate the field exploration program, and collect near-surface samples of selected stream channel materials;
- Laboratory testing of selected samples obtained from the site to assist in characterizing the material properties of the streambed and bank sediments encountered;
- Performing field exploration consisting of advancing six (6) cone penetration test soundings to depths of approximately 43 to 50 feet; and
- Preparing this Preliminary Geotechnical Report for the project that provides our opinions and recommendations regarding:
  - Geologic and seismic setting;
  - Soil and groundwater conditions encountered;
  - Predominant soil and formational units in the project area;
  - Historical seismicity including the impact that the 2003 San Simeon Earthquake had on the site;
  - Potential for the site to be impacted by geologic hazards (such as strong ground motion, fault rupture, liquefaction, seismic settlement, landsliding, flooding, tsunami or seiche, or dam inundation);
  - Potential for erosion, hydrocollapse, subsidence, expansive or collapsible soil conditions;
  - Potential to encounter naturally occurring asbestos or radon gases;
  - Areas that pose geologic hazards;

- Potential for geologic conditions to cause site alterations (such as grading) to adversely impact the project;
- Construction or geotechnical considerations that could impact the project, such as the need for dewatering, excavation characteristics of the geologic materials, and anticipated grading;
- A discussion of the existing levees, and alternatives to dredge the creek, and raise the levees;
- Anticipated site preparation, grading, and slope inclinations that can be used for preliminary design and planning (and subject to change based on design-level studies); and
- Mitigation measures for project development and preliminary design as necessary to address potentially significant impacts.

2.3 FIELD EXPLORATION

Field exploration activities consisted of performing six (6) electric cone penetration test (CPT) soundings, collecting hand samples from the creek, and performing a hand auger boring adjacent to the levee. The logs of the CPT soundings and hand auger boring are presented in Appendix A. The approximate locations of the CPT soundings, hand samples and hand auger boring are shown on Plate 2 – Field Exploration Plan.

2.3.1 Cone Penetration Testing

Fugro Geosciences of Santa Fe Springs, California performed the CPT work for this project on July 22, 2008. CPT soundings were advanced to depths of approximately 43 to 50 feet below the ground surface. The CPT soundings were performed using an electronic piezocone penetrometer. The penetrometer was advanced into the ground using a hydraulic ram mounted within a truck having a weight of at least 20 tons. The piezocone has a diameter of approximately 1.7 inches. Cone tip resistance (q_c), sleeve friction (f_s), and penetration pore pressures measured behind the tip (u_2) were recorded during penetration using an on-board computer. Data were collected from the penetrometer at approximately 2 centimeter intervals to provide a nearly continuous profile of the subsurface conditions encountered during penetration. The friction ratio (FR) was computed for each value of q_c and f_s recorded. The data was retrieved electronically for use in subsequent geotechnical analyses. CPT data and soil behavior type classifications were used in conjunction with historical boring information to evaluate soil boundaries encountered at the site.

2.3.2 Hand Samples

Fugro personnel collected thirteen (13) bulk samples from within the Arroyo Grande Creek channel on July 14 and 22, 2008. Samples of the sediments were collected from the active streambed and from bars and bank materials above the water surface in the creek. Descriptions of the samples obtained are included with the laboratory test results in Appendix B.

2.3.3 Hand Auger Boring

One hand auger boring was advanced adjacent to the southern levee by Fugro on August 14, 2008. The hand auger had a diameter of 4 inches, and was excavated in the agricultural field east adjacent to the southern levee just north of Creek Road. The hand auger boring was drilled to a depth of approximately 4½ feet. Samples were obtained at selected intervals from the boring using a hand-driven modified California sampler and from excavated cuttings. The hand driven sampler had an outside diameter of approximately 3 inches, and contained six (6) 1-inch high brass rings. The sampler was driven using a 5-pound slide hammer.

2.4 LABORATORY TESTING

Laboratory tests for grain size distribution and direct shear strength were performed on selected samples recovered from the field exploration program. The tests were performed in general accordance with the applicable standards of ASTM. The results of the tests are presented in Appendix B.

2.5 PREVIOUS STUDIES

The U.S. Geological Survey (Holzer et al., 2004) previously performed a geotechnical study in the project vicinity. The study focused on 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 Levee within the project limits. The soundings were performed in this area of the levee because the USGS observed evidence of instability of the levee and liquefaction within the field adjacent to the levee. The data from those CPT soundings were used to assist in our characterization of the subsurface conditions for this report. The logs of those CPT soundings performed by the USGS are included with the Fugro CPT logs in Appendix A. The approximate locations of the CPT soundings performed by the USGS are also shown on Plate 2.

We reviewed logs of test borings from Caltrans (1956, 1984) and San Luis Obispo County (1984) as part of geotechnical investigations for the State Route 1 Bridge and 22nd Street Bridge, respectively. This boring information was used to help characterize the subsurface profile for the site. The approximate locations of the bridge borings are shown on Plate 2.

2.6 GENERAL CONDITIONS

Fugro prepared the conclusions and professional opinions presented in this report in accordance with generally accepted geotechnical engineering principals and practices at the time and location this report was prepared. This statement is in lieu of all warranties, expressed or implied.

This report has been prepared for San Luis Obispo County and their authorized agents only. It may not contain sufficient information for the purposes of other parties or other uses. If any changes are made in the project as described in this report, the conclusions and recommendations contained in this report should not be considered valid unless Fugro reviews the changes and modifies and approves, in writing, the conclusions and recommendations of this report. The report and drawings contained in this report are preliminary, intended for design-input purposes; they are not intended to act as construction drawings or specifications.

Soil and rock deposits will vary in type, strength, and other geotechnical properties between points of observation and exploration. Additionally, groundwater and soil moisture conditions can also vary seasonally or for other reasons. Therefore, we do not and cannot have complete knowledge of the subsurface conditions underlying the site. The conclusions and recommendations presented in this report are based upon the findings at the points of exploration, and interpolation and extrapolation of information between and beyond the points of observation, and are subject to confirmation based on the conditions revealed during construction.

The scope of services did not include any environmental assessments for the presence or absence of hazardous/toxic materials in the soil, surface water, groundwater, or atmosphere. Any statements or absence of statements, in this report or data presented herein regarding odors, unusual or suspicious items, or conditions observed are strictly for descriptive purposes and are not intended to convey engineering judgment regarding potential hazardous/toxic assessment. Site conditions

3. SITE CONDITIONS

3.1 GEOLOGIC SETTING

The project is located in the Arroyo Grande and Cienega Valleys and within the Coast Ranges geologic and geomorphic province. That 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, some pre-Jurassic, along with Paleocene-age to Recent rocks are present. The surficial geology in the project vicinity, as mapped by Hall et al. (1973), is shown on Plate 3 – Regional Geologic Map.

The Arroyo Grande and Cienega Valleys and adjacent 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, dip gently to the west, and are underlain by bedrock consisting of Pismo Sandstone or similar sedimentary rocks.

As shown on Plates 2 and 3, the predominant geologic units mapped in the study area are surficial sediments comprised of dune sand deposits (Qs), older-stabilized dune sand deposits (Qos), and alluvium (Qal). The dune sands (Qs and Qos) mapped by Hall et al. (1973) are referred to as eolian deposits (Qe) by Hanson et al. (1994) on Plate 6. Hall identified older dune sands as eolian deposits that have been stabilized and subsequently covered by vegetation. The alluvium is associated with sediment that has been deposited along Arroyo Grande Creek and Los Berros Creek, and the floor of the Arroyo Grande and Cienega Valleys. Surficial sediments are primarily underlain by weakly consolidated units of the age-equivalent of Paso Robles Formation and Careaga Sandstone.

Also depicted on Plate 2, a portion of the site along the creek was previously occupied by dune sand and an extensive pre-settlement Estero, according to an 1873-1874 map produced by the U.S. Coast Survey (Holzer et al., 2004). According to the USGS (2004) report, this area was subsequently "subdivided and turned into developable lots by leveling dunes and filling in swamp areas with dune sand in March 1927." Presumably, the creek alignment was altered as a consequence of this development. The approximate limits of the Pre-Existing Estero reported by Holzer et al. are noted on Plate 2.

3.2 SUBSURFACE CONDITIONS

The subsurface conditions encountered generally consisted of artificial fill (Af) materials overlying alluvium deposits (Qal). Logs for this and previous explorations are presented in Appendix A. The locations of the explorations are shown on Plate 2. Subsurface profiles summarizing our interpretation of the soil conditions encountered along the alignment of Arroyo Grande Creek within the project limits are shown on Plates 4a and 4b. A discussion of the geologic units encountered is provided below. Our interpretation of subsurface conditions is based on the CPT correlations developed by Robertson and Campanella (1986) and our hand auger boring log, and is generally supplemented by logs of previous explorations (USGS, 2004; Caltrans, 1956, 1984; San Luis Obispo County, 1984).

Artificial Fill (Af). Artificial fill materials were encountered in each of the CPT soundings advanced through the existing levee. Fill materials were encountered from the ground surface to approximately 2½ to 10½ feet below the ground surface. The artificial fill generally consisted of the earth materials placed during the construction of the existing levee, except in C-2 advanced within an adjacent parking lot (near the intersection of Halcyon Road and Highway 1). 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).

Alluvium Deposits (Qal). The alluvium encountered likely contained undifferentiated units of floodplain, fluvial, and estuarine sediments deposited along Los Berros Creek and Arroyo Grande Creek. The alluvium was encountered below the artificial fill materials to the maximum depth explored, approximately 43 to 50 feet below the existing ground surface. The alluvium encountered has been characterized as two predominant units of sandy alluvium (Qal1, Qal2), and three predominant units of fine-grained alluvium that were encountered at various depths within and below the sandy alluvium (Qal3, Qal4 and Qal5). Our interpretation of the subsurface conditions is shown on Plates 4a and 4b - Subsurface Profile.

Qal1. This unit consisted predominantly of loose to medium dense sandy material encountered below the levee fill and/or surficial clay units. The sandy alluvium was interbedded with various units of the fine grained alluvium as shown on Plates 4a and 4b. The unit was encountered from at or near the creekbed elevation to depths of approximately 10 to 15 feet below the creek bed where penetrated. This upper sand unit consists of mostly silty sand (SM) to sandy silt (ML) and sand (SP or SW). This unit would also include the gravel and gravelly sand (SP or SW) streambed material.

Qal2. This unit consisted predominantly of dense to very dense sandy alluvium encountered below the upper Qal1 sand unit at a depth of approximately 10 to 15 feet below the streambed elevation. This lower sand unit consists mostly of sand (SP/SW), silty sand (SM) and gravelly sand or gravel (GP/GW). The layer is interbedded at various depths with finer grained alluvial units (Qal4), as shown on Plates 4a and 4b. The USGS soundings (SOC 035, 036 and 037) encountered materials classified as very dense cemented or overconsolidated sand (SP/SW) or clayey sand (SC). Where penetrated near and downstream of Highway 1, this unit was underlain by a deeper fine grained alluvium (Qal5) at depths of approximately 30 to 55 feet below the creek bed. The unit was encountered to the maximum depth explored, approximately 40 feet below the creek bed in C-1.

Qal3. This unit consisted of a shallow layer of predominantly stiff to very stiff clay and silt that was encountered near or just below the levee fill in most of the explorations (see Plates 4a and 4b). The thickness of this unit ranged from approximately 2 to 15 feet. The unit is generally thin (less than 4 feet thick) downstream of Highway 1, and increases in thickness upstream of Highway 1. This unit consisted of mostly clay (CL/CH), silty clay (CL-ML), sandy silt (ML) and clayey silt (ML), and hard cemented or overconsolidated fine grained material.

The hand auger boring (H-1) was drilled near the Creek Road adjacent to the southern levee to obtain a sample of this material for direct shear testing (used in our slope stability analyses). Based on the test results, the sample of the clayey sand had a friction angle of approximately 38 degrees and a cohesion of approximately 100 pounds per square foot.

Qal4. This unit consisted of 2- to 10-foot-thick layers and lenses of stiff to very stiff fine grained alluvium that was interbedded at various depths throughout the sandy Qal1 and Qal2 units (Plates 4a and 4b). A zone of about 15 feet of soft to medium stiff clay was encountered in the USGS CPT sounding 37. The soft clay is likely estuarine deposits associated with the pre-settlement Estero noted on Plate 2.

Qal5. This unit consisted of a deeper, very stiff to hard fine grained alluvium encountered at depths ranging from approximately 30 to 50 feet below the creekbed in USGS CPT soundings 35 and 36, and Fugro's CPT sounding C-3. This unit is inferred to underlie all other units within the alluvium, to the maximum depth explored, approximately 95 feet below the creekbed in USGS Sounding 35. This unit consists mostly of sediment classified as clay (CL/CH), silty clay (CL-ML), sandy silt (ML), and clayey silt (ML).

3.3 GROUNDWATER CONDITIONS

Groundwater was encountered in C-3 during our July 2008 field exploration program at a depth of approximately 14 feet below the ground surface. The sounding holes created by C-1, C-2, C-4, C-5, and C-6 caved following removal of the CPT probe at approximate depths of 9, 9, 11, 11, and 9½ feet, respectively. Groundwater levels and caved surfaces were typically encountered at approximately the same elevation as the water elevation in Arroyo Grande Creek. Groundwater was encountered at a depth of approximately 3 feet (elevation +17 feet) in the hand auger boring. During our field exploration program, the water in Arroyo Grande Creek was observed to be approximately ½ to 2½ feet deep. Variations in groundwater levels and soil moisture conditions will occur depending on changes in precipitation, runoff, tidal fluctuations, irrigation schedules, and other factors.

3.4 SEISMIC CONDITIONS

3.4.1 Faulting

The locations of the main faults mapped in the Central Coast area are shown on Plate 5 – Regional Fault Map. The majority of the faults within the Coast Ranges province and the Sierra de Salinas belt generally trend north-northwest. The California Geological Survey (CGS 1996, formerly the California Division of Mines and Geology) considers major faulting within the project vicinity to be related to the San Luis Range fault zone (a compilation of several named fault strands), the Los Osos fault, the offshore Hosgri fault, and the San Andreas fault. The CGS fault database consists of active and potentially active faults that are considered by the CGS to be capable of affecting regional seismicity in California.

Fugro utilized the fault search routine in FRISKSP (Blake, 2000) to identify active and potentially active mapped faults and fault segments within a 62-mile radius of the project vicinity. The site coordinates (latitude and longitude) for the Arroyo Grande Creek Waterways Management Plan vicinity were estimated to be 35.0952° latitude and -120.6030° longitude. Summarized below are nine (9) faults and fault segments that were considered to be the most capable of producing high ground motion within the project vicinity. Additional information is presented in the California Geological Survey (CGS, 2002) fault database.

Summary of Fault Characteristics

Fault	Approximate Distance From Site (mile)	Maximum Moment Magnitude (M_w)	Fault or Fault Segment Length (km)	Slip Rate (mm/yr)
San Luis Range (S. Margin)	1.8	7.2	64 ± 6	0.2 ± 0.1
Los Osos	6.2	7.0	44 ± 4	0.5 ± 0.4
Casmalia (Orcutt Frontal Fault)	11	6.5	29 ± 3	0.3 ± 0.2
Hosgri	14	7.5	169 ± 17	2.5 ± 1.0
Rinconada	16	7.5	190 ± 19	1.0 ± 1.0
Lions Head	16	6.6	41 ± 4	0.02 ± 0.02
Los Alamos – Baseline	28	6.9	28 ± 3	0.7 ± 0.7
San Juan	31	7.1	68 ± 7	1.0 ± 1.0
San Andreas (Cholame)	42	7.3	63 ± 6	34 ± 5

San Luis Range Fault System. The San Luis Range fault system is the closest mapped fault to the site. The California Geologic Survey (CGS, 2002) groups the Oceano, Wilmar Avenue and several other faults as the San Luis Range fault system, which they consider to be potentially active. The Wilmar Avenue and Oceano faults, shown on Plate 6 – Local Fault Map, are interpreted by CGS to be a part of the San Luis Range fault system. No known active faults cross the site and the site is not located within a designated Alquist-Priolo Earthquake Fault Zone.

The mapped locations of the Wilmar Avenue and Oceano faults shown on Plate 6 are inferred offsets in well logs and steps in the Franciscan bedrock from geophysical data. Within the Cienega Valley, the inferred locations of the faults are concealed by relatively deep alluvium. It is our opinion that the presence of the faults does not pose a significant fault rupture hazard to the project. However, significant ground motion could impact the site if an earthquake were to occur on the San Luis Range fault system within the life of the project.

3.4.2 Historical Seismicity

The project is located within a seismically active region of Central California. Historical records indicate that the area has been subject to various seismic events over the last 183 years (PG&E, 1988). A summary of Magnitude 2 and greater seismic events recorded from 1933 through March 2008 by the Council of the National Seismic System (CNSS 2008) are presented on Plate 7 - Historical Seismicity Map. Examples of relatively strong ground motion that has reportedly been experienced near the project area are the seismic events of 1830, 1857, 1913, 1916, 1917, 1952, 1966, 1980, and 2003.

The 1830 event is estimated to be an approximately M5.0 earthquake that occurred from a poorly located source near San Luis Obispo. The effects of the 1830 event were generally observed between the Los Osos and Rinconada faults. The 1857 event (the Fort Tejon earthquake) occurred on the Mojave segment of the San Andreas fault, and reportedly resulted in damage in central and southern California. The 1913 event is estimated to be an approximately M5 earthquake that occurred along the southwestern margin of the San Luis/Pismo block near Arroyo Grande. The 1916 event is estimated to be an approximately M5.0 earthquake that occurred near Avila, possibly along the Los Osos fault or faults along the southwestern margin of the San Luis/Pismo block. The 1917 event is estimated to be an approximately M5.0 earthquake that occurred near Lopez Canyon between the Rinconada and West Huasna faults. The 1952 earthquake is estimated to be a M6.0 earthquake occurring within the Nacimiento Fault Zone. The 1966 event (the Parkfield earthquake) is estimated to be an approximately M6.0 earthquake that occurred on the San Andreas fault. The 1980 event is estimated to be an approximately M5.0 earthquake that occurred offshore near Point Sal along the Casmalia fault zone, and near its intersection with the Hosgri fault.

The 2003 event (the San Simeon Earthquake) is estimated to have been a M6.5 earthquake resulting in a ground acceleration of about 0.29 ± 0.04g in the project vicinity (Holzer et al., 2004). The epicenter of the 2003 earthquake was located approximately 51 miles northwest of the site, near the Nacimiento fault zone, and near the previous M6.0 1952 Bryson Earthquake. According to Holzer et al. both the Bryson and San Simeon Earthquakes caused damage in Oceano. Evidence of liquefaction in the fields along Cardoza Ranch (Plate 2) and displacement of the Arroyo Grande Creek levee were both documented by the Holzer et al. team following the 2003 earthquake.

4. GEOTECHNICAL ANALYSIS

4.1 SEISMIC HAZARD ANALYSIS

A preliminary probabilistic seismic hazard evaluation for the site was performed using the computer program FRISKSP (Blake, 2000) and the USGS Hazard Calculator program based on the 2007 California Building Code (CBC). The current CBC was adopted by the County in January 2008, and was used to define the seismic hazard exposure for this preliminary evaluation. The CBC seismic design code is referenced to the American Society of Civil Engineers ASCE 7-05 report. The program FRISKSP is based on FRISK (McGuire, 1978) and has been modified for the probabilistic estimations of seismic hazards using three-dimensional earthquake sources. The results of our preliminary evaluation are tabulated below.

Our evaluation was used to estimate earthquake effects corresponding to the Maximum Considered Earthquake (MCE). The MCE is defined by the code as an earthquake having a 2 percent chance of being exceeded in 50 years (Statistical Return Period of approximately once every 2,475 years). Design earthquake ground motions for liquefaction and other geotechnical analyses are defined as two-thirds ($^2/_3$) of the corresponding MCE ground motions.

Based on velocity data estimated in the USGS (Holzer et al., 2004) study and subsurface conditions encountered at the site, the Soil Profile Type selected for our evaluations was Site Class D, “S_D”. This soil profile type corresponds to a stiff soil profile with an average shear wave velocity ranging between 600 and 1,200 feet per second (180 and 360 meters per second), according to the CBC (2007). The average velocity for the upper 100 feet was estimated at approximately 224 meters per second (m/s) for explorations SOC035, SOC036 and SOC037. Although liquefaction can be a basis for modifying the site class, only portions of the site were estimated to have a potential for liquefaction and associated loss in strength under the MCE (discussed in Section 4.2 of this report).

FRISKSP was used to estimate the peak horizontal acceleration using the attenuation relationship proposed by Boore et al. (1997) and assuming an average shear wave velocity of 250 m/s in the upper 100 feet. The MCE was estimated to result in an approximately peak horizontal ground acceleration of 0.7g, and is assumed to occur from an M7.0 event on the San Luis Range Fault System for the purposes of our evaluation. The ground motion was reduced by two-thirds to 0.46g as input to our seismic hazards evaluation.

4.2 LIQUEFACTION AND SEISMIC SETTLEMENT

Liquefaction is defined as the loss of soil strength due to an increase in soil pore water pressures that results from seismic ground shaking. In order for liquefaction to occur, three general geotechnical conditions need to occur: 1) groundwater is present within the potentially liquefiable material; 2) the soil is granular and meets a specific range of grain sizes; and 3) the soil is in a loose state of low relative density. If those conditions are present and strong ground motion occurs, portions of the soil column could liquefy, depending upon the intensity and duration of the strong ground motion. Seismic settlement can occur in relatively loose sands, similar to soil types that are vulnerable to liquefaction, but can also occur in soils that are unsaturated and above the groundwater table.

The manifestation and damage that can be associated with liquefaction is strongly dependent on the duration of the ground motion. Liquefaction and seismic settlement hazards were evaluated using NCEER guidelines (Youd and Idriss, 2001) for the design M7.0 earthquake having a ground acceleration of 0.46g. Earthquakes that occur closer to a site generally result in higher ground motions than a similar magnitude earthquake that could occur away from the site. The design earthquake ground motion (0.46g) is higher than the San Simeon Earthquake ground motion (0.25g, adjusted for site-specific amplification effects). The stronger ground motion from the design earthquake would likely result from a near-field earthquake occurring within only 1 to 6 miles of the site, much closer than the San Simeon Earthquake. For purposes of comparison, we also conducted liquefaction analyses using data from the San Simeon Earthquake effects (M6.5 and 0.25g). The USGS (2004) study reports that liquefaction resulting from the San Simeon Earthquake significantly impacted the south levee within the western limits of the project.

Field data from the CPT soundings were used to estimate liquefaction and seismic settlement for the analysis. These data were then imported into a geographic information system (GIS) to spatially orient the digital information. Liquefaction analyses were subsequently performed using a programmed algorithm. The results of the analyses are presented with the subsurface profiles presented on Plates 4a and 4b, and on logs of the individual CPT soundings in Appendix C. The red lines on these plates are the estimated CPT tip resistance needed to resist liquefaction for the seismic conditions considered. A blue zone between the red line and the CPT tip resistance indicates a zone of potentially liquefiable soil.

Various soil layers within the sandy alluvium units (Qal1 and Qal2 on Plates 4a and 4b) are potentially liquefiable under the design earthquake. The fine-grained units of the alluvium (Qal3, Qal4 and Qal5 on Plates 4a and 4b) consist mostly of clay and are not considered susceptible to liquefaction. The existing levee fill (Af on Plates 4a and 4b), though underlain by the potentially liquefiable foundation support soil, appears to be relatively compact and has a low potential for liquefaction.

The potentially liquefiable soil was encountered within two zones of the sandy alluvium: an approximately 13-foot thickness of sand encountered just below the levee within the Qal1 unit at the west end of the project, and relatively thin, interbedded loose to medium dense sand layers within the Qal1 and Qal2 units encountered at various depths and locations over the site. The first area (near Cordova Ranch) has the greatest potential for liquefaction, and is within the Pre-settlement Estero area where liquefaction resulted in damage to the south levee following the San Simeon Earthquake. Our analysis suggests that the interbedded sandy units identified outside the Pre-settlement Estero area are generally denser and likely did not experience significant liquefaction in response to the San Simeon Earthquake.

Manifestation of liquefaction could impact the existing or proposed levee as settlement, instability, or cracking of the levee. We estimate that approximately 2 to 9 inches of seismic settlement could occur along the levee due to liquefaction under the design earthquake. Seismic settlement is estimated to be approximately 2 to 4 inches upstream of about Creek Road and approximately 3 to 9 inches within the Pre-settlement Estero Area downstream of about Creek Road. An evaluation of potential instability of the levee associated with liquefaction is discussed in the following section. The estimated higher settlement downstream of Creek Road is the same area where instability and settlement of the levee was reported following the December 2003 San Simeon Earthquake.

4.3 SLOPE STABILITY

The purpose of the slope stability analysis was to provide a basis for recommending slope inclinations for the preliminary design of the proposed levee improvements, and to evaluate the stability of the proposed embankments relative to the geotechnical feasibility of raising the levees. Slope stability analyses were evaluated for static loading conditions, pseudostatic (earthquake) loading, and post-liquefaction static loading conditions. The loading conditions analyzed as well as the results of our slope stability analyses are presented in Appendix D.

Slope stability analyses were performed for typical cross sections estimated at a location on the north levee embankment in the vicinity of Sta. 72, and at a location on the south levee embankment near Sta. 30 on the Cardoza Ranch that was destabilized by the 2003 San Simeon Earthquake. For both sections, slope stability was evaluated for the interior (creek side) and exterior (land side) levee slopes. The surface profiles at the cross section locations were selected based on cross sections provided by SH+G (2008b). The stability of the existing levees at these two locations was estimated under the existing static slope conditions, and considering liquefaction of the foundation support soil that reportedly occurred during the 2003 San Simeon Earthquake. The estimated stability of the existing slope levee provides a basis for evaluating the impact raising the levee will have on slope stability.

Two proposed embankment configurations were evaluated, each with six (6) feet of artificial fill placed above the existing embankment crest elevation. The first proposed configuration was evaluated with the raised levee centered on the centerline of the existing levee, and with the exterior and interior slope graded to an inclination of 2h:1v. The second proposed configuration was evaluated with the crest of the raised levee moved landward with a flatter interior slope that would match the existing approximately 3.5h:1v slope inclination. The exterior slope was evaluated using a 2h:1v inclination, the same as the first configuration.

4.3.1 Slope Stability Criteria

For the purpose of evaluating analytical results, 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, and at least 1.1 under pseudostatic (earthquake) loading conditions when using a horizontal pseudostatic coefficient of 0.15. These values are consistent with local practice and CDMG (1997) guidelines for slope stability evaluations. A factor of safety of 1.0 represents the theoretical boundary below which a slope is no longer stable and experiences failure. Factors of safety greater than 1.0, such as those stated above, are typically used to define stable slope conditions in practice to help account for uncertainties in characterizing subsurface conditions and limitations of analyses used to evaluate slope stability. We considered the potential for liquefaction to impact the levee slopes in the analysis. Ground motions and liquefaction generated by the 2003 San Simeon earthquake are reported to have resulted in damage to a portion of the southern levee and sand boils near the Cardoza Ranch (USGS, 2004).

4.3.2 Analysis Methods

The slope stability analyses were performed using the computer program GSTABL7 (Gregory, 2001). GSTABL7 was used with STEDwin (Van Aller 2002) to estimate factors of safety for slope stability under static and pseudostatic loading conditions. GSTABL7 requires the user to input the ground surface profile; subsurface profile; soil properties including unit weight (γ), friction angle (ϕ), and cohesion (c); groundwater levels; and the analysis method to be used. Plots of the output, soil properties, and conditions used for the analyses are presented in Appendix C. Slope stability analyses were performed using the modified Bishop method to estimate factors of safety for circular failure surfaces. A key to the results of our slope stability analyses is presented on Plate C-1 in Appendix C.

4.3.3 Selection of Shear Strength Parameters

For our static load stability analyses, “static” shear strength parameters were assigned to selected subsurface units based on correlations with CPT data. The shear strength of sand units were modeled as cohesionless, based on a phi-only (ϕ) analysis estimated from the CPT data. The shear strength of fine-grained units was modeled as solely cohesive, based on the undrained shear strength estimated from the CPT data (S_u, noted as the cohesion intercept, c). Direct shear strength testing was performed on a relatively thin unit of clayey sand (SC) encountered at the base of levee embankments, because the strength of this unit was found to significantly influence the stability results. The layer was modeled as having both friction (ϕ) and cohesion (c) based on the additional direct shear test.

For our post-liquefaction stability analyses, “static” strength parameters were assigned to compacted fill, alluvium encountered above the groundwater table, medium dense “liquefiable” sand, and fine-grained soil layers because these units were considered as having limited or low potential for strength loss due to liquefaction. Post-liquefaction undrained residual shear strength values ($S_{u,r}$) were assigned to liquefiable soil units using correlations to CPT data and methods recommended by Seed and Harder (1990), which were mainly the loose sand units below the groundwater table (Qal1 on Plates 4a and 4b). The post-liquefaction undrained residual shear strength value was assigned as an equivalent value of cohesion (c) with a frictional angle (ϕ) equal to zero.

4.3.4 Groundwater Conditions

The groundwater levels used in our slope stability analyses were based on our field observations discussed in Section 3.3 of this report. The groundwater level was modeled near or above the existing water level in the creek. Rapid drawdown can occur in poorly drained soil as flood water recedes, typically resulting in surficial instability or slumping of the slope face. Specific analysis for rapid drawdown conditions was not performed, because the existing embankment soil is relatively well-drained sandy material and in our opinion should experience drainage to draw water away from the slope face as the flood water recedes. Additionally, the interior slopes of the existing channel are heavily stabilized by vegetation, except in local areas upstream of Highway 1, where some scouring of the slope has occurred.

4.3.5 Summary of Slope Stability Results

Preliminary plans (SH+G 2008a,b) show that the proposed levees will be raised approximately 3 to 6 feet above the existing top of levee. We estimated factors of safety for the existing and two proposed slope configurations described above. Each configuration was evaluated for two locations: one in the vicinity of Sta. 72 that is upstream of the 22nd Street Bridge, and one in the vicinity of Sta. 30 on the Cardoza Ranch. The estimated factors of safety for the existing and proposed levee slope conditions are generally considered stable under static loads. However, the estimated factors of safety for the existing and proposed embankment conditions are considered unstable when considering post-liquefaction of the underlying foundation support soils (mainly within the Qal1 unit shown on Plates 4a and 4b) in the vicinity of the Cardoza Ranch. Instability of the levee associated with liquefaction mainly occurs because the excess porewater pressure generated by the design earthquake is sufficient to essentially force loosely packed sand particles apart causing the soil to lose strength.

Sta. 72 Vicinity, North Levee Upstream of 22nd Street. The estimated factors of safety for this vicinity exceed those needed for slope stability for the existing and proposed conditions. The estimated factors of safety were greater than 1.7 for static loading conditions, and greater than 1.2 for pseudostatic (earthquake) loading conditions. The soils encountered in this area, although prone to liquefaction and moderate seismic settlement under the design earthquake, do not appear to be prone to significant loss in strength in response to liquefaction that would cause the estimated factor of safety of the slope to be considered unstable. For preliminary design, this evaluation generally suggests that the existing and proposed levee slope configurations considered in our evaluations are relatively stable under static and earthquake loading conditions upstream of about Creek Road (outside the limits of the Pre-settlement Estero noted on Plate 2). A summary of the slope stability results for this vicinity is provided in the following table.

Summary of Slope Stability Results for Sta. 72 Vicinity on North Levee upstream of 22nd Street Bridge

Condition		Estimated Factor of Safety		
		Static Loading	Pseudostatic (earthquake) Loading	Post-Liquefaction
Existing	Interior 3.5h:1v Slope	2.5	1.5	2.5
	Exterior 2h:1v Slope	1.7	1.2	1.7
Proposed Configuration 1: 6-foot levee raise centered on existing levee	Interior 2h:1v Slope	1.9	1.3	1.8
	Exterior 2h:1v Slope	1.7	1.2	1.7
Proposed Configuration 2: 6-foot levee centered outside existing channel and levee)	Interior 3.5h:1v Slope	2.5	1.5	2.2
	Exterior 2h:1v Slope	1.7	1.2	1.7

Sta. 30 Vicinity, South Levee on Cardoza Ranch. The estimated factors of safety for this vicinity exceed those needed for slope stability for the existing and proposed conditions when considering static loads, but are potentially unstable when considering post-liquefaction conditions associated with the design earthquake. This is essentially the same areas where instability of the levee was reported by the USGS (Holzer et al. 2003) following the December 2003 San Simeon Earthquake. The estimated factors of safety for the existing levee when considering post-liquefaction conditions were approximately 0.8 to 1.1, and generally below the minimum factor of safety of 1.1 considered to be stable by the County guidelines when considering earthquake loading conditions. The estimated factor of safety for post-liquefaction conditions falls to 0.5 to 0.8 when considering the proposed levee configurations. For preliminary design, this evaluation generally suggests that the existing and proposed levee slopes are relatively stable under static loads, and potentially unstable when considering earthquake (post-liquefaction) conditions downstream of about Creek Road (within the limits of the Pre-settlement Estero noted on Plate 2). A summary of the slope results for this vicinity is provided in the following table.

Slope Stability Results for Sta. 30 Vicinity on South Levee on Cardoza Ranch

Condition		Estimated Factor of Safety		
		Static Loading	Pseudostatic (earthquake) Loading	Post-Liquefaction
Existing	Interior 3.5h:1v Slope	2.6	1.5	0.8
	Exterior 1.5-2h:1v Slope	1.9	1.3	1.1
Proposed Configuration 1: 6-foot levee raise centered on existing levee	Interior 2h:1v Slope	1.9	1.3	0.5
	Exterior 2h:1v Slope	1.9	1.3	0.8
Proposed Configuration 2: 6-foot levee centered outside existing channel and levee)	Interior 3.5h:1v Slope	2.6	1.5	0.7
	Exterior 2h:1v Slope	1.9	1.3	0.8

5. GEOLOGIC HAZARDS AND GEOTECHNICAL CONSIDERATIONS

The following sections present a summary of geologic hazards that were evaluated for the project, our opinion regarding the potential for the hazards to impact the project, and preliminary recommendations for mitigation of the hazard, if needed.

5.1 APPROACH

The County has provided input regarding how potential impacts to the levee that may be related to earthquake/seismic related hazards should be evaluated. Earthquake related hazards and their associated impacts have been evaluated and discussed specific to the project. However, the County has stated that the project will not include potentially costly mitigations for seismic hazards that may damage the levee. We understand that the County's approach to mitigating seismic hazards will generally be to repair damages in response to earthquakes, should they occur. The County feels that given economic constraints, the most beneficial use of the available funds would be to provide increased flood protection. A factor in this decision is the unlikeliness that there would be full flows in Arroyo Grande Creek at the same time as a damaging earthquake. It is anticipated that if an earthquake occurs and damage is realized, that the County would have the opportunity to make repairs to the levee system before high flows would inundate the channel. The County will consider alternatives to mitigate or partially-mitigate seismic hazards if they can be relatively easily accomplished within the economic constraints of project.

The assessment of hazards is therefore discussed relative to potential impacts to the project, relative to the existing levee conditions, the general type of mitigation that may be needed to address seismic related hazards, and whether or not we recommend that potential impacts of the hazard be considered in the County operation, maintenance and emergency response planning for the levee.

5.2 FAULT RUPTURE

Fault rupture is the displacement of the ground surface created by movement along a fault plane during an earthquake. The project vicinity is not located within a designated Alquist-Priolo Earthquake Fault Hazard Zone. The Alquist-Priolo Earthquake Fault Zoning Act identifies areas of known active faults, and the main purpose of the act is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. While habitable structures can be sited away from known active faults, uninhabited infrastructure, such as the levees proposed for this project, may not be able to be sited away from faults and therefore would have to cross any fault that were present.

A fault rupture hazard would exist where the levee would cross directly on an active fault, and rupture of that fault could displace the ground surface upon which the levee is located. The closest mapped active fault to the project vicinity is the Oceano fault. The Oceano fault is considered potentially active, and to be a part of the San Luis Range fault system. The Oceano fault is mapped approximately 1,000 feet southwest of the western terminus of the project, as shown on Plate 6. The potential for fault rupture to impact the project site is considered low and no mitigation for fault rupture is recommended.

Mitigation: None anticipated.

5.3 STRONG GROUND MOTION

The potential exists for strong ground motion to affect the project during the design lifetime. Strong ground motion (shaking) can occur in response to local or regional earthquakes. The project site is located within a seismically active area, and has been impacted by historic earthquakes in the recent past (such as the 2003 San Simeon Earthquake). The recency of the San Simeon Earthquake however does not suggest that the project area is more prone to earthquakes, or has a greater frequency of earthquakes, than it did prior to 2003. In general, the primary effects will be those phenomena associated with shaking and/or ground acceleration. Those effects are discussed in subsequent sections of this report regarding liquefaction, seismic settlement, ground lurching, and slope instability.

As discussed in Section 4.1 of this report, the design earthquake for this project is estimated to be a M7.0 event with a corresponding peak ground acceleration of approximately 0.46g. Design earthquake ground motions for liquefaction and other geotechnical analyses are defined as two-thirds ($^2/_3$) of the corresponding MCE ground motions. The MCE was defined based on the CBC as an earthquake having a 2 percent chance of being exceeded in 50 years (Statistical Return Period of approximately once every 2,475 years).

Mitigation: Seismic data and site classification for the design of levees should be reviewed and updated in the design-level Geotechnical Report in accordance with applicable County codes, ordinances, and guidelines. The report should provide ground motion parameters (magnitude and peak ground acceleration) for use in geotechnical analyses, such as for evaluating slope stability, liquefaction, and seismic settlement.

5.4 LIQUEFACTION AND SEISMIC SETTLEMENT

As discussed in Section 4.2, the existing levee is underlain by geologic units that may contain sediments susceptible to liquefaction. The potentially liquefiable soil was encountered within two zones of the sandy alluvium: 1) an approximately 13-foot thickness of sand encountered just below the levee within the Qal1 unit (see Plate 4a) at the west end of the project, and 2) relatively thin, interbedded loose to medium dense sand layers within the Qal1 and Qal2 units encountered at various depths and locations over the site. The first area (near Cordova Ranch) has the greatest potential for liquefaction, and is within the Pre-settlement Estero area where liquefaction and seismic settlement damaged the southern levee following the San Simeon Earthquake in 2003. Our analysis suggests that the interbedded sandy units identified outside the Pre-settlement Estero area are generally denser and likely did not experience significant liquefaction in response to the San Simeon Earthquake.

Manifestation of liquefaction could impact the existing or proposed levees as settlement, instability, or cracking of the levees. We estimate that approximately 2 to 9 inches of seismic settlement could occur along the levees due to liquefaction under the design earthquake. Seismic settlement is estimated to be approximately 2 to 4 inches upstream of about Creek Road and approximately 3 to 9 inches within the Pre-settlement Estero Area downstream of about Creek Road. An evaluation of potential instability of the levees associated with liquefaction is discussed in the following section. The estimated higher settlement downstream of Creek Road is within the area where instability and settlement of the levees was reported following the December 2003 San Simeon Earthquake.

Mitigation of liquefaction potential can be relatively costly. Mitigation methods for this project could consist of either removal and replacement of potentially liquefiable soils with properly compacted fill (estimated to be at least 13 feet below the existing streambed near Cardoza Ranch), or in-situ ground improvement to deeply compact the soil and thereby reduce the potential for liquefaction and seismic settlement to impact the levees, or widening the crest width and designing the levee with flatter slopes to help limit slope movement associated with liquefaction and slope instability (however, right-of-way and channel constraints may limit the feasibility and practicality of this mitigation method).

Alternatively, liquefaction and seismic hazards can be addressed in an Emergency Response Plan (ERP) for the levee improvements. The ERP should recognize the potential for liquefaction and seismic hazards to impact the levee, and delineate specific high hazard areas that should be inspected for damage following an earthquake.

Mitigation: A design-level geotechnical report should be prepared to evaluate potential mitigation methods for liquefaction and seismic settlement, and/or address geotechnical issues that should be considered in the ERP. An ERP should be prepared as part of the design to identify high seismic hazard areas along the levees and protocols for responding and inspecting the levee following a damaging earthquake.

5.5 GROUND LURCHING

Ground lurching occurs as the ground is accelerated during a seismic event. As evidenced by the Loma Prieta, Landers, Northridge, and San Simeon Earthquakes, the effects of ground lurching can damage earthen fills. Ground lurching occurs due to detachment of underlying stratigraphic units, allowing near-surface soil to move differentially from underlying soil. The site is within a seismically active region of Central California that is prone to moderate to large earthquakes. It is therefore our opinion that there is a potential for ground lurching to impact the site. Ground lurching is generally not a geologic hazard that can be prevented, and therefore is mitigated by implementing preparedness measures.

Mitigation: Address in ERP with other seismic hazards.

5.6 LANDSLIDING AND SLOPE INSTABILITY

5.6.1 Landslides

The project site is generally on relatively flat terrain and not in areas that would be subject to large-scale landslides. The site is not within an area of mapped landslides, unstable formations, or known instability that would impact the levees or creek.

Mitigation: None anticipated.

5.6.2 Static Slope Stability

Destabilization of a slope occurs when the driving mechanisms associated with the slope exceed the resistance capacity of the soils comprising the slope. We performed preliminary slope stability analyses of selected portions of the slopes to evaluate slope stability and the geotechnical feasibility of raising the levee. The slope stability evaluation is discussed in Section 4.3 of this report. Failure surfaces may be surficial or deep-seated, with varying degrees of soil displacement as a consequence. The estimated factors of safety for the existing slopes and proposed embankment configurations are considered stable under static loading conditions. Design and construction of slopes should be further evaluated in subsequent design-level geotechnical reports. The destabilization of the embankment slopes could also be triggered by bank erosion/scour, undercutting the toe of slopes, grading, animal burrows, or other factors that should be periodically reviewed and maintained following construction.

Mitigation: The design-level geotechnical report should be prepared to recommend final slope inclinations for design of the levee improvements. Periodic review and maintenance of the improved channel and levee should be provided to help maintain vegetation, remove debris, and repair areas of scour, erosion, burrowing, or other changes to the channel slopes (see Scour and Erosion, Section 5.8).

5.6.3 Seismic Slope Stability and Lateral Spreads

We evaluated the stability of existing and proposed levee embankments under pseudo-static (earthquake) load conditions and post-liquefaction conditions, as discussed in Section 4.3 of this report). The destabilization of a slope can be triggered by forces (ground accelerations) associated with seismic activity. Additionally, a reduction in strength (resistance capacity) of constituent soils may be a consequence of seismically-induced liquefaction, potentially resulting in slope instability of the levee slopes and/or stream banks (a type of lateral spreading). Lateral spreading typically develops on sloping ground underlain by liquefiable soils or where free-face conditions can develop in a liquefiable soil, such as along a river bank or drainage. According to the USGS report (Holzer et al. 2004), lateral spreading was observed in areas along the perimeter of the Oceano Lagoon (north of the project site) following the December 2003 San Simeon Earthquake.

For preliminary design, the slope stability evaluation suggests that the existing and proposed levee embankments are generally stable under earthquake loading and post-liquefaction conditions upstream of about Creek Road. However, the existing and proposed embankments for the levee are potentially unstable within the Pre-settlement Estero area downstream of Creek Road (see Plate 2). Our evaluation also suggests that there is a potential for liquefaction and instability to impact the levee within the Pre-settlement Estero area whether the levee is raised or not. Mitigation of liquefaction hazards, as discussed in Section 5.4 of this report, would also help improve the stability of the levee slopes, but likely would be costly.

Mitigation: Address in ERP with other seismic hazards. The main mitigation for slope instability associated with seismic hazards in the ERP will be for the County to respond to earthquakes, and repair areas that may be damaged by these hazards. The design-level geotechnical report should address the potential for slope instability to occur in association with liquefaction, the extent to which the hazard could impact the design of improvements, and whether the hazard can be mitigated by modifying the geometry of the raised levee within the scope, right-of-way, and economic constraints of the project.

5.7 SUBSIDENCE AND COLLAPSE

The project site is not in an area where the withdrawal of subsurface fluids is known to have caused ground subsidence. The greatest potential for subsidence would be if potentially compressible soils were impacted by lowering of the groundwater table during construction dewatering. The buoyancy of the soil above a specific depth decreases as groundwater levels are lowered. Lowering of the groundwater level therefore increases the effective weight of the soil above that depth, which can cause the soil to subside (settle) under the increased weight of the ground above it.

Our subsurface exploration and geologic maps indicate the project area is underlain by heterogeneous alluvium deposits. The alluvium is currently saturated from near the creekbed elevation downward. We do not anticipate that dewatering will be necessary for construction purposes. However, if dewatering is planned, the potential for subsidence in association with lowering of the groundwater table should be evaluated.

Mitigation: None anticipated.

5.8 SCOUR AND EROSION

SH+G is performing the hydraulic analysis and estimating scour depths along Arroyo Grande Creek and Los Berros Creek for this project. As input to their analysis, Fugro obtained samples of selected streambed and stream channel materials within the project extent and performed grain size analysis. The stream channel deposits observed along the streambed consist predominantly of gravel and sand. The bank materials generally consist of interbedded layers of erodable granular and fine-grained soils. Erosion of the channel slopes has occurred in localized areas of scour observed during our July 2008 site visits, particularly in areas upstream of Highway 1.

Graded fill slopes associated with the levee improvements will be subject to sheet and rill erosion. Erosion of soils can be accelerated where soils are exposed directly to runoff and/or areas of concentrated storm runoff, such as at culvert outlets. Site drainage and landscape improvements can be designed to reduce the potential for soil erosion. We observed abundant vegetation along the interior levee slopes and within the creek channel, which likely decreases the susceptibility of surficial soils to erosion.

The stream channel is a dynamic environment that will likely change and respond to changes in flow and rainfall seasonally. The existing levee slopes within the channel of Arroyo Grande are mostly stabilized by vegetation with graded slope inclinations of about 3:1 or flatter. Maintaining vegetation within the channel and maintaining the channel slopes can be used to mitigate the affects of scour and erosion.

Mitigation: On-going maintenance or other measures should be provided to reduce the potential for scour of the levee slopes. Erosion control measures, such as hydro-seeding, erosion control matting, and maintenance, should be provided to reduce the potential for erosion while vegetation is being established on new slopes. On-going maintenance of the slopes should be provided, as-needed, to assist in establishing appropriate vegetation, to repair areas where localized scour and erosion may impact slopes, and to remove debris from the channel that may dam or adversely channel the flow of water within the channel. Energy dissipation and erosion control devices should be provided at outlets of drainage pipes and in areas where there are concentrated flows of runoff to reduce the potential for erosion.

5.9 EXPANSIVE SOILS

Expansive soil generally consists of fine-grained soil of high plasticity (clay) that can damage near-surface improvements in response to shrinking and swelling associated with changes in soil moisture content. The expansion potential of the soil used to construct a levee can influence the strength and permeability of the levee. While clay material near the core of an embankment can help to limit seepage through the embankment, shrinking and swelling of the clay soil can also influence the stability and maintenance of the slope face. The existing levees appear to be constructed of predominantly sandy sediment having a low potential for expansion, therefore, surficial soils having a high potential for expansion are not anticipated to impact the levee improvements.

Mitigation: The design-level geotechnical report should provide recommendations for fill material that can be used in raising the levee. The recommendations should consider the expansion potential and other geotechnical properties of the soil relative to controlling the seepage and slope stability conditions for the new levees.

5.10 HYDROCOLLAPSE POTENTIAL

Hydrocollapse or hydroconsolidation describes soils that are prone to settling when subjected to wetting or saturation. Hydroconsolidation can result in differential settlement and possible cracking of the levee, particularly if the soils vulnerable to collapse are left in-place below the levee fill. The levee fill itself will be constructed of compacted fill that should not be prone to excessive settlement or collapse due to wetting. Shallow near surface soils, such as expansive clay soil and loose dune sand may be vulnerable to collapse. Near surface soils that may be vulnerable to collapse are typically removed during site preparation and grading and replaced with compacted (engineered) fill. Soils below the groundwater (creekbed) level are not prone to post-construction settlement associated with hydrocollapse.

Mitigation: The design-level geotechnical report should provide recommendations for site preparation and grading to reduce the potential for settlement associated with hydrocollapse to impact the levee.

5.11 TSUNAMIS AND INUNDATION

Tsunamis are long-period sea waves created due to seismic events or submarine landslides and have historically occurred in the project region. Tsunamis can range in height from a few feet to greater than 50 feet, and can result in run-ups, or bores, extending great distances up streams, rivers, and creeks. As evidenced by recent events around the world, tsunamis can have devastating impacts on coastal areas. The project vicinity is located at elevations ranging from approximately el. +11 feet above mean sea level (MSL) to approximately el. +63 feet MSL near the city limits of Arroyo Grande. The County of San Luis Obispo has prepared web-based tsunami inundation maps (http://www.sloplanning-maps.org/ed.asp?bhcp=1) that show coastal areas that may be vulnerable to inundation from tsunami below about el. +40 feet MSL. The inundation zones are generally the coastal areas along San Luis Bay, and low lying areas along Arroyo Grande Creek. Nearly the entire project site is located below the estimated tsunami run-up elevation shown on the County website. As a result, tsunami run-ups may be considered a potential hazard to the existing levee and surrounding area. The presence of the levees would not increase the susceptibility of the project vicinity, and may provide moderate protection from smaller events should they occur.

According to Kilbourne and Mualchin (1980), the following historical tsunamis have occurred in the project region:

Historical Tsunami Run-up

Year	Estimated Tsunami Generation Location	Estimated Impact Location	Estimated Tsunami Run-up (feet)
1868[1]	Unknown	Morro Bay	Unknown
1878[2]	Unknown	Morro Bay	Unknown
1927	Local	Pismo Beach	6 feet
1946	Aleutian Trench	San Luis Obispo Bay	4-5 feet
1960	Chile-Peru Trench	Central Coast	>3 feet
1964	Gulf of Alaska	Central Coast	>3 feet
1	Speculative		
2	Reportedly overtopped the sand spit that separates the bay from the ocean (SLO County 1999).		

Mitigation: None anticipated. Tsunami hazards are typically addressed by developing warning systems and evacuation plans for coastal areas. The San Luis Obispo County Office of Emergency Services is responsible for the emergency response plan.

5.12 DAM INUNDATION

The project site is located downstream of Lopez Lake and two dams: the Lopez Canyon Dam and the Lopez Terminal Dam. According to the County of San Luis Obispo Safety Element (1999), the entire project extent is subject to inundation due to dam failure.

Mitigation: None anticipated. Dam inundation hazards are typically addressed by developing warning systems and evacuation plans for vulnerable areas. The San Luis Obispo County Office of Emergency Services is responsible for the emergency response plan.

5.13 NATURALLY OCCURRING ASBESTOS

Naturally occurring asbestos (NOA) is common in serpentine rock throughout San Luis Obispo County. The California Air Resources Board has identified serpentine rock as having the potential to contain asbestos. Serpentine rock is typically a constituent of Franciscan Formation mélange, which has not been mapped or encountered within the project limits. The grading for the project should therefore not encounter areas containing serpentine rock. Therefore, it is our opinion that there is a low potential for NOA to impact the project. If encountered, mitigation for NOA typically consists of dust control during earthwork operations to reduce the potential for asbestos dust from being an inhalation hazard.

Mitigation: The County will likely require a letter prepared by a geotechnical professional for the project that specifically identifies whether or not NOA is considered to be a potential hazard for the project.

5.14 RADON GASES

Radon gases are generally associated with Mesozoic granitic rocks and derivative Tertiary sedimentary rocks, and Tertiary marine sedimentary rocks. Radon hazards are generally related to an accumulation of radon gases within homes and housing structures and do not apply to the proposed levee project. The San Luis Obispo County Safety Element (1999) has identified these geologic formations as having high equivalent uranium (eU) concentrations. These formations have not been mapped or encountered within the project site. We do not anticipate components of the project will be planned for areas potentially containing rocks with high eU concentrations, nor would the raising of the levee have any impact on this hazard. Therefore, it is our opinion that there is a low potential for this hazard to impact the project.

Mitigation: None anticipated.

5.15 EMBANKMENT SEEPAGE AND PIPING

During sustained high-flow events, water permeating through the levee embankments may daylight on the exterior levee slopes, resulting in localized erosion of embankment material. Continued seepage and erosion can lead to piping, which generally consists of a tunnel-like void in the embankment that results from erosion of the embankment fill caused by uncontrolled seepage daylighting on the face of the exterior slope of the levee. The existing levee appears to be constructed of compacted sandy material that could be vulnerable to piping in the event that sustained flows at flood levels within the creek occurred.

Steady state seepage refers to the stabilized water level and zone of seepage through the levee at a sustained water level within the flow channel. The potential for steady state seepage to develop within the embankment is generally expected to be relatively low because the storm events for the project are likely to have a short duration (typically only a few hours in duration). We anticipate the typical duration of high-flow events may be short enough that a hydraulic gradient capable of daylighting on the exterior slope is unlikely to develop. We did not observe visual evidence of seepage or erosion of the existing embankment material that would indicate that piping or seepage through the levee has occurred in the past.

Mitigation for seepage and piping can consist of providing low permeability fill materials within the levee embankment to slow the rate of seepage through the embankment and/or providing drainage on the outer slopes of the levee to collect and control seepage. Drainage materials, if used, are designed with graded-granular filters that will help to retain the levee fill where the seepage exits the embankment and prevent piping. The design-level geotechnical study should include a detailed seepage analysis of the levee considering the flood levels and storm durations. It is likely that the design of the new levees can include provisions for using a layer of low-permeability materials within the embankment to control seepage. The near-surface alluvium encountered adjacent to the levees appears suitable for use as low-permeability material but would need to be evaluated for the project.

Mitigation: The design-level geotechnical report should address and evaluate seepage conditions through the embankment for the design storm events and water levels, and address the need for control of seepage and drainage to avoid piping and seepage from daylighting on the exterior slopes of the levee.

5.16 FOUNDATION SEEPAGE

Foundation seepage refers to underflow beneath the levee that results when the higher water level (high gradient) in the creeks infiltrates the creekbed, and then flows beneath the levee to the lower water level outside the levee (low gradient). Similar to embankment seepage discussed above, uncontrolled seepage daylighting beyond the exterior slope of the levee can result in boils, piping, and instability of the foundation soils where the seepage exits the ground. Piping of the subsurface can erode foundation materials and potentially destabilize the embankment.

A hand auger boring drilled adjacent to the exterior slope of the levee near Creek Road encountered groundwater at a depth of about 3 feet below the ground surface. Water was flowing in Arroyo Grande Creek at the time of the exploration. The water level suggests that the foundation soils beneath the levee embankments are saturated to some extent by the normal dry-season water flow within the creek. As a result, it is possible that rising water levels within the channel may increase the rate of seepage beneath the embankment relatively quickly.

The exit gradient refers to the hydraulic gradient where the foundation seepage will daylight on the outside of the levee slopes. The critical gradient refers to when seepage force exceeds the effective weight of the soil, heaves the soil, and typically causes a boil to form beyond the exterior slope of the levee. For design, exit gradients should be subcritical and are preferred to be 5 to 6 times below critical. We preliminarily evaluated seepage forces beneath the embankment near Creek Road considering the 20-year water surface elevation as defined by SH+G (2008b). The exit gradients were estimated to be subcritical for the raised levee condition, but by a factor of about 2, less than the optimal factor of 5 to 6.

The design-level geotechnical study should include a detailed seepage analysis of the levee foundation considering the flood levels and storm durations. Mitigation for foundation seepage can consist of cutoff walls, impervious blankets, or relief wells or drainage systems to control or reduce exit gradients.

Mitigation: The design-level geotechnical report should address and evaluate seepage conditions through the embankment foundation for the design storm events and water levels, and address the need for control of seepage and drainage to avoid piping and seepage from daylighting beyond the exterior slopes of the levees.

5.17 VEGETATION MANAGEMENT

Vegetation growing within the channel can block flows and reduce flood protection. The existing channel is relatively heavily vegetated with brush and small trees. Management of vegetation can impact seepage conditions if the root systems of dying or cut trees are left in-place to decay within the embankment. The County was performing a vegetation management program with the California Conservation Corps at the time of our field work. The program generally consisted of trimming low limbs from trees within the channel, and cutting smaller brush and vegetation on the channel slopes. Root holes and voids left from the decayed or pulled roots can shorten seepage paths through the embankment increasing the potential for seepage or piping to extend through the embankment.

Mitigation: Management of the vegetation within the Arroyo Grande Creek channel should include removal of dead trees, and repair of voids left from pulled or decaying roots by filling the voids with properly compacted soil.

5.18 SEDIMENT REMOVAL - DREDGING

Accumulation of sediment within the channel of Arroyo Grande Creek can reduce flood protection by blocking flow within the channel. Sediment will be removed from the existing channel as part of the project. Disposal of sediment will require that the sediments within the channel be characterized to evaluate whether or not the sediments are compatible with the disposal area in accordance with U.S. Army Corps requirements. Characterization typically includes laboratory tests for grain size and chemical compatibility. The properties of the sediment are then compared to potential disposal sites being considered to identify a suitable site for disposal. Typical disposal sites can include beach replenishment with sandy material, agricultural fields to replace lost fine-grained sediment, stockpiles to provide construction material resources, or as on-site fill material for the levee construction.

The sediment observed within the channel appears to be comprised of sand and gravel bars that have formed within the channel. Based on review of the project plans and water level observed during our field observations, most of the sediment that likely will be removed appears to be near or above the water level in the creek. If so, the sediment therefore likely would be removed by mechanical methods (such as by an excavator or other earth moving equipment).

Mitigation: The design-level geotechnical report should include characterization of the channel sediment that will be removed, and evaluate the suitability of the material for on-site use during the levee construction. The report should also discuss anticipated excavation conditions (above or below water) and appropriate excavation methods.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF FINDINGS

- The soils encountered along the project extent consisted of the existing levee fill material founded on alluvial deposits. The levee fill consisted of mostly medium dense to very dense sandy materials. The alluvium was encountered to the maximum depths explored, approximately 100 feet below the ground surface, and consisted of interbedded loose to very dense sandy soils and medium stiff to hard clay materials (see Plates 4a and 4b). Water was observed flowing in the creek at the time of our July 2008 field exploration program. Groundwater was encountered as shallow as approximately 9 feet below the existing top of levee and about 3 feet below the exterior toe of the levee, in explorations advanced for this study.

- The levees and channel along Arroyo Grande Creek were constructed in the late 1950's as a U.S. Department of Agriculture, Soil Conservation Service project (USDA 1956). The location of the creek is controlled by channels and levees, and portions of the creek were relocated as part of the construction of the levee system. The existing earthen levee is about 3 to 12 feet above adjacent grades. The USDA (1956) plans show the levees were designed with a 15-foot wide crest and side slopes graded to inclinations of 1½ h:1v to 2h:1v on the exterior slopes and 3h:1v on the interior channel slopes. The existing levees are less pronounced and more intermittent upstream of Highway 1, where the design height of the levee is generally less than about 3 feet above adjacent grades as shown on the plans. The existing stream channel upstream of Highway 1 is increasingly incised to the east, with local areas of near vertical creek bank and erosion.

- Geologic hazards relating to fault rupture, landsliding, subsidence, hydrocollapse, naturally occurring asbestos, and radon gases are unlikely to impact the project. The site is located within the inundation area identified by the County for failure of Lopez Canyon Dam or tsunami. The site is located within a seismically active area, and could be impacted by seismic hazards related to liquefaction, seismic settlement and slope instability. The County stated that their approach to mitigating seismic hazards will be to repair damages in response to earthquakes should they occur, and to focus the project on improving flood protection.

- Geotechnical considerations relating to scour, erosion, and seepage should be considered in the design, construction, and maintenance of the project. A detailed seepage analysis of the proposed raised levee configuration and design flood conditions should be provided to evaluate whether or not specific measures, such as provisions for drainage, low permeability materials, or flatter slopes will need to be included in the project design.

- The western limits of the project are located within an area underlain by a Pre-settlement Estero that has subsequently been filled in as a result of development and realignment of the channel. This area was documented by the County and USGS (Holzer et al. 2003) as an area where relatively extensive liquefaction and lateral spreading occurred (including damage to a portion of the southern levee) in response to the 2003 San Simeon Earthquake. The existing and proposed levees in this area have the potential to be impacted by liquefaction of the ground beneath the embankment, incur estimated seismic settlements of up to approximately 9 inches, and result in slope instability for the design earthquake. Upstream of Creek Road, the proposed and existing levees were estimated to be stable under the design earthquake but could experience seismic settlements of approximately 2 to 4 inches. Mitigation for these hazards should be considered in the emergency response and maintenance plan for the project.

- Slope stability analyses of the preliminary levee configurations suggest that the levee can be raised to the conceptual design height and should be stable under static loading and the anticipated flood levels. However, the stability of the levees likely would be compromised by liquefaction of the foundation soil within the Pre-

Settlement Estero area west of about Creek Road. Because it is unlikely that there would be full flows in Arroyo Grande Creek at the same time as a damaging earthquake, the County anticipates that if an earthquake were to occur and damage is realized, they would have the opportunity to make repairs to the levee system before high flows would inundate the channel. The existing levee is vulnerable to this potential hazard whether the height of the levee is raised to improve flood protection or not.

- ❖ The existing channel is relatively heavily vegetated with brush and small trees. Management of vegetation can impact seepage conditions if the root systems of dying or cut trees are left in-place to decay within the embankment. The County was performing a vegetation management program with the California Conservation Corps at the time of our field work. The program generally consisted of trimming low limbs from trees within the channel, and cutting smaller brush and vegetation on the channel slopes. Root holes and voids left from decayed or pulled roots can shorten seepage paths through the embankment increasing the potential for seepage or piping to extend through the embankment. Management of the vegetation should include removal of dead trees, and repair of voids left from pulled or decaying roots by filling the voids with properly compacted soil.
- ❖ Sediment will be removed from the existing channel as part of the project. The sediment that we observed within the channel is mostly comprised of sand and gravel bars that have formed within the channel. Based on review of the project plans and water level observed during our field observations, most of the sediment that likely will be removed appears to be near or above the water level in the creek. If so, the sediment would likely be removed using mechanical methods (such by an excavator or other earth-moving equipment). If excavation depths are lower, and/or the water levels higher, hydraulic dredging equipment may be used to clear saturated sediment from channels that are below the water level.

6.2 GEOTECHNICAL CONSIDERATIONS FOR CONSTRUCTION

6.2.1 Site Preparation and Grading

Grading for the improvements is likely to consist of placing fill material to raise and widen the existing levees. Prior to grading, the site should be cleared and grubbed. Where relatively small (less than approximately 1 foot) increases in the levee height may occur, the grading will likely be performed within the footprint of the existing levee. Prior to placing fill over the existing levee material, the surface of the existing fill should be scarified and compacted in-place to provide a suitable surface for placing additional fill. Voids or depressions left from clearing and grubbing, or possible rodent holes, should be filled with compacted material. Compacted fill can then be placed to finished grade.

Where higher grade raises are proposed and new fill will be placed beyond the footprint of the existing levee, additional site preparation could be needed prior to placing fill. The near-surface soil within the agricultural fields adjacent to the existing levees is likely loose, and should be removed prior to placing fill material. Site preparation in these areas will likely consist of removing the existing soil from areas to receive fill to a depth of about 2 to 3 feet below the existing ground surface. The new fill can then be placed on the undisturbed subgrade. Soft or yielding subgrade conditions should be stabilized by placing a mat of dry, compacted fill over the undisturbed subgrade. Where fill is placed over the existing fill, the new fill should be keyed and benched several feet into the existing levee slope to provide a uniform transition with the existing levee fill. The final grading and depth of removal should be evaluated during the design-level geotechnical evaluation.

6.2.2 Use of On-site Soil

Excavated on-site soil that is free or organics and deleterious materials should generally be suitable for use in levee construction. Dredged or wet soil removed from excavations will need to be dried to a moisture content suitable for compaction prior to being placed as compacted fill. Fine-grained soil that appears to be present to a depth of several feet within the agricultural fields may be suitable to provide a blanket of impervious fill within the new levees. The quality of and need for this material should be considered in the design-level geotechnical study.

6.2.3 Groundwater

Groundwater was encountered at approximately 3 feet below the existing ground surface near Creek Road. Groundwater levels will vary depending on the time of construction, and should be considered in the excavation plans for the project. Dewatering and control of groundwater will likely be needed for excavations performed within the existing channel, or extending more than about 2 to 3 feet below the existing ground surface.

6.2.4 Excavation

The existing soil encountered along the levee can likely be excavated using conventional earth-moving equipment. Excavations extending below the levee or within the channel will need to consider the potential for encountering wet and yielding ground. Wet soils within the channel, or below the adjacent grade within the agricultural fields, will likely not support heavy construction traffic, such as self-loading scrapers or haul trucks, without stabilization. Subgrade stabilization and maintenance of haul roads will likely be needed to provide suitable access for construction traffic.

6.3 GEOTECHNICAL CONSIDERATIONS FOR DESIGN

The design of the levee will be geotechnically intensive. This preliminary evaluation identified geotechnical considerations relating to slope stability, seepage, and grading that should be considered in the design of the project. The design-level geotechnical study will likely involve additional slope stability and seepage analyses to provide specific recommendations for design, and to confirm the preliminary slope inclinations provided in this report. The report will also provide material requirements for compacted fill, low-permeability materials, and drainage as needed for the improvements based on the results of the additional analyses.

6.4 COMPARISON OF EXISTING AND PROPOSED CONDITIONS

Because the existing and proposed levees are vulnerable to various geologic hazards, our assessment of hazards is discussed relative to potential impacts to the project and relative to the existing levee conditions. The following table provides a comparison of the existing and proposed raised-levee conditions relative to the geologic hazards and geotechnical considerations that were evaluated for the project.

The following is the ranking of hazards that we used in the comparison.

Low: There is a low potential for the hazard to impact the project, because either review of the hazard suggests there is no potential for it to occur, the hazard has not been documented to be present at the site, the hazard has already been mitigated by the existing levee, or it will be mitigated as part of normal design and construction practice.

Moderate. There is a potential for the hazard to impact the project, the hazard can either only be partially mitigated or mitigation of the hazard reduces the risk of damage but it cannot be completely mitigated, or the site could be impacted by a hazard that has a low or uncertain rate of recurrence.

High. The hazard is likely to impact the project within the design life of the project, or the hazard is present and requires mitigation by applicable design standards and codes.

Comparison of Geologic Impacts to Existing Condition

Hazard	Description of Hazard	Potential to Impact the Existing Levee	Change due to Raising Levee	Comments
Fault Rupture	Rupture of a fault beneath a site or structure that can cause upheaval, cracking, and displacement of ground surface.	Low	Same	There are no known active faults that cross the project.
Seismic Shaking	Ground motion that results from nearby or regional earthquakes. The design earthquake is a M7.0 event resulting in a peak horizontal ground acceleration of about 46% of gravity that should be considered in geotechnical analyses for slope stability and liquefaction.	High	Nearly the same	See liquefaction and slope stability hazards.
Liquefaction and Seismic Settlement	Loss of strength and displacement of ground surface that normally occurs in loose sandy soil below the groundwater table. Portions of the soil column beneath Arroyo Grande Creek are prone to liquefaction and seismic settlement under the design earthquake effects, particularly downstream of about Creek Road.	High	Same	Hazard likely to be addressed by emergency response planning (ERP).
Slope Instability – static loading	The stability of the levee embankment under normal static (not earthquake) loads that may occur at existing or flood level conditions.	Low	Same	Factors of safety above minimums for stability for existing and proposed levee.

Hazard	Description of Hazard	Potential to Impact the Existing Levee	Change due to Raising Levee	Comments
Slope Instability – seismic loading including lateral spreads **downstream of Creek Road**	The reduced stability of the levee embankment when considering horizontal forces, liquefaction of the foundation support soil, and potential lateral displacement that could occur in response to the design earthquake.	High	Nearly the same	Hazard likely to be addressed by ERP.
Slope Instability – seismic loading including lateral spreads **upstream of Creek Road**	Same as above.	Low to Moderate	Nearly the same	Factors of safety above minimums for stability for existing and proposed levee. Address in ERP.
Ground Lurching	Detachment of underlying stratigraphic units within the ground, allowing near-surface soil to move differentially from underlying soil, as a result of inertial forces associated with an earthquake.	Moderate	Same	Address in ERP.
Landslides	The potential for a site to be unstable as a result of the location being underlain by existing landslides. The area along Arroyo Grande Creek is flat and not prone to landslides.	Low	Same	No existing landslides.
Subsidence	Settlement of the ground surface due to extraction of fluids, such as may occur due to pumping from an oil field or water well. Subsidence is common where there are highly compressible soils in areas where the groundwater table is artificially lowered causing the effective weight of the soil to increase.	Low	Same	Lowering of the groundwater table is not anticipated.
Scour and Erosion	Removal of sediment within the creek, along its banks, or the surface of the levees due to stream flow. Scour and erosion can cause degradation of the streambed or bank erosion that can cause slopes to be unstable. Vegetation within the existing channel and on the levee slope is the primary protection of the slopes within the existing channel.	Moderate	Same	Scour conditions to be addressed in the design of levees. Maintenance of channel should include debris removal that may cause localized scour.
Expansive Soils	Shrinking and swelling of a soil in response to changes in soil moisture. Shrinking and swelling of soil within a levee could result in fissures or cracks that can lead to seepage.	Low	Same	Levee materials encountered predominantly consisted of granular soils having low expansion potential.
Hydrocollapse	Settlement that occurs within a soil with relatively high porosity in response to wetting of the soil, typically due to irrigation, flooding, or rainfall.	Low	Same	Soils are either not susceptible or will be removed and replaced with compacted fill during normal site preparation and grading.
Tsunami	Long-period sea waves created due to seismic events or submarine landslides, that can bore up coastal rivers and streams causing flooding and destruction due to fast moving water and severe erosion. The project site is located within the coastal inundation zones shown on the County website.	Moderate	Reduced	Some increased flood protection will be provided by higher levees, but final levee height is below the County estimated depth of inundation.

Hazard	Description of Hazard	Potential to Impact the Existing Levee	Change due to Raising Levee	Comments
Dam Inundation	Flooding due to failure or breach of an upstream dam or impoundment. The site is downstream and within the inundation zone for Lopez Dam.	High	Reduced	Some increased flood protection will be provided by higher levees, but the levees will not be designed to retain flooding due to a dam failure.
Naturally Occurring Asbestos	Potential for air-born dust particles to cause an inhalation hazard, particularly to construction workers performing earthwork or causing dust.	Low	Same	Serpentinitic rocks in San Luis Obispo County are known to contain asbestos, but have not been mapped or encountered within project vicinity.
Radon Gases	Potential for geologic formations containing equivalent uranium concentrations to cause inhalation hazards within homes.	Low	Same	Hazard not applicable to levee project, and is not known to be present within the project limits.
Embankment Seepage and Piping	Erosion and potential instability of the levee resulting from uncontrolled seepage through the levee embankment, and subsequent erosion of the levee embankment due to seepage forces daylighting on the outside slope of the levee. Raising the levee can increase the potential hydraulic gradient through the levee, and the severity of this potential hazard.	Low	Increased	The anticipated short duration for anticipated high-flow events may not have sufficient duration to cause steady-state seepage that would impact the levee. Because the impacts of seepage are important to the stability of hydraulic earth structures, seepage and any necessary mitigation should be addressed in the design of the levees. The existing levee does not appear to have been impacted by uncontrolled seepage or piping.
Foundation Seepage	Erosion and potential instability of the levee resulting from uncontrolled seepage beneath the levee embankment, and subsequent piping of the foundation support soil due to seepage forces daylighting outside of the levee footprint. Raising the levee can increase the potential hydraulic gradient through the levee, and the severity of this potential hazard.	Low to moderate	Increased	The anticipated short duration anticipated for high-flow events may not have sufficient duration to cause steady-state seepage that would impact the levee. However, because the impacts of seepage are important to the stability of hydraulic earth structures, seepage and any necessary mitigation should be addressed in the design of levee. The existing levee does not appear to have been impacted by uncontrolled seepage or piping beneath the levee.

Hazard	Description of Hazard	Potential to Impact the Existing Levee	Change due to Raising Levee	Comments
Vegetation Management	Vegetation growing within the channel can block flows and reduce flood protection. The existing channel is relatively heavily vegetated with brush and small trees. Management of vegetation can impact seepage conditions if the root systems of dying or cut trees are left in-place to decay within the embankment. Root holes and voids left from the decayed or pulled roots can shorten seepage paths through the embankment increasing the potential for seepage or piping to extend through the embankment.	High	Same	Management of the vegetation should include removal of dead trees, and repair of voids left from pulled or decaying roots by filling the voids with properly compacted soil for either the existing or proposed levee condition.
Sediment Removal – Dredging	Accumulation of sediment within the channel of Arroyo Grande Creek and reduction of flood protection by blocking flow within the channel. Existing sediment within Arroyo Grande Creek will be removed as part of the project, and will need to be disposed of or re-used onsite.	High	Same	Ongoing maintenance of the channel should include periodic removal of sediment for either the existing or proposed conditions.

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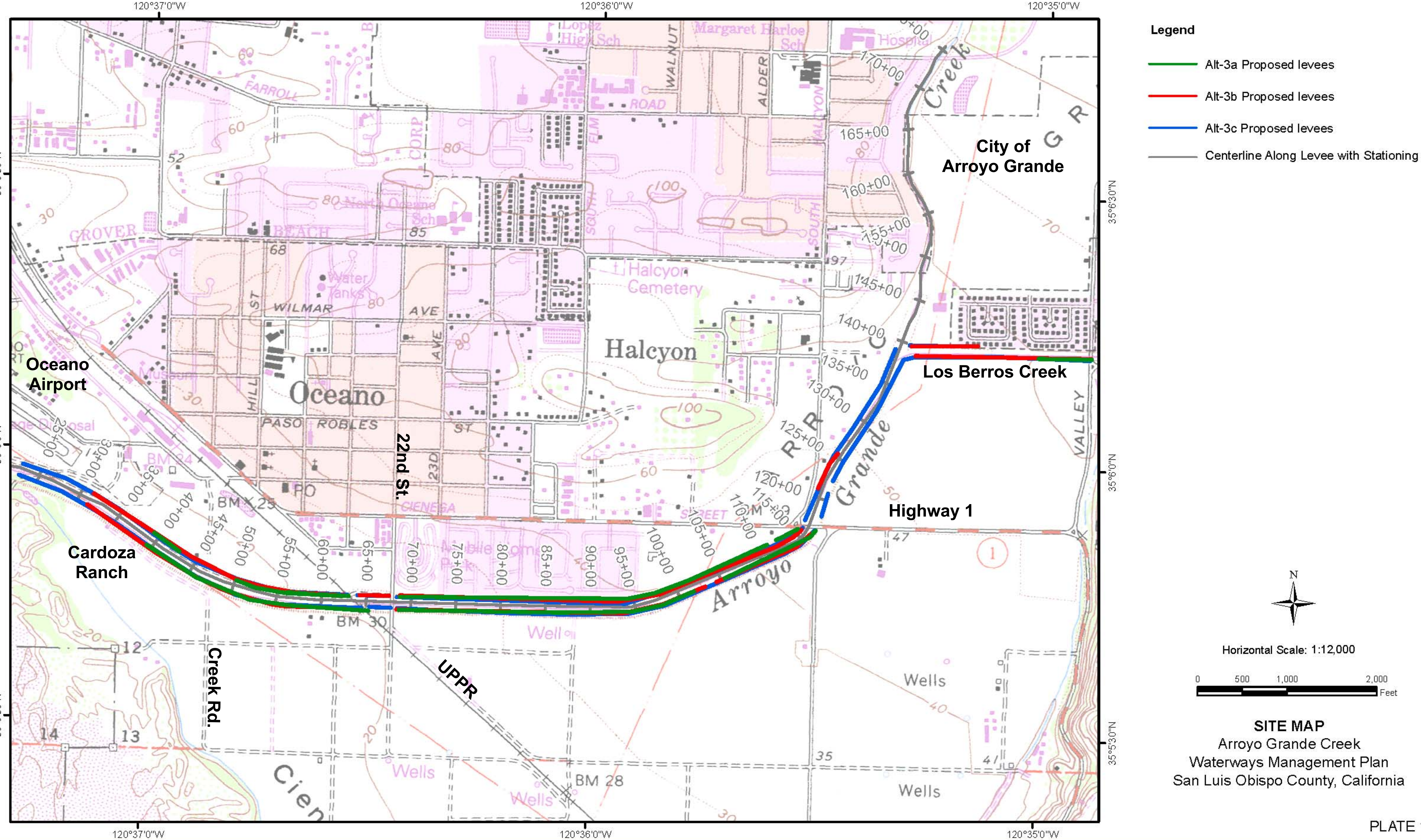
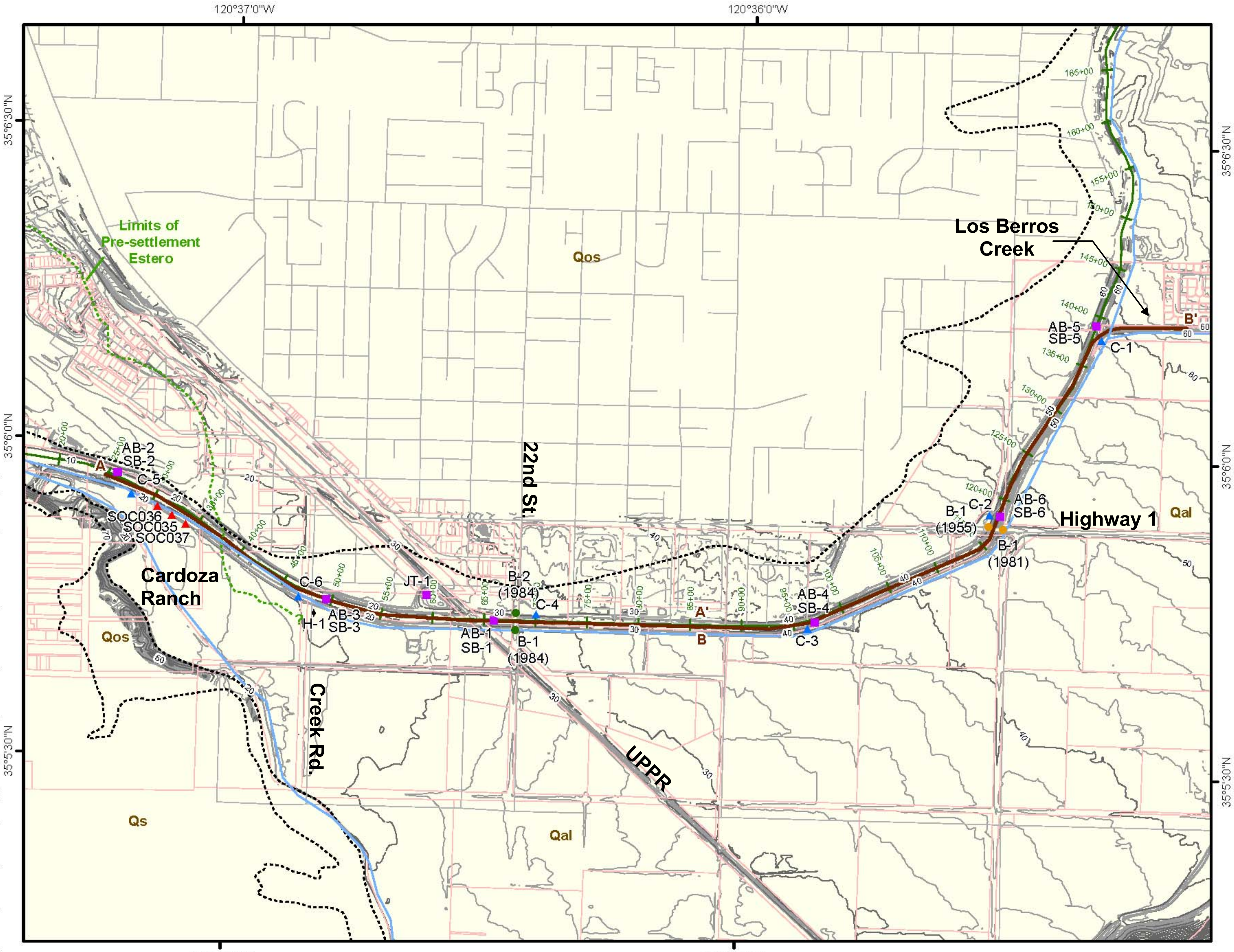
PLATES

County of San Luis Obispo
Project No. 3014.029



SITE MAP
Arroyo Grande Creek
Waterways Management Plan
San Luis Obispo County, California

PLATE 1



Legend

Approximate Exploration Locations

- Fugro CPT
- USGS SCPT
- Caltrans Boring (Year of Study)
- SLO County Boring (Year of Study)
- Hand Auger Boring
- Hand Samples
  - SB Collected from Streambed
  - AB Collected Above Water Surface
  - JT Collected from J.Taylor's Property
- Profile Line
- Centerline Along Levee with Stationing
- Roads
- 10 foot contour
- 2 foot contour
- Parcels within Zones 1 and 1a

Geology

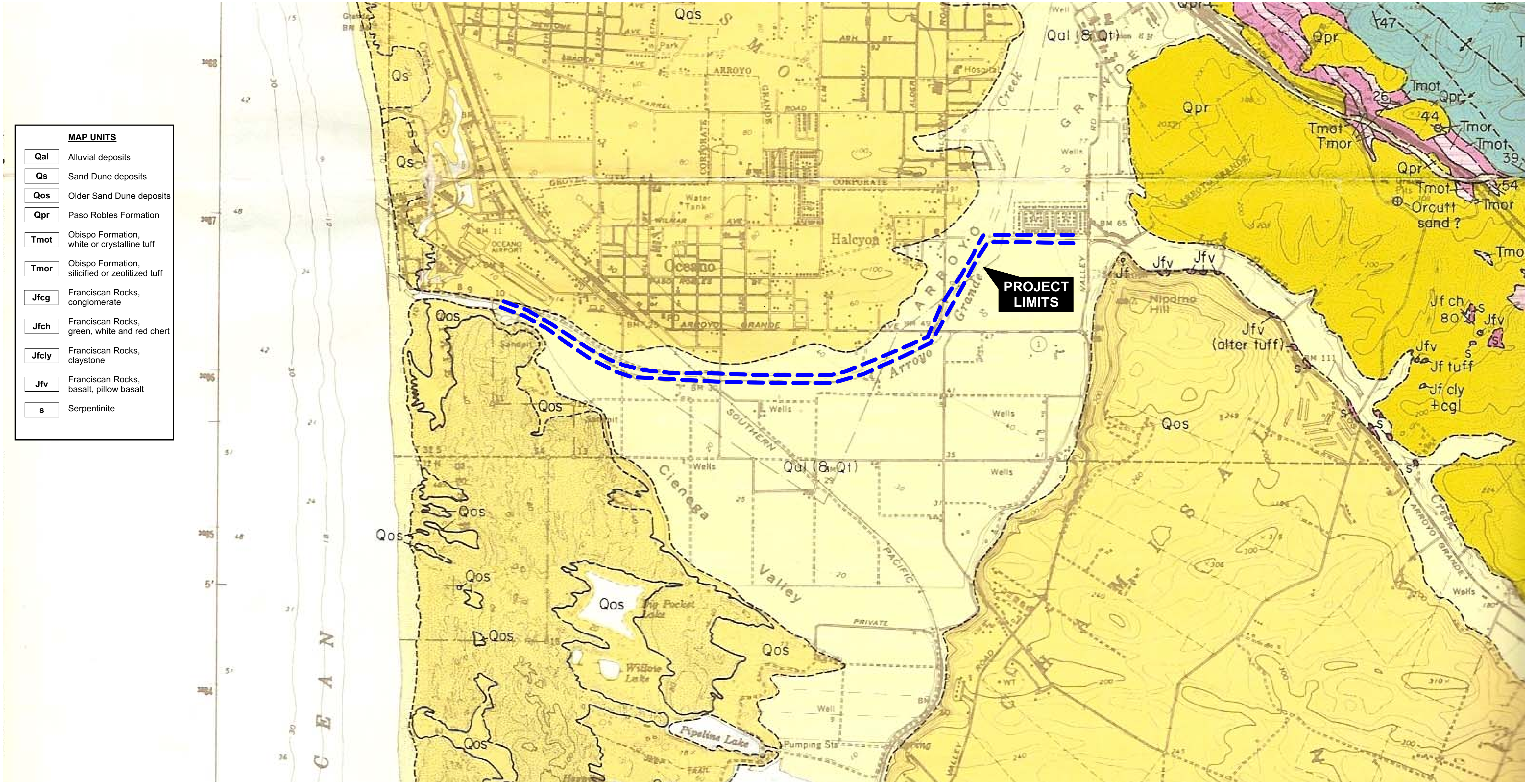
- Contact
- Limits of Pre-settlement Estero
- Qal Alluvial Deposits
- Qs Sand Dune Deposits
- Qos Older Sand Dune Deposits

N

Horizontal Scale: 1:12,000

1,000 500 0 1,000 Feet

FIELD EXPLORATION PLAN
Arroyo Grande Creek
Waterways Management Plan
San Luis Obispo County, California



BASE MAP SOURCE: Geology of the Arroyo Grande 15' Quadrangle, San Luis Obispo County (Hall, 1973).

LEGEND

- Contact - Dashed where approximately located or inferred; queried where doubtful; dotted where concealed
- High-angle fault - Dashed where approximately located or inferred; dotted where concealed and inferred; queried where uncertain. Arrows show relative direction of movement on cross sections when known; queried where uncertain.
- Thrust or reverse fault - Dashed where approximately located or inferred, dotted where concealed and inferred; queried where concealed or doubtful. Sawteeth on upper plate. Dip of fault plane between 30° and 80°
- Photo lineament - Queried where uncertain
- Synform - Trace of axis at surface. Dashed where approximately located. Flanks coverate downward in folds and in rocks whose stratigraphic sequence is unknown.
- Antiform - Trace of axis at surface. Dashed where approximately located. Flanks diverge downward in folds and in rocks whose stratigraphic sequence is unknown.
- Strike and dip of beds uncertain

Marker beds

- Conglomerate or gravel bed
- Sandstone
- Siltstone or diatomaceous siltstone
- Tuff
- Breccia

- 30 Strike and dip of flow banding
- x 6193 Megafossil locality - U.C.L.A. locality number
- Vollmer Ranch name/property owner

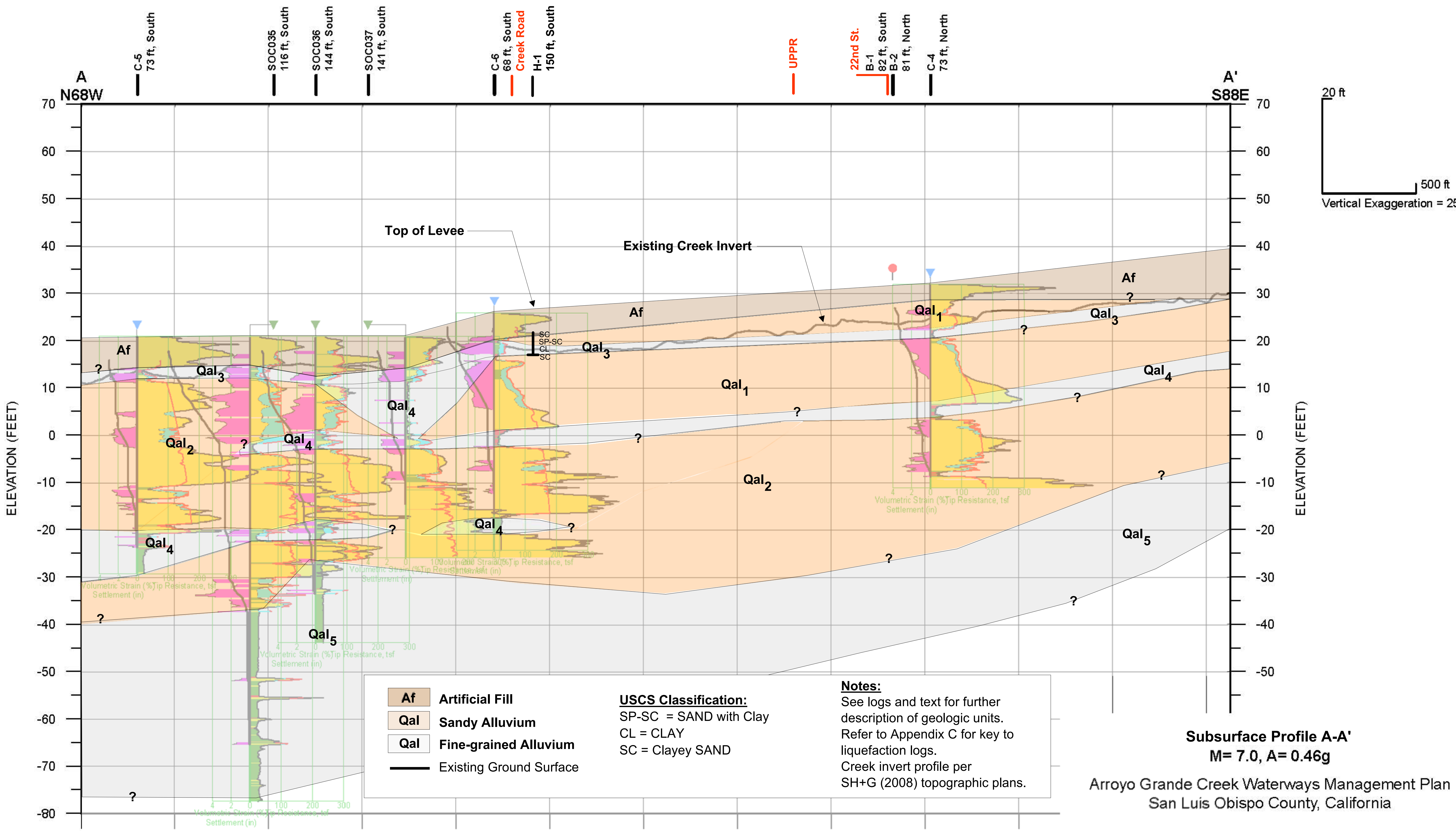
NORTH

0 1000 2000

FEET

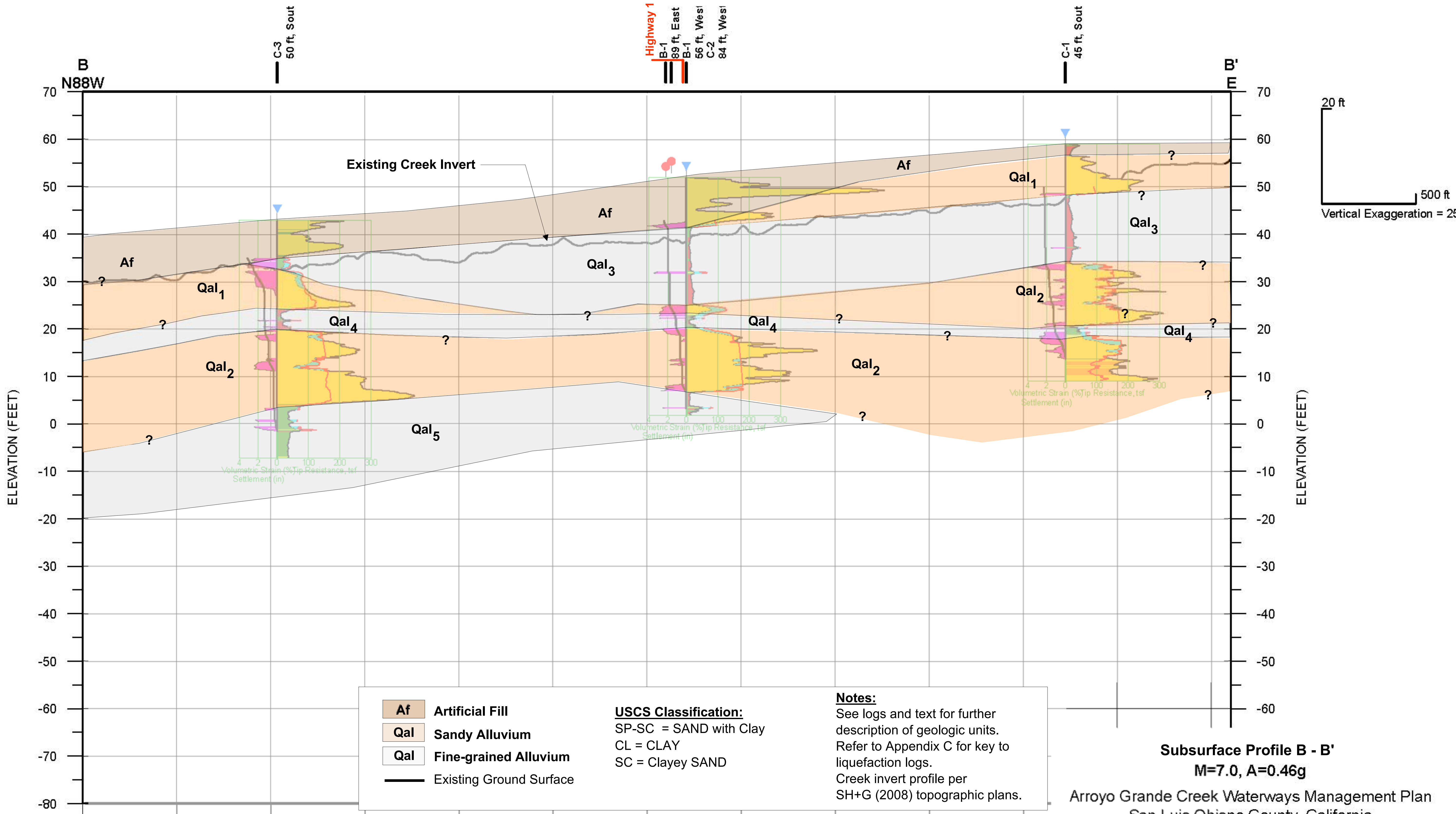
REGIONAL GEOLOGIC MAP
Arroyo Grande Creek
Waterways Management Plan
San Luis Obispo County, California

PLATE 3



Subsurface Profile A-A'
M= 7.0, A= 0.46g

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

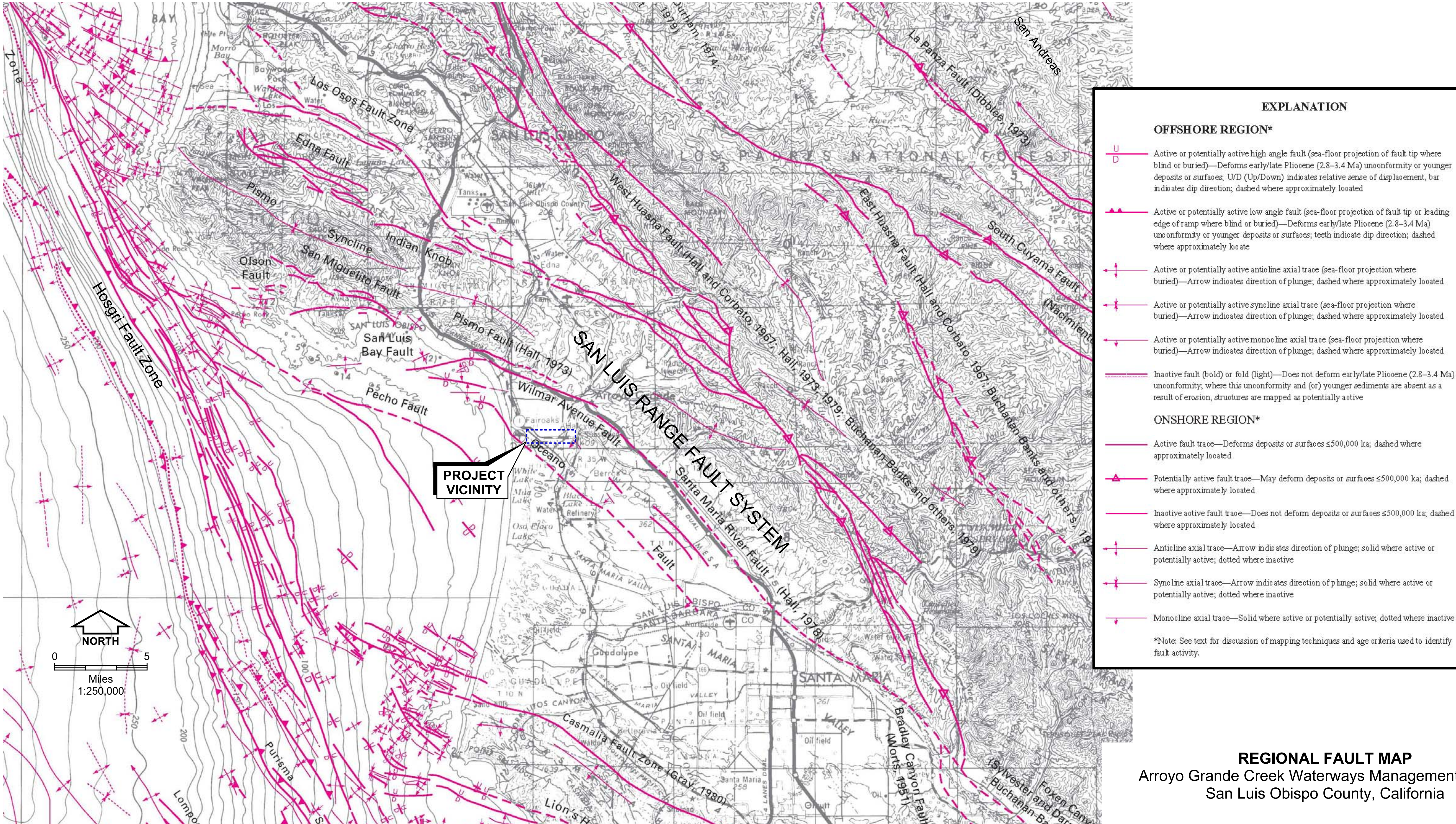


Subsurface Profile B - B'
M=7.0, A=0.46g

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE 4b

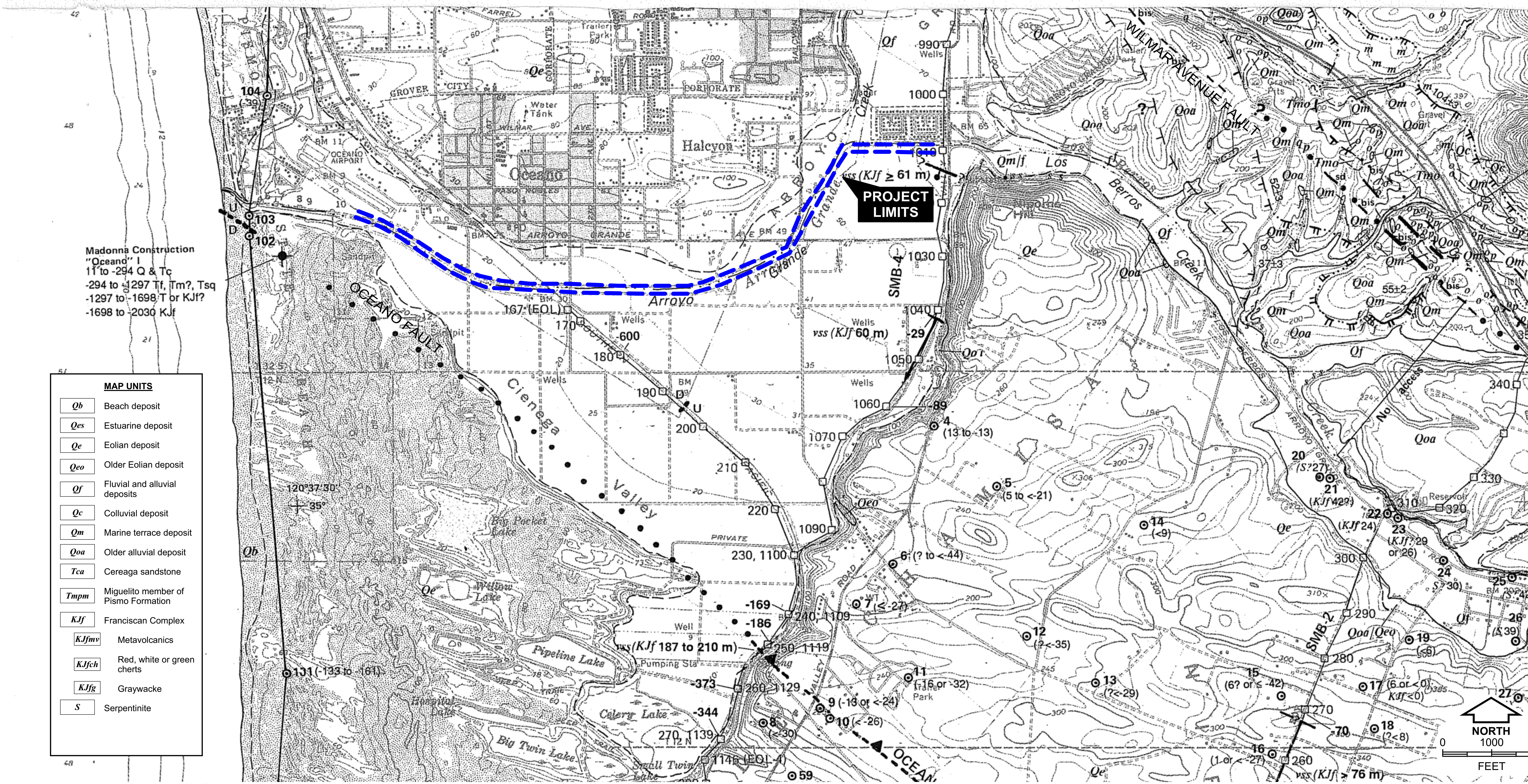
N:\Projects\3014_SLOCounty\3014-029_Arroyo_Grande_Creek\GISData\Sect\Xsect_2008_July\MXD\ProfileB.mxd, 08/11/08, CDean



REGIONAL FAULT MAP
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE 5

BASE MAP: Lettis et al. (2004), Faults and Folds in Onshore and Offsore Regions of South-Central California.



BASE MAP SOURCE: Quaternary Geologic Map of the Southern Margin of the San Luis Range from Shell Beach to the Santa Maria Valley, South-Central California, Plate 3 (Hanson et al., 1994).

LEGEND

Fault - Dashed where approximately located; dotted where concealed; U = up/D = down indicates relative sense of displacement; small arrow and number indicate strike and dip of fault exposed in outcrop; sawteeth on upper plate of thrust fault

Aerial photo lineament - Or fault-related feature; dashed where less distinct; queried where uncertain; hachures indicate topographic scarp and show direction; ld = linear drainage, tc = tonal contrast, v = vegetation lineament, dd = deflected drainage, bis = break in slope, s = saddle, shb = side hill bench

Marine terrace strandline - Solid where well constrained; double dot dash where concealed; dotted where eroded; altitude shown in meters

Contact - Dashed where approximately located or inferred; queried where uncertain

Strike and dip of bedding

Syncline - Showing trace of axial surfaces and direction of plunge

Anticline - Showing trace of axial surface and direction of plunge

GS-4 Tca — Borehole - GS-1 - U.S. Geological Survey (unpublished data, G. Yates, Water Resource Division); MBO-2 - California Department of Water Resources (1972); altitude of subsurface of formations shown in meters

Borehole - Completed as part of Long-Term Seismic Program (PG&E, 1988)

Exploratory oil well - Producer, name of well, and depth (meters) are indicated

Closed depression

Spring

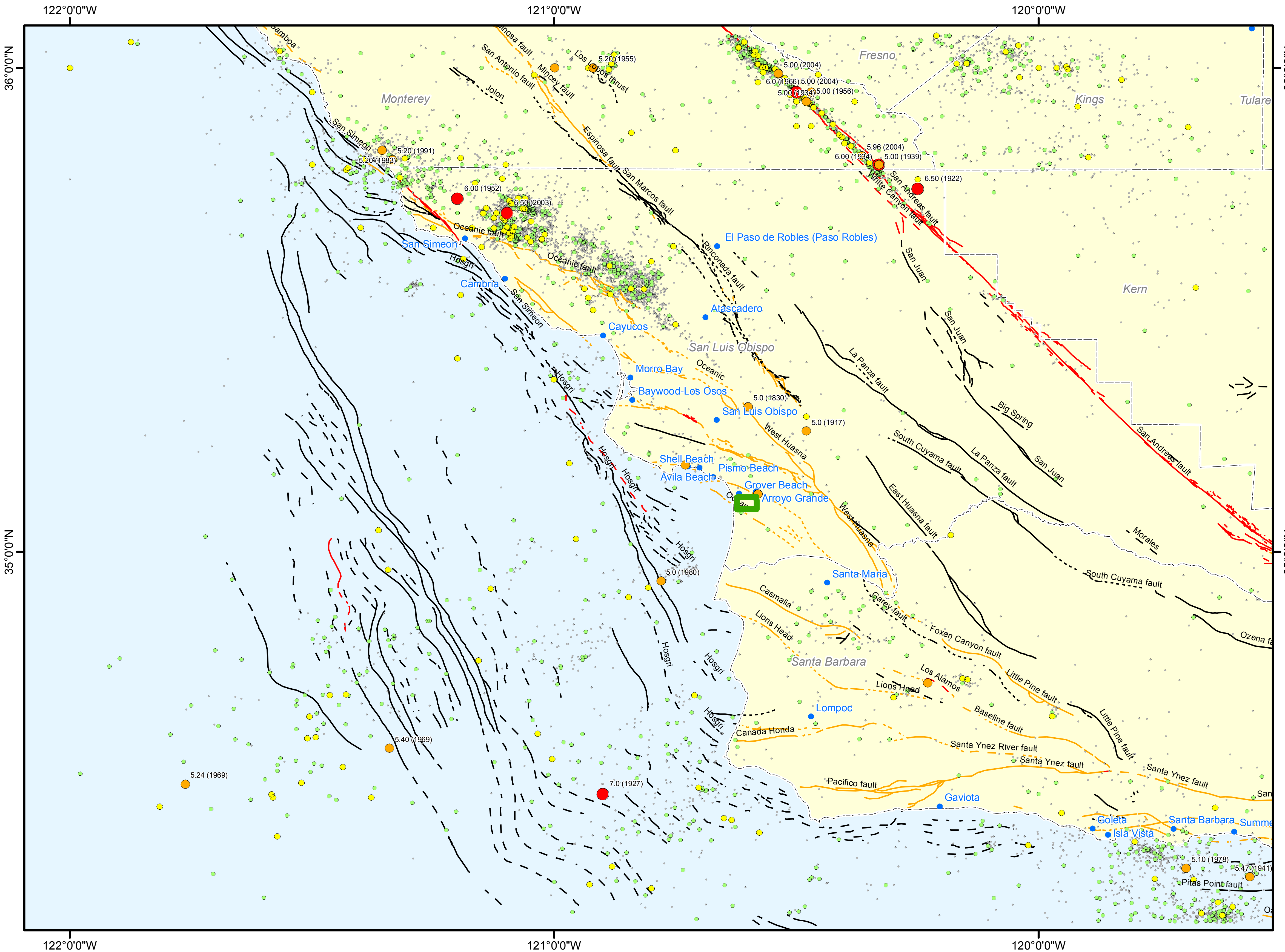
Bedrock exposure

Limit of mapping

LOCAL FAULT MAP
Arroyo Grande Creek
Waterways Management Plan
San Luis Obispo County, California

PLATE 6

County of San Luis Obispo
Project No. 3014.029



Legend

Project Area

Earthquake Magnitude
Magnitudes equal to and greater than 5 are labeled.

2.0 - 2.9
3.0 - 3.9
4.0 - 4.9
5.0 - 5.9
>6.0

Faults (dashed where inferred, dotted where concealed)

Active Fault
Potentially Active Fault
Inactive Fault

Source:

1) Earthquake Data:
Earthquake epicenters from:
a) ANSS Composite Catalog Search, 1933 to 2008, <www.ncedc.org/anss/> (downloaded March 2008)
b) "Seismotectonic framework, coastal central California", Seismotectonics of the Central California Coast Range, Special Paper 292, Geological Society of America, 1994.

2) Faults:
a) Bryant, 2005
b) Jennings, 1994

N

0 7.5 15 30 Miles

HISTORICAL SEISMICITY MAP
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE 7

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APPENDIX A

LOCATION: The drill hole location referencing local landmarks or coordinates

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

ELEVATION, ft	DEPTH, ft	MATERIAL DESCRIPTION	
		Well graded GRAVEL (GW)	COARSE GRAINED
-12	2	Poorly graded GRAVEL (GP)	COARSE GRAINED
-14	4	Well graded SAND (SW)	COARSE GRAINED
-16	6	Poorly graded SAND (SP)	COARSE GRAINED
-18	8	Silty SAND (SM)	COARSE GRAINED
-20	10	Clayey SAND (SC)	COARSE GRAINED
-22	12	Silty, Clayey SAND (SC-SM)	COARSE GRAINED
-24	14	Elastic SILT (MH)	FINE GRAINED
-26	16	SILT (ML)	FINE GRAINED
-28	18	Silty CLAY (CL-ML)	FINE GRAINED
-30	20	Fat CLAY (CH)	FINE GRAINED
-32	22	Lean CLAY (CL)	FINE GRAINED
-34	24	CONGLOMERATE	ROCK
-36	26	SANDSTONE	ROCK
-38	28	SILTSTONE	ROCK
-40	30	MUDSTONE	ROCK
-42	32	CLAYSTONE	ROCK
-44	34	BASALT	ROCK
-46	36	ANDESITE BRECCIA	ROCK
-48	38	Paving and/or Base Materials	

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	

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

ELEVATION, ft	DEPTH, ft	MATERIAL SYMBOL	SAMPLE NO.	SAMPLERS	SAMPLER BLOW COUNT	LOCATION: Approximately 25' south of South Levee, and approximately 14' east of Creek Road SURFACE EL: 20 ft +/- (rel. MSL datum) 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
						ALLUVIUM (Qal) TOPSOIL: loose, dry							
						Clayey SAND (SC): loose to medium dense, dark brown, moist							
			1				107	92	12	48			
			2										
18	2					Poorly-graded SAND with clay (SP-SC): loose, light brown, moist to wet							
						Lean CLAY (CL): soft to medium stiff, moist to wet							
			3										
						Clayey SAND (SC): medium dense, brown, wet							
16	4		4										
14	6												
12	8												

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: 4.5 ft
DEPTH TO WATER: 3.0 ft

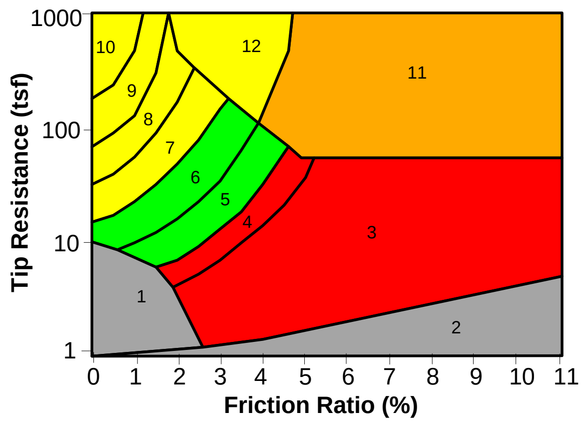
DRILLING DATE: August 14, 2008

DRILLING METHOD: 4-inch-dia. Hand Auger
DRILLED BY: C.Stoehr
LOGGED BY: C.Stoehr

LOG OF BORING NO. H-1

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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)

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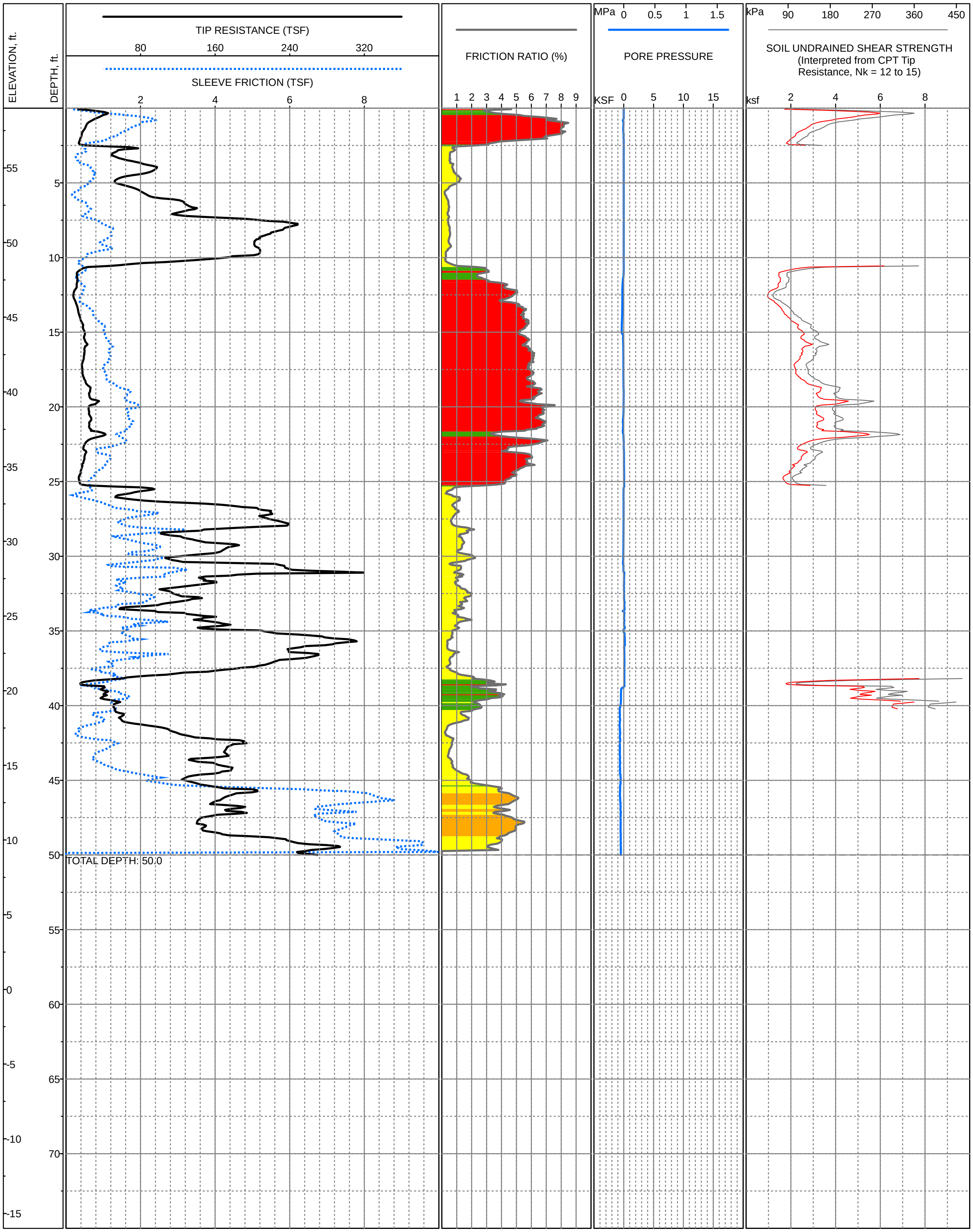
KEY TO CPT LOGS
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

County of San Luis Obispo
Project No. 3014.029



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

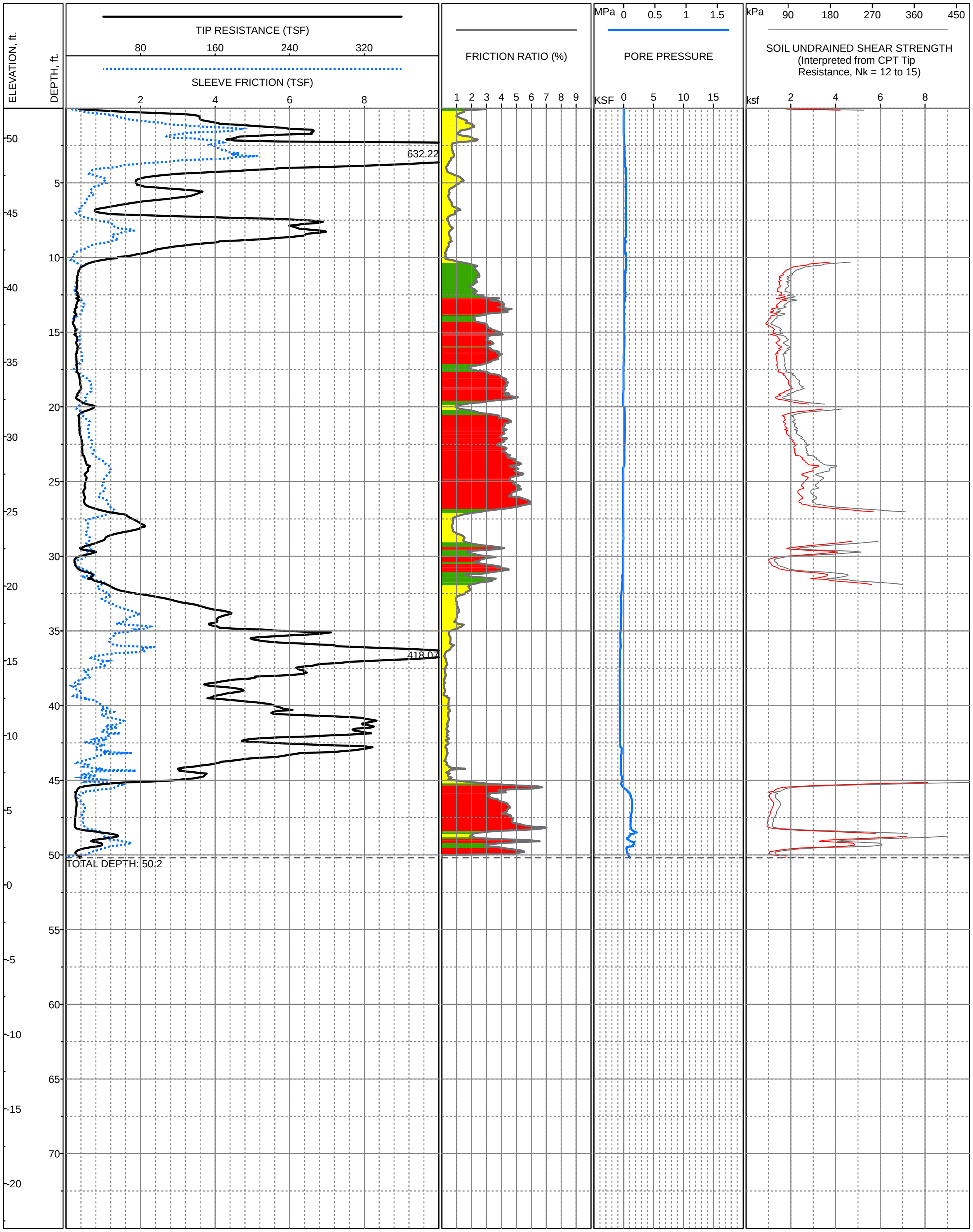
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J.Blanchard

LOG OF C-1

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

PLATE A-4

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



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

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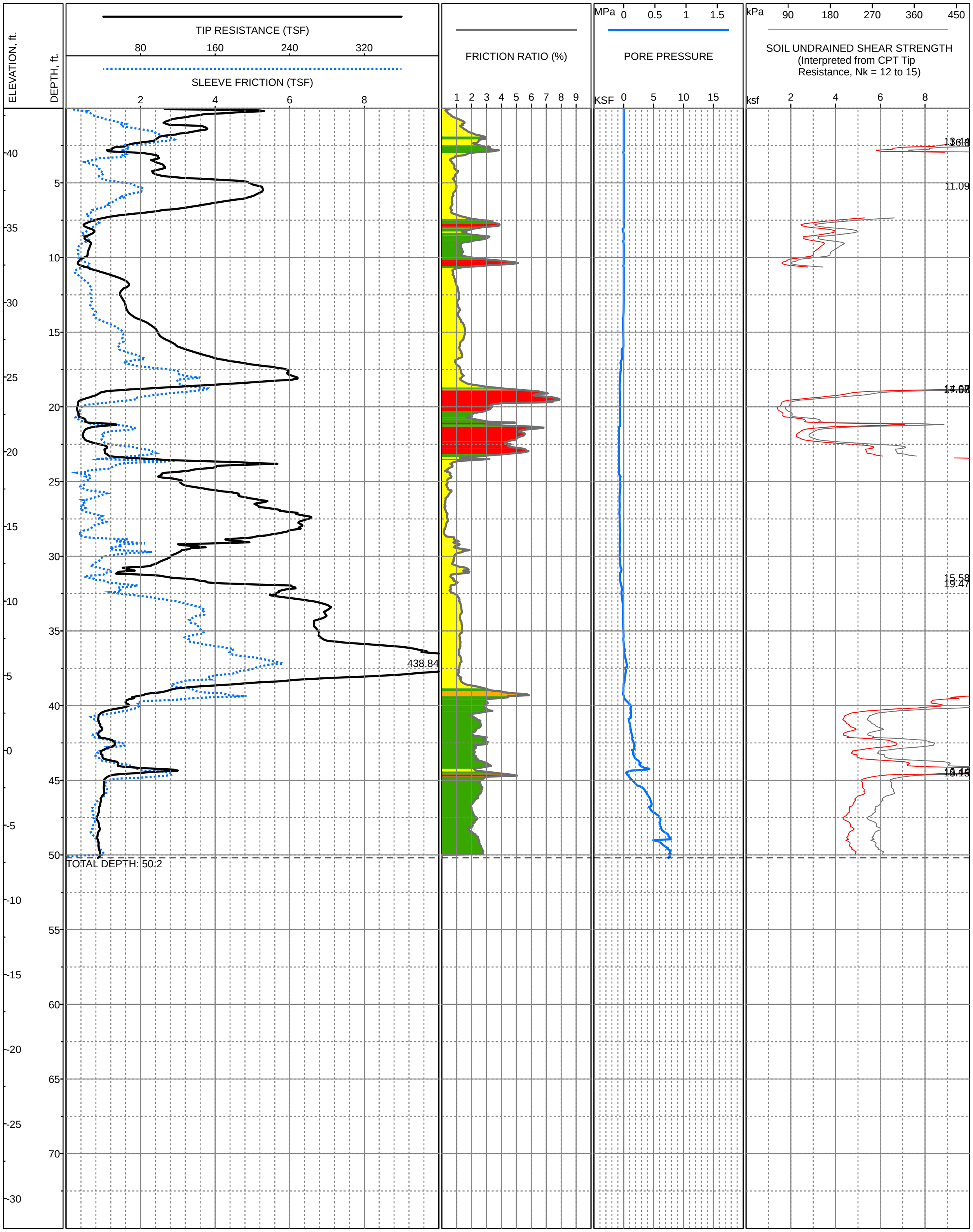

COORDINATES: 2,231,087.37N 5,784,635.85W
SURFACE EL: 43.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

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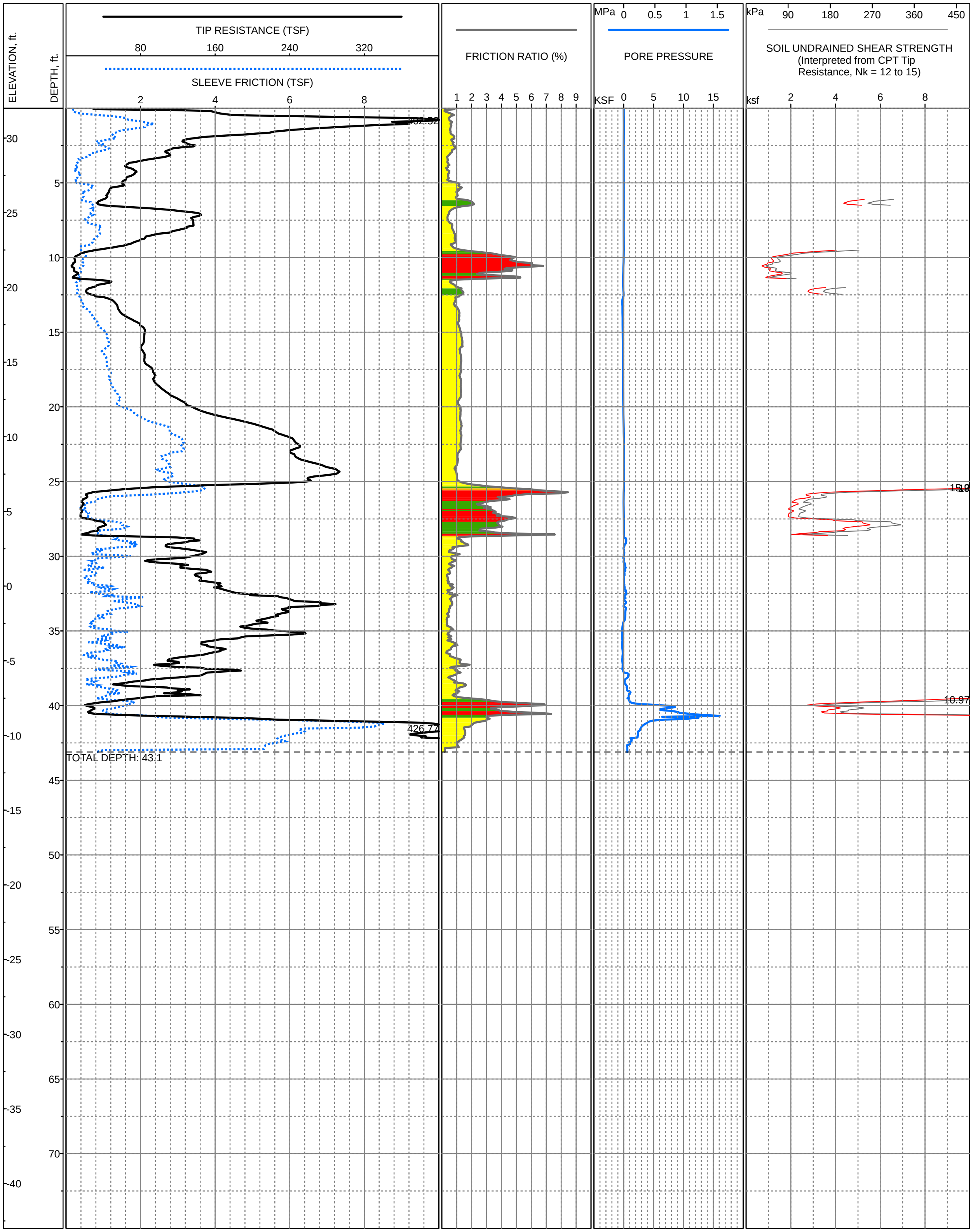
County of San Luis Obispo
Project No. 3014.029



COORDINATES: 2,231,221.08N 5,782,003.06W
SURFACE EL: 32.0ft +/- (MSL)
COMPLETION DEPTH: 43.1ft
TESTDATE: 7/22/2008

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

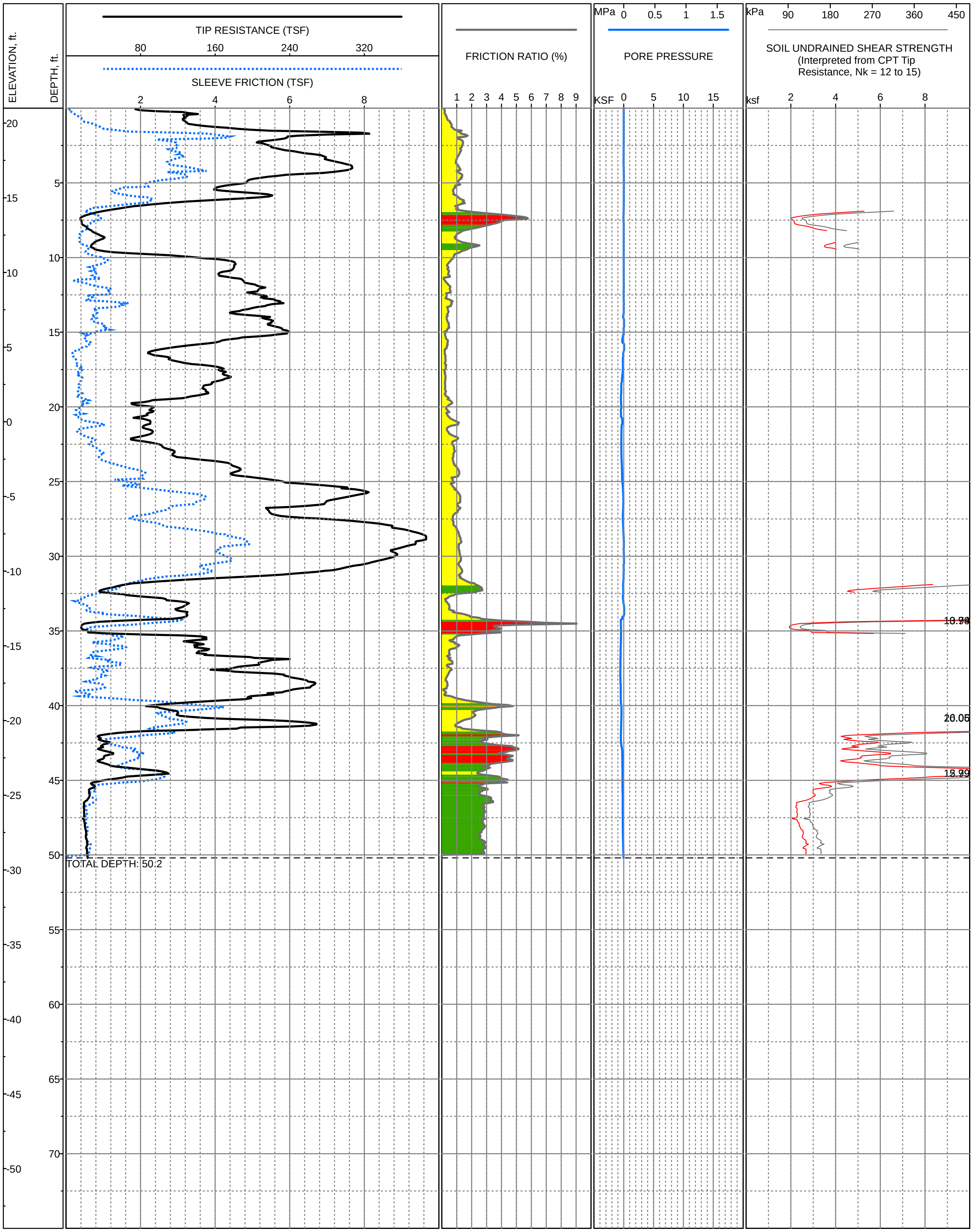
LOG OF C-4

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

PLATE A-7

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

FUGRO



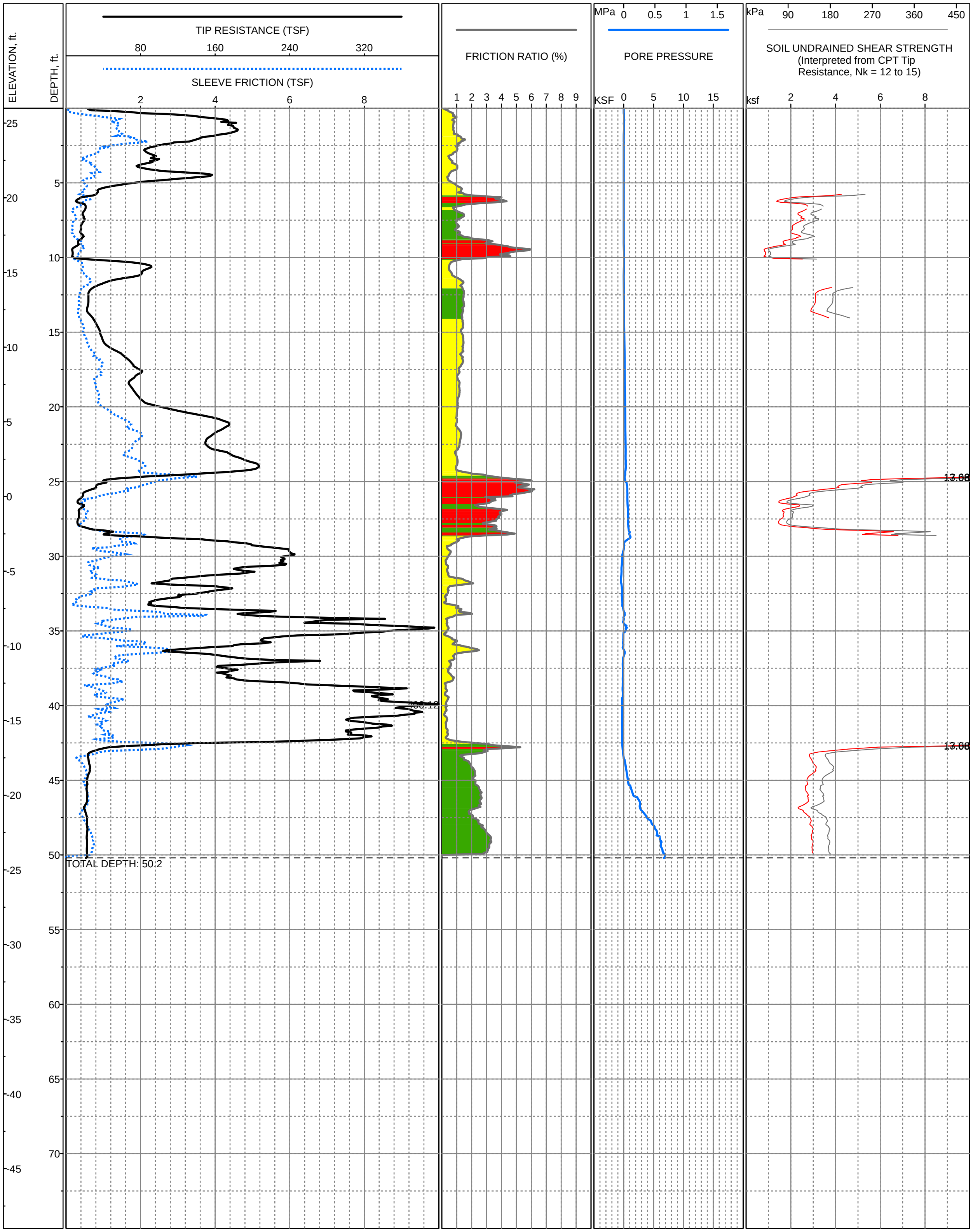
COORDINATES: 2,232,390.00N 5,778,074.64W
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF C-5

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

County of San Luis Obispo
Project No. 3014.029



COORDINATES: 2,231,397.63N 5,779,691.56W
SURFACE EL: 26.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

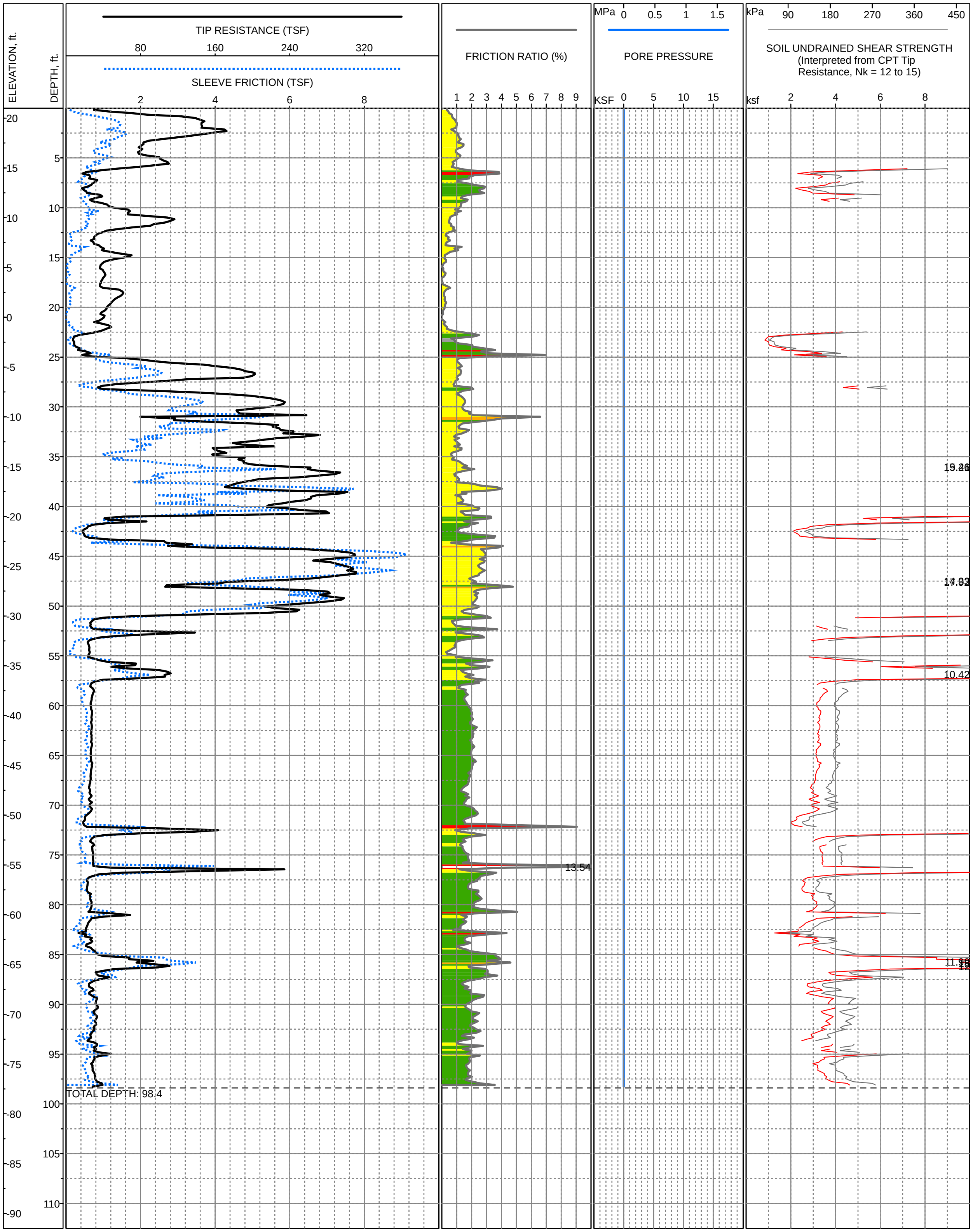
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J.Blanchard

LOG OF C-6
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

PLATE A-9

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

County of San Luis Obispo
Project No. 3014.029



LOCATION: South Levee, Approx. 3350 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 98.4ft
TESTDATE: 3/5/2004

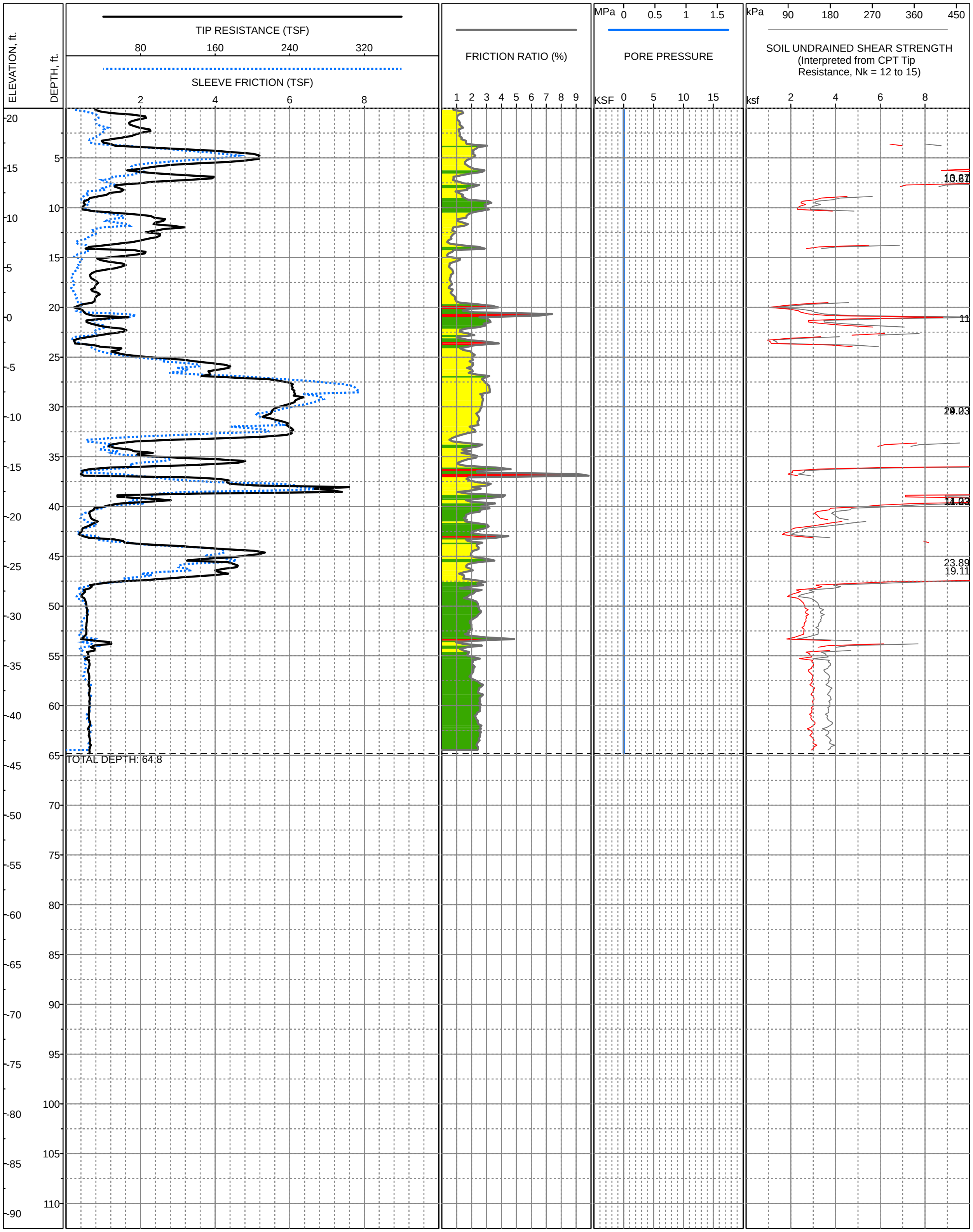
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J.Blanchard

LOG OF SOC035

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

PLATE A-10

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\USGS_2004\Logs\Logs_Su_2008_Aug\MXD\CPTLog_Su.mxd,08/29/2008,ksheil



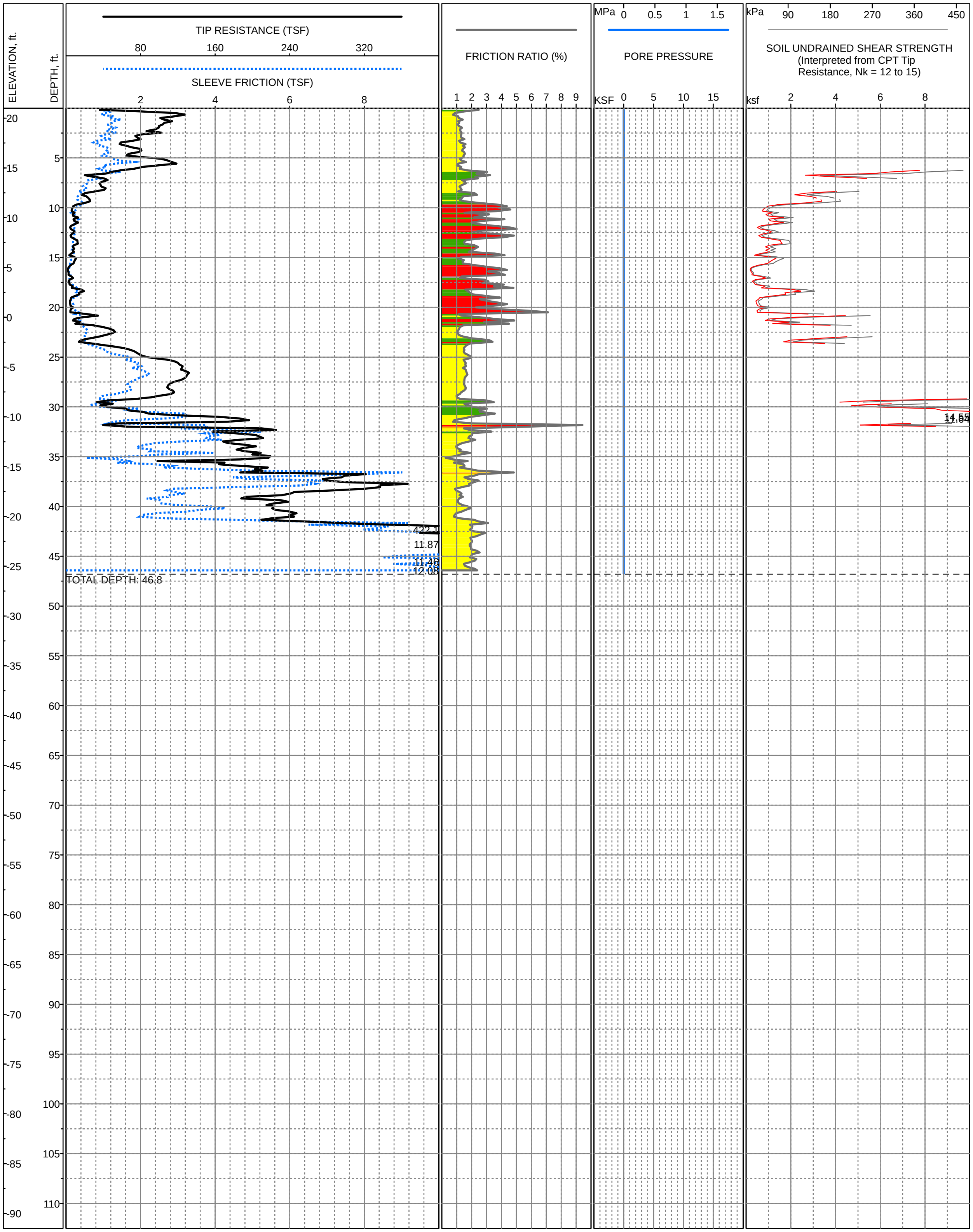
LOCATION: South Levee, Approx. 3500 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 64.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J.Blanchard

LOG OF SOC036

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\USGS_2004\Logs\Logs_Su_2008_Aug\MXD\CPTLog_Su.mxd,08/29/2008,ksheil



LOCATION: South Levee, Approx. 3250 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 46.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J.Blanchard

LOG OF SOC037

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo, California

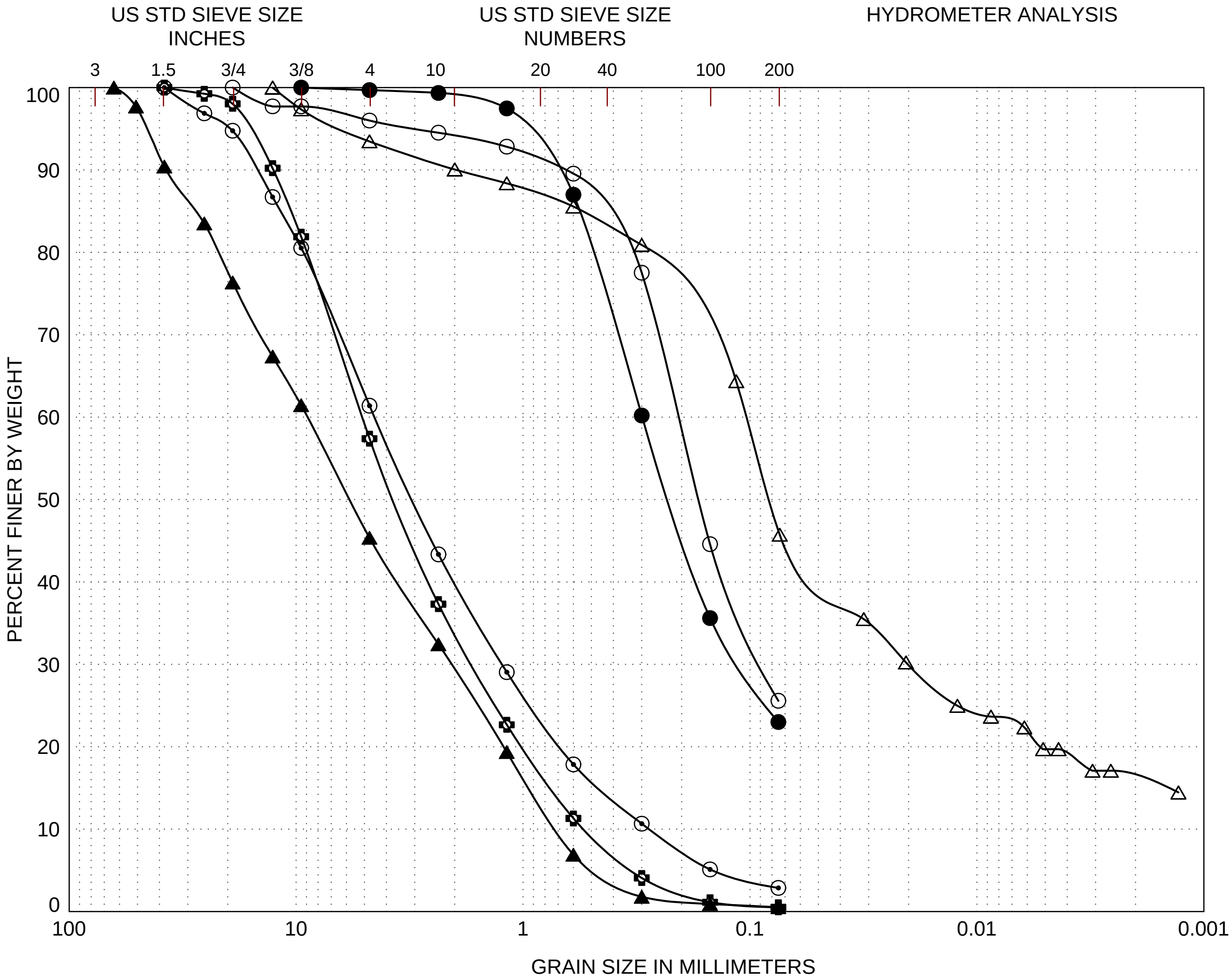
N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\USGS_2004\Logs\Logs_Su_2008_Aug\MXD\CPTLog_Su.mxd,08/29/2008,ksheil

Appendix B

DRILL HOLE	DEPTH, ft	SAMPLE NUMBER	MATERIAL DESCRIPTION	UWW pcf	UDW pcf	MC %	FINES %	ATTERBERG LIMITS		COMPACTION TEST		DIRECT SHEAR		COMPRESSIVE STRENGTH TESTS		CORROSIVITY TESTS				R-VALUE	EXPANSION INDEX	SAND EQUIVALENT (SE)	Permeability, cm/s
								LL	PI	MAX DD pcf	OPT MC %	C ksf	PHI deg	Qu, ksf	S_u (Cell Prs.) ksf	R	pH	Cl	So_4 (%)				
AB-1	0.0		Silty SAND (SM)				26																
AB-2	0.0		Silty SAND (SM)				23																
AB-6	0.0		Silty SAND (SM)				46																
H-1	1.0	1	Clayey SAND (SC)	107	92	12	48					0.1	38										
SB-1	0.0		Poorly-graded GRAVEL with sand (GP)				1																
SB-2	0.0		Well-graded SAND with gravel (SW)				3																
SB-6	0.0		Well-graded SAND with gravel (SW)				1																

SUMMARY OF LABORATORY TEST RESULTS

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

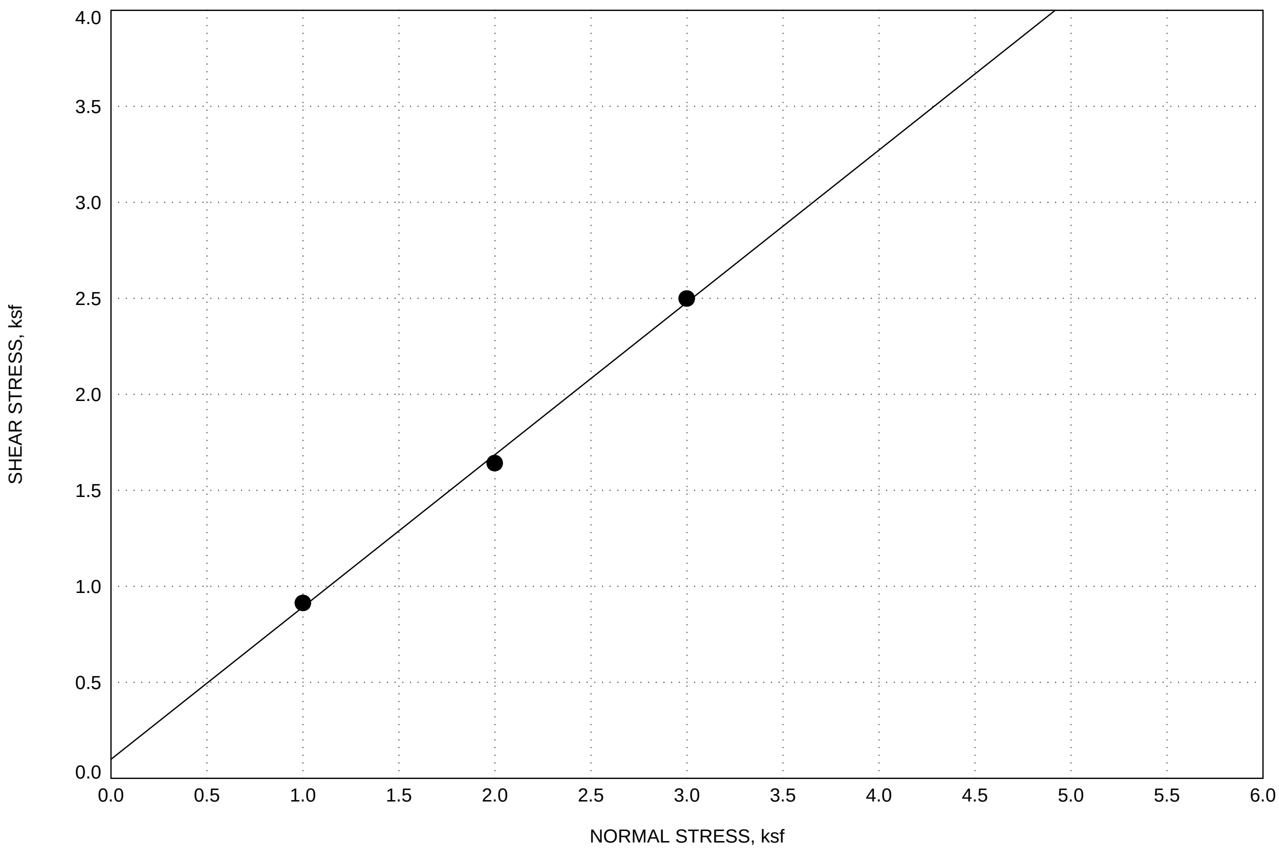


GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

LEGEND			CLASSIFICATION	Cc	Cu
	(location)	(depth,ft)			
○	AB-1	0.0	Silty SAND (SM)		
●	AB-2	0.0	Silty SAND (SM)		
△	AB-6	0.0	Silty SAND (SM)		
▲	SB-1	0.0	Poorly-graded GRAVEL with sand (GP)	0.7	12.6
⊙	SB-2	0.0	Well-graded SAND with gravel (SW)	1.2	16.3
✪	SB-6	0.0	Well-graded SAND with gravel (SW)	1.0	9.7

GRAIN SIZE CURVES
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE B-2

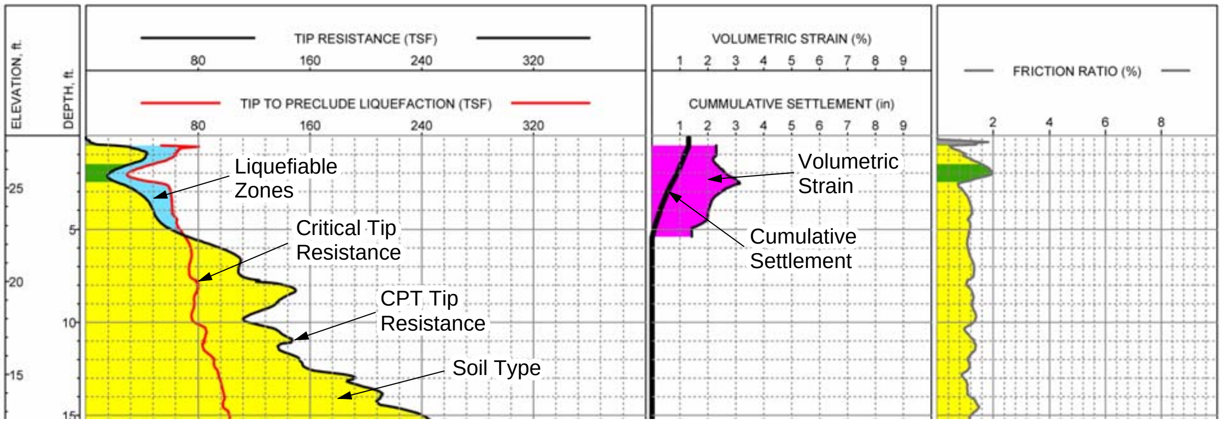


COHESION, ksf	0.1
ANGLE OF INTERNAL FRICTION, deg	38
LOCATION	H-1
DEPTH, ft	1
MOISTURE CONTENT, %	17
UNIT DRY WEIGHT, pcf	92
MATERIAL DESCRIPTION	Clayey SAND (SC)
SAMPLE CONDITION	Ring Sample

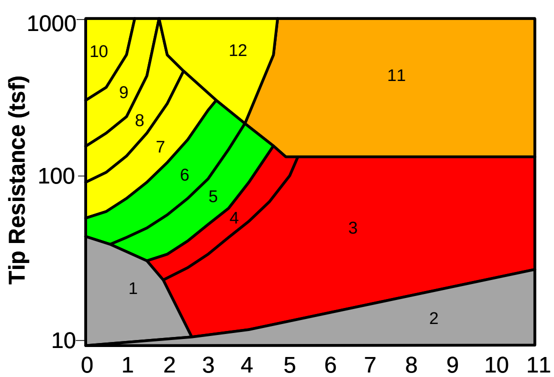
DIRECT SHEAR TEST RESULTS
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE B-3

APPENDIX C



COLOR LEGEND FOR FRICTION RATIO TRACES



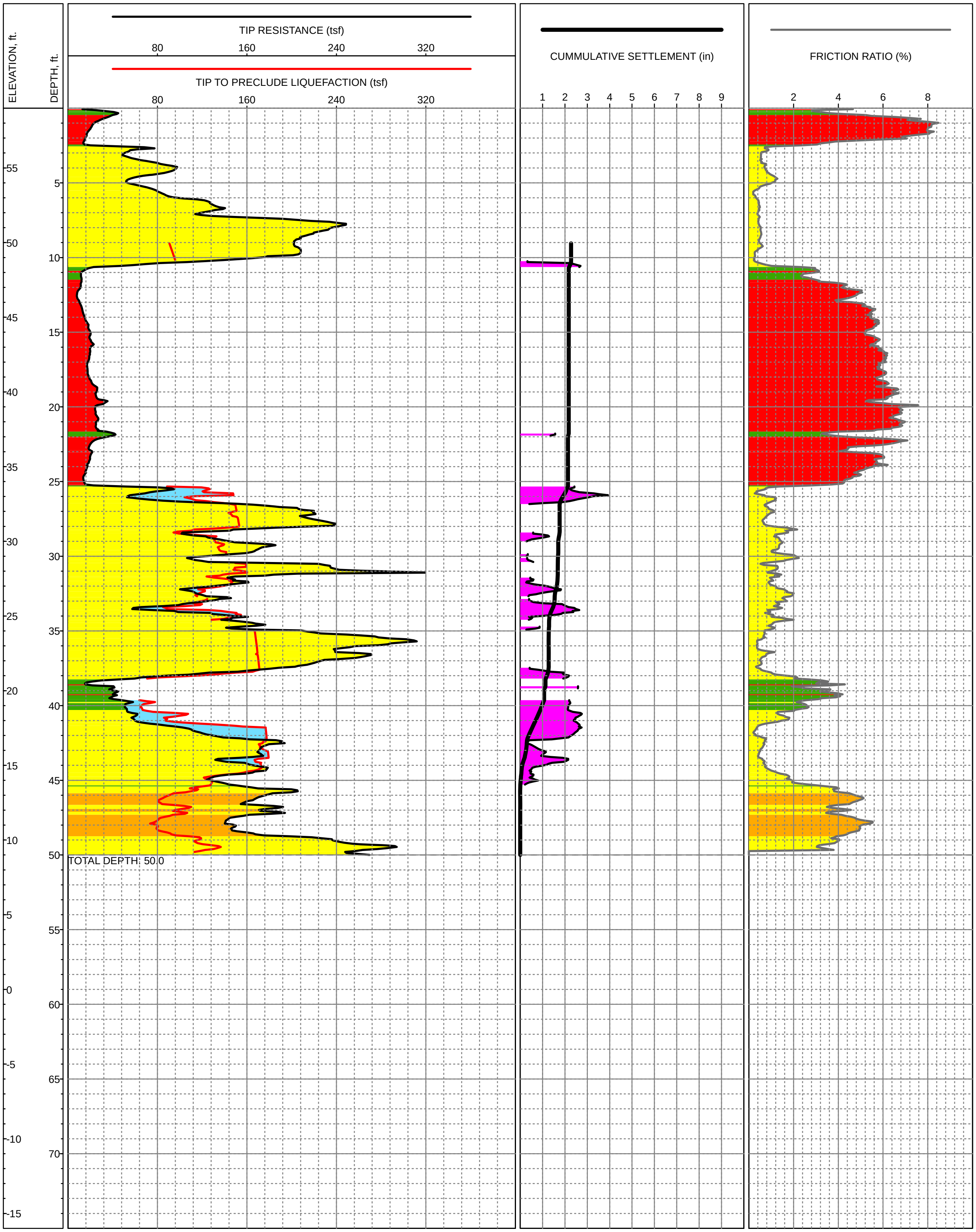
Zone	Soil Behavior Type	U.S.C.S.
1	Sensitive Fine-grained	OL-CH
2	Organic Material	OL-OH
3	Clay	CH
4	Silty Clay to Clay	CL-CH
5	Clayey Silt to Silty Clay	MH-CL
6	Sandy Silt to Clayey Silt	ML-MH
7	Silty Sand to Sandy Silt	SM-ML
8	Sand to Silty Sand	SM-SP
9	Sand	SW-SP
10	Gravelly Sand to Sand	SW-GW
11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

*overconsolidated or cemented

CPT CORRELATION CHART
(Robertson and Campanella, 1984)

KEY TO CPT LOGS

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



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

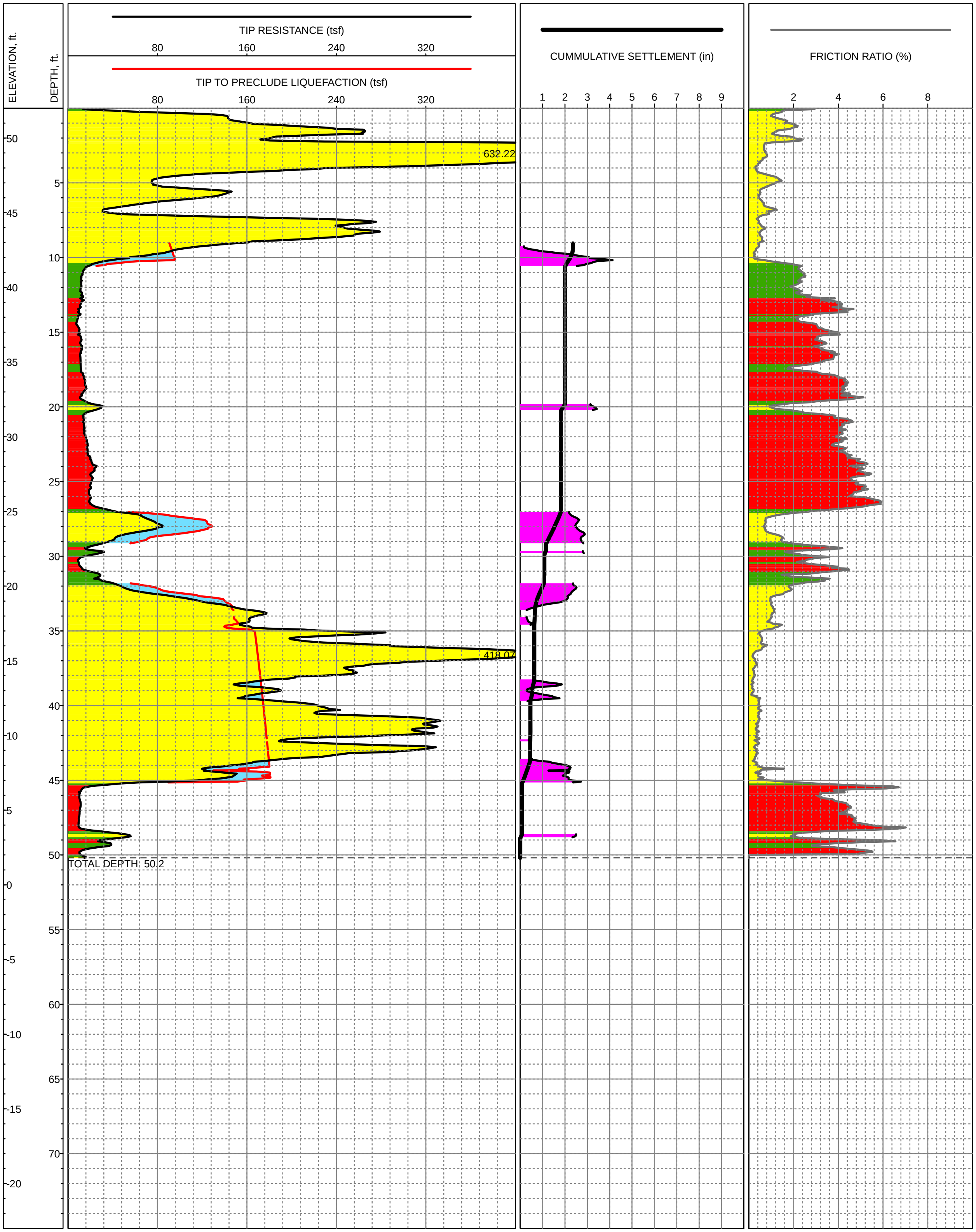
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J Blanchard

LOG OF CPT C-1, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil

County of San Luis Obispo
Project No. 3014.029



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 CPT C-2, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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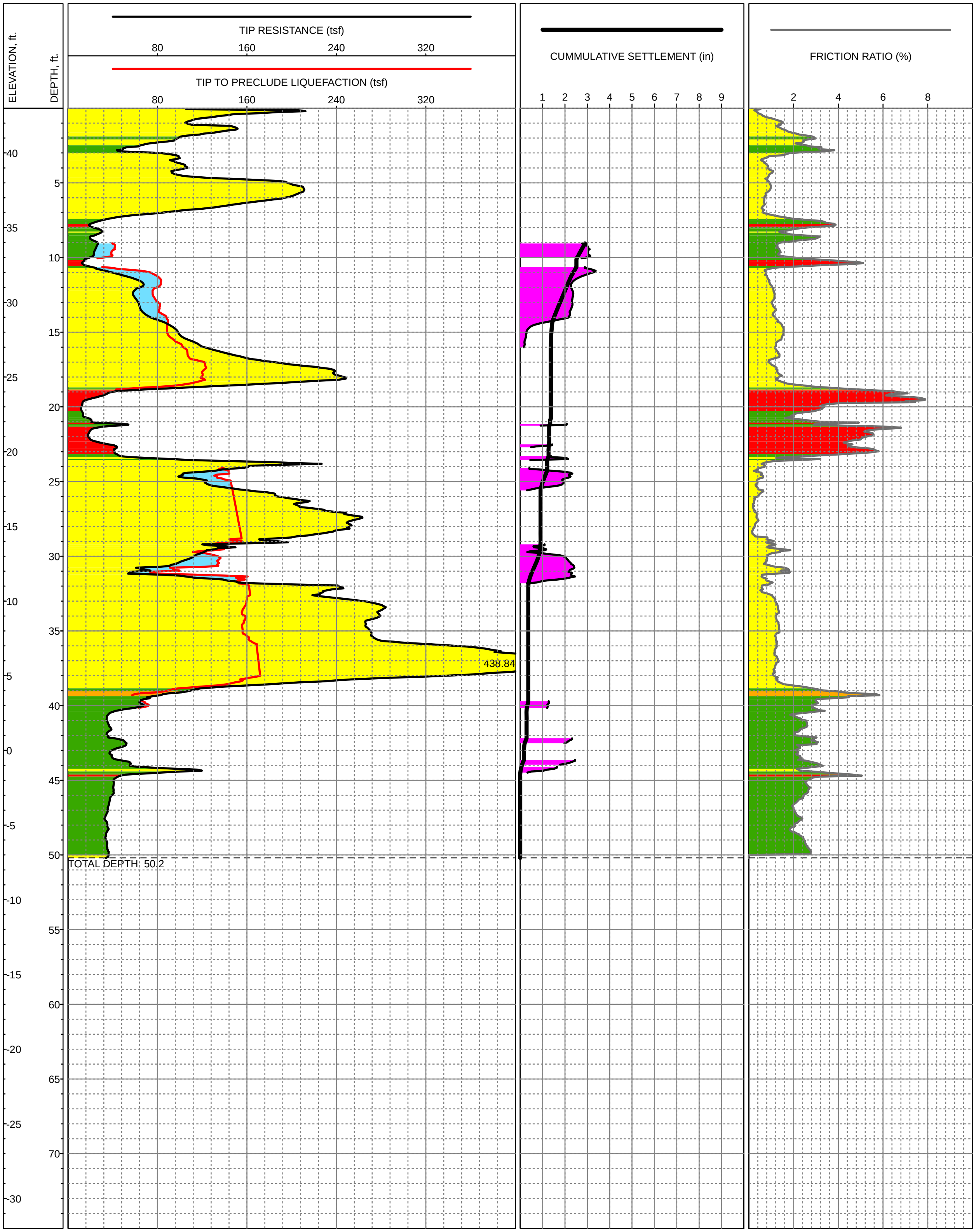
County of San Luis Obispo
Project No. 3014.029



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 CPT C-3, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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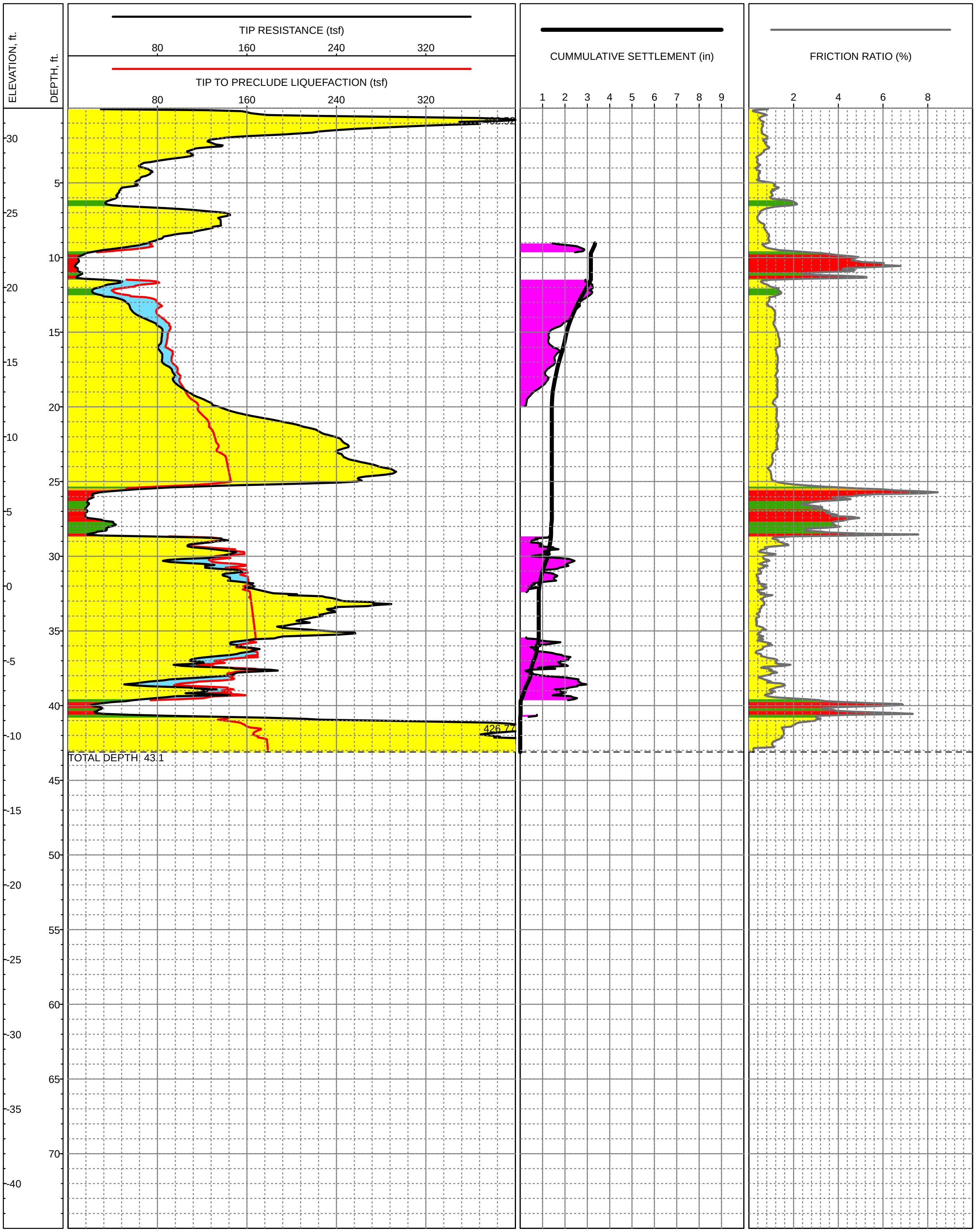
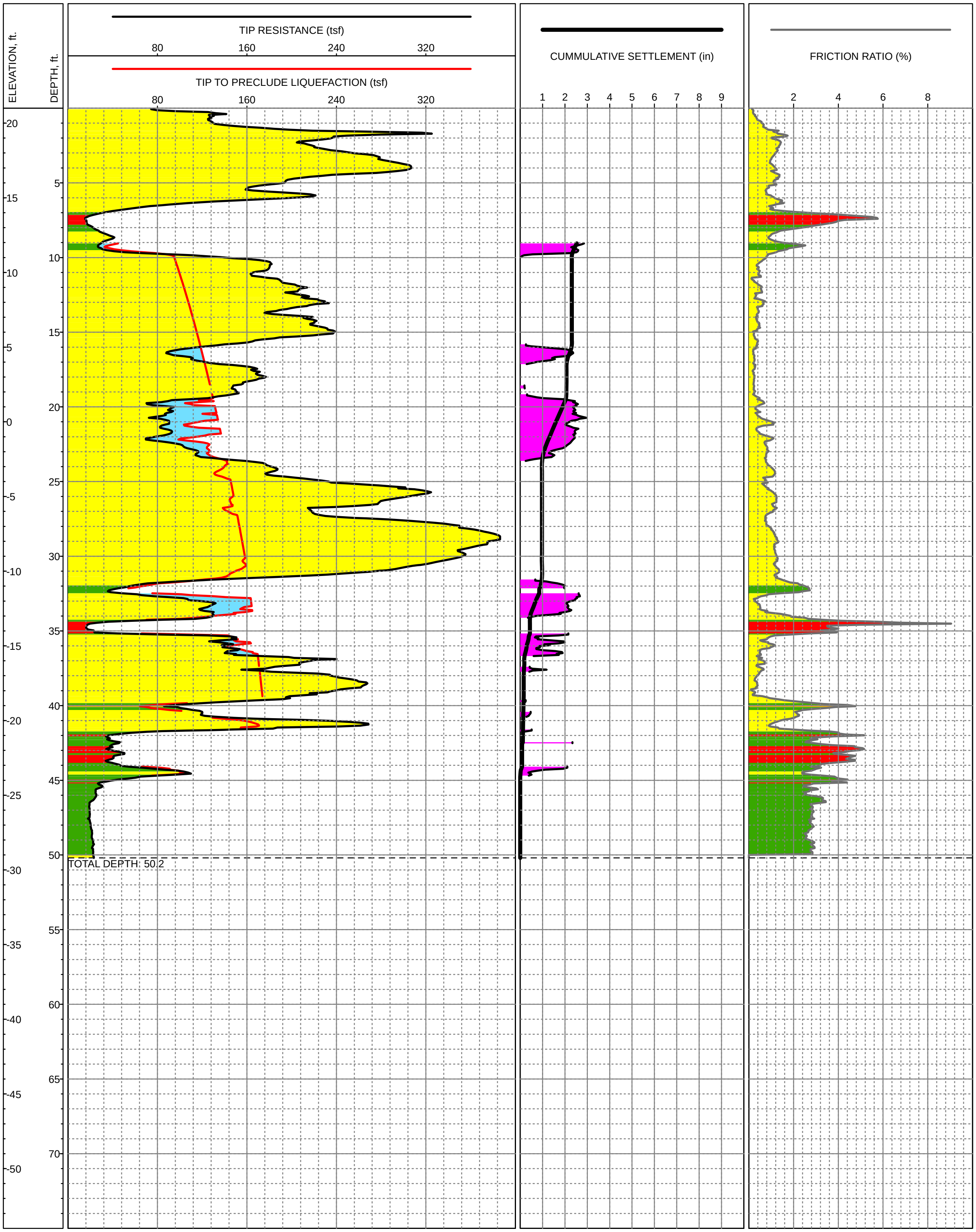


COORDINATES: 2,231,221.08N 5,782,003.06W
SURFACE EL: 32.0ft +/- (MSL)
COMPLETION DEPTH: 43.1ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-4, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



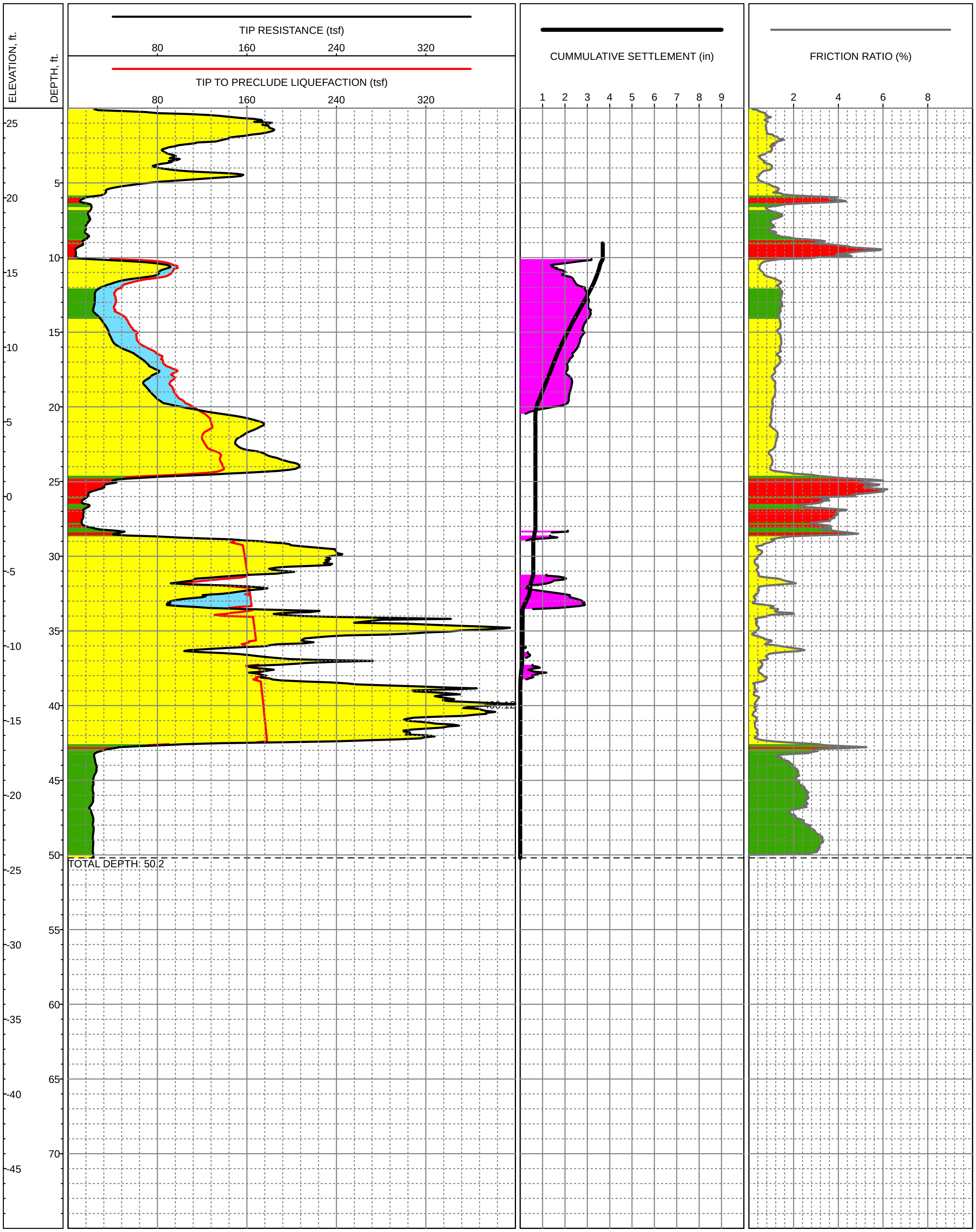
COORDINATES: 2,232,390.00N 5,778,074.64W
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-5, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil



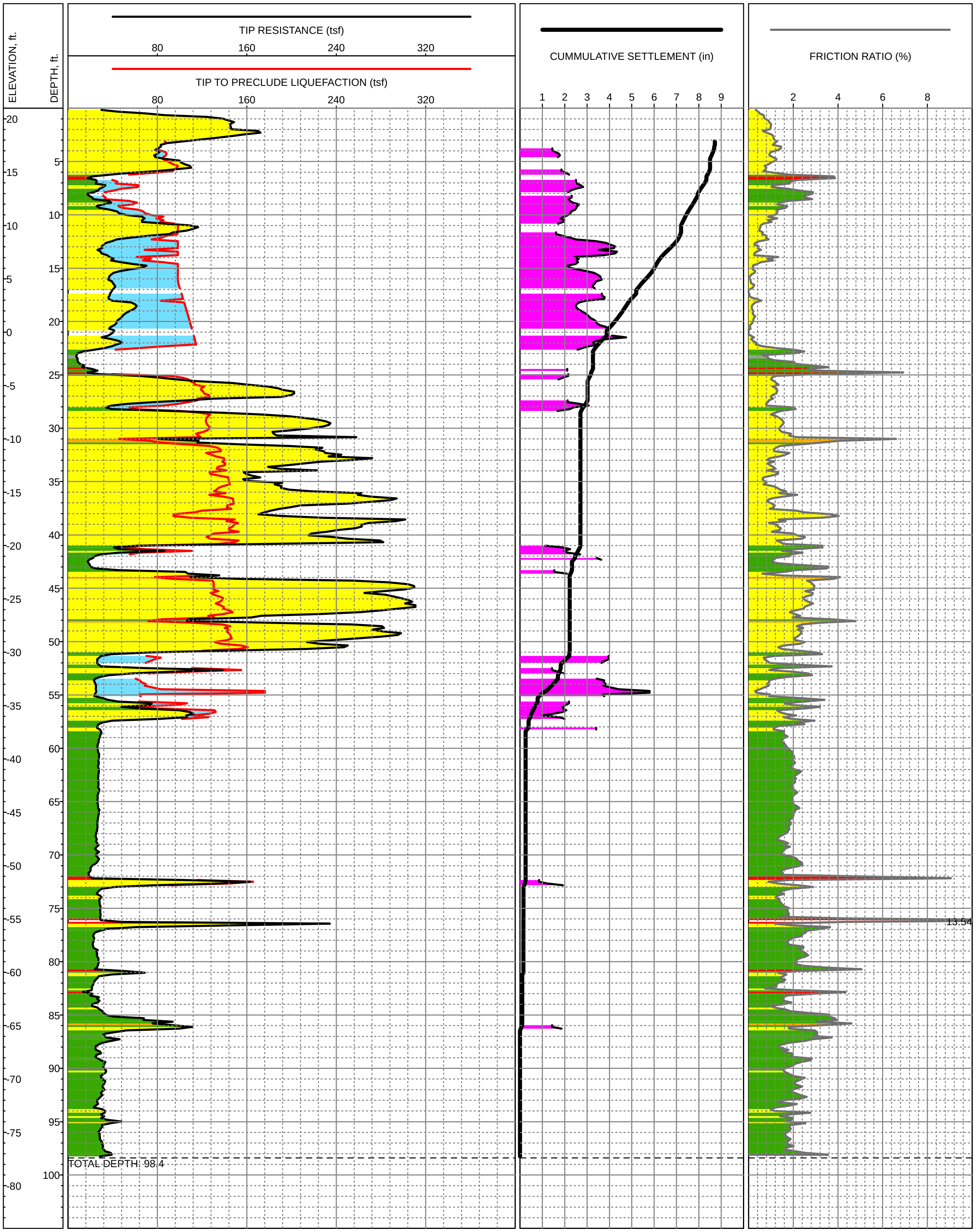
COORDINATES: 2,231,397.63N 5,779,691.56W
SURFACE EL: 26.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-6, M7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

County of San Luis Obispo
Project No. 3014.029



LOCATION: South Levee, Approx. 3350 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 98.4ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC035, M=7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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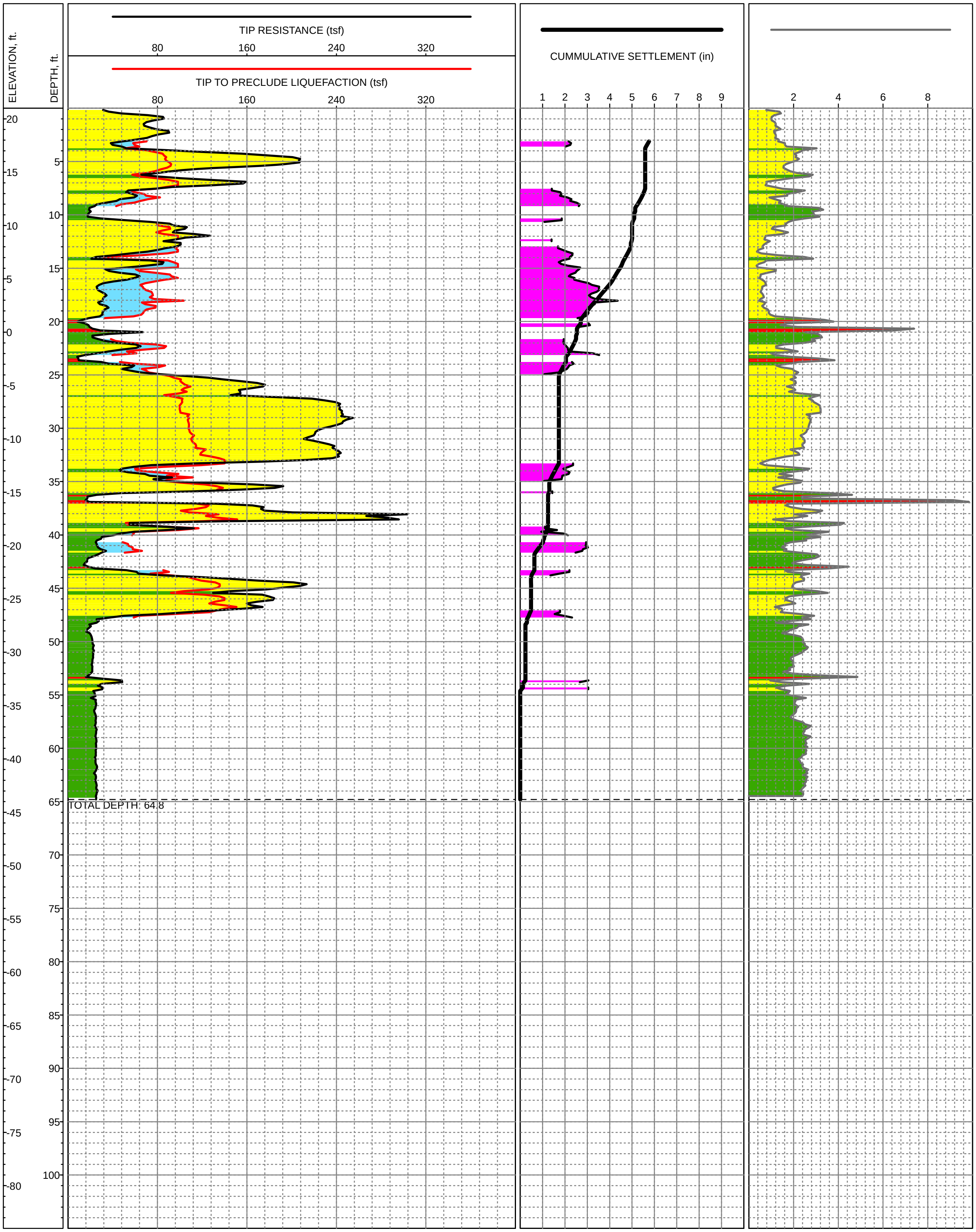
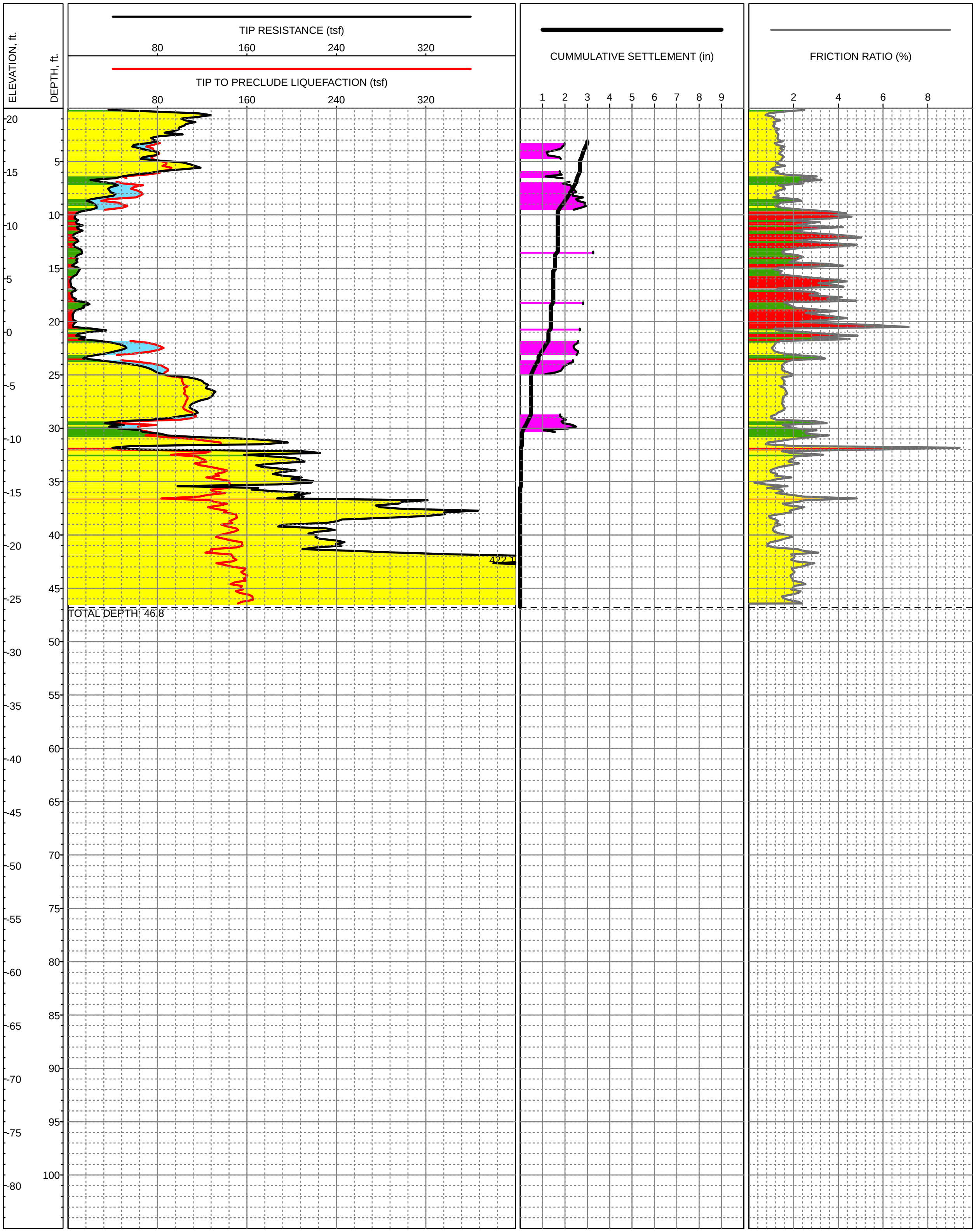


LOCATION: South Levee, Approx. 3500 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 64.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC036, M=7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



LOCATION: South Levee, Approx. 3250 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 46.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC037, M=7.0, a=0.46

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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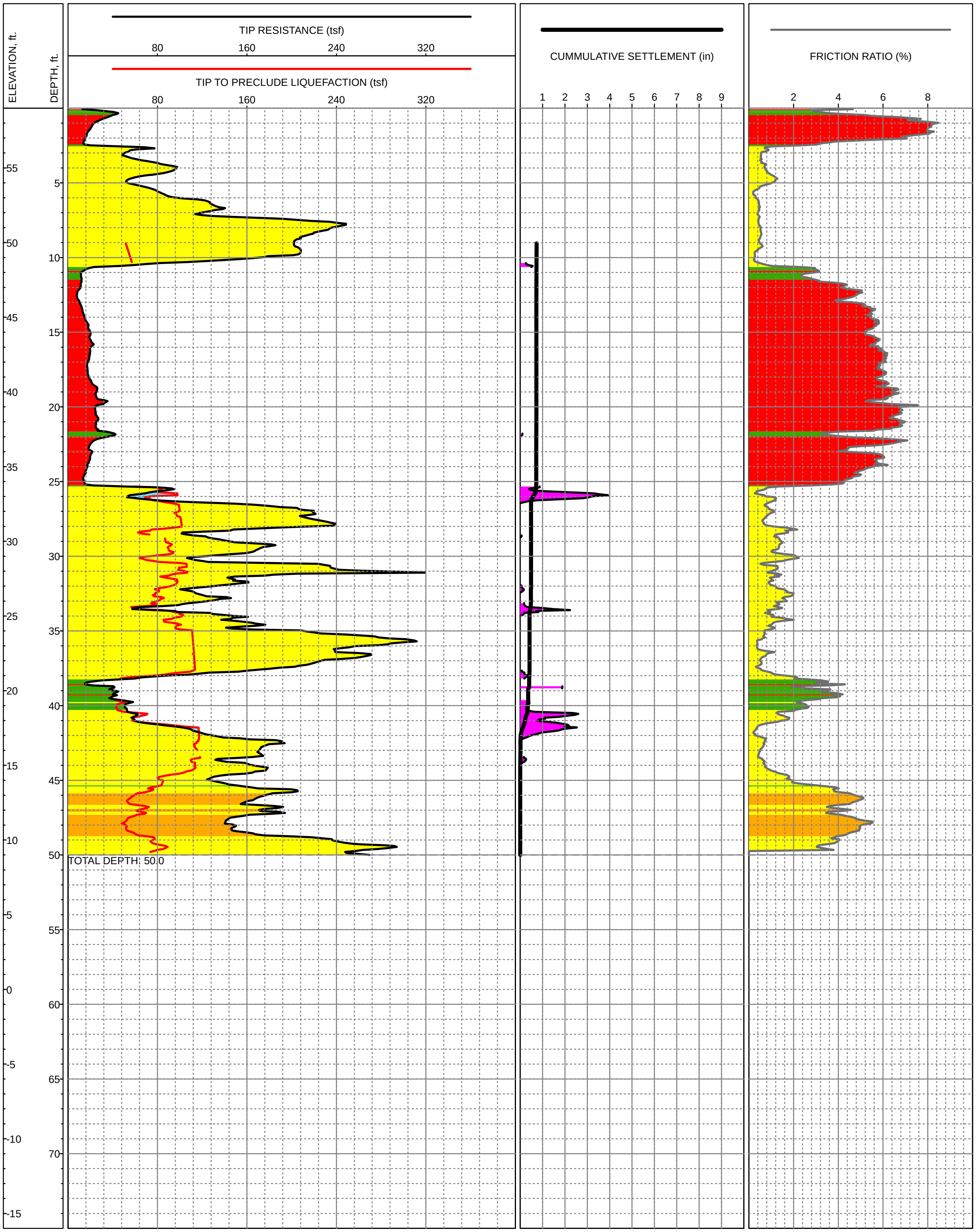
County of San Luis Obispo
Project No. 3014.029



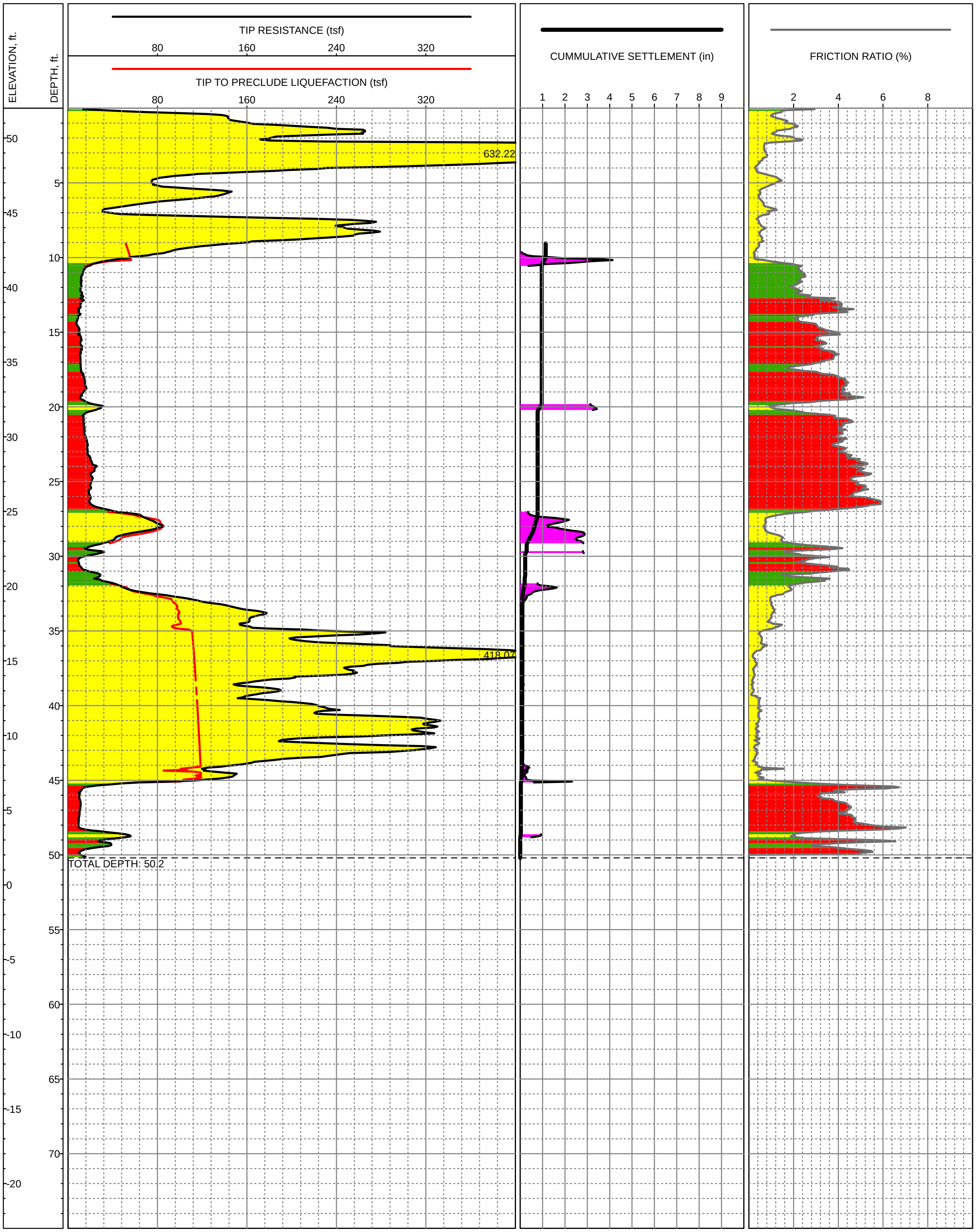
COORDINATES: 2,233,857.20N 5,787,490.08W
SURFACE EL: 59.0ft +/- (MSL)
COMPLETION DEPTH: 50.0ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-1, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil



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

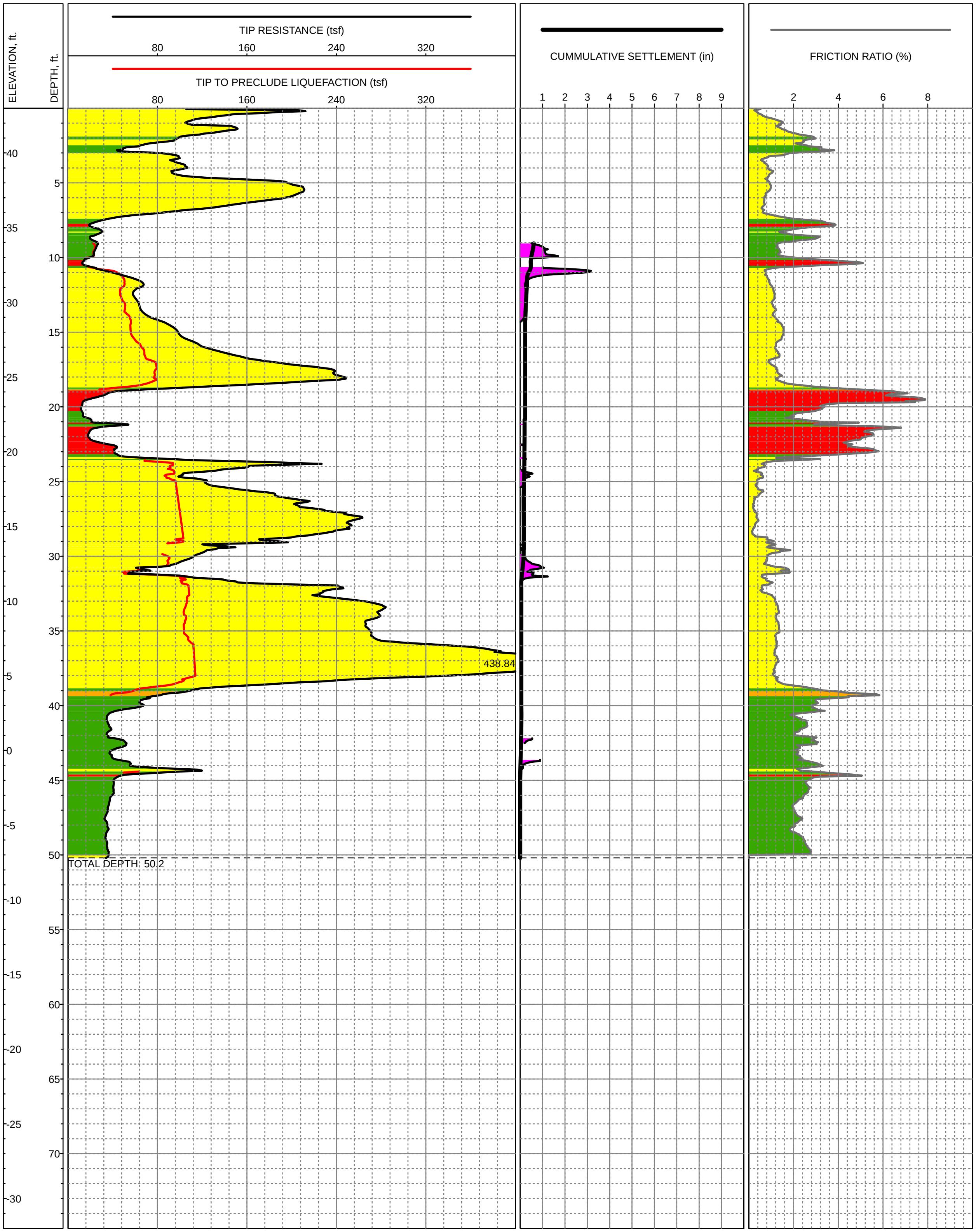
EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: Fugro Geosciences
REVIEWED BY: J Blanchard

LOG OF CPT C-2, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil

County of San Luis Obispo
Project No. 3014.029

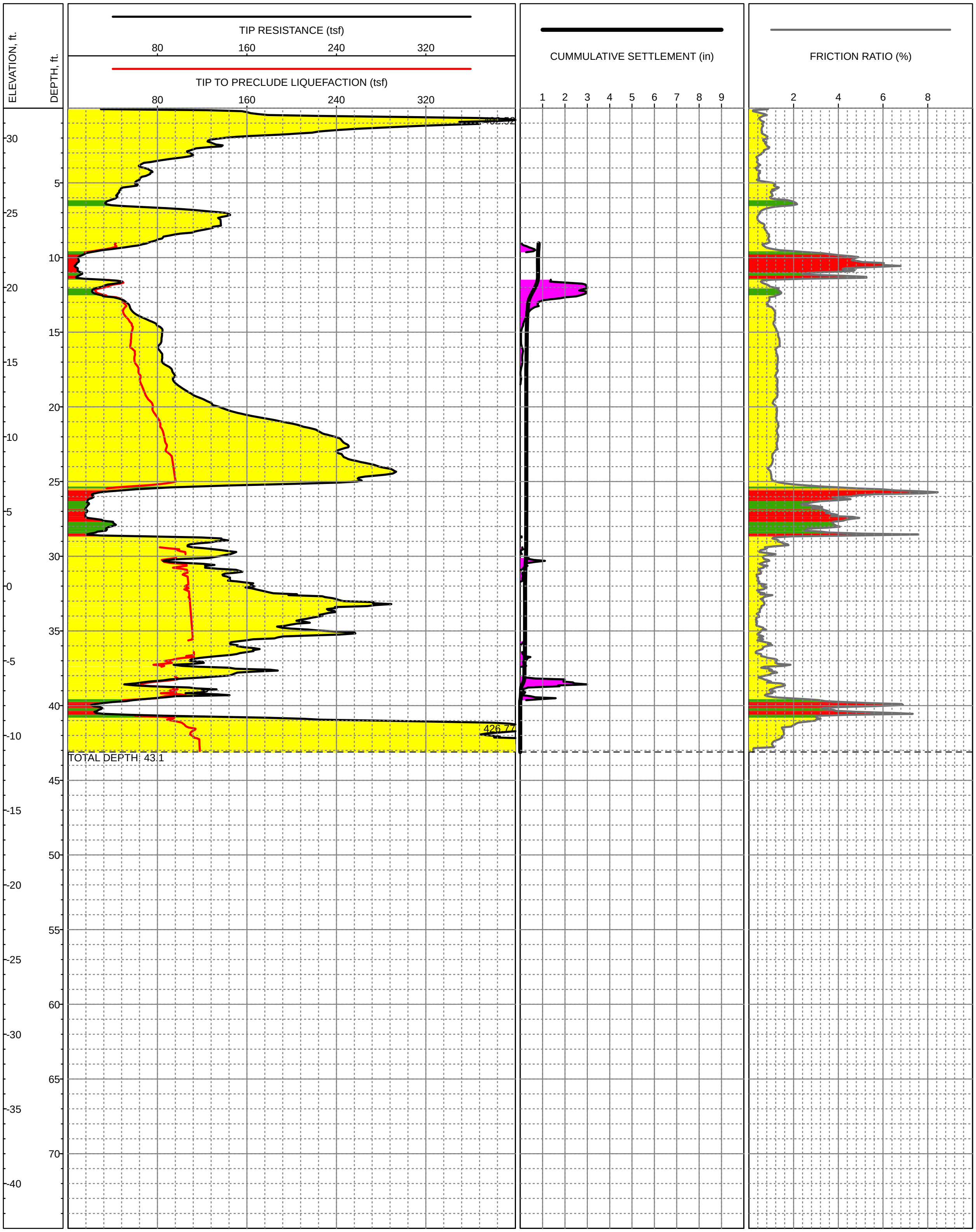


COORDINATES: 2,231,087.37N 5,784,635.85W
SURFACE EL: 43.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-3, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

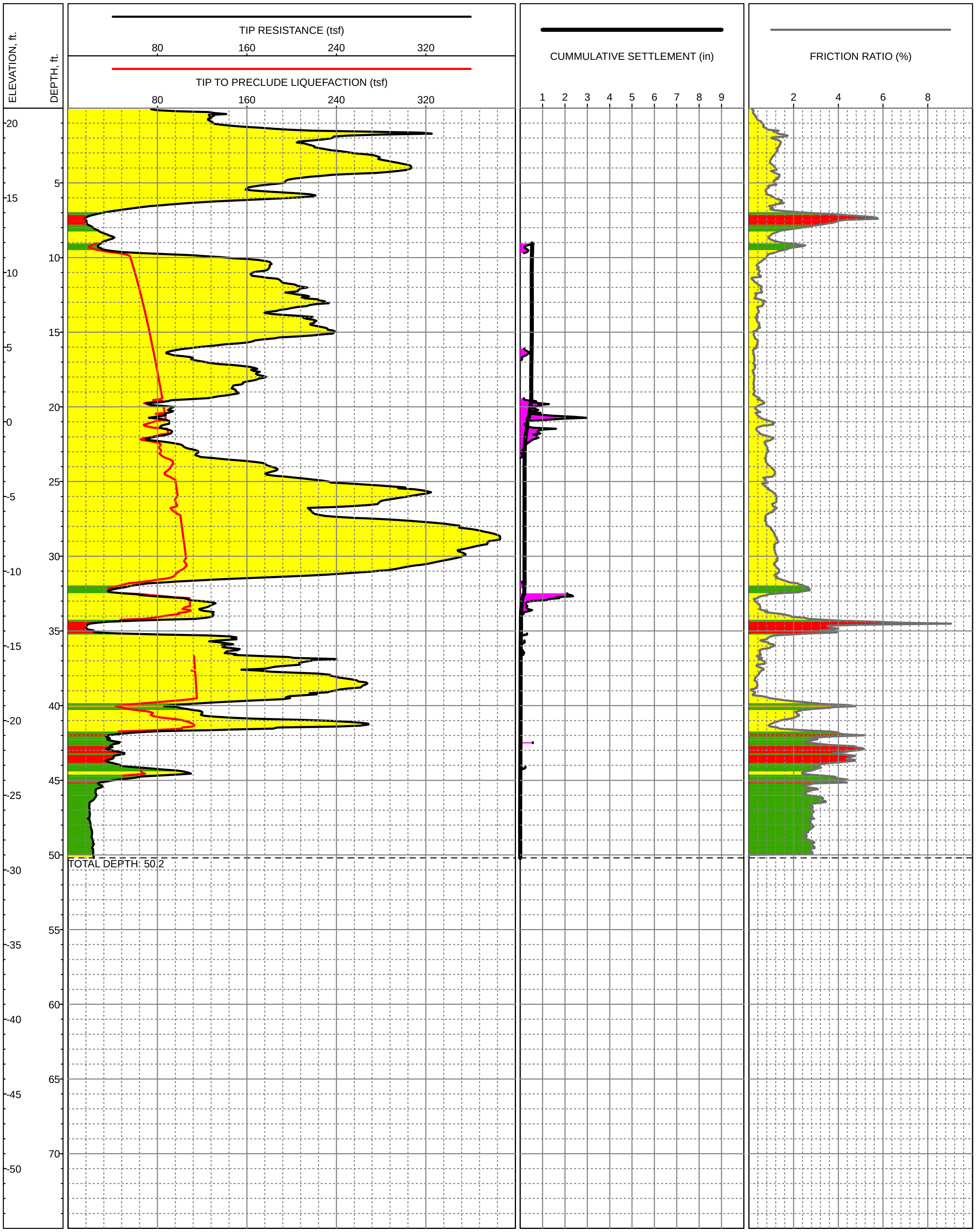


COORDINATES: 2,231,221.08N 5,782,003.06W
SURFACE EL: 32.0ft +/- (MSL)
COMPLETION DEPTH: 43.1ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-4, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



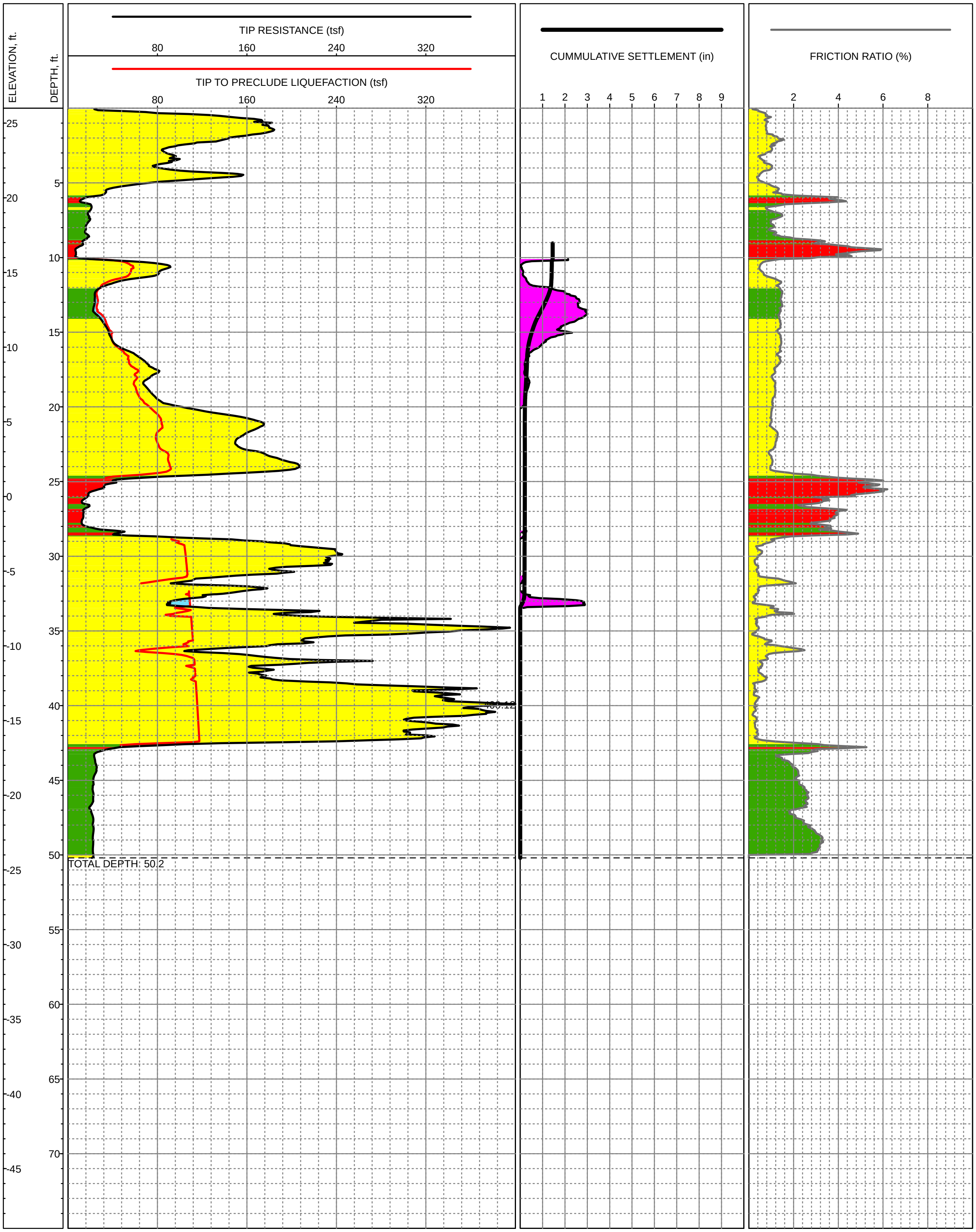
COORDINATES: 2,232,390.00N 5,778,074.64W
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-5, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil



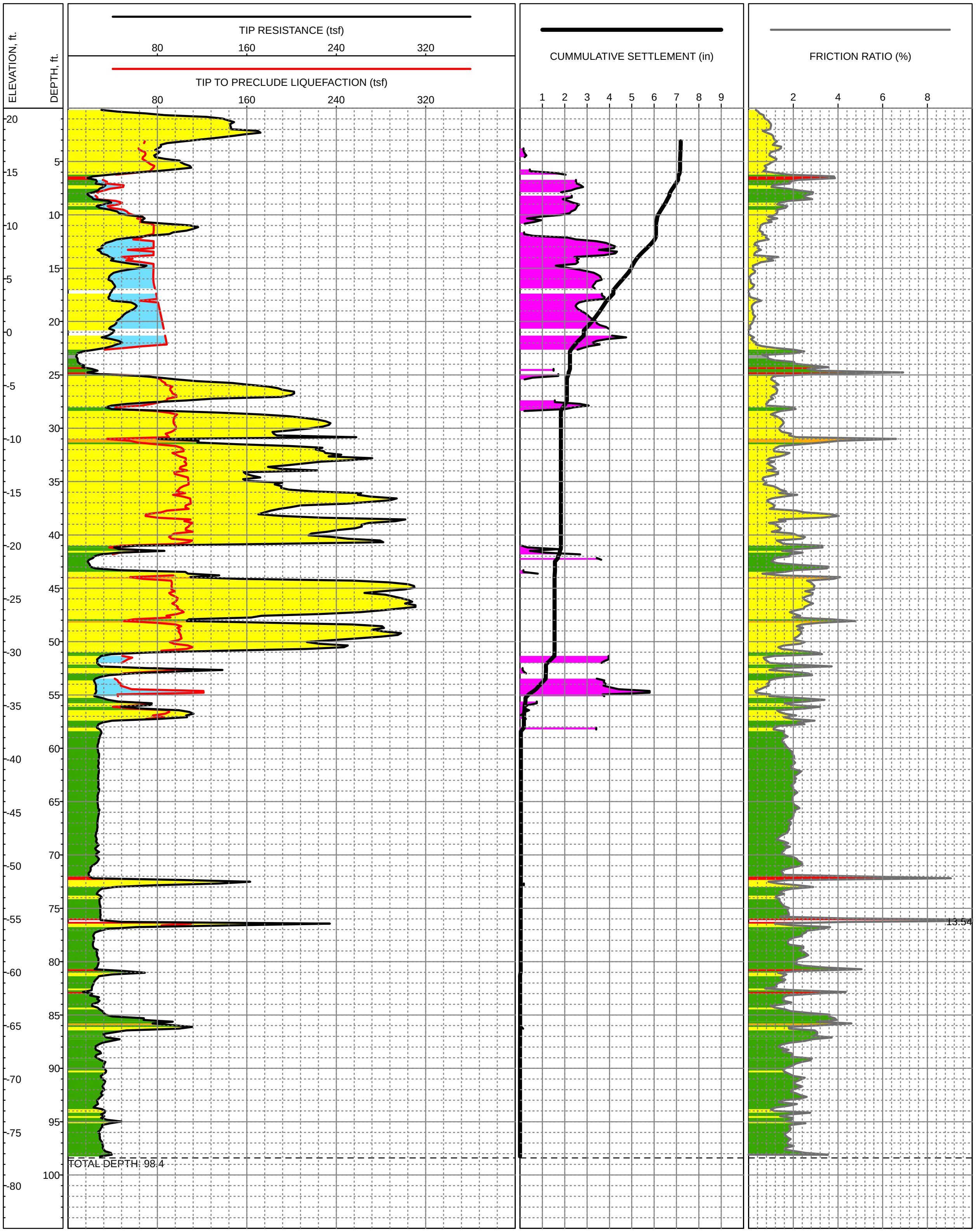
COORDINATES: 2,231,397.63N 5,779,691.56W
SURFACE EL: 26.0ft +/- (MSL)
COMPLETION DEPTH: 50.2ft
TESTDATE: 7/22/2008

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

LOG OF CPT C-6, M6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\2008\Logs\Logs_Liq_2008_July\MXD\CPTLogs_Liq.mxd,08/29/2008,ksheil



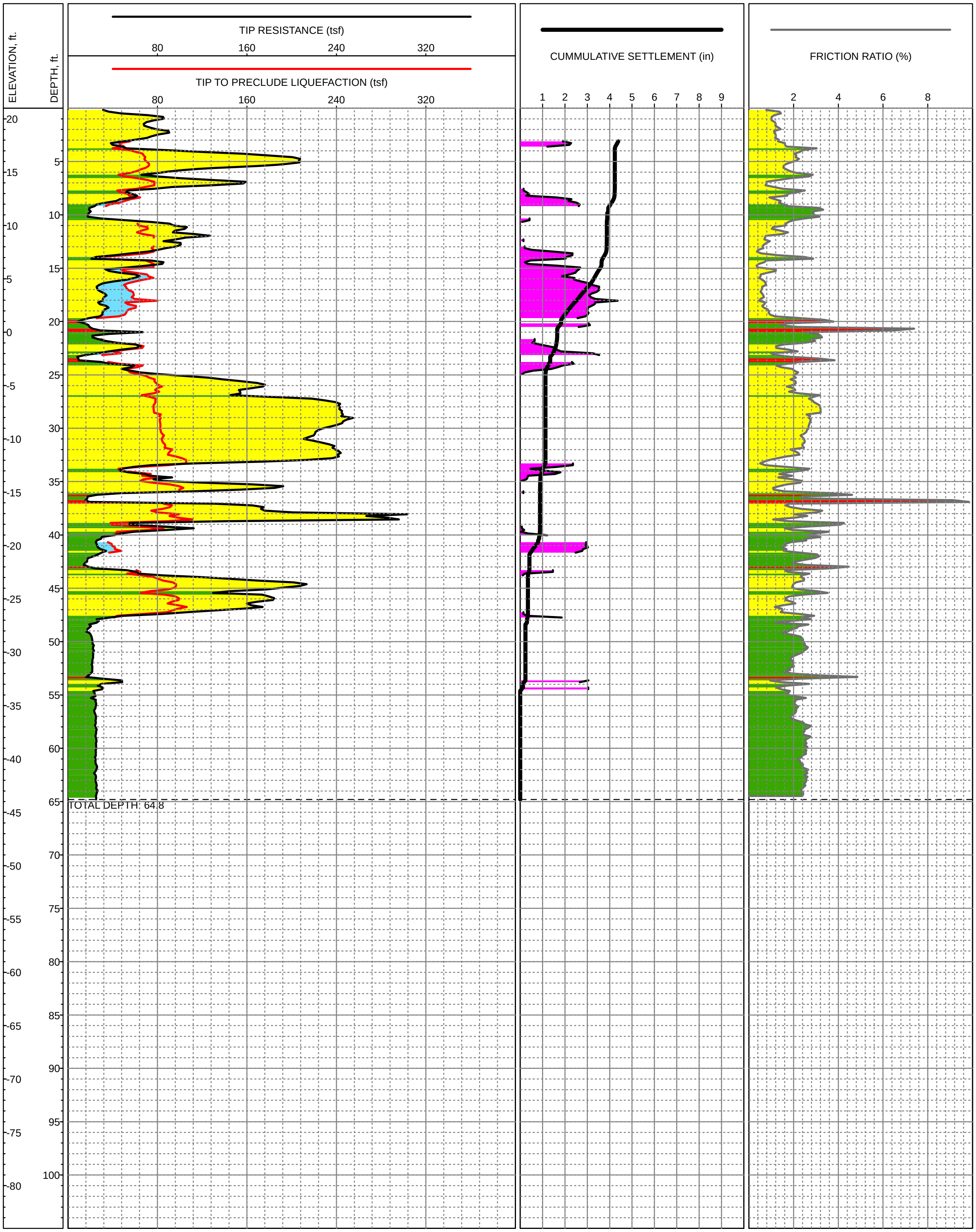
LOCATION: South Levee, Approx. 3350 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 98.4ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC035, M=6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

N:\Projects\3014_SLOcounty\3014-029_Arroyo_Grande_Creek\Explorations\CPT\USGS_2004\Logs\Logs_LiquM7.0_A0.46_2008_08_01\MXD\CPTLogs_Liq7_46.mxd,08/29/2008,ksheil



LOCATION: South Levee, Approx. 3500 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 64.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC036, M=6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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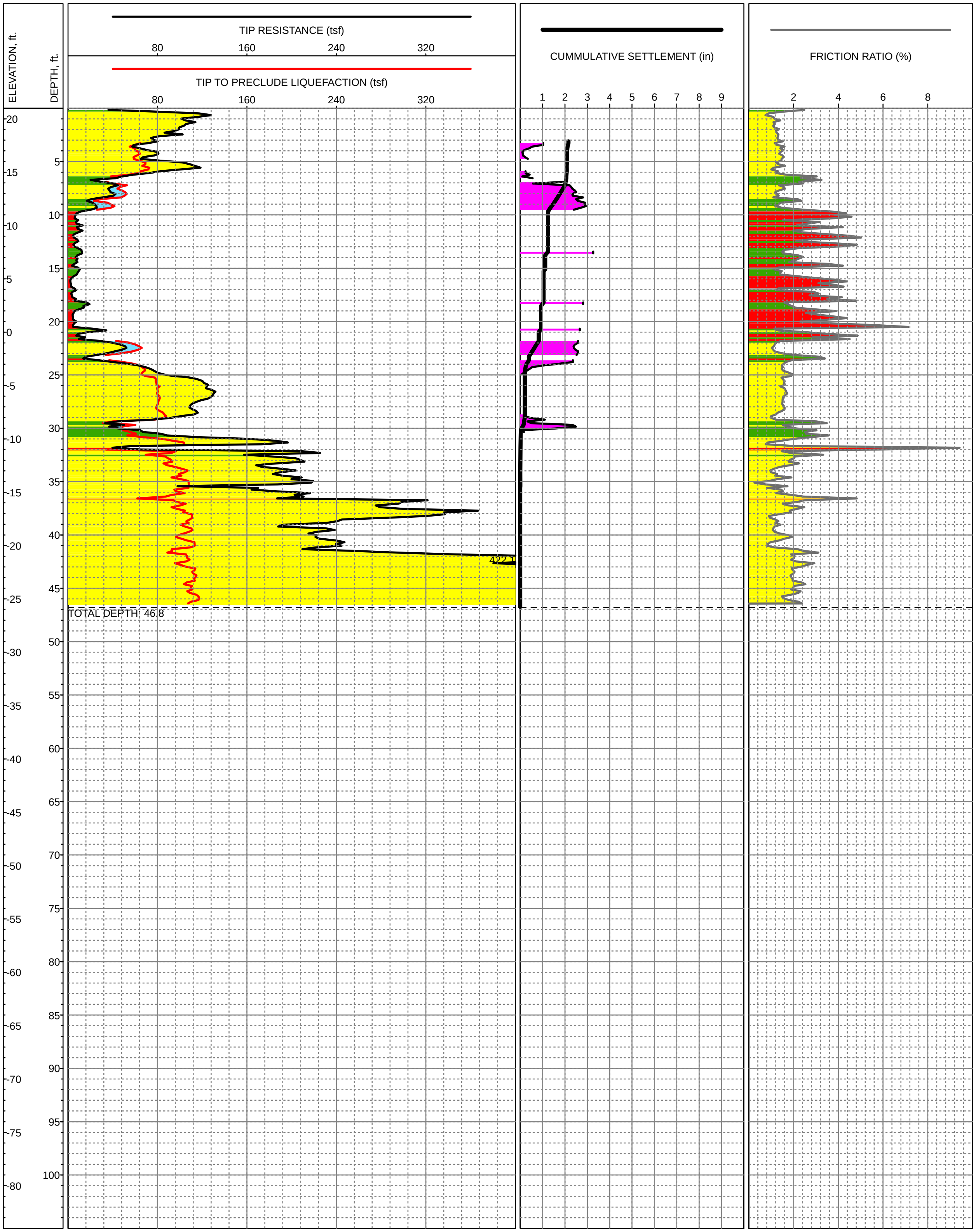

LOCATION: South Levee, Approx. 3250 ft northwest of 22nd St. Bridge
SURFACE EL: 21.0ft +/- (MSL)
COMPLETION DEPTH: 46.8ft
TESTDATE: 3/5/2004

EXPLORATION METHOD: Cone Penetrometer
PERFORMED BY: USGS
REVIEWED BY: J Blanchard

LOG OF CPT SOC037, M=6.5, a=0.25

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

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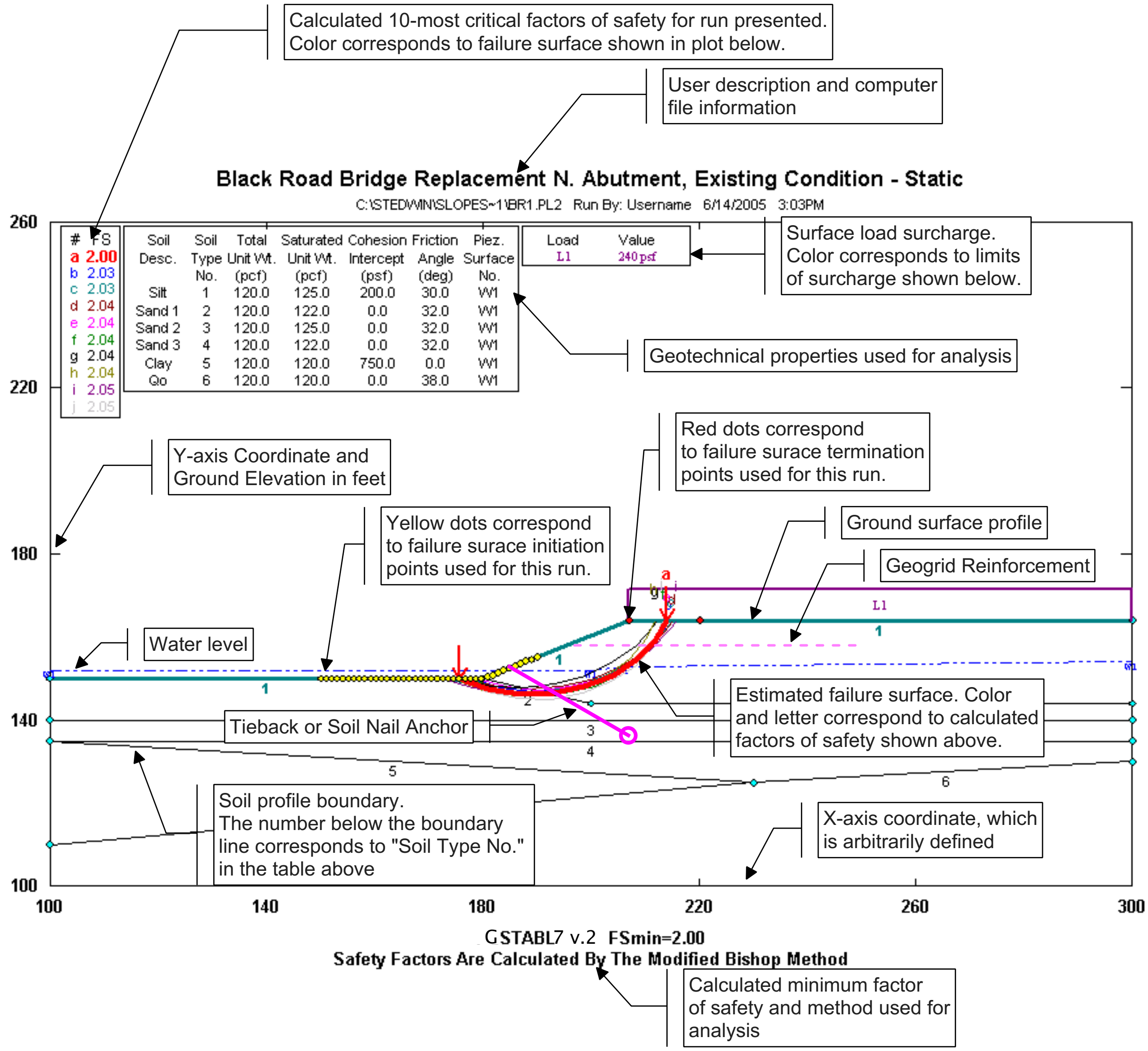
APPENDIX D



Notes:

1. Plots are shown for run with least calculated factor of safety. Additional termination and initiation limits may have been considered. Typically over 100 surfaces are calculated for each run.

2. Discussion of the results and methodology is provided in the text of the report.

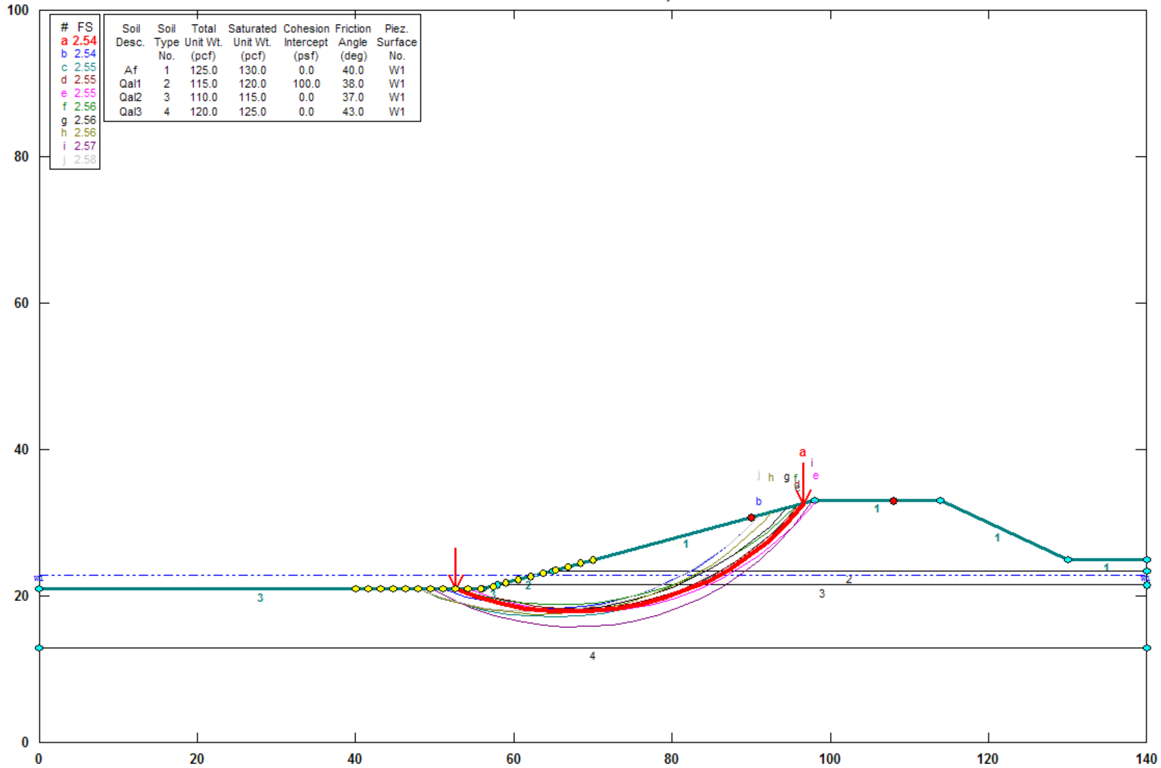
3. The surface and subsurface boundaries are approximate and represent only a generalization of interpreted and inferred subsurface conditions estimated from limited points of exploration.

KEY TO SLOPE STABILITY PLOTS

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County,California

Arroyo Grande Creek, North Levee - Interior Slope, Static Strength 2

F:\FUGROS~1\SANLUI~3\3014~1.029\SLOPES~1\NLEVEEB3.PL2 Run By: Gresham D Eckrich 8/27/2008 4:08PM



GSTABL7 v.2 FSmin=2.54
Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

ESTIMATED FACTORS OF SAFETY

Static Loading Condition: 2.5

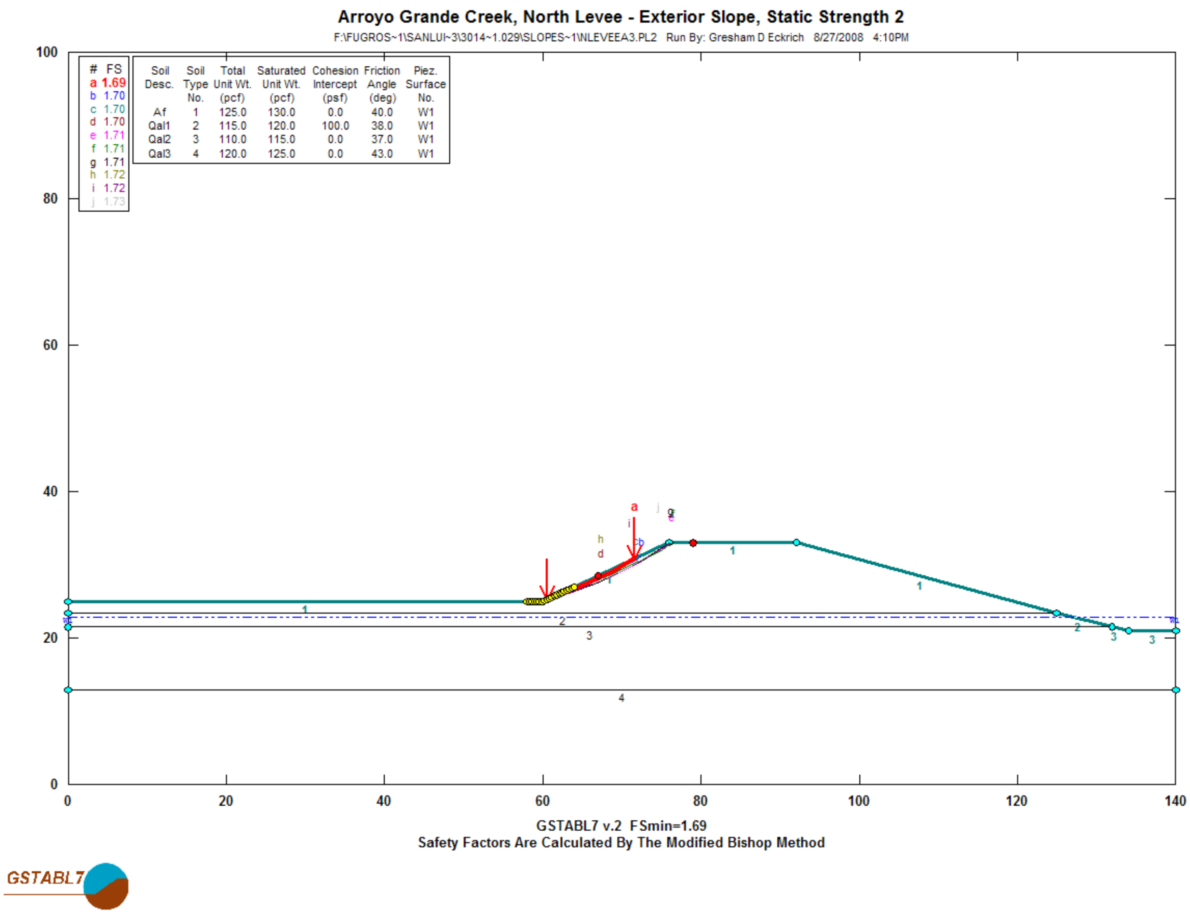
Pseudostatic Loading Condition: 1.5

Pseudostatic Coefficient: 0.15

Condition: Existing Interior Slope, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-2



ESTIMATED FACTORS OF SAFETY

Static Loading Condition: **1.7**

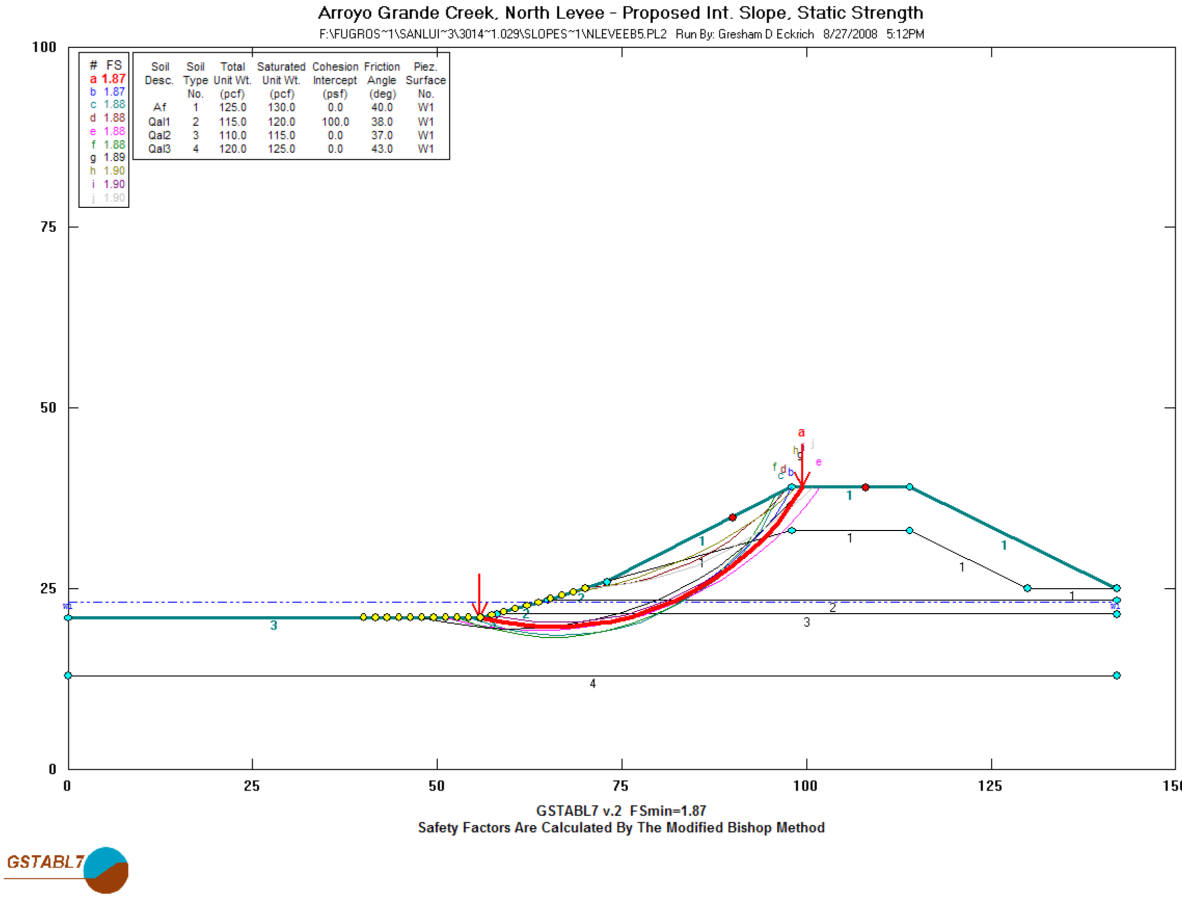
Pseudostatic Loading Condition: **1.2**

Pseudostatic Coefficient: **0.15**

Condition: Existing Exterior Slope, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



ESTIMATED FACTORS OF SAFETY

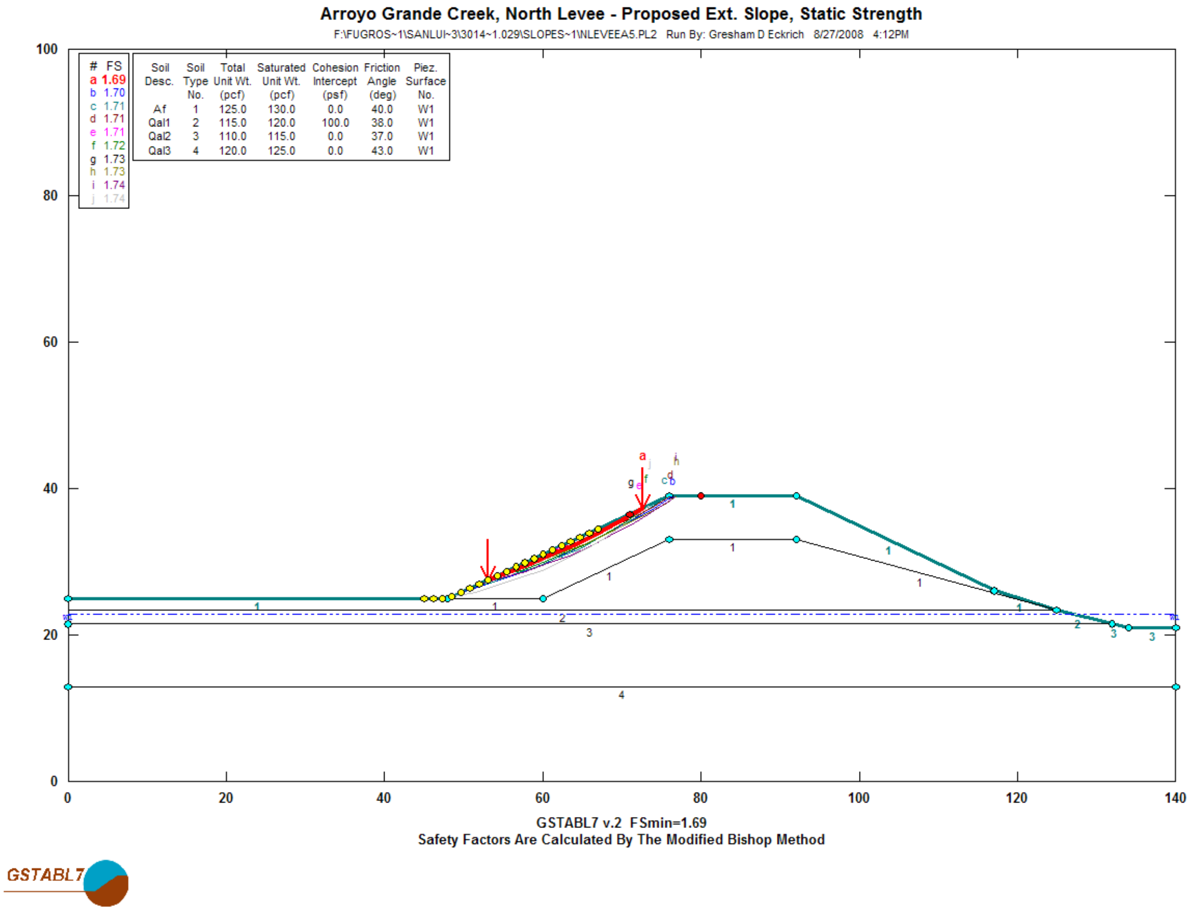
Static Loading Condition: **1.9**

Pseudostatic Loading Condition: **1.3**

Pseudostatic Coefficient: **0.15**

Condition: Proposed Interior Slope 1, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



ESTIMATED FACTORS OF SAFETY

Static Loading Condition: **1.7**

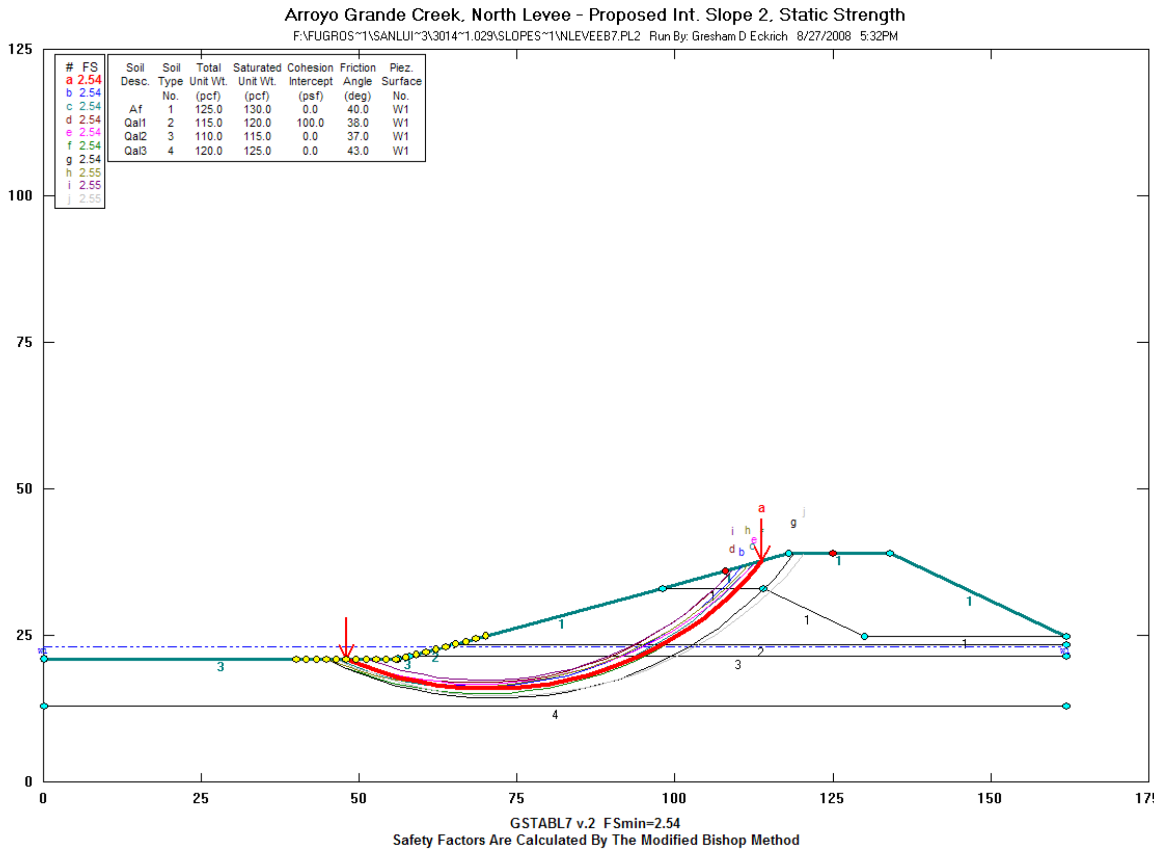
Pseudostatic Loading Condition: **1.2**

Pseudostatic Coefficient: **0.15**

Condition: Proposed Exterior Slope 1, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-5



GSTABL7

ESTIMATED FACTORS OF SAFETY

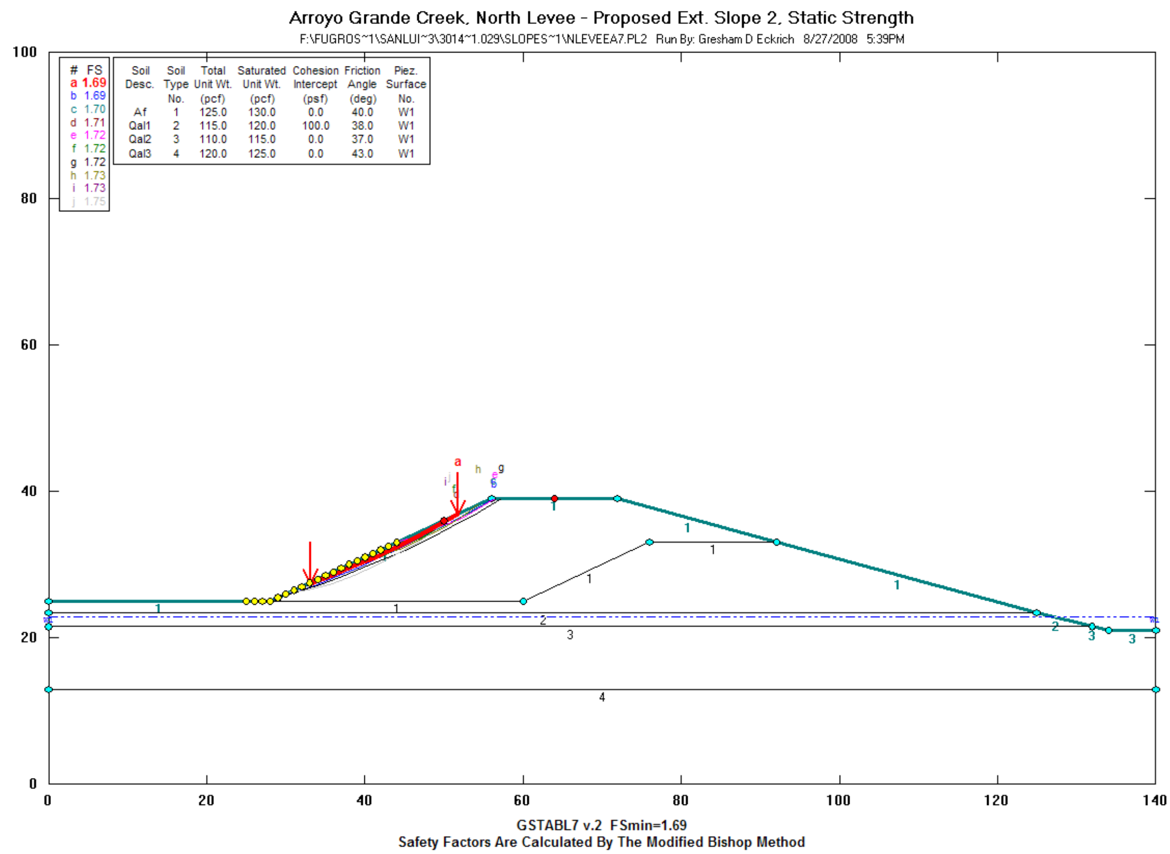
Static Loading Condition: **2.5**

Pseudostatic Loading Condition: **1.5**

Pseudostatic Coefficient: **0.15**

Condition: Proposed Interior Slope 2, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



GSTABL7

ESTIMATED FACTORS OF SAFETY

Static Loading Condition: 1.7

Pseudostatic Loading Condition: 1.2

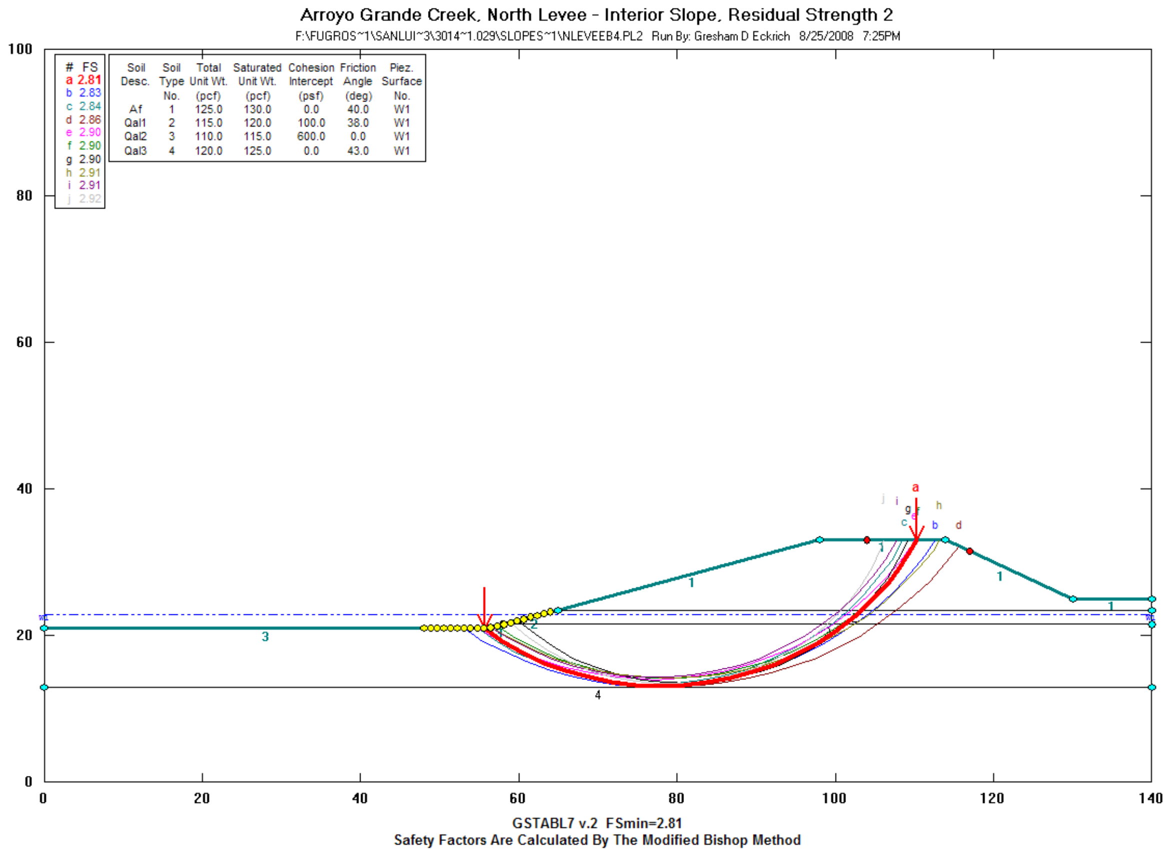
Pseudostatic Coefficient: 0.15

Condition: Proposed Exterior Slope 2, Static Loading

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-7



GSTABL7

<u>ESTIMATED FACTOR OF SAFETY</u>

Post-Liquefaction Condition: 2.5

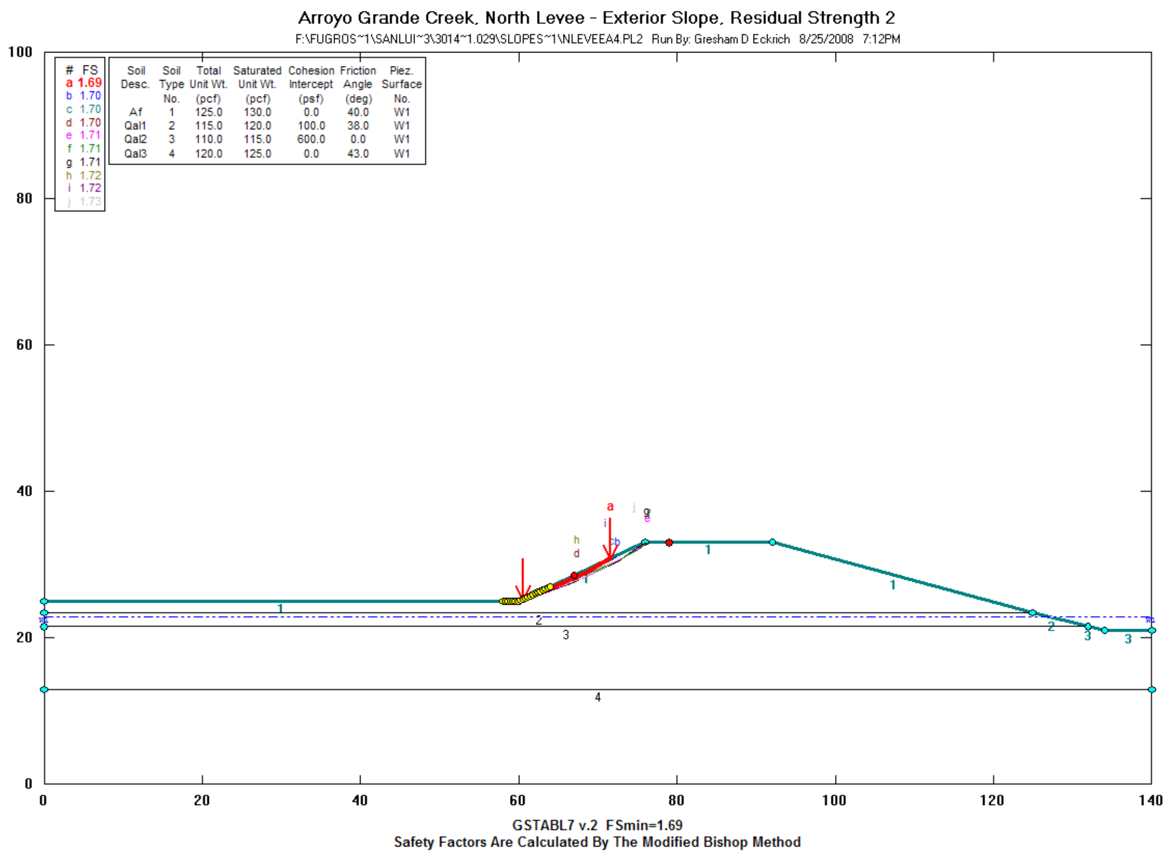
Condition: Existing Interior Slope

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan

San Luis Obispo County, California

PLATE D-8



GSTABL7

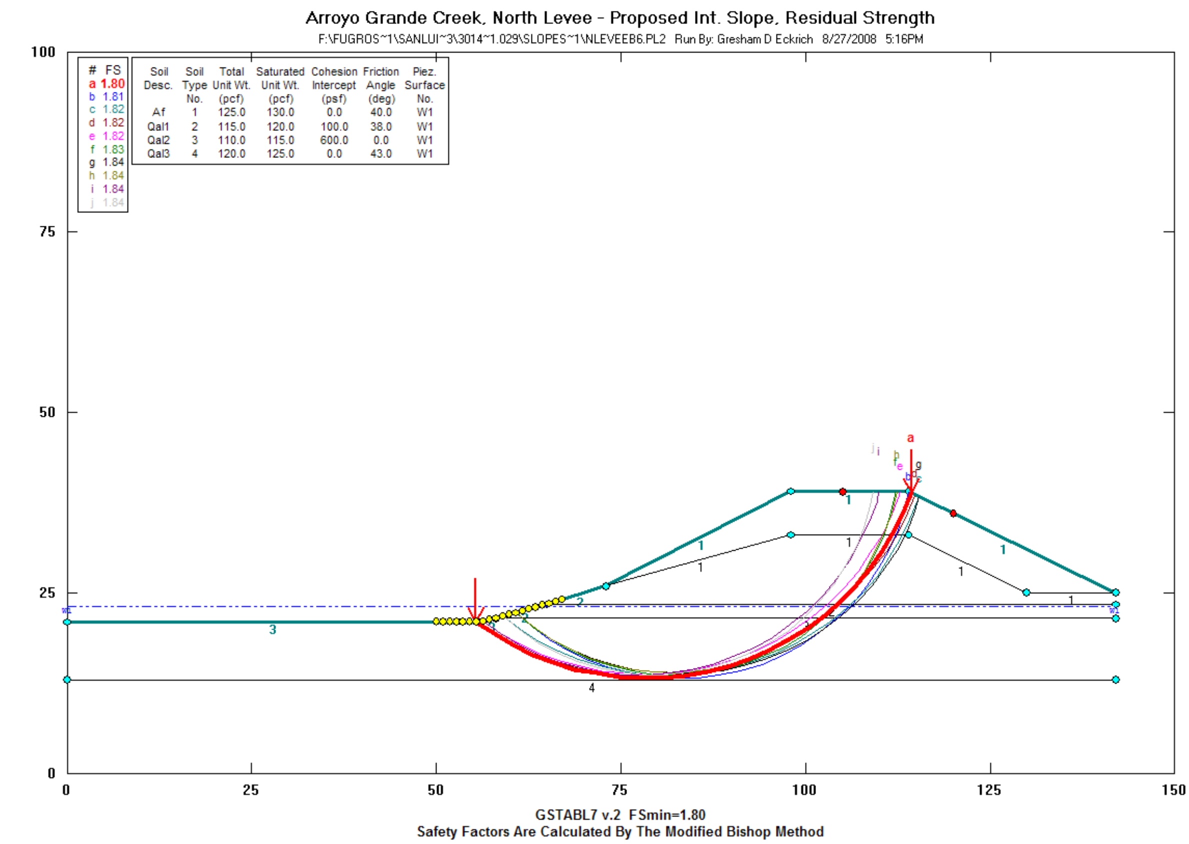
ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 1.7

Condition: Existing Exterior Slope

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-9



ESTIMATED FACTOR OF SAFETY

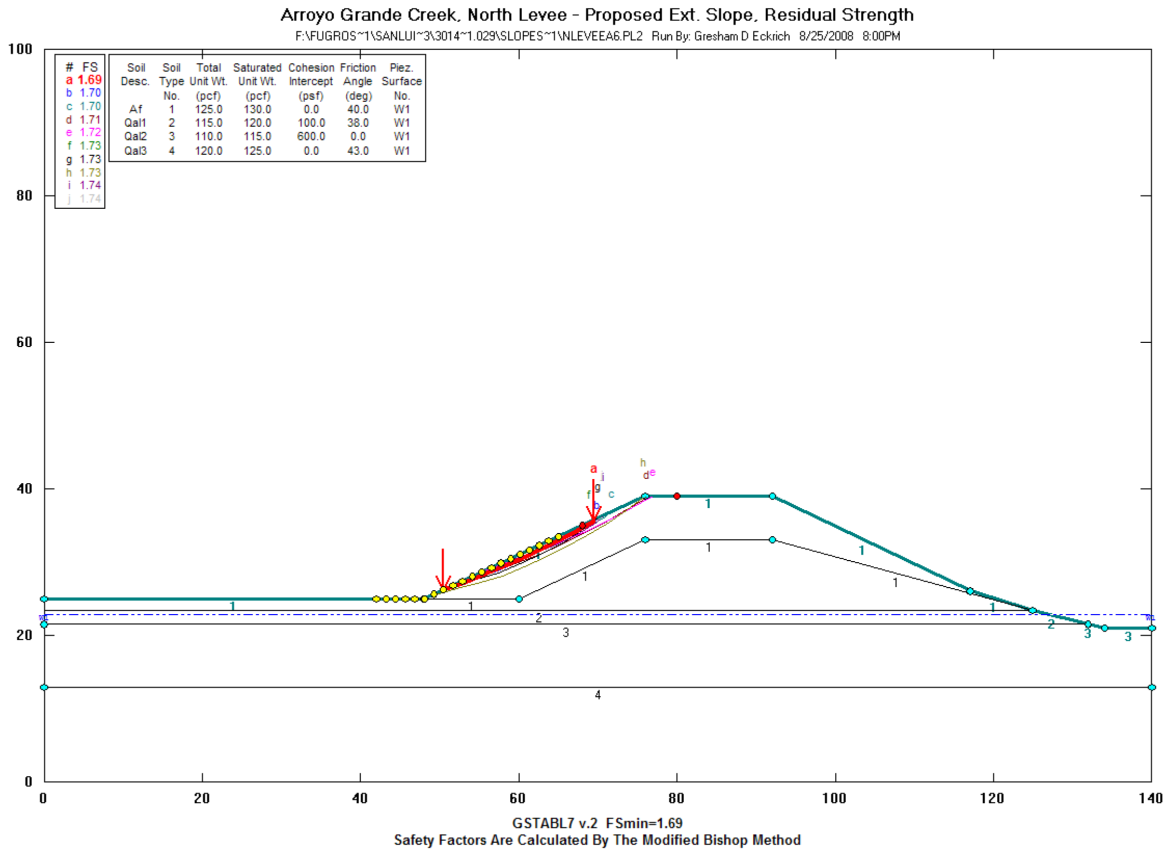
Post-Liquefaction Condition: 1.8

Condition: Proposed Interior Slope 1

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-10



GSTABL7

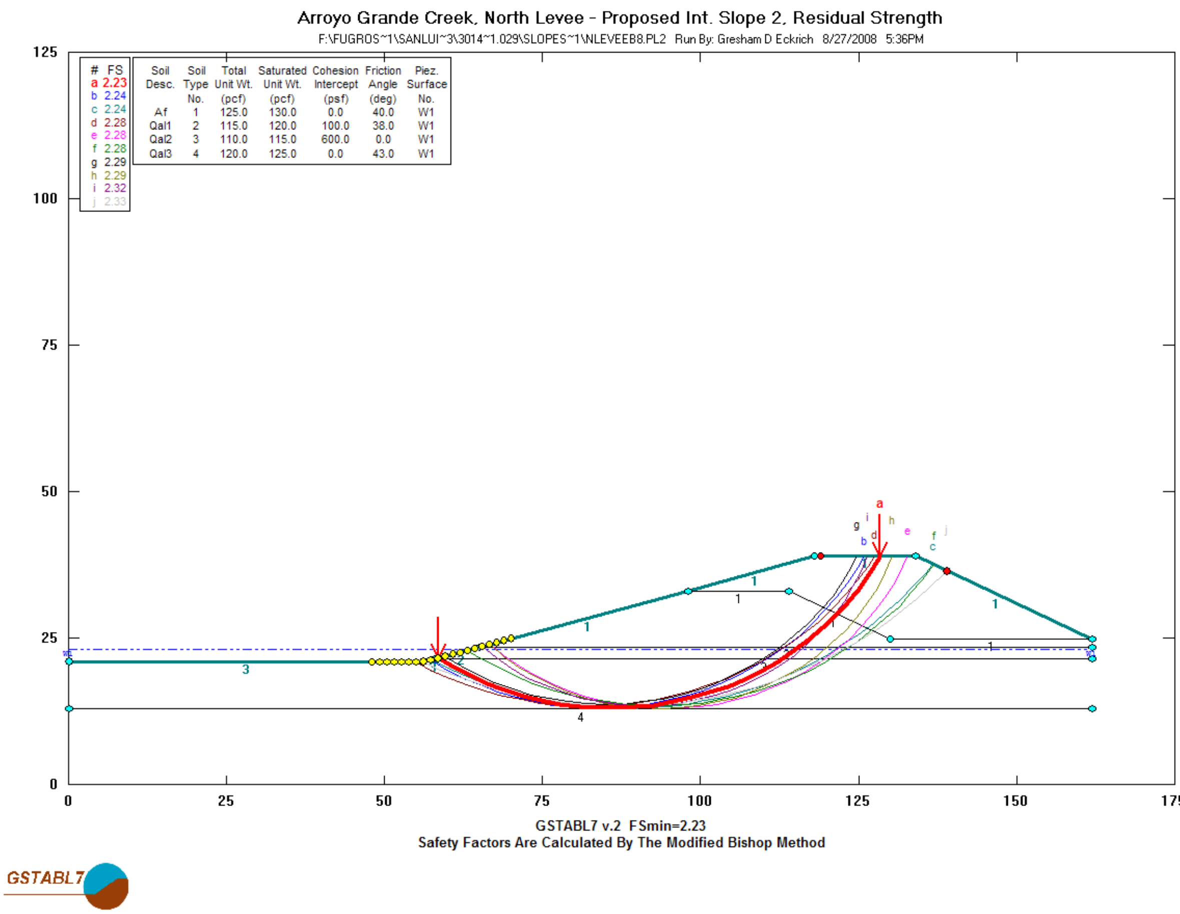
ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 1.7

Condition: Proposed Exterior Slope 1

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-11

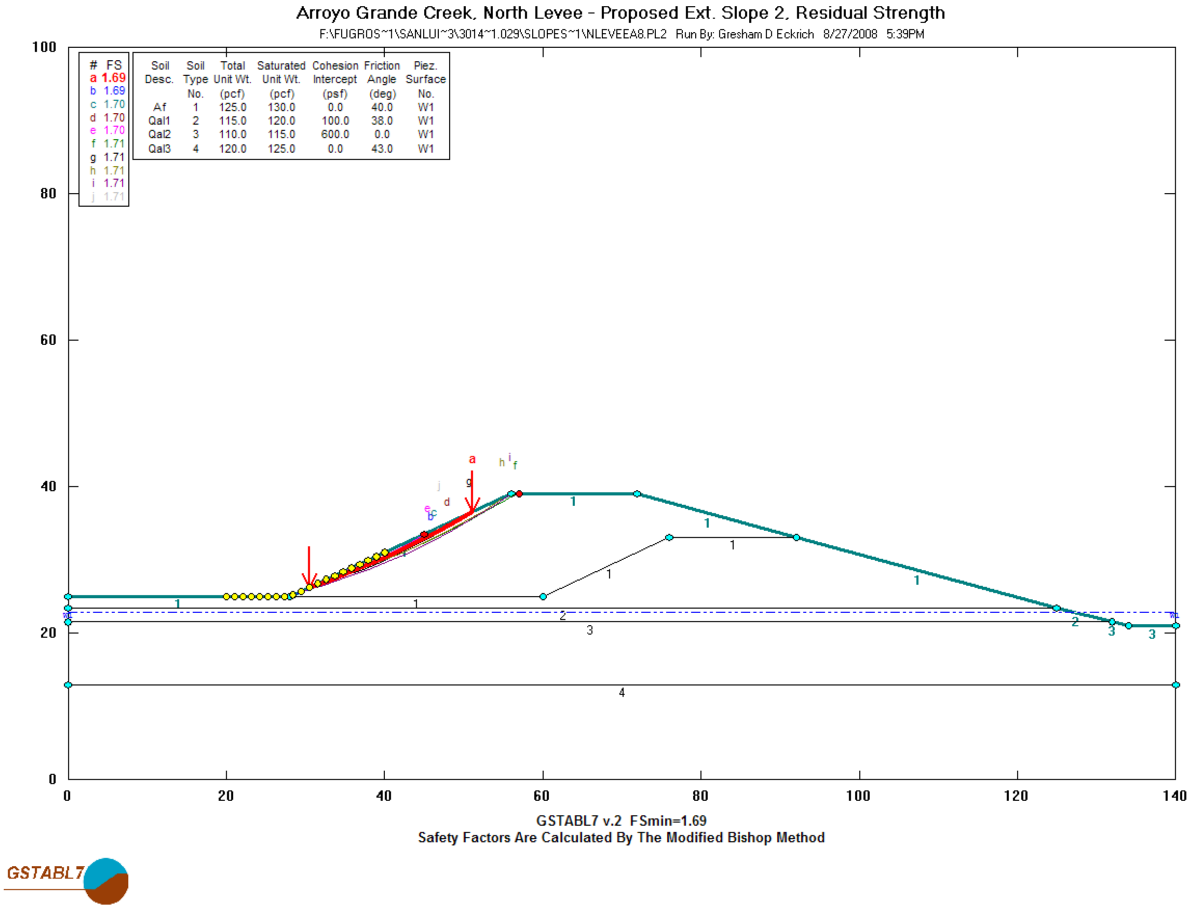


ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 2.2

Condition: Proposed Interior Slope 2

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

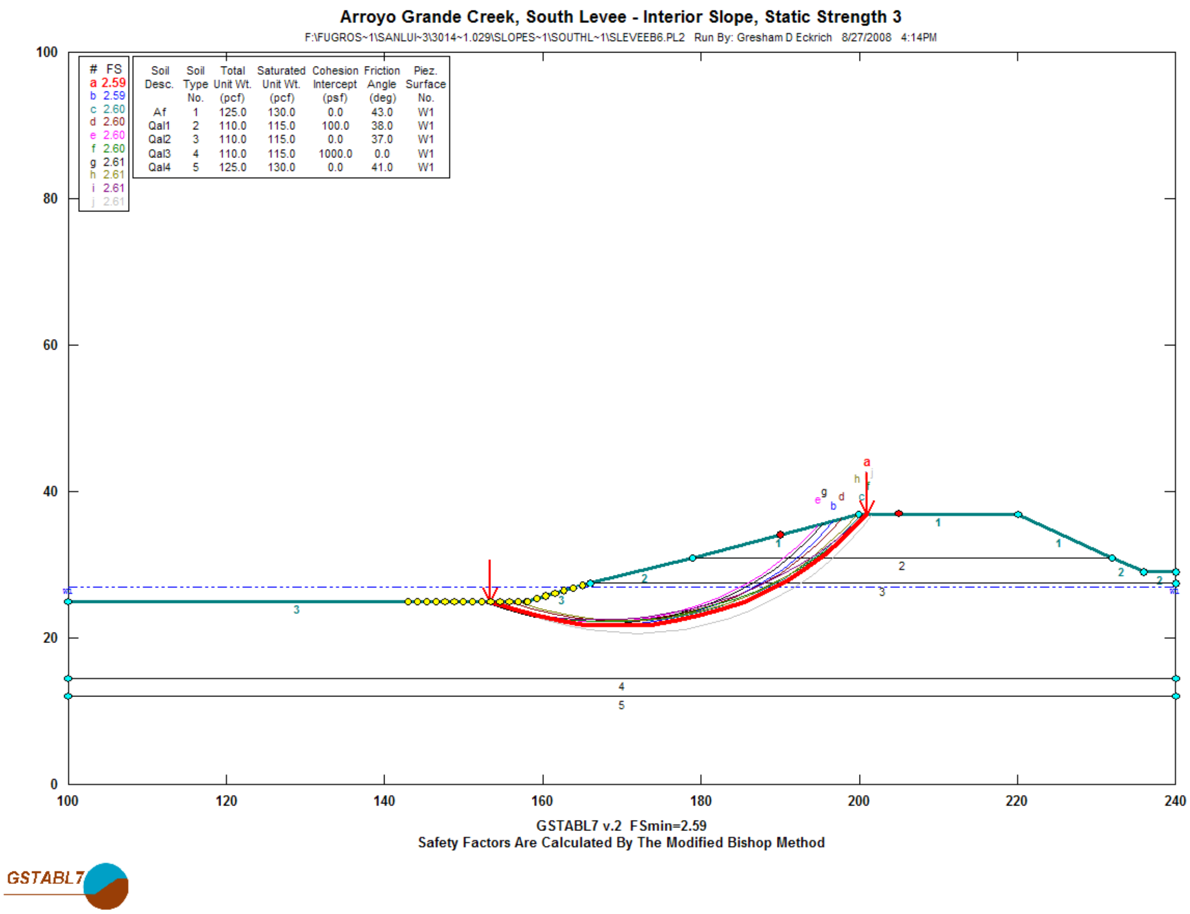


ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 1.7

Condition: Proposed Exterior Slope 2

SLOPE STABILITY PLOT FOR NORTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



ESTIMATED FACTORS OF SAFETY

Static Loading Condition: 2.6

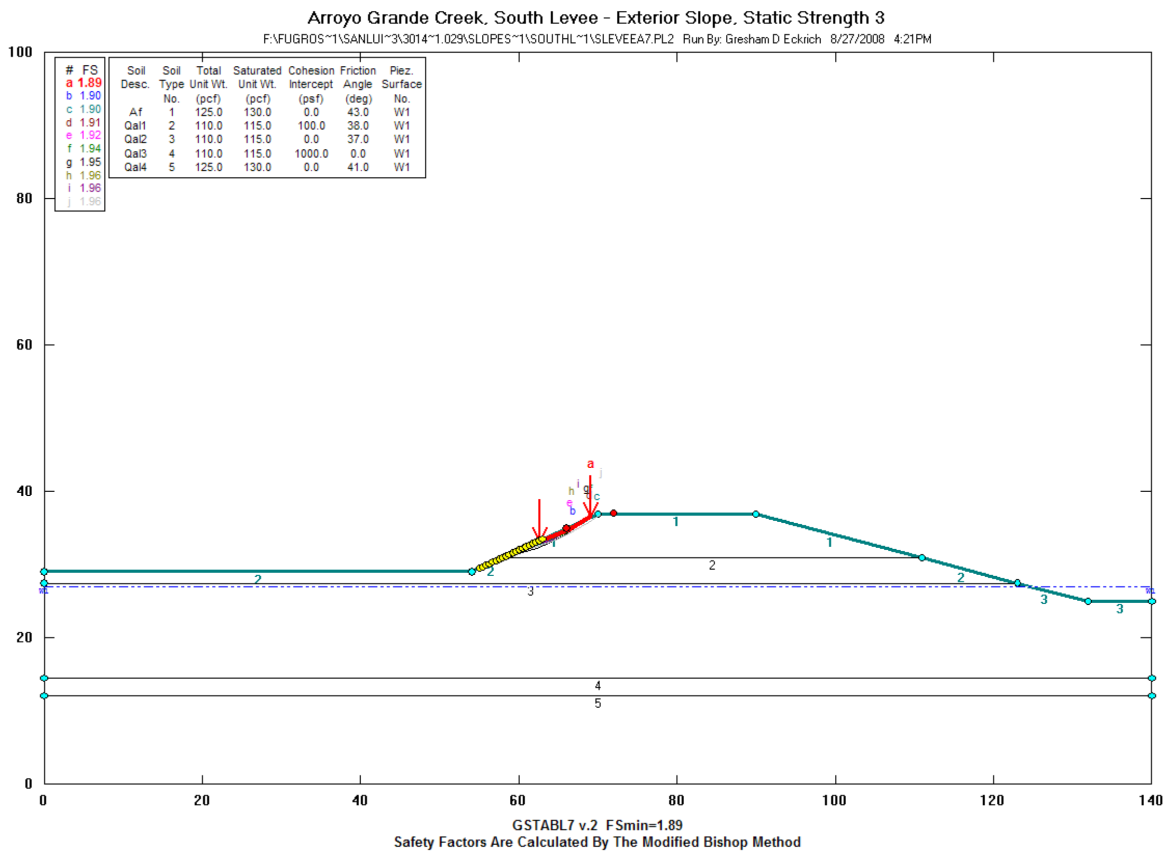
Pseudostatic Loading Condition: 1.5

Pseudostatic Coefficient: 0.15

Condition: Existing Interior Slope, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-14



GSTABL7

ESTIMATED FACTORS OF SAFETY

Static Loading Condition: **1.9**

Pseudostatic Loading Condition: **1.3**

Pseudostatic Coefficient: **0.15**

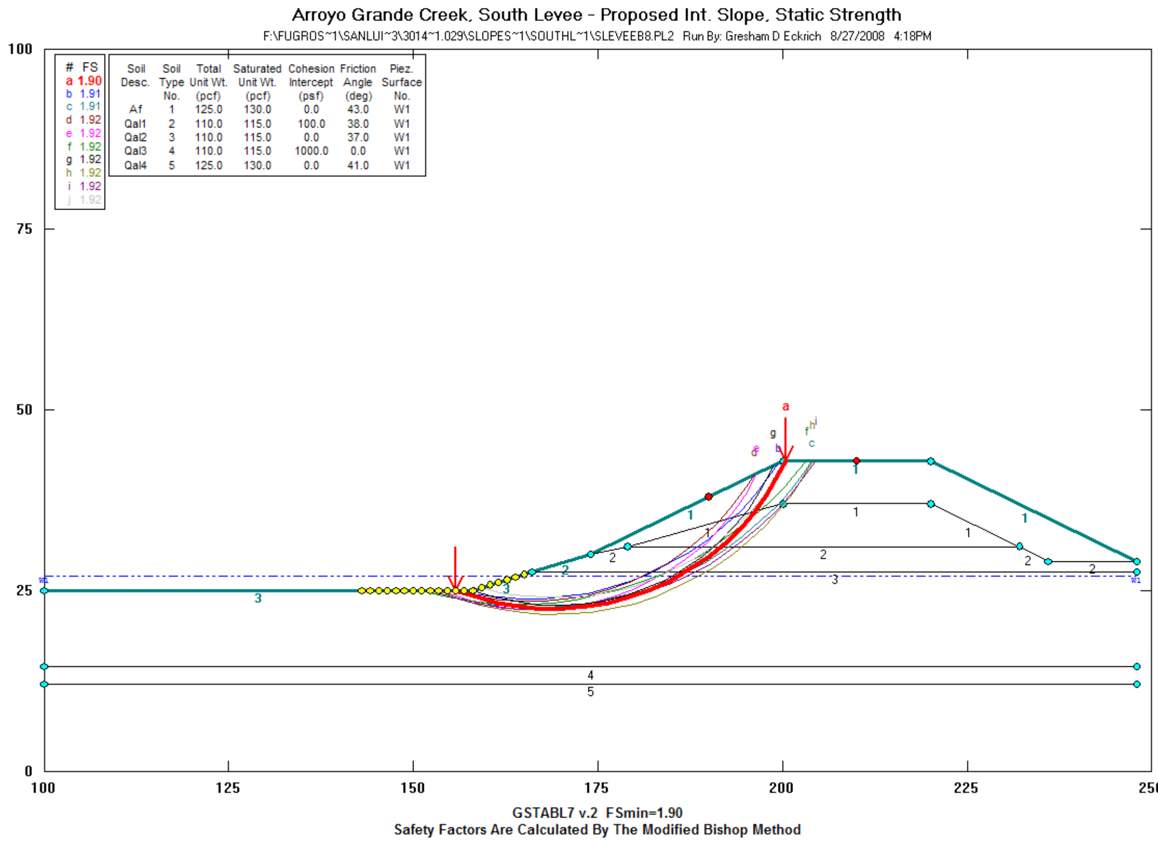
Condition: Existing Exterior Slope, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan

San Luis Obispo County, California

PLATE D-15



ESTIMATED FACTORS OF SAFETY

Static Loading Condition: **1.9**

Pseudostatic Loading Condition: **1.3**

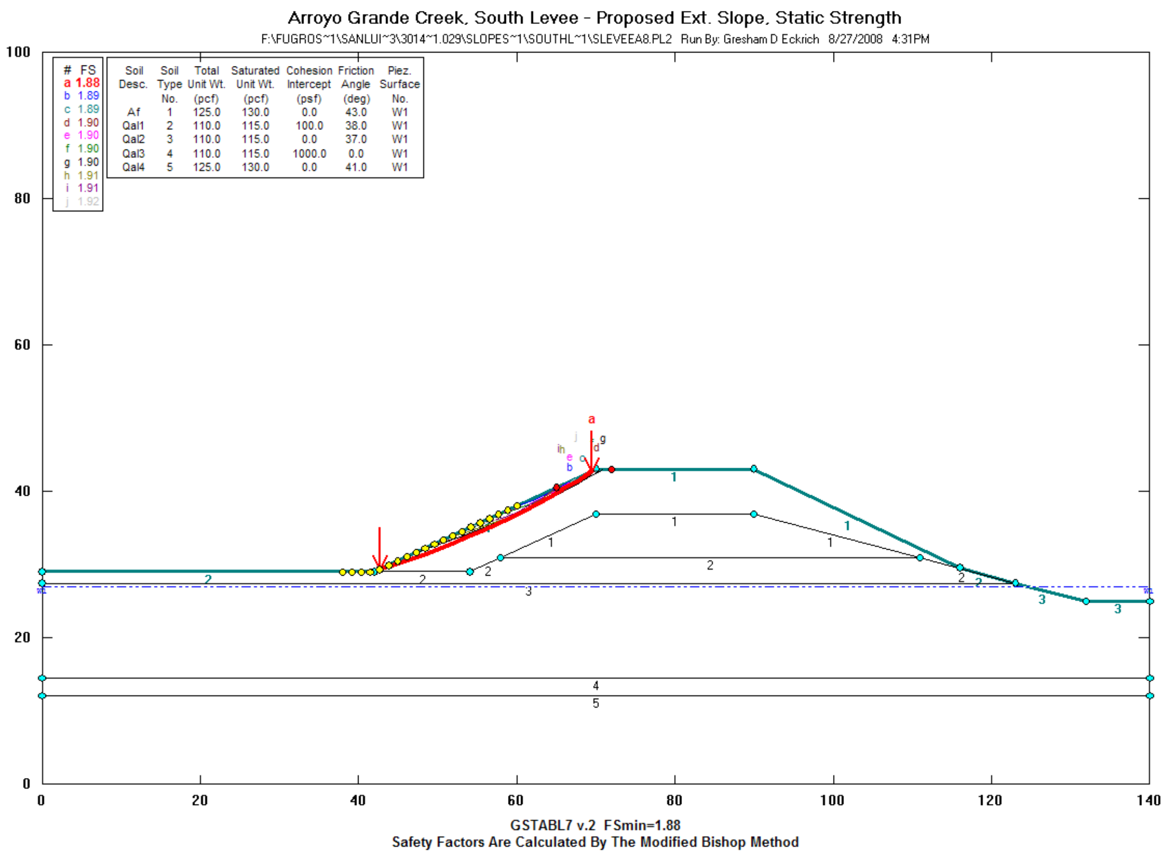
Pseudostatic Coefficient: **0.15**

Condition: Proposed Interior Slope 1, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-16



#	FS
a	1.88
b	1.89
c	1.89
d	1.90
e	1.90
f	1.90
g	1.90
h	1.91
i	1.91
j	1.92

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Af	1	125.0	130.0	0.0	43.0	W1
Qal1	2	110.0	115.0	100.0	38.0	W1
Qal2	3	110.0	115.0	0.0	37.0	W1
Qal3	4	110.0	115.0	1000.0	0.0	W1
Qal4	5	125.0	130.0	0.0	41.0	W1

GSTABL7

ESTIMATED FACTORS OF SAFETY

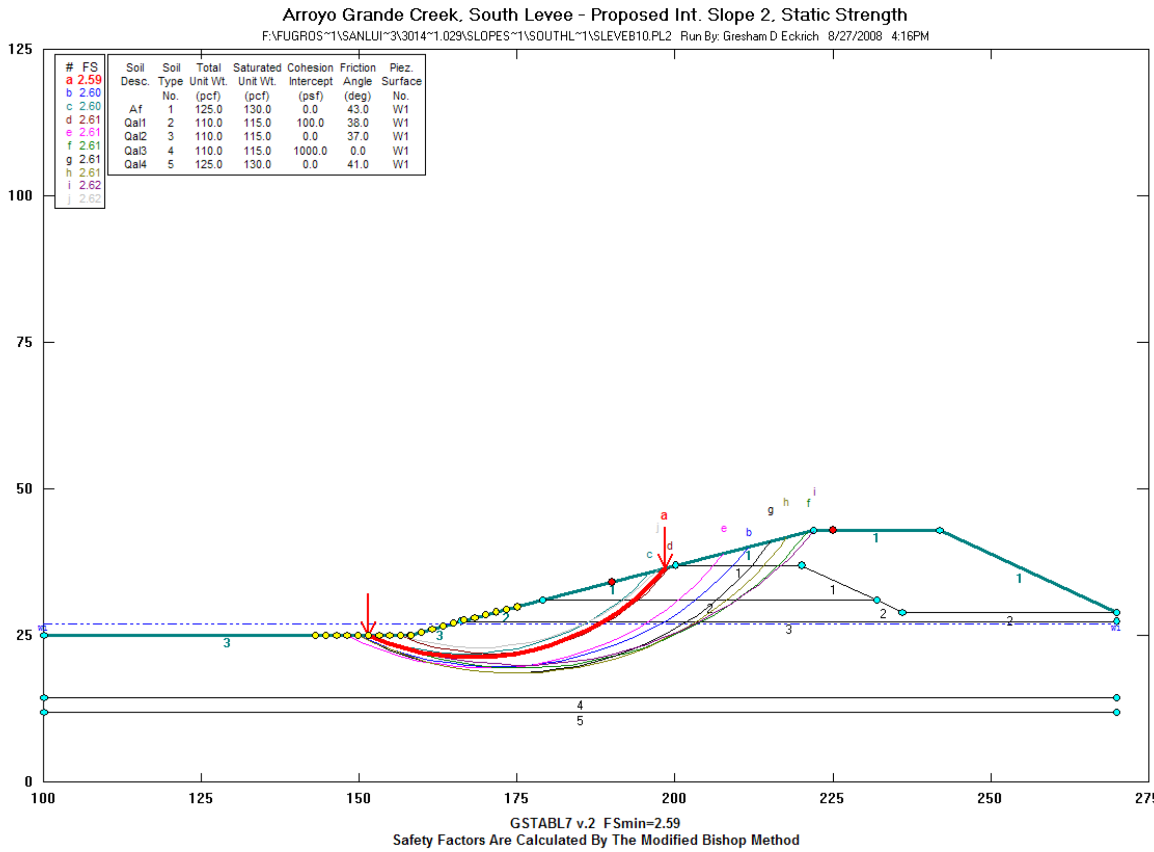
Static Loading Condition: 1.9

Pseudostatic Loading Condition: 1.3

Pseudostatic Coefficient: 0.15

Condition: Proposed Exterior Slope 1, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



GSTABL7

ESTIMATED FACTORS OF SAFETY

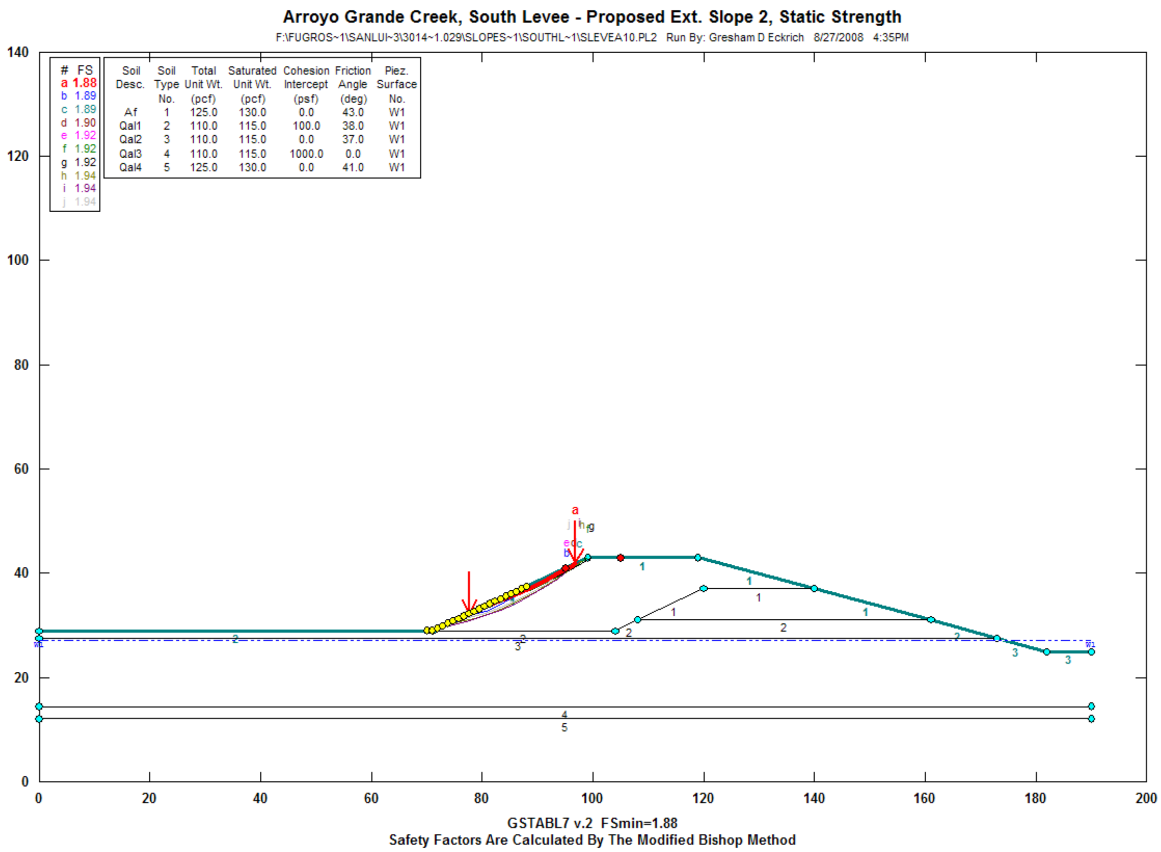
Static Loading Condition: **2.6**

Pseudostatic Loading Condition: **1.5**

Pseudostatic Coefficient: **0.15**

Condition: Proposed Interior Slope 2, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



GSTABL7

ESTIMATED FACTORS OF SAFETY

Static Loading Condition: 1.9

Pseudostatic Loading Condition: 1.3

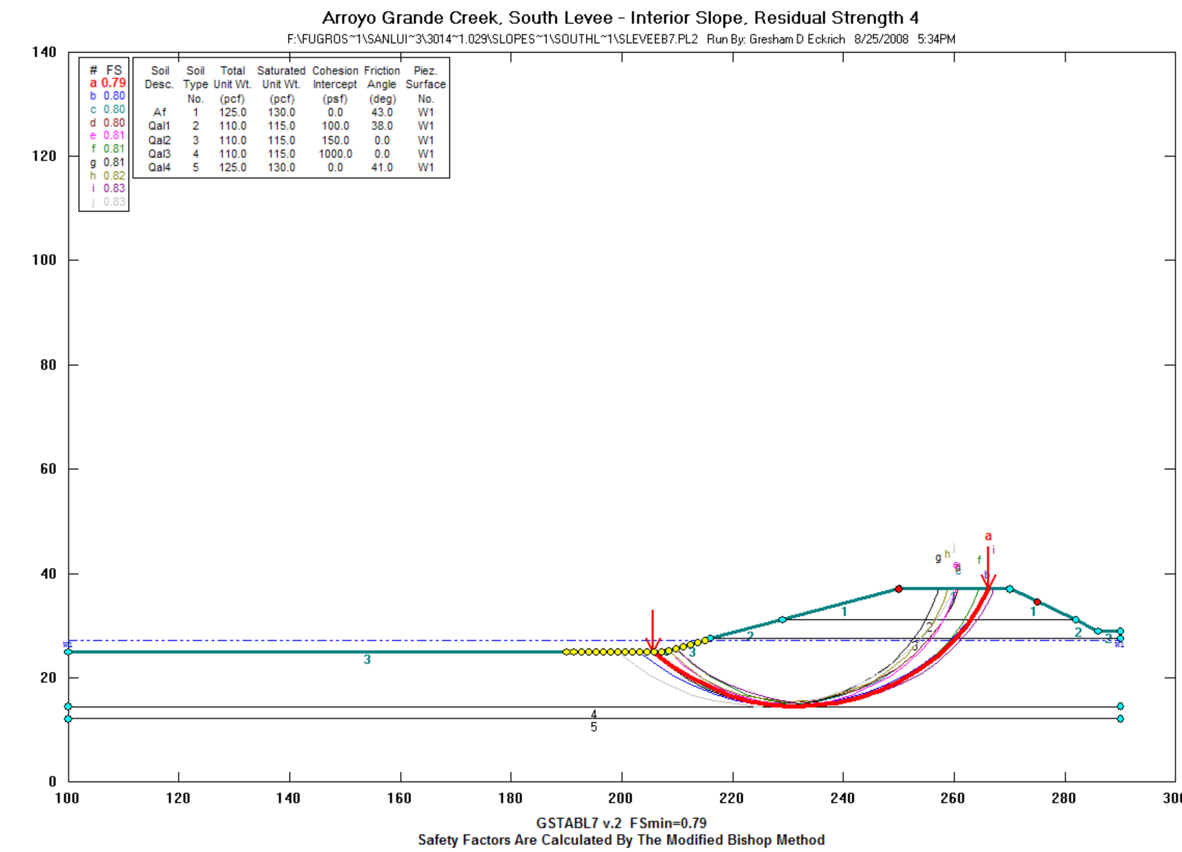
Pseudostatic Coefficient: 0.15

Condition: Proposed Exterior Slope 2, Static Loading

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan

San Luis Obispo County, California



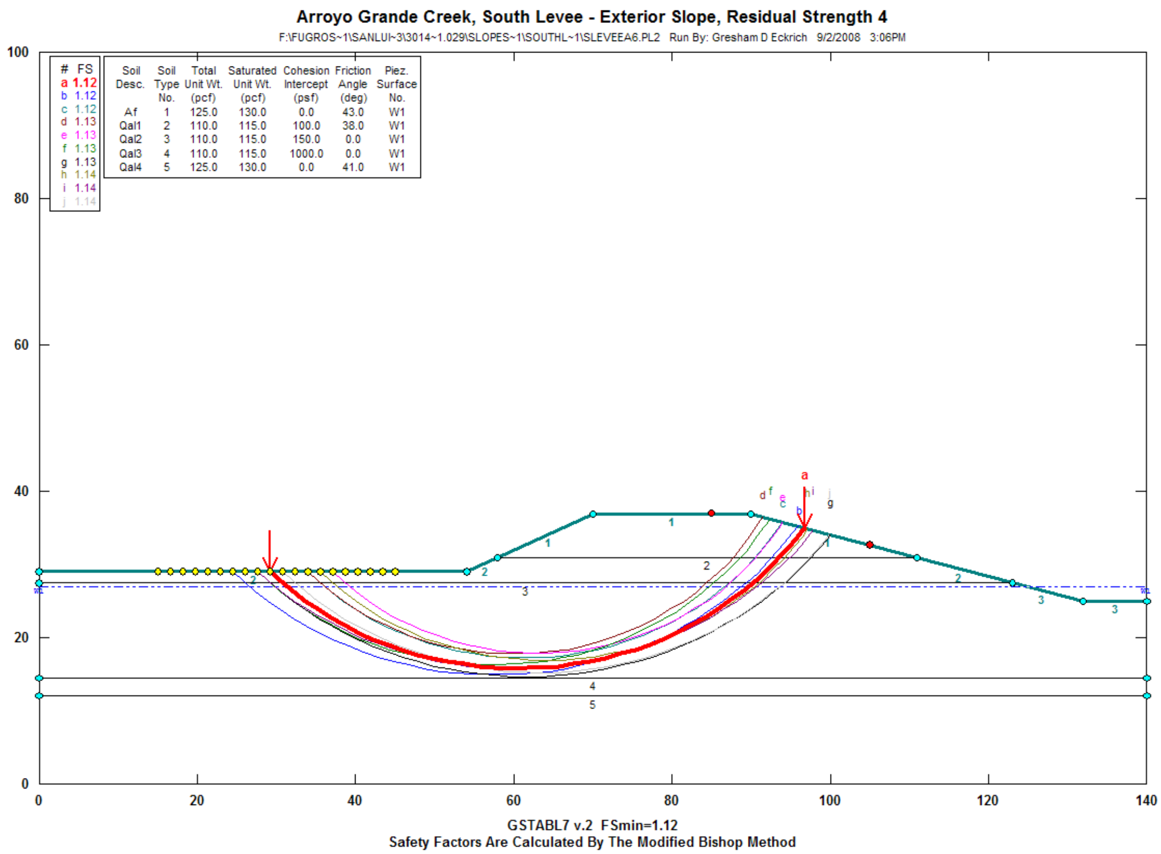
GSTABL7

ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 0.8

Condition: Existing Interior Slope

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California



GSTABL7

ESTIMATED FACTOR OF SAFETY

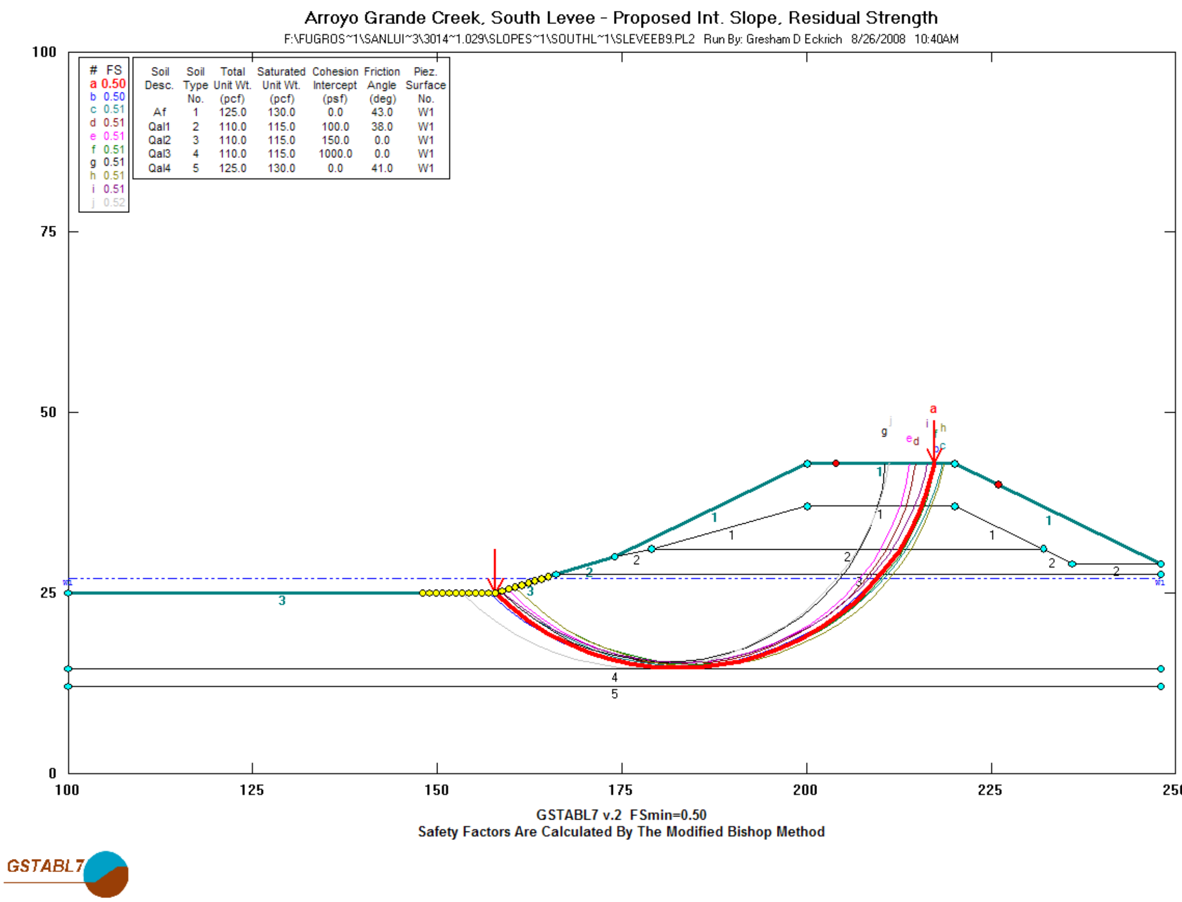
Post-Liquefaction Condition: 1.1

Condition: Existing Exterior Slope

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT

Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-21



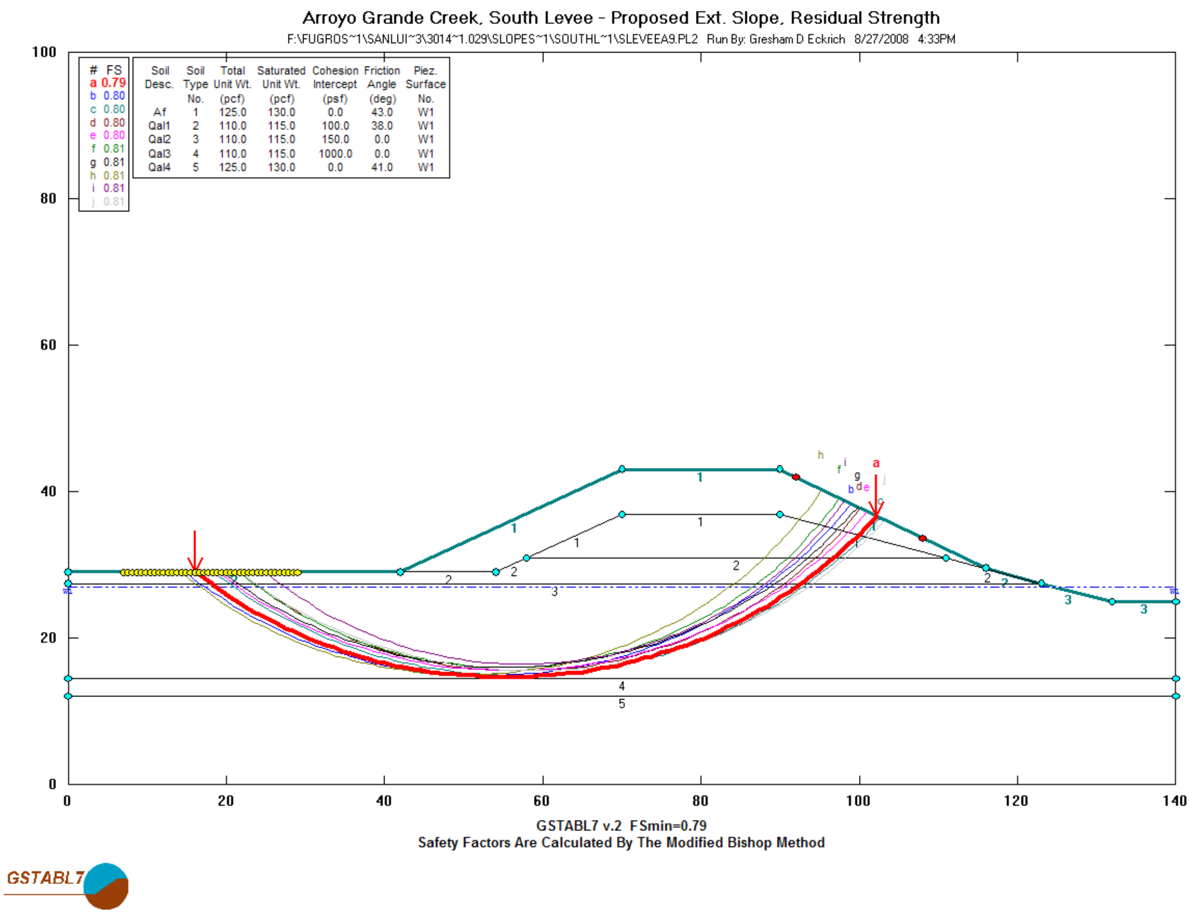
ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 0.5

Condition: Proposed Interior Slope 1

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-22



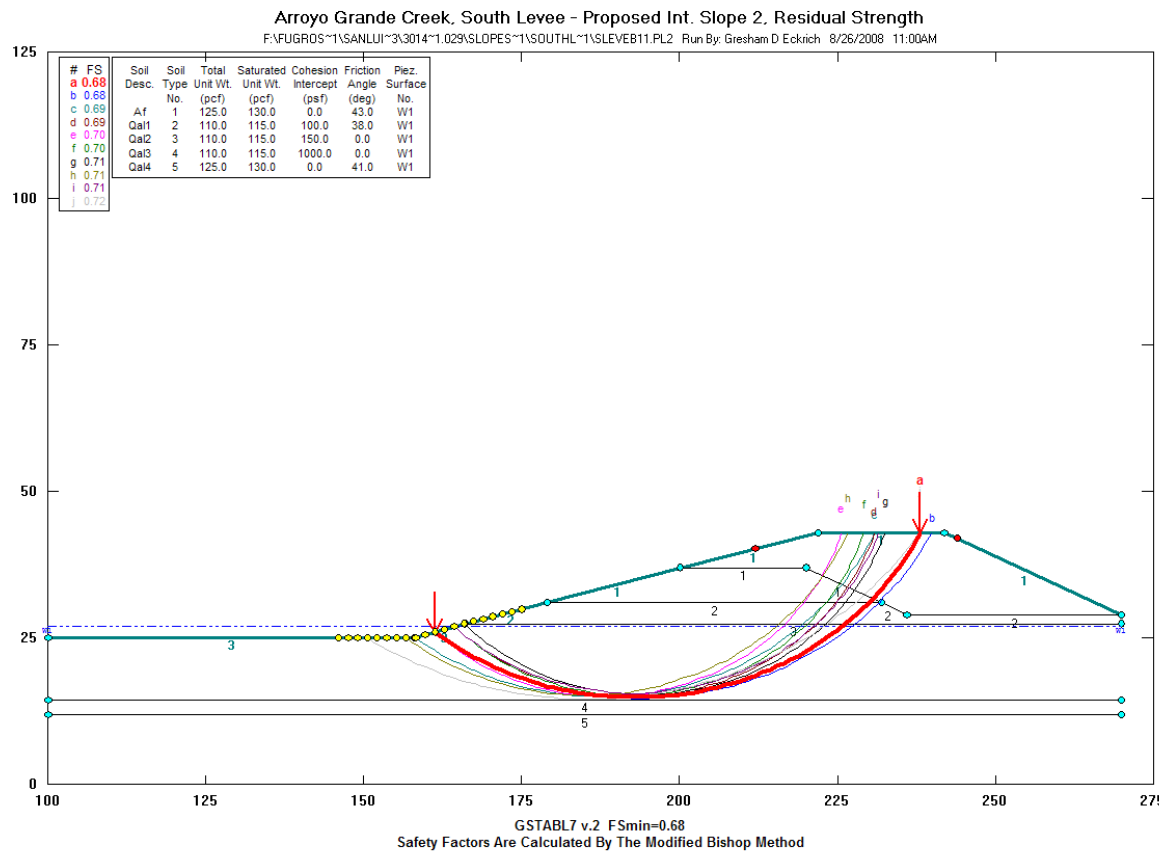
ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 0.8

Condition: Proposed Exterior Slope 1

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-23



GSTABL7

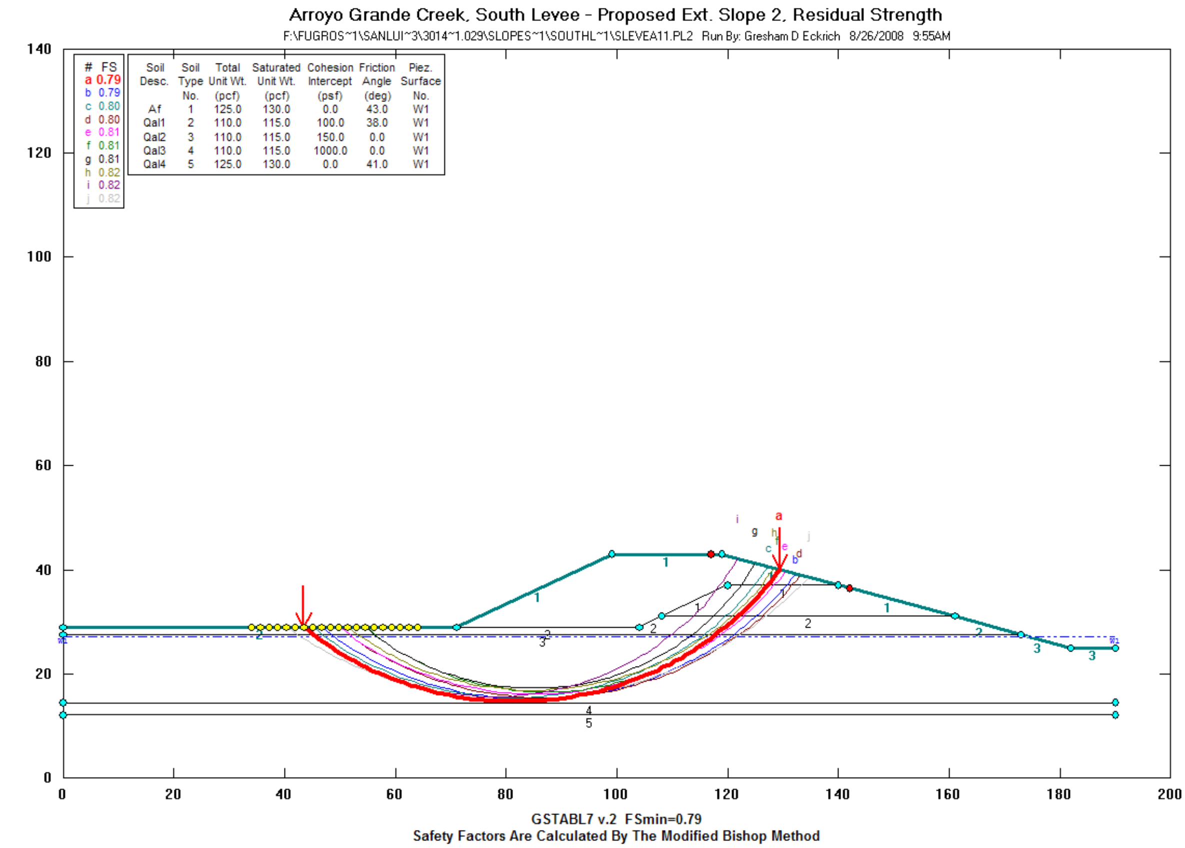
ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 0.7

Condition: Proposed Interior Slope 2

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-24



ESTIMATED FACTOR OF SAFETY

Post-Liquefaction Condition: 0.8

Condition: Proposed Exterior Slope 2

SLOPE STABILITY PLOT FOR SOUTH LEVEE EMBANKMENT
Arroyo Grande Creek Waterways Management Plan
San Luis Obispo County, California

PLATE D-25