Appendix 4.7-A – Preliminary Geotechnical Engineering Report

Preliminary Geotechnical Engineering Report

Gates Substation
Huron, California
April 23, 2019
Terracon Project No. NA195027

Prepared for:
LS Power Development, LLC
Chesterfield, MO

Prepared by:
Terracon Consultants, Inc.
Lodi, California

April 23, 2019

LS Power Development, LLC
16150 Main Circle Drive, Suite 310
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Attn: Jim Anderson, P.E.
P: (636) 534-3318
E: JAnderson@LSPower.com

Re: Preliminary Geotechnical Engineering Report
Gates Substation
West Jayne Avenue
Huron, California
Terracon Project No. NA195027

Dear Mr. Anderson:

We have completed the Preliminary Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. PNA195027 dated March 14, 2019. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,

Terracon Consultants, Inc.

REGISTERED PROFESSIONAL ENGINEER FREDERICK MAURER JR. No. 2035 Exp. 6/22 GEOTECHNICAL STATE OF CALIFORNIA

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Note: This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the ***GeoReport*** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES
SITE LOCATION AND EXPLORATION PLANS
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SUPPORTING INFORMATION

Note: Refer to each individual Attachment for a listing of contents.

REPORT SUMMARY

Topic [1]	Overview Statement [2]
Project Description	The project will consist of adding several structures to the north of the existing substation. The project will include 1-2 A-frame structures for a 500kV tower, a transformer pad for the 500kV tower, a control building that will house specialized equipment, and some other lightly loaded buildings.
Geotechnical Characterization	■ Subsurface materials encountered within the vicinity of the proposed substation improvements generally consisted of interbedded medium stiff to stiff silt with variable sand, still to very stiff lean clay with variable silt, and loose to medium dense silty sand with variable gravel to depths of 41 to 45 feet, underlain by medium dense to very dense poorly graded to silty sand with variable gravel to the maximum depth explored of 51½ feet. ■ Groundwater was not encountered at any time during our investigation.
Earthwork	Earthwork for this project will consist of some over-excavation and recompaction beneath the proposed structures, as discussed within the body of this report.
Shallow Foundations	■ The proposed mechanical and electrical equipment for the proposed substation may be supported on either a reinforced concrete mat slab foundation or shallow spread footing foundations. ■ The control building and lightly loaded ancillary structures may be supported on shallow spread footing foundations.
Deep Foundations	The proposed A-frame tower structures may be supported on cast-in-place drilled pier foundations.
General Comments	This section contains important information about the limitations of this preliminary geotechnical engineering report and indicates that we will be performing supplemental geotechnical investigation of the project site and providing a supplemental geotechnical engineering report at the time of final design.

1. If the reader is reviewing this report as a pdf, the topics above can be used to access the appropriate section of the report by simply clicking on the topic itself.
2. This summary is for convenience only. It should be used in conjunction with the entire report for design purposes.

Preliminary Geotechnical Engineering Report

Gates Substation
West Jayne Avenue
Huron, California
Terracon Project No. NA195027
April 23, 2019

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed Gates Substation improvements to be located on West Jayne Avenue in Huron, California. The purpose of these services is to provide information and preliminary geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Site preparation and earthwork
- Seismic site classification per 2016 CBC
- Foundation design and construction
- Floor slab design and construction
- Excavation considerations

The geotechnical engineering Scope of Services for this project included the advancement of two (2) test borings to depths of approximately 51½ feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs and as separate graphs in the **Exploration Results** section.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	■ The project is located on the north side of West Jayne Avenue near Huron, California. ■ The approximate coordinates of the site are 36.1456°N and 120.1263°W See **Site Location**
Existing Improvements	The project site is an existing substation. The location of the proposed improvements currently consists of agricultural land.

Item	Description
Current Ground Cover	Vineyard.
Existing Topography	Relatively flat.
Geology	■ The site is located in the Great Valley Geomorphic Province of California. The Great Valley is characterized mainly by sedimentary strata emanating from the denudation of the bounding mountain ranges, the Sierra Nevada and Coast Ranges. ■ The surface geology at the site is characterized as Quaternary Alluvium, which is comprised of alluvial gravel, sand, and clay of valley areas according to the "Geologic Map of the Coalinga and Guijarral Hills Quadrangles, California" by the Dibblee Geological Foundation (T.W. Dibblee, 2007, Scale: 1:24,000).

PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Item	Description
Information Provided	Project information was relayed to us from the client through John Romano of Terracon in a series of emails from March 12 through March 15, 2019.
Project Description	The project will consist of adding several structures to the existing substation.
Proposed Structures	The project will include 1-2 A-frame structures for a 500kV tower, a transformer pad for the 500kV tower, a control building that will house specialized equipment, and some other lightly loaded buildings.
Building Construction	We have assumed some of the structures will be lightly loaded wood- or light gauge steel-framed, possible concrete masonry unit (CMU) block wall exteriors with concrete slab-on-grade floors.
Finished Floor Elevation	Anticipated to be within 1 to 2 feet of existing grade.
Maximum Loads	■ Walls: 1 to 2 kips per linear foot (klf) ■ Columns: 20 to 30 kips ■ Slabs: 150 pounds per square foot (psf)
Grading/Slopes	We have assumed up to 1 to 2 feet of cut and 1 to 2 feet of fill will be required to develop final grade.

GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section and the GeoModel can be found in the **Figures** section of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	**Silt**	Variable sand, fine to medium grained, brown to light brown, medium stiff to very stiff
2	**Silty Sand**	With variable gravel, fine to coarse grained, light brown, loose to medium dense
3	**Lean to Silty Clay**	Fine grained, low plasticity, light brown and tan to dark brown, stiff to very stiff.
4	**Poorly Graded to Silty Sand**	Fine to coarse grained, subangular gravel, tan and brown to light brown, medium dense to very dense

Groundwater

The boreholes were observed while drilling and after completion for the presence and level of groundwater. Groundwater was not encountered in our test borings while drilling, or for the short duration the borings remained open.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structures may be higher or lower than anticipated. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

SEISMIC CONSIDERATIONS

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the 2016 California Building Code (CBC). Based on the soil properties encountered at the site and as described on the exploration logs and results, it is our professional opinion that the **Seismic Site Classification is D**. Subsurface explorations at this site were extended to a maximum depth of 51½ feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

LIQUEFACTION

Liquefaction is a mode of ground failure that results from the generation of high pore water pressures during earthquake ground shaking, causing loss of shear strength. Liquefaction is typically a hazard where loose sandy soils or non-plastic fine-grained soils exist below groundwater. The California Geologic Survey (CGS) has designated certain areas within California as potential liquefaction hazard zones. These are areas considered at a risk of liquefaction-related ground failure during a seismic event, based upon mapped surficial deposits and the presence of a relatively shallow water table. The project site is not located within a liquefaction hazard zone mapped by the CGS.

FIELD SOIL RESISTIVITY TESTING

Field Measurements of soil resistivity were performed on April 4th and 5th, 2019 in general accordance with ASTM Test Method G-57, and IEEE Standard 81, using the Wenner Four-Electrode Method. The soil resistivity testing was performed near the center of the test locations identified in the Exploration Plan provided in **Site Location and Exploration Plans**. The Wenner arrangement (equal electrode spacing) was used with the "a" spacing incrementally increasing. The "a" spacing is generally considered to be the depth of influence of the test.

A total of ten (10) in-situ electrical resistivity tests were performed at the project site with "a" spacings of 1, 2.5, 5, 10, 15, 20, 30, and 50 feet. Test results are presented in the table below:

a-Spacing		B-1 North-South Measured Resistance	B-1 North-South Apparent Resistivity	B-1 East-West Measured Resistance	B-1 East-West Apparent Resistivity
[feet]	[cm]	[Ohms]	[Ohms-cm]	[Ohms]	[Ohms-cm]
1	30.48	11.03	2,112	11.28	2,160
2.5	76.20	5.08	2,434	4.80	2,296
5	152.40	2.26	2,165	2.24	2,144
10	304.80	1.18	2,250	1.10	2,097
15	457.20	0.88	2,534	0.82	2,356

a-Spacing		B-1 North-South Measured Resistance	B-1 North-South Apparent Resistivity	B-1 East-West Measured Resistance	B-1 East-West Apparent Resistivity
[feet]	[cm]	[Ohms]	[Ohms-cm]	[Ohms]	[Ohms-cm]
20	609.60	0.72	2,742	0.66	2,513
30	914.40	0.47	2,695	0.47	2,677
50	1524.00	0.31	2,959	0.28	2,643

GEOTECHNICAL OVERVIEW

The near surface, medium stiff silt soils could become unstable with typical earthwork and construction traffic, especially after precipitation events. Effective site drainage should be completed early in the construction sequence and maintained after construction to avoid potential issues. If possible, the grading should be performed during the warmer and drier times of the year. If grading is performed during the winter months, an increased risk for possible undercutting and replacement of unstable subgrade will persist. Additional site preparation recommendations, including subgrade improvement and fill placement, are provided in the **Earthwork** section.

The proposed mechanical and electrical equipment for the proposed substation may be supported on either a reinforced concrete mat slab foundation or shallow spread footing foundation. The control building and lightly loaded ancillary structures may be supported on shallow spread footing foundations. The **Shallow Foundations** section addresses support of the building bearing on native soils recompacted as engineered fill. The **Floor Slabs** section addresses slab-on-grade support of the building.

The **General Comments** section provides an understanding of the report limitations.

EARTHWORK

The following recommendations include site preparation, excavation, subgrade preparation and placement of engineered fills on the project. The recommendations presented for design and construction of earth supported elements including foundations and slabs are contingent upon following the recommendations outlined in this section.

Earthwork on the project should be observed and evaluated by Terracon. The evaluation of earthwork should include observation and testing of engineered fill, subgrade preparation, foundation bearing soils, and other geotechnical conditions exposed during the construction of the project.

Site Preparation

Strip and remove existing vegetation, debris, and other deleterious materials from proposed structure areas. Exposed surfaces should be free of mounds and depressions which could prevent uniform compaction. The site should be initially graded to create a relatively level surface to receive fill and provide for a relatively uniform thickness of fill beneath proposed building structures.

Subgrade Preparation

Due to the low bearing capacity of the near surface soils, foundations and floor slabs should bear on engineered fill. Engineered fill should extend to a minimum depth of 12 inches below the bottom of foundations, or 2 feet below existing grades, whichever is greater. Grading for the proposed substation improvements should incorporate the limits of the improvement footprints plus a lateral distance of 5 feet beyond the outside edge of perimeter footings.

Subgrade soils beneath exterior slabs should be scarified, moisture conditioned, and compacted to a minimum depth of 10 inches. The moisture content and compaction of subgrade soils should be maintained until slab construction.

Exposed areas which will receive fill, once properly cleared and benched where necessary, should be scarified to a minimum depth of 10 inches, moisture conditioned, and compacted per the compaction requirements in this report.

Based upon the subsurface conditions determined from the geotechnical exploration, subgrade soils exposed during construction are anticipated to be relatively workable. However, the workability of the subgrade may be affected by precipitation, repetitive construction traffic or other factors. If unworkable conditions develop, workability may be improved by scarifying and drying.

Fill Material Types

All fill materials should be inorganic soils free of vegetation, debris, and fragments larger than three inches in size. Pea gravel or other similar non-cementitious, poorly-graded materials should not be used as fill or backfill without the prior approval of the geotechnical engineer.

Clean on-site soils or approved imported materials may be used as fill material for the following

- general site grading
- foundation areas
- slab-on-grade floor
- foundation backfill
- trench backfill
- exterior slabs-on-grade

Imported soils for use as fill material within proposed building and structure areas should conform to low volume change materials as indicated in the following specifications:

Gradation	Percent Finer by Weight (ASTM C 136)
3”	100
No. 4 Sieve	50-100
No. 200 Sieve	10-40

- Liquid Limit .... 30 (max)
- Plasticity Index .... 15 (max)
- Maximum expansion index* .... 20 (max)

*ASTM D 4829

The contractor shall notify the Geotechnical Engineer of import sources sufficiently ahead of their use so that the sources can be observed and approved as to the physical characteristic of the import material. For all import material, the contractor shall also submit current verified reports from a recognized analytical laboratory indicating that the import has a "not applicable" (Class S0) potential for sulfate attack based upon current ACI criteria and is "mildly corrosive" to ferrous metal and copper. The reports shall be accompanied by a written statement from the contractor that the laboratory test results are representative of all import material that will be brought to the job.

Engineered fill should be placed and compacted in horizontal lifts, using equipment and procedures that will produce recommended moisture contents and densities throughout the lift. Fill lifts should not exceed 10 inches loose thickness.

Fill Compaction Requirements

Recommended compaction and moisture content criteria for engineered fill materials are as follows:

Material Type and Location	Per the Modified Proctor Test (ASTM D 1557)		
	Minimum Compaction Requirement (%)	Range of Moisture Contents for Compaction Above Optimum	
		Minimum	Maximum
On-site soils and low volume change imported fill:			
Beneath foundations:	90	0%	+3%
Beneath interior slabs:	90	0%	+3%

Material Type and Location	Per the Modified Proctor Test (ASTM D 1557)		
	Minimum Compaction Requirement (%)	Range of Moisture Contents for Compaction Above Optimum	
		Minimum	Maximum
Utility Trenches*:	90	0%	+3%
Bottom of excavation receiving fill:	90	0%	+3%

* Upper 12 inches should be compacted to 95% within structural areas. Low-volume change imported soils should be used in structural areas.

We recommend that compacted native soil or any engineered fill be tested for moisture content and relative compaction during placement. Should the results of the in-place density tests indicate the specified moisture content or compaction requirements have not been met, the area represented by the test should be reworked and retested as required until the specified moisture content and relative compaction requirements are achieved.

Grading and Drainage

All grades must provide effective drainage away from the structures during and after construction and should be maintained throughout the life of the structures. Water retained next to the structures can result in soil movements greater than those discussed in this report. Greater movements can result in unacceptable differential floor slab and/or foundation movements, cracked slabs and walls, and roof leaks. The roof should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet from the building.

Exposed ground should be sloped and maintained at a minimum 5% away from the structures for at least 10 feet beyond the perimeter of the structures. Locally, flatter grades may be necessary to transition ADA access requirements for flatwork. After building construction and landscaping have been completed, final grades should be verified to document effective drainage has been achieved. Grades around the structures should also be periodically inspected and adjusted, as necessary, as part of the structures' maintenance program. Where paving or flatwork abuts the structure, a maintenance program should be established to effectively seal and maintain joints and prevent surface water infiltration.

Earthwork Construction Considerations

Shallow excavations for the proposed structures are anticipated to be accomplished with conventional construction equipment. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of floor slabs. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation and topsoil, proofrolling, and mitigation of areas delineated by the proofroll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked, as necessary, until approved by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 1,000 square feet of compacted fill in the structure areas. One density and water content test should be performed for every 50 linear feet of compacted utility trench backfill.

In areas of foundation excavations, the bearing subgrade should be evaluated under the direction of the Geotechnical Engineer. If unanticipated conditions are encountered, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

SHALLOW FOUNDATIONS

If the site has been prepared in accordance with the requirements noted in **Earthwork**, the following design parameters are applicable for shallow foundations.

Design Parameters – Compressive Loads

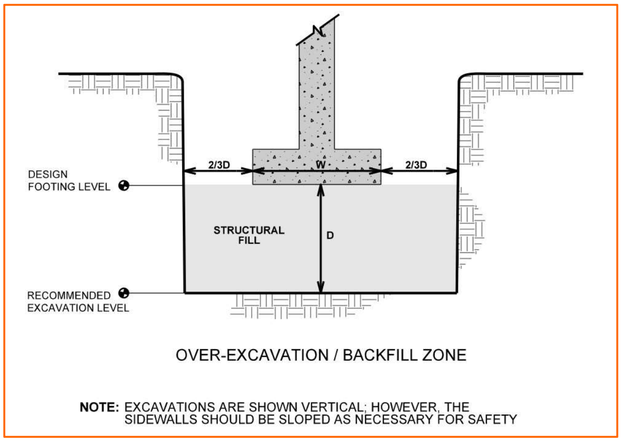
Item	Description
Maximum Net Allowable Bearing pressure [1, 2]	2,500 psf
Required Bearing Stratum [3]	12 inches of native soils recompacted as engineered fill.
Minimum Foundation Dimensions	Columns: 24 inches Continuous: 12 inches
Maximum Foundation Dimensions	Columns: 72 inches Continuous: 24 inches
Ultimate Passive Resistance [4] (equivalent fluid pressures)	350 pcf
Ultimate Coefficient of Sliding Friction [5]	0.30
Minimum Embedment below Finished Grade [6]	12 inches
Estimated Total Settlement from Structural Loads [2]	Less than about 1 inch
Estimated Differential Settlement [2, 7]	About 2/3 of total settlement

1. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. An appropriate factor of safety has been applied. These bearing pressures can be increased by 1/3 for transient loads unless those loads have been factored to account for transient conditions. Values assume that exterior grades are relatively flat around the structure.
2. Values provided are for maximum loads noted in **Project Description**.
3. Unsuitable or soft soils should be over-excavated and replaced per the recommendations presented in the **Earthwork**.
4. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted structural fill be placed against the vertical footing face. If passive resistance is used to resist lateral loads, the base friction should be reduced by 25 percent.
5. Can be used to compute sliding resistance where foundations are placed on suitable soil/materials. Should be neglected for foundations subject to net uplift conditions.
6. Embedment necessary to minimize the effects of seasonal water content variations. Finished grade is defined as the lowest adjacent grade within five feet of the foundation for perimeter (exterior) footings.
7. Differential settlements are as measured over a span of 50 feet.

Shallow Spread Footing Foundation Construction Considerations

As noted in **Earthwork**, the footing excavations should be evaluated under the direction of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the footing excavations should be removed/reconditioned before foundation concrete is placed.

Over-excavation for structural fill placement below footings should be conducted as shown below. The over-excavation should be backfilled up to the footing base elevation, with engineered fill placed, as recommended in the **Earthwork** section.



To ensure foundations have adequate support, special care should be taken when footings are located adjacent to trenches. The bottom of such footings should be at least 1 foot below an imaginary plane with an inclination of 1.5 horizontal to 1.0 vertical extending upward from the nearest edge of the adjacent trench.

MAT FOUNDATIONS

Substation improvements may be supported on mat slab foundations. If the site has been prepared in accordance with the requirements noted in **Earthwork** and the mat foundation rests on a minimum of 12 inches of over excavated native soils that have been recompacted as engineered fill, the following design parameters are applicable.

Mat Width (feet)[1]	Allowable Bearing Capacity (psf)[2, 3]	Modulus of Subgrade Reaction (pci)[4]
Minimum 6	1,500	150
10 or more	1,000	150

1. Interpolate for mat width between 6 and 10 feet.
2. Factor of safety of 3 or allowable settlement of 1.0 inch
3. These bearing pressures can be increased by 1/3 for transient loads unless those loads have been factored to account for transient conditions.
4. Allowable settlement of 1.0 inch

Since there are several factors that will control the design of mat foundations besides vertical load, Terracon should be consulted when the final foundation depth and width are determined to assist the structural designer in the evaluation of anticipated settlement.

As stated in the table above, a modulus of subgrade reaction (kv) of 150 pounds per cubic inch (pci) may be used for the structural design. Other details including treatment of loose foundation soils, superstructure reinforcement and observation of foundation excavations as outlined in the **Earthwork** section of this report are applicable for the design and construction of a mat foundation at the site.

The subgrade modulus (kv) for the mat is affected by the size of the mat foundation and would vary according the following equation:

kv = Kv1 x (B+1)2 /(4 x B2)

Where: kv is the modulus for the size footing being analyzed
B is the width of the mat foundation.

If using the pseudo-coupled method of mat design, the modulus of subgrade reaction (k_v) values for the perimeter should be twice the central values, and the integral of all the values over the area of the mat should be equal to the average. Terracon should be contacted if additional k_v recommendations are necessary for the pseudo-coupled method.

DEEP FOUNDATIONS

We recommend that the transmission tower structures be supported on a cast-in-drilled-hole (CIDH) concrete pile (drilled shaft) foundation. Recommendations for drilled shaft foundations are presented in the following paragraphs.

Drilled Shaft Design Parameters

Soil design parameters are provided below in the **Drilled Shaft Design Summary** table for the design of drilled shaft foundations. The values presented for allowable side friction and end bearing include a factor of safety. The upper 2 feet of subgrade should be neglected as far as providing support for the drilled pier.

Drilled Shaft Design Summary [1]				
Approximate Elevation (feet)	Stratigraphy [2]		Allowable Skin Friction (psf) [3]	Allowable End Bearing Pressure (psf) [4]
	No.	Material		
2 to 9	1	Silty Sand to Sandy Silt	50	3,500
9 to 14	3	Lean Clay and Silty Clay	400	12,000
14 to 26	2/4	Poorly Graded to Silty Sand	200	12,500

Drilled Shaft Design Summary [1]				
Approximate Elevation (feet)	Stratigraphy [2]		Allowable Skin Friction (psf) [3]	Allowable End Bearing Pressure (psf) [4]
	No.	Material		
26 to 34	3	Lean Clay	260	4,500
34 to 51	4	Poorly Graded to Silty Sand	650	85,000

1. Design capacities are dependent upon the method of installation, and quality control parameters. The values provided are estimates and should be verified when installation protocol have been finalized.
2. See **Subsurface Profile** in **Geotechnical Characterization** for more details on stratigraphy.
3. Applicable for compressive loading only. Reduce to 2/3 of values shown for uplift loading. Effective weight of shaft can be added to uplift load capacity. Skin friction values are calculated for the midpoint of the layer.
4. End bearing capacities are calculated at the bottom of the layer.

Tensile reinforcement should extend to the bottom of shafts subjected to uplift loading.

Drilled shafts should have a minimum (center-to-center) spacing of three diameters. Closer spacing may require a reduction in axial load capacity. Axial capacity reduction can be determined by comparing the allowable axial capacity determined from the sum of individual piles in a group versus the capacity calculated using the perimeter and base of the pile group acting as a unit. The lesser of the two capacities should be used in design.

A minimum shaft diameter of 12 inches should be used. Drilled shafts should have a minimum length of 10 feet.

Post-construction settlements of drilled shafts designed and constructed as described in this report are estimated to range from about ½ to ¾ inch. Differential settlement between individual shafts is expected to be ½ to ⅔ of the total settlement.

Drilled Shaft Lateral Loading

The following table lists input values for use in LPILE analyses. LPILE estimates values of k_h and E_{50} based on strength; however, non-default values of k_h should be used where provided. Since deflection or a service limit criterion will most likely control lateral capacity design, no safety/resistance factor is included with the parameters.

Stratigraphy [1]		L-Pile Soil Model	S_u (psf) [2]	ϕ [2]	γ (pcf) [2]	Strain Factor ε_{50} [2]	k (pci) [2]
No.	**Material**						
1	Silty Sand to Sandy Silt	Sand (Reese)	---	30°	105	---	25
2	Silty Sand	Sand (Reese)		32°	1015	--	90
3	Lean Clay and Silty Clay	Stiff Clay w/o Free Water	2,000	---	120	0.005	400
4	Poorly Graded to Silty Sand	Sand (Reese)	---	34°	115	---	225

1. See **Subsurface Profile** in **Geotechnical Characterization** for more details on Stratigraphy.
2. Definition of Terms:
   - S_u: Undrained shear strength
   - ϕ: Internal friction angle,
   - γ: Moist unit weight
   - ε_{50}: Non-default E50 strain
   - k: Horizontal modulus of subgrade reaction
   - q_u: Non-default soil modulus – static. Refer to software guidelines for cyclic loading.

The load capacities provided herein are based on the stresses induced in the supporting soil strata. The structural capacity of the shafts should be checked to assure they can safely accommodate the combined stresses induced by axial and lateral forces. Lateral deflections of shafts should be evaluated using an appropriate analysis method, and will depend upon the pier's diameter, length, configuration, stiffness and "fixed head" or "free head" condition. We can provide additional analyses and estimates of lateral deflections for specific loading conditions upon request. The load-carrying capacity of shafts may be increased by increasing the diameter and/or length.

Drilled Shaft Construction Considerations

Sandy and gravelly subgrade materials were encountered with in the area of the proposed substation improvements. To prevent collapse of the sidewalls, the use of temporary steel casing and/or slurry drilling procedures may be required for construction of the drilled shaft foundations. The drilled shaft contractor and foundation design engineer should be informed of these risks.

If casing is removed during concrete placement, care should be exercised to maintain concrete inside the casing at a sufficient level to resist earth pressures present on a casing exterior. Water or loose soil should be removed from the bottom of the drilled shafts prior to placement of the concrete.

Use of a telescoping casing arrangement can be considered to avoid handling long casing lengths. The lower casing should be of sufficient length and stiffness and have an appropriate cutting edge to allow it to be firmly seated into the soil. If possible, any excess water should be evacuated from the casing to place concrete in the "dry."

Care should be taken to not disturb the sides and bottom of the excavation during construction. The bottom of the shaft excavation should be free of loose material before concrete placement. Concrete should be placed as soon as possible after the foundation excavation is completed, to reduce potential disturbance of the bearing surface.

Concrete for "dry" drilled shaft construction should have a slump of about 5 to 7 inches. Concrete should be directed into the shaft utilizing a centering chute. Concrete for "wet" shaft construction would require higher slump concrete.

While withdrawing casing, care should be exercised to maintain concrete inside the casing at a sufficient level to resist earth pressures acting on the casing exterior. Arching of the concrete, loss of seal and other problems can occur during casing removal and result in contamination of the drilled shaft. These conditions should be considered during the design and construction phases. Placement of loose soil backfill should not be permitted around the casing prior to removal.

The drilled shaft installation process should be performed under the direction of the Geotechnical Engineer. The Geotechnical Engineer should document the shaft installation process including soil and groundwater conditions encountered, consistency with expected conditions, and details of the installed shaft.

FLOOR SLABS

Design parameters for floor slabs assume the requirements for **Earthwork** have been followed. Specific attention should be given to positive drainage away from the structure and positive drainage of the aggregate base beneath the floor slab.

Floor Slab Design Parameters

Item	Description
Floor Slab Support [1]	For floor slab areas covered with moisture sensitive flooring -Minimum 4 inches of free-draining (less than 6% passing the U.S. No. 200 sieve) crushed aggregate [2] For industrial floor slabs- Minimum of 6 inches of Class 2 aggregate base compacted to at least 95% of the maximum dry density obtained in the ASTM D1557 test method.
Estimated Modulus of Subgrade Reaction [3]	150 pounds per square inch per inch (psi/in) for point loads

1. Floor slabs should be structurally independent of building footings or walls to reduce the possibility of floor slab cracking caused by differential movements between the slab and foundation.
2. Other design considerations such as condensation development could warrant more extensive design provisions.
3. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in **Earthwork**, and the floor slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.

The use of a vapor retarder should be considered beneath concrete slabs on grade covered with wood, tile, carpet, or other moisture sensitive or impervious coverings, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

Saw-cut control joints should be placed in the slab to help control the location and extent of cracking. For additional recommendations refer to the ACI Design Manual. Joints or cracks should be sealed with a water-proof, non-extruding compressible compound specifically recommended for heavy duty concrete pavement and wet environments.

Where floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or floor slab cracks beyond the length of the structural dowels. The Structural Engineer should account for potential differential settlement through use of sufficient control joints, appropriate reinforcing or other means.

Floor Slab Construction Considerations

Finished subgrade, within and for at least 10 feet beyond the floor slab, should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or desiccated prior to construction of floor slabs, the affected material should be removed and structural fill should be added to replace the resulting excavation. Final conditioning of the finished subgrade should be performed immediately prior to placement of the floor slab support course.

The Geotechnical Engineer should approve the condition of the floor slab subgrades immediately prior to placement of the floor slab support course, reinforcing steel, and concrete. Attention should be paid to high traffic areas that were rutted and disturbed earlier, and to areas where backfilled trenches are located.

CORROSIVITY

The table below lists the results of laboratory soluble sulfate, soluble chloride, electrical resistivity, and pH testing. The values may be used to estimate potential corrosive characteristics of the on-site soils with respect to contact with the various underground materials which will be used for project construction.

Corrosivity Test Results Summary						
Boring	Sample Depth (feet)	Soil Description	Soluble Sulfate (ppm)	Soluble Chloride (ppm)	Electrical Resistivity (Ω-cm)	pH
B-2	1.0	Sandy Silt	134	140	795	8.54

The sulfate test results indicate that the soil from boring B-2 classifies as Class S0 according to Table 19.3.1.1 of ACI 318-14. This indicates that the sulfate level is negligible when considering corrosion to concrete.

GENERAL COMMENTS

Our analysis and opinions in this preliminary report are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. In order to supplement the data obtained, we will be performing a supplemental geotechnical investigation, including additional test borings and laboratory testing, to refine our analysis and opinions.

Terracon should also be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

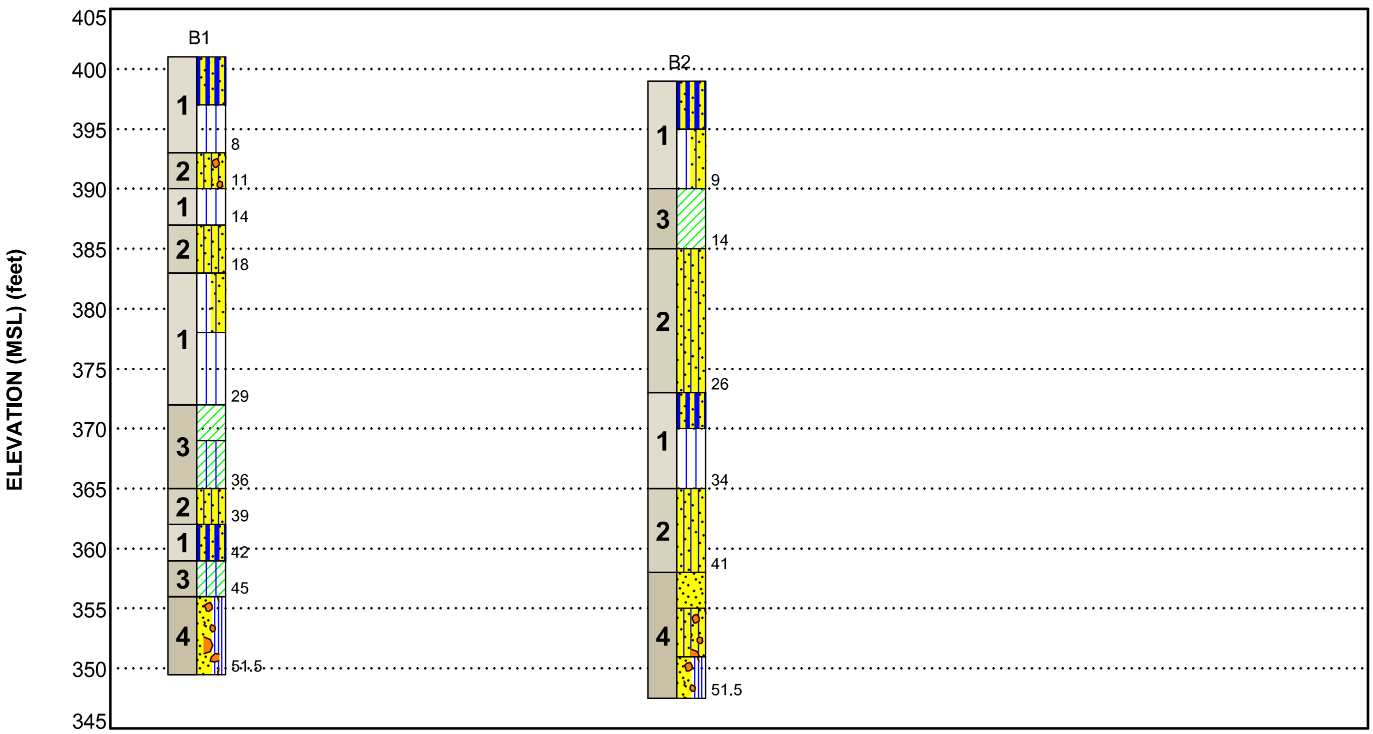
FIGURES

Contents:
GeoModel

GEOMODEL

CAISO Voltage Support ■ Huron, CA

4/23/2019 ■ Terracon Project No. NA195027



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description
1	Silt	Variable sand, fine to medium grained, brown to light brown, medium stiff to very stiff
2	Silty Sand	With variable gravel, fine to coarse grained, light brown, loose to medium dense
3	Lean to Silty Clay	Fine grained, low plasticity, light brown and tan to dark brown, stiff to very stiff.
4	Poorly Graded to Silty Sand	Fine to coarse grained, subangular gravel, tan and brown to light brown, medium dense to very dense

LEGEND

- Sandy Silt
- Silt
- Silty Sand with Gravel
- Silty Sand
- Silt with Sand
- Lean Clay
- Silty Clay
- Poorly-graded Sand with Silt and Gravel
- Poorly-graded Sand

- First Water Observation
- Second Water Observation
- Third Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time.
Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.
Numbers adjacent to soil column indicate depth below ground surface.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet)	Planned Location
2	51½	Structure area

Boring Layout and Elevations: Unless otherwise noted, Terracon personnel provided the boring layout. Coordinates were obtained with a handheld GPS unit (estimated horizontal accuracy of about ±10 feet) and approximate elevations were obtained by interpolation from Google Earth Imagery. If elevations and a more precise boring layout are desired, we recommend borings be surveyed.

Subsurface Exploration Procedures: We advanced the borings with a track-mounted rotary drill rig using continuous hollow stem flight augers. We obtained samples at depths of 1 foot and 5 feet and at intervals of 5 feet thereafter. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. A 2.5-inch O.D. split-barrel Modified California sampling spoon with 2.0-inch I.D. tube lined sampler was used for sampling. Tube-lined, split-barrel sampling procedures are similar to standard split spoon sampling procedure; however, blow counts are not equivalent to the SPT blow counts. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D1140 Standard Test Method for Determining the Amount of Material Finer than No. 200 Sieve by Soil Washing

The laboratory testing program included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System.

SITE LOCATION AND EXPLORATION PLANS

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted above.

SITE LOCATION

Gates Substation ■ Huron, California

April 23, 2019 ■ Terracon Project No. NA195027

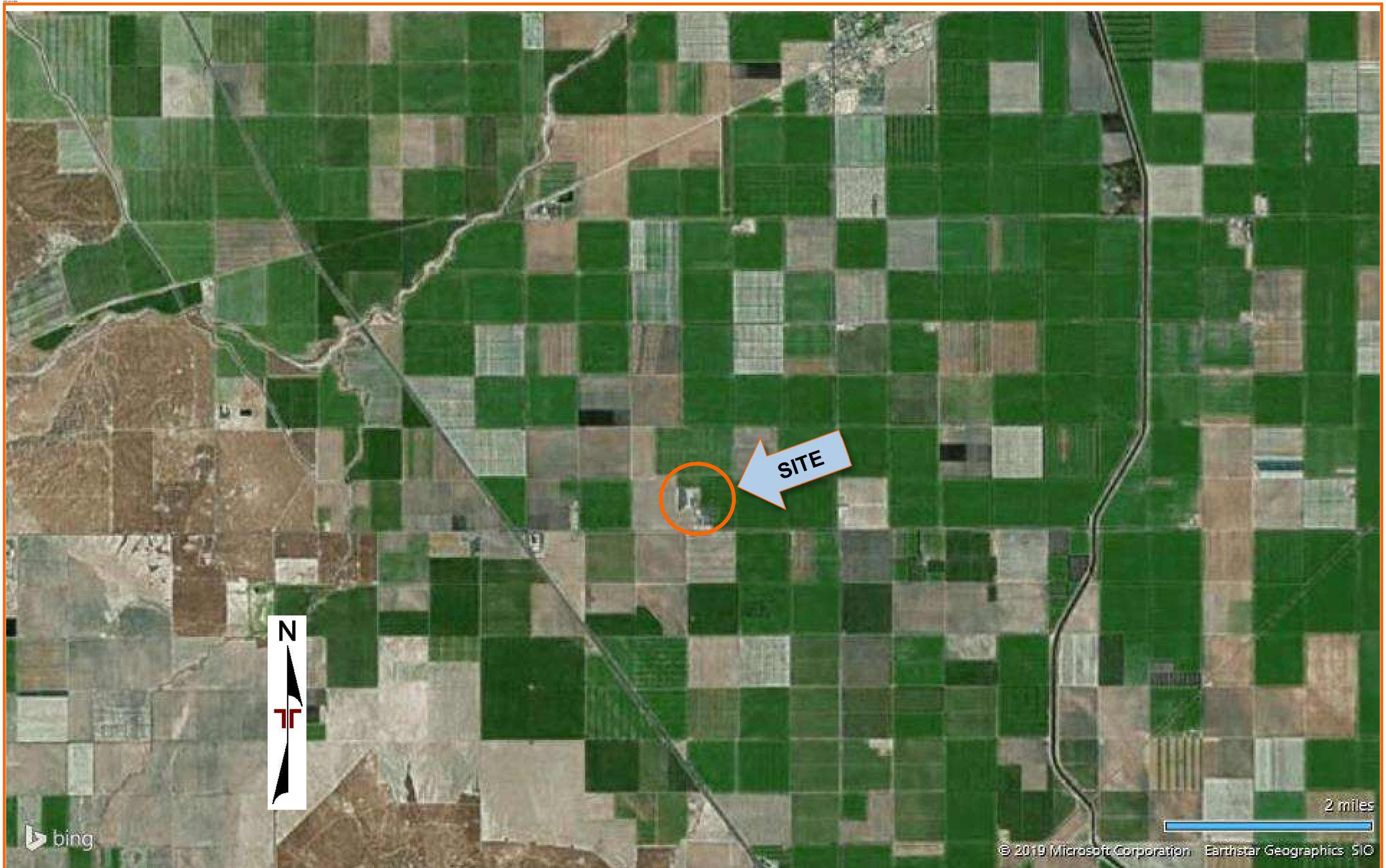


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

Gates Substation ■ Huron, California

April 23, 2019 ■ Terracon Project No. NA195027

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Boring Logs (B-1 through B-2)
Atterberg Limits
Corrosion Test Results

Note: All attachments are one page unless noted above.

BORING LOG NO. B1

PROJECT: Gates Substation

CLIENT: LS Power Development LLC
Chesterfield, MO

SITE: West Jayne Avenue
Huron, CA

LOCATION See Exploration Plan

Latitude: 36.1456° Longitude: -120.1263°

MODEL LAYER	DEPTH	DESCRIPTION	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1	4.0	**SANDY SILT (ML)**, fine grained, brown, medium stiff	4-4-4 N=8		13			
1	8.0	**SILT (ML)**, brown, medium stiff	3-3-5		23	80		
2	11.0	**POORLY GRADED GRAVEL WITH SILT (SP-SM)**, trace gravel, fine to medium grained, light brown, loose	4-3-4 N=7		18			
1	14.0	**SILT (ML)**, fine grained, light brown, medium stiff						
2	18.0	**SILTY SAND (SM)**, fine to medium grained, light brown, loose	5-5-7		7	97		47
1	23.0	**SILT WITH SAND (ML)**, fine to medium grained, light tan, stiff	3-5-5 N=10		17			80
1	29.0	**SILT (ML)**, trace sand, fine to medium grained, brown, stiff	4-6-7		15	101		92
3	32.0	**LEAN CLAY (CL)**, light brown, stiff	5-5-6 N=11		16		33-21-12	
3	36.0	**SILTY CLAY (CL-ML)**, brown to dark brown, very stiff	7-12-16		15	101		23
2	39.0	**SILTY SAND (SM)**, fine to medium grained, light tan, medium dense						
1	42.0	**SANDY SILT (ML)**, fine grained, brown, stiff	3-5-8 N=13		21			
3	45.0	**SILTY CLAY (CL-ML)**, brown, stiff						
4		**POORLY GRADED SAND WITH SILTY CLAY AND GRAVEL (SP-SM)**, fine to coarse grained, tan, dense	12-19-25		4	103		
	51.5	medium dense	10-11-11 N=22		4			

Boring Terminated at 51.5 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
6 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were estimated using Google Earth.

Notes:

WATER LEVEL OBSERVATIONS

Water level not determined

Terracon
902 Industrial Way
Lodi, CA

Boring Started: 03-29-2019

Boring Completed: 03-29-2019

Drill Rig: D50

Driller: R. Anderson

Project No.: NA195027

BORING LOG NO. B2

PROJECT: Gates Substation

CLIENT: LS Power Development LLC
Chesterfield, MO

SITE: West Jayne Avenue
Huron, CA

LOCATION See Exploration Plan

Latitude: 36.1456° Longitude: -120.1252°

MODEL LAYER	DEPTH (Ft.)	DESCRIPTION
1	0.0–4.0	**SANDY SILT (ML)**, fine grained, brown, very stiff
1	4.0–9.0	**SILT WITH SAND (ML)**, fine grained, brown, medium stiff
3	9.0–14.0	**LEAN CLAY (CL)**, tan, stiff
2	14.0–18.0	**SILTY SAND (SM)**, fine to medium grained, brown, medium dense
4	18.0–26.0	**SILTY SAND (SM)**, fine to medium grained, light brown, medium dense
1	26.0–29.0	**SANDY SILT (ML)**, fine grained, light brown, stiff
3	29.0–34.0	**LEAN CLAY (CL)**, brown, stiff
2	34.0–41.0	**SILTY SAND (SM)**, fine to medium grained, light brown, medium dense
4	41.0–44.0	**POORLY GRADED SAND (SP)**, fine to coarse grained, light brown, medium dense
4	44.0–48.0	**SILTY SAND WITH GRAVEL (SM)**, fine to coarse grained, brown, dense
4	48.0–51.5	**POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM)**, fine to coarse grained, subangular, light brown to light tan, very dense
	51.5	***Boring Terminated at 51.5 Feet***

DEPTH (Ft.) (approx.)	FIELD TEST RESULTS	LABORATORY HP (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2.5	10-10-9		8	99		
5	2-2-3 N=5		17			80
10	3-4-6	4.0 (HP)	23	90	29-19-10	
15	3-5-4 N=9		5			22
20	5-7-7		5	99		15
25	6-5-6 N=11		13			
30	4-7-11		25	106	42-26-16	
35	7-10-11 N=21		7			24
40	10-13-18		8	92		
45	20-23-23 N=46		6			
50	32-42-33		4	113		

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
6 Inch Hollow Stem Auger

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were estimated using Google Earth.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
902 Industrial Way
Lodi, CA

Boring Started: 03-29-2019

Boring Completed: 03-29-2019

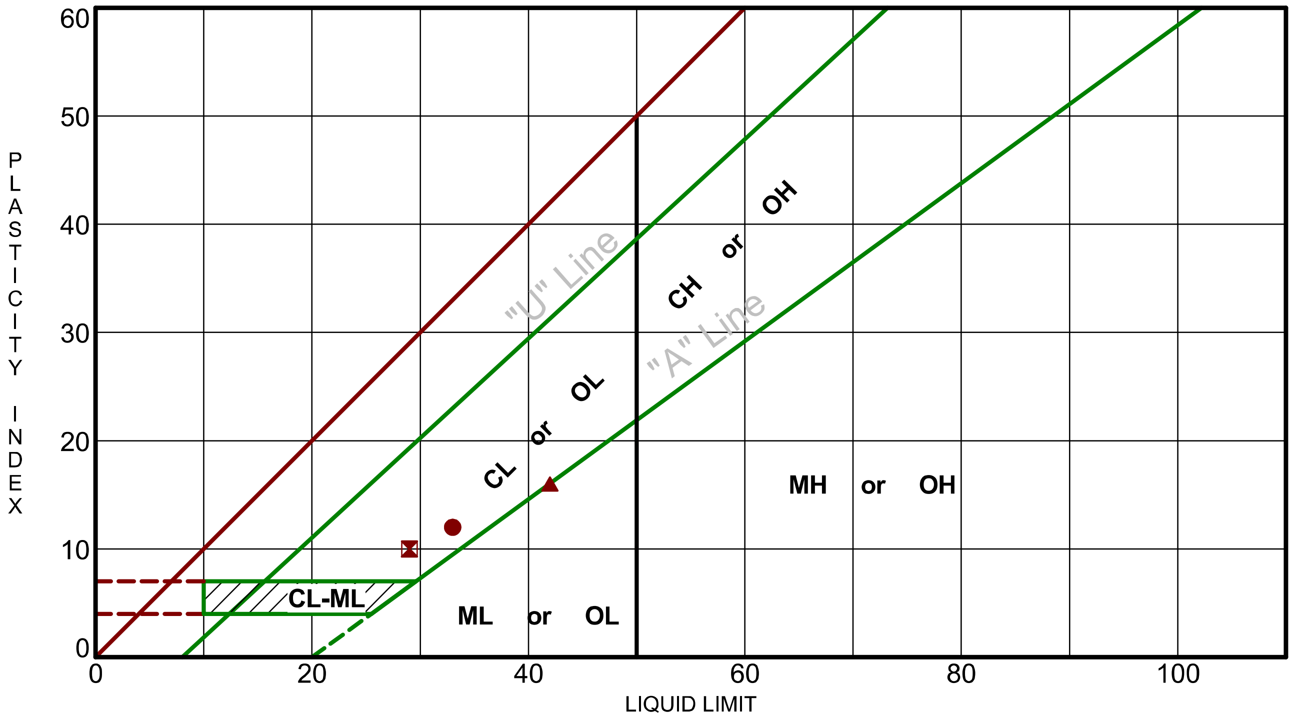
Drill Rig: D50

Driller: R. Anderson

Project No.: NA195027

ATTERBERG LIMITS RESULTS

ASTM D4318



Boring ID		Depth	LL	PL	PI	Fines	USCS	Description
●	B1	30 - 31.5	33	21	12		CL	LEAN CLAY
⊠	B2	10 - 11.5	29	19	10		CL	LEAN CLAY
▲	B2	30 - 31.5	42	26	16		CL	LEAN CLAY

PROJECT: Gates Substation

SITE: West Jayne Avenue
Huron, CA

Terracon
902 Industrial Way
Lodi, CA

PROJECT NUMBER: NA195027

CLIENT: LS Power Development LLC
Chesterfield, MO

CHEMICAL LABORATORY TEST REPORT

Project Number: NA195027
Service Date: 04/11/19
Report Date: 04/17/19
Task:

Terracon
750 Pilot Road, Suite F
Las Vegas, Nevada 89119
(702) 597-9393

Client

LS Power Development LLC
Chesterfield, MO

Project

CAISO Voltage Support

Sample Submitted By: Terracon (NA) **Date Received:** 4/9/2019 **Lab No.: 19-0391**

Results of Corrosion Analysis

Sample Number	1
Sample Location	B2
Sample Depth (ft.)	1.0-2.5
pH Analysis, AWWA 4500 H	8.54
Water Soluble Sulfate (SO4), ASTM C 1580 (mg/kg)	134
Sulfides, AWWA 4500-S D, (mg/kg)	Nil
Chlorides, ASTM D 512, (mg/kg)	140
Red-Ox, AWWA 2580, (mV)	+682
Total Salts, AWWA 2520 B, (mg/kg)	1882
Resistivity, ASTM G 57, (ohm-cm)	795

Analyzed By: Trisha Campo

Trisha Campo
Chemist

SUPPORTING INFORMATION

Contents:

General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Gates Substation ■ Huron, CA

April 16, 2019 ■ Terracon Project No. NA195027

Terracon GeoReport

SAMPLING	WATER LEVEL	FIELD TESTS
Modified California Ring Sampler Standard Penetration Test	**Water Initially Encountered** **Water Level After a Specified Period of Time** **Water Level After a Specified Period of Time** Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	**N** – **Standard Penetration Test Resistance (Blows/Ft.)** **(HP)** – **Hand Penetrometer** **(T)** – **Torvane** **(DCP)** – **Dynamic Cone Penetrometer** **UC** – **Unconfined Compressive Strength** **(PID)** – **Photo-Ionization Detector** **(OVA)** – **Organic Vapor Analyzer**

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance			CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance			
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (tsf)**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**
Very Loose	0 - 3	0 - 6	Very Soft	less than 0.25	0 - 1	< 3
Loose	4 - 9	7 - 18	Soft	0.25 to 0.50	2 - 4	3 - 4
Medium Dense	10 - 29	19 - 58	Medium Stiff	0.50 to 1.00	4 - 8	5 - 9
Dense	30 - 50	59 - 98	Stiff	1.00 to 2.00	8 - 15	10 - 18
Very Dense	> 50	> 99	Very Stiff	2.00 to 4.00	15 - 30	19 - 42
			Hard	> 4.00	> 30	> 42

RELATIVE PROPORTIONS OF SAND AND GRAVEL		RELATIVE PROPORTIONS OF FINES	
Descriptive Term(s) of other constituents	Percent of Dry Weight	**Descriptive Term(s) of other constituents**	**Percent of Dry Weight**
Trace	<15	Trace	<5
With	15-29	With	5-12
Modifier	>30	Modifier	>12

GRAIN SIZE TERMINOLOGY		PLASTICITY DESCRIPTION	
Major Component of Sample	**Particle Size**	**Term**	**Plasticity Index**
Boulders	Over 12 in. (300 mm)	Non-plastic	0
Cobbles	12 in. to 3 in. (300mm to 75mm)	Low	1 - 10
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)	Medium	11 - 30
Sand	#4 to #200 sieve (4.75mm to 0.075mm	High	> 30
Silt or Clay	Passing #200 sieve (0.075mm)		

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]	GW	Well-graded gravel [F]
			$Cu < 4$ and/or $[Cc<1$ or $Cc>3.0]$ [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]	SW	Well-graded sand [I]
			$Cu < 6$ and/or $[Cc<1$ or $Cc>3.0]$ [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	$PI > 7$ and plots on or above "A"	CL	Lean clay [K, L, M]
			$PI < 4$ or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [K, L, M, N]
					Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic Silt [K, L, M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [K, L, M, P]
					Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains $\geq$ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains $\geq$ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains $\geq$ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains $\geq$ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] $PI \geq 4$ and plots on or above "A" line.

[O] $PI < 4$ or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.