Geotechnical Engineering Report

Vollmer Substation

Colorado Springs, Colorado

September 17, 2018

Terracon Project No. 20185082

Prepared for:

Tri-State Generation and Transmission Association, Inc.

Westminster, Colorado

Prepared by:

Terracon Consultants, Inc.

Colorado Springs, Colorado

September 17, 2018

Tri-State Generation and Transmission Association, Inc.
1100 West 116th Avenue
Westminster, Colorado 80234

Attn: Ms. Shevy Newman
P: (303) 452-6111
E: snewman@tristategt.com

Re: Geotechnical Engineering Report
Vollmer Substation
NE of E Woodmen Road and Brule Road
Colorado Springs, Colorado
Terracon Project No. 20185082

Dear Ms. Newman:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the project referenced above. This study was performed in general accordance with Terracon Proposal No. P23185082 dated July 18, 2018 and Master Services Agreement TS-CONSULT-LR-08282015, dated May 15, 2018. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations and floor slabs for the proposed project.

We appreciate the opportunity to be of service to you on this project. Materials testing and construction observation services are provided by Terracon as well. We would be pleased to discuss these services with you. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Tyler A. Compton, P.E.*
Senior Staff Engineer
*Registered in New Mexico

Robert M. Hernandez, P.E.
Geotechnical Services Manager

COLORADO LICENSED PROFESSIONAL ENGINEER ROBERT MICHAEL HERNANDEZ PE-44312

REPORT TOPICS

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 Terracon GeoReport logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

REPORT SUMMARY

Topic [1]	Overview Statement [2]
Project Description	Proposed 115kV Vollmer Substation outside of Colorado Springs, Colorado. We understand the substation will have a footprint on the order of 195 feet by 265 feet.
Subsurface Conditions	Sand soils to about 10 to 22 feet below existing ground surface (bgs). Claystone to about 22 to 29½ feet bgs. Clayey sandstone to about 29½ to 30 feet bgs. Groundwater was not encountered at the time of our field exploration.
Earthwork	On-site sand soils are suitable for re-use as structural fill, and as general fill outside of structural areas. We recommend remolded swell testing be performed on samples of any potentially expansive soils encountered during construction.
Shallow Foundations	Shallow foundations are considered suitable for support of the control building and select equipment. Allowable bearing pressure depends on application. See **Shallow Foundations** section for more information. Expected movement: About 1-inch total, differential of about ½ to ¾ of total movement.
Deep Foundations	A drilled pier deep foundation system is considered suitable for support of switches and transmission line structures. Direct embed poles are considered suitable provided the material (on-site soils or crushed gravel) used to backfill the anulus between the pole and the soil profile is compacted to the recommendations of this report. A specialty contractor, and the manufacturer, should be contacted to aid in the use and design of products such as "Poleset" and helical anchors.
Floor Slabs	Floor slabs-on-grade used for structures such as the control building should be founded on a minimum of 2 feet of compacted structural fill.
Unpaved Access Road	We have assumed a traffic loading of 10,000 ESALs over a 20 year design life. ■ 8.0 inches of aggregate base course ■ 12.0 inches of compacted structural fill
Construction Observation and Testing	Close monitoring of the construction operations and implementing drainage recommendations discussed herein will be critical in achieving the intended foundation, slab, and pavement performance. We therefore recommend that Terracon be retained to monitor this portion of the work.
General Comments	This section contains important information about the limitations of this geotechnical engineering report.

Topic [1]	Overview Statement [2]

1. If the reader is reviewing this report as a pdf, the topics (bold orange font) 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. It should be recognized that specific details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein.

Geotechnical Engineering Report
Vollmer Substation
NE of E Woodmen Road and Brule Road
Colorado Springs, Colorado
Terracon Project No. 20185082
September 17, 2018

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed Vollmer Substation to be located northeast of the intersection of East Woodmen Road and Brule Road in Colorado Springs, Colorado. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and rock conditions
- Groundwater conditions
- Site preparation and earthwork
- Foundation design and construction
- Floor system design and construction
- Seismic considerations
- Lateral earth pressures
- Aggregate-surfaced road design and construction

The geotechnical engineering scope of services for this project included the advancement of five test borings to depths ranging from approximately 29½ to 30 feet below existing site grades, and one test pit excavated to a depth of about 10 feet below existing site grade.

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 and bedrock samples obtained from the site during the field exploration are included on the boring logs and as separate graphs in the **Exploration Results** section of this report.

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 site is located northeast of the intersection of East Woodmen Road and Brule Road in Colorado Springs, Colorado. See **Site Location**.
Existing Improvements	The site is located on undeveloped land. Residential housing is located to the southwest and east of the site. The remaining land surrounding the site is undeveloped.
Current Ground Cover	The site is well vegetated with grass and weeds.
Existing Topography	Relatively flat. The site appeared to slope down to the south at an estimated gradient of less than 25H:1V (Horizontal:Vertical).
Geology	Alluvial soils overlying bedrock of the upper part of the Dawson Arkose.

We also collected photographs at the time of our field exploration program. Representative photos are provided in our **Photography Log**.

PHOTOGRAPHY LOG

Facing North from Boring B-3

Facing South from Boring B-3

PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed in the project planning stage. 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	Borehole location map and Soils Investigation Specification provided by Tri-State on July 16, 2018, and a preliminary site plan in dwg format provided on September 12, 2018.
Project Description	Tri-State will be constructing a new 115kV Vollmer Substation outside of Colorado Springs, Colorado. We understand the substation will have a footprint on the order of 195 feet by 265 feet.

Item	Description
Proposed Construction	Based on the provided preliminary site plan we anticipate the substation will include the following: ■ An approximately 15 foot by 25 foot control building. ■ Two transformers each on mats with approximate dimensions of 22 feet by 31 feet. ■ Switches and transmission line structures. We anticipate the control building will be supported on a slab-on-grade founded on conventional shallow spread footings. The equipment is anticipated to be founded on mat foundations and drilled pier foundations, however, foundations to be considered also include: ■ Natural backfill (or compacted crushed gravel) compacted around wood pole ■ Poleset ■ Power torque-installed screw anchors for guys ■ Augured piers from 3 to 6 feet in diameter and from 10 to 30 feet in depth ■ Spread footings ■ Slabs-on-grade with compacted rock bed
Maximum Loads	Structural loads were not available at the time of our report preparation. We anticipate the following structural loads based on our experience with similar projects. ■ Control building: 2 kips per linear foot. ■ Transformer: 100 to 200 kips. ■ Switches and transmission line structures: 5 kips vertical, 3 kips shear, 125 ft-kip moment.
Grading/Slopes	We anticipate minor cuts and fills on the order of 2 feet or less will be required to achieve final site grades.
Below-grade Structures	None anticipated.
Roadways	Internal aggregate-surfaced roadways. We assume low volume traffic with an estimated 10,000 ESALs over a 20 year design period.

GEOTECHNICAL CHARACTERIZATION

Regional Geology

The proposed area is located within the Colorado Piedmont section of the Great Plains physiographic province. The Colorado Piedmont, formed during Late Tertiary and Early quaternary time (approximately two-million years ago), is a broad, erosional trench which separates the Southern Rocky Mountains from the High Plains. Structurally, the site lies along the southeast flank of the Denver Basin. During the Late Mesozoic and Early Cenozoic Periods (approximately seventy million years ago), intense tectonic activity occurred, causing the uplifting of the Front Range and associated down warping of the Denver Basin to the east. Relatively flat uplands and broad valleys characterize the present-day topography of the Colorado Piedmont in this region.

Site Geology

Surficial geologic conditions at the site, as mapped by the United States Geological Survey (USGS) ([1]Moore, 2002), consist of alluvial sand, silt, clay, and gravel of the post-Piney Creek, Piney Creek, pre-Piney Creek, and Broadway Alluvium. Bedrock mapped in the site vicinity includes the upper part of the Dawson Formation consisting of arkosic sandstone, conglomerate, and shale.

Geologic Hazards

Geotechnical and geologic considerations such as avalanches, landslides, rock falls, mudflows, unstable or potentially unstable slopes, seismic effects, ground subsidence, sinkholes, faults, accelerated erosion areas, and shallow groundwater can be of major concern when evaluating a site. Based on review of geologic and topographic maps, our site visit, and the geographical location of the site, it is our opinion that the previously listed geologic hazards are not of concern at this site.

Expansive soils were observed in our borings at the time of our field exploration. In addition, low density, potentially compressible soils were also observed. It is our opinion that these soils can be mitigated through remedial earthwork techniques for support of shallow foundations and slabs at this site provided the conclusions and recommendations contained in this report are followed during construction.

Increased sheet surface sheet flow may be possible due to relatively strong storm events. Final site grading may impact the potential for flooding or ponding at localized areas within the site. Site grades should be established to allow storm water to drain away from the site. We also recommend a site specific drainage study be performed.

Near surface soils at the site are susceptible to frost heave. Footings should be placed a minimum of 30 inches below finished grade for frost protection and to provide for confinement of bearing soils.

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[1] Moore, D.W., Straub, A.W., Berry M.E., Baker M.L., Brandt T.R., 2002, **Generalized Surficial Geologic Map of the Pueblo 1° x 2° Quadrangle**: U.S. Geological Survey, Miscellaneous Field Studies Map MF-2388, Scale 1:250,000.

Subsurface Profile

We have developed a general characterization of the subsurface soil and groundwater conditions based upon our review of the data and our understanding of the geologic setting and planned construction. The following table provides our geotechnical characterization.

The geotechnical characterization forms the basis of our geotechnical calculations and evaluation of site preparation, foundation options, and aggregate-surface roadway options. As noted in **General Comments**, the characterization is based upon widely spaced exploration points across the site, and variations are likely.

Stratum	Approximate Depth to Bottom of Stratum (feet)	Material Description	Consistency/Density
1 [1]	10 to 22	Sand soils with variable silt, clay and gravel contents	Very loose to dense
2 [2,3,4]	22 to 29½	Claystone	Medium hard to very hard
3 [5]	29½ to 30	Clayey sandstone	Hard to very hard

1. Test Pit TP1 terminated in Stratum 1 at a planned depth of 10 feet, total depth unknown.
2. Stratum 2 not encountered in Boring BH4.
3. Boring BH3 terminated in Stratum 2 at a planned depth of 29½ feet, total depth unknown.
4. Lense/layer of claystone (Stratum 2) encountered between sandstone layers (Stratum 3) in Boring BH5.
5. Borings BH1, BH2, BH4, and BH5 terminated in Stratum 3 at planned depths of 29½ to 30 feet, total depth unknown.

Conditions encountered at each boring location are indicated on the individual boring logs shown in the **Exploration Results** section and are attached to this report. Stratification boundaries on the boring logs represent the approximate location of changes in native soil types; in situ, the transition between materials may be gradual.

Relatively undisturbed, representative samples of the subsurface materials were obtained for laboratory consolidation/expansion testing. Laboratory test results indicate that a sample of the clayey sand soils tested exhibited low compression at in-situ water contents. When exposed to increases in moisture content, the clayey sand soils tested exhibited moderate expansion followed by low to moderate compression at increased loadings.

Laboratory test results indicate that the well-graded sand soils (SW, and SW-SM) tested exhibit low compression at in-situ water contents. When exposed to increases in moisture content, the well-graded sand soils tested exhibit low compression potential followed by further low compression at increased loadings.

Groundwater Conditions

Groundwater was not encountered in the borings at the time of our field study. The borings were observed for the presence of groundwater during and after completion of drilling. 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 structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

GEOTECHNICAL OVERVIEW

Based on the results of our field investigation, laboratory testing program and geotechnical analyses, development of the site is considered feasible from a geotechnical viewpoint provided that the conclusions and considerations provided herein are incorporated into the design and construction of the project.

The on-site sand soils are generally suitable for support of the proposed structures; however, a sample of the clayey sand soils did exhibit expansive potential when exposed to increases in moisture content. In addition, the observed surficial soils have relatively low dry densities, which indicate a higher potential for compression at increased loading. This report provides recommendations to help mitigate the effects of soil shrinkage and expansion.

We anticipate the control building will be supported on shallow spread footings, and equipment, such as the transformers, will be supported on mat foundations. To reduce potential movements and increase bearing capacities, shallow foundations should bear on a minimum of 2 feet of compacted structural fill. Floor slabs should also be founded on a minimum of 2 feet of compacted structural fill. The on-site sand soils are considered suitable for re-use as structural fill.

Review of the clayey sand soil sample obtained at a depth of 4 feet below existing site grade in Boring BH1 indicates a more clayey material than observed in other borings at this site. It is anticipated that this may be an isolated lens or thin layer. Indications of a continuous deposit of a potentially more expansive material, compared to other samples obtained at this site, were not observed in the samples or in the auger cuttings. However, because we are interpolating between samples, other areas of potentially expansive soils may be exposed at the time of construction. We recommend Terracon be retained to observe the foundation bearing soils prior to construction to observe that these conditions are similar throughout the foundation bearing subgrade. Additional earthwork recommendations may be required should differing conditions be observed from what was observed in our borings. We also recommend remolded swell testing be performed should indications of potentially more expansive material be observed at the time of construction.

We anticipate switches and transmission line structures may require deep foundations to resist overturning forces. A drilled pier deep foundation is considered suitable for support of switches and transmission line structures. This report presents recommendations for the design and construction of drilled pier foundations. Soils encountered on the project site are granular and prone to caving. A steel casing and/or slurry drilling procedures may be needed, and we recommend a drilled shaft contractor be provided a copy of our report to make their own judgements.

We understand that direct embed wood poles, the proprietary product "Poleset", and power torque-installed screw anchors for guys are also being considered for this project. These options are generally suitable for this project, and support of the proposed structures.

We understand that either on-site soils or imported crushed gravel will be used to backfill the annulus between the direct embed poles and the surrounding soil profile. We recommend the soils or crushed gravel be compacted to the recommendations of this report. Flowable fill or lean concrete is also suitable to fill the annulus between the embedded poles and soil profile. Additional recommendations for direct embed poles can be found in the **Deep Foundations** section of this report.

Both "Poleset" and helical anchors are proprietary systems, and we recommend that the manufacturer and a specialty contractor be contacted to aid in their use and design.

Additional site preparation recommendations including subgrade improvement and fill placement are provided in the **Earthwork** section.

The **Unpaved Access Roads** section addresses the design of aggregate surfaced roadways at the site.

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

EARTHWORK

Earthwork will include clearing and grubbing, excavations and fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria as necessary to render the site in the state considered in our geotechnical engineering evaluation for foundations, slabs, and unpaved access roads.

Site Preparation

Prior to placing any fill, strip and remove existing vegetation, topsoil, and any other deleterious materials from the proposed construction areas.

The subgrade should be proof-rolled with an adequately loaded vehicle such as a fully loaded tandem axle dump truck. The proof-rolling should be performed under the direction of the Geotechnical Engineer. Areas excessively deflecting under the proof-roll should be delineated and subsequently addressed by the Geotechnical Engineer. Such areas should either be removed or modified by stabilizing with geotextile. Excessively wet or dry material should either be removed or moisture conditioned and recompacted.

The bottom of foundation excavations should also be probed with a metal T-probe to aid in locating loose, soft, or otherwise undesirable areas. Unacceptable soil or loose slough should be removed or mitigated in place prior to placing fill or foundation concrete.

Fill Material Types

Fill required to achieve design grade should be classified as structural fill and general fill. Structural fill is material used below or within 5 feet of structures and within 12-inches of roadway subgrade. General fill is material used to achieve grade outside of these areas. Earthen materials used for structural and general fill should meet the following material property requirements:

Soil Type [1]	USCS Classification	Acceptable Locations for Placement
On-site sand soils	SC, SM, SW-SM, SP-SM, & SW	The on-site sand soils are considered acceptable for re-use as structural fill beneath foundations, slabs, and aggregate-surfaced roadways. The on-site sand soils may also be re-used as general fill outside of structural areas. We also recommend remolded swell testing be performed on the on-site soils should indications of potentially more expansive soils be observed at the time of construction.
Imported soils	Varies	Imported soils meeting the gradation and properties outlined herein can be considered suitable for use as structural and/or general fill.

1. Structural and general fill should consist of approved materials free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to use on this site.

Imported soils for use as structural and/or general fill should conform to the following:

Gradation	Percent finer by weight (ASTM C136)
3"	100
No. 4 Sieve	50-100
No. 200 Sieve	35 (max)

- Liquid Limit...30 (max)
- Plastic Index...10 (max)
- Maximum Expansive Potential (%).............................1.5*

*Measured on a sample compacted to approximately 95 percent of the ASTM D698 maximum dry density at one percent below optimum water content. The sample is confined under a 150 psf surcharge and submerged.

Compaction Requirements

Structural and general fill should meet the following compaction requirements.

Item	Structural Fill
Maximum lift thickness	8 inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack, plate compactor) is used
Minimum compaction requirements [1, 2, 3]	95% of the materials maximum dry density for foundations, slabs, and aggregate-surfaced road subgrade (depths greater than 12 inches from road subgrade) 98% of the materials maximum dry density for the upper 12 inches of aggregate-surfaced road subgrade
Water content range [2]	Within three percent of optimum water content

1. We recommend that engineered fill be tested for water content and compaction during placement. Should the results of the in-place density tests indicate the specified water or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified water and compaction requirements are achieved.
2. Maximum dry density and optimum water content as determined by the Standard Proctor test (D698).
3. If the granular material is a coarse sand or gravel, or of a uniform size, or has a low fines content, compaction comparison to relative density may be more appropriate. In this case, granular materials should be compacted to at least 70% relative density (ASTM D 4253 and D 4254).
4. Water levels should be maintained low enough to allow for satisfactory compaction to be achieved without the compacted fill material becoming unstable under the weight of construction equipment or during proof-rolling. Indications of unstable soil can include pumping or rutting.

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 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. Rooves should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet away from buildings.

Exposed ground should be sloped and maintained at a minimum 5 percent away from structures for at least 10 feet beyond the perimeter of structures. After construction, 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 structure's maintenance program. Where flatwork abuts the structures 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. Deeper excavations that encounter bedrock are expected to become more difficult and may necessitate the use of specialized equipment or techniques. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of floor slabs and roadways. 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 freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to foundation, floor slab, or roadway 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 top soil, proof-rolling and mitigation of areas delineated by the proof-roll 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 2,500 square feet of compacted fill in the building and foundation areas, and 5,000 square feet in aggregate-surfaced roadway areas. One density and water content test is also recommended 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. In the event that 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

We assume the control building will be supported on spread footings or a mat foundation, and the transformers, and various equipment, will be supported on mat foundations. Spread footings and mat foundations bearing on structural fill are considered suitable for support of the building and equipment. If the site has been prepared in accordance with the requirements noted in **Earthwork**, the following deign parameters are applicable for shallow foundations.

Spread Footings - Design Recommendations

Item	Description
Maximum Net Allowable Bearing Pressure [1, 2]	Columns and Continuous: 2,500 psf (foundations bearing on structural fill) Mat: 1,000 psf (foundations bearing on structural fill)

Item	Description
Modulus of Subgrade Reaction [8]	6½ pounds per square inch per inch (psi/in) for anticipated pressure and estimated deflection. $$k = \frac{q}{\Delta}$$
Required Bearing Stratum [3]	Minimum 2 feet of compacted structural fill
Foundation Dimensions	Columns: Min. 24 inches Max. 7 feet Continuous: Min. 16 inches Max. 3 feet Mat: Max. width 34 feet
Ultimate Passive Resistance [4] **(equivalent fluid pressures)**	360 pcf (on-site or imported granular fill)
Ultimate Coefficient of Sliding Friction [5]	0.35 (on-site or imported granular soils)
Minimum Embedment below Finished Grade [6]	30 inches
Estimated Total movement from Structural Loads [2]	About 1 inch
Estimated Differential movement [2, 7]	About ½ to ¾ 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 no steeper than 20% within 10 feet of structure.
2. Values provided are for maximum loads noted in Project Description. The foundation movement will depend upon the variations within the subsurface soil profile, the structural loading conditions, the embedment depth of the footings, the thickness of compacted fill, the quality of the earthwork operations, and maintaining uniform soil water content throughout the life of the structure. The estimated movements are based on maintaining uniform soil water content during the life of the structure. Additional foundation movements could occur if water from any source infiltrates the foundation soils; therefore, proper drainage and irrigation practices should be incorporated into the design and operation of the facility. Failure to maintain soil water content and positive drainage will nullify the movement estimates provided above.
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.
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 frost and/or seasonal water content variations. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.
7. Differential settlements are as measured over a span of 40 feet.

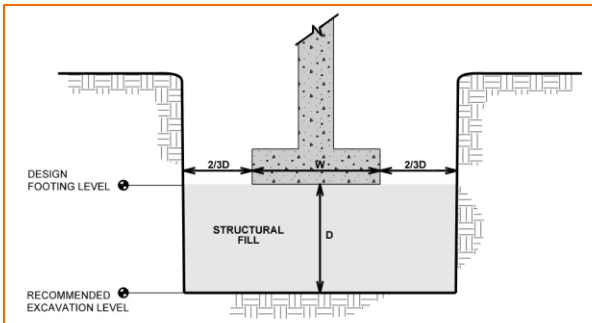
Item	Description
8.	The modulus of subgrade reaction for mat foundations is a relationship between allowable bearing pressure and deflection. Without knowing the loading conditions for each of the individual foundations, we have provided a design modulus value based on the recommended allowable bearing pressure and estimated settlement. Supplemental modulus values could be calculated if a list of foundation applications, loading conditions, and dimensions are provided to Terracon for review.

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.

If unsuitable bearing soils are encountered at the base of the planned footing excavation, additional measures will need to be taken to stabilize the bearing soils. This could include additional over-excavation and replacement, stabilization with geotextile, or replacement of the unsuitable soils with lean concrete. Unstable subgrade conditions should be observed by Terracon or a qualified third-party testing agency to assess the subgrade and provide suitable alternatives for stabilization. Stabilized areas should be proof-rolled prior to continuing construction to assess the stability of the subgrade.

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 structural fill placed as recommended in the **Earthwork** section.



OVER-EXCAVATION / BACKFILL ZONE

NOTE: EXCAVATIONS ARE SHOWN VERTICAL; HOWEVER, THE SIDEWALLS SHOULD BE SLOPED AS NECESSARY FOR SAFETY

DEEP FOUNDATIONS

Drilled Pier Design Recommendations

The soil design parameters provided in the **Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis** found in the **Supporting Information** at the end of this report should be used for the design of drilled pier foundations. The maximum end bearing pressures given in the table are based on the cross-sectional area of the tip of the pier. Skin friction (Sd) and lateral resistance should be applied to the surface area of the pier or for that given length interval below a depth of 36 inches. We recommend neglecting skin friction and lateral resistance for the upper 36 inches of piers because of the effects of frost penetration and disturbance. The combination of skin friction and end bearing pressure can be used to determine the vertical compression capacity. The skin friction value should be used to determine the uplift capacity of the soil and bedrock. Lateral load design parameters are valid for maximum soil strain of 1 percent for the native soils and ½ percent for the bedrock acting over a distance of one pier diameter. We have included commonly used LPILE parameters for lateral load and overturning design. LPILE parameters are ultimate values; therefore, appropriate factors of safety should be applied in the pile/pier design. We also recommend the following parameters:

Description	Straight Shaft Piles/Piers
Minimum pier length	10 feet
Minimum pier diameter	18 inches
Minimum spacing between piers	3 pier diameters
Pier concrete slump (uncased pier)	4 to 6 inches
Pier concrete slump (cased piers)	7 to 9 inches
Approximate total movement [1]	1 inch

1. The foundation movement will depend upon the variations within the subsurface soil profile, the structural loading conditions, the quality of the earthwork operations, and maintaining uniform soil water content throughout the life of the structure. The estimated movements are based on maintaining uniform soil water content during the life of the structure. Additional foundation movements could occur if water from any source infiltrates the foundation soils; therefore, proper drainage and irrigation practices should be incorporated into the design and operation of the facility. Failure to maintain soil water content and positive drainage will nullify the movement estimates provided above.

Larger pier diameters and longer lengths may be necessary to satisfy other structural engineering requirements of the design. In designing to resist uplift loading, two-thirds (2/3) of the allowable skin friction values provided for compressive loading could be used along with the effective weight of the pile/pier. Skin friction should not be used in the soil profile if slurry or other "wet" shaft techniques are used for installation. Tensile reinforcement should extend to the bottom of pile/pier subjected to uplift loading. All piers should be reinforced full-depth for the applied axial, lateral and uplift stresses imposed.

Piers should be considered to work in group action if the horizontal spacing is less than three pier diameters. A minimum practical horizontal spacing between piers of at least three diameters should be maintained, and adjacent piers should bear at the same elevation. The capacity of individual piers must be reduced when considering the effects of group action. Capacity reduction is a function of pier spacing and the number of piers within a group. If group action analyses are necessary, capacity reduction factors can be provided for the analyses.

Drilled Piers Construction Considerations

Drilling to design depths should be possible with single-flight power augers equipped with rock teeth. Difficult drilling should be anticipated due to the presence of potentially caving sand soils and very hard bedrock. Pier concrete should be placed soon after completion of drilling and cleaning. Due to potential sloughing and raveling, foundation concrete quantities may exceed calculated geometric volumes.

Granular soils with the potential to cave were widely encountered across the project site and the use of steel casing and/or slurry drilling procedures may be needed. The drilled shaft contractor should be provided with a copy of our report to make their own judgements.

A tremie should be used for concrete placement if temporary casings and/or slurry drilling procedures are required. If casing is used for pier construction, it should be withdrawn in a slow, continuous manner maintaining a sufficient head of concrete to prevent infiltration of water or the creation of voids in pier concrete. Pier concrete should have a relatively high fluidity when placed in cased pier holes or through a tremie.

Free-fall concrete placement is not considered suitable for construction. The use of a bottom-dump hopper, or an elephant's trunk discharging near the bottom of the hole where concrete segregation will be minimized, is recommended. Shaft bearing surfaces must be free of loose materials prior to concrete placement.

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/rock and groundwater conditions encountered, consistency with expected conditions, and details of the installed shaft.

Direct Embed Construction Considerations

Wood construction will be utilized for direct embedded poles. Typical embedment depths are at least 10 percent of the pole height plus an additional 2 feet. Based on the encountered soils, it is our opinion that this type of construction is considered suitable for the proposed wood embedded poles.

It is our understanding that on-site soil or crushed gravel is typically used to fill the annulus between the direct embeds poles and the surrounding soil profile. We recommend the soil or crushed gravel be compacted as recommended in the **Earthwork** section of this report. Flowable fill or lean concrete is also considered suitable to fill the annulus between embedded poles and the surrounding soil profile.

Should on-site soils or crushed gravel be used, we recommend a minimum 6-inch clear span between the pole and surrounding earth to provide adequate compaction of the material. A minimum 3-inch separation between the pole and surrounding soils is considered suitable when using lean concrete as backfill.

Helical Guy Anchor Considerations

Helical piers typically consist of galvanized steel tubing with one to three helical plates located near the bearing tip. Based on soils encountered in our borings, helical piers may work for the soil profiles, but not within the encountered bedrock profile. The helical plates should be spaced no closer than 3 times the diameter of the upper helical plate. Capacity of helical piers is based on torque achieved during installation, helical plate size, and shaft type. The helical piers should be installed per the manufactures' recommendations. Uplift capacities are a function of soil unit weights and friction angles.

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 7-10.

Description	Value
2015 International Building Code Site Classification (IBC) [1]	D [2]
Site Latitude	38.9564
Site Longitude	-104.6514
S_S Spectral Acceleration for a Short Period [3]	0.172g
S_1 Spectral Acceleration for a 1-Second Period [3]	0.058g

Description	Value

1. Seismic site classification in general accordance with the *2015 International Building Code*, which refers to ASCE 7-10.
2. The 2015 International Building Code (IBC) uses a site profile extending to a depth of 100 feet for seismic site classification. Borings at this site were extended to a maximum depth of 30 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.
3. In general accordance with the *2017 Pikes Peak Regional Building Code*.

FLOOR SYSTEMS

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.

Item	Description
Floor Slab Support [1]	A minimum of 2 feet of compacted structural fill.
Estimated Modulus of Subgrade Reaction [2]	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. 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 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 Systems - 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.

UNPAVED ACCESS ROADS

General Comments

Roadways for this project are expected to consist of aggregate surfaced roads. Terracon has evaluated aggregate sections over prepared subgrades and aggregate sections over prepared subgrades.

Access Road Recommendations

Design traffic loads and volumes were not available for our analysis. We used a CBR value of 5 for the design of aggregate surfaced access roads based on our experience with soils in the area. Roadway subgrades should be prepared as recommended in the **Earthwork** section of this report. On-site sand soils can be re-used as compacted structural fill within roadway areas.

Section thickness design of the aggregate surfaced roadways for the project has been based on the procedures outlined in the 1993 *Guideline for Design of Pavement Structures* by the American Association of State Highway and Transportation Officials (AASHTO) for low volume design. We have provided several alternatives for construction of aggregate surfaced roadways depending on the amount of risk the owner is willing to accept with respect to subgrade support, particularly during extended wet periods.

The following design sections do not take into account heavy traffic that may occur during construction. The following thickness recommendations assume approximately 10,000 Equivalent Single Axial Loads (ESALs) and rut depth of 1.5 to 2 inches is acceptable. These design assumptions are based on pick-up truck traffic for operations and maintenance after construction operations have been completed. Based on the subsurface conditions encountered at the borings, the assumed traffic, subgrade support, and our experience on similar projects, we recommend the following:

Terracon Recommended Aggregate Thickness Roadway Section	
Aggregate Base Course (in.)	**Compacted Structural Fill (in.)** [2]
8.0	12.0

1. On-site sand soils are considered suitable for reuse as structural fill.

Aggregate base course should consist of a blend of sand and gravel which meets Colorado Department of Transportation (CDOT) Class 5 or 6 specifications. Aggregate base course should be placed and compacted as recommended in the **Earthwork** section of this report.

Access Road Construction Recommendations

Site grading is generally accomplished early in the construction phase. However, as construction proceeds, the subgrade may be disturbed due to construction traffic, desiccation, or rainfall. As a result, the subgrade construction and corrective action will be required. If subgrade soils become unstable, we recommend removing the soft or yielding soils and replacing the material with approved imported fill. As an alternative, consideration can be given to placing geogrid and additional base course on top of the unstable area. We estimate 12 to 24 inches of base course may be required to stabilize the roadway, depending on the severity of the unstable subgrade.

Positive surface drainage of the roadway and subgrade should be provided and maintained. The roadway should be sloped to provide surface water drainage at all times. Water should not be allowed to remain within the roadway section and subgrade soils. In addition, the subgrade soils should be prepared in accordance with the Earthwork section of this report. The following recommendations should be considered at minimum:

- Site grading at a minimum 2% grade away from the roadways
- The subgrade surfaces have a minimum ¼ inch per foot slope to promote proper surface drainage
- Consider appropriate edge drainage and ditches/culverts
- The roadway subgrade should be slightly above surrounding grades to promote positive drainage. Aggregate base course should not be placed in a “trough” condition within the roadway section that is prone to holding water.

We emphasize that gravel surfaced roadways, regardless of the section thickness or subgrade preparation measures, will require on-going maintenance and repairs to keep them in a serviceable condition. It is not practical to design a gravel section of sufficient thickness that on-going maintenance will not be required. This is due to the porous nature of the gravel that will allow precipitation and surface water to infiltrate and soften the subgrade soils, and the limited near surface strength of unconfined gravel that makes it susceptible to rutting. When potholes, ruts, depressions or yielding subgrades develop they must be addressed as soon as possible in order to avoid major repairs. Failure to make timely repairs will result in more rapid deterioration of the roadways, making more extensive repairs necessary. The roadways should be carefully reevaluated at the time of the use by heavy equipment or critical component delivery for signs of disturbance or excessive rutting. Roadway reevaluation should include proof rolling immediately prior to use by heavy or critical equipment, particularly after a rainfall event. If disturbance and/or excessive wetting have occurred, roadway areas should be reworked, moisture conditioned (if necessary), and properly compacted as indicated in this report.

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 (percent)**	**Soluble Chloride (percent)**	**Electrical Resistivity (Ω-cm)**	**pH**
BH1	1 to 5	Sand soils	< 0.001	0.0003	5,718	6.5
BH2	1 to 10	Sand soils	< 0.001	0.0006	4,634	6.5
BH3	1 to 10	Sand soils	0.003	0.0016	5,048	6.2
BH4	1 to 5	Sand soils	< 0.001	0.0004	8,734	6.6

Results of soluble sulfate testing indicate samples of the on-site soils tested possess negligible sulfate concentrations when classified in accordance with Table 4.3.1 of the ACI Design Manual. Concrete should be designed in accordance with the provisions of the ACI Design Manual, Section 318, Chapter 4.

GENERAL COMMENTS

As the project progresses, we address assumptions by incorporating information provided by the design team, if any. Revised project information that reflects actual conditions important to our services is reflected in the final report. The design team should collaborate with Terracon to confirm these assumptions and to prepare the final design plans and specifications. This facilitates the incorporation of our opinions related to implementation of our geotechnical recommendations. Any information conveyed prior to the final report is for informational purposes only and should not be considered or used for decision-making purposes.

Our analysis and opinions 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. Terracon should be retained as the Geotechnical Engineer, where noted in the final 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.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings/Test Pits	Boring/Test Pit Depth (feet) [1]	Location
5 Borings	29½ to 30	Proposed electrical substation
1 Test Pit	10	Proposed electrical substation

1. Below existing site grade.

Boring and Test Pit Layout and Elevations: Boring and test pit locations and coordinates were provided by our client before field exploration. Latitude/longitude coordinates were obtained in the field with a handheld GPS unit (estimated horizontal accuracy of about ±20 feet). A site specific topographic map was not available at the time of our report preparation to obtain ground surface elevations at our boring and test pit locations.

Subsurface Exploration Procedures: We advanced the soil borings with a truck-mounted drill rig using continuous flight solid-stem augers. Four samples were obtained in the upper 10 feet of each boring 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 was 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 3-inch outer diameter split-barrel sampling spoon with 2.5-inch inner diameter ring lined sampler was used for sampling in the upper 14 feet. Ring-lined, split-barrel sampling procedures were similar to standard split spoon sampling procedure; however, blow counts were recorded for 6-inch intervals for a total of 12 inches of penetration. The samples were placed in appropriate containers, taken to our soil laboratory for testing, and classified by a geotechnical engineer. In addition, we observed and recorded groundwater levels during drilling and sampling procedures.

Our exploration team prepared field boring logs as part of standard drilling operations which included the sampling depths, penetration distances, and other relevant sampling information. Field logs include visual classifications of materials encountered during drilling, and our interpretation of subsurface conditions between samples. Final boring logs, prepared from field logs, represent the geotechnical engineer's interpretation, and include modifications based on observations and laboratory tests.

Test Pits: A Takeuchi TB240 compact excavator equipped with a 24-inch bucket was utilized to excavate one test pit to a depth of about 10 feet below existing site grade. The test pit was excavated on August 14, 2018 and bulk samples of the site soils were obtained from the test pit at various depths. No laboratory testing was performed on the bulk samples, but the samples were examined by an engineer in our lab to visually classify the soils and compare to the soils obtained from the adjacent borings. After completion the test pit was backfilled in two-foot-thick loose lifts and compacted with the excavator bucket.

Pressuremeter Testing: Presuremeter testing was performed on August 7, 2018 utilizing a TEXAM pressuremeter in general accordance with ASTM D4719-07. A cylindrical probe was inserted into an open borehole and supported at the test depth. Test measurements were then taken by inflating the probe's flexible membrane. The pressure on the soil and the relative increase in cavity radius were measured to develop an in-situ stress-strain curve of the material tested. The pressuremeter test was repeated at various depths, in various borings, in order to obtain the in-situ soil pressiometric modulus parameter of site soils and bedrock. The results of the pressuremeter testing are presented in **Exploration Results** attached to this report.

Soil Electric Resistivity: One set of two perpendicular lines of soil electrical resistivity data was obtained in accordance with ASTM G57 Wenner Four Electrode Method on August 15, 2018. Field testing was performed at "a" spacings of 2, 3, 5, 7, 10, 20, 30, 50, 100, 200, and 300 feet using an ABEM Terrametter SAS 1000 resistivity meter. The results of the electrical resistivity testing are presented in **Exploration Results** attached to this report.

Laboratory Testing

The project engineer reviewed the field data and assigned various laboratory tests to better understand the engineering properties of the various soil and rock 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 due to 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 D422 Standard Test Method for Particle-Size Analysis of Soils
- ASTM D4546 - 14 Standard Test Methods for One-Dimensional Swell or Collapse of Soils
- Corrosivity test suite (chlorides, soluble sulfates, resistivity, and pH)

Our 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 (USCS).

Rock classification is conducted using locally accepted practices for engineering purposes. Boring log rock classification is determined using the Description of Rock Properties included in the **Supporting Information** attached to this report.

SITE LOCATION AND EXPLORATION PLANS

SITE LOCATION

Vollmer Substation ■ Colorado Springs, CO
September 13, 2018 ■ Terracon Project No. 23185082

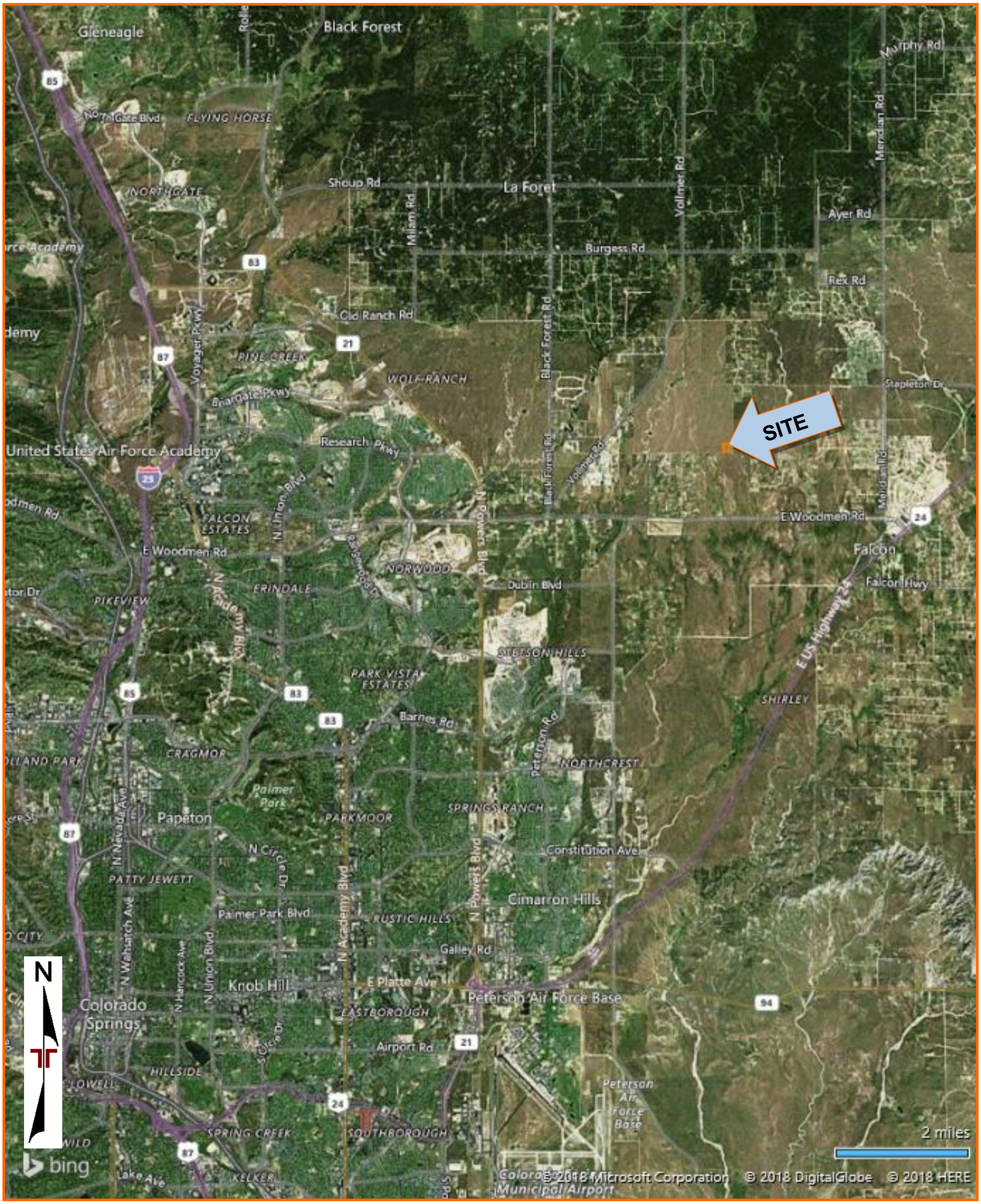


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY QUADRANGLES INCLUDE: FALCON NW, CO (1/1/1994).

SITE VICINITY

Vollmer Substation ■ Colorado Springs, CO
September 13, 2018 ■ Terracon Project No. 23185082

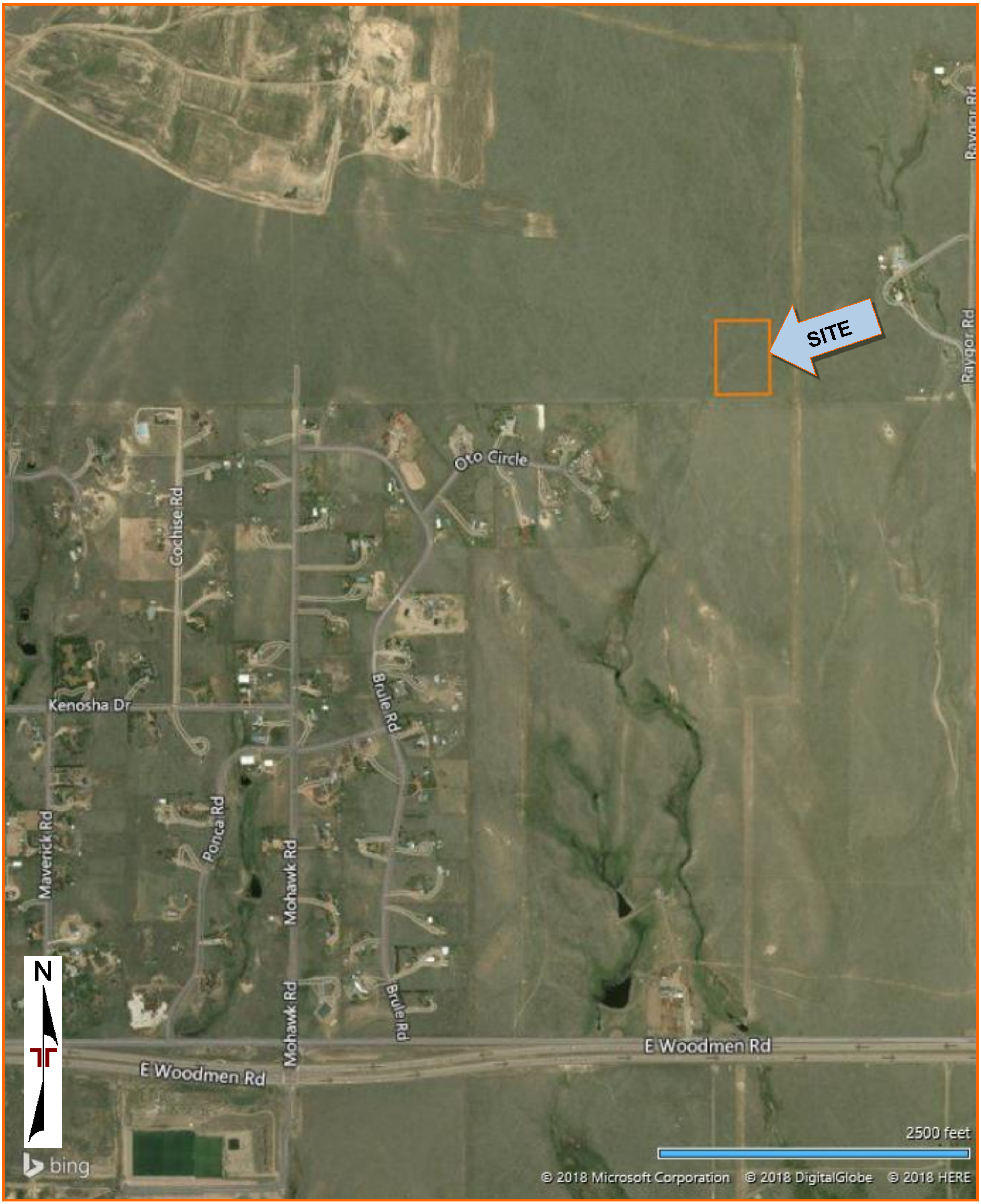


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN WITH OVERLAY OF PROVIDED LOCATIONS

Vollmer Substation ■ Colorado Springs, CO

September 13, 2018 ■ Terracon Project No. 23185082

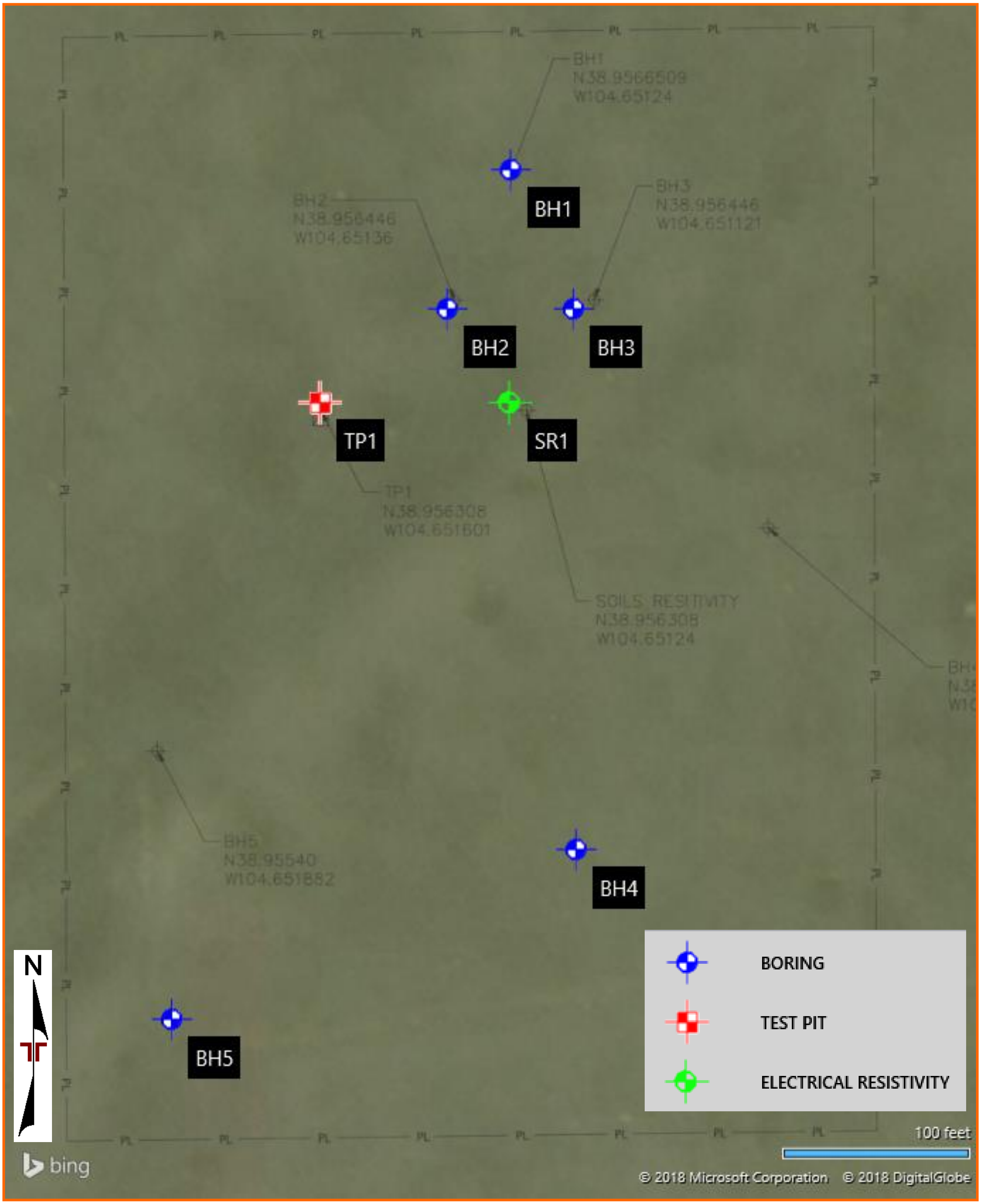


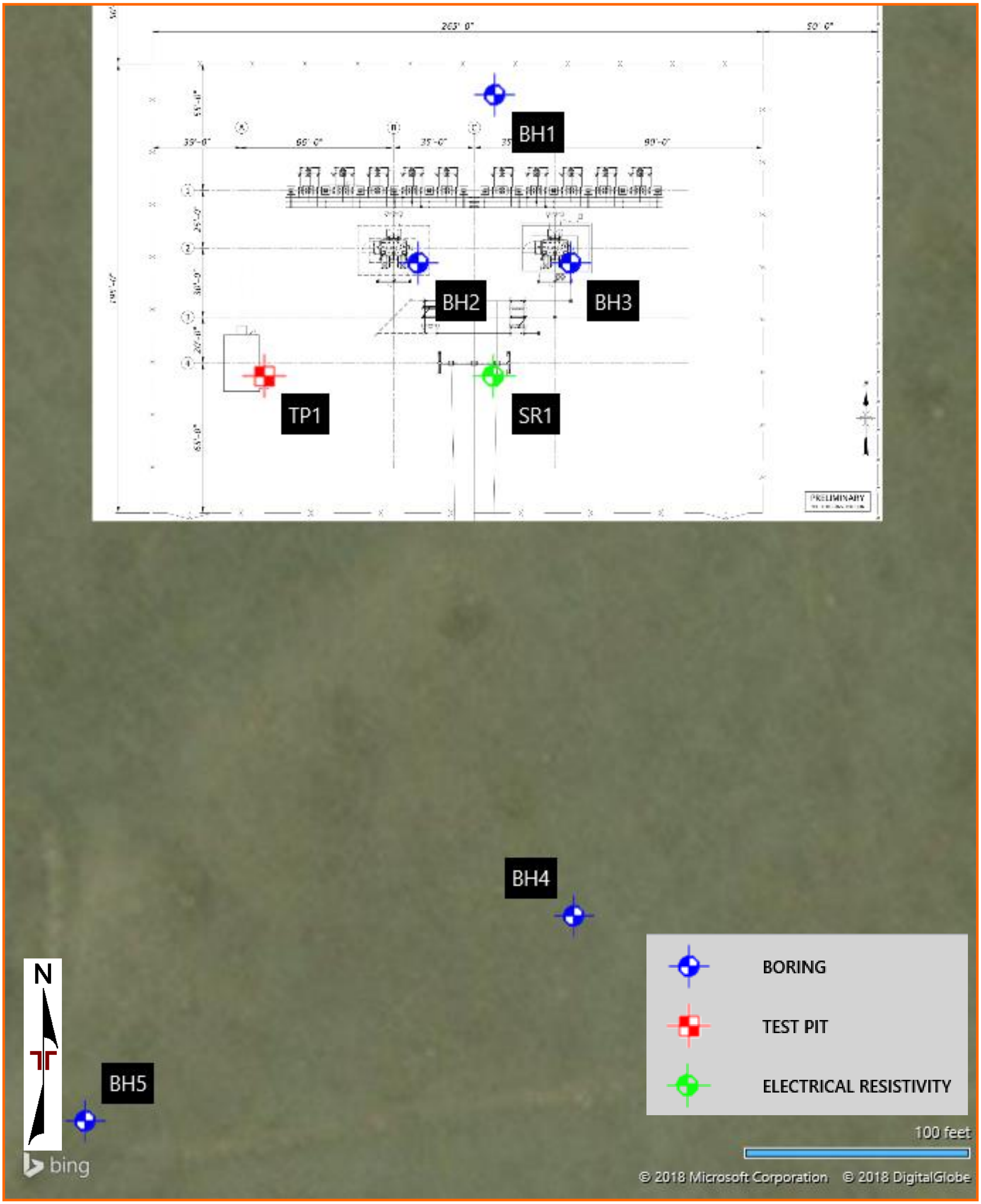
DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN WITH SITE PLAN OVERLAY

Vollmer Substation ■ Colorado Springs, CO

September 13, 2018 ■ Terracon Project No. 23185082



AERIAL PHOTOGRAPHY PROVIDED
BY MICROSOFT BING MAPS

EXPLORATION RESULTS

BORING LOG NO. BH1

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road Colorado Springs, CO

LOCATION See Exploration Plan

Latitude: 38.9567° Longitude: -104.6512°

Depth to base (Ft.)	Material Description	Sample Depth (Ft.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI	Percent Fines
3.5	**SILTY SAND (SM)**, fine to coarse grained, brown, loose, trace gravel, with rootlets		6-8	3	95	NP	23
4.5	**CLAYEY SAND (SC)**, fine to coarse grained, brown, medium dense						
	WELL GRADED SAND WITH SILT (SW-SM), fine to coarse grained, brown, medium dense to dense	5	9-10	1	96	NP	12
			14-13	4	106		
17.0	with iron oxidation.	10	14-26	8	117	NP	10
		15	35-50/6"	8	110	NP	9
27.0	**CLAYSTONE**, gray, hard to very hard, with iron oxidation and salt deposits	20	20-32-38 N=70	12			
		25	33-50/4" N-50/4"	11			
29.5	**CLAYEY SANDSTONE**, fine to medium grained, brown to gray, very hard		50/4" N=50/4"	6			
	Boring Terminated at 29.5 Feet						

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

Hammer Type: Automatic

Advancement Method:
4 1/2-inch Solid 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.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
4172 Center Park Dr
Colorado Springs, CO

Boring Started: 08-07-2018	Boring Completed: 08-07-2018
Drill Rig: CME 45	Driller: Vine Laboratories
Project No.: 23185082	

BORING LOG NO. BH2

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

LOCATION See Exploration Plan

Latitude: 38.9564° Longitude: -104.6514°

Graphic Log Depth (Ft.)	Material Description	Sample Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI	Percent Fines
	CLAYEY SAND (SC), fine to coarse grained, brown, medium dense, trace gravel, with rootlets								
					7-16	9	97		
3.5	**WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)**, fine to coarse grained, brown, medium dense								
		5			12-16	2	115	NP	6
8.5	Pressuremeter test performed at 7.5 feet								
	SILTY SAND (SM), fine to coarse grained, light brown, medium dense, trace gravel Sample too disturbed to determine unit weight at 9 feet	10			7-15	9		NP	14
12.0	**POORLY GRADED SAND WITH SILT (SP-SM)**, fine to coarse grained, light brown, medium dense Pressuremeter test performed at 14 feet	15			15-31	13	97	NP	6
17.0	**CLAYSTONE**, gray, medium hard to hard, with iron oxidation	20			15-15-17 N=32	14			
22.0	**CLAYEY SANDSTONE**, fine to medium grained, brown to gray, very hard, with iron oxidation	25			50/6" N=50/6"	13			
29.5					50/4" N=50/4"	9			
	Boring Terminated at 29.5 Feet								

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

Hammer Type: Automatic

Advancement Method:
4 1/2-inch Solid 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.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
4172 Center Park Dr
Colorado Springs, CO

Boring Started: 08-07-2018	Boring Completed: 08-07-2018
Drill Rig: CME 45	Driller: Vine Laboratories
Project No.: 23185082	

BORING LOG NO. BH3

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road Colorado Springs, CO

LOCATION See Exploration Plan

Latitude: 38.9564° Longitude: -104.6511°

Graphic Log depth	Material Description	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI	Percent Fines
	CLAYEY SAND (SC), fine to coarse grained, brown, loose, trace gravel, with rootlets to 2 feet				7-7	2	103		
					6-8	4	98	28-15-13	23
6.0	**WELL GRADED SAND WITH SILT (SW-SM)**, fine to coarse grained, light brown, loose to dense, trace gravel	5							
					15-20	7	121	NP	9
	Pressuremeter test performed at 9.5 feet	10							
		15			7-10	11	98		
		20			20-20-22 N=42	10			
22.0	**CLAYSTONE**, gray, very hard								
	Pressuremeter test performed at 25.5 feet	25			50/4" N=50/4"	6			
29.5					50/4" N=50/4"	10			
	Boring Terminated at 29.5 Feet								

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

Hammer Type: Automatic

Advancement Method:
4 1/2-inch Solid 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.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

4172 Center Park Dr
Colorado Springs, CO

Boring Started: 08-07-2018	Boring Completed: 08-07-2018
Drill Rig: CME 45	Driller: Vine Laboratories
Project No.: 23185082	

BORING LOG NO. BH4

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road Colorado Springs, CO

LOCATION See Exploration Plan

Latitude: 38.9557° Longitude: -104.6511°

Depth / Material Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
SILTY SAND (SM), fine to medium grained, brown, very loose to loose, trace gravel, with rootlets to 2 feet				4-4	5	94	NP	23
				3-3	2	98		
6.0 **WELL GRADED SAND (SW)**, fine to coarse grained, light brown, loose	5							
				7-10	3	105	NP	4
	10			8-5	7	98		
12.0 **CLAYEY SANDSTONE**, fine to coarse grained, light gray, hard to very hard, with iron oxidation								
	15			26-50/4"	9	117	44-15-29	19
	20			33-50/5" N=50/5"	11			
	25			50/5" N-50/5"	9			
29.5				50/5" N=50/5"	7			

Boring Terminated at 29.5 Feet

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

Hammer Type: Automatic

Advancement Method:
4 1/2-inch Solid 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.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
4172 Center Park Dr
Colorado Springs, CO

Boring Started: 08-08-2018	Boring Completed: 08-08-2018
Drill Rig: CME 45	Driller: Vine Laboratories
Project No.: 23185082	

BORING LOG NO. BH5

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road Colorado Springs, CO

LOCATION See Exploration Plan

Latitude: 38.9554° Longitude: -104.6519°

Depth (Ft.)	Description	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits LL-PL-PI	Percent Fines
0–3.5	**SILTY SAND (SM)**, fine to coarse grained, brown, loose, with rootlets to 2 feet	7-10	3	95		
3.5–12.0	**WELL GRADED SAND WITH SILT (SW-SM)**, fine to coarse grained, light brown, medium dense	12-15	2	109	NP	7
		12-14	5	102		
		13-14	9	106	NP	5
12.0–22.0	**CLAYEY SANDSTONE**, fine to coarse grained, brown to gray, hard to very hard, with iron oxidation	35-50/5"	7	119	34-17-17	7
		38-50/5" N=50/5"	8			
22.0–27.0	**CLAYSTONE**, gray, very hard, with iron oxidation	12-22-50/3" N=72/8"	16			
27.0–30.0	**CLAYEY SANDSTONE**, fine to coarse grained, brown to gray, very hard	30-50/6" N=50/6"	14			

Boring Terminated at 30 Feet

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

Hammer Type: Automatic

Advancement Method:
4 1/2-inch Solid 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.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
4172 Center Park Dr
Colorado Springs, CO

Boring Started: 08-08-2018	Boring Completed: 08-08-2018
Drill Rig: CME 45	Driller: Vine Laboratories
Project No.: 23185082	

TEST PIT LOG NO. TP1

PROJECT: Vollmer Substation

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 38.9563° Longitude: -104.6516°	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	CLAYEY SAND (SC), fine to coarse grained, brown			Grab					
2.0	**WELL GRADED SAND WITH SILT (SW-SM)**, fine to coarse grained, light brown, trace gravel with gravel at 4 feet	5		Grab Grab Grab					
10.0	***Test Pit Terminated at 10 Feet***	10							

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

Hammer Type: Automatic

Advancement Method:
24" Bucket

Abandonment Method:
Test pit backfilled and compacted with excavator bucket in two foot thick loose lifts

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.

Notes:

WATER LEVEL OBSERVATIONS

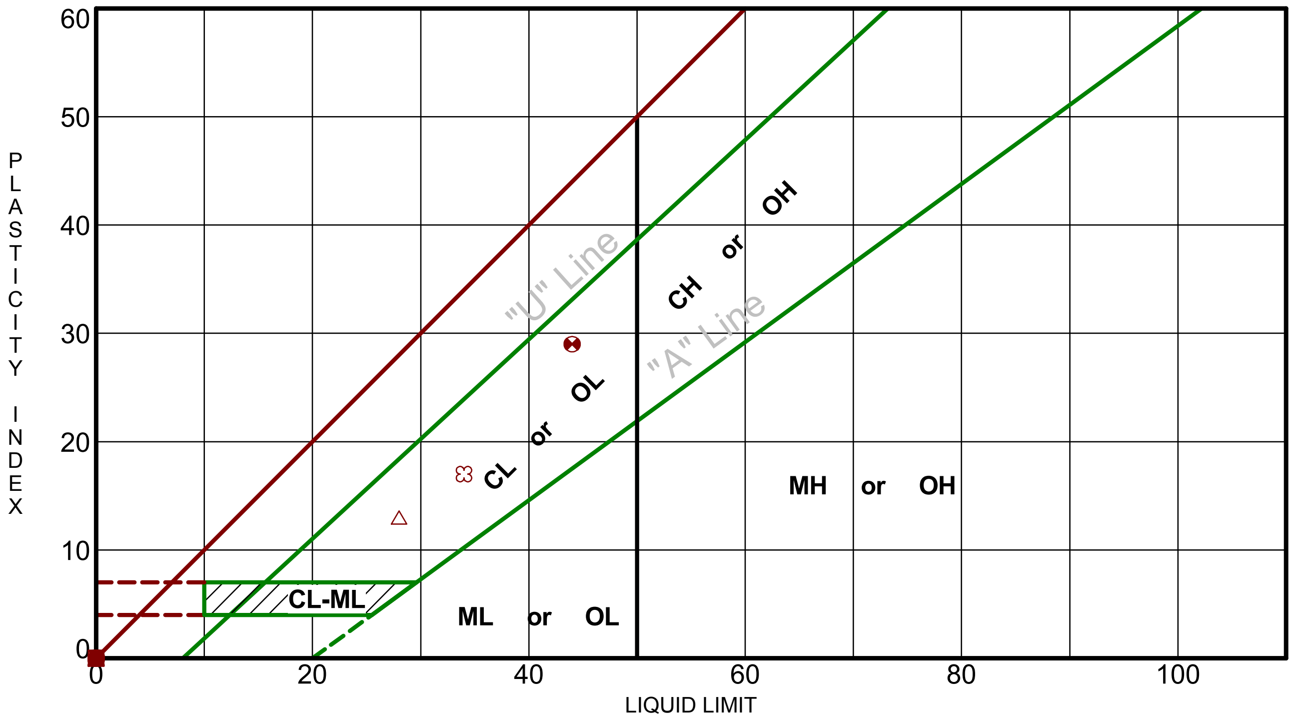
Groundwater not encountered

Terracon
4172 Center Park Dr
Colorado Springs, CO

Test Pit Started: 08-14-2018	Test Pit Completed: 08-14-2018
Excavator: Takeuchi TB240	Operator: Liquid Structures
Project No.: 23185082	

ATTERBERG LIMITS RESULTS

ASTM D4318



	Boring ID	Depth	LL	PL	PI	Fines	USCS	Description
●	BH1	2 - 3	NP	NP	NP	23	SM	SILTY SAND
⊠	BH1	4 - 5	NP	NP	NP	12	SW-SM	WELL-GRADED SAND with SILT
▲	BH1	9 - 10	NP	NP	NP	10	SW-SM	WELL-GRADED SAND with SILT
★	BH1	14 - 15	NP	NP	NP	9	SW-SM	WELL-GRADED SAND with SILT
⊙	BH2	4 - 5	NP	NP	NP	6	SW-SM	WELL-GRADED SAND with SILT and GRAVEL
✿	BH2	9 - 10	NP	NP	NP	14	SM	SILTY SAND
○	BH2	14 - 15	NP	NP	NP	6	SP-SM	POORLY GRADED SAND with SILT
△	BH3	4 - 5	28	15	13	23	SC	CLAYEY SAND
⊗	BH3	7 - 8	NP	NP	NP	9	SW-SM	WELL-GRADED SAND with SILT
⊕	BH4	2 - 3	NP	NP	NP	23	SM	SILTY SAND
□	BH4	7 - 8	NP	NP	NP	4	SW	WELL-GRADED SAND
⊗	BH4	14 - 15	44	15	29	19		CLAYEY SANDSTONE
◕	BH5	4 - 5	NP	NP	NP	7	SW-SM	WELL-GRADED SAND with SILT
☆	BH5	9 - 10	NP	NP	NP	5	SW-SM	WELL-GRADED SAND with SILT
✿	BH5	14 - 15	34	17	17	7		CLAYEY SANDSTONE

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

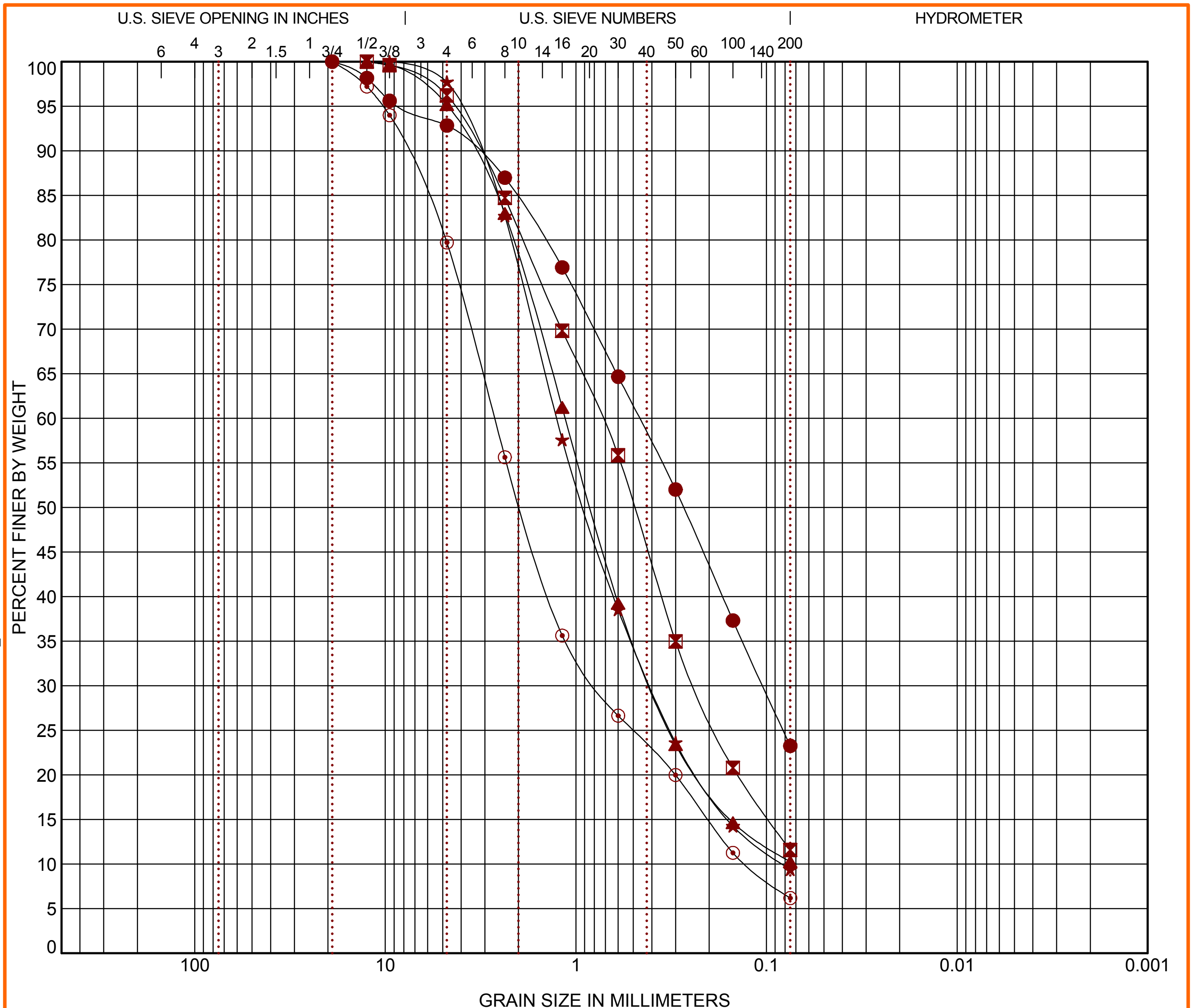
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	BH1	2 - 3	SILTY SAND (SM)	3	NP	NP	NP		
⊠	BH1	4 - 5	WELL-GRADED SAND with SILT (SW-SM)	1	NP	NP	NP	1.13	11.00
▲	BH1	9 - 10	WELL-GRADED SAND with SILT (SW-SM)	8	NP	NP	NP	1.96	15.77
★	BH1	14 - 15	WELL-GRADED SAND with SILT (SW-SM)	8	NP	NP	NP	1.58	15.40
⊙	BH2	4 - 5	WELL-GRADED SAND with SILT and GRAVEL (SW-SM)	2	NP	NP	NP	1.76	21.21

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	BH1	2 - 3	19	0.465	0.105		7.2	69.6		23.3	
⊠	BH1	4 - 5	12.5	0.734	0.235		3.8	84.7		11.6	
▲	BH1	9 - 10	12.5	1.137	0.401		4.8	84.9		10.3	
★	BH1	14 - 15	9.5	1.261	0.403	0.082	2.3	88.4		9.4	
⊙	BH2	4 - 5	19	2.679	0.773	0.126	20.3	73.5		6.2	

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

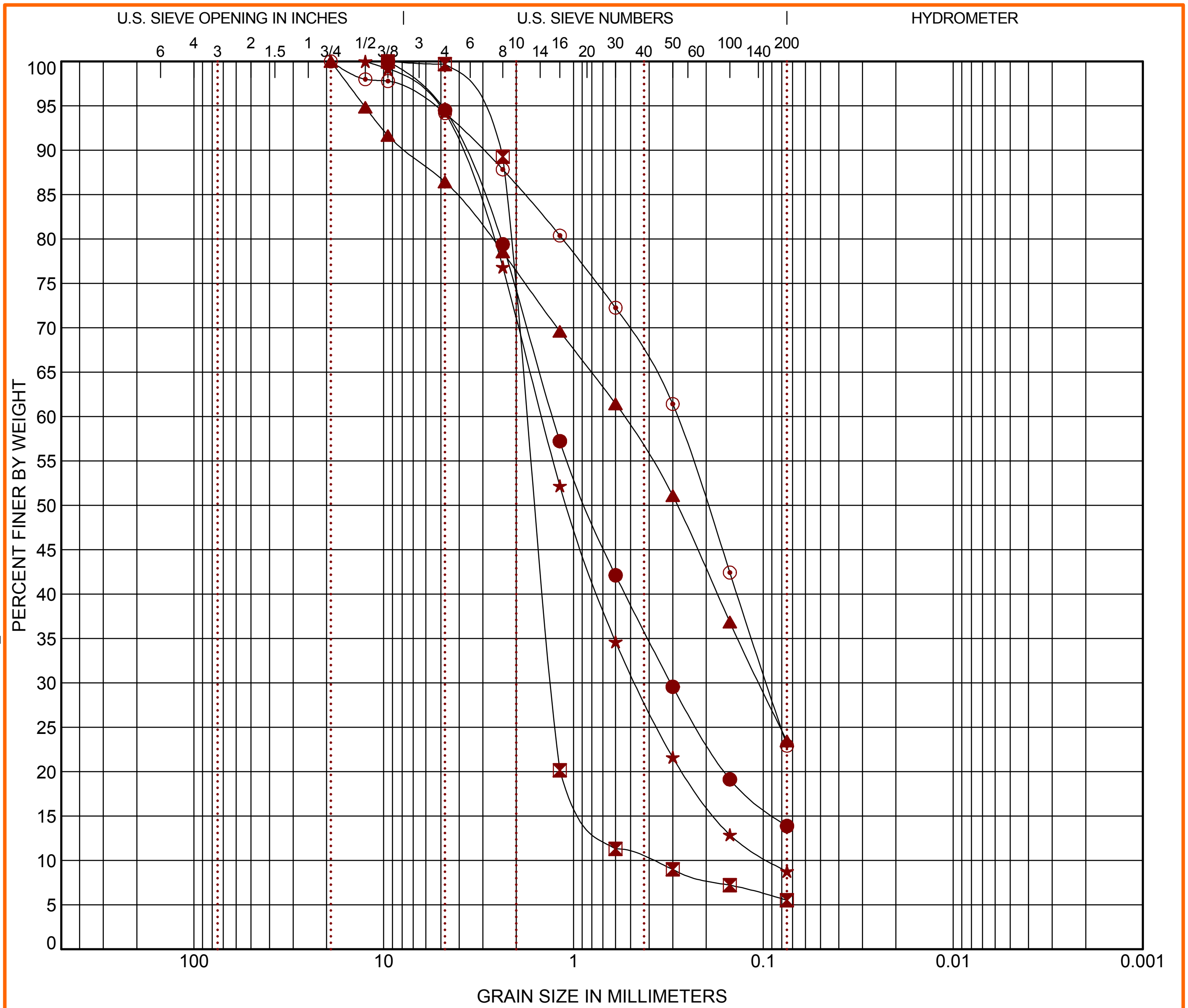
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
●	BH2	9 - 10	SILTY SAND (SM)	9	NP	NP	NP		
⊠	BH2	14 - 15	POORLY GRADED SAND with SILT (SP-SM)	13	NP	NP	NP	2.38	4.34
▲	BH3	4 - 5	CLAYEY SAND (SC)	4	28	15	13		
★	BH3	7 - 8	WELL-GRADED SAND with SILT (SW-SM)	7	NP	NP	NP	1.62	15.94
⊙	BH4	2 - 3	SILTY SAND (SM)	5	NP	NP	NP		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	BH2	9 - 10	9.5	1.287	0.307		5.5	80.6		13.9	
⊠	BH2	14 - 15	9.5	1.76	1.302	0.406	0.3	94.2		5.5	
▲	BH3	4 - 5	19	0.545	0.105		13.6	63.0		23.5	
★	BH3	7 - 8	12.5	1.47	0.469	0.092	5.8	85.4		8.8	
⊙	BH4	2 - 3	19	0.285	0.096		5.8	71.3		22.9	

PROJECT: Vollmer Substation

PROJECT NUMBER: 23185082

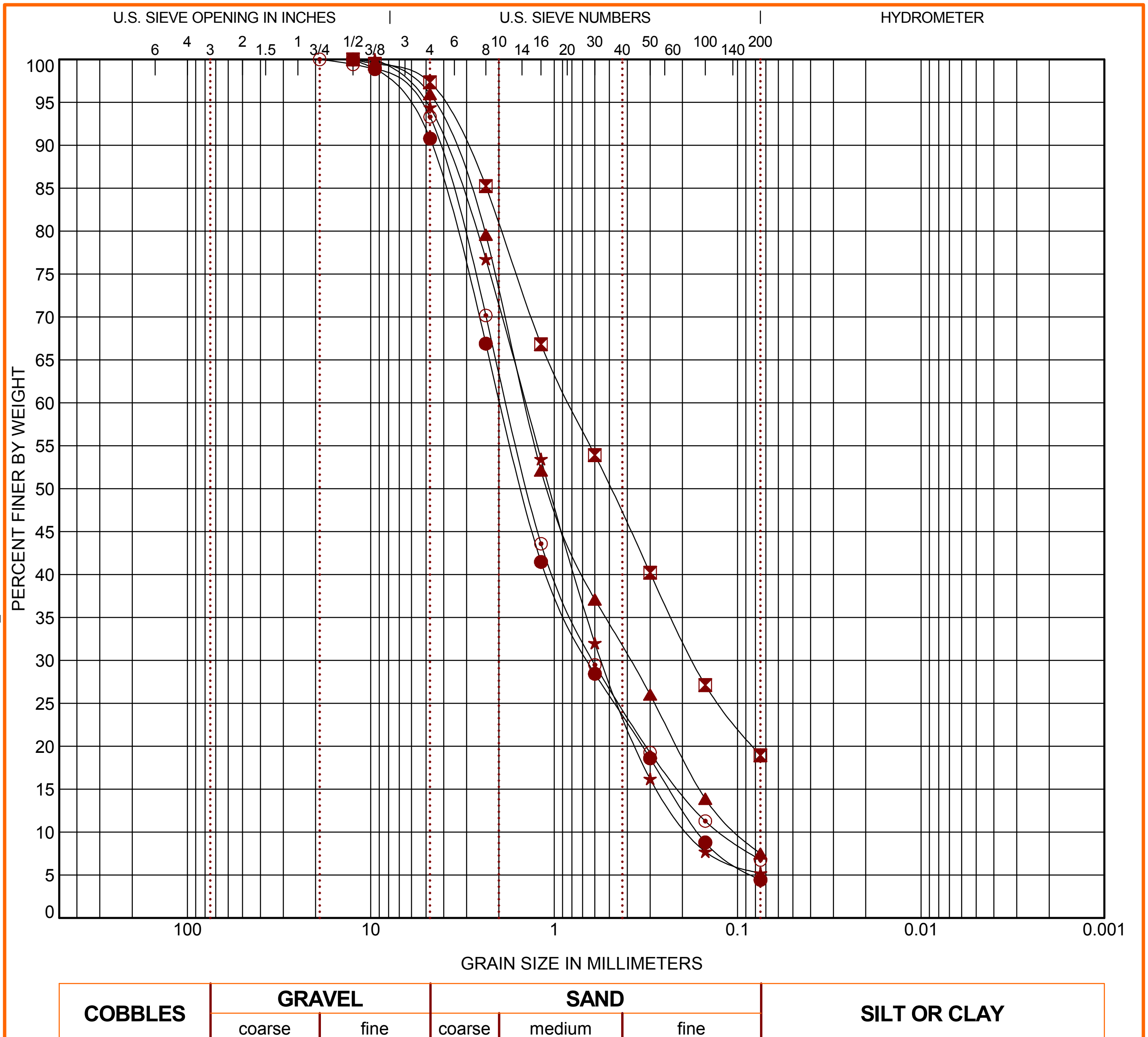
SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

Terracon
4172 Center Park Dr
Colorado Springs, CO

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



Boring ID	Depth	USCS Classification	WC (%)	LL	PL	PI	Cc	Cu
● BH4	7 - 8	WELL-GRADED SAND (SW)	3	NP	NP	NP	1.33	11.97
⊠ BH4	14 - 15	CLAYEY SANDSTONE	9	44	15	29		
▲ BH5	4 - 5	WELL-GRADED SAND with SILT (SW-SM)	2	NP	NP	NP	1.05	14.63
★ BH5	9 - 10	WELL-GRADED SAND with SILT (SW-SM)	9	NP	NP	NP	1.16	7.94
⊙ BH5	14 - 15	CLAYEY SANDSTONE	7	34	17	17	1.70	14.69

Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
● BH4	7 - 8	12.5	1.956	0.651	0.163	9.2	86.3		4.4	
⊠ BH4	14 - 15	12.5	0.825	0.175		2.7	78.4		18.9	
▲ BH5	4 - 5	12.5	1.44	0.385	0.098	4.0	88.5		7.5	
★ BH5	9 - 10	9.5	1.434	0.549	0.181	5.6	89.2		5.2	
⊙ BH5	14 - 15	19	1.81	0.615	0.123	6.7	86.5		6.8	

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

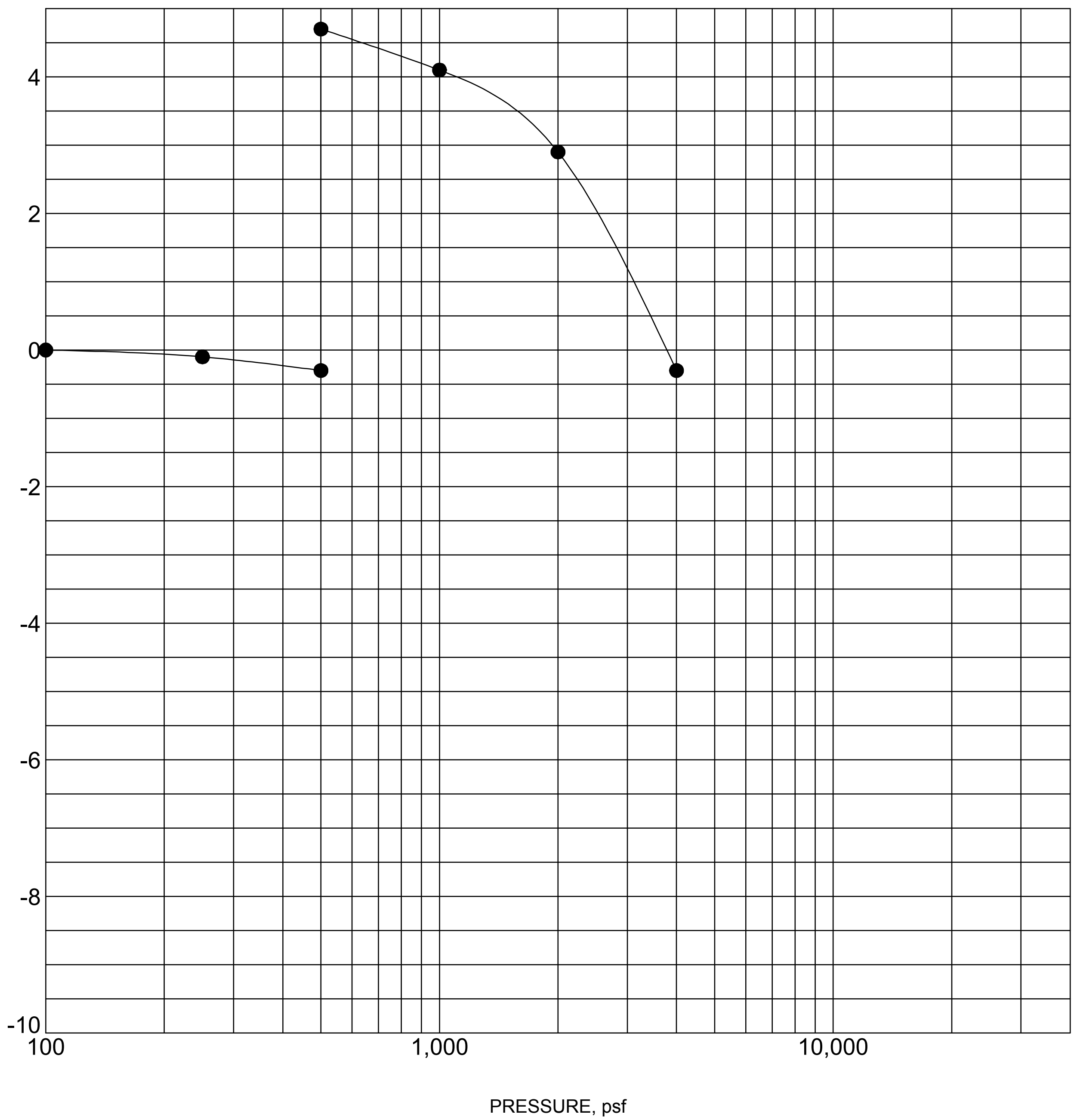
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification		Classification	γ_d, pcf	WC, %
●	BH1 4 - 5 ft	CLAYEY SAND (SC)	102	8

NOTES: Sample inundated with water at 500 pounds per square foot (psf).

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. TC_CONSOL_STRAIN-USCS 23185082 VOLLMER SUBSTATIO.GPJ TERRACON_DATATEMPLATE.GDT 9/12/18

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

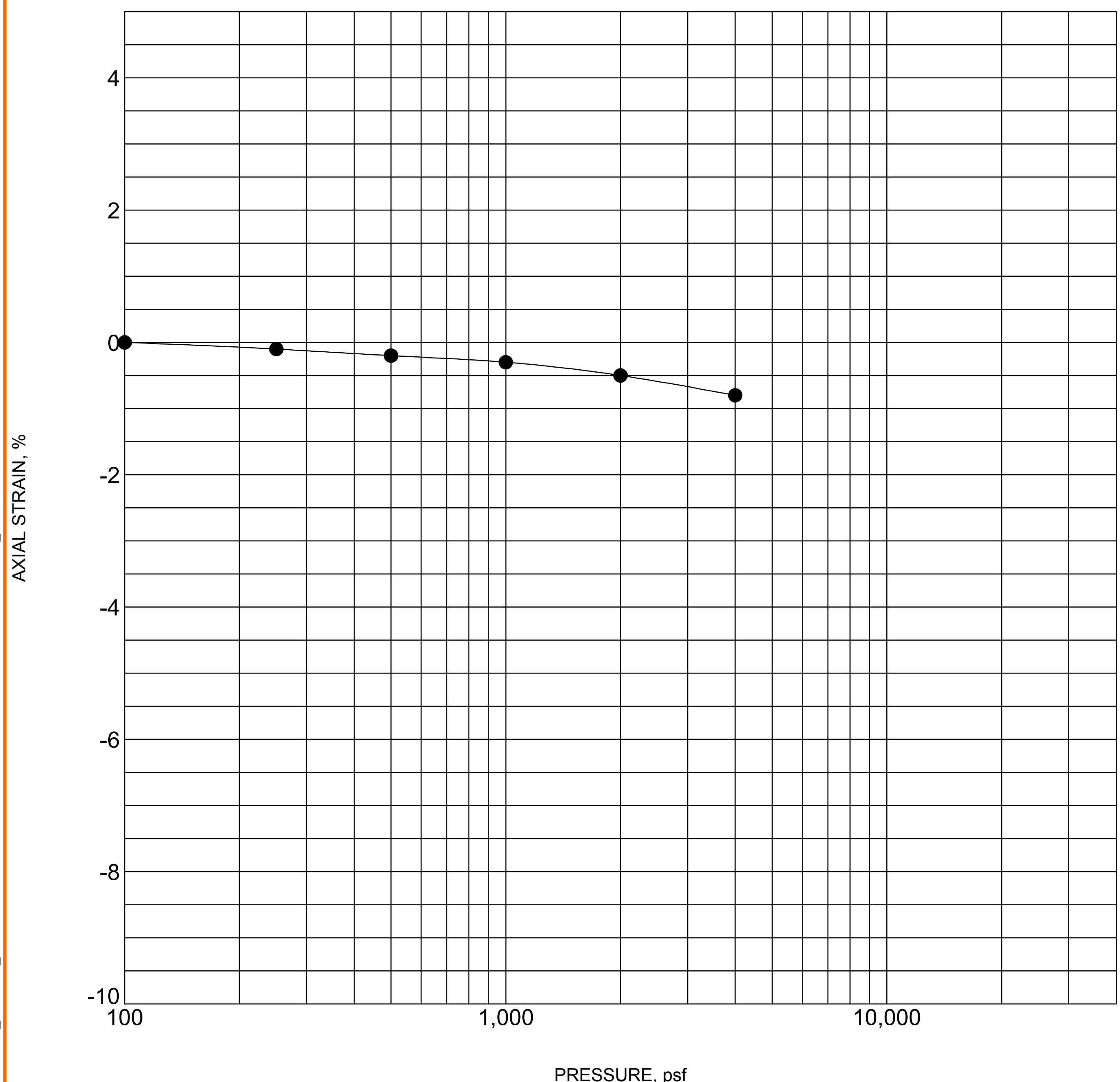
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification		Classification	γ_d, pcf	WC, %
●	BH3 7 - 8 ft	WELL-GRADED SAND with SILT(SW-SM)	121	7

NOTES: Sample inundated with water at 500 pounds per square foot (psf).

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

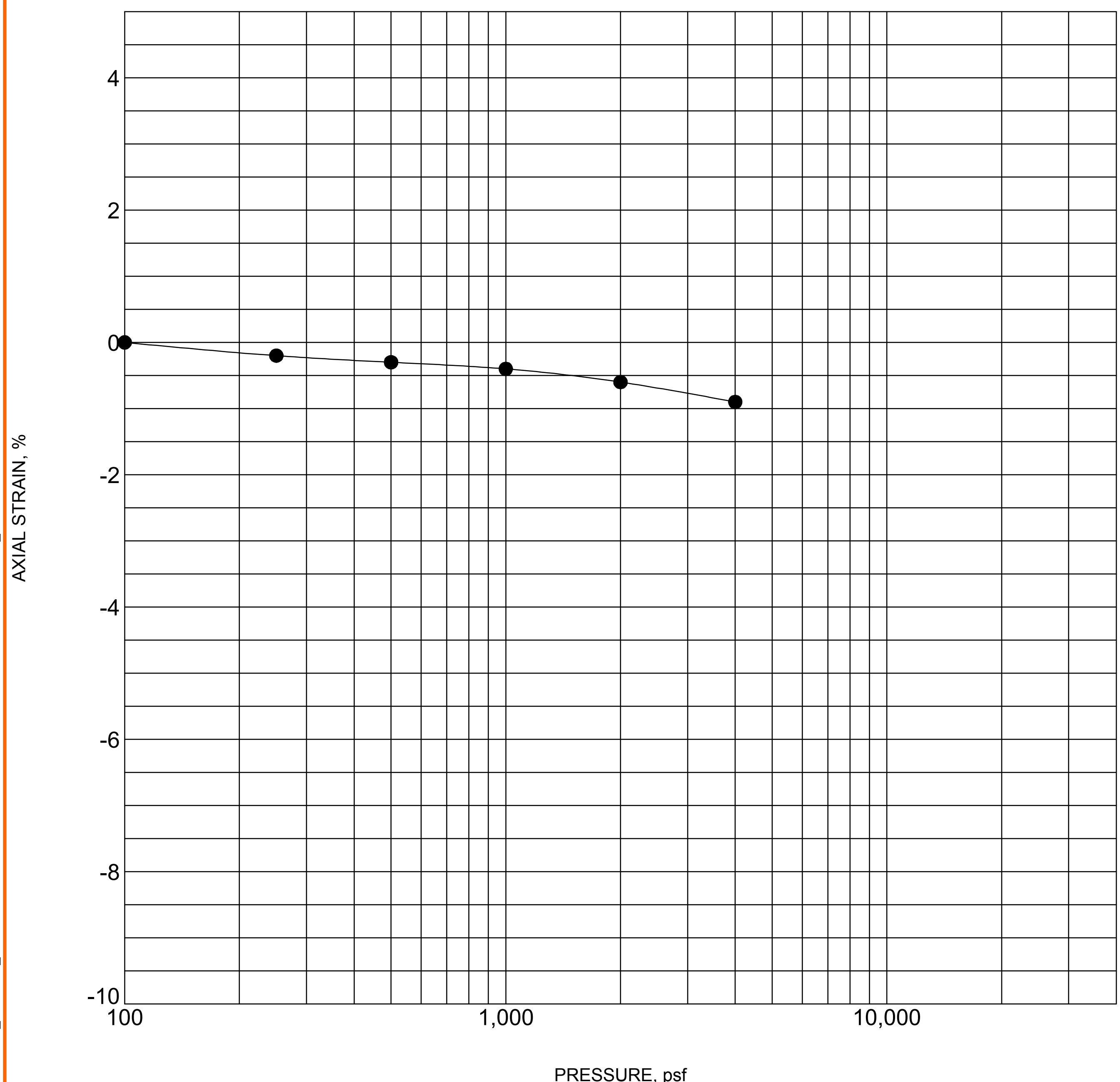
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification			Classification	γ_d, pcf	WC, %
●	BH4	9 - 10 ft	WELL GRADED SAND (SW)	98	7

NOTES: Sample inundated with water at 500 pounds per square foot (psf).

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

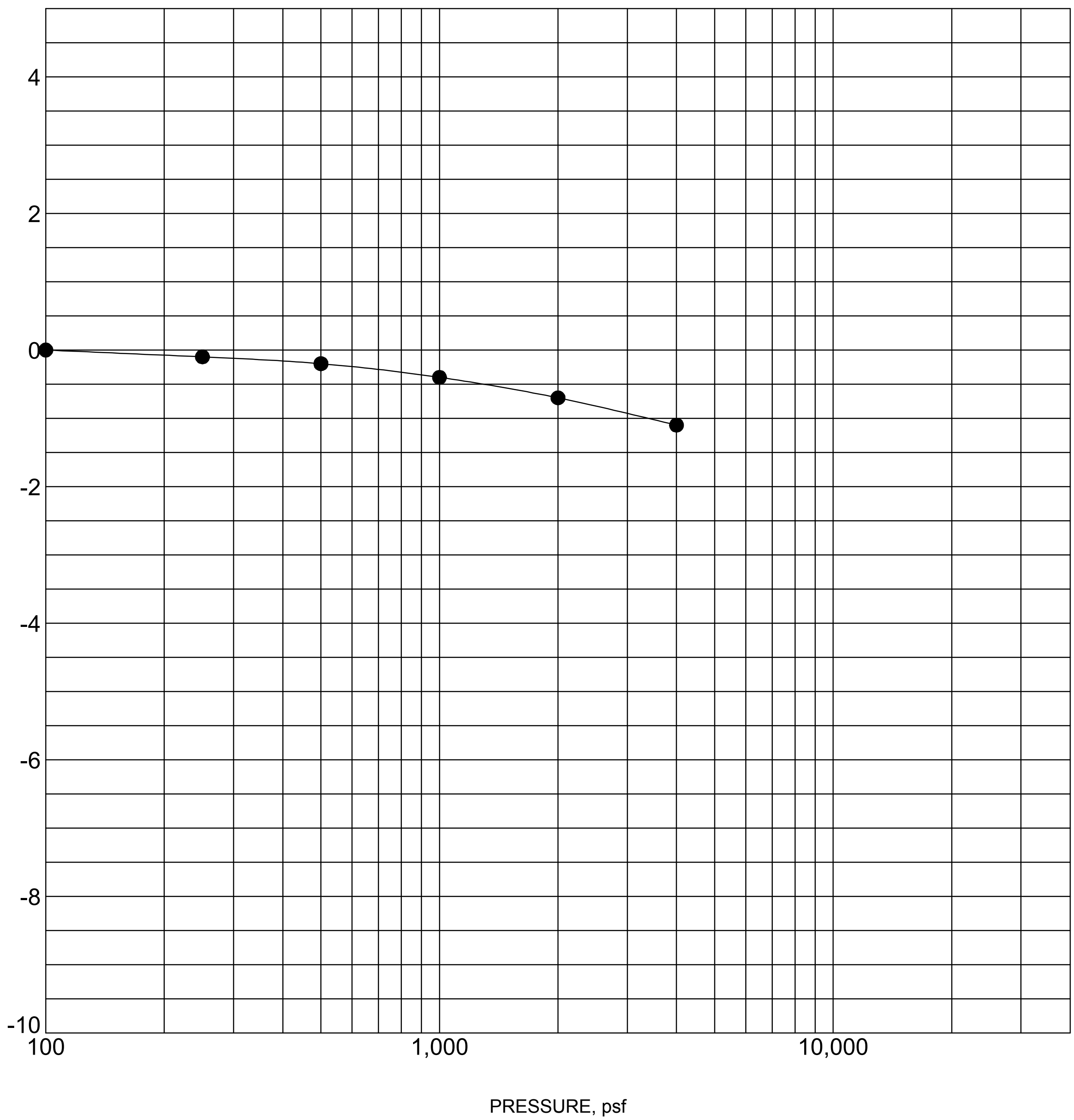
Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification		Classification	γ_d, pcf	WC, %
●	BH5 4 - 5 ft	WELL-GRADED SAND with SILT(SW-SM)	109	2

NOTES: Sample inundated with water at 500 pounds per square foot (psf).

PROJECT: Vollmer Substation

SITE: N.E. of E. Woodmen Road and Brule Road
Colorado Springs, CO

Terracon
4172 Center Park Dr
Colorado Springs, CO

PROJECT NUMBER: 23185082

CLIENT: Tri State Generation & Transmission Assoc Inc
Denver, CO

Colorado Analytical LABORATORIES, INC.

Analytical Results

TASK NO: 180912031

Report To: Tyler Compton
Company: Terracon, Inc. - Colo Springs
4172 Center Park Drive
Colo. Springs CO 80916

Bill To: Tyler Compton
Company: Terracon, Inc. - Accounts Payable
18001 W. 106th St
Suite 300
Olathe KS 66061

Task No.: 180912031
Client PO:
Client Project: Vollmer Substation 23185082

Date Received: 9/12/18
Date Reported: 9/17/18
Matrix: Soil - Geotech

Customer Sample ID BH1 @ 1-5 Ft.
Lab Number: 180912031-01

Test	Result	Method
Chloride - Water Soluble	**0.0003 %**	AASHTO T291-91/ ASTM D4327
pH	**6.5 units**	AASHTO T289-91
Resistivity	**5718 ohm.cm**	AASHTO T288-91
Sulfate - Water Soluble	**< 0.001 %**	AASHTO T290-91/ ASTM D4327

Customer Sample ID BH2 @ 1-10 Ft.
Lab Number: 180912031-02

Test	Result	Method
Chloride - Water Soluble	**0.0006 %**	AASHTO T291-91/ ASTM D4327
pH	**6.5 units**	AASHTO T289-91
Resistivity	**4634 ohm.cm**	AASHTO T288-91
Sulfate - Water Soluble	**< 0.001 %**	AASHTO T290-91/ ASTM D4327

Customer Sample ID BH3 @ 1-10 Ft.
Lab Number: 180912031-03

Test	Result	Method
Chloride - Water Soluble	**0.0016 %**	AASHTO T291-91/ ASTM D4327
pH	**6.2 units**	AASHTO T289-91
Resistivity	**5048 ohm.cm**	AASHTO T288-91
Sulfate - Water Soluble	**0.003 %**	AASHTO T290-91/ ASTM D4327

Abbreviations/ References:

AASHTO - American Association of State Highway and Transportation Officials.
ASTM - American Society for Testing and Materials.
ASA - American Society of Agronomy.
DIPRA - Ductile Iron Pipe Research Association Handbook of Ductile Iron Pipe.

DATA APPROVED FOR RELEASE BY

Colorado Analytical LABORATORIES, INC.

Analytical Results

TASK NO: 180912031

Report To: Tyler Compton
Company: Terracon, Inc. - Colo Springs
4172 Center Park Drive
Colo. Springs CO 80916

Bill To: Tyler Compton
Company: Terracon, Inc. - Accounts Payable
18001 W. 106th St
Suite 300
Olathe KS 66061

Task No.: 180912031
Client PO:
Client Project: Vollmer Substation 23185082

Date Received: 9/12/18
Date Reported: 9/17/18
Matrix: Soil - Geotech

Customer Sample ID BH4 @ 1-5 Ft.
Lab Number: 180912031-04

Test	Result	Method
Chloride - Water Soluble	**0.0004 %**	AASHTO T291-91/ ASTM D4327
pH	**6.6 units**	AASHTO T289-91
Resistivity	**8734 ohm.cm**	AASHTO T288-91
Sulfate - Water Soluble	**< 0.001 %**	AASHTO T290-91/ ASTM D4327

Abbreviations/ References:

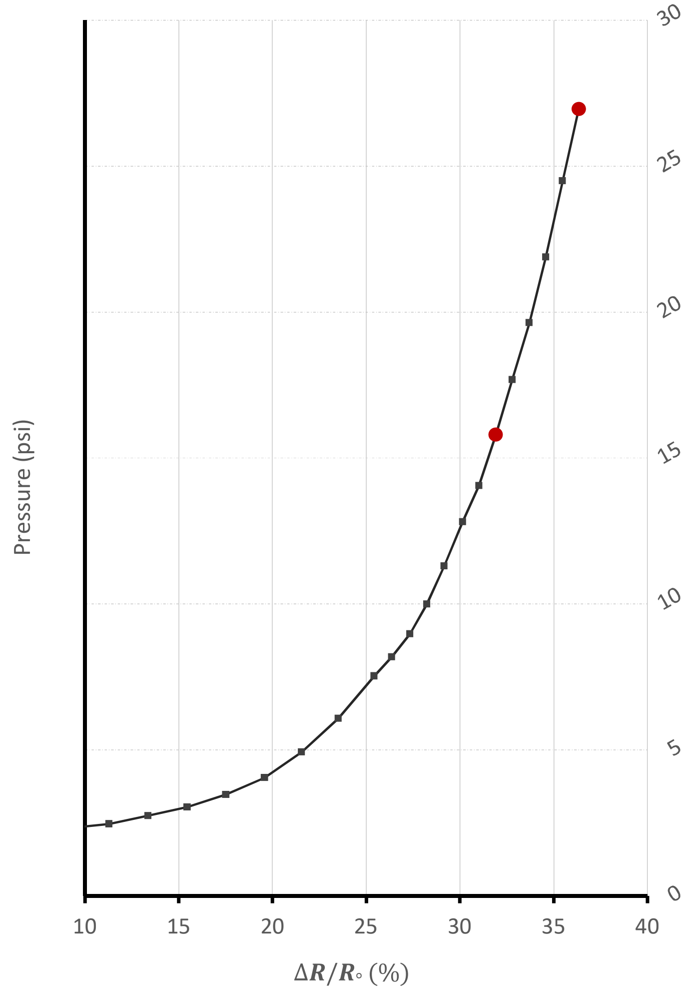
AASHTO - American Association of State Highway and Transportation Officials.
ASTM - American Society for Testing and Materials.
ASA - American Society of Agronomy.
DIPRA - Ductile Iron Pipe Research Association Handbook of Ductile Iron Pipe.

DATA APPROVED FOR RELEASE BY

PRESSUREMETER TEST DATA

Project:	23185082	Use of a slotted casing:	No
Borehole I.D.	B-2	Test depth:	7.50 ft
Test date: (mm/dd/yyyy)	08/07/2018	Manometer Height Above Ground:	1.64 ft
Test number:	1	Poisson's Ratio of Soil or Rock:	0.33
Probe size:	N	Fluid Density (g/cc):	1.000
Pressure Calibration Reference:	08/07/2018 - 1		
Volume Calibration Reference:	08/07/2018 - 1		

Raw Readings		Corrected Readings			
Pressure psi	Volume in³	Pressure psi	Volume in³	$\Delta R/R_\circ$ %	
0	0.0	3	0.0	0.00	
3	4.7	2	4.7	2.28	
4	9.6	2	9.6	4.61	
4	14.5	2	14.5	6.86	
5	19.4	2	19.4	9.09	
5	24.4	2	24.4	11.29	
6	29.2	3	29.2	13.36	
6	34.1	3	34.1	15.46	
7	39.0	3	39.0	17.52	
8	44.0	4	44.0	19.58	
9	48.9	5	48.8	21.56	
10	53.8	6	53.7	23.51	
11	58.6	8	58.6	25.43	
12	61.1	8	61.0	26.36	
13	63.6	9	63.5	27.34	
14	66.0	10	65.9	28.24	
15	68.4	11	68.3	29.16	
17	71.0	13	70.9	30.15	
18	73.3	14	73.3	31.02	
20	75.7	16	75.7	31.91	◄
22	78.1	18	78.1	32.80	
24	80.6	20	80.5	33.71	
26	83.0	22	82.9	34.58	
29	85.5	24	85.4	35.48	
31	87.9	27	87.8	36.33	◄



Remarks

Pressuremeter test zone prepared with 3" roller bit with axial fluid injection. Test zone was significantly oversized due to washing out and caving during drilling. Accordingly, the Yield Pressure was not obtained prior to the maximum volume being reached.

Test Results

Pressuremeter Modulus E[1]:	450	psi
Ultimate Pressure P_L[2]:	n.a.	
Ratio E / P_L:	n.a.	
Yield Pressure P_F:	n.a.	
Ratio P_L / P_F:	n.a.	

[1] The Pressuremeter Modulus was calculated using the straight line (pseudo-elastic) boundaries graphically represented in **RED**.

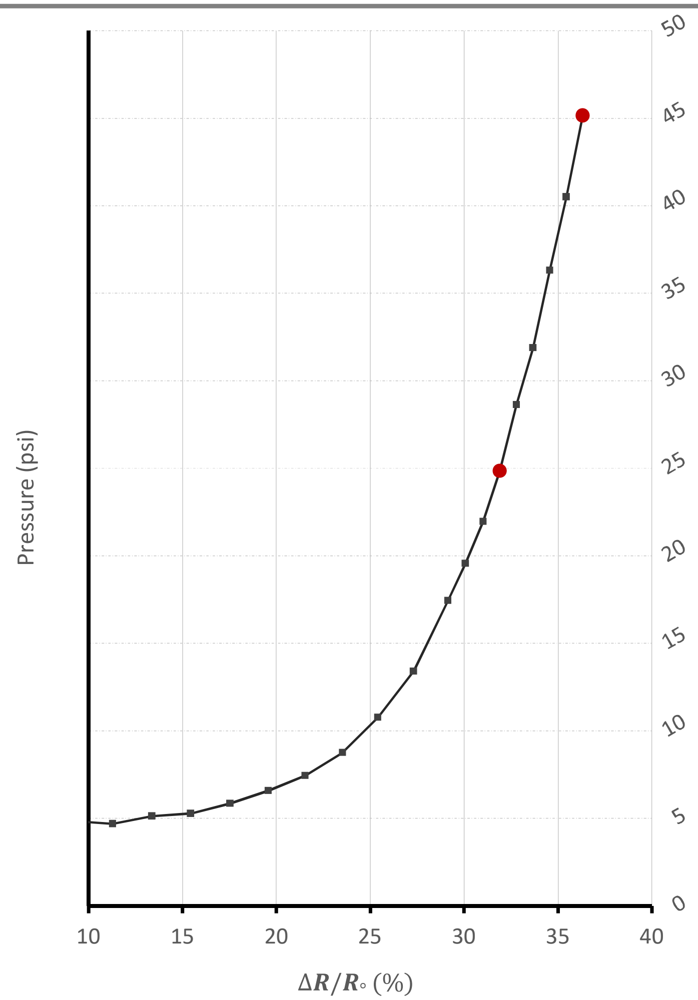
[2] Ultimate Pressure, P_L is estimated using a best fit polynomial curve extrapolated in 20 iterations using the Newton-Raphson method. While graphical extrapoloation is considered to be the recommended method for estimating $P_{L,}$ caution must be excercised in regards to it's use, particularly when the maximum radial strain value is low due to the stiffness of the material tested.

TEXAM COMPANION V.3.4.1

PRESSUREMETER TEST DATA

Project:	23185082		Use of a slotted casing:	No
Borehole I.D.	B-2		Test depth:	14.00 ft
Test date: (mm/dd/yyyy)	08/07/2018		Manometer Height Above Ground:	1.64 ft
Test number:	2		Poisson's Ratio of Soil or Rock:	0.33
Probe size:	N		Fluid Density (g/cc):	1.000
Pressure Calibration Reference:	08/07/2018 - 1			
Volume Calibration Reference:	08/07/2018 - 1			

Raw Readings		Corrected Readings			
Pressure psi	Volume in³	Pressure psi	Volume in³	$\Delta R/R_\circ$ %	
0	0.0	6	0.0	0.00	
2	4.8	5	4.8	2.31	
3	9.7	5	9.7	4.63	
4	14.5	5	14.5	6.86	
4	19.4	5	19.4	9.07	
5	24.4	5	24.4	11.29	
5	29.2	5	29.2	13.37	
6	34.0	5	34.0	15.44	
6	39.0	6	39.0	17.54	
7	43.9	7	43.9	19.56	
8	48.8	7	48.8	21.54	
10	53.8	9	53.8	23.53	
12	58.6	11	58.6	25.42	
15	63.5	13	63.5	27.31	
19	68.4	17	68.3	29.15	
21	70.8	20	70.7	30.08	
23	73.3	22	73.3	31.02	
26	75.7	25	75.6	31.90	◀
30	78.2	29	78.0	32.79	
33	80.6	32	80.5	33.68	
38	83.1	36	82.9	34.57	
42	85.5	41	85.3	35.44	
47	87.9	45	87.7	36.31	◀



Remarks

Pressuremeter test zone prepared with 3" roller bit with axial fluid injection. Test zone was significantly oversized due to washing out and caving during drilling. Accordingly, the Yield Pressure was not obtained prior to the maximum volume being reached.

Test Results

Pressuremeter Modulus E[1]:	821	psi
Ultimate Pressure P_L[2]:	n.a.	
Ratio E / P_L:	n.a.	
Yield Pressure P_F:	n.a.	
Ratio P_L / P_F:	n.a.	

[1] The Pressuremeter Modulus was calculated using the straight line (pseudo-elastic) boundaries graphically represented in **RED**.

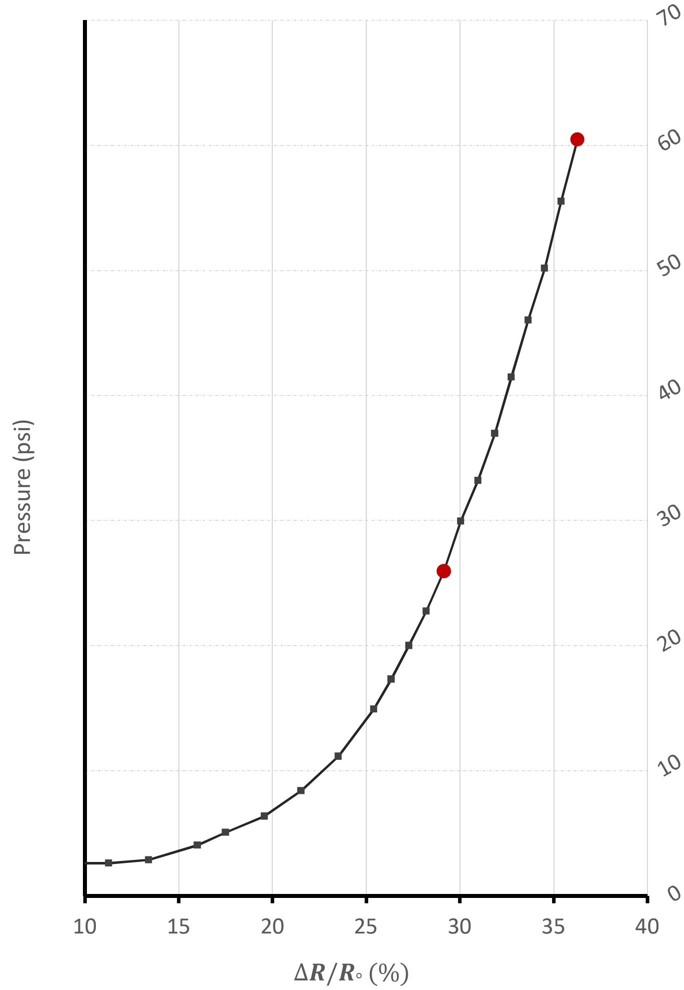
[2] Ultimate Pressure, P_L is estimated using a best fit polynomial curve extrapolated in 20 iterations using the Newton-Raphson method. While graphical extrapoloation is considered to be the recommended method for estimating $P_{L,}$ caution must be excercised in regards to it's use, particularly when the maximum radial strain value is low due to the stiffness of the material tested.

TEXAM COMPANION V.3.4.1

PRESSUREMETER TEST DATA

Project:	23185082	Use of a slotted casing:	No
Borehole I.D.	B-3	Test depth:	9.50 ft
Test date: (mm/dd/yyyy)	08/07/2018	Manometer Height Above Ground:	1.64 ft
Test number:	3	Poisson's Ratio of Soil or Rock:	0.33
Probe size:	N	Fluid Density (g/cc):	1.000
Pressure Calibration Reference:	08/07/2018 - 1		
Volume Calibration Reference:	08/07/2018 - 1		

Raw Readings		Corrected Readings			
Pressure psi	Volume in³	Pressure psi	Volume in³	$\Delta R/R_\circ$ %	
0	0.0	4	0.0	0.00	
2	4.7	3	4.7	2.29	
3	9.7	2	9.7	4.62	
4	14.5	3	14.5	6.85	
4	19.4	3	19.4	9.08	
4	24.3	3	24.3	11.27	
5	29.3	3	29.2	13.40	
6	35.4	4	35.3	16.00	
7	39.0	5	38.9	17.51	
9	43.9	6	43.9	19.56	
11	48.8	8	48.8	21.53	
14	53.8	11	53.7	23.51	
18	58.6	15	58.5	25.41	
20	61.0	17	60.9	26.34	
23	63.5	20	63.4	27.28	
26	65.9	23	65.8	28.21	
29	68.4	26	68.3	29.15	◄
33	70.8	30	70.7	30.05	
36	73.3	33	73.1	30.97	
40	75.7	37	75.5	31.86	
45	78.1	41	77.9	32.74	
49	80.5	46	80.3	33.64	
54	83.0	50	82.8	34.52	
59	85.4	56	85.2	35.40	
64	87.9	60	87.6	36.27	◄



Remarks

Pressuremeter test zone prepared with 3" roller bit with axial fluid injection. Test zone was significantly oversized due to washing out and caving during drilling. Accordingly, the Yield Pressure was not obtained prior to the maximum volume being reached.

Test Results

Pressuremeter Modulus E[1]:	857	psi
Ultimate Pressure P_L[2]:	n.a.	
Ratio E / P_L:	n.a.	
Yield Pressure P_F:	n.a.	
Ratio P_L / P_F:	n.a.	

[1] The Pressuremeter Modulus was calculated using the straight line (pseudo-elastic) boundaries graphically represented in **RED**.

[2] Ultimate Pressure, P_L is estimated using a best fit polynomial curve extrapolated in 20 iterations using the Newton-Raphson method. While graphical extrapoloation is considered to be the recommended method for estimating $P_{L,}$ caution must be excercised in regards to it's use, particularly when the maximum radial strain value is low due to the stiffness of the material tested.

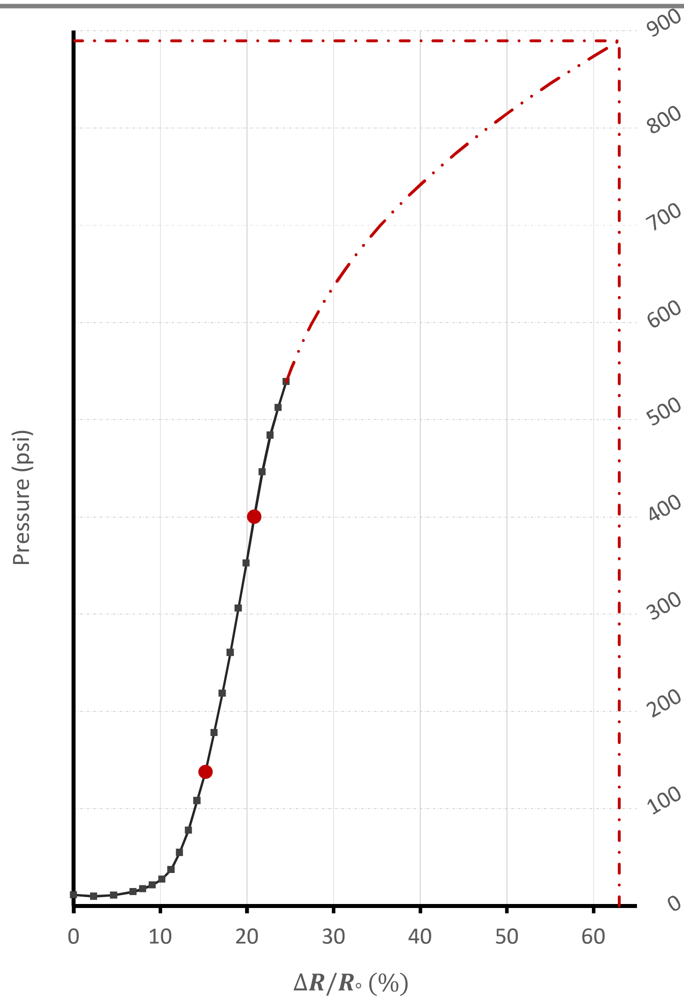
TEXAM COMPANION V.3.4.1

PRESSUREMETER TEST DATA

MAPES IN-SITU

Project:	23185082	Use of a slotted casing:	No	
Borehole I.D.	B-3	Test depth:	25.50	ft
Test date: (mm/dd/yyyy)	08/07/2018	Manometer Height Above Ground:	1.64	ft
Test number:	5	Poisson's Ratio of Soil or Rock:	0.33	
Probe size:	N	Fluid Density (g/cc):	1.000	
Pressure Calibration Reference:	08/07/2018 - 1			
Volume Calibration Reference:	08/07/2018 - 1			

Raw Readings		Corrected Readings			
Pressure psi	Volume in³	Pressure psi	Volume in³	$\Delta R/R_\circ$ %	
0	0.0	11	0.0	0.00	
3	4.8	10	4.8	2.33	
4	9.7	11	9.7	4.63	
8	14.6	14	14.5	6.87	
12	17.0	17	17.0	7.98	
16	19.5	21	19.4	9.08	
22	22.0	27	21.9	10.18	
32	24.4	37	24.2	11.23	
50	26.8	55	26.6	12.25	
73	29.2	78	28.9	13.25	
103	31.6	108	31.2	14.24	
133	34.0	138	33.5	15.22	◄
174	36.5	178	35.8	16.20	
214	38.9	219	38.1	17.16	
256	41.3	260	40.4	18.10	
302	43.8	306	42.6	19.02	
348	46.2	352	44.8	19.94	
396	48.6	400	47.1	20.85	◄
442	51.0	446	49.3	21.76	
480	53.5	484	51.6	22.68	
508	55.9	512	54.0	23.60	
535	58.4	539	56.3	24.53	



Remarks

Pressuremeter test zone prepared with 3" drag bit with axial fluid injection. Membrane ruptured during loading phase after the last data point shown. Accordingly, the test was not carried out to the maximum pressure / volume possible with the equipment used.

Test Results

Pressuremeter Modulus E [1]:	7,325	psi
Ultimate Pressure P_L [2]:	890	psi
Ratio E / P_L:	8.23	
Yield Pressure P_F:	400	psi
Ratio P_L / P_F:	2.22	

[1] The Pressuremeter Modulus was calculated using the straight line (pseudo-elastic) boundaries graphically represented in **RED**.

[2] Ultimate Pressure, P_L is estimated using a best fit polynomial curve extrapolated in 20 iterations using the Newton-Raphson method. While graphical extrapoloation is considered to be the recommended method for estimating $P_{L,}$ caution must be excercised in regards to it's use, particularly when the maximum radial strain value is low due to the stiffness of the material tested.

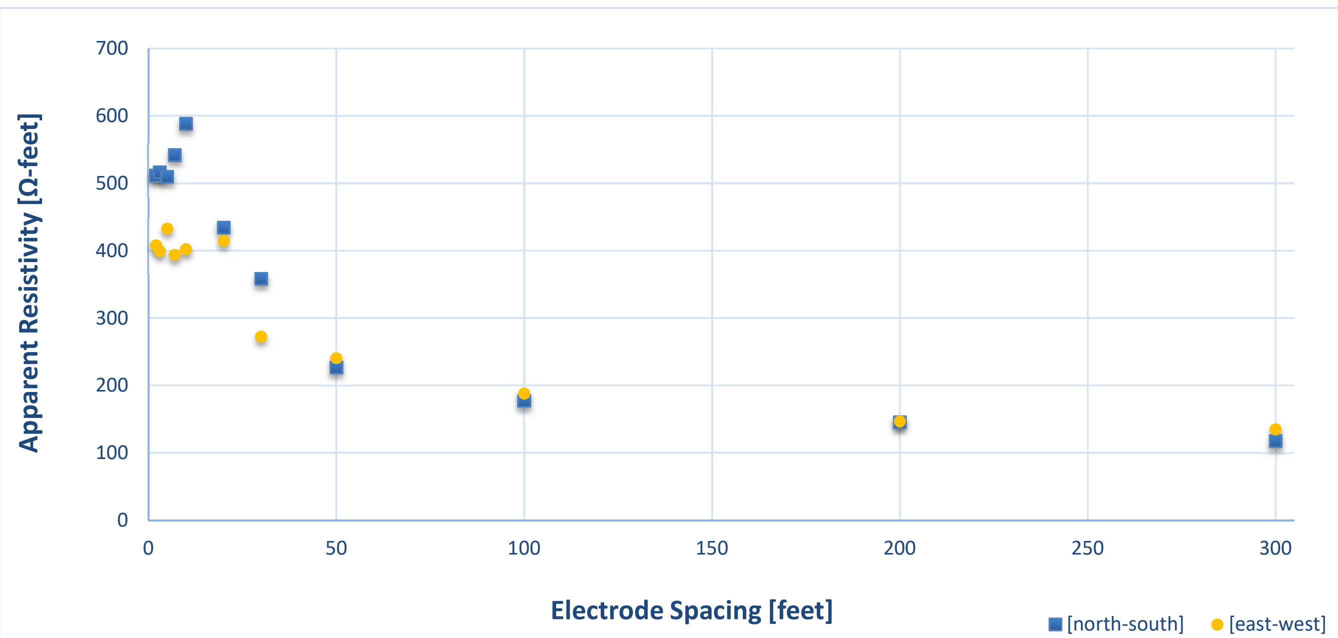
TEXAM COMPANION V.3.4.1

Electrical Resistivity Soundings - Wenner Array (IEEE)

Project	Vollmer Substation	**Coordinates**	38.956308, -104.651240
Test ID	ER-1	**Surface Soil**	Moist sand
Project No.	P2018032	**Instrument**	ABEM Terrameter SAS 1000
Test Date	8/15/2018	**Field Calibration**	100.04 ohms / 100 ohms

Electrode Spacing (A)	Measured Resistance (Ω)		Apparent Resistivity (Ω-feet)	
[feet]	[north-south]	[east-west]	[north-south]	[east-west]
2	40.723	32.475	512	408
3	27.406	21.196	517	400
5	16.231	13.774	510	433
7	12.318	8.955	542	394
10	9.367	6.399	589	402
20	3.456	3.298	434	414
30	1.902	1.447	359	273
50	0.722	0.766	227	241
100	0.282	0.299	177	188
200	0.116	0.117	146	147
300	0.062	0.072	117	135

Notes: Soil was moist with good electrode contact.



Recommended LPILE & FAD Design Parameters

Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis

Boring B-1												
Soil/ Bedrock Type	Layer (feet)	Total Unit Weight (pcf)	Friction Angle (°)	Undrained Shear Strength (psf)	Ultimate Pressure for Vertical Loading [1]		LPILE Parameters				MFAD Parameters
					End Bearing (psf) [2]	Skin Friction (psf) [3]	Soil Code	Horizontal Modulus of Subgrade Reaction (pci)		Strain at 50% of Maximum Stress, E_{50}	Modulus of Deformation (psi)
								Static	Cyclic		
Sand	3 to 4.5	97	28	---	N/A	60	Sand (Reese)	25	---	---	400
Sand	4.5 to 12	110	30	---	8,500	150	Sand (Reese)	90	---	---	600 [4]
Sand	12 to 17	119	34	---	15,500	275	Sand (Reese)	225	---	---	600 [4]
Claystone	17 to 22	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]
Claystone	22 to 27	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]
Sandstone	25 to 35	130	36	---	38,500	600	Sand (Reese)	125	---	---	7,000

1. Provided values are ultimate and not working values. An appropriate factor of safety or load reduction factor should be applied by the design engineer.
2. Applicable for a minimum length of at least 10 feet below existing grade.
3. Skin friction should not be used in the soil profile if slurry or other “wet” shaft techniques are used for installation
4. Design value based on correlation with Pressuremeter Test Results from similar materials tested in Borings BH2 and BH3.

Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis

Boring B-2											
Soil/ Bedrock Type	Layer (feet)	Total Unit Weight (pcf)	Friction Angle (°)	Undrained Shear Strength (psf)	Ultimate Pressure for Vertical Loading [1]		LPILE Parameters				MFAD Parameters
					End Bearing (psf) [2]	Skin Friction (psf) [3]	Soil Code	Horizontal Modulus of Subgrade Reaction (pci)		Strain at 50% of Maximum Stress, E_{50}	Modulus of Deformation (psi)
								Static	Cyclic		
Sand	3 to 8.5	117	30	---	N/A	100	Sand (Reese)	90	---	---	400 [4]
Sand	8.5 to 17	110	31	---	14,500	250	Sand (Reese)	90	---	---	800 [4]
Claystone	17 to 22	125	--	2,000	18,000	800	Stiff clay w/o free water	1,000	400	0.005	2,000
Sandstone	22 to 29.5	130	---	4,000	38,500	600	Sand (Reese)	225	---	---	7,000

1. Provided values are ultimate and not working values. An appropriate factor of safety or load reduction factor should be applied by the design engineer.
2. Applicable for a minimum length of at least 10 feet below existing grade.
3. Skin friction should not be used in the soil profile if slurry or other “wet” shaft techniques are used for installation
4. Based on Pressuremeter Test Results.

Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis

Boring B-3											
Soil/ Bedrock Type	Layer (feet)	Total Unit Weight (pcf)	Friction Angle (°)	Undrained Shear Strength (psf)	Ultimate Pressure for Vertical Loading [1]		LPILE Parameters				MFAD Parameters
					End Bearing (psf) [2]	Skin Friction (psf) [3]	Soil Code	Horizontal Modulus of Subgrade Reaction (pci)		Strain at 50% of Maximum Stress, E_{50}	Modulus of Deformation (psi)
								Static	Cyclic		
Sand	3 to 6	102	28	---	N/A	50	Sand (Reese)	25	---	---	400 [5]
Sand	6 to 12	129	31	---	13,500	225	Sand (Reese)	90	---	---	800 [4]
Sand	12 to 17	109	29	---	16,500	265	Sand (Reese)	90	---	---	800 [4]
Sand	17 to 22	110	34	---	22,000	450	Sand (Reese)	225	---	---	800 [4]
Claystone	22 to 27	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]
Claystone	25 to 35	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]

1. Provided values are ultimate and not working values. An appropriate factor of safety or load reduction factor should be applied by the design engineer.
2. Applicable for a minimum length of at least 10 feet below existing grade.
3. Skin friction should not be used in the soil profile if slurry or other “wet” shaft techniques are used for installation.
4. Based on Pressuremeter Test Results.
5. Design value based on correlation with Pressuremeter Test Results from similar material tested in Boring BH2.

Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis

Boring B-4											
Soil/ Bedrock Type	Layer (feet)	Total Unit Weight (pcf)	Friction Angle (°)	Undrained Shear Strength (psf)	Ultimate Pressure for Vertical Loading [1]		LPILE Parameters				MFAD Parameters
					End Bearing (psf) [2]	Skin Friction (psf) [3]	Soil Code	Horizontal Modulus of Subgrade Reaction (pci)		Strain at 50% of Maximum Stress, E_{50}	Modulus of Deformation (psi)
								Static	Cyclic		
Sand	3 to 6	100	25	---	N/A	40	Sand (Reese)	25	---	---	175
Sand	6 to 12	105	28	---	7,300	140	Sand (Reese)	25	---	---	600 [4]
Claystone	12 to 29.5	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]

1. Provided values are ultimate and not working values. An appropriate factor of safety or load reduction factor should be applied by the design engineer.
2. Applicable for a minimum length of at least 10 feet below existing grade.
3. Skin friction should not be used in the soil profile if slurry or other “wet” shaft techniques are used for installation
4. Design value based on correlation with Pressuremeter Test Results from similar materials tested in Borings BH2 and BH3.

Recommended Soil and Bedrock Parameters for LPILE and FAD Analysis

Boring B-5											
Soil/ Bedrock Type	Layer (feet)	Total Unit Weight (pcf)	Friction Angle (°)	Undrained Shear Strength (psf)	Ultimate Pressure for Vertical Loading [1]		LPILE Parameters				MFAD Parameters
					End Bearing (psf) [2]	Skin Friction (psf) [3]	Soil Code	Horizontal Modulus of Subgrade Reaction (pci)		Strain at 50% of Maximum Stress, E_{50}	Modulus of Deformation (psi)
								Static	Cyclic		
Sand	3 to 12	107	30	---	6,400	110	Sand (Reese)	25	---	---	800 [4]
Sandstone	12 to 17	125	36	---	22,000	325	Sand (Reese)	225	---	---	6,000
Sandstone	17 to 22	130	36	---	32,000	500	Sand (Reese)	225	---	---	7,000
Claystone	22 to 27	130	---	4,000	36,000	1,600	Stiff clay w/o free water	2,000	800	0.005	7,000 [4]
Sandstone	27 to 30	130	36	----	38,500	600	Sand (Reese)	225	---	---	7,000

1. Provided values are ultimate and not working values. An appropriate factor of safety or load reduction factor should be applied by the design engineer.
2. Applicable for a minimum length of at least 10 feet below existing grade.
3. Skin friction should not be used in the soil profile if slurry or other "wet" shaft techniques are used for installation
4. Design value based on correlation with Pressuremeter Test Results from similar materials tested in Borings BH2 and BH3.

SUPPORTING INFORMATION

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Vollmer Substation ■ Colorado Springs, CO

September 14, 2018 ■ Terracon Project No. 23185082

Terracon GeoReport

SAMPLING	WATER LEVEL	FIELD TESTS
Modified Dames & Moore Ring Sampler; Grab Sample; 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				BEDROCK		
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.**	**Ring Sampler Blows/Ft.**	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**
Very Loose	0 - 3	0 - 6	Very Soft	less than 0.25	0 - 1	< 3	< 30	< 20	Weathered
Loose	4 - 9	7 - 18	Soft	0.25 to 0.50	2 - 4	3 - 4	30 - 49	20 - 29	Firm
Medium Dense	10 - 29	19 - 58	Medium Stiff	0.50 to 1.00	4 - 8	5 - 9	50 - 89	30 - 49	Medium Hard
Dense	30 - 50	59 - 98	Stiff	1.00 to 2.00	8 - 15	10 - 18	90 - 119	50 - 79	Hard
Very Dense	> 50	≥ 99	Very Stiff	2.00 to 4.00	15 - 30	19 - 42	> 119	>79	Very Hard
			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

Vollmer Substation ■ Colorado Springs, Colorado

September 17, 2018 ■ Terracon Project No. 20185082

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 $1 > Cc > 3$ [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 $1 > Cc > 3$ [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] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[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.

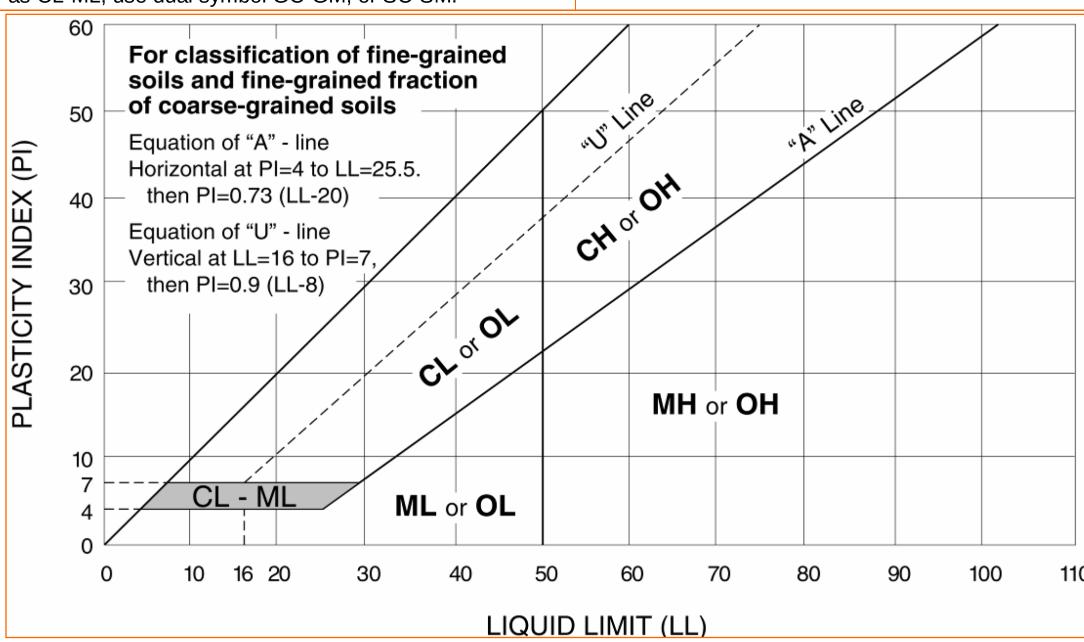
[M] If soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



DESCRIPTION OF ROCK PROPERTIES

Terracon GeoReport

WEATHERING	
Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" no discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)	
Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding, and Foliation Spacing in Rock [1]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

1. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

Rock Quality Designator (RQD) [1]

RQD, as a percentage	Diagnostic description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

1. RQD (given as a percentage) = length of core in pieces 4 inches and longer / length of run

Joint Openness Descriptors

Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly Open
1/32 to 1/8 in.	Moderately Open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately Wide
Greater than 0.1 ft.	Wide

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.