Via E-Mail

BERLOGAR STEVENS & ASSOCIATES

December 19, 2018
Job No. 3995.100

Ms. Nicole D. Moore, Director of Forward Planning
Warmington Residential Northern California
2400 Camino Ramon, Suite 234
San Ramon, California 94583

Subject: ***** DRAFT *****
Due Diligence Geotechnical Investigation
East D Street
APN: 007-700-003, -005, -006 and -007
Petaluma, California

Dear Ms. Moore:

In response to your request, Berlogar Stevens & Associates (BSA) is pleased to submit our Due Diligence Geotechnical Investigation report for the subject site. Our understanding of the currently proposed development is presented below. As discussed below, it is our opinion that, from a geotechnical engineering perspective, it is feasible to develop the site as currently envisioned. However, the site has been determined to be underlain by compressible and liquefiable soils. Placement of new fills and loads associated with the buildings will induce settlement due to consolidation of underlying Bay Mud in portions of the site. In the event that seismic activity on one of the many faults in the area causes moderate to strong ground shaking, seismic-induced settlement, and potentially ground failure could occur as a result of liquefaction of cyclic-induced softening of saturated soils. The compressibility of Bay Mud soils and liquefaction potential of the site should be investigated and evaluated further as discussed below. Our scope of services, findings, conclusions and preliminary recommendations are presented in detail below.

PROJECT SITE AND PROPOSED DEVELOPMENT

The site is located in the southwest portion of the City of Petaluma, along the northeast side of the Petaluma River, as shown on the Vicinity Map, Plate 1. The irregular-shaped project site consists of five parcels along with the current southeast extension of Copeland Street from East D Street. The proposed project site has a combined area of about 6.4 acres. Portions of the site were previously developed with four single-story industrial-type buildings evident in a Google Earth aerial photograph dated February 2018. The site surrounds the man-made McNear Canal, which was created through excavation. The Petaluma River is located along the south-southwest (south) side of the site. The site is relatively flat.

It is our understanding that the current proposal is for a residential development consisting of multi-family attached townhomes. The townhomes, which may be up to 8-units per structure, are anticipated to be three-story wood-frame buildings. We have not been provided with specific information regarding building loads. Three story wood-frame structures are generally relatively lightly loaded. Based on our experience with similar developments, a uniform bearing pressure of 400 pounds per square foot (psf) is assumed. Parking will be at-grade. Development of the site will include construction of underground utilities, paved roads, and parking areas and landscaping. Grading of the site will be required to construct building pads and to provide for surface drainage of the site. Site grading is anticipated to include fills of about 3 feet or less in depth.

PURPOSE AND SCOPE

The purpose of our investigation was to identify geologic and geotechnical conditions at the site that have the potential to increase development costs, complexity and/or schedule. The focus of our investigation was the potential presence of compressible Bay Mud deposits and potentially liquefiable soils. The scope of services for this investigation was in accordance with our proposal of September 27, 2018 and included the following:

- Examination of historical topographic maps and aerial photographs of the site and vicinity;
- Review of readily available published geotechnical and geologic literature, and geologic maps pertinent to the area;
- Subsurface exploration;
- Engineering analysis; and
- Preparation of this report.

FIELD EXPLORATION

Field exploration for this investigation consisted of Cone Penetration Tests (CPTs). Permits for CPTs were obtained from Sonoma County Permit and Resource Management. Eight CPTs were conducted using a 25-ton CPT rig on November 19, 2018.

The CPTs were conducted by Middle Earth Geo Testing using a 15 cm^2 cone with a net area ratio of 0.8, in general accordance with ASTM Test Method D5778-12. The CPTs were advanced to depths of between 31 and 50 feet below the existing ground surface. Upon completion of the CPTs, they were backfilled with neat cement grout in accordance with the requirements of Sonoma County.

The CPT logs presenting the data graphically along with the interpreted Soil Behavior Types for each soil profile are presented in Appendix A. The approximate locations of the CPTs are shown on the attached Site Plan, Plate 2. These locations are approximate and were determined based on pacing and orientation from existing features on the site.

SUBSURFACE SOIL CONDITIONS

The geologic maps show the south portion of the site, generally southwest of Copeland Street, as underlain by Young Bay Mud deposits. Bay Mud sediments are estuarian deposits most frequently associated with soft, compressible, lean to fat clay deposits. Bay Mud deposits also may include silt, peat and fine sands. The northeastern portion of the site is mapped as underlain by Terrace Deposits, which are predominately sands, silts and gravels with some clay. A Geologic Deposits map, Plate 3, is attached.

The soil profiles encountered in CPTs 1-4, located on the south side of the site, between the Petaluma River and the McNear Canal, are predominately clays with some relatively thin interbeds of silty sand/sandy silt soils. The clay soils below the depths of about 6 to 10 feet were found to have low tip resistant, indicative of medium stiff to soft soils. The CPT data and interpreted soil behavior type of “clay” is consistent with compressible Bay Mud deposits. The soft clay layer varies from about 7 to 12 feet in thickness across the area. A thin layer of sand was logged at a depth of about 21 feet bgs in CPT-1, with a sand deposit also shown between 21 and 23 feet bgs in CPT-2.

The soil profile logged in CPT-8, located near the west side of the site, southwest of Copeland Street, is not consistent with those logged in CPT-1 through CPT-4. This CPT was located near the mapped boundary between the Terrace Deposits and Bay Mud geologic units. Medium stiff to stiff clay soils are indicated in the upper 11 feet CPT-8, with dense sands and medium dense silty sand/sandy silt logged between about 11 and 19 feet bgs. Stiff clay/silty clay were encountered below. CPTs 6 and 7 were located north of Copeland Street, in the area mapped as Terrace Deposits. The soil behavior types determined by interpretation of the CPT data are consistent with those found in CPT-8. Medium dense to loose silty sand/sandy silt deposits were detected along with dense sand deposits. The soils below about 20 feet are interpreted to be predominately clay and silty clay. The soil profile at the east end of the site on the north side of the canal is predominately interpreted as clay and silty clay with a few interbeds of silty sand/sandy silt. The clay soils appear to be medium stiff to stiff based on cone tip resistance.

GEOLOGIC HAZARDS

FAULTING AND SEISMICITY

The San Francisco Bay Area is considered by geologists and seismologists to be one of the most seismically active regions in the United States. The site is seismically dominated by the presence of the active San Andreas fault system. The San Andreas fault system is the general boundary between the northward moving Pacific Plate and the southward moving North American Plate. In the San Francisco Bay Area, relative plate movement is distributed across a complex system of generally strike-slip, right lateral parallel and subparallel faults, the most notable being the San Andreas, Hayward and Calaveras faults. Mapped active faults capable of causing strong to intense ground shaking at the site include the San Andreas fault, located about 14.7 miles southwest of the site, the Hayward fault northeast extension, mapped approximately 13.8 miles south-southeast of the site, and the Rodgers Creek fault, located approximately 5.1 miles to the northeast. The location of these and other faults in the region are shown on Plate 3.

The site will likely be subject to at least one moderate to severe earthquake and associated seismic shaking during the useful life of the planned development, as well as periodic slight to moderate earthquakes. The probability of one or more earthquakes of magnitude 6.7 (Richter scale) or higher occurring in the in the San Francisco Bay Area is evaluated by the Working Group on California Earthquake Probabilities (WGCEP) on a periodic basis, as are the probabilities of earthquakes of varying magnitudes on each of the major faults. WGCEP is responsible for developing Uniform California Earthquake Forecasts (UCERFs). The 2014 WGCEP published UCERF3 in 2015. The faults with the greater probability of a moment magnitude of 6.7 or higher earthquake between 2014 and 2044 are the Hayward fault at 14.3 percent, the Calaveras fault at 7.4 percent and the San Andreas fault at 6.4 percent, as shown on Plate 4. According to WGCEP, the overall probability of a moment magnitude 6.7 or greater earthquake occurring in the San Francisco Region during the next 30 years (starting from 2014) is 72 percent.

SURFACE FAULT GROUND-RUPTURE HAZARD

We reviewed the Regulatory Maps available on the California Department of Conservation web site. The Regulatory Maps include maps of Earthquake Fault Zones issued by the California Geological Survey (CGS). The site is not located within a designated State of California Alquist-Priolo Earthquake Fault Zone for active faults. According to CGS, the closest known active fault within a State-designated Earthquake Fault Zone is the Rodgers Creek fault, at a distance of approximately 5.18 miles northeast of the site. Based on this information, the potential for surface fault ground-rupture to occur at the site is judged to be very low.

GROUND SHAKING

Although ground rupture is not considered to be a concern at the subject site, the site will likely be subject to varying degrees of ground shaking associated with seismic activity. There is a moderate probability of a design level earthquake occurring in the region during the useful life of the planned development as well as periodic slight to moderate earthquakes. Some degree of structural damage due to stronger seismic shaking should be expected at the site, but the risk can be reduced through adherence to seismic design codes. Seismic design parameters are discussed below under Conclusions.

Although ground rupture is not considered to be a concern at the subject site, as with all sites in the San Francisco Bay Area, the site should be expected to experience at least one moderate to large earthquake during the lifespan of the development. The U.S. Geological Survey (USGS) Earthquake Hazards Program website includes an interactive U.S. Seismic Design Maps tool that can be used to obtain the seismic design values and response spectra. The Peak Ground

Acceleration (PGA) as well as spectral accelerations for short (0.2 second) and moderately long (1.0 second) periods are determined based on the site location, selected building code, and site soil classification. The site is located at approximately 38.2353 degrees north latitude and 122.6339 degrees west longitude.

With the presence of liquefiable soils, according to Section 20.3.1 of ASCE/SEI 7-10, where soils are vulnerable to potential failure or collapse under seismic loading, such as the liquefiable soils that underlie much of the site, the site should be classified as Site Class F. ASCE/SEI 7-10 Section 20.2 stipulates that "A site response analysis in accordance with Section 21.1 shall be provided for Site Class F soils, unless the exception to Section 20.3.1 is applicable." Although the site could be classified as Site Class F, requiring a site-specific response analysis, Section 20.3.1 includes the following: "EXCEPTION: For structures having fundamental periods of vibration equal to or less than 0.5s, site response analysis is not required to determine spectral accelerations for liquefiable soils. Rather, a site class is permitted to be determined in accordance with Section 20.3 and the corresponding values of Fa and Fv determined from Tables 11.4-1 and 11.4-2." It is our understanding that this exception would apply for the proposed project. This should be confirmed by the Structural Engineer. Based on this exception, the northeastern portion of the site is considered to be site soil classification Type D. With more than 10 feet of soft, compressible Bay Mud deposits indicated in at least a portion of the southwest side of the site, site soil classification Type E is considered to be applicable to at least a portion of the southwest side of the site. According to the U.S. Seismic Design Maps tool, the peak ground acceleration (PGA) based on a probability of exceedance of 10% in 50 years (return period of 475 years) is 0.60g for a stiff soil site (Site soil classification Type D) and 0.54g for a soft soil site (Site soil classification Type E). The estimated mean earthquake magnitude at the site, obtained from the USGS 2008 Interactive Deaggregation website, is 6.98.

SEISMIC HAZARD ZONES IN CALIFORNIA

Seismic Hazard Zone Maps are produced by the CGS. The maps identify areas where soil liquefaction and earthquake-induced landslides are most likely to occur. The hazard zones are based on areas where there have been historic occurrences of liquefaction and/or landslide movement, or where local topographic, local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements. The site is located outside of the area where maps have been completed. San Francisco Bay regional geology and liquefaction potential are presented in the U.S. Geologic Survey Open-File Report 06-1037 (Wentworth 2006). Liquefaction susceptibility of the region, which includes the site, is shown on Sheet 2 of 2 (map scale 1:200,000). The Sonoma County Hazard Mitigation Plan, Figure 8.1, Major Earthquake Fault Zones & Areas of Liquefaction, also address the liquefaction potential of the region. Both maps show the site as having a moderate liquefaction potential in the area mapped as Bay Mud, with a high liquefaction potential where Terrace Deposits are mapped. Our assessment of the liquefaction potential is discussed below.

The site is not proximal to hillsides. However, there are sloping ground conditions along the banks of the river and the canal. Slope stability is discussed below.

LIQUEFACTION AND LIQUEFACTION INDUCED GROUND DEFORMATIONS

Liquefaction

Liquefaction is a temporary transformation of saturated soil into a viscous liquid during strong to violent ground shaking from a major earthquake. This transformation occurs as a result of a substantial loss of strength due to excess pore pressure generated by strong ground shaking. Historically, the potential for liquefaction has been associated with cohesionless soils such as sands and silty sands. Current practice in liquefaction evaluation now includes sands, silty sands and gravels, as well as silts and even some clay soils. Primary factors affecting the potential for a soil to undergo liquefaction include: depth to groundwater, soil type, relative density of granular soils, moisture content and Plasticity Index of fine-grained soils, initial confining (overburden) pressure, and intensity and duration of ground shaking.

While fine-grained soil (clays and silts) may not undergo complete liquefaction, these soils may be susceptible to cyclic softening. Liquefaction and cyclic softening both result in reduced shear strength. In general, compressible soils, consisting of plastic silts or clays, do not generate excess pore water pressure to the same extent or as quickly as less compressible soils such as relatively clean sands. Thus, silty and clayey soils tend to be less susceptible to liquefaction-type behaviors than sandy soils. Where mapping of liquefaction potential includes areas of Bay Mud, a moderate liquefaction susceptibility is typically assigned to this unit due to high ground-water levels (often tidally influenced) and the possible presence of sand lenses within the mud and peat. Even though Bay Mud areas are included in areas susceptible to liquefaction, “The mud itself is unlikely to liquefy due to the abundance of clay” (Wentworth, et al, 2006).

The occurrence of liquefaction can cause loss of, or reduced, support for foundations, significant ground deformation due to settlement within sandy liquefiable layers as pore pressures dissipate, and/or flow failures in sloping ground or where open faces are present (lateral spreading) (NCEER 1998), and ground-surface disruption (fissures and sand boils). During a major earthquake, buildings, structures, railroads, roadways and utilities underlain by potentially liquefiable soil may experience differential settlement through reconsolidation of the liquefied soil. The details of our liquefaction analysis and our findings are discussed below.

Lateral Spreading

Lateral spreading is a potential hazard associated with liquefaction. This phenomenon occurs when a subsurface soil layer liquefies and the upper non-liquefiable crust slides down gradient as large blocks over the liquefied soil toward a free-face (such as a descending slope, an incised river channel or open body of water), creating extensional ground cracking or fissures. The lateral spread analysis completed as part of the CLiq program analysis of the CPT data indicates a lateral spread potential in each of the 8 CPT profiles analyzed. Where clay soils are not fully liquefiable but do undergo cyclic softening as a result of seismic shaking, flow failure at sloping ground is a possibility. The CPT analyses reports for liquefaction, including lateral spreading potential, are included in the attached Appendix A. Our evaluation of lateral spreading potential and recommendations for further investigation and evaluation are discussed below.

Ground-Surface Disruption Potential

Liquefaction-induced ground-surface disruption or sand boils occur when the sudden increase in pore water pressure in a layer of saturated, clean, loose sand or silty sand results in sufficient water pressure to break through the overlying soil mantle with venting to the ground surface. When this occurs, the liquefied sand blows out through the rupture, which is referred to as ejecta, resulting in ground-surface disruption. The occurrence of ground-surface disruption can result in diminished support for foundations and increased differential settlement of structures on shallow foundations. Where structures are founded on shallow foundations with integral concrete slabs-on-grade floors, or mat-slab concrete foundations, increased settlement typically occurs at the building perimeter where supporting soils are displaced from below the foundation.

Based on work by Ishihara (1985) and Youd and Garris (1995), a capping layer of non-liquefiable material over a liquefiable layer should have a ratio of capping layer thickness to liquefiable layer thickness of about 3:1 to prevent the occurrence of ground-surface disruption. We evaluated the site data based on the empirical relationships developed by Ishihara, and Youd and Garris. It is our opinion that the potential for ground-surface disruption to occur is generally low with the exception of the area of CPT-7 which is low to moderate.

Seismic-Induced Compaction Of Unsaturated Sands

Strong ground shaking associated with seismic activity can cause seismically-induced compaction or densification of unsaturated sands and loose fill. The potential impact of seismic-induced settlement of sands or fills above the groundwater is settlement of the ground surface and structures supported on shallow foundations on the site. The soil encountered above the groundwater table consists of stiff to very stiff cohesive clay and medium dense to dense sands and gravel fills. It is our opinion that the potential for seismic-induced settlement of the soils above the groundwater is low for this site.

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

General

It is our opinion that development of the site as proposed and discussed herein is feasible from a geotechnical engineering perspective. However, there are geotechnical and geologic conditions that will impact site development costs. These include the presence of compressible and liquefiable soils, uncontrolled fills blanketing the site and shallow groundwater. Mitigation measures will be required to address the compressible and liquefiable soils. Additional assessment of the compressible and potentially liquefiable soils, the magnitude of loads to be applied to the site due to fill placement and structural loads, the site development schedule and building performance criteria are all considerations in foundation selection and the possible need for ground improvement. The need for ground improvement, potentially consisting of a surcharge program over the portion of the site south of Copeland Street and between the river and the canal, as shown on the Site Plan, as well as ground improvement at the northern portion of the site, potential limited to the canal frontage, should be considered at this time.

LIQUEFACTION

The liquefaction potential of the site was investigated with cone penetration tests. The CPT data from this investigation was analyzed using the software CLiq (version 2.2.1.9). CLiq was developed by GeoLogismiki, specifically for use in analyzing CPT data in accordance with the recognized procedures based on the current state of practice for liquefaction analysis as discussed in the CGS Special Publication 117A. A groundwater level of 5 feet below the ground surface at the time of the earthquake was used in our analyses. An earthquake magnitude, M_W, of 7.0 which represents the mean (for all sources) earthquake magnitude with a 10 percent probability of exceedance in 50 years, as obtained using the Unified Hazard Tool deaggregation program, and a peak ground acceleration of 0.60 g were used in the analysis.

The analysis results for CPTs 1-4, in the south area of the site where Bay Mud deposits are present, show liquefaction-induced site settlement is generally less than 1-1/2 inches where the soil profile is clay, with an increase to a maximum of about 2-1/4 inches when the underlying clay & silty clay with interbedded silty sand & sandy silt layers are considered. Based on our experience with evaluating Bay Mud sites using the CPT, the indicated settlement is likely over-estimated. The soil profile at CPT-5, located in the area mapped as Terrace Deposits, is primarily clay & silty clay. The CPT data analysis indicates that the clay & silty clay layer between about 13-1/2 and 25-1/2 feet bgs is liquefiable, with a settlement potential of about 1 inch. As with the Bay Mud deposits, the liquefication potential and the liquefaction-related settlement of this clay layer are likely over-estimated and should be evaluated further. Drilling, soil sampling and laboratory testing of soil samples should be conducted to assess the Plasticity Index of the clay deposits to allow for a refined liquefaction analysis. Adjustments to the CPT data interpretation can then be made to obtain project site-specific settlement calculations. Cyclic softening of the clay soils is likely to occur. This could have an impact on the stability of the river and canal banks. This is discussed under Lateral Spreading, below.

The analysis results for CPTs 6-8, located at the west (East D street) side of the site, in the area mapped as Terrace Deposits, indicates a moderate potential for silty sand & sandy silt deposits present in the upper 10 to 18 feet of the site to liquefy as a result of the design basis earthquake, with silty sand & sandy silt deposits below 10 to 18 feet having a low liquefaction potential.

Analysis of CPT-6 data also shows a liquefiable zone between 37 and 45 feet bgs where a soft clay layer was encountered. The estimated ground settlement for the soil profiles logged in CPTs 6-8, exclusive of the clay layer below the depth of about 36 feet in CPT-6, ranges from about 1 to 2-3/4 inches.

The magnitude of liquefaction-related settlement is less than three inches, based on evaluation of the CPT data and without correction for clay soils. With total estimated settlement less than 4 inches, consideration of the recommendations regarding structures on shallow foundations where liquefiable soils are present as discussed in CGS Special Publication 117A, and our past experience with similar projects on site identified as potentially liquefiable, use of a shallow foundation consisting of structural concrete slabs-on-grade may be feasible without the need for ground improvement. However, the potential settlement associated with consolidation of underlying Bay Mud deposits in at least the southwest side of the site, and the potential for lateral spreading or flow failure of the banks of the river and/or canal must also be considered.

LATERAL SPREADING

Lateral spreading or flow failure potential is indicated for the soil profiles at CPTs 1-5. Each of these soil profiles is predominately clay or clay & silty clay. As with the liquefaction potential, the lateral spread potential is likely over-estimated by the software. However, some strength reduction of the clays as a result of cyclic softening could potentially occur. Although lateral spreading may not occur, flow failure of the clay slopes at the river and canal banks could potentially occur. Soil samples should be collected and tested, and the test data used in slope stability analysis. Bathymetric maps should be obtained or bathymetric surveys performed to obtain information regarding the profiles of the submerged slopes for use in slope stability analyses. Lateral spreading potential is also indicated at CPTs 6-8 where silty sand & sandy silt layers were interpreted. As with the clay soils layers, further assessment including soil sampling and testing is suggested for the silty sand & sandy silt.

Where lateral spreading or flow failure potential are confirmed through additional investigation and analyses, mitigation measures consisting of ground improvement would need to be considered.

COMPRESSIBLE SOIL

The application of new loads in excess of prior loading history on sites underlain by Bay Mud deposits can result in consolidation of the Bay Mud. This in turn will result in surface settlement and settlement of structures on shallow foundations. Where a future building straddles area of the site with varied past loading history or moderate to significant variations on the thickness of the compressible layer, differential settlement will result. Variations in past and future loading, as well as in the thicknesses of the Bay Mud can result in differential settlement that may impact surface improvement such roadways and concrete flatwork, and underground utilities.

The actual magnitude of total and differential settlements that will occur at the site and time rate of consolidation settlement of the Young Bay Mud are dependent on a number of variables including: 1) the thickness and variation in the thickness of the Bay Mud, 2) the presence of sand layers within the Young Bay Mud deposit, 3) compressibility and permeability of the Bay Mud, 4) prior loading history on the underlying Bay Mud, and 5) the magnitude of new loads.

We conducted a preliminary evaluation of the potential settlement due to static loading of 800 pounds per square foot (assumes 3 feet of fill plus 400 psf for foundation loads) based on our prior experience on Bay Mud sites. The compressible soils range in thickness from about 6 to 12 feet. Based on our analysis, we estimate that settlement due to primary consolidation may be on the order of 8 to 14 inches over the next 20 years. The rate of consolidation is a function of the soil permeability as well as the length of the drainage path. The length of the drainage path is the thickness of the Bay Mud where drainage only occurs at one boundary of the soil and is one-half the thickness where drainage can occur at both the top and bottom of the layer. Assuming single drainage, 90 percent of the estimated consolidation is estimated to occur in about 2-1/2 years after the load is applied for a 6-foot layer of Bay Mud, and about 10 years after load application for a 12-foot thick layer. Where double drainage is present, 90 percent consolidation is estimated in about 3-years and 1-year after load application for the 12- and 6-foot layers of Bay Mud, respectively.

The actual settlement potential should be evaluated as part of the design level geotechnical investigation based on laboratory test data from soil samples collected form the site, the design grading and the building loads provided by the project designers. Preconsolidating the site through the placement of a surcharge may need to be considered for improved overall site performance. In areas that are not preconsolidated through a surcharge program, surface gradients along roadways should be designed steeper than is customary where possible to allow for some loss of gradient should differential settlement of the site occur.

<u>Preconsolidation with Wick Drains and Surcharge</u>

The intent of a surcharge program is to reduce the future settlement potential where compressible soils are present. The amount of required surcharge is a direct function of the planned future load. The weight of the surcharge would need to include both the future loading of the planned structures and any required fill to achieve design site grades, plus an added driving force. A surcharge on the order of 8 feet above pad grade should be considered for preliminary budgeting purposes. The inclusion of wick drains installed in the Bay Mud will significantly reduce the required time for the surcharge program. With wicks spaced at 4 feet on-centers in an equilateral triangular pattern, a surcharge period of 12 months is expected. Post-surcharge settlement due to secondary consolidation of clay soils that have been surcharged is estimated to be on the order of 1 to 2 inches in the next 20 years.

If a surcharge program that incorporates wick drains to expedite the consolidation process is to be considered, the disposal of wick discharge water will need to be considered in the design and implementation of the surcharge. A NPDES permit will be required if the intent is to discharge the collected water into the municipal storm drain system or directly into the canal.

Performance of a surcharge program would mitigate the effects of consolidation of the underlying Bay Mud soils but would not mitigate the potential impacts of liquefiable soils. Additional or alternate ground improvement measures would be needed to mitigate liquefaction and its associated impacts, as discussed below.

GROUND IMPROVEMENT

Where the settlement potential due to consolidation of the underlying Bay Mud combined with confirmed potential for lateral spreading or flow failure to occur at the site, ground improvement techniques for improved soil strength or densification on the site could potentially consist of grouting, cement deep soil mixing (CDSM), and vibro-replacement stone columns. Mobilization and installation costs, the lateral extent of ground improvement required beyond the building envelope, the possible presence of contaminated soil and/or groundwater at the site and the amount of spoils generated, are all considerations in selection of a ground improvement option. Selection of the method of ground improvement should be made in consultation with a specialty contractor that has the capabilities to provide a broad array of methods. With consideration of both compressible soils as well as liquefiable soils, Cement Deep Soil Mixing (CDSM) may be the optimal solution. CDSM is a soil improvement method that consists of mixing cement with in-situ soils, typically using mixing shafts containing auger cutting heads, discontinuous flights, and mixing paddles to construct soil-cement columns. The columns can be overlapped to form walls or cells, or can be installed in isolated locations to reinforce a mass of soil. Ground improvement is commonly conducted as a design-build operation.

UNCONTROLLED FILL

The site has had previous development activities and is blanketed by uncontrolled fills on the order of 3 to 5 feet thick. The quality of the uncontrolled fill should be evaluated during the Design Level Geotechnical Investigation to determine if the existing fill or any portion of the needs to be removed and then replaced as engineered fill. For preliminary planning purposes we suggest that a budget line item be included for removal and replacement of three feet of soil across the site.

FOUNDATION CONSIDERATIONS

Shallow Foundations

For a shallow foundation system to be feasible, settlement due to consolidation combined with any seismic induced settlement would need to be considered in foundation design and must be within an acceptable range for the selected performance level. This may include designing the foundation based on life-safety and recognizing that large-scale settlement could occur with a design level earthquake. Unless ground improvement is performed to reduce consolidation settlement, and liquefaction potential where lateral spreading potential is confirmed, the concrete slab-on-grade would need to be designed as a relatively rigid structure to distribute the building loads over the building footprint, reducing the potential for differential settlement at load bearing walls and columns. Slab thickness could potentially be on the order of 15 inches with the addition of deepened stiffening beams.

Deep Foundations

Where seismic-induced settlement associated with liquefaction is not acceptable and ground improvement is found to not be a feasible solution, a deep foundation will need to be considered. This could potential consist of: 1) Auger Cast piles, 2) Cast in Drilled Hole (CIDH) Shafts (also known as CIDH Piles or more commonly as drilled piers), 3) Cast in Steel Shell (CISS) concrete piles, or 4) 14-inch-square, prestressed, precast driven concrete piles. Each of these options will gain support through skin friction in the underlying very stiff clays and dense sands.

Auger cast piles are similar to CDSM. The cement-treated soil strength is typically higher than that of a CDSM column and the pile is constructed with steel reinforcement. As with conventional drilled, cast-in-place piles, there is a potential for caving, squeezing of Young Bay Mud, and groundwater conditions at the site to impact the construction of the pile. The contractor would need to evaluate if casing will be required to control caving through the artificial fill and Young Bay Mud layers.

Construction of various types of CIDH and CISS piles produce drill spoils that would need to be controlled and ultimately off-hauled. Drilling at the site could potentially produce spoils that contain contaminates that require special handling and disposal. Caving of granular soils and squeezing of the Bay Mud deposits are also concerns with respect to constructability of CIDH piles.

CIDH and CISS piles constructed as a displacement-type pile would minimize the generation of spoils. The use of CIDH full section soil displacement piles (i.e. Fundex piles) or displacement CISS concrete piles (i.e. Tubex or EDTTEX), or driven precast concrete piles should be considered if a deep foundation is desired. Proprietary pile systems (i.e. Fundex, Tubex, EDTTEX) are designed and installed by specialty contractors. Driven concrete piles are also displacement piles. As such they do not generate spoils that would need to be off-hauled. The scope of this due diligence investigation is not adequate for development of deep foundation design recommendations.

There are disadvantages to the use of deep foundations on an unimproved site compared to a site that has undergone ground improvement and has been designed with the intent of using shallow foundations for support of the structures. Where structures are pile supported, additional details will need to be developed and implemented in the design and construction of entry stairs and walks, for utilities to be located below the ground floor slab (typically only the sanitary sewer) and where utilities enter the structure. This is due to the potential for the site to settle away from the structure where new loads are added to the site from the placement of fill.

UNDERGROUND UTILITY CONSIDERATIONS

Where buildings are pile supported, site settlement can still occur in the areas of compressible soil outside of the building pads. Settlement that results from loads imposed by the new fills required to achieve design grades will need to be considered in design of underground utilities and the connections of those utilities to the buildings. Utilities located below the ground floor slabs of pile supported buildings should be tied to the slab and flexible connections are recommended for underground utilities that enter pile supported buildings. Utilities on the project should be designed with either flexible materials or with flexible joints that allow the utility line to move without breaking. In areas that are not preconsolidated through a surcharge program, gravity utilities should be designed as steep as practical to accommodate loss of slope due to differential settlement.

Where utilities are installed within the soft clay layer, the weight of the utility backfill will be heavier than the soft clayey deposits removed, resulting in undesirable potential settlement of the utility pipeline. The use of special “lightweight fill” may need to be considered to reduce additional loading on the compressible deposits.

Where the site is preconsolidated through a wick drain and surcharge program, and where the liquefaction potential has been mitigated, no special provisions related to ground movement would be required for installation of underground utilities.

ADDITIONAL GEOTECHNICAL ENGINEERING SERVICES

A design level geotechnical investigation of the site is needed. Additional site exploration and analyses of the site conditions should be conducted specific to the site plan and with consideration of the planned grading activities at the site. The design level investigation should include further evaluation of liquefaction potential and slope stability, as well as additional assessment of the consolidation characteristics and settlement potential for the underlying Bay Mud deposits. Project-specific recommendations can then be developed based on the additional data and analyses as well as with consideration of the developer’s desires regarding site ground improvement and foundation types to be used.

LIMITATIONS

The conclusions and preliminary recommendations presented in this report are based upon the information provided to us regarding the proposed project, review of unpublished geologic reports and maps, subsurface data obtained from eight cone penetration tests, our experience with similar projects and sites, and professional judgment. This assessment has been conducted in accordance with currently accepted standards of geotechnical engineering practice in the geographic area of the site; no other warranty, expressed or implied, is offered or made. In the event that changes in the nature, design or location of the proposed project are planned or if subsurface conditions differ from those described in the reports made available to us, then the conclusions and preliminary recommendations in this report shall be considered invalid, unless the changes are reviewed and the conclusions and recommendations modified or approved in writing by BSA. In light of this, there is a practical limit to the usefulness of this report without critical review. Although the time limit for this review is strictly arbitrary, it is suggested that two years from the date of this report be considered a reasonable time for the usefulness of this report.

Site conditions described in this report are those existing at the time of our field exploration and are not necessarily representative of such conditions at other locations or times. The CPT plots and soil behavior types interpreted from the CPT data show subsurface conditions at the locations and on the dates indicated. It is not warranted that they are representative of such conditions elsewhere or at other times. The locations of the field explorations were estimated by pacing from existing surface features at the site; they should be considered approximate only.

Respectfully submitted,

BERLOGAR STEVENS & ASSOCIATES

DRAFT

Gregory J. Ruf
Principal Engineer
GE 2940

DRAFT

Frank Berlogar
Principal Engineer
RCE 20383

GJR/FB:

Attachments: References
Plate 1 – Vicinity Map
Plate 2 – Site Plan
Plate 3 – Geologic Deposits
Plate 4 – Fault Map
Plate 5 – Liquefaction Map
Appendix A – CPT Data and Liquefaction Analysis Report

Copies: Addressee

U:\@@@Public\1-Pleasanton\3995 East D St Petaluma\100 DD GI\3995 Due Diligence Geotechnical Assessment - DRAFT - 30964.doc

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PLATES

JOB NUMBER: 3995.100 DATE: 12-3-18 BY: CC

N

0 2000'

1"=2000'

VICINITY MAP

EAST D STREET

EAST D STREET AT COPELAND STREET

PETALUMA, CALIFORNIA

FOR

WARMINGTON RESIDENTIAL NORTHERN CALIFORNIA DIVISION

BASE: PORTION OF U.S.G.S. 7.5 MINUTE TOPOGRAPHIC QUADRANGLE, PETALUMA

DRAWN BY: CC

DATE: 12-4-18

JOB NUMBER: 3995.100

N

0 100

1"=100'

EXPLANATION

PROJECT BOUNDARY

CPT-8 CPT LOCATION

POTENTIAL SURCHARGE AREA

SITE PLAN

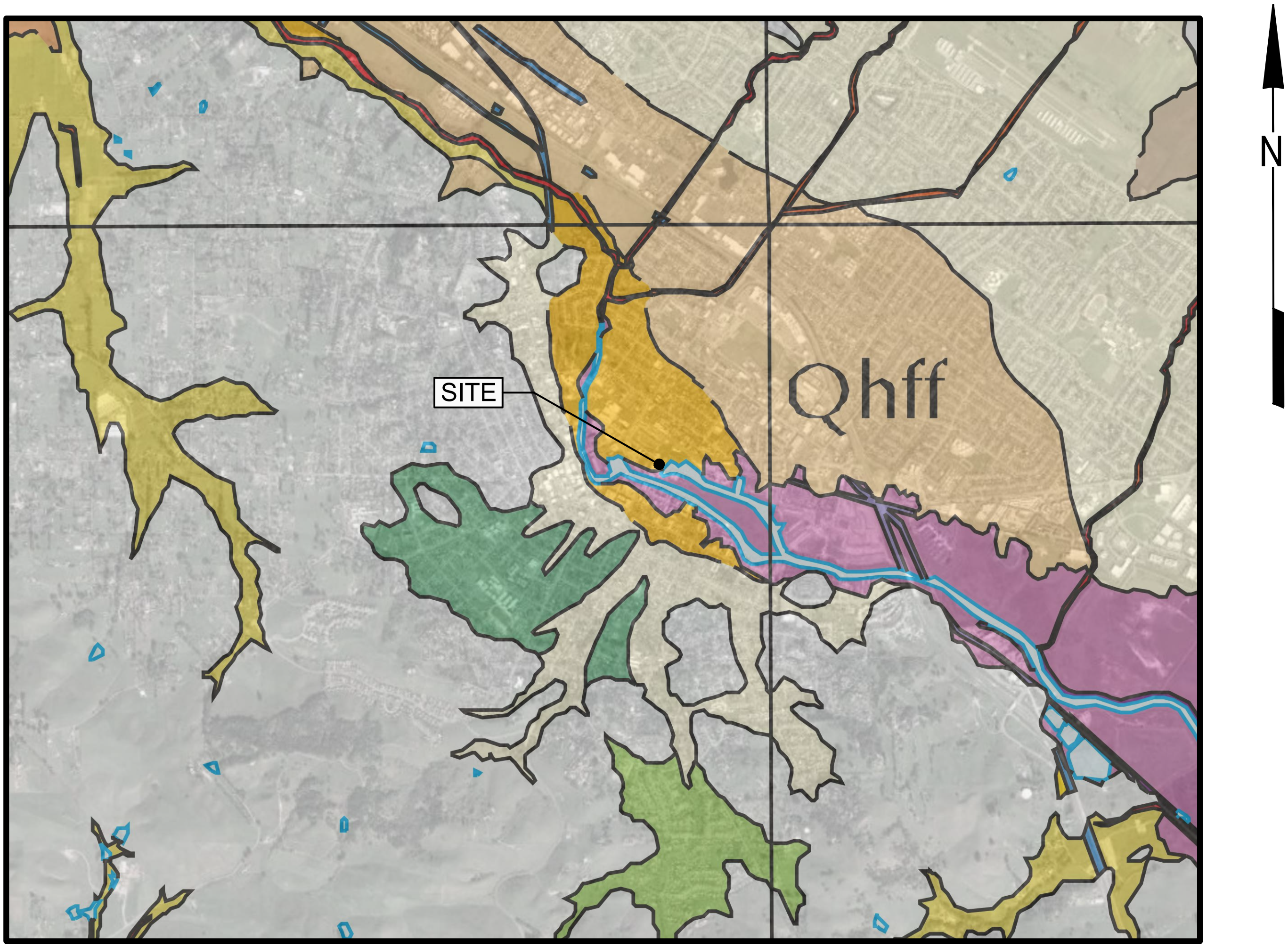
EAST D STREET

EAST D STREET AT COPELAND STREET
PETALUMA, CALIFORNIA
FOR
WARMINGTON RESIDENTIAL
NORTHERN CALIFORNIA DIVISION

Berlogar Stevens & Associates

SOIL ENGINEERS * ENGINEERING GEOLOGISTS

PLATE 2



JOB NUMBER: 3995.100 DATE: 12-3-18 BY: CC

0 4000'

1"=4000'

Qhbm	SAN FRANCISCO BAY MUD
Qhty	SREAM TERRACE DEPOSITS

GEOLOGIC DEPOSITS

EAST D STREET

EAST D STREET AT COPELAND STREET

PETALUMA, CALIFORNIA

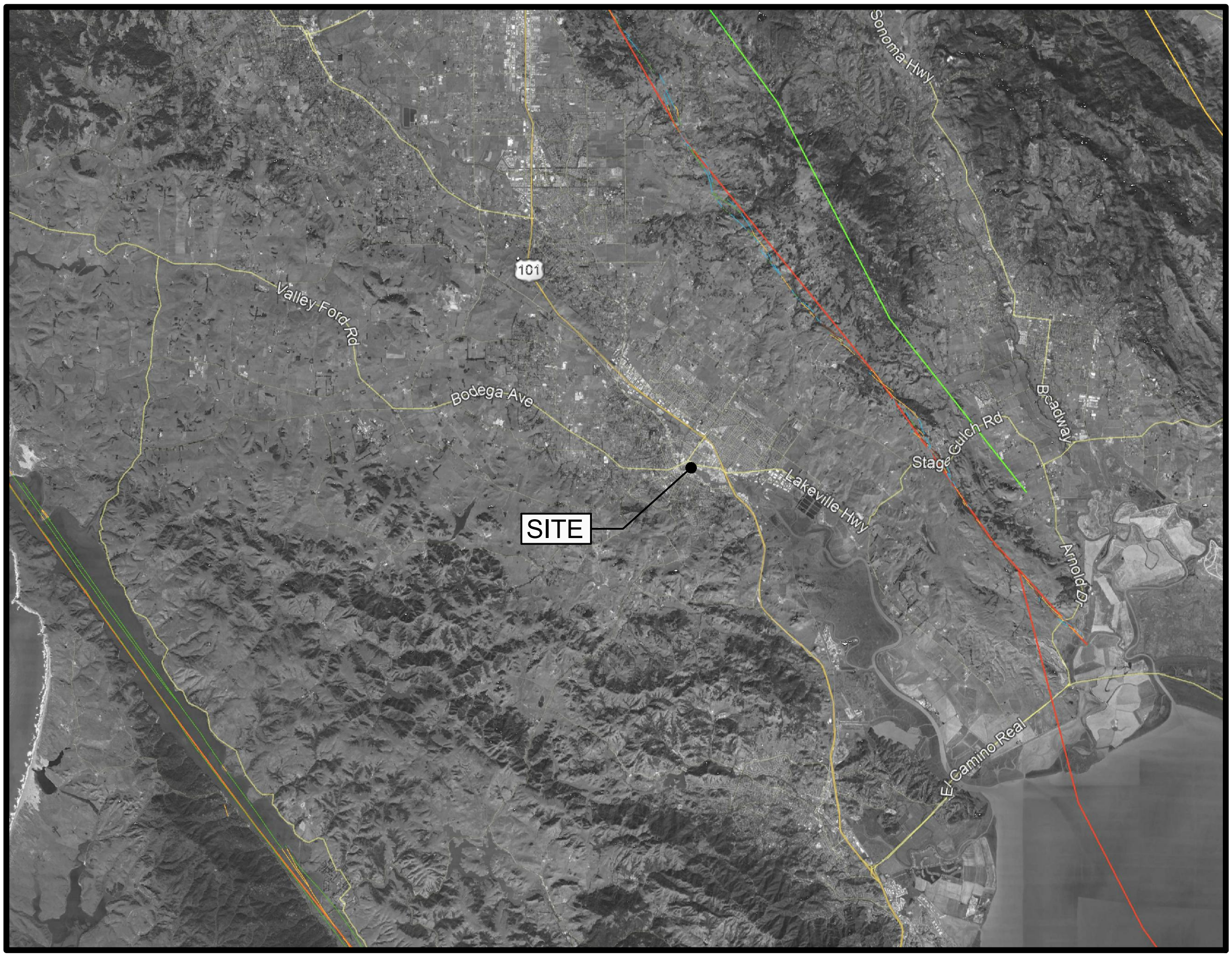
FOR

WARMINGTON RESIDENTIAL NORTHERN CALIFORNIA DIVISION

BASE: MAPS OF QUATERNARY DEPOSITS AND LIQUEFACTION SUSCEPTIBILITY IN THE CENTRAL SAN FRANCISCO BAY REGION, CA, QUATERNARY DEPOSITS BY: ROBERT C. WITTER, KEITH L. KNUDSEN, JANET M. SOWERS, CARL M. WENTWORTH, RICHARD D. KOEHLER, AND CAROLYN E. RANDOLPH, 2006, OFR 06-1037 SHEET 1 OF 2

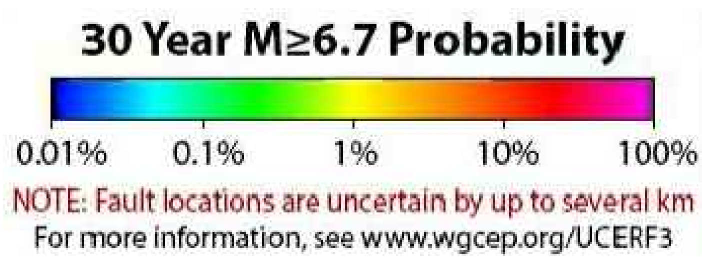
PLATE 3

JOB NUMBER: 3995.100 DATE: 12-3-18 BY: CC



0 5 miles

1"= 5 miles



FAULT MAP

EAST D STREET

EAST D STREET AT COPELAND STREET

PETALUMA, CALIFORNIA

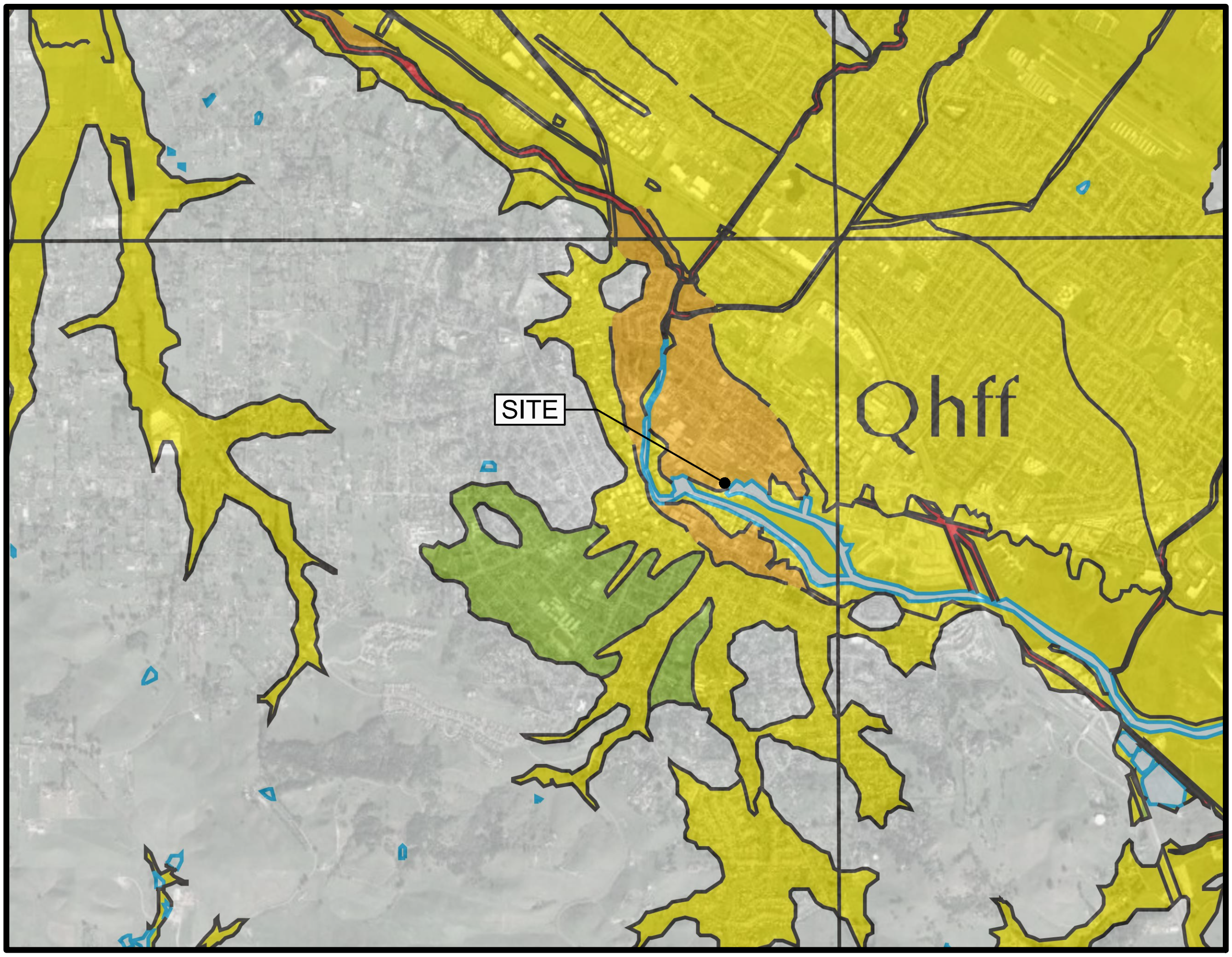
FOR

WARMINGTON RESIDENTIAL NORTHERN CALIFORNIA DIVISION

BASE: UCERF3: A NEW EARTHQUAKE FORECAST FOR CALIFORNIA'S COMPLEX FAULT SYSTEM, BY EDWARD H. FIELD AND MEMBERS OF THE 2014 WGCEP

PLATE 4

JOB NUMBER: 3995.100 DATE: 12-3-18 BY: CC



LIQUEFACTION SUSCEPTIBILITY

- VERY HIGH
- HIGH
- MODERATE
- LOW
- VERY LOW

LIQUEFACTION MAP

EAST D STREET

EAST D STREET AT COPELAND STREET

PETALUMA, CALIFORNIA

FOR

WARMINGTON RESIDENTIAL NORTHERN CALIFORNIA DIVISION

BASE: MAPS OF QUATERNARY DEPOSITS AND LIQUEFACTION SUSCEPTIBILITY IN THE CENTRAL SAN FRANCISCO BAY REGION, CA, LIQUEFACTION SUSCEPTIBILITY BY: ROBERT C. WITTER, KEITH L. KNUDSEN, JANET M. SOWERS, CARL M. WENTWORTH, RICHARD D. KOEHLER, AND CAROLYN E. RANDOLPH, 2006, OFR 06-1037 SHEET 2 OF 2

PLATE 5

APPENDIX A

CPT Data and Liquefaction Analysis Report

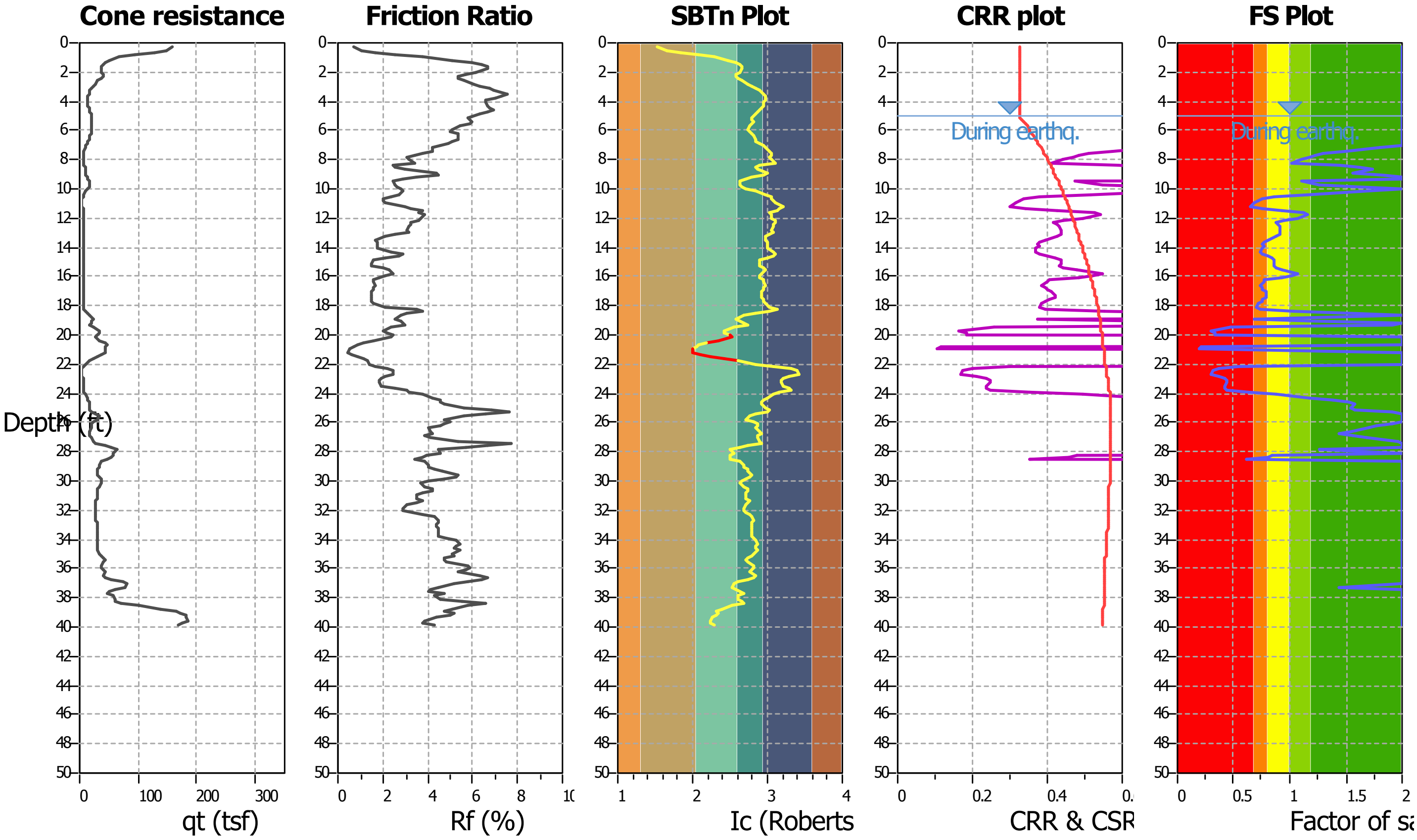
LIQUEFACTION ANALYSIS REPORT

Project title : East D Street **Location : Petaluma, CA**

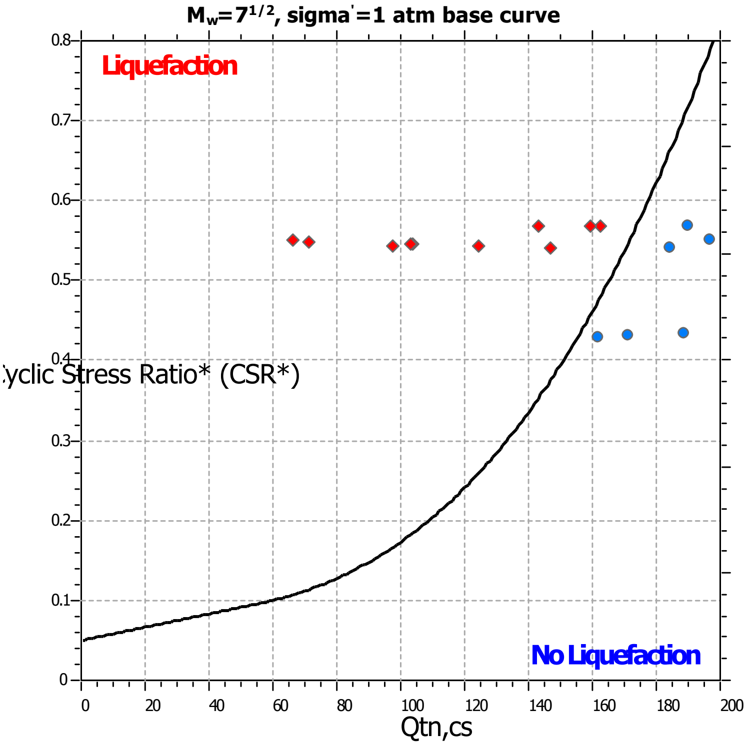
CPT file : CPT-01

Input parameters and analysis data

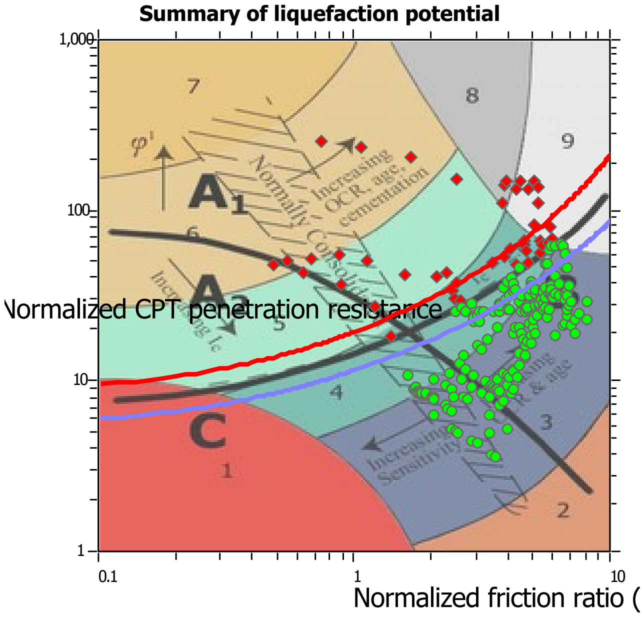
Parameter	Value
Analysis method:	Robertson (2009)
Fines correction method:	Robertson (2009)
Points to test:	Based on Ic value
Earthquake magnitude M_w:	7.00
Peak ground acceleration:	0.60
G.W.T. (in-situ):	8.00 ft
G.W.T. (earthq.):	5.00 ft
Average results interval:	3
Ic cut-off value:	2.60
Unit weight calculation:	Based on SBT
Use fill:	No
Fill height:	N/A
Fill weight:	N/A
Trans. detect. applied:	Yes
K_σ applied:	Yes
Clay like behavior applied:	All soils
Limit depth applied:	Yes
Limit depth:	50.00 ft
MSF method:	Method based



M_w=7$^{1/2}$, sigma'=1 atm base curve

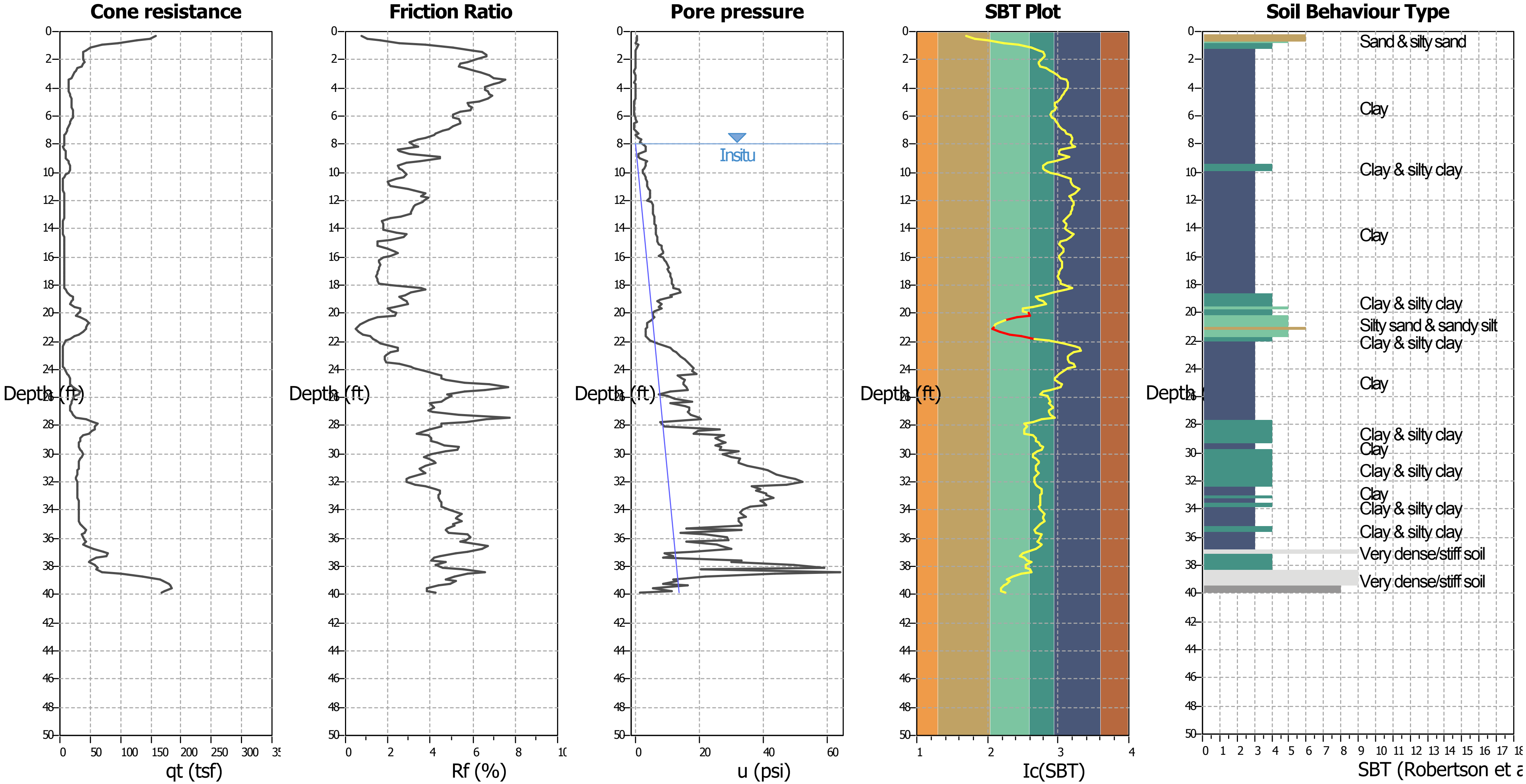


Summary of liquefaction potential



Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



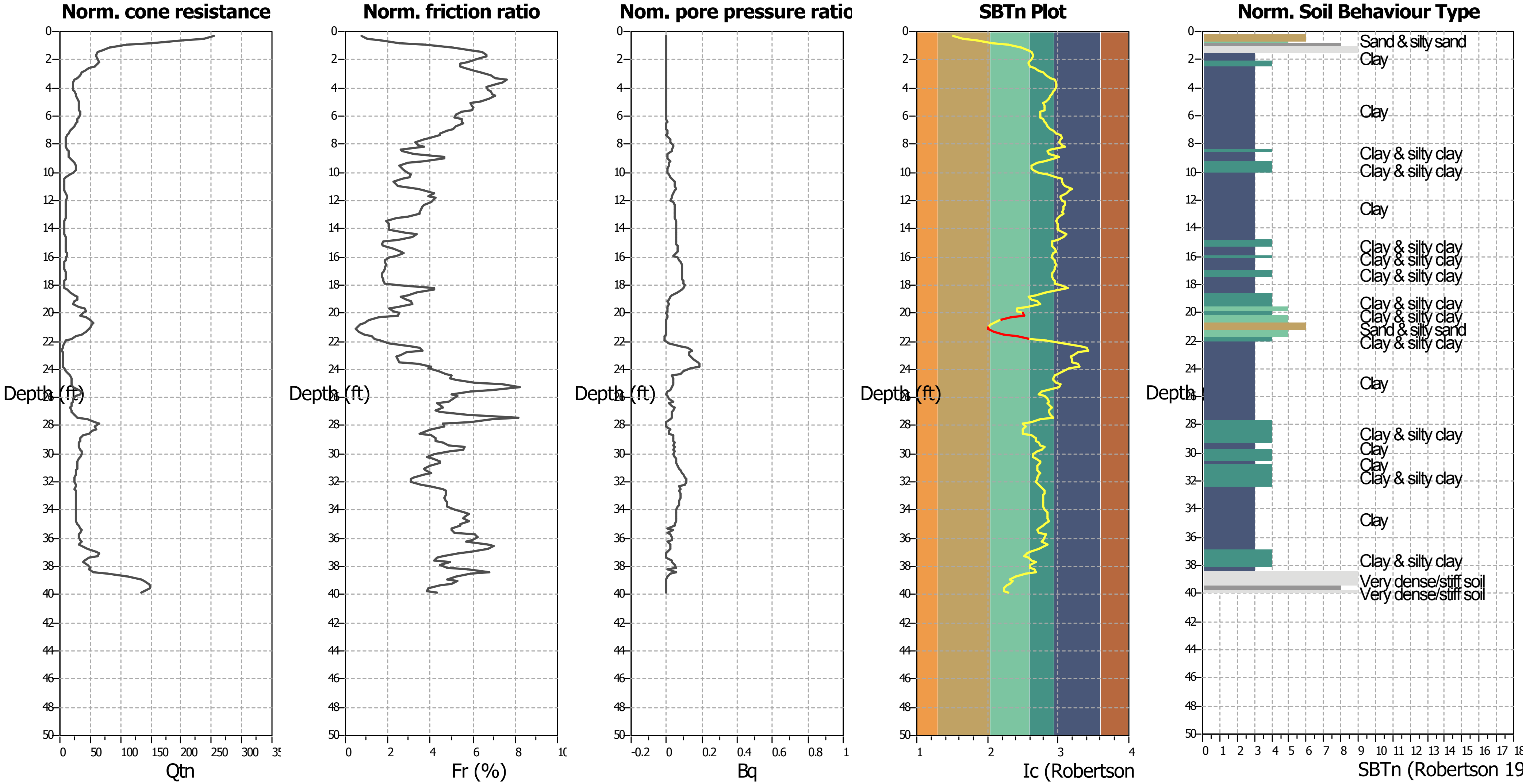
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A		
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes		
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes		
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils		
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes		
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft		

SBT legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

CPT basic interpretation plots (normalized)



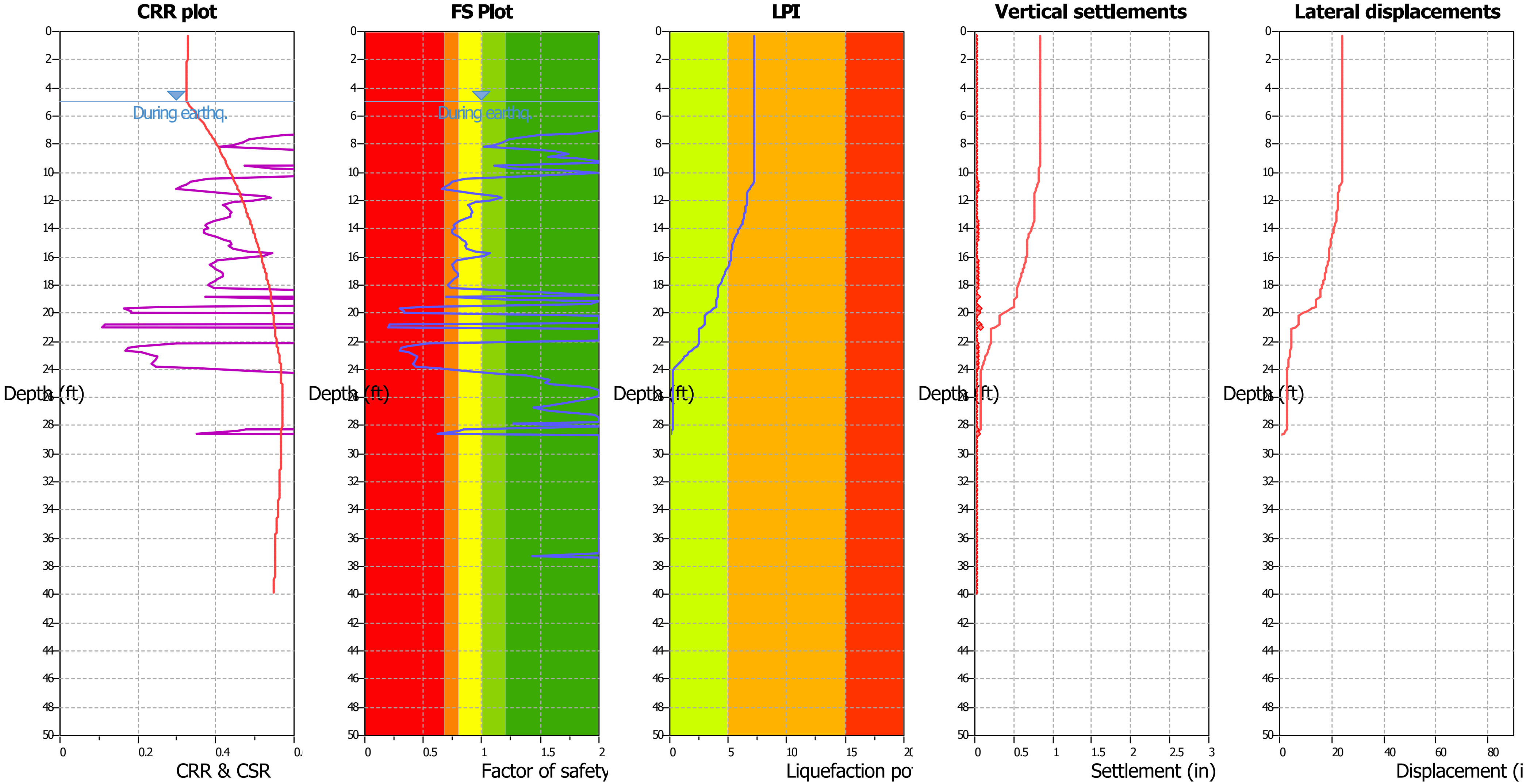
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

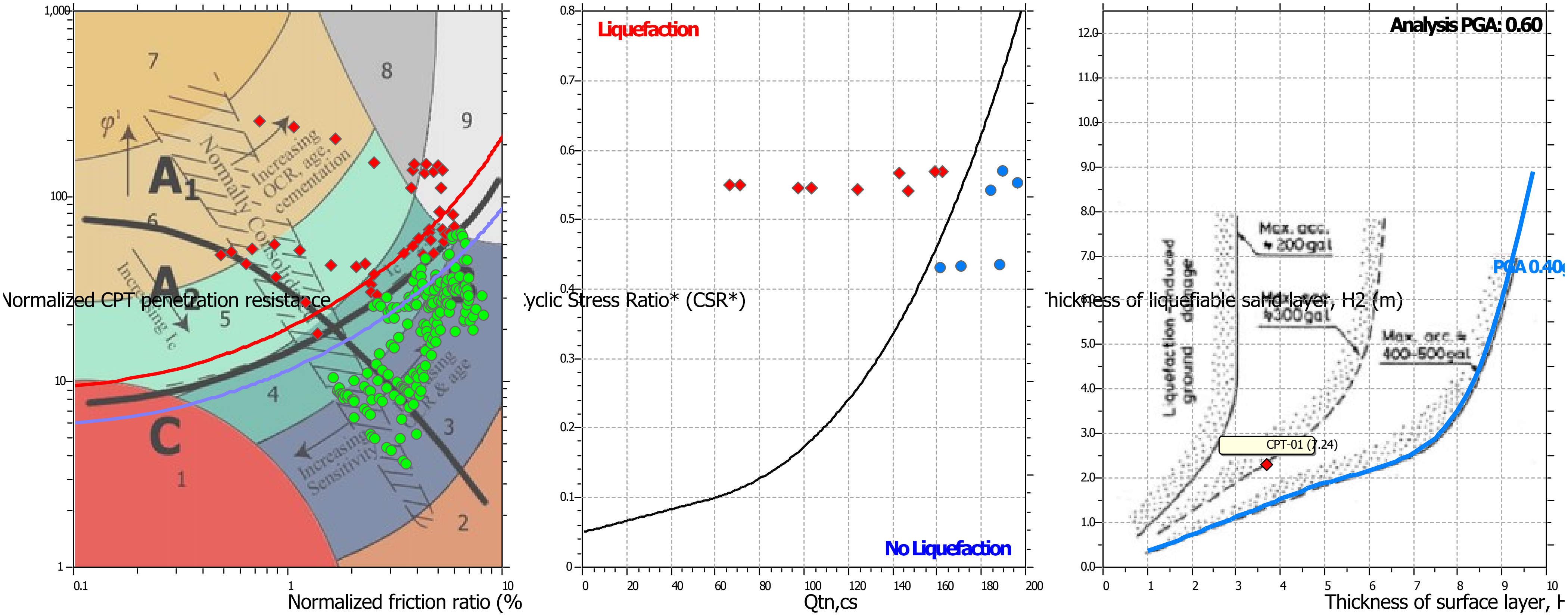
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

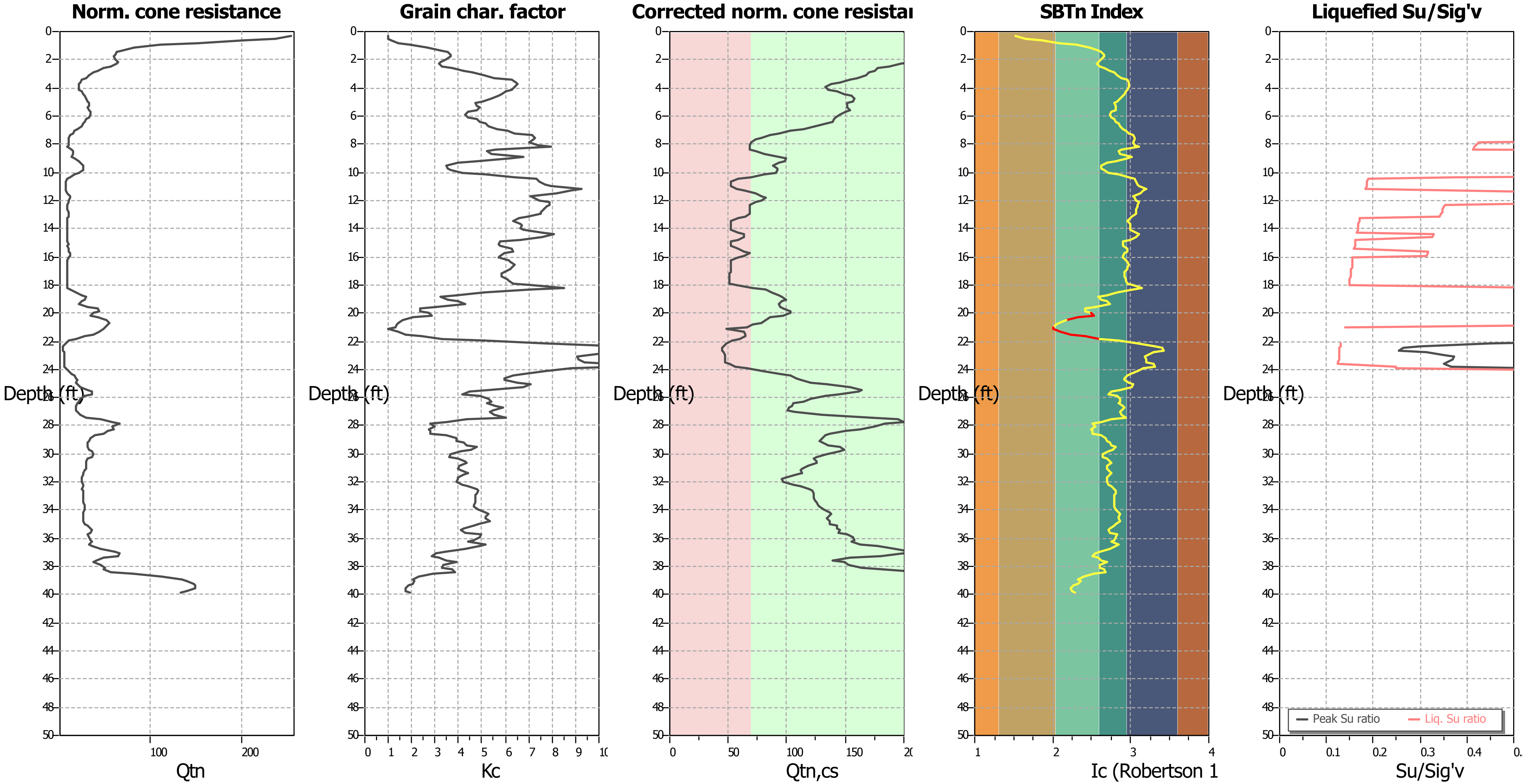
Liquefaction analysis summary plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

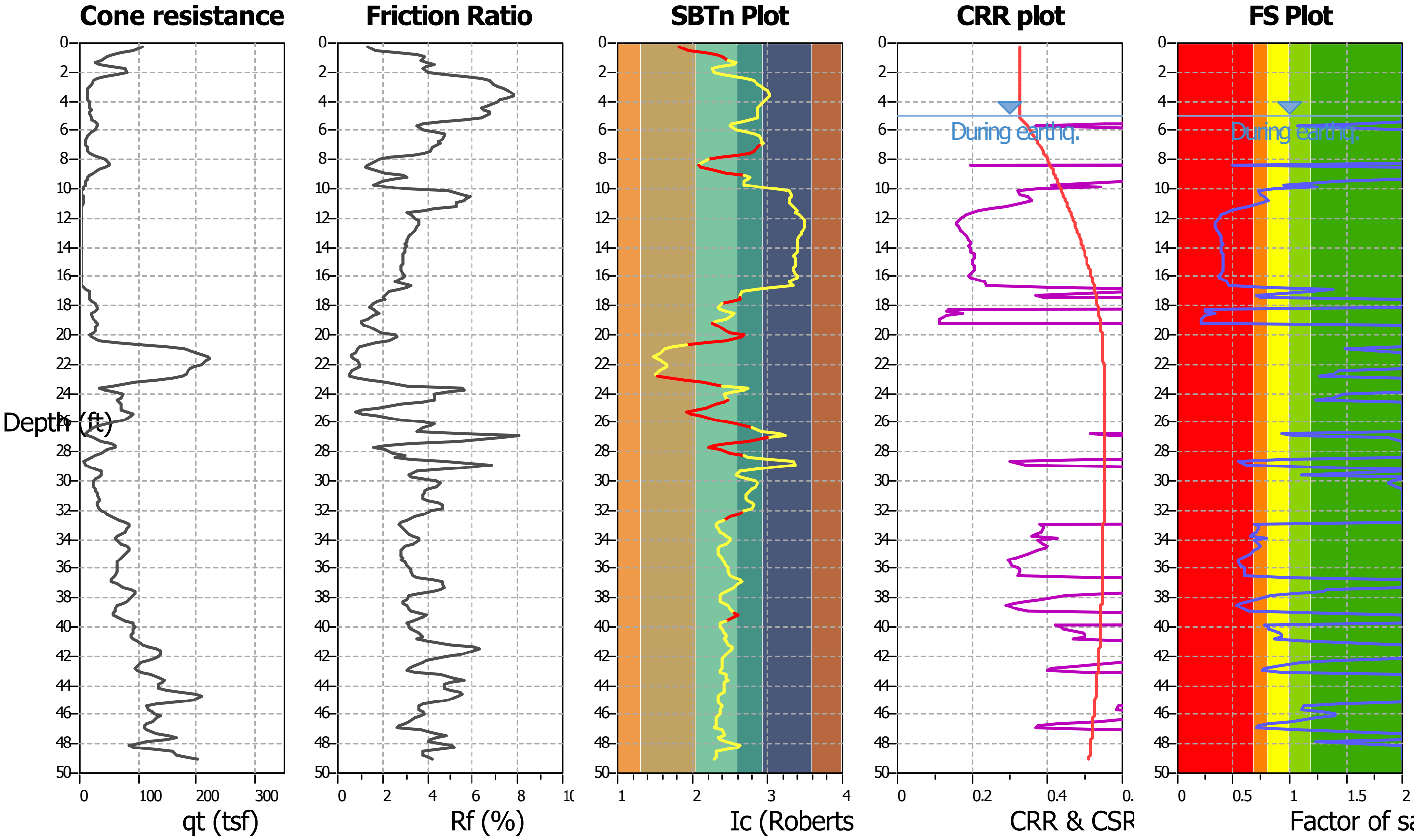
LIQUEFACTION ANALYSIS REPORT

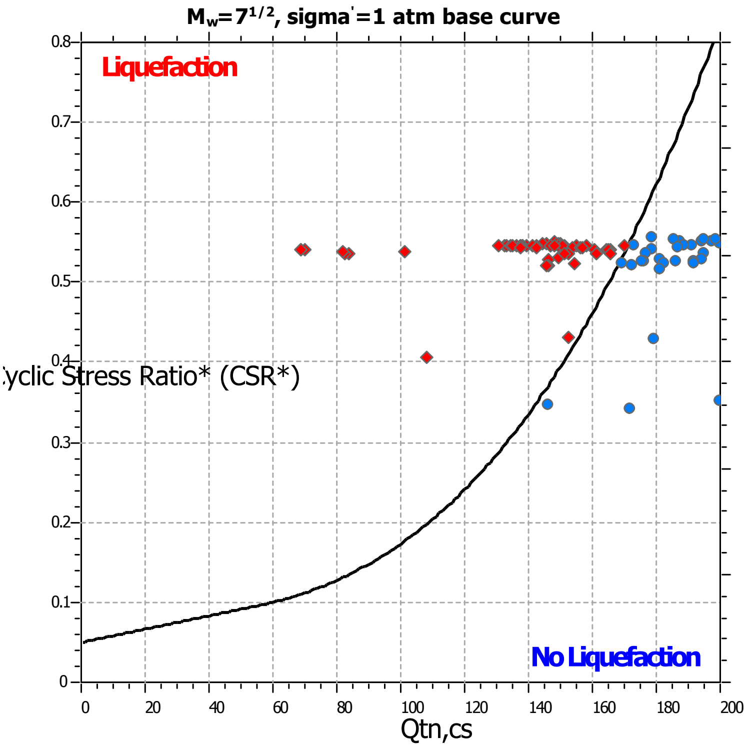
Project title : East D Street **Location : Petaluma, CA**

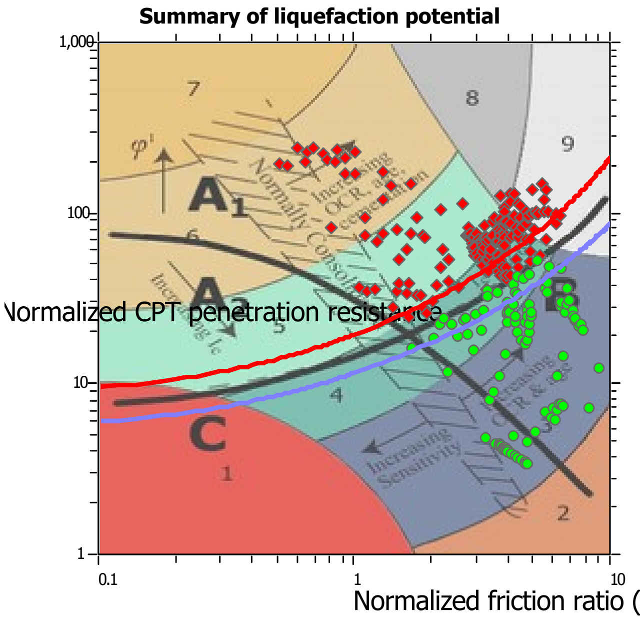
CPT file : CPT-02

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

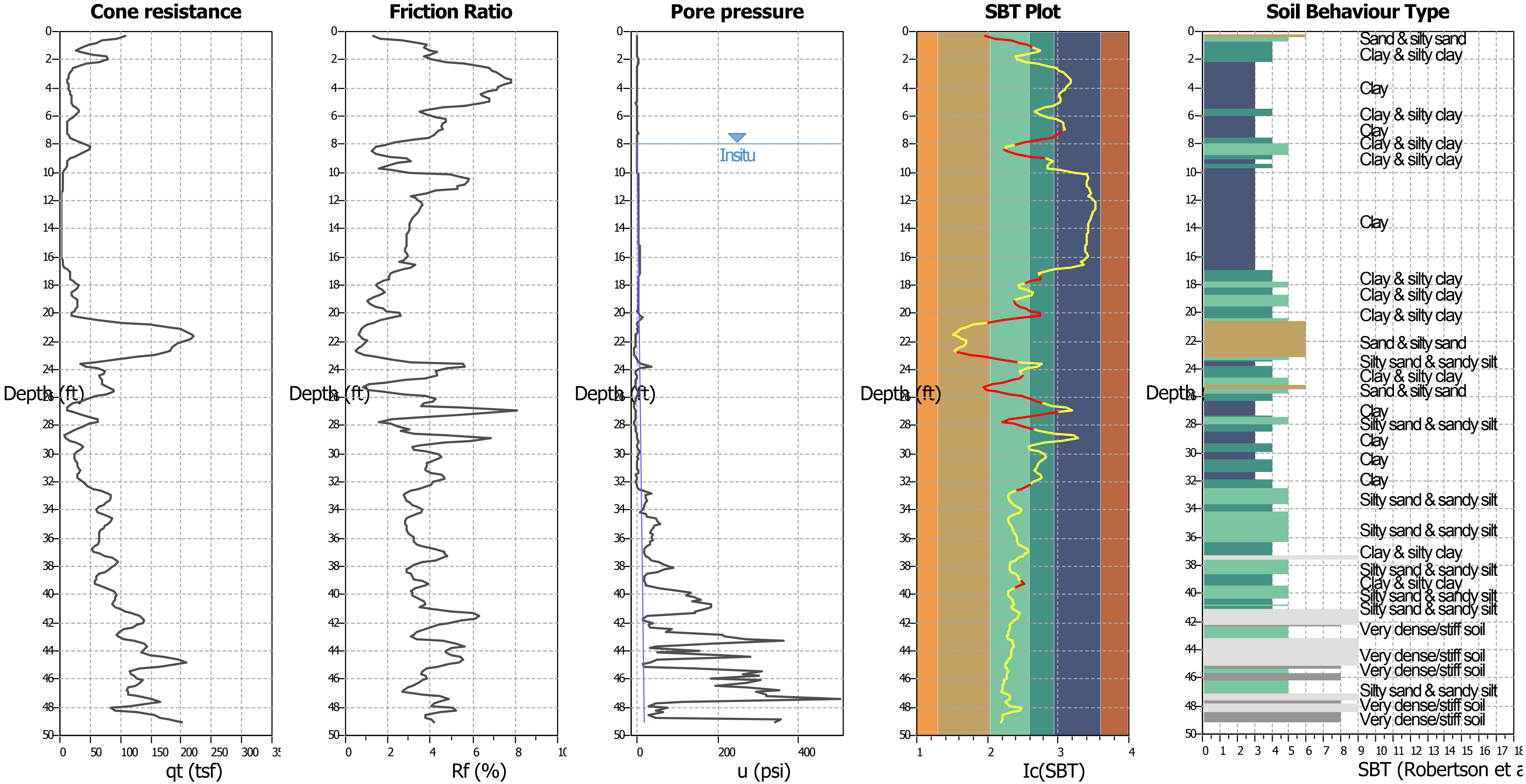






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



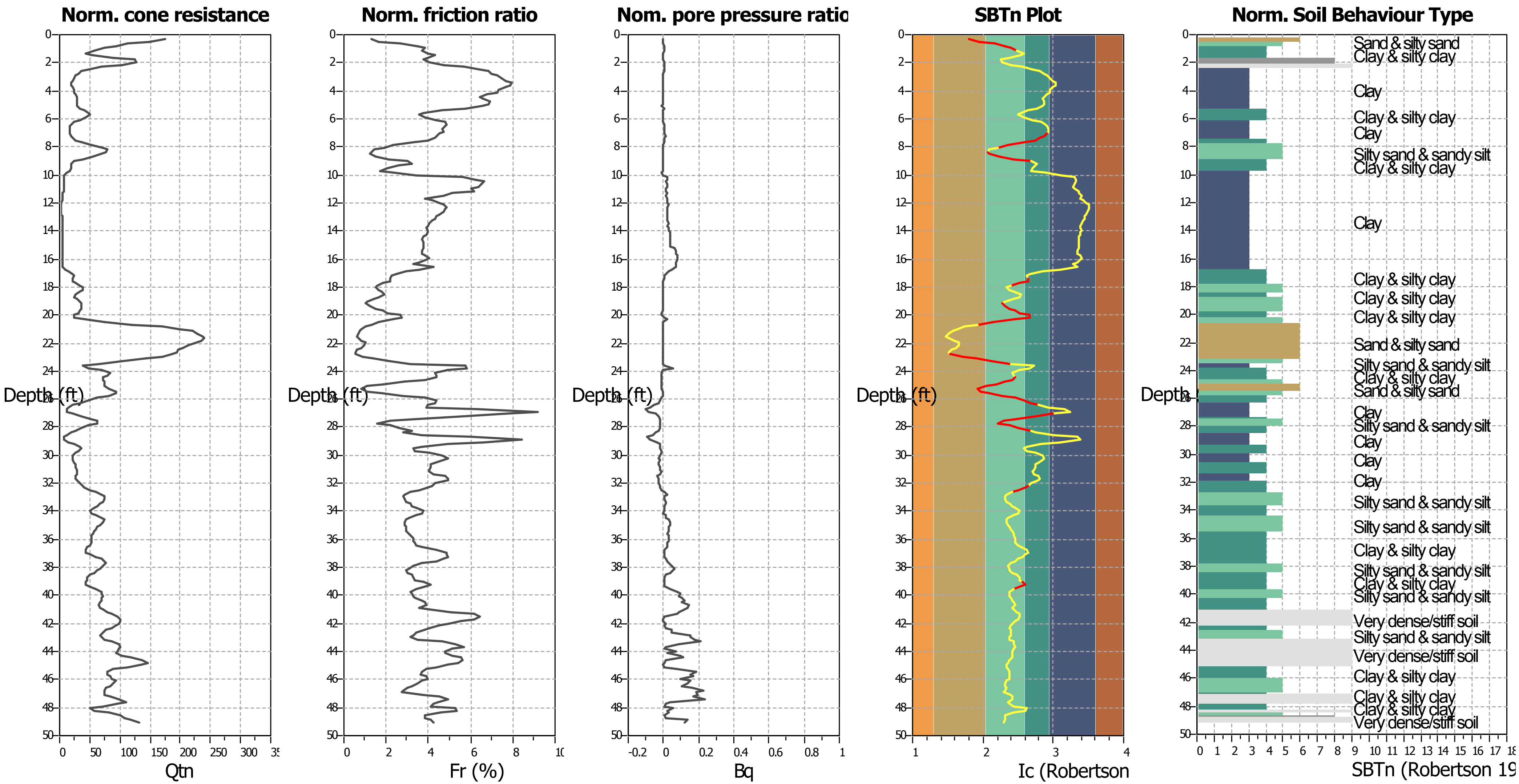
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



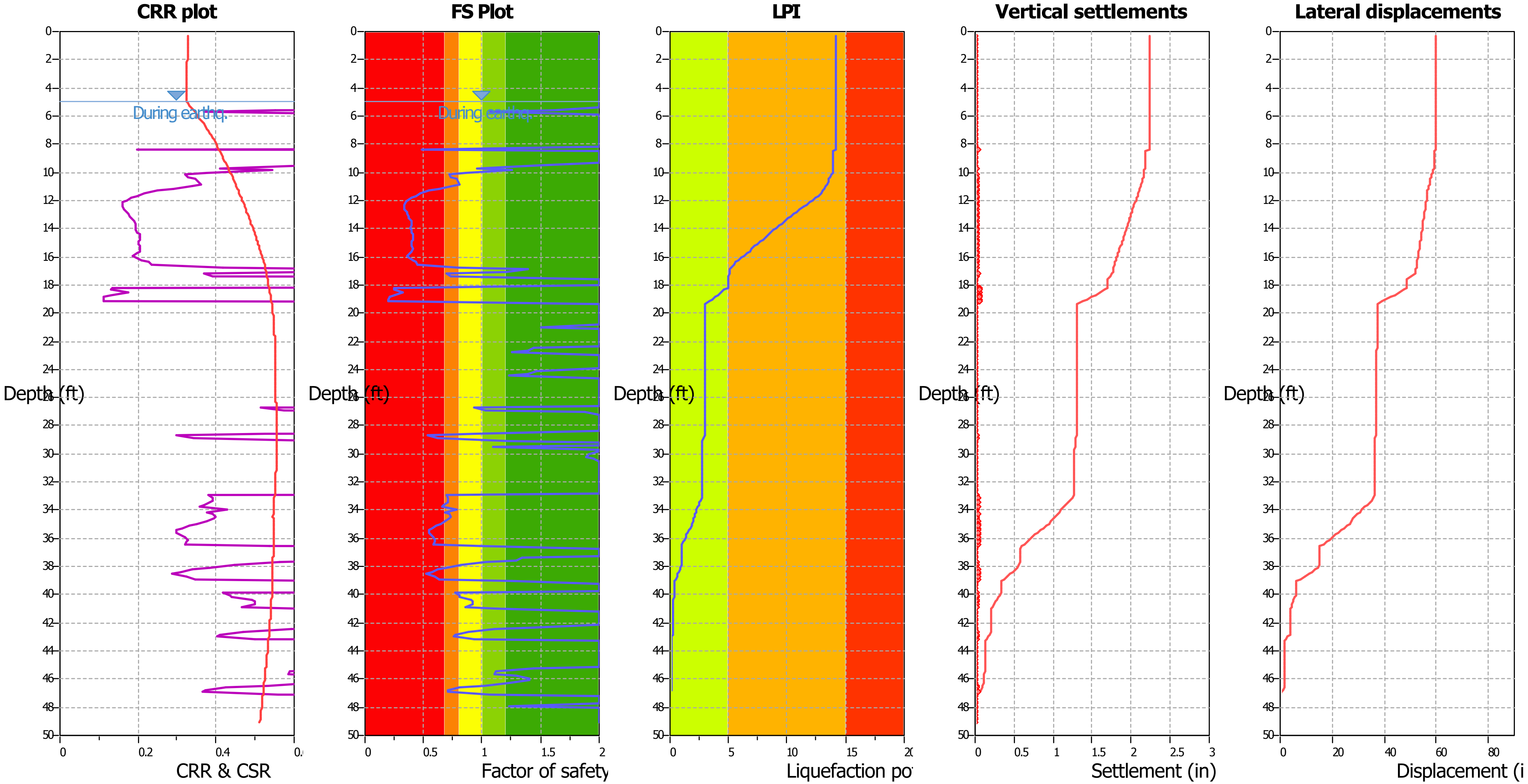
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

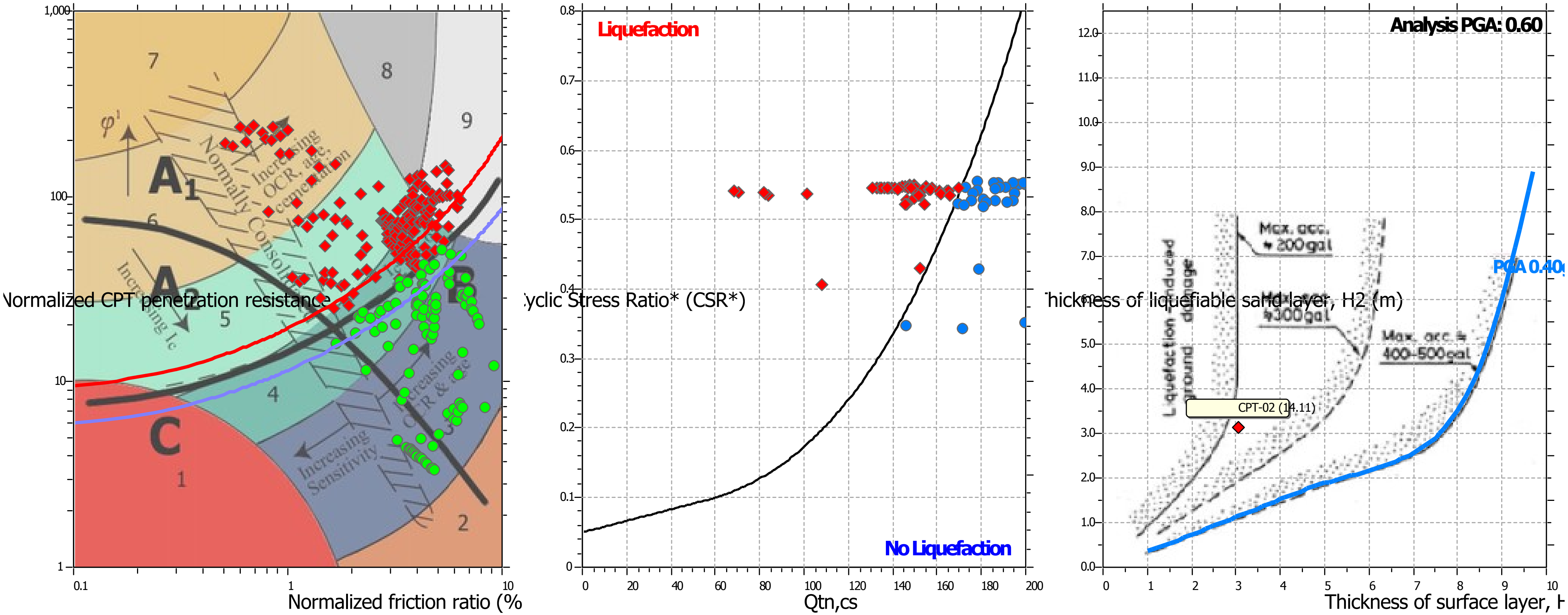
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

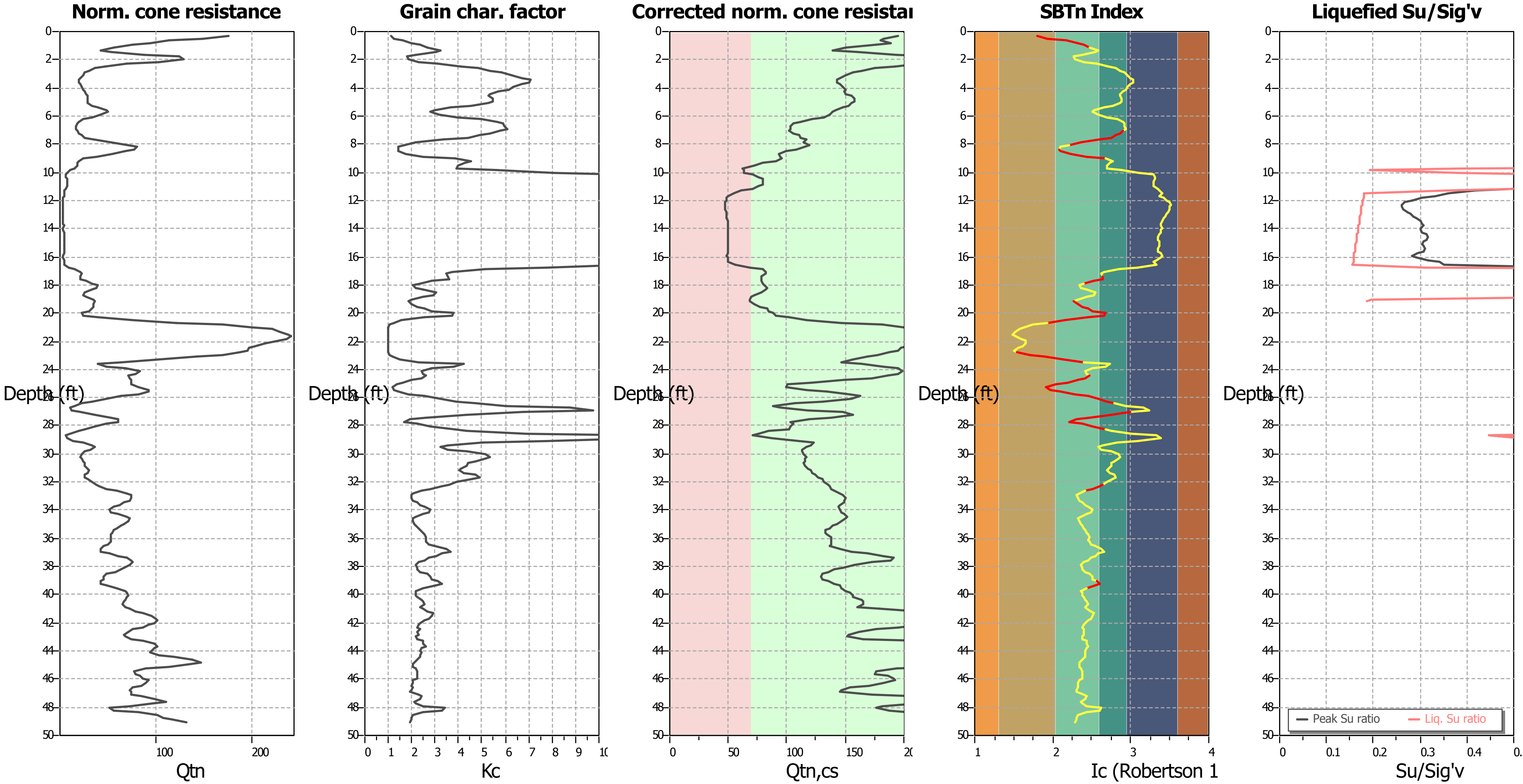
Liquefaction analysis summary plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

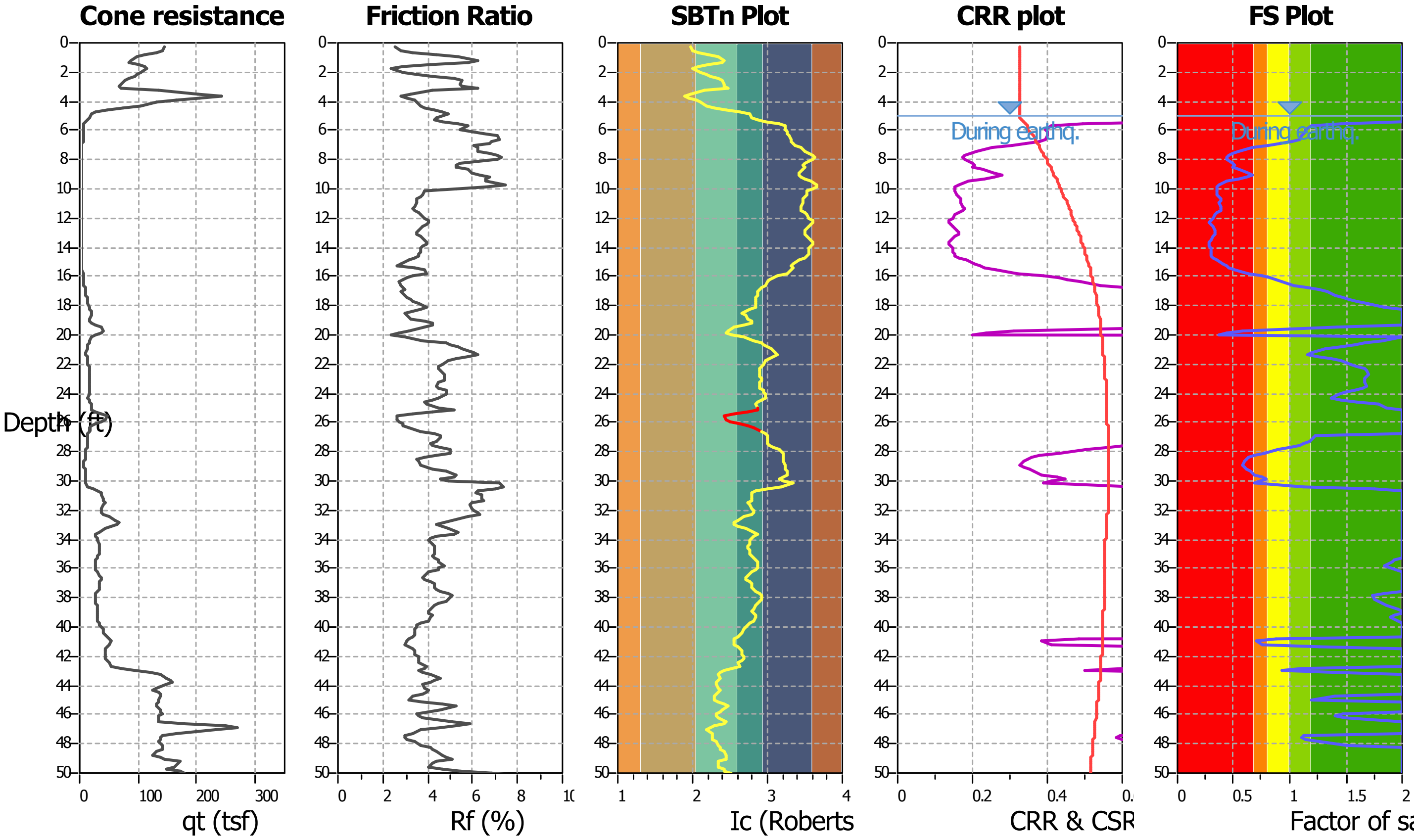
LIQUEFACTION ANALYSIS REPORT

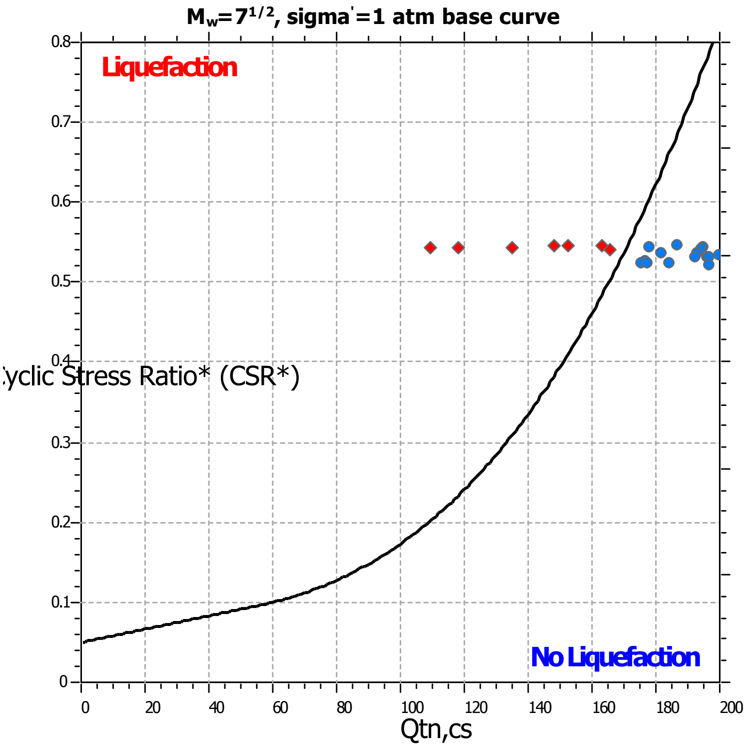
Project title : East D Street **Location : Petaluma, CA**

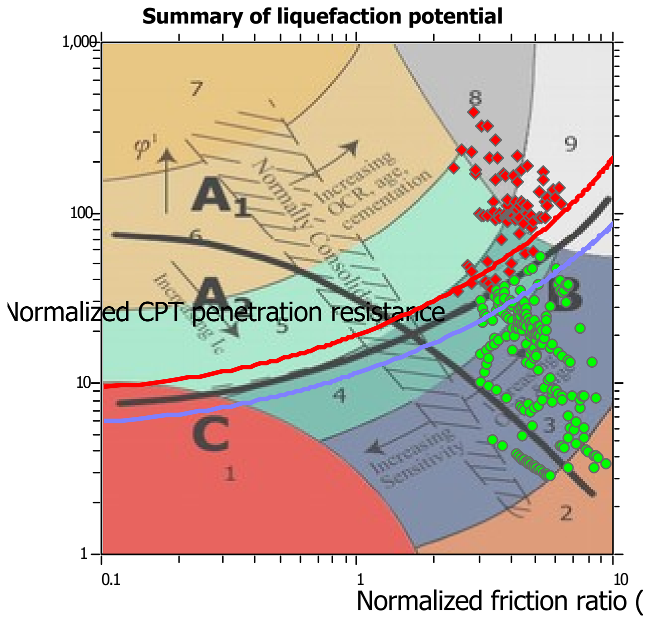
CPT file : CPT-03

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

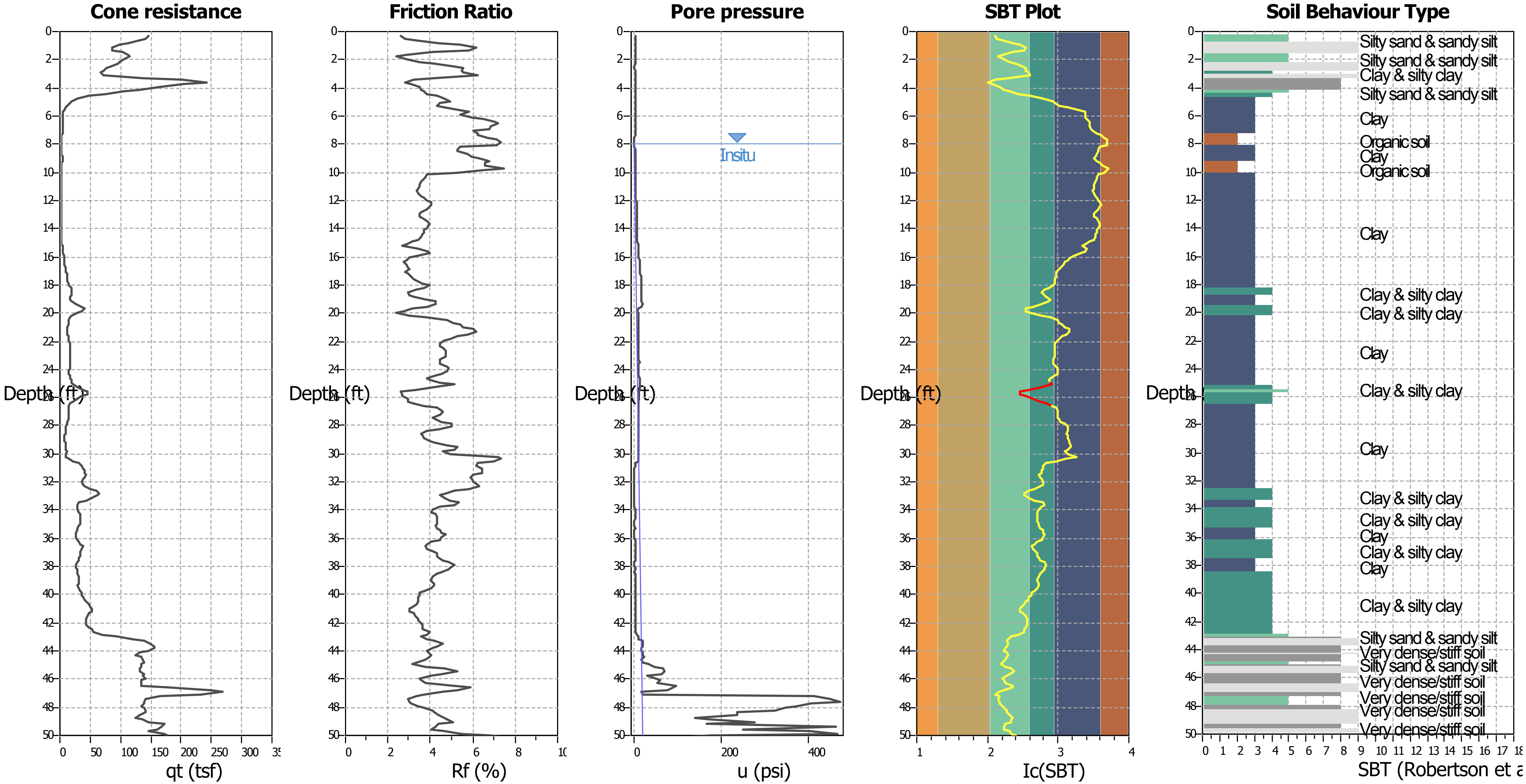






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



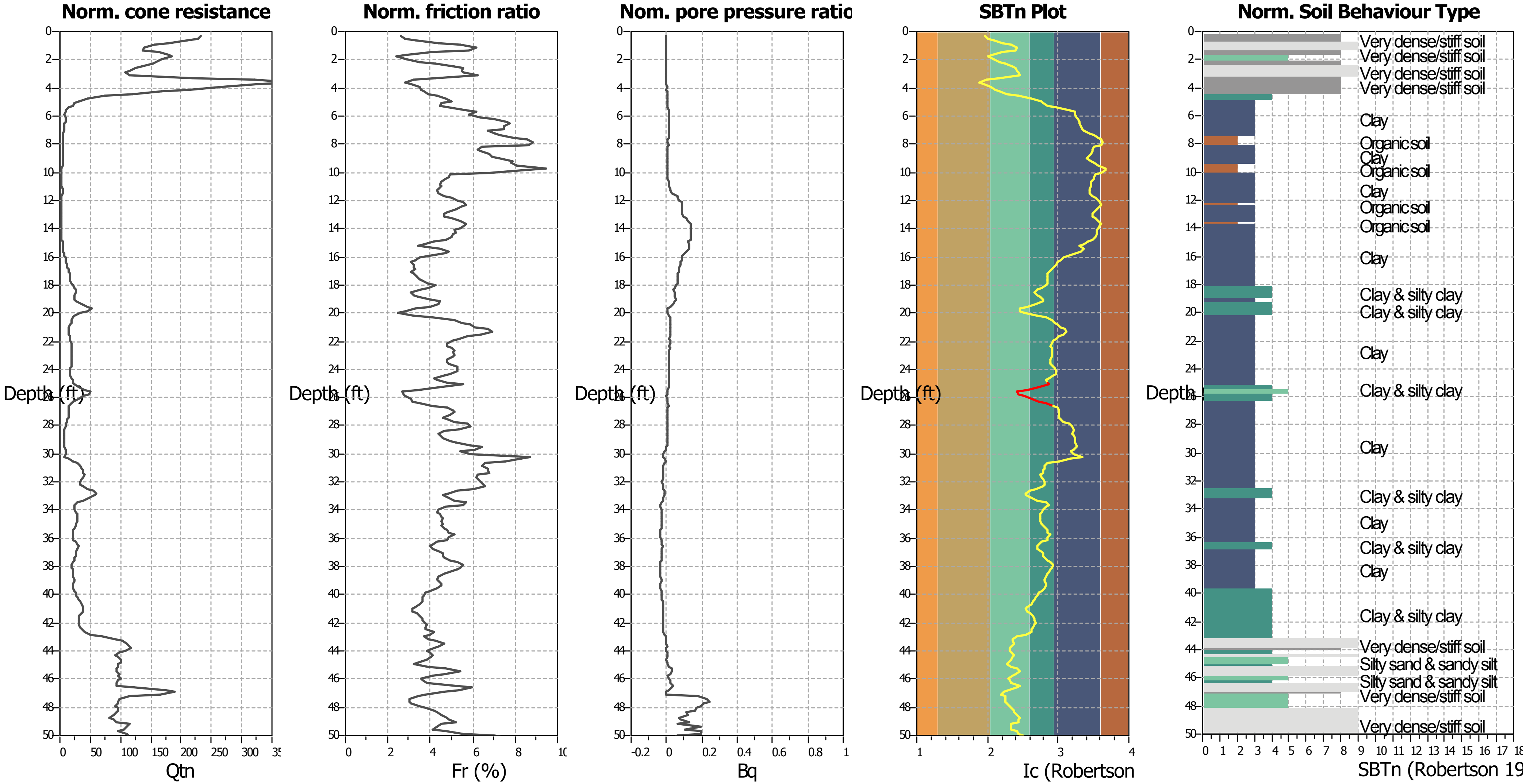
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

CPT basic interpretation plots (normalized)



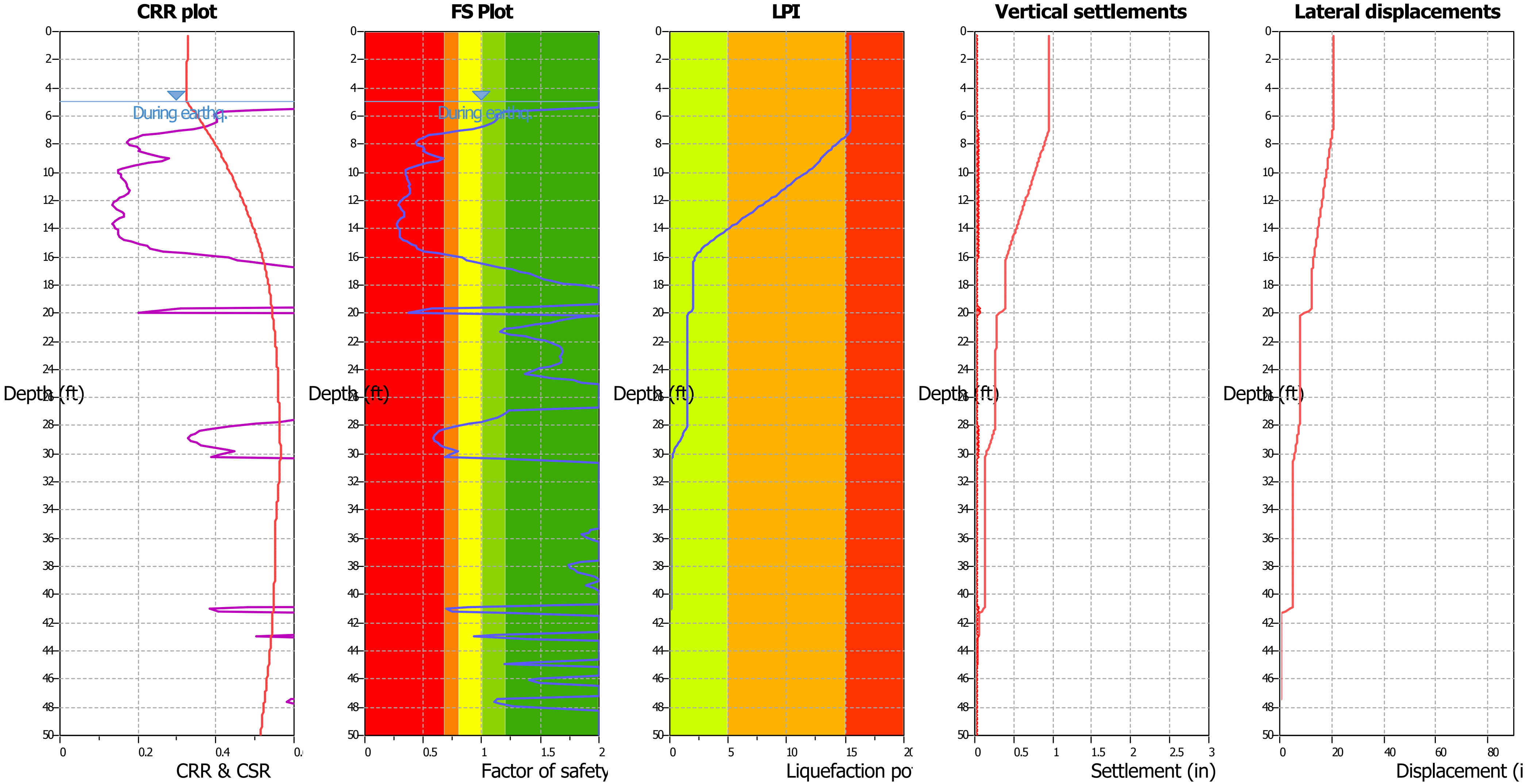
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

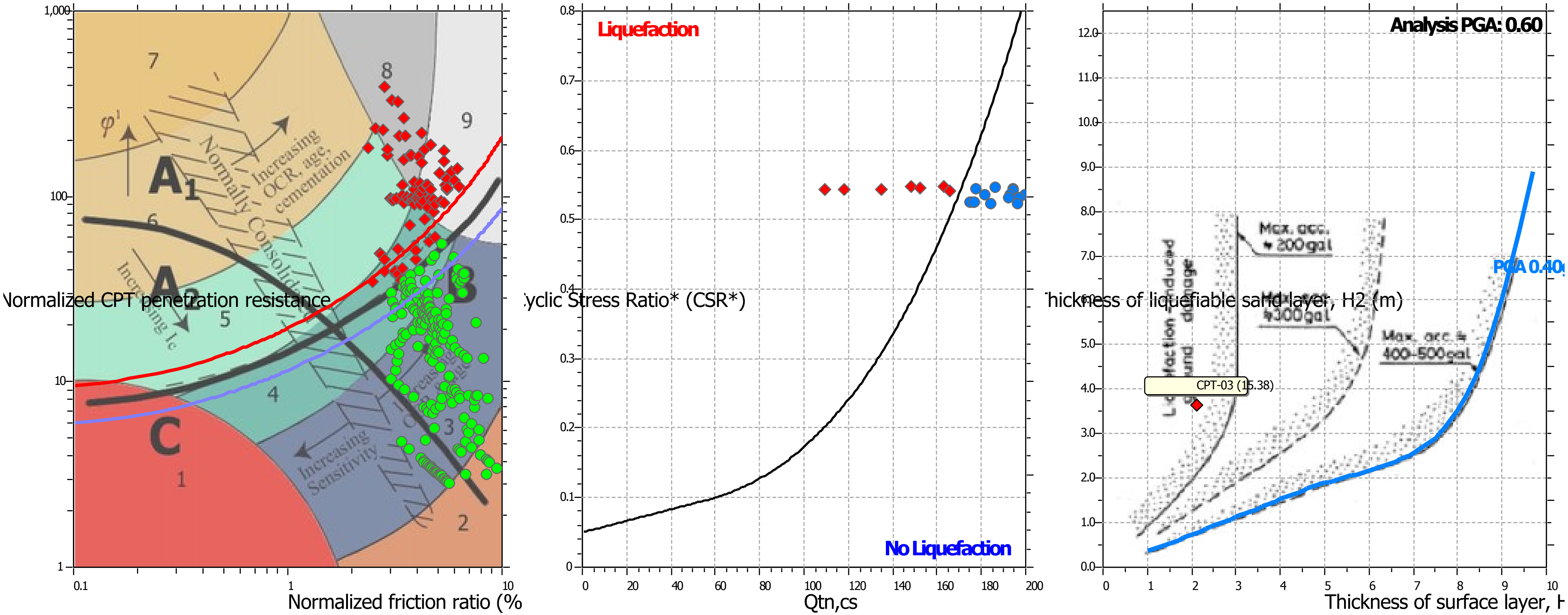
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

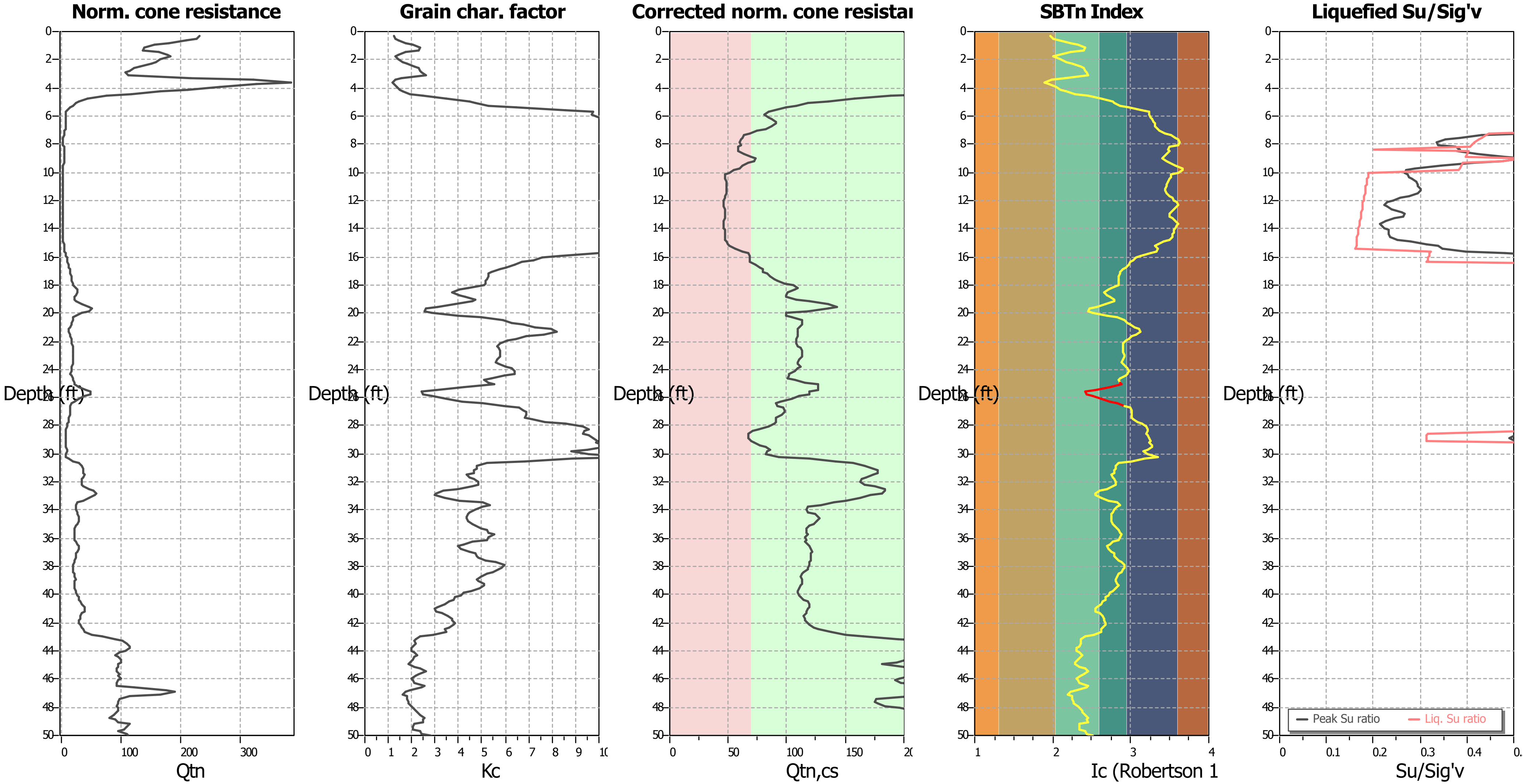
Liquefaction analysis summary plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

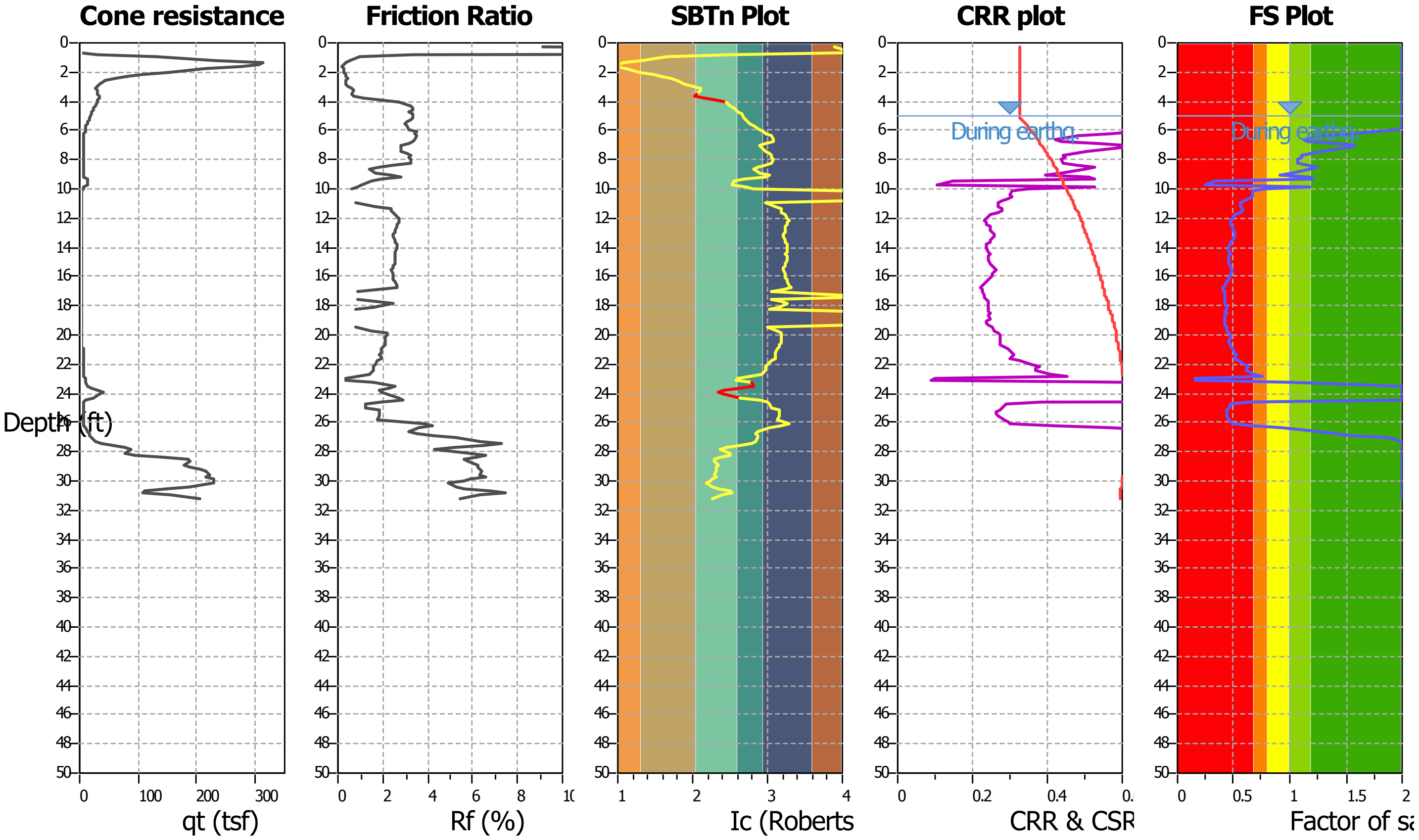
LIQUEFACTION ANALYSIS REPORT

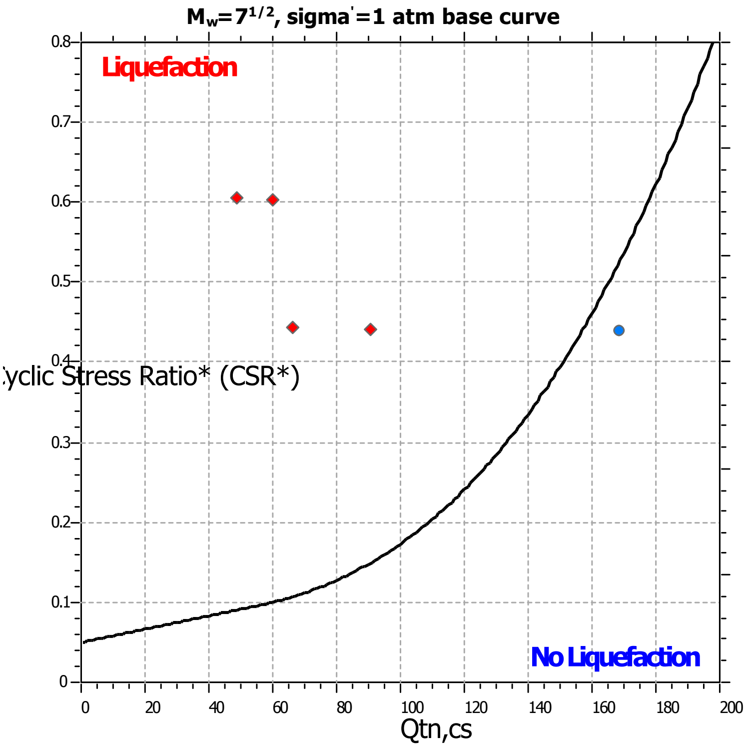
Project title : East D Street **Location : Petaluma, CA**

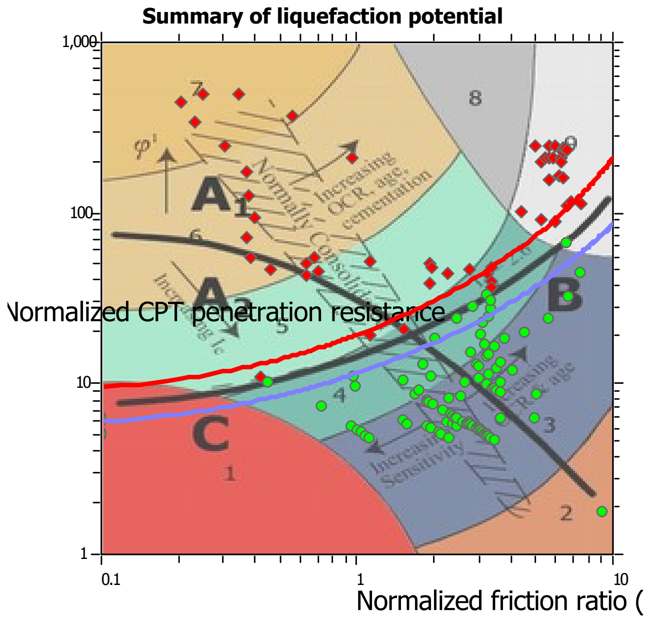
CPT file : CPT-04

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

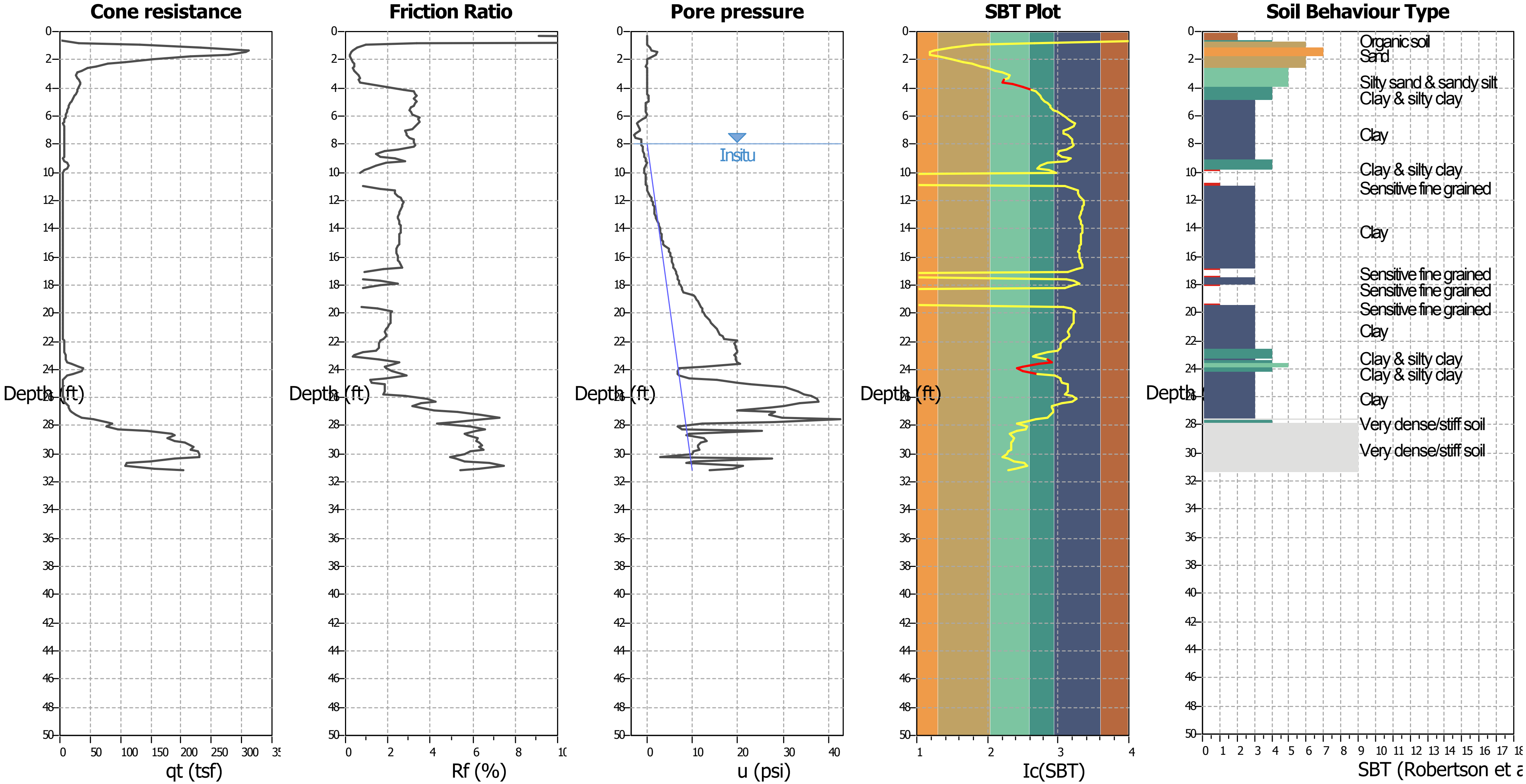






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



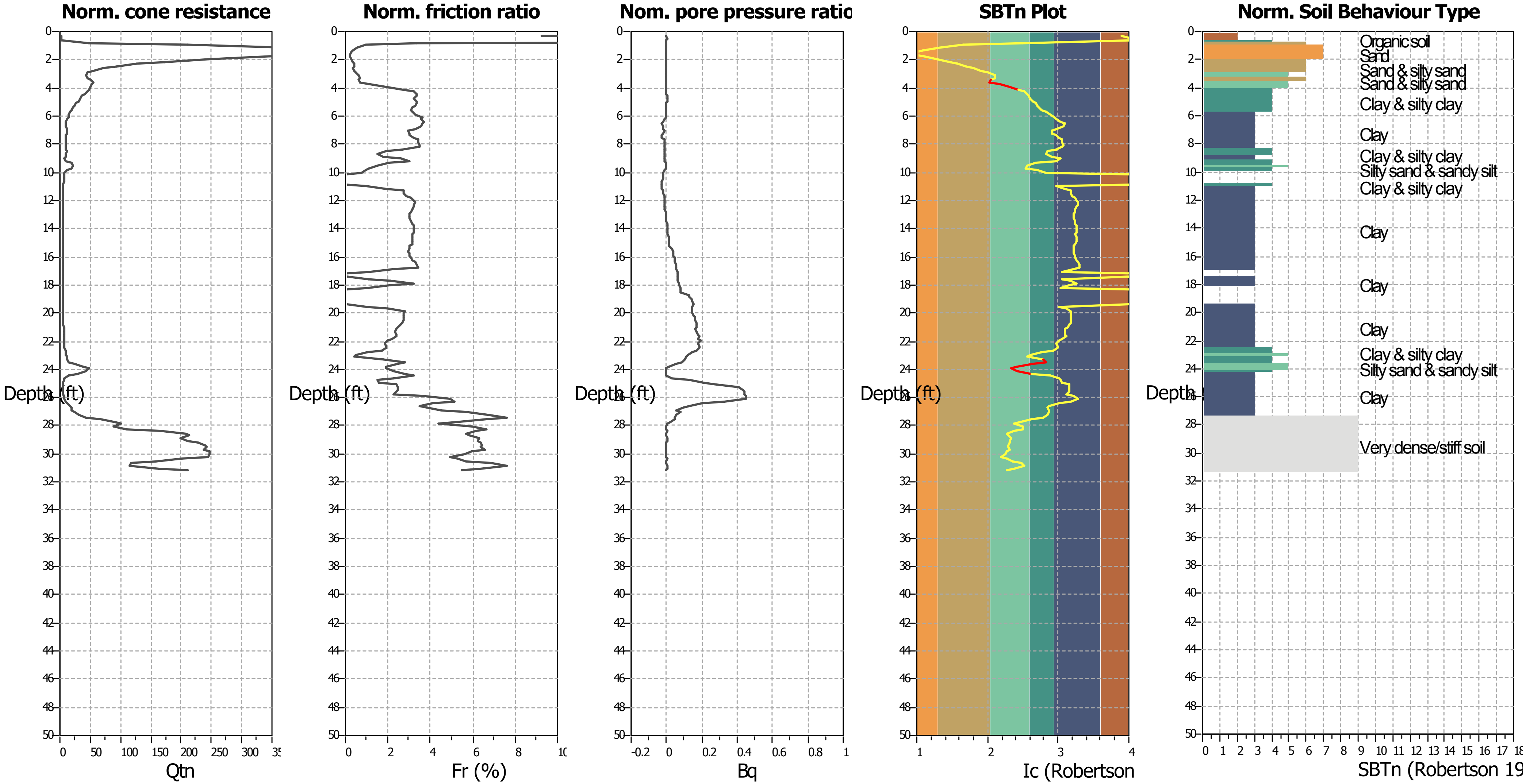
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A		
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes		
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes		
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils		
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes		
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft		

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



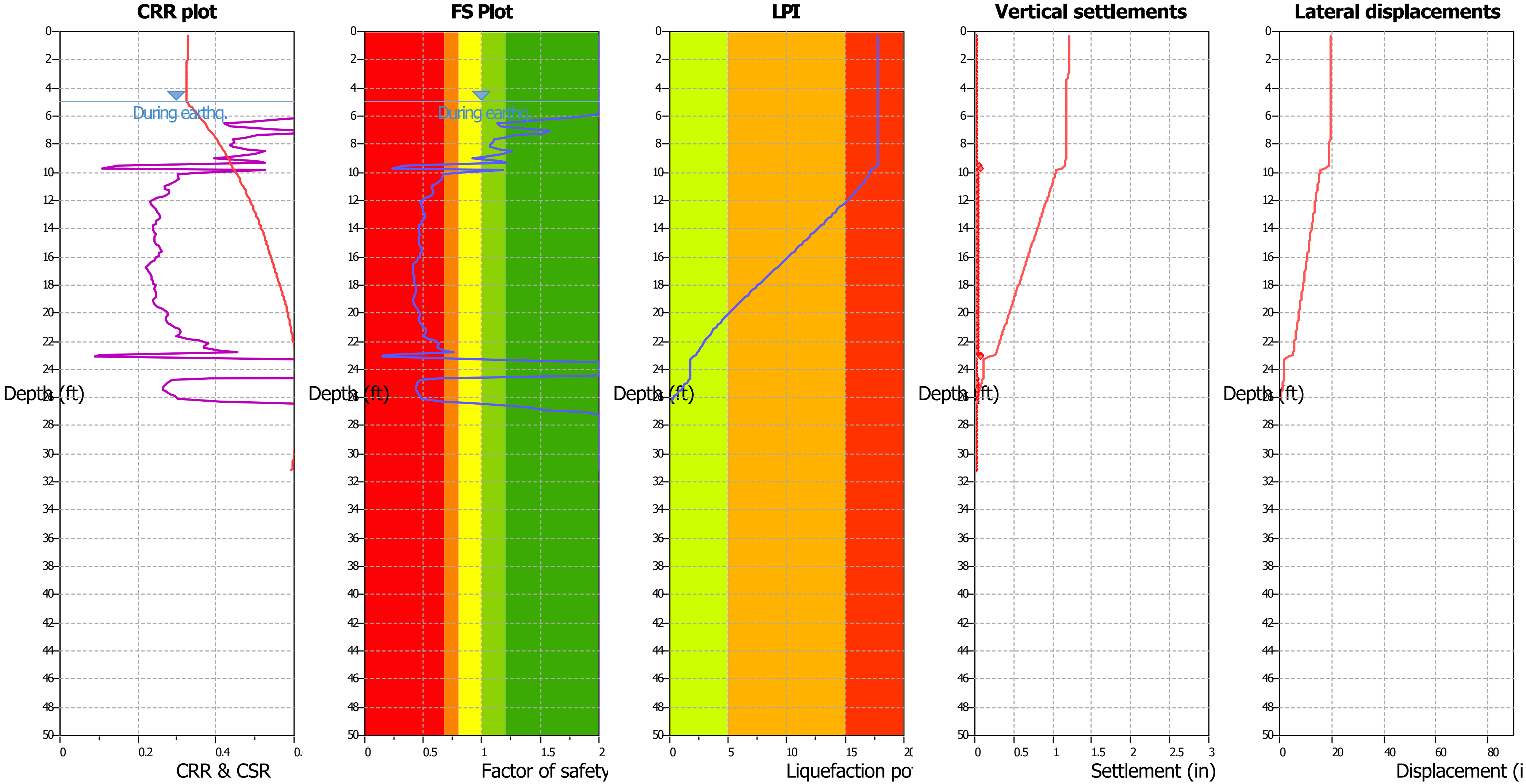
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

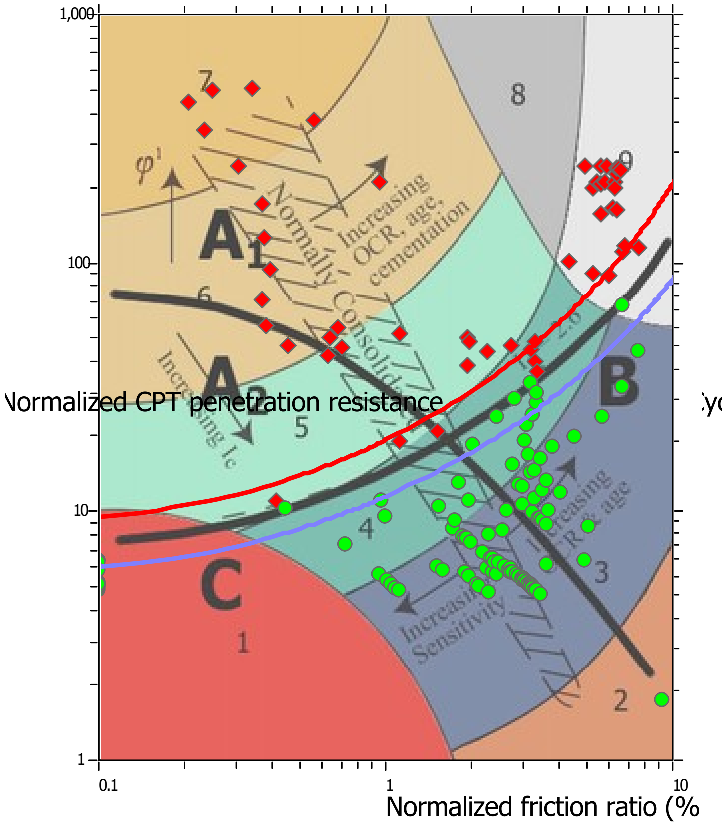
F.S. color scheme

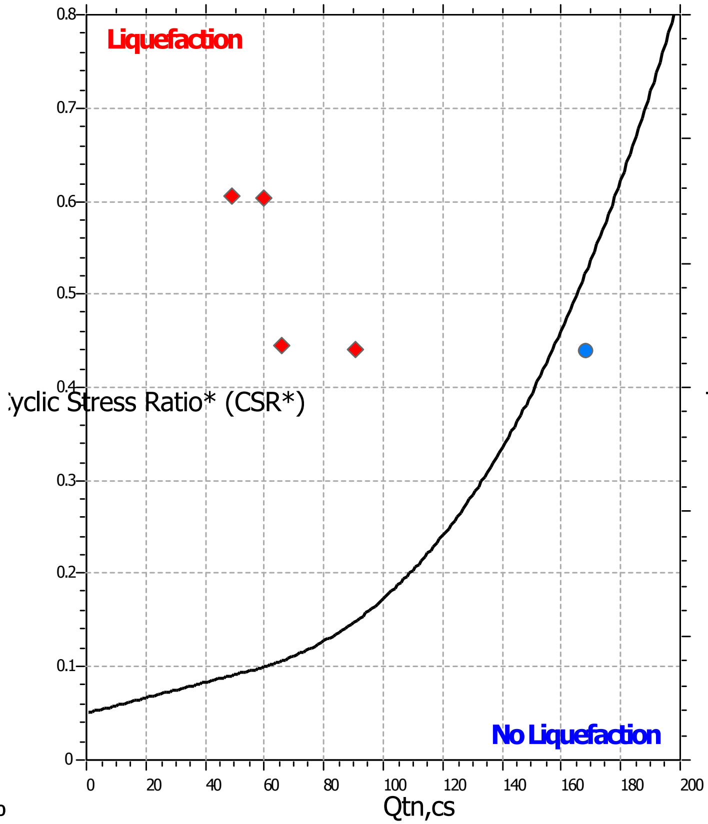
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

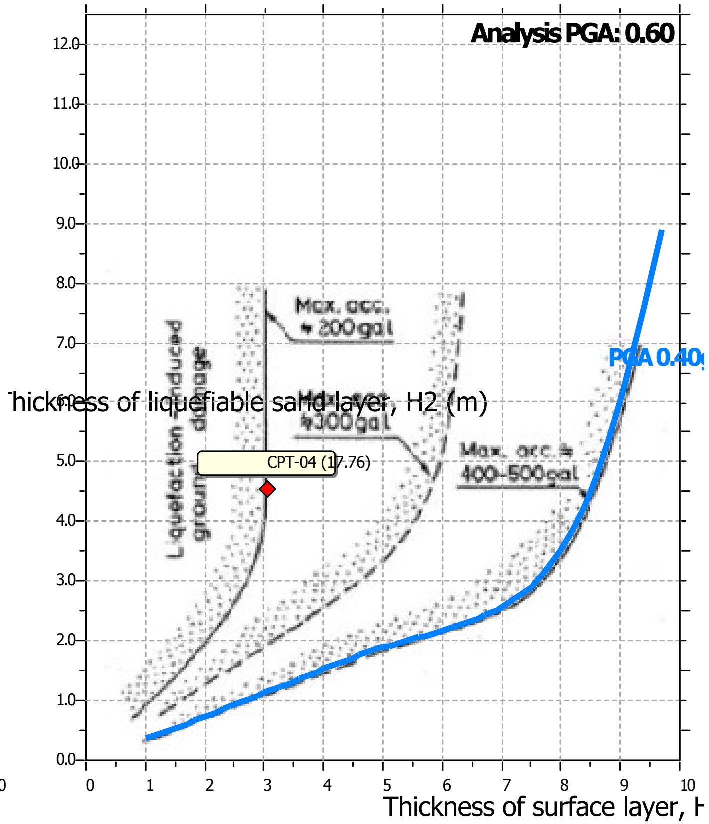
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



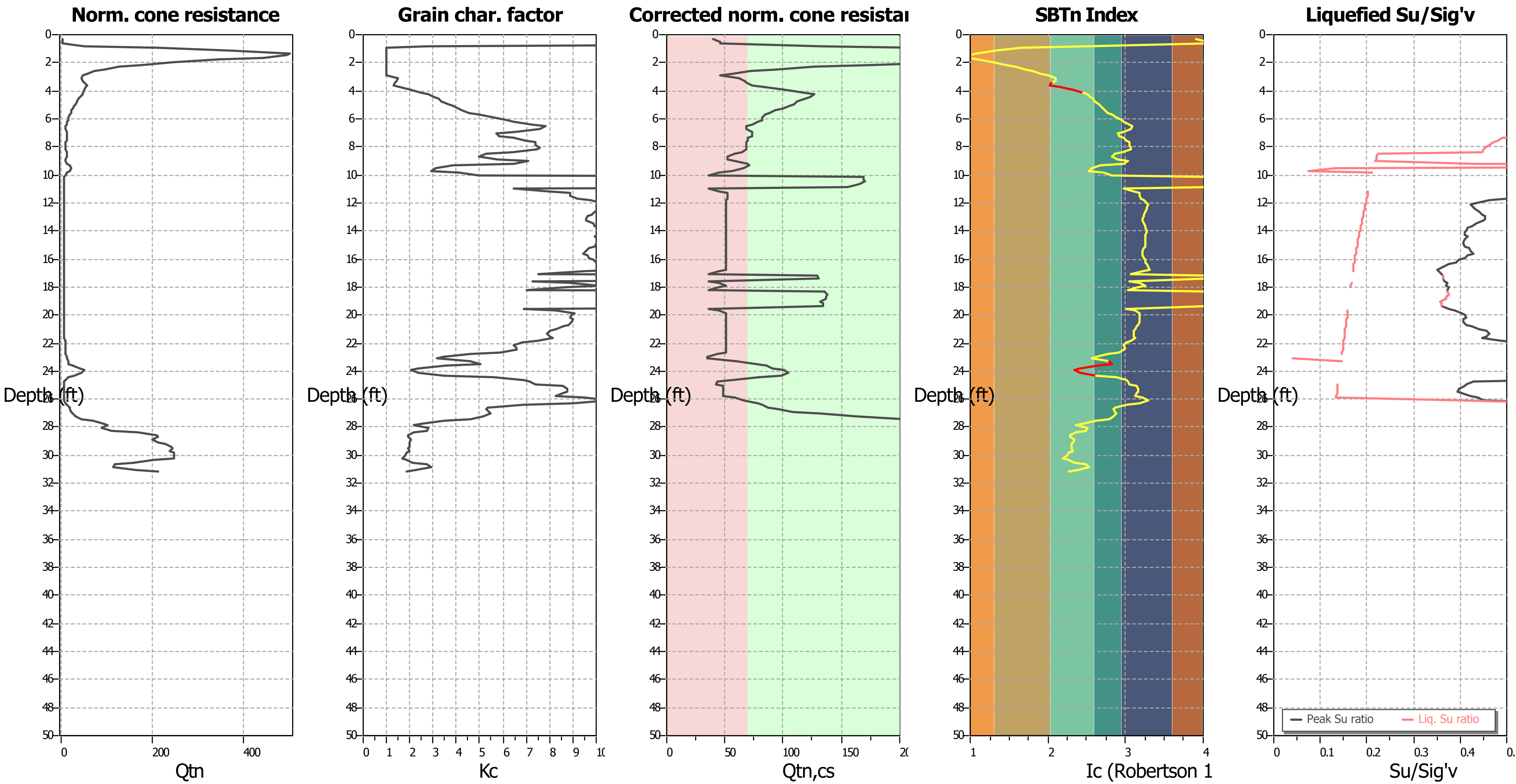




Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Berlogar, Stevens & Associates, Inc.
Pleasanton, California

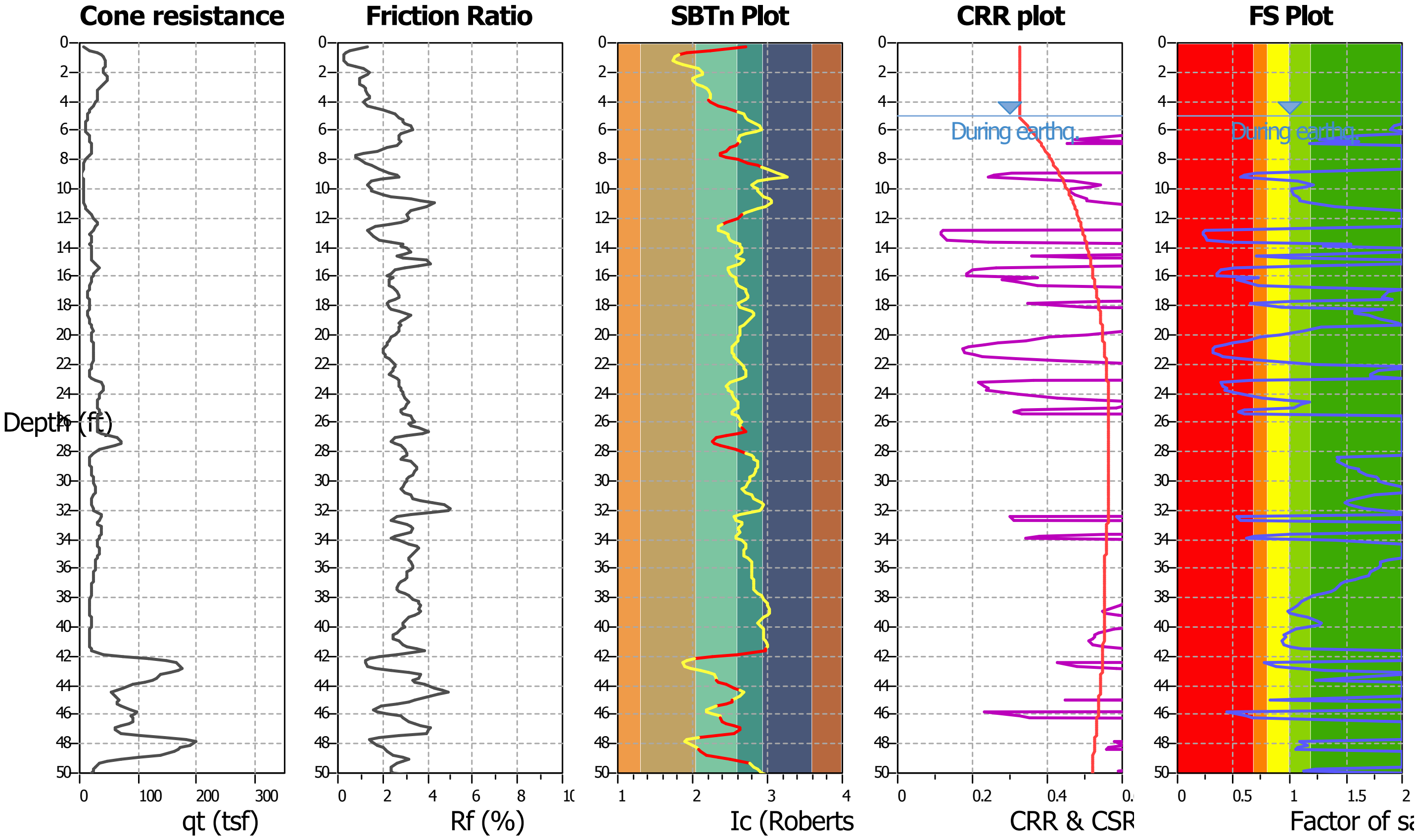
LIQUEFACTION ANALYSIS REPORT

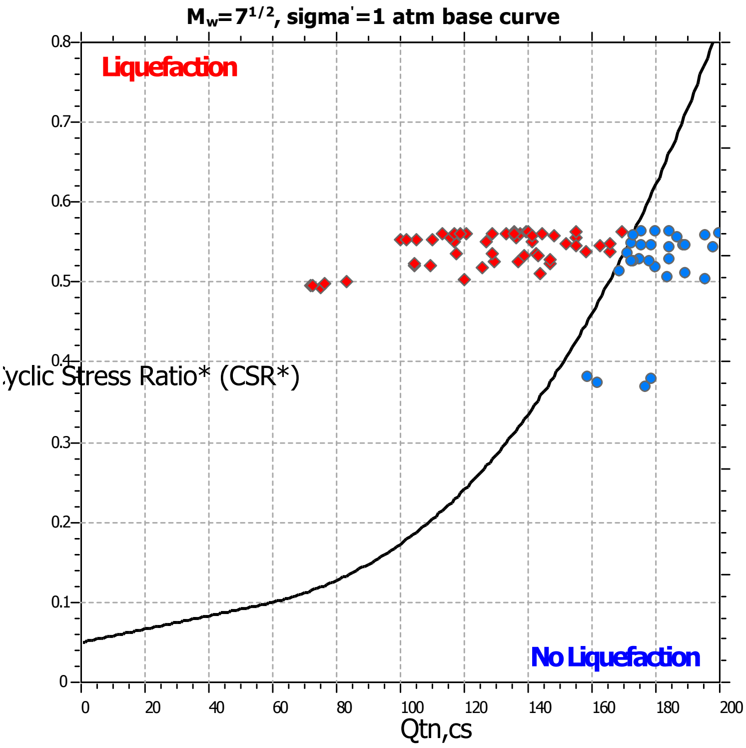
Project title : East D Street **Location : Petaluma, CA**

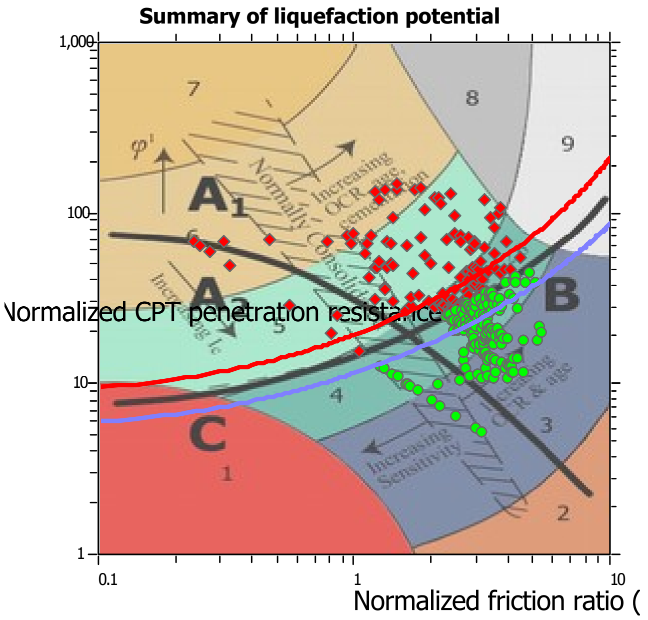
CPT file : CPT-05

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

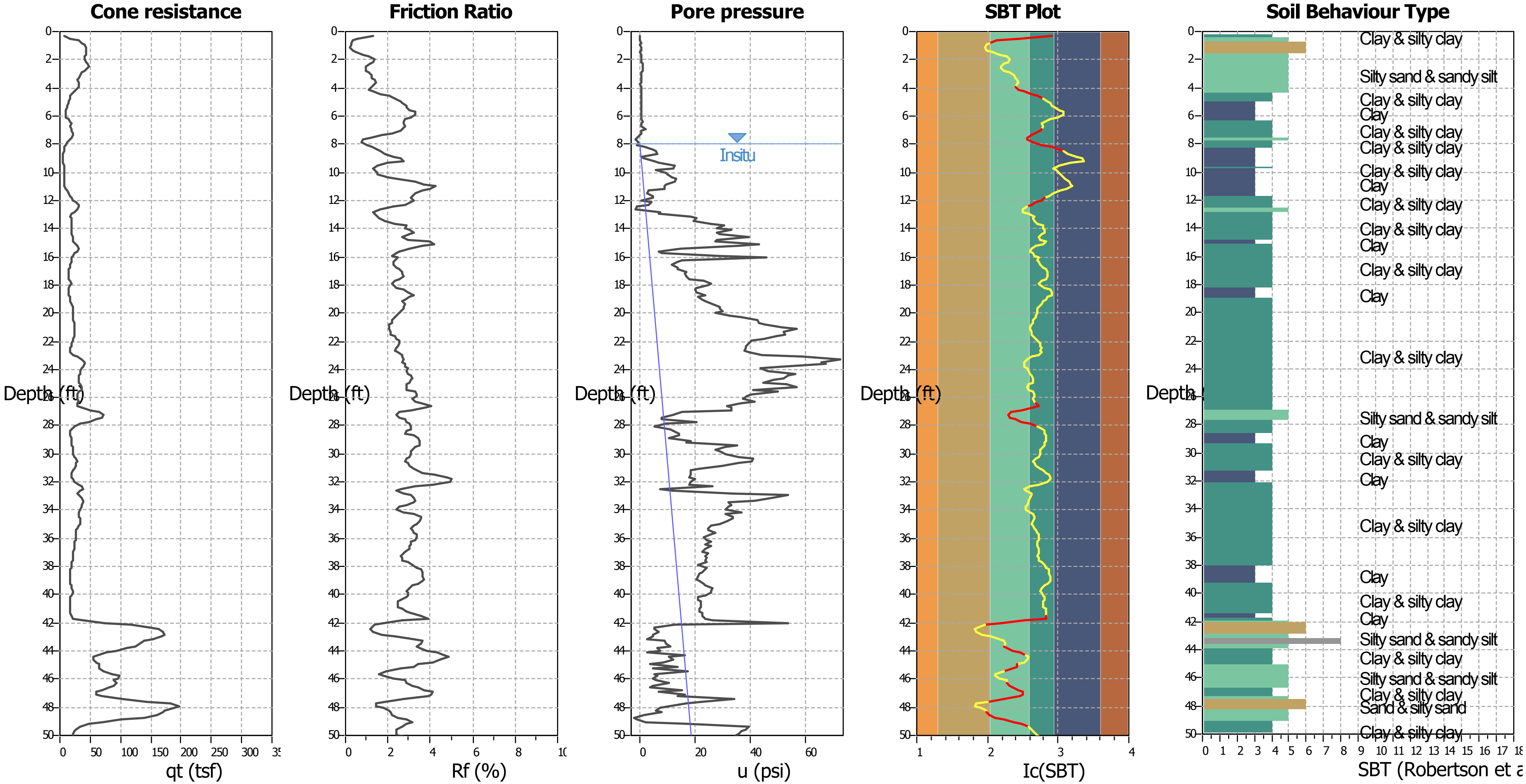






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



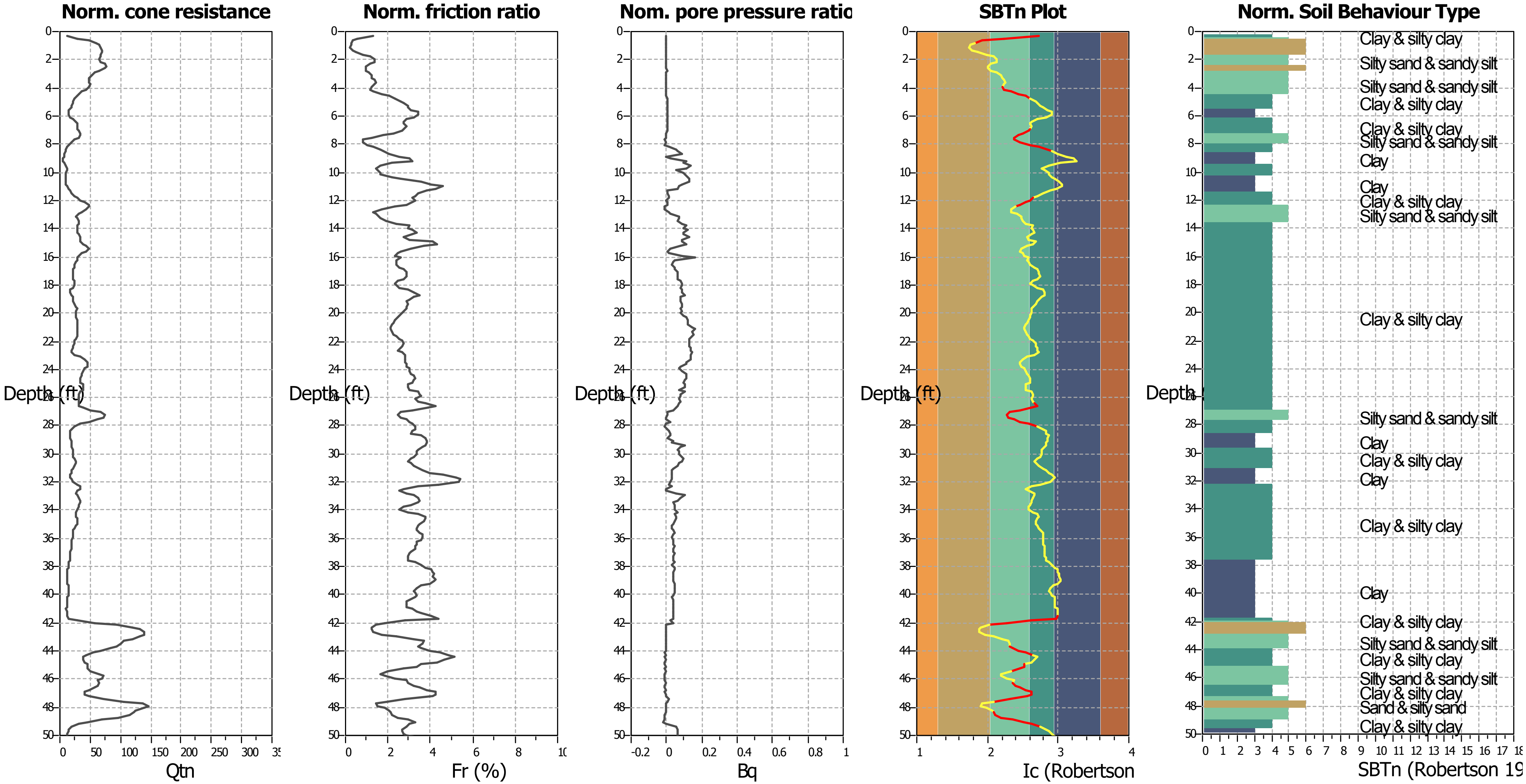
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBT legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

CPT basic interpretation plots (normalized)



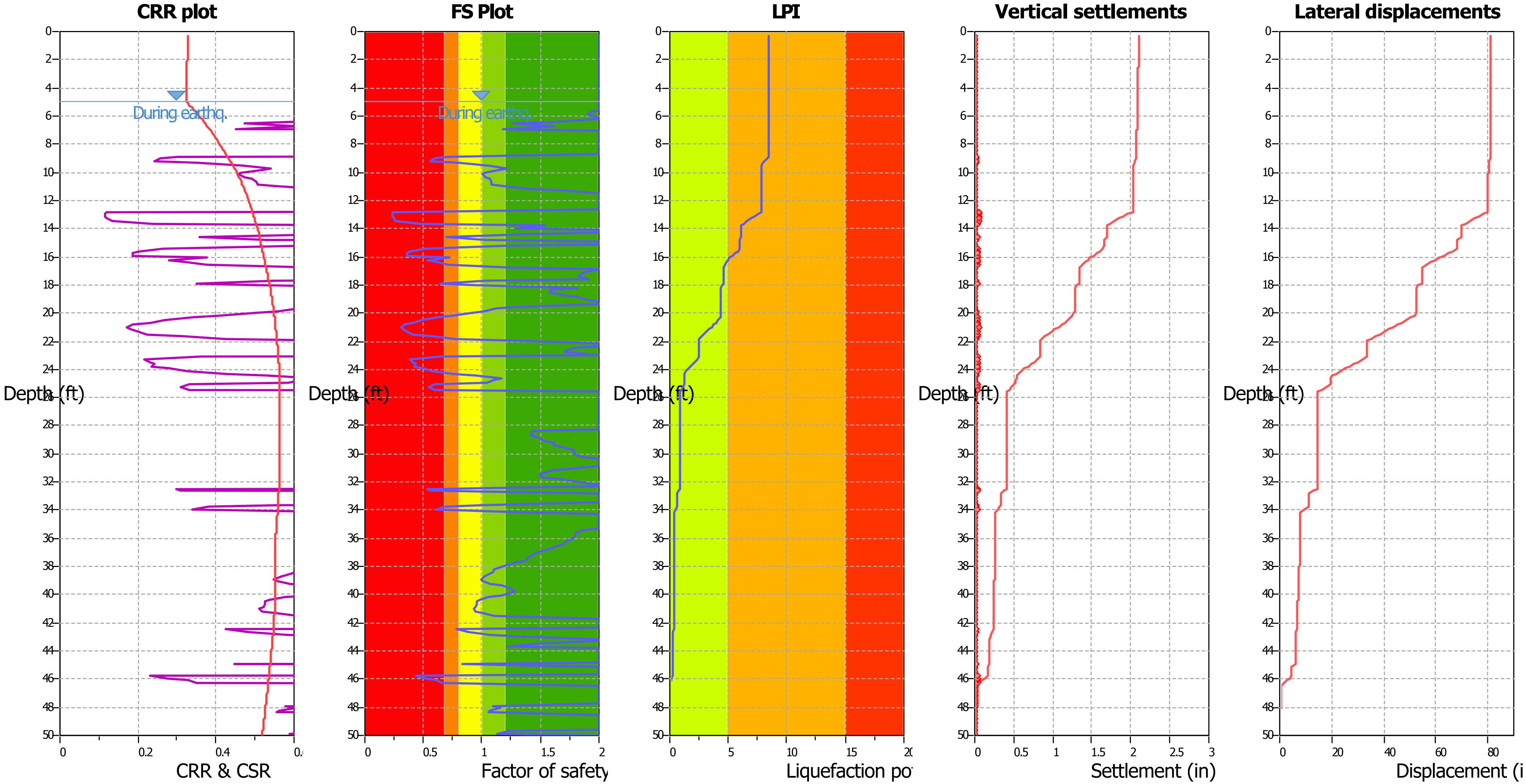
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

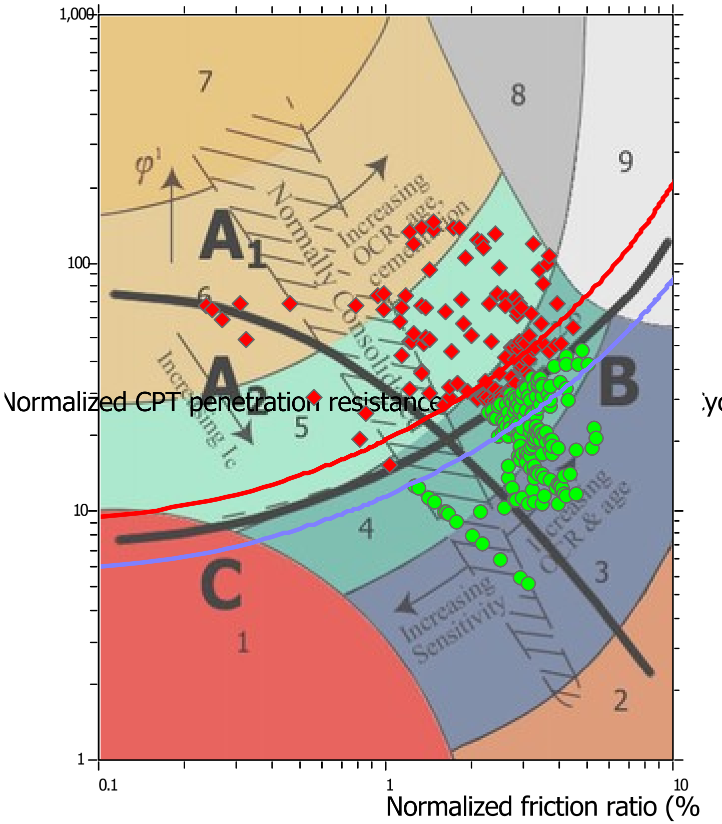
F.S. color scheme

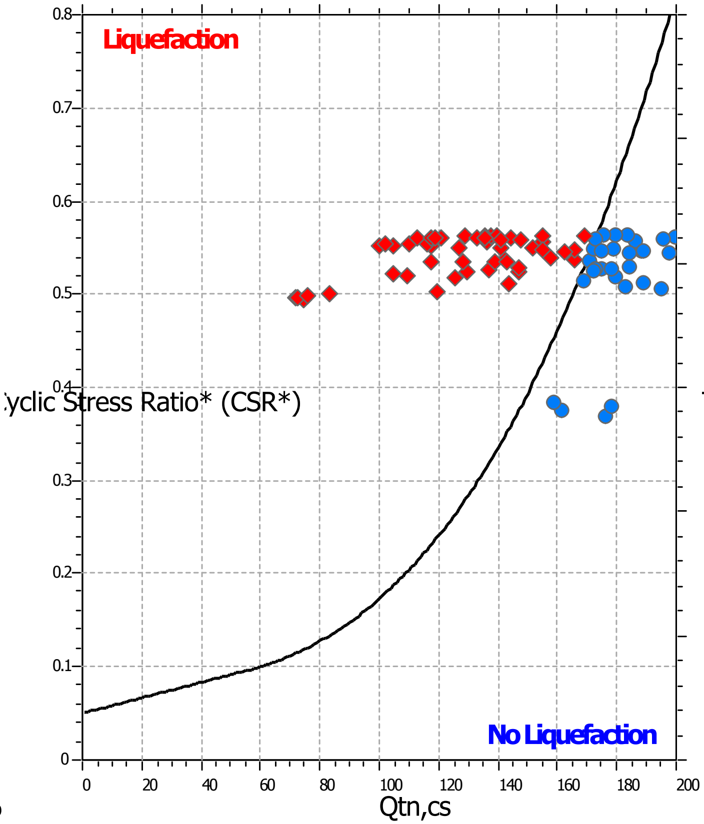
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

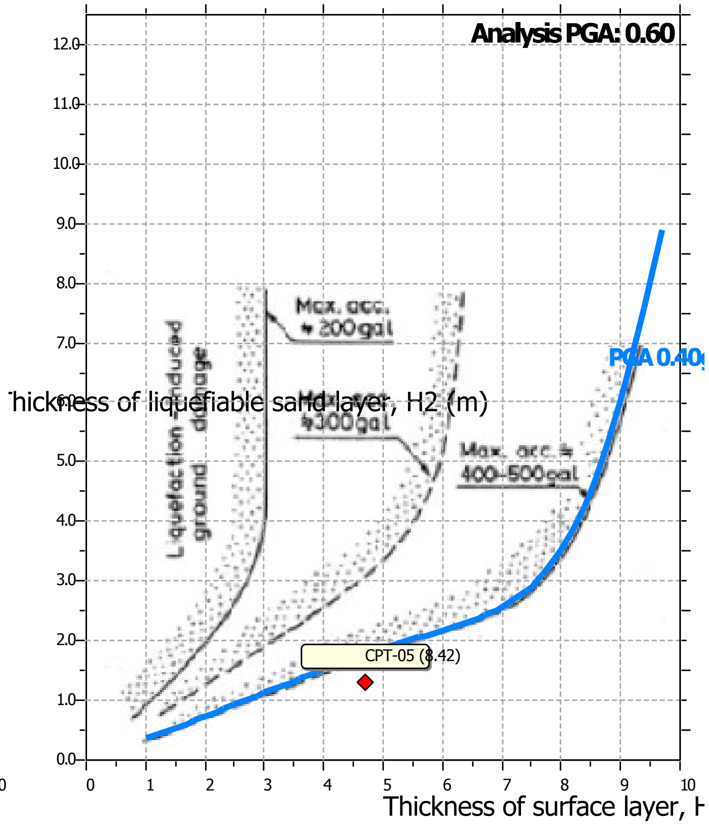
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



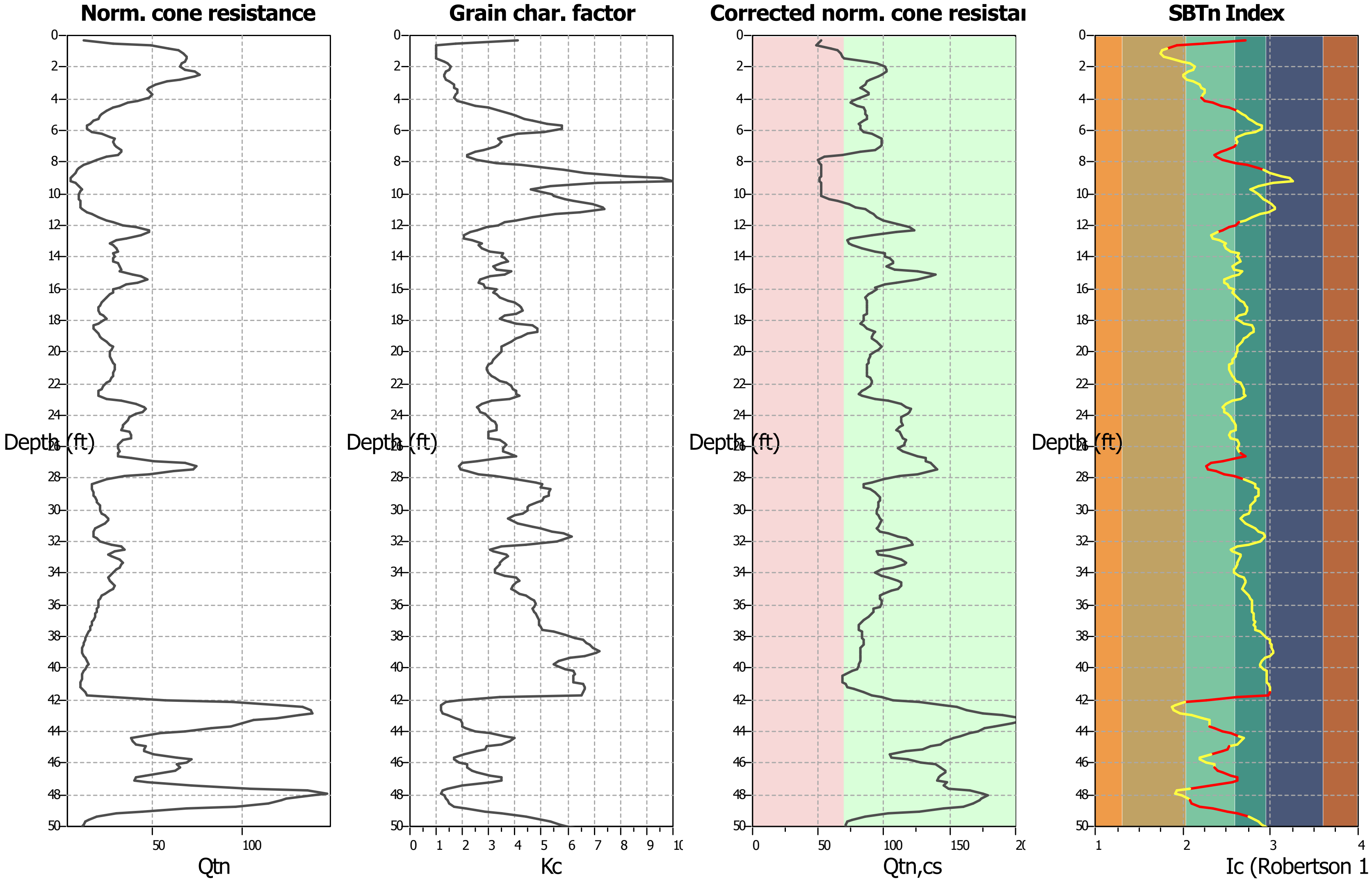




Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Berlogar, Stevens & Associates, Inc.
Pleasanton, California

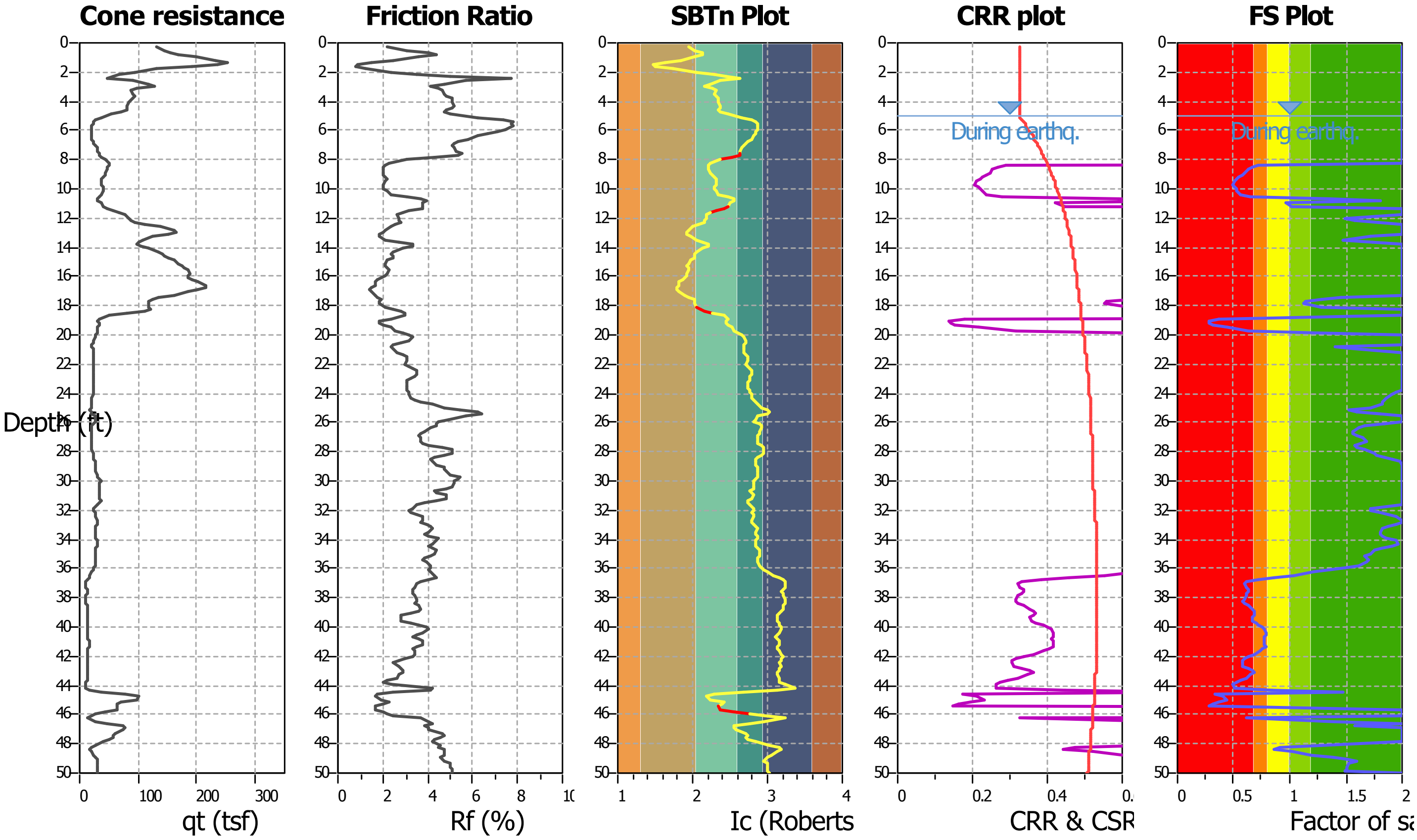
LIQUEFACTION ANALYSIS REPORT

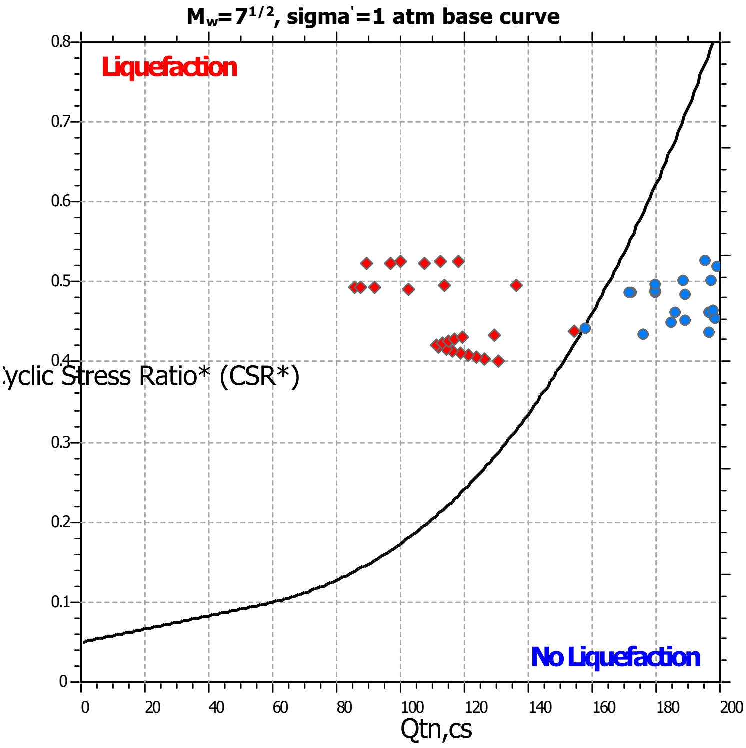
Project title : East D Street **Location : Petaluma, CA**

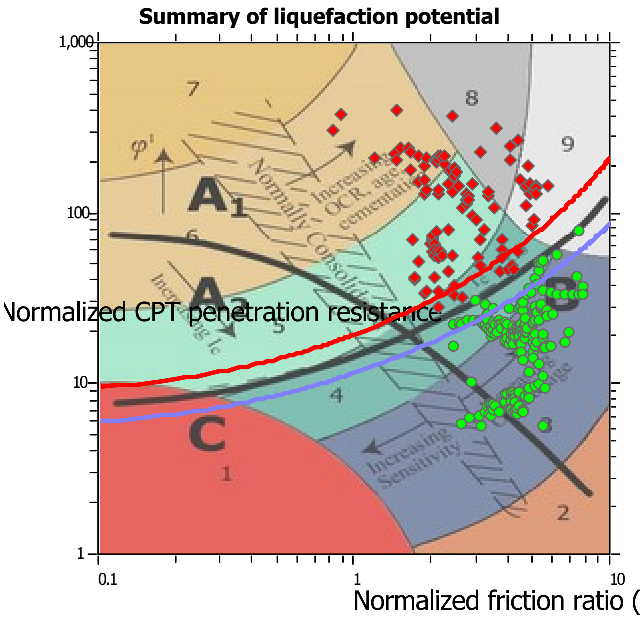
CPT file : CPT-06

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

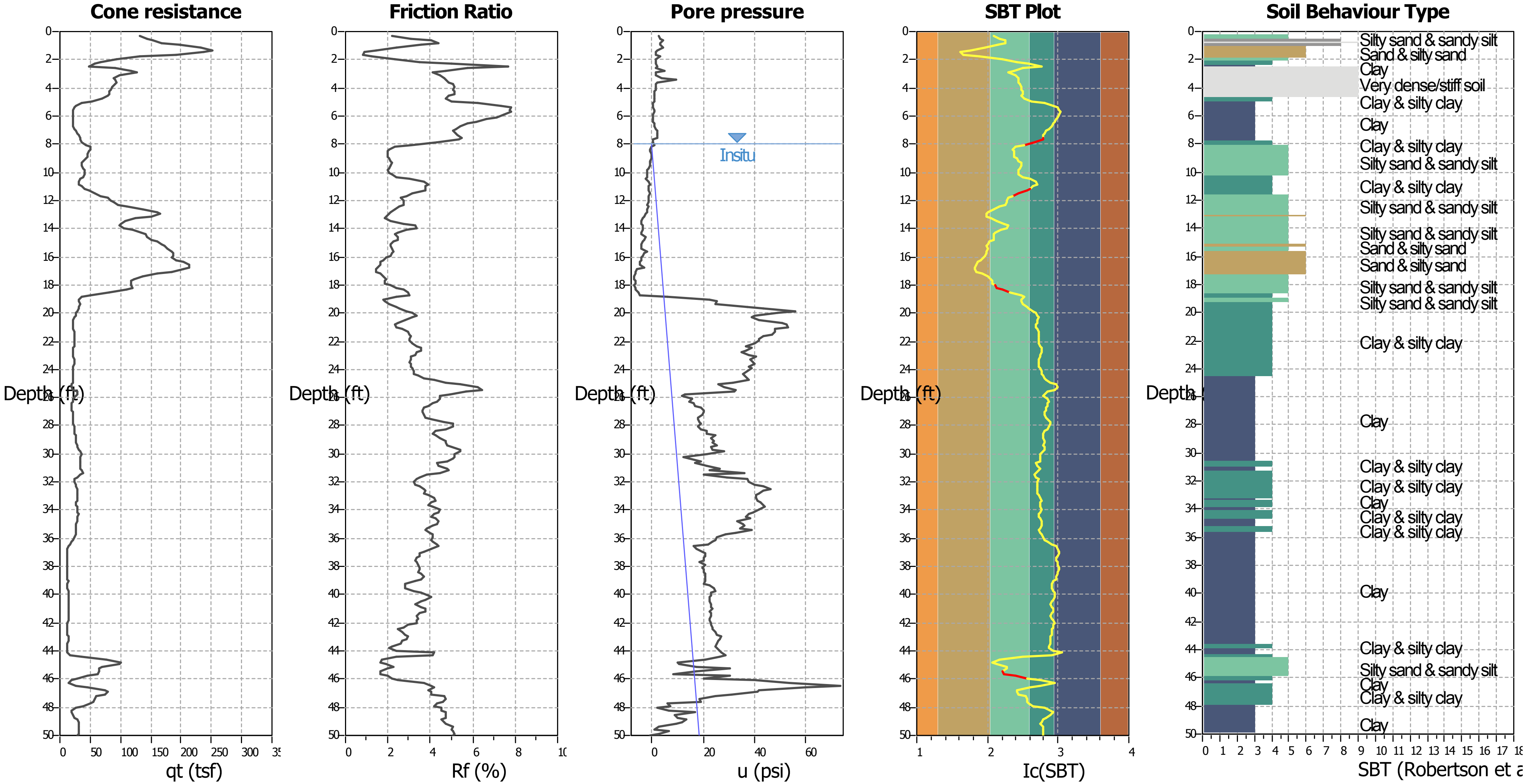






Zone A_1 : Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



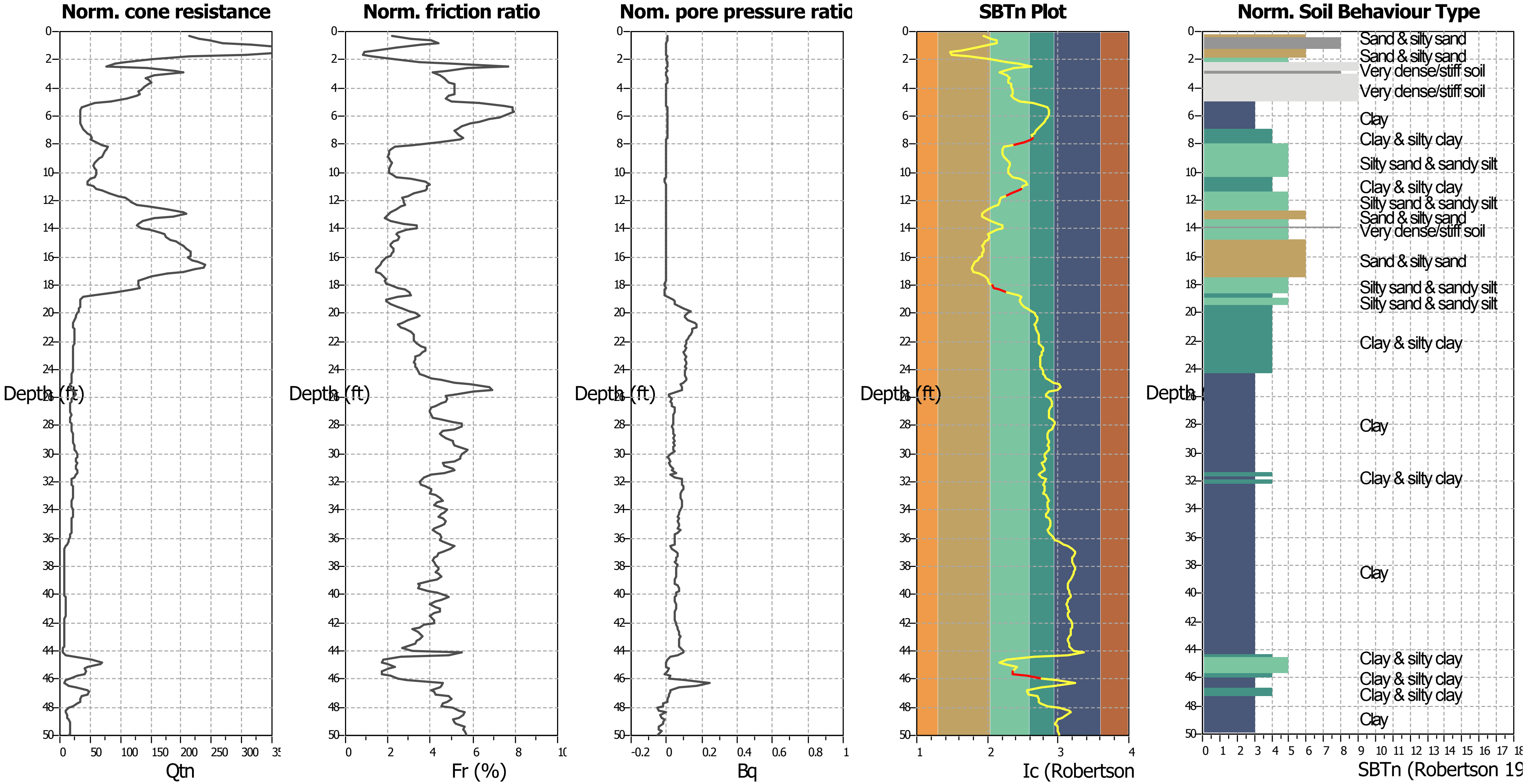
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

CPT basic interpretation plots (normalized)



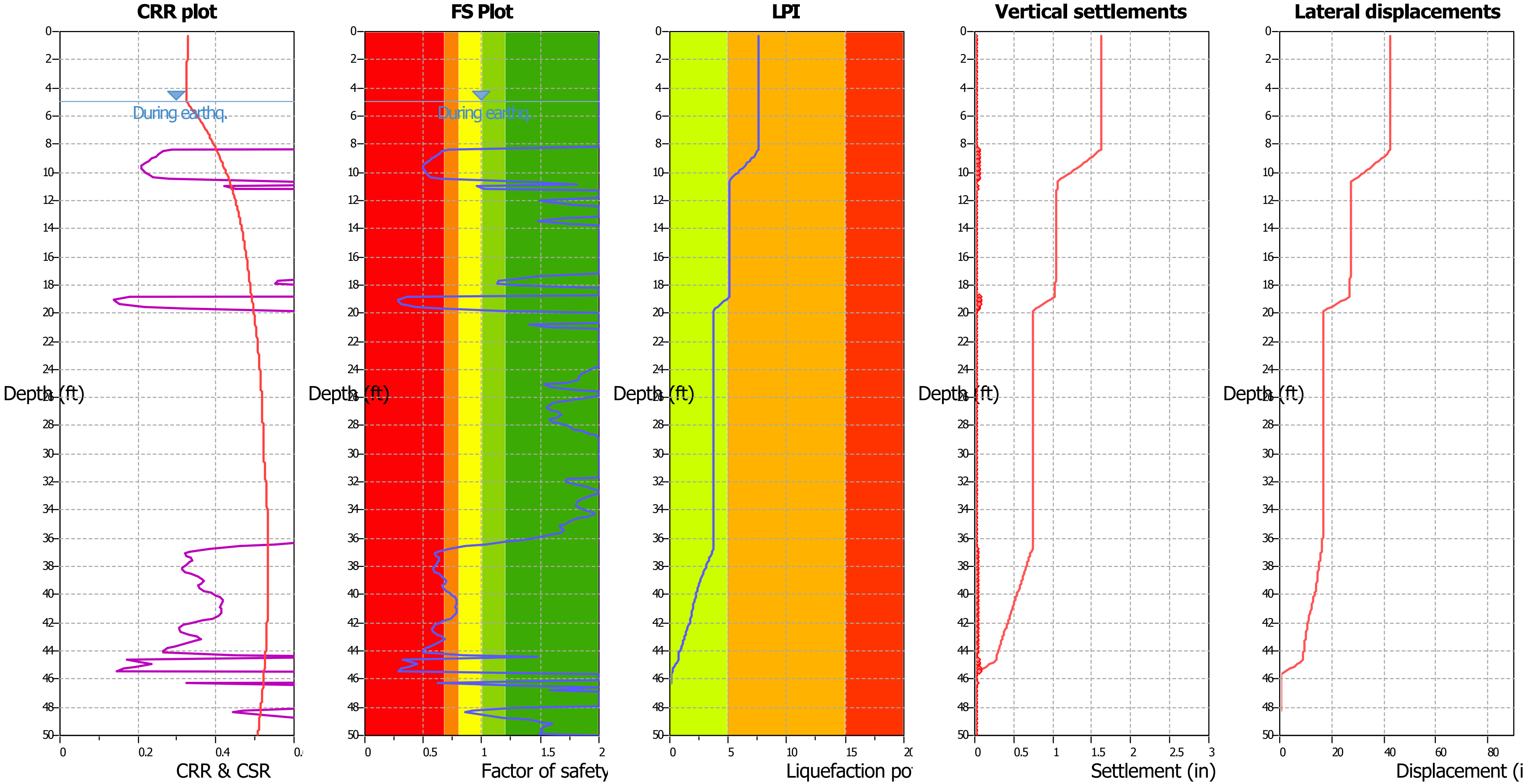
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

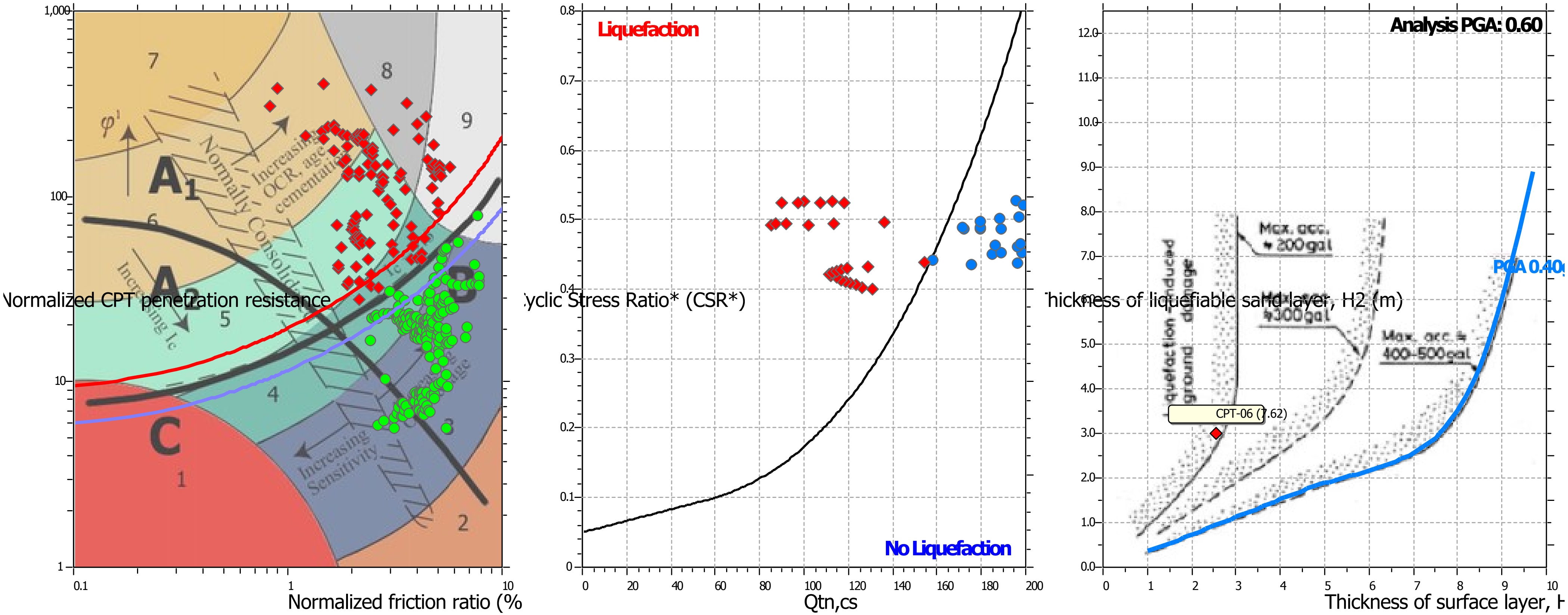
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

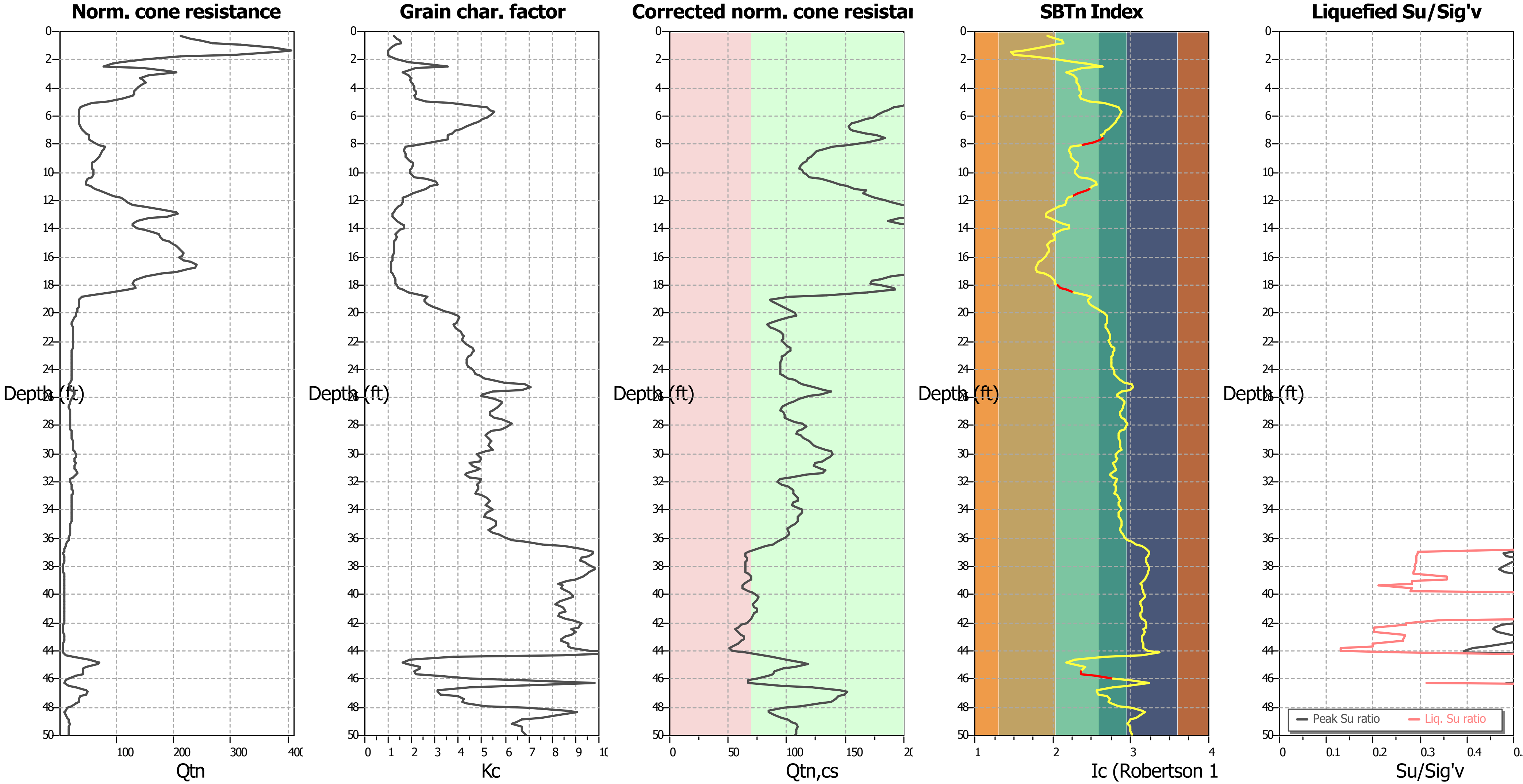
Liquefaction analysis summary plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

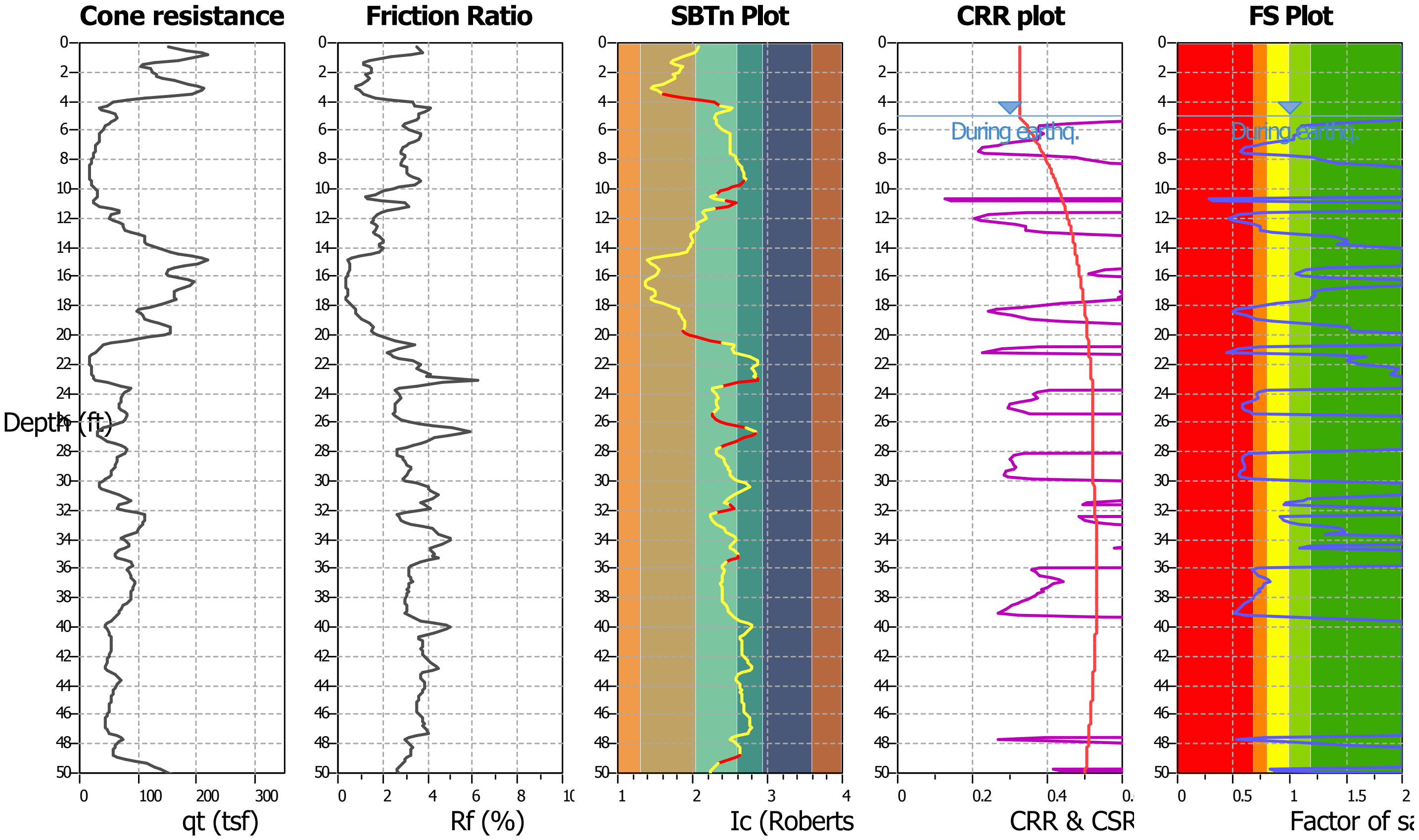
LIQUEFACTION ANALYSIS REPORT

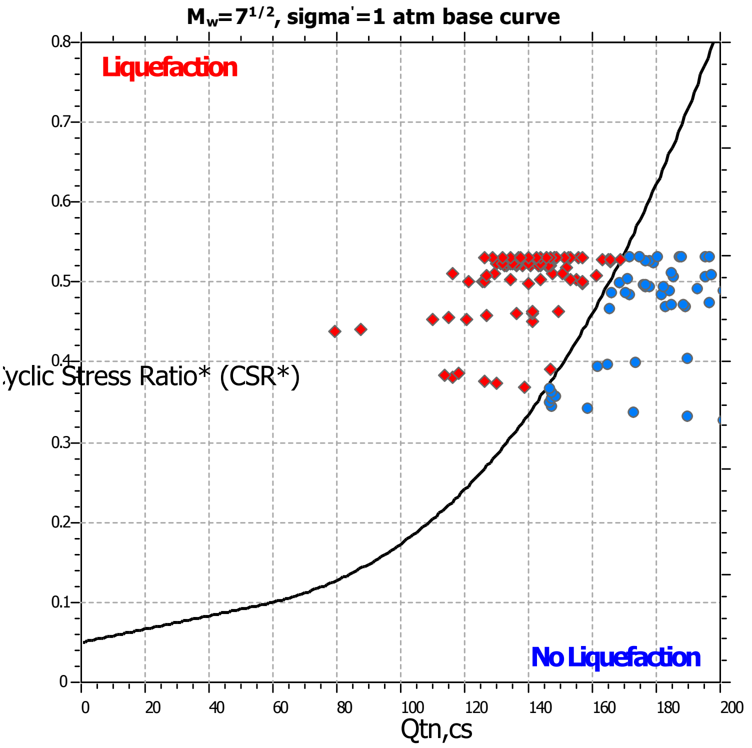
Project title : East D Street **Location : Petaluma, CA**

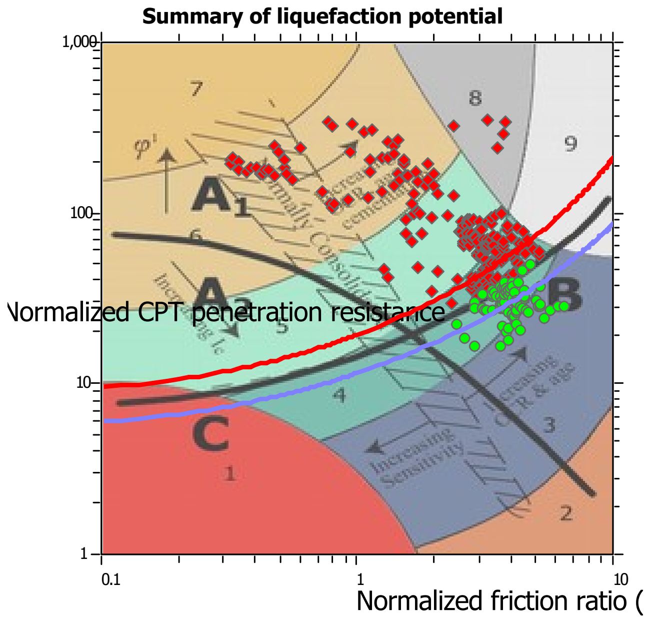
CPT file : CPT-07

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

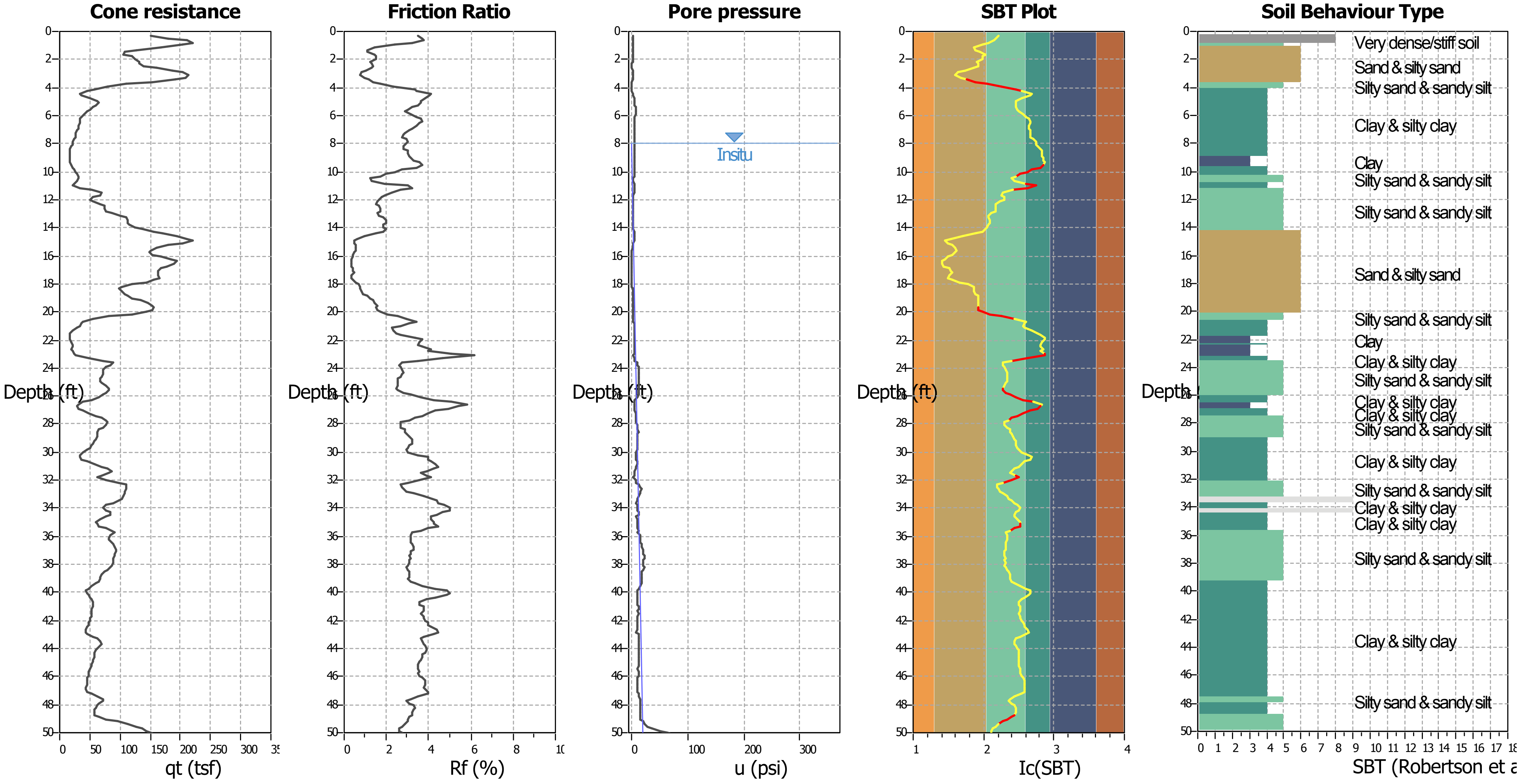






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



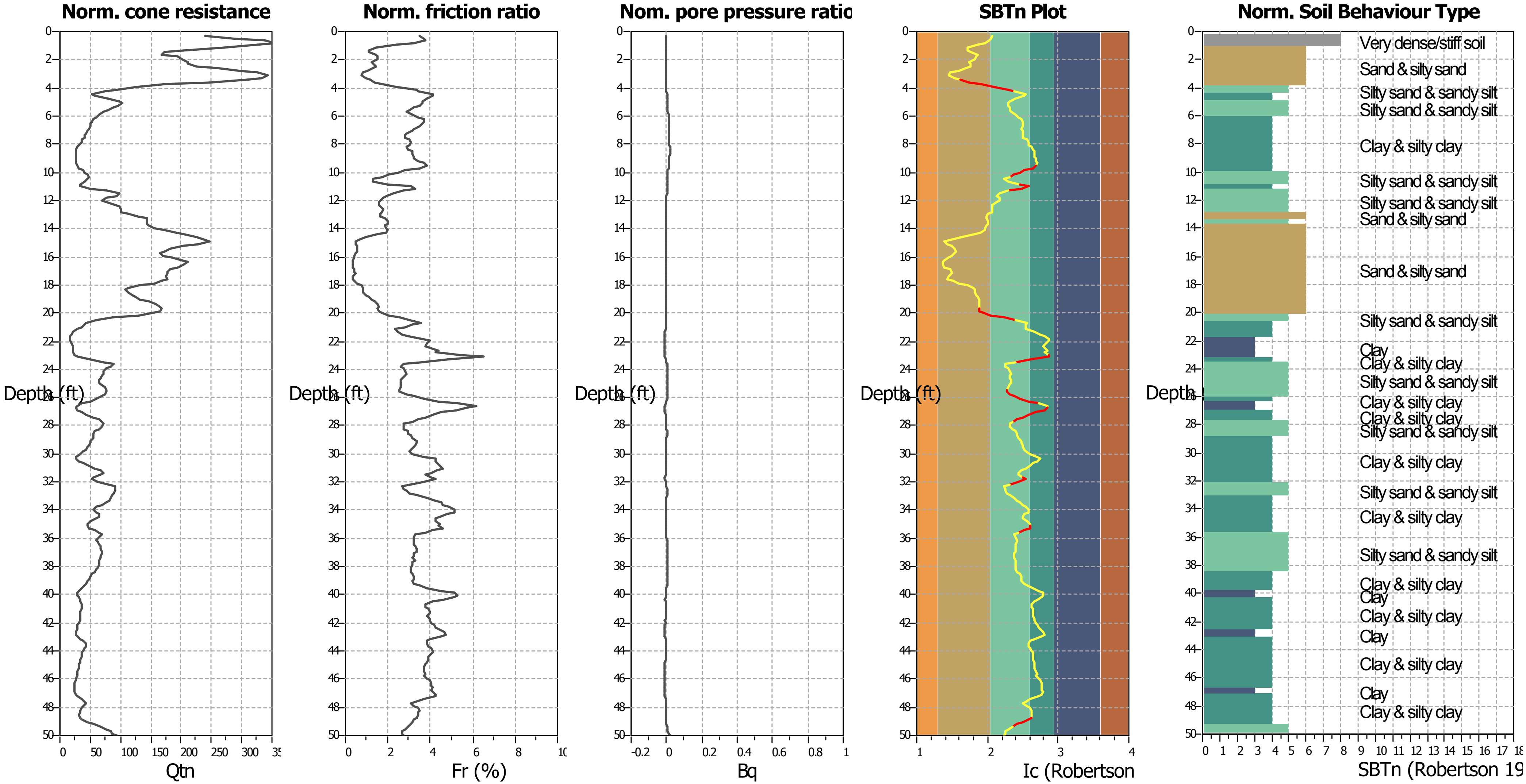
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A		
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes		
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes		
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils		
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes		
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft		

SBT legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

CPT basic interpretation plots (normalized)



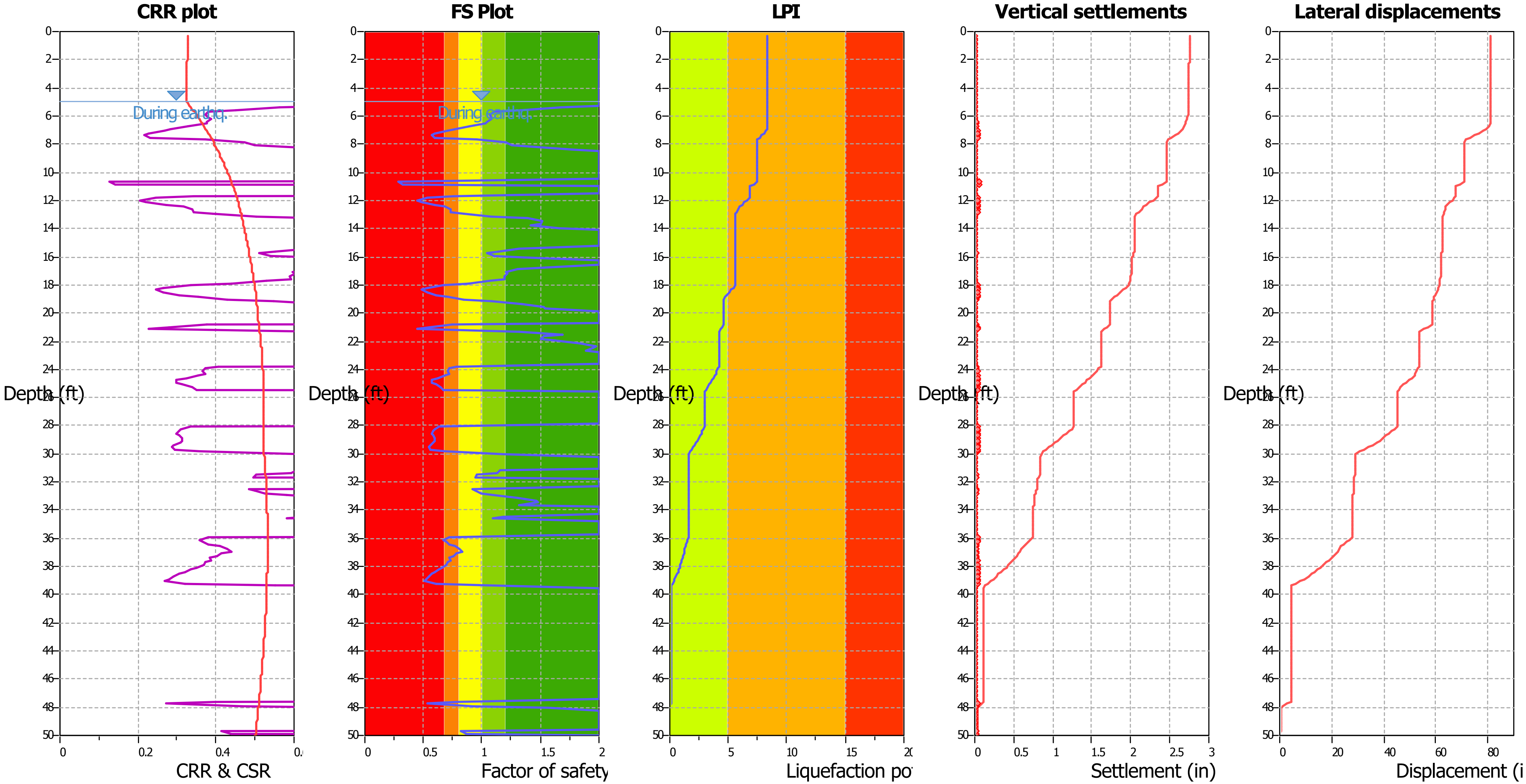
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

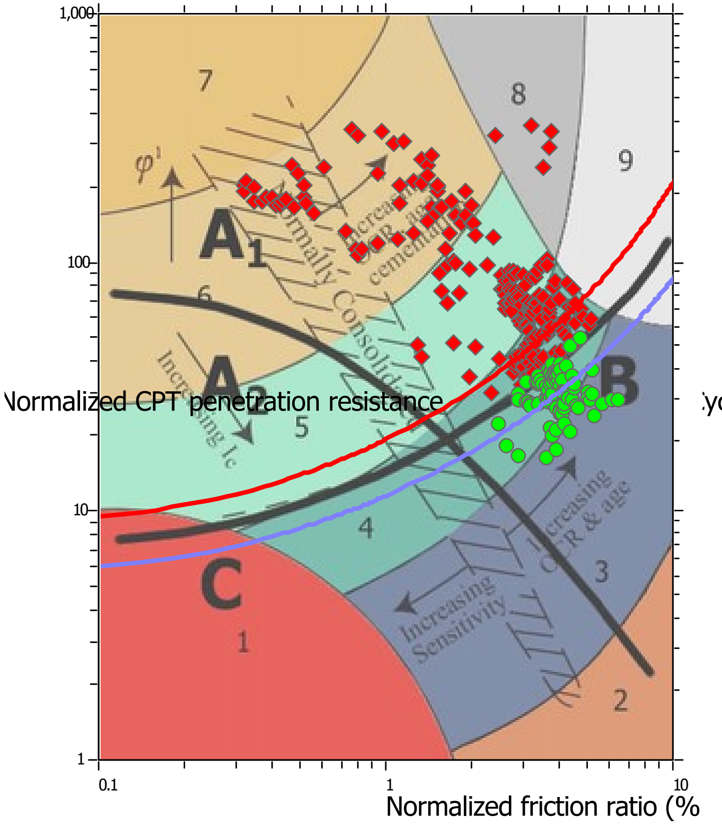
F.S. color scheme

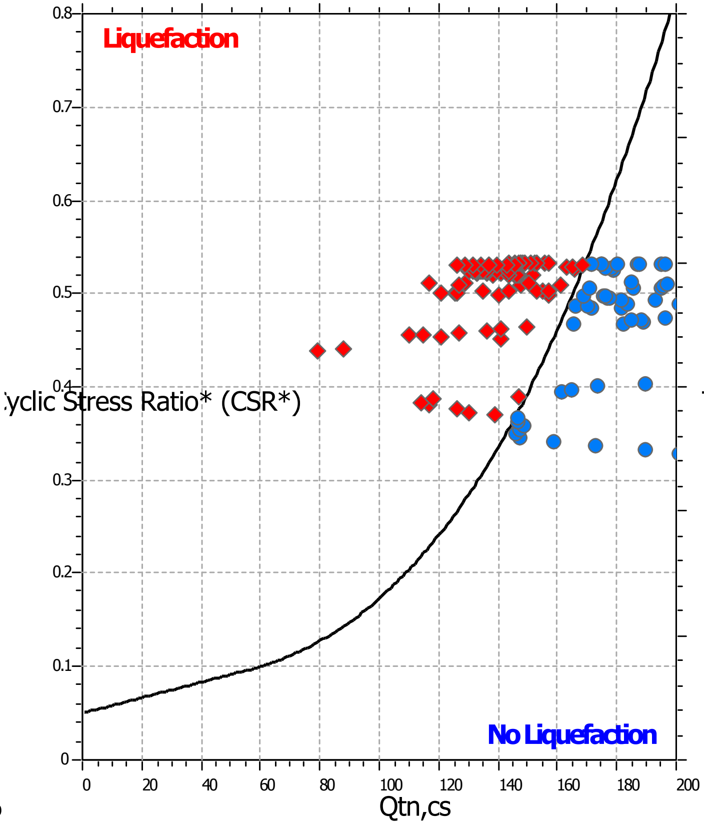
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

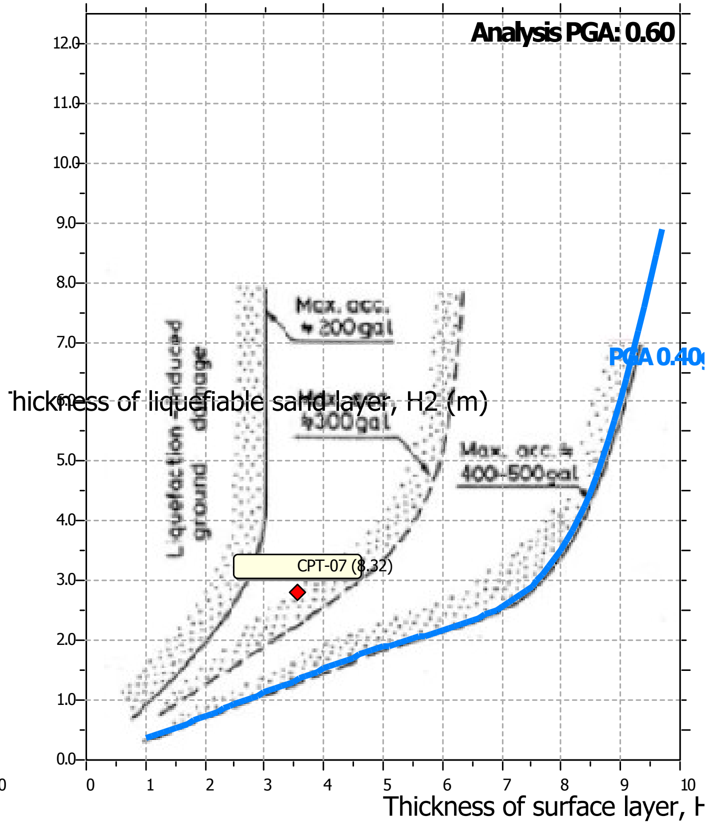
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



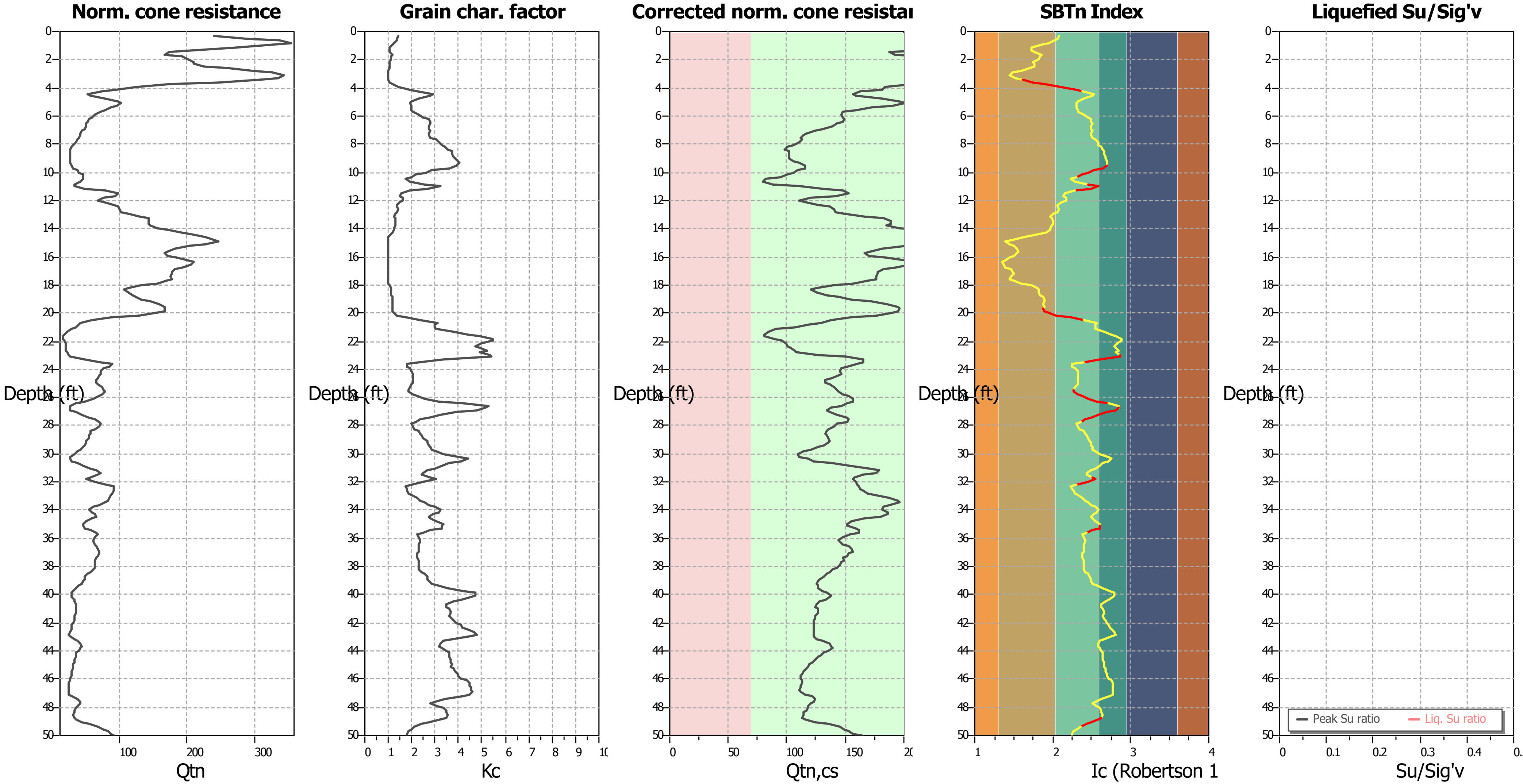




Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Berlogar, Stevens & Associates, Inc.
Pleasanton, California

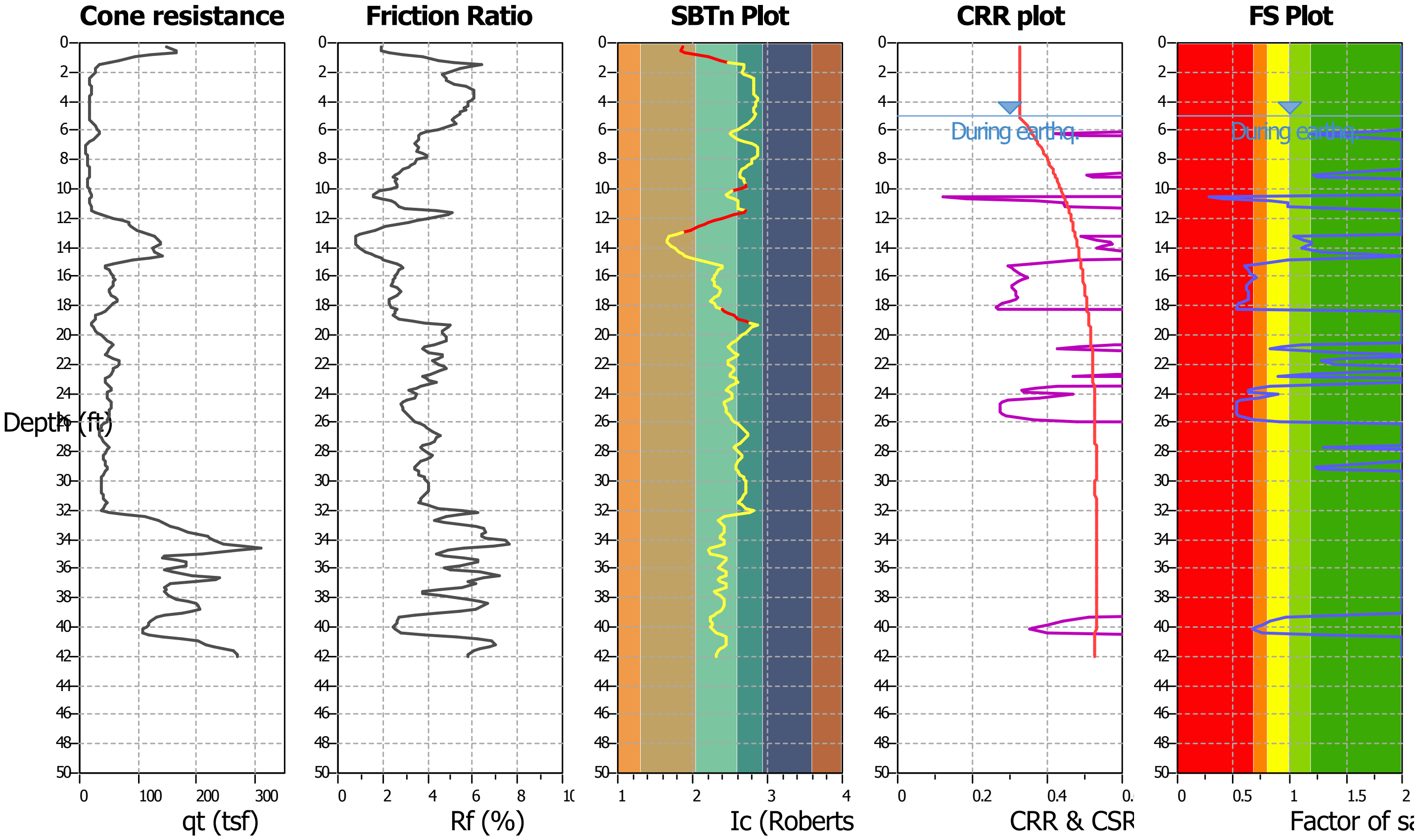
LIQUEFACTION ANALYSIS REPORT

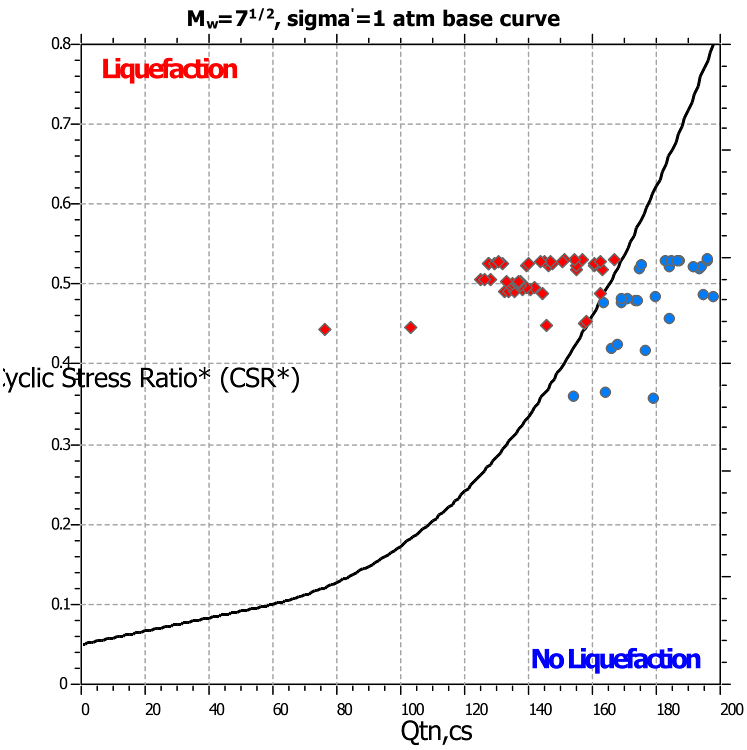
Project title : East D Street **Location : Petaluma, CA**

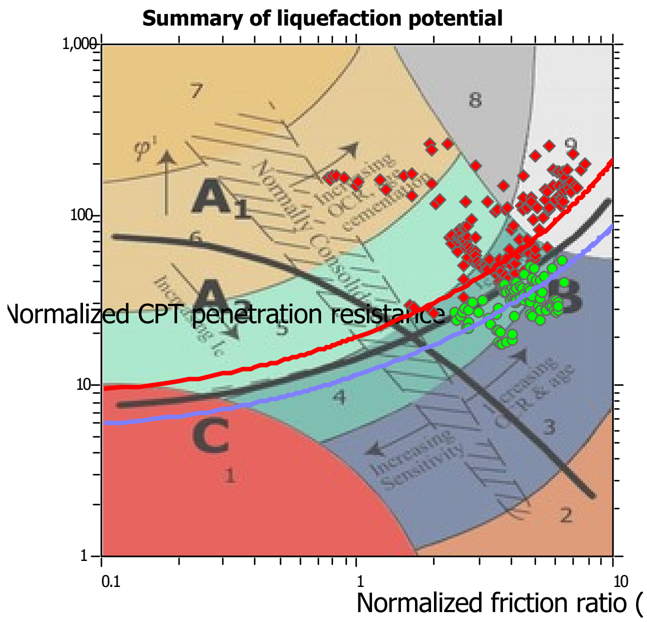
CPT file : CPT-08

Input parameters and analysis data

Analysis method:	Robertson (2009)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	All soils
Fines correction method:	Robertson (2009)	G.W.T. (earthq.):	5.00 ft	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	50.00 ft
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.60	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

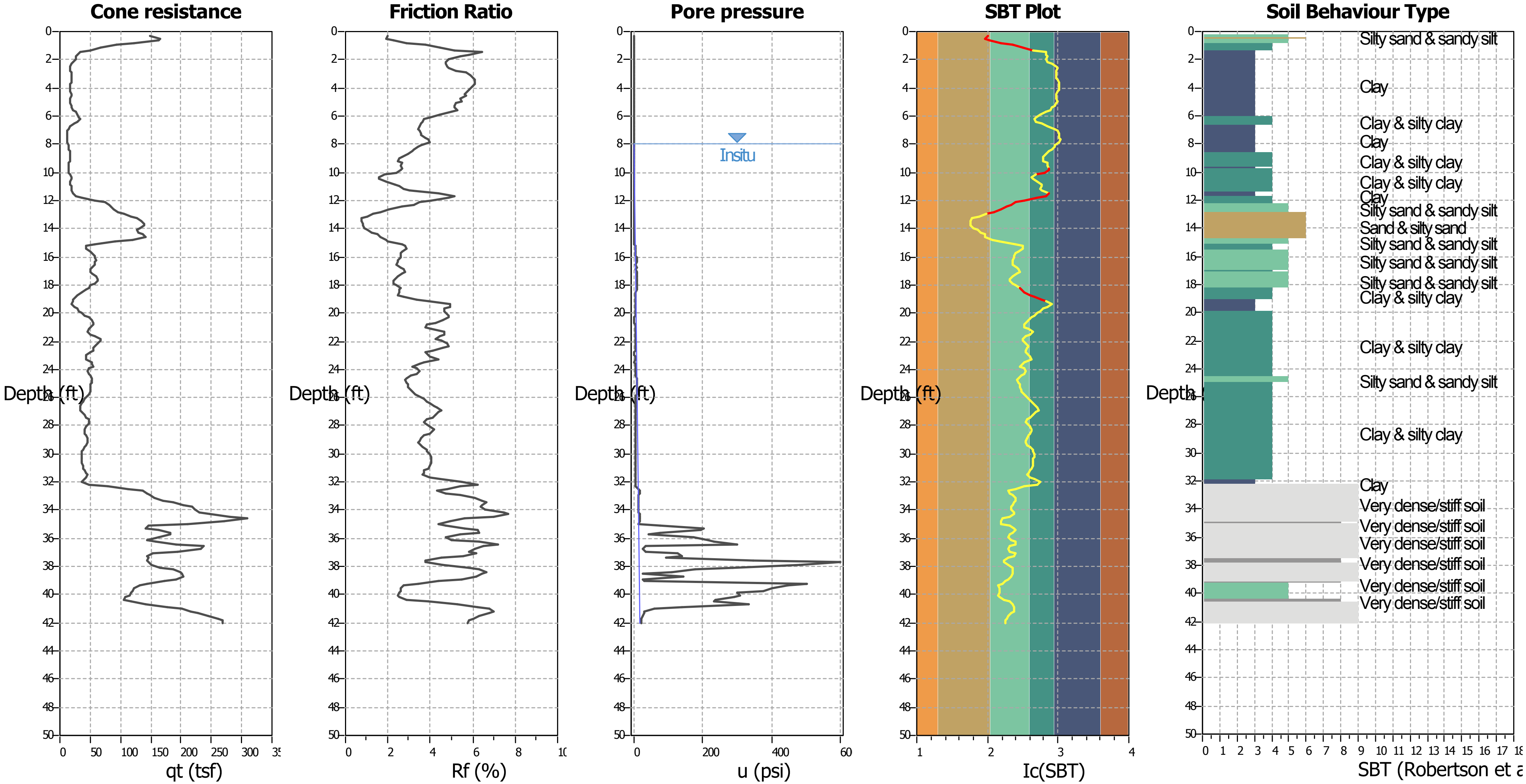






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



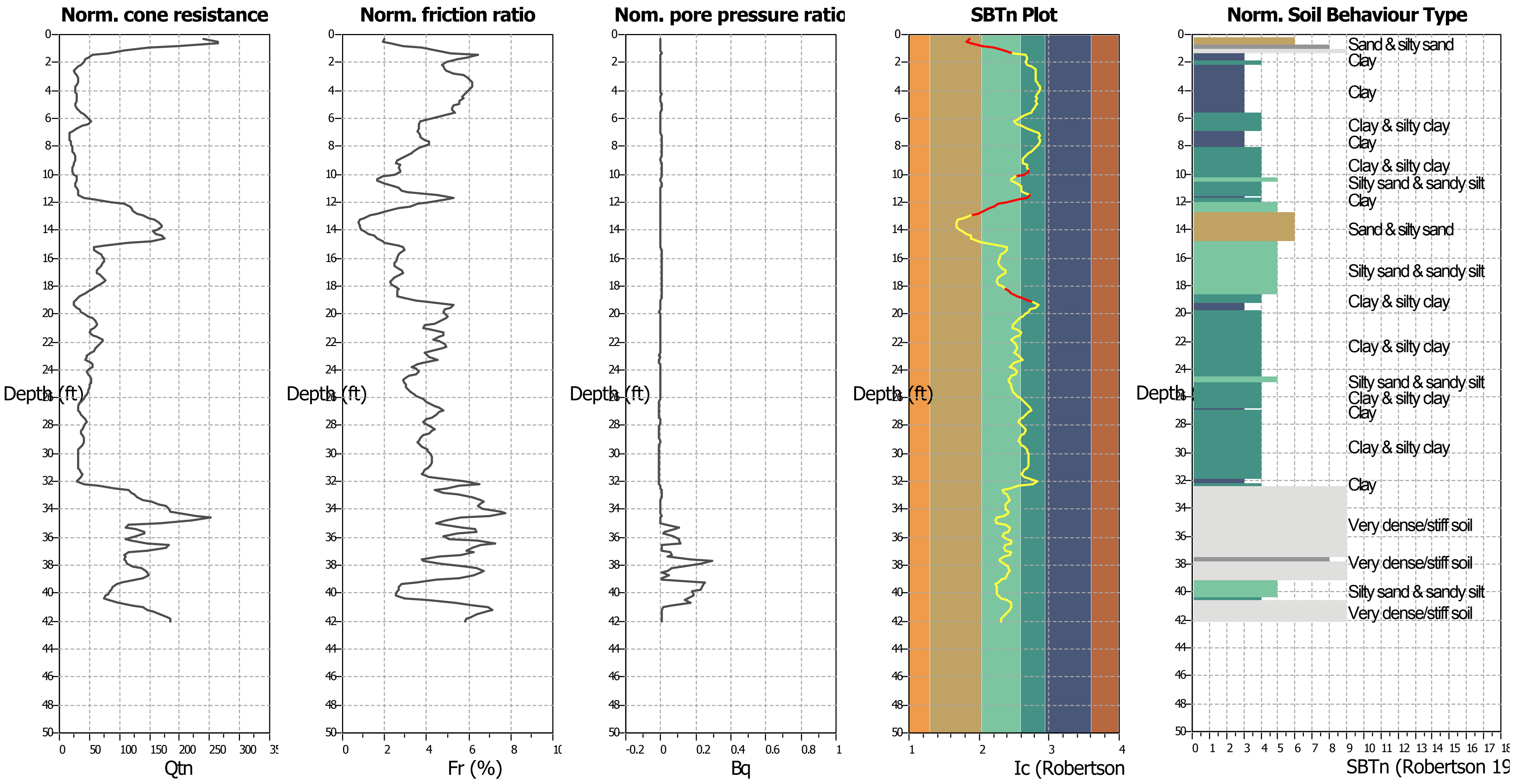
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A		
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes		
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes		
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils		
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes		
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft		

SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

CPT basic interpretation plots (normalized)



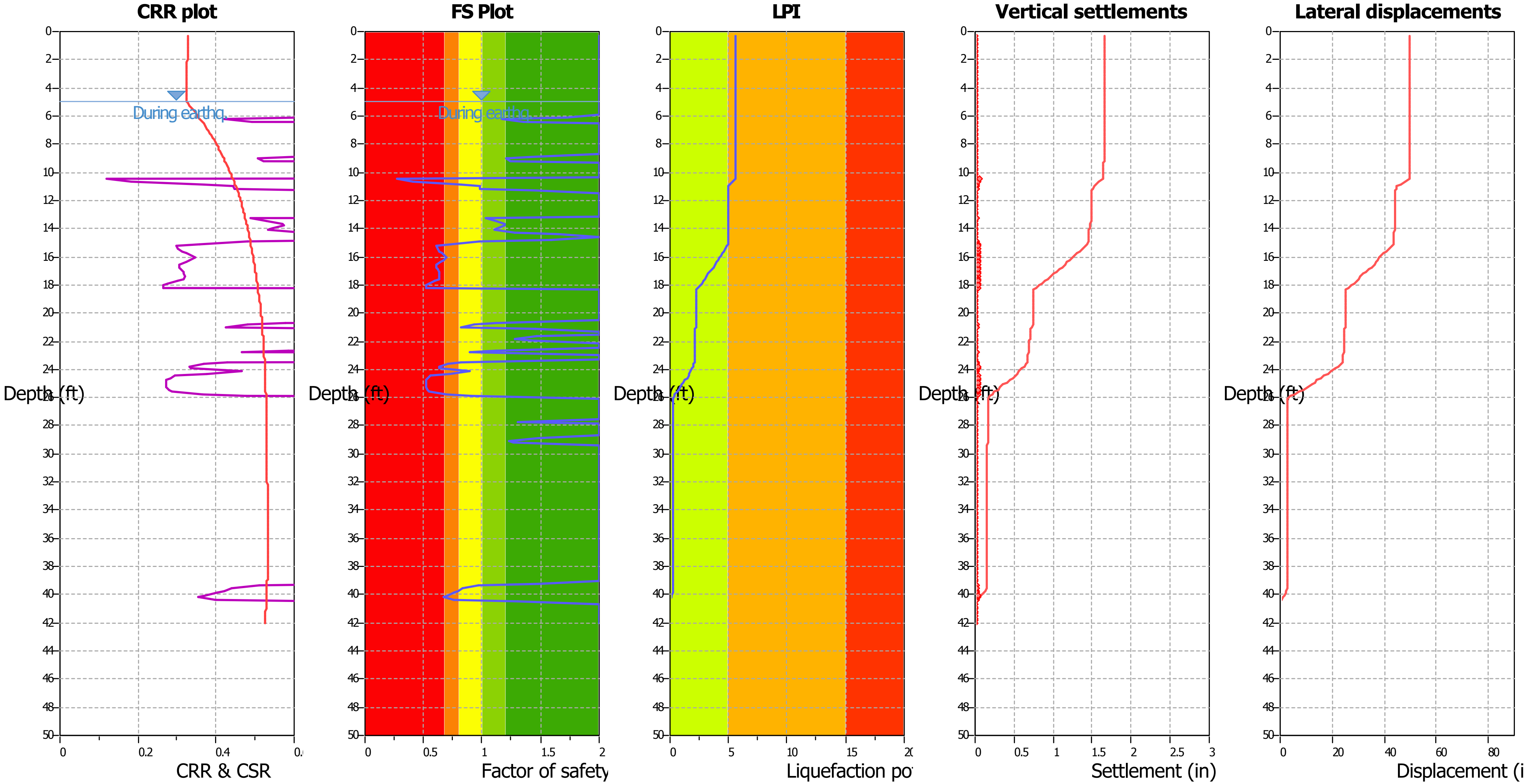
Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

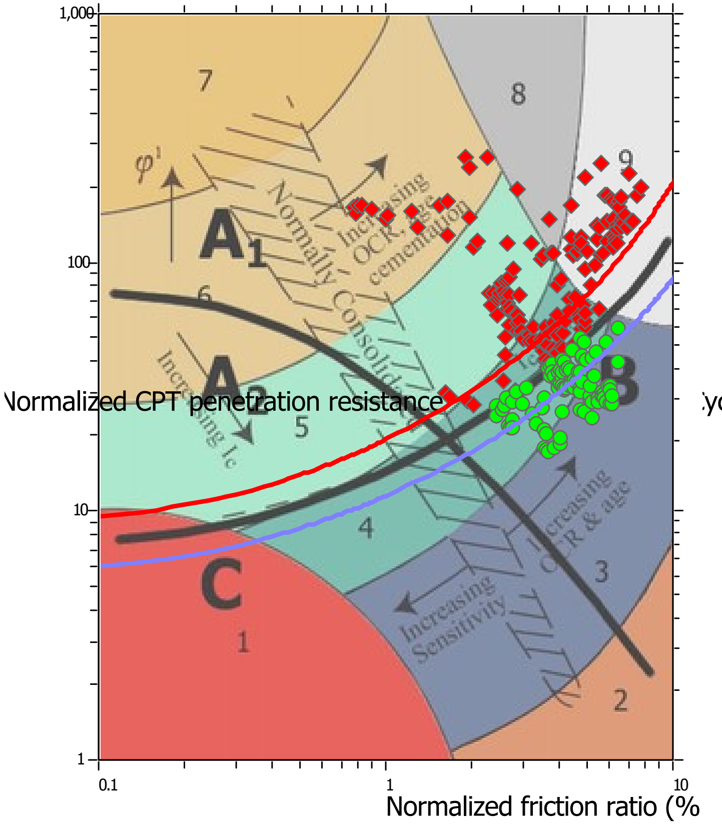
F.S. color scheme

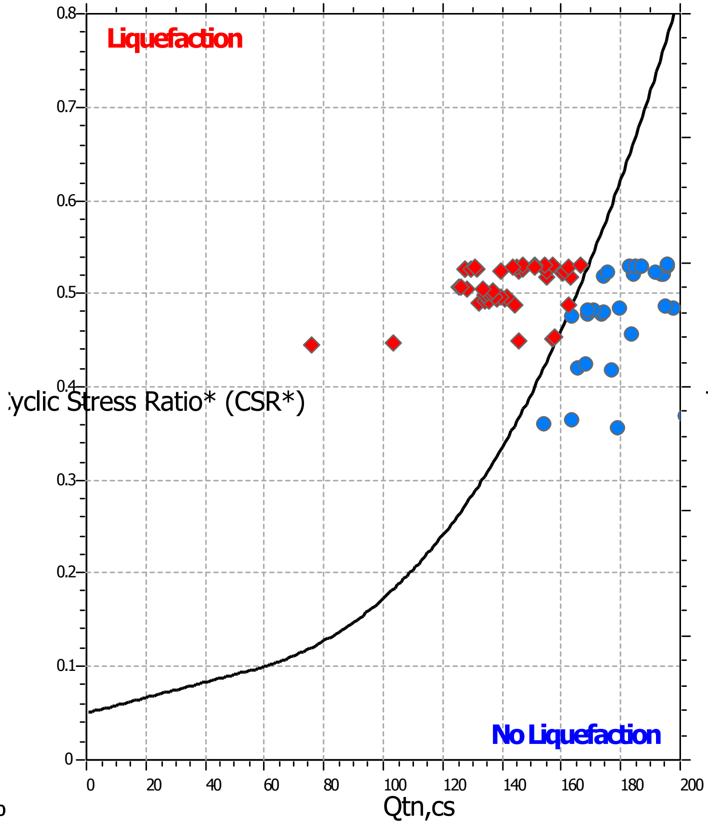
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

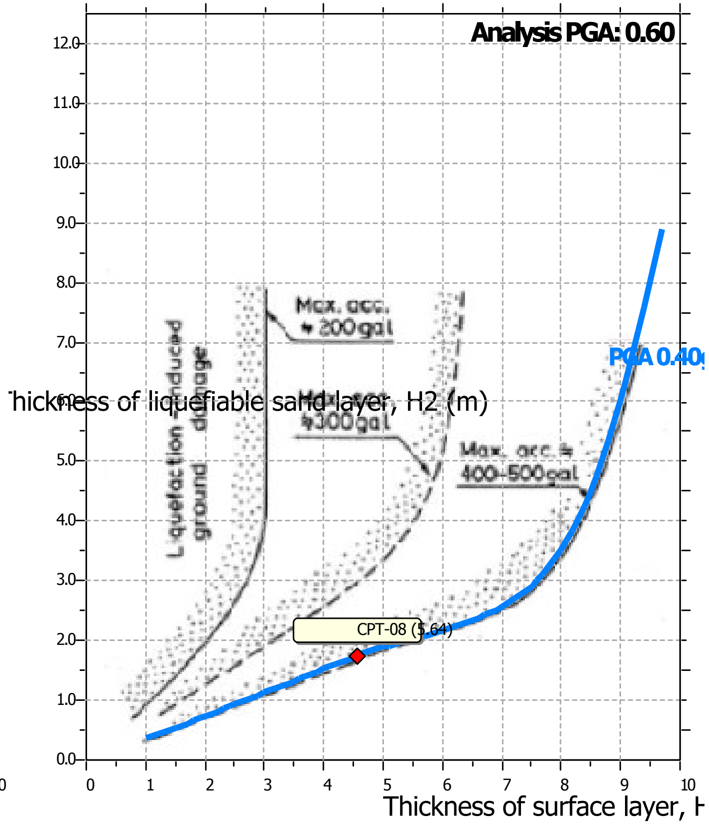
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



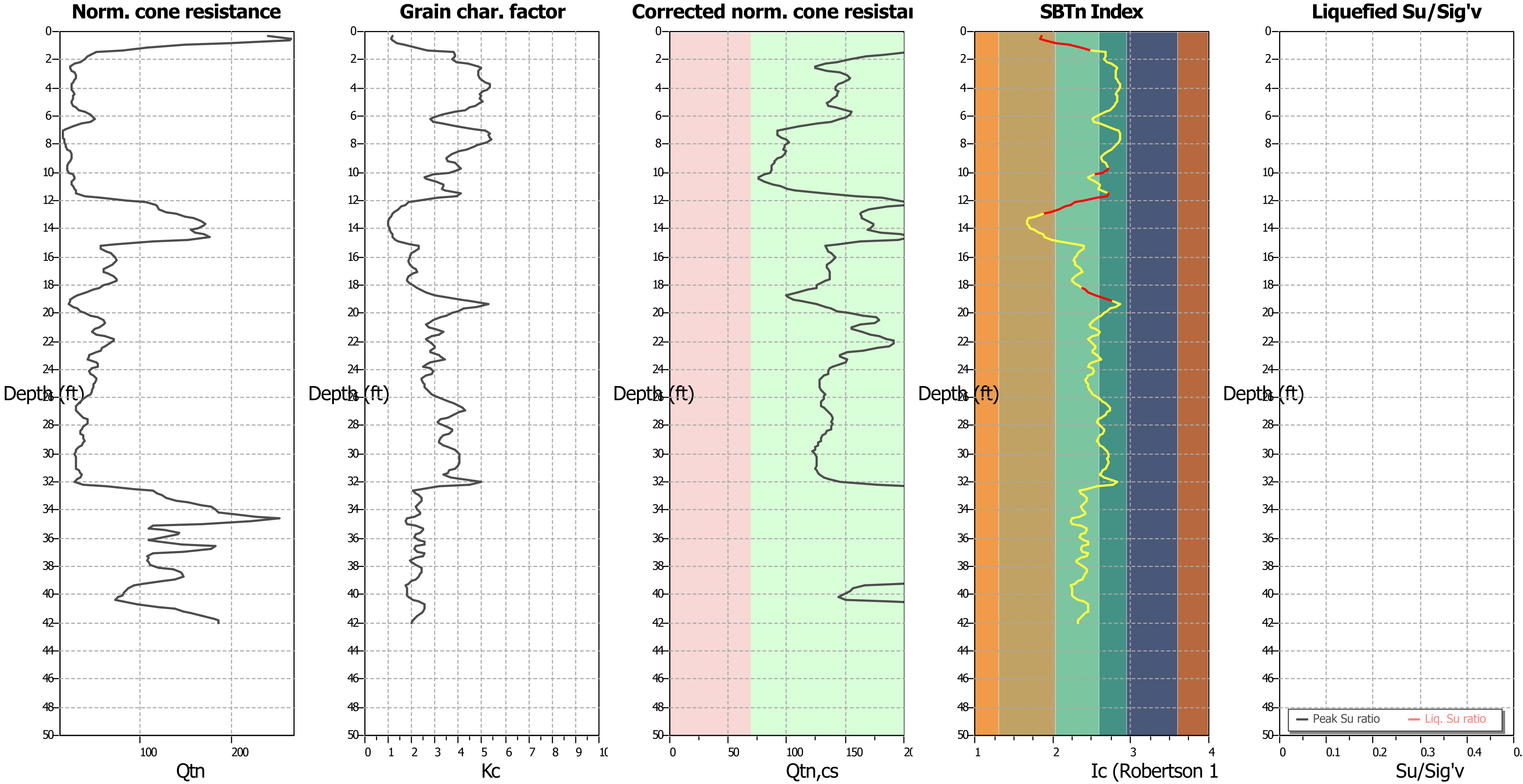




Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Robertson (2009)	Depth to water table (erthq.):	5.00 ft	Fill weight:	N/A
Fines correction method:	Robertson (2009)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	All soils
Peak ground acceleration:	0.60	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	50.00 ft