Geotechnical Engineering Report

Proposed Seven Clans Avenue Substation
Tahlequah, Oklahoma

July 02, 2018

Terracon Project No. 04185092

Prepared for:

OG&E Electric Services
Oklahoma City, Oklahoma

Prepared by:

Terracon Consultants, Inc.
Tulsa, Oklahoma

Terracon

July 2, 2018

OG&E Electrical Services
P.O. Box 321, Mail Code M105
Oklahoma City, Oklahoma 73101-0321

Attn: Mr. Neil Chaves, Substation Engineer
P: (405) 553 8528
E: ChavesNG@oge.com

Re: Geotechnical Engineering Report
Red Fern Substation
Tahlequah, Oklahoma
OG&E PO # 4500871719
Terracon Project No. 04175218

Dear Mr. Chaves:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. Our services were performed per the Scope of Services provided by OG&E and authorized by Purchase Order PO number 4500893890 dated April 13, 2018. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning general earthwork and the design and construction of foundations for the proposed substation.

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

Sincerely,
Terracon Consultants, Inc.
Cert. Of Auth. #CA-4531 exp. 6/30/19

Saba M. Gebretsadik, P.E. (TX)
Staff Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
BRADLEY MARK WATTS
16526
OKLAHOMA
7/2/18

Bradley M. Watts, P.E.
Oklahoma No. 16526

SMG:SMG:cj
Copies to: Addressee (1 via mail, 1 via email)

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GEOTECHNICAL ENGINEERING REPORT
PROPOSED SEVEN CLANS SUBSTATION
TAHLEQUAH, OKLAHOMA

Terracon Project No. 04185092
July 02, 2018

1.0 INTRODUCTION

This geotechnical engineering report has been completed for the proposed OG&E Seven Clans Avenue Substation to be constructed in Tahlequah, Oklahoma (see Exhibit A-1 – Site Location Map). Three borings, designated B-1, B-2, and B-3, were performed for the project to depths of approximately 18.6 to 35 feet below the existing ground surface. Borings B-2 and B-3 were drilled for the dead end structures, which will be supported on drilled pier foundations. Boring B-1 was drilled for the proposed transformer which will be supported on a shallow foundation. Logs of the borings along with a site location map and boring location plan are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil and rock conditions
- groundwater conditions
- general earthwork
- foundation design and construction
- seismic site classification

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Figure A-2, Boring Location Plan.
Proposed development	We understand that a new substation will be constructed on the site. The project will include installing steel poles on drilled piers and a transformer on a shallow mat foundation.
Maximum structural loads	D-5 Line Terminal/Dead End Structures (Borings B-2 and B-3): Moment: 316.9 kip-ft (given) Horizontal: 10.25 kips (given) Compression: 5.5 kips (given) Transformer (Boring B-1): Compression: 50 to 150 kips (assumed)

Item	Description
Proposed grading	We have not been provided with a grading plan at the time of this report. However, we assume that maximum cut and fill depths on the order of about 2 to 3 feet, relative to the existing grades, will be necessary to achieve the proposed grades.

2.2 Site Location and Description

Item	Description
Location	Near the northeast corner of South Muskogee Avenue and East Willis Road / D0790 Road in Tahlequah, Oklahoma.
Existing improvements	None.
Current ground cover	Grass.
Existing topography	Based on surface elevation at our boring locations, the site appears to slope gently up from the north to the south. A maximum surface elevation difference of approximately 2.5 feet was measured at the borings.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Subsurface Profile

Based on the results of the borings, subsurface conditions across the site can be generalized as follows:

Stratum	Approximate Depth to Bottom of Stratum	Material Description	Comments
Surface	3 to 4 inches	Topsoil and vegetation	N/A
1 [1, 2]	Encountered to the termination depths of 18.6 to 35 feet	Lean clay and fat clay with varying amounts of broken gravel and hard chert layers; and broken chert with varying amounts of clay layers	Clay: Stiff to very stiff Broken chert: Hard

1. Soft to medium stiff fat clay was encountered below a depth of about 28 feet in boring B-2.
2. Auger refusal was realized in boring B-3 at a depth of about 32.5 feet on hard chert.

In the laboratory, collected samples were tested for moisture content and Atterberg limits. Laboratory test results are included on the boring logs in Appendix A.

Conditions encountered at each boring location are indicated on the individual boring logs in Appendix A. Stratification boundaries on the boring logs represent the approximate location of changes in soil and rock types; in-situ, the transition between materials may be gradual.

3.2 Groundwater

The boreholes were observed while drilling and immediately after completion for the presence and level of groundwater. The water levels observed in the boreholes can be found on the boring logs in Appendix A, and are summarized below.

Groundwater Level Observations		
	Groundwater depths (feet)	
Boring	**While Drilling**	**After Boring**
B-1	Not encountered	Not encountered
B-2	Not encountered	Not encountered
B-3	Not encountered to 13 feet	Not measured [1]

1. Accurate groundwater level measurement could not be taken after rock coring was started because the water used in the rock coring procedure masks the presence and level of groundwater.

The groundwater level observations made during our exploration provide an indication of the groundwater conditions at the time the borings were drilled. Longer monitoring in piezometers or cased holes, sealed from the influence of surface water, would be required to evaluate longer-term groundwater conditions. During some periods of the year, perched water could be present at various depths. Fluctuations in groundwater levels should be expected throughout the year depending upon variations in the amount of rainfall, runoff, evaporation, and other hydrological factors not apparent at the time the boring was performed.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Excavations into the cherty clays, broken chert or chert may encounter significant construction difficulties. It should be recognized that subsurface materials are not truly bedrock, but rather a regolith (heterogeneous mixture of unconsolidated rocky material and clay) left by the solution weathering of the parent cherty limestone. As such, the materials encountered within the depths of the exploration are highly variable both vertically and horizontally in composition (gravel, rock, clay content), consistency, density, hardness and capacity. Given the high degree of variability in the chert, broken chert to cherty clay layers, some cost increases above normal excavation costs should be anticipated. Some layers of broken chert and chert are relatively thick, interlocked and very hard. Other layers appear to be randomly interspersed with ledges or boulders embedded in a clay matrix. Both will be very difficult to excavate or grade, with conventional excavation equipment and will require other special excavation techniques. Contractors should also be made aware of the relative strength of the chert, which can exhibit intact unconfined strengths in excess of 35,000 psi, which will cause significant wear and damage to conventional excavation equipment. In our opinion and our experience on past projects, the variability of the overall stratum and the hardness of the chert layers will incur significantly higher excavation and foundation installation costs compared to normal installation.

We understand that shallow and deep foundations are planned for the proposed substation. More specifically, we understand that drilled pier foundations are planned at/near borings B-2 and B-3 and a mat foundation is planned at/near boring B-1.

Based on the results of our exploration, steel poles installed to resist relatively high vertical and/or lateral loads can be supported by drilled piers. Recommendations for drilled pier foundations are provided in section **4.3 Drilled Pier Foundations**.

The proposed transformer can be supported by a shallow mat foundation bearing on the native very stiff cherty lean clay or tested and approved new engineered fill. Recommendations for a shallow mat foundation are provided in section **4.4 Shallow Foundations**.

Close observation and testing will be required during subgrade preparation and foundation construction to verify that suitable bearing materials are encountered. Recommendations regarding earthwork and the design and construction of foundations are provided in the following sections.

4.2 Earthwork

4.2.1 Site Preparation

Areas within the limits of construction should be stripped and cleared of surface gravel, debris, and any other deleterious material.

After stripping, grubbing and completing necessary grading cuts, but prior to placing any new fill, the exposed soil subgrade should be proofrolled to aid in locating soft, unstable areas. Proofrolling should be performed with a loaded tandem axle dump truck weighing at least 25 tons. Any low strength, unstable soils identified by the proofrolling should be overexcavated and replaced with tested and approved fill as indicated in section **4.2.2 Select Fill Materials**, if they cannot be adequately stabilized in-place. Areas too small to proofroll should be evaluated by a representative of the geotechnical engineer.

After completing the proofrolling, and before placing any fill, the exposed soil subgrade should be compacted as recommended in Section **4.2.3 Compaction Requirements**.

4.2.2 Fill Materials Types

Engineered fill materials should meet the following material property requirements:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Imported Low Volume Change (LVC) Material [2]	CL or SC $8 \leq PI \leq 18$	Acceptable in all locations.
On-Site Clay Soils	CL or CH	Acceptable in all locations, pending further evaluation and approval during construction. [3]
On-Site Broken Chert	N/A	Not acceptable as engineered fill due to the expectation that the materials contains oversize rock (> 3 inches) and low percentage of fines.

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris and contain maximum rock size of 3 inches. 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.
2. Approved, low plasticity cohesive soil having a Plasticity Index (PI) between 8 and 18 and containing at least 15% fines (material passing the No. 200 sieve, based on dry weight).
3. The quantity of suitable on-site clays may be limited and will need to be further evaluated at the time of construction. On-site clay soils suitable for use as engineered fill should contain at least 15% fines (material passing the No. 200 sieve, based on dry weight) and contain a maximum rock size of 3 inches. The potential exists that the on-site clays could contain oversize rock pieces in such quantity that it may not be practical to remove the rock so that the material meets the stated criteria.

4.2.3 Compaction Requirements

The subgrade and fill should be moisture conditioned and compacted using the recommendations in the following table.

Item	Description
Subgrade Scarification Depth	9 inches
Fill Lift Thickness [1]	9 inches or less in loose thickness
Compaction Requirements [2]	At least 95% of the materials maximum standard Proctor dry density (ASTM D-698).
Moisture Content	Imported LVC Material and On-Site Clay Soils: Within minus 1 to plus 3 percent of the material's optimum moisture content, determined in accordance with ASTM D-698.

1. Thinner lifts are recommended in confined areas or when hand-operated compaction equipment is used.
2. We recommend that engineered fills (including compacted subgrade) be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

The recommended moisture content should be maintained in the scarified and compacted subgrade and fills until fills are completed and shallow foundations are constructed.

4.2.4 Site Drainage

All grades must provide effective drainage away from the structures during and after construction. Water permitted to pond next to the structures can result in greater soil movements than those discussed in this report. These greater movements can result in unacceptable differential floor slab movements, cracked slabs and walls, and roof leaks. Estimated movements described in this report are based on effective drainage for the life of the structure and cannot be relied upon if effective drainage is not maintained.

Exposed ground should be sloped at a minimum 5 percent away from the proposed structures for at least 10 feet beyond their perimeter. After project construction, we recommend verifying final grades to document that effective drainage has been achieved. Grades around the structures should also be periodically inspected and adjusted as necessary, as part of the project's maintenance program.

4.2.5 Earthwork Construction Considerations

Upon completion of filling and grading, care should be taken to maintain the subgrade moisture content prior to construction of foundations. Construction traffic over the completed subgrade should be avoided to the extent practical. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become frozen, excessively wetted or dried, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior to construction of new fills or mat/pad foundations.

The grading contractor, by his contract, is usually responsible for designing and constructing stable, temporary excavations and should shore, slope or bench the sides of the excavations as required, to maintain stability of both the excavation sides and bottom. All excavations should comply with applicable local, state and federal safety regulations, including the current OSHA Excavation and Trench Safety Standards.

The geotechnical engineer should be retained during the construction phase of the project to provide observation and testing during subgrade preparation and earthwork.

4.3 Drilled Pier Foundations

Based on the subsurface conditions encountered, the dead end structures can be supported on drilled pier foundations. The tables attached in Appendix C, present allowable design criteria for the drilled pier foundations. The tables include the parameters required for the LPILE and MFAD computer programs and for conventional limit equilibrium analysis.

In the tables, the net allowable bearing pressure has a safety factor of at least 3. Also, the allowable side friction and allowable passive pressure values have safety factors of at least 2. Design soil parameters shown in the tables are applicable to the natural, undisturbed soils and should not be applied to disturbed materials or newly placed fill materials. Because soil strength varies due to frost action and moisture variations, we recommend neglecting passive pressure and frictional resistance forces for the soils within 2 feet of the ground surface.

The straight shaft piers should have a minimum diameter of 24 inches and be provided with enough steel reinforcement to provide adequate structural integrity. We anticipate that temporary casing may be needed to prevent caving of the excavation sides; however, the final determination should be made at the time of construction.

Groundwater was not encountered in the borings at the time of this investigation. However, the need for dewatering should be determined based on actual conditions encountered during construction. The need for dewatering will depend on the pier length and actual groundwater conditions at the time of construction. Prior to placing concrete, water or sloughed material should be removed from the base of the drilled piers. If water is encountered and it cannot be removed, the concrete should be pumped from the bottom of the pier excavation to the top, displacing the water to the surface. To facilitate pier construction, concrete should be on-site and ready for placement as pier excavations are completed.

A heavy-duty pier rig equipped with a rock auger and a rock coring bit will be required to complete the pier excavation. The contractor should anticipate difficulties in advancing drilled piers in the clay and chert materials at this site.

Drilled pier foundations designed and constructed according to the recommendations provided above and bearing within approved mateials should experience total long-term settlements of 1 inch or less.

A Terracon representative should observe all foundation excavations to evaluate the suitability of the bearing materials and to verify that conditions in the excavations are consistent with those encountered in the test borings. If unsuitable materials are encountered at planned depths, it may be necessary to deepen the foundation excavations.

4.4 Shallow Foundations

The proposed transformer to be constructed at/near boring B-1 can be supported on a mat foundation, bearing on the native very stiff cherty lean clay or tested and approved, engineered fill. Design recommendations for shallow foundations are presented in the following section.

4.4.1 Shallow Foundation Design Recommendations

Description	Design
Foundation type	Mat foundation
Net allowable bearing pressure [1]	2,000 psf
Minimum depth below lowest adjacent finished grade [2]	24 inches
Estimated total and differential movement	≤ 1 inch
Allowable passive pressure [3]	750 psf
Allowable coefficient of sliding friction [4]	0.15

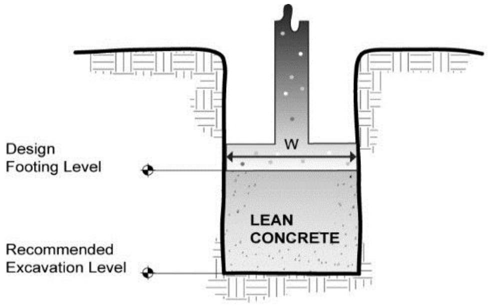
1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the foundation base elevation. The recommended allowable bearing pressure is based on the shallow mat foundation bearing on the very stiff cherty lean clay or tested and approved, engineered fill.
2. Minimum depth will provide frost protection.
3. Allowable passive pressure considers a rectangular pressure distribution and factor of safety of about 2. Passive pressure value applies to undisturbed, native very stiff cherty lean clay or approved, new engineered fill. Passive resistance should be neglected for the upper 2 feet of the soil below the final adjacent grade due to strength loss from freeze-thaw and moisture changes.
4. Coefficient of friction value has a factor of safety of 2.

Uplift resistance for shallow foundations may be computed as the sum of the weight of the foundation element and the weight of the soil overlying the foundation. We recommend using a soil unit weight of 115 pounds per cubic foot (pcf) for engineered fill overlying shallow foundations.

4.4.2 Shallow Foundation Construction Considerations

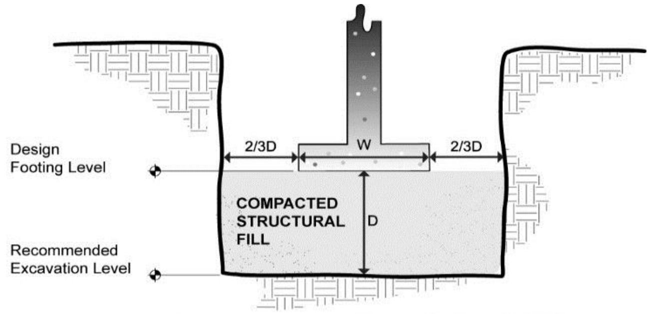
Shallow foundation excavations should be free of loose and disturbed material, debris, and water when concrete is placed. Concrete should be placed as soon as possible after excavation is completed to reduce the potential for wetting, drying, or disturbance of the bearing materials.

To verify that suitable bearing materials are encountered, we recommend the base of all foundation excavations be observed and evaluated by the geotechnical engineer prior to placing reinforcing steel and concrete. If unsuitable bearing soils are encountered in footing excavations, the excavations should be extended deeper to suitable soils and the footings could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations as shown in Figure 1 below. The footings could also bear on properly compacted engineered fill extending down to the suitable soils. Overexcavation for compacted backfill placement below footings should extend laterally beyond all edges of the footings at least 8 inches per foot of overexcavation depth below footing base elevation. The overexcavation should then be backfilled up to the footing base elevation with approved engineered fill material. The overexcavation and backfill procedure is shown in Figure 2 below.



Lean Concrete Backfill

Figure 1



Overexcavation / Backfill

Figure 2

NOTE: Excavations in sketches shown vertical for convenience. Excavations should be sloped as necessary for safety.

4.5 Seismic Considerations

Code Used	Site Classification
2015 International Building Code (IBC) [1]	D

1. In general accordance with the *2015 International Building Code*; Table 20.3-1, Chapter 20, ASCE 7.

5.0 GENERAL COMMENTS

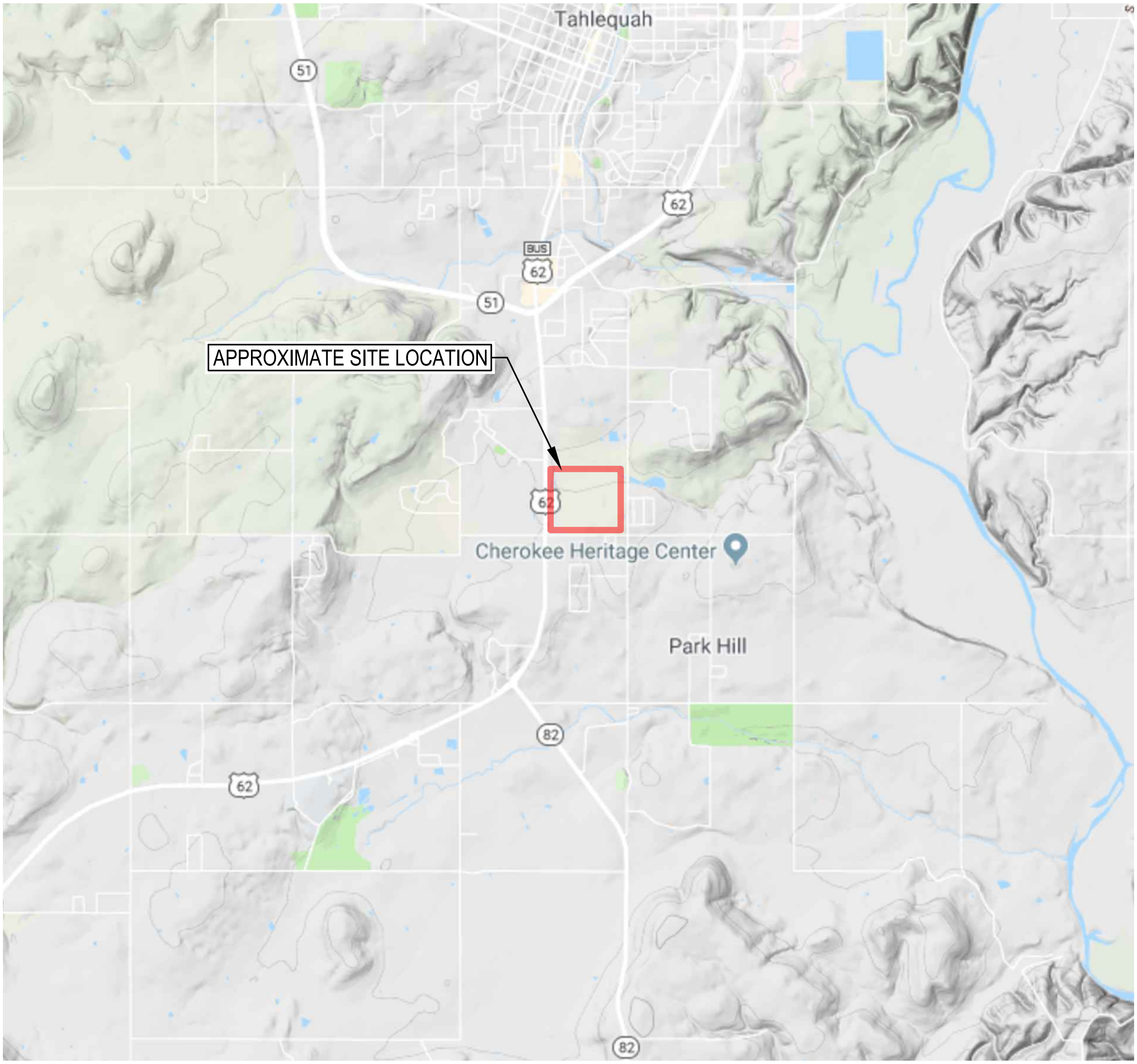
Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide observation and testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, 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. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological 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.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION



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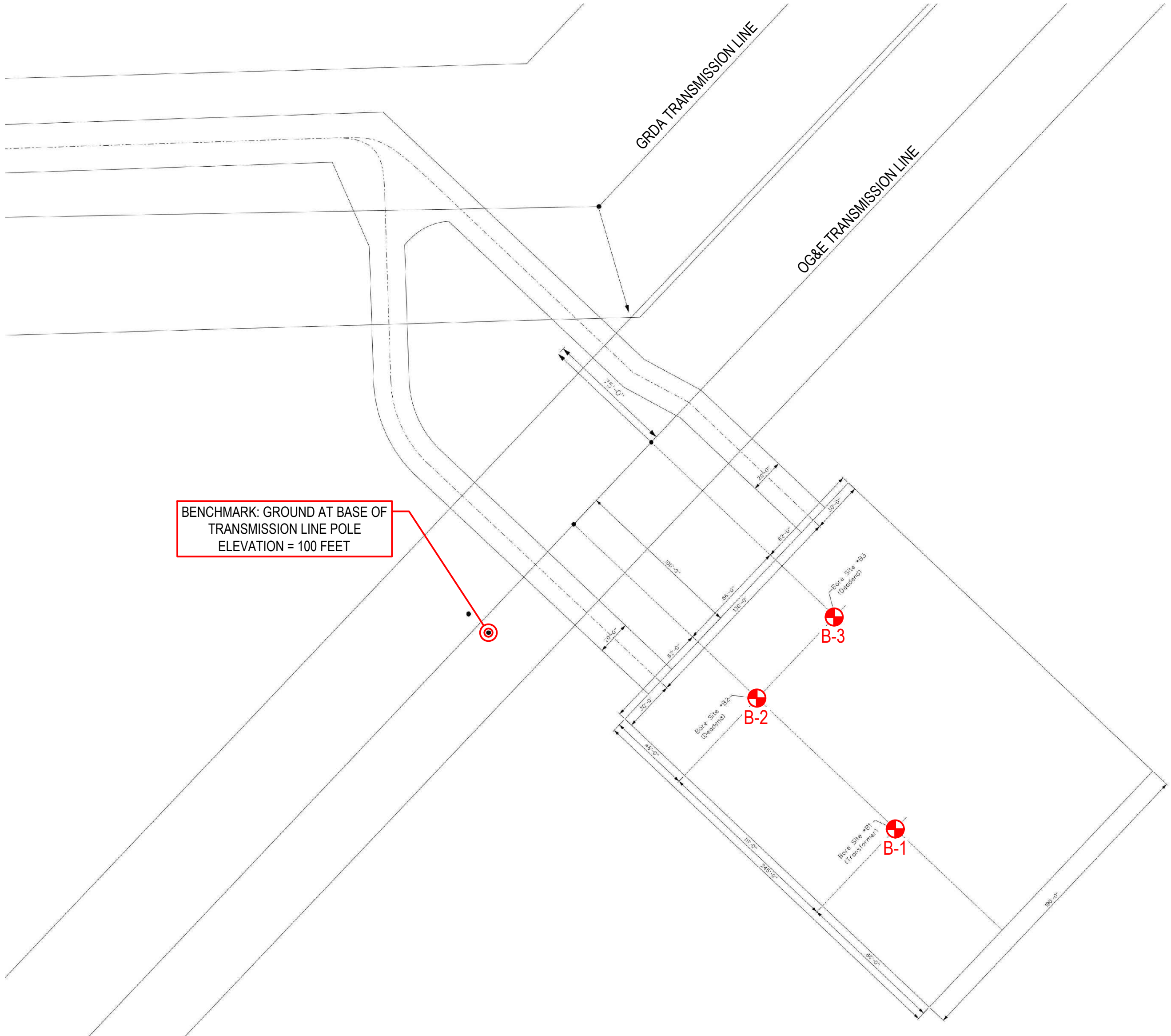
5000 0 5000

APPROXIMATE SCALE IN FEET

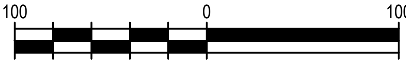
N

Project Mngr: SG	Project No. 04185092	SITE LOCATION MAP	EXHIBIT NO.
Drawn By: MM	Scale: SEE BAR SCALE	GEOTECHNICAL EXPLORATION PROPOSED SEVEN CLANS AVENUE SUBSTATION TAHLEQUAH, OKLAHOMA	A-1
Checked By: SG	File No. 04185092		
Approved By: BMW	Date: JULY 2018		

Terracon
Consulting Engineers and Scientists
9522 EAST 47TH PLACE, UNIT D TULSA, OKLAHOMA 74145
PH. (918) 250-0461 FAX. (918) 250-4570



BASE DRAWING PROVIDED BY OKLAHOMA GAS AND ELECTRIC COMPANY



LEGEND
BORING LOCATION

N

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

Project Mngr: SG	Project No. 04185092		
Drawn By: MM	Scale: SEE BAR SCALE		
Checked By: SG	File No. 04185092		
Approved By: BMW	Date: JULY 2018		

Terracon
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9522 EAST 47TH PLACE, UNIT D TULSA, OKLAHOMA 74145
PH. (918) 250-0461 FAX. (918) 250-4570

BORING LOCATION PLAN

GEOTECHNICAL EXPLORATION
PROPOSED SEVEN CLANS AVENUE SUBSTATION
TAHLEQUAH, OKLAHOMA

EXHIBIT NO.
A-2

Field Exploration Description

The boring locations were established in the field by OG&E. Terracon determined the approximate ground surface elevations at the borings using an engineer's level. The ground at the base of a transmission line pole located west of the site was used as a benchmark (see Boring Location Plan for benchmark location). The approximate ground surface elevations at the borings are shown on the boring logs, based on an arbitrary elevation of 100.0 feet for the benchmark. The elevations shown on the logs have been rounded to the nearest 0.5 feet. The elevations should be considered accurate only to the degree implied by the methods used to define them.

We drilled the borings with an ATV-mounted rotary drill rig using continuous flight augers to advance the boreholes. Representative samples were obtained by the split-barrel sampling procedure. The split-barrel sampling procedure uses a standard 2-inch, O.D. split-barrel sampling spoon that is driven into the bottom of the boring with a 140-pound drive hammer falling 30 inches. The number of blows required to advance the sampling spoon the last 12 inches, or less, of an 18-inch sampling interval or portion thereof, is recorded as the standard penetration resistance value, N. The N value is used to estimate the in-situ relative density of cohesionless soils and to a lesser degree of accuracy, the consistency of cohesive soils and the hardness of weathered bedrock. The thin-walled sampling procedure uses a standard 3-inch, O.D. tube (Shelby tube) that is pushed hydraulically into the soil to recover relatively undisturbed samples of cohesive soils.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. Generally, a greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The sampling depths, penetration distances, and N values are reported on the boring logs. The samples were tagged for identification, sealed to reduce moisture loss and returned to the laboratory for further examination, testing and classification.

We attempted rock coring at boring B-3 at a depth of 13 feet using a NQ-size diamond bit core barrel upon encountering apparently hard bedrock. However, after coring 6 inches of rock, clay soils were encountered and thus we reverted to auger drilling and split spoon sampling. After the 6-inch core sample was retrieved, it was placed in a core box and logged. The rock was visually classified and the percent recovery and Rock Quality Designation (RQD) was determined for the core run. The percent recovery is a ratio of the recovered sample length to the cored length, expressed as a percentage. The RQD is the total length of core pieces at least 4 inches in length divided by the length of core run, expressed as a percentage.

Field Exploration Description (Cont'd)

A field log of each boring was prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's interpretation of the field logs and include modifications based on laboratory observation and tests of the samples.

BORING LOG NO. B-1

PROJECT: Seven Clans Avenue Substation

CLIENT: Oklahoma Gas & Electric Oklahoma City, OK

SITE: US-62 and E Willis Road Tahlequah, OK

LOCATION See Exhibit A-2

Surface Elev.: 107.5 (Ft.)

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS		WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	3" Topsoil **CHERTY LEAN CLAY (CL)**, with hard chert seams, brown with white, very stiff				X	16	10-17-24 N=41		14	37-15-22	
					X	16	14-11-38 N=49		11		
5.0		102.5	5								
	BROKEN CHERT+, with clay, reddish brown with white, hard				X	16	20-35-50/3"		13		
8.5		99									
	LEAN CLAY (CL), with broken chert, red with white, very stiff				X	18	20-28-16 N=44		18		
			10								
14.0		93.5			X	9	38-50/3"		26		
	BROKEN CHERT+, with clay layers, white with red, hard		15								
18.6		89			X	0	50/1"				
	Boring Terminated at 18.6 Feet										

Stratification lines are approximate. In-situ, the transition may be gradual.
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling
Not Encountered After Boring

Terracon
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 06-13-2018	Boring Completed: 06-13-2018
Drill Rig: ATV 735	Driller: MR
Project No.: 04185092	Exhibit: A-4

BORING LOG NO. B-2

PROJECT: Seven Clans Avenue Substation

CLIENT: Oklahoma Gas & Electric Oklahoma City, OK

SITE: US-62 and E Willis Road Tahlequah, OK

LOCATION See Exhibit A-2

Surface Elev.: 107.0 (Ft.)

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)
	3" Topsoil **BROKEN CHERT+**, with clay layers, white and gray, hard			X	18	11-25-28 N=53	11
2.5		104.5		X	9	17-50/3"	10
	BROKEN CHERT+, with clay layers, white with red, hard		5	X	2	50/2"	9
				X	10	18-50/4"	19
			10				
				X	1	50/1"	10
			15				
				X	5	50/5"	19
			20				

Columns also present (no entries): WATER LEVEL OBSERVATIONS, ATTERBERG LIMITS LL-PL-PI, PERCENT FINES.

Stratification lines are approximate. In-situ, the transition may be gradual.
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling
Not Encountered After Boring

Terracon
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 06-13-2018	Boring Completed: 06-13-2018
Drill Rig: ATV 735	Driller: MR
Project No.: 04185092	Exhibit: A-5

BORING LOG NO. B-2

PROJECT: Seven Clans Avenue Substation

CLIENT: Oklahoma Gas & Electric, Oklahoma City, OK

SITE: US-62 and E Willis Road, Tahlequah, OK

LOCATION See Exhibit A-2

Surface Elev.: 107.0 (Ft.)

DEPTH	Material Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS		WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	BROKEN CHERT+, with clay layers, white with red, hard *(continued)*										
					X	0	50/1"				
			25								
28.0		79									
	FAT CLAY (CH), red, soft to medium stiff										
					X	18	5-2-2 N=4				
			30								
	- with hard broken chert below about 33.5 feet				X	14	3-1-20 N=21				
35.0		72	35								
	Boring Terminated at 35 Feet										

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

+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling

Not Encountered After Boring

Terracon
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 06-13-2018	Boring Completed: 06-13-2018
Drill Rig: ATV 735	Driller: MR
Project No.: 04185092	Exhibit: A-5

BORING LOG NO. B-3

PROJECT: Seven Clans Avenue Substation

CLIENT: Oklahoma Gas & Electric
Oklahoma City, OK

SITE: US-62 and E Willis Road
Tahlequah, OK

LOCATION See Exhibit A-2

Surface Elev.: 105.0 (Ft.)

DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS		WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	4" Topsoil **BROKEN CHERT+**, with clay layers, white and brown, hard					18	6-38-44 N=82		4		
2.0	**BROKEN CHERT+**, with clay layers, brown and white, hard	103				10	24-50/4"		8		
			5			6	50/6"		7		
7.0	**FAT CLAY (CH)**, with broken chert and hard chert layers, red with white, stiff to very stiff	98				18	11-16-22 N=38		24		
			10								
							50/0"				
	- hard chert layer at 13 feet					6	REC=100% RQD=0%				
						6	20-50/3"		9		
			15								
						14	37-7-7 N=14		25		
			20								

Stratification lines are approximate. In-situ, the transition may be gradual.
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger to 13 feet, Diamond Core Bit below 13 feet, Power Auger below 13.5 feet

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not Encountered to 13 feet While Drilling

Terracon
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 06-13-2018	Boring Completed: 06-13-2018
Drill Rig: ATV 735	Driller: MR
Project No.: 04185092	Exhibit: A-6

BORING LOG NO. B-3

PROJECT: Seven Clans Avenue Substation

**CLIENT: Oklahoma Gas & Electric
Oklahoma City, OK**

**SITE: US-62 and E Willis Road
Tahlequah, OK**

LOCATION See Exhibit A-2

Surface Elev.: 105.0 (Ft.)

GRAPHIC LOG	DEPTH / DESCRIPTION / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS		WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
	FAT CLAY (CH), with broken chert and hard chert layers, red with white, stiff to very stiff *(continued)*									
				X	4	50/4"		17		
		25								
				X	14	9-10-3 N=13		27		
		30								
	32.5 — 72.5			X	3	50/3"				
	Auger Refusal at 32.5 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger to 13 feet, Diamond Core Bit below 13 feet, Power Auger below 13.5 feet

Abandonment Method:

See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
Not Encountered to 13 feet While Drilling

Terracon
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 06-13-2018	Boring Completed: 06-13-2018
Drill Rig: ATV 735	Driller: MR
Project No.: 04185092	Exhibit: A-6

APPENDIX B
LABORATORY TESTING

Laboratory Testing

Samples retrieved during the field exploration were taken to the laboratory for further observation by the project geotechnical engineer and were classified in accordance with the Unified Soil Classification System (USCS) described in Appendix D. Bedrock materials were classified according to the General Notes and described using commonly accepted geotechnical terminology. The field descriptions were modified as necessary and an applicable laboratory testing program was formulated to determine engineering properties of the subsurface materials.

Laboratory tests were conducted on select soil and rock samples. The laboratory test results are presented on the boring logs next to the respective samples. Laboratory tests were performed in general accordance with the applicable ASTM, local or other accepted standards.

Selected soil and rock samples obtained from the site were tested for the following engineering properties:

- Visual Classification (ASTM D2488)
- Water Content (ASTM D 2216)
- Atterberg Limits (ASTM D 4318)

Procedural standards noted above are for reference to methodology in general. In some cases variations to methods are applied as a result of local practices or professional judgment.

APPENDIX C
FOUNDATION DESIGN TABLES

TABLE A.1

BORING B-2
AXIAL AND LATERAL CAPACITY ANALYSES
SOIL/ROCK PARAMETERS

Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Depth to Bottom of Soil/Rock Layer (feet)	Effective Unit Weight (pcf)	Net Allowable Bearing Pressure (psf)	Allowable Side Friction		Allowable Passive Pressure		Undrained Shear Strength (psf)	Friction Angle (degrees)
			Initial Value (psf)	Increase per Foot of Depth (psf)	Initial Value (psf)	Increase per Foot of Depth (psf)		
2	110	---	0	17	0	150	0	28
28	110	1,500 [4]	54	27	510	255	0	40
35	110	1,500 [4]	250	---	250	---	500	0

Notes:

1. Design depth to groundwater is assumed to be greater than about 35 feet.
2. The net allowable bearing pressure refers to the pressure at the foundation bearing level in excess of the minimum surrounding overburden pressure. The net allowable bearing pressure has a safety factor on the order of 3. A minimum penetration of 2 feet or one pier diameter, whichever is greater, into the desired bearing strata should be achieved to use the recommended allowable end bearing pressure.
3. The allowable side friction and passive pressure in cohesive soils and bedrock are based on a rectangular pressure distribution. The allowable side friction and passive pressure in granular soils are based on a triangular pressure distribution. The allowable side friction and passive pressure values have a safety factor of approximately 2.
4. Bearing capacity assumes the pier bearing in this layer has a length to diameter ratio of at least 4. If pier length to diameter ratio is less than 4, the allowable bearing pressure used in design should be reduced by multiplying the value shown in the table by a factor of 0.67.

TABLE A.2

BORING B-3
AXIAL AND LATERAL CAPACITY ANALYSES
SOIL/ROCK PARAMETERS

Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Depth to Bottom of Soil/Rock Layer (feet)	Effective Unit Weight (pcf)	Net Allowable Bearing Pressure (psf)	Allowable Side Friction		Allowable Passive Pressure		Undrained Shear Strength (psf)	Friction Angle (degrees)
			Initial Value (psf)	Increase per Foot of Depth (psf)	Initial Value (psf)	Increase per Foot of Depth (psf)		
2.0	110	---	0	17	0	150	0	28
7.0	110	5,000	54	27	510	255	0	40
32.5	110	6,000 [4]	550	---	2,200	---	2,200	0

Notes:

1. Design depth to groundwater is assumed to be greater than about 32.5 feet.
2. The net allowable bearing pressure refers to the pressure at the foundation bearing level in excess of the minimum surrounding overburden pressure. The net allowable bearing pressure has a safety factor on the order of 3. A minimum penetration of 2 feet or one pier diameter, whichever is greater, into the desired bearing strata should be achieved to use the recommended allowable end bearing pressure.
3. The allowable side friction and passive pressure in cohesive soils and bedrock are based on a rectangular pressure distribution. The allowable side friction and passive pressure in granular soils are based on a triangular pressure distribution. The allowable side friction and passive pressure values have a safety factor of approximately 2.
4. Bearing capacity assumes the pier, bearing in this layer, has a length to diameter ratio of at least 4. If pier length to diameter ratio is less than 4, the allowable bearing pressure used in design should be reduced by multiplying the value shown in the table by a factor of 0.67.

TABLE B.1

Boring B-2
LATERAL CAPACITY ANALYSES
DESIGN SOIL PARAMETERS FOR
UNDRAINED CONDITIONS
Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Soil Layer	LPILE Soil Type		Depth to Soil Layer Top (feet)	Depth to Soil Layer Bottom (feet)	LPILE Soil Modulus k[2] (pci)	Effective Unit Weight (pcf)	Undrained Shear Strength[3] (psf)	Internal Friction Angle (degrees)	RQD[4] (%)	LPILE Soil Strain Factor e_{50}/k_{rm}
1	Sand	(4)	0	2	61	110	0	28		----
2	Sand	(4)	2	28	323	110	0	40		----
3	Soft Clay	(1)	28	35	332	110	500	0		0.0153

NOTES:

1. Design depth to subsurface water is greater than about 35 feet.
2. Value given for **Weak Rock** is E_{ri} in psi. See report text for cyclic loading.
3. Uniaxial compressive strength for rock, in psi
4. Value given for RQD estimated from field data and sample examination.

TABLE B.2

Boring B-3
LATERAL CAPACITY ANALYSES
DESIGN SOIL PARAMETERS FOR
UNDRAINED CONDITIONS
Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Soil Layer	**LPILE** Soil Type		Depth to Soil Layer Top (feet)	Depth to Soil Layer Bottom (feet)	**LPILE** Soil Modulus k[2] (pci)	Effective Unit Weight (pcf)	Undrained Shear Strength[3] (psf)	Internal Friction Angle (degrees)	RQD[4] (%)	**LPILE** Soil Strain Factor e_{50}/k_{rm}
1	Sand	(4)	0	2	61	110	0	28		----
2	Sand	(4)	2	7	323	110	0	40		----
3	Stiff Clay without Free Water	(3)	7	32.5	660	110	2200	0		0.0067

NOTES:

1. Design depth to subsurface water is greater than about 32.5 feet.
2. Value given for **Weak Rock** is E_{ri} in psi. See report text for cyclic loading.
3. Uniaxial compressive strength for rock, in psi
4. Value given for RQD estimated from field data and sample examination.

TABLE C.1

BORING B-2
MFAD 5.0/HFAD 5.0 ANALYSES
SOIL/ROCK PARAMETERS

Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Soil/Rock Layer Number	Layer Type	Depth to Bottom of Layer (feet)	Effective Unit Weight [1] (pcf)	Deformation Modulus [2] (ksi)	Effective Friction Angle (degrees)	Undrained Shear Strength or Rock Effective Cohesion (ksf)	Allowable Rock/Concrete Bond Strength [3] (ksf)
1	Soil	2	110	1.7	28	0	---
2	Soil	28	110	5	40	0	---
4	Soil	35	110	0.32	0	0.5	---

Notes:

1. Design depth to groundwater is assumed to be greater than about 35 feet.
2. Deformation modulus determined based on the data in the following papers: (A) DiGioia, A.M., Donovan, T.D., and Cortese, F.J., "A Multi-Layered/Pressuremeter Approach to Laterally Loaded Rigid Caisson Design", presented at the seminar on Lateral Pressures Related to Large Diameter Pipes, Piles, Tunnels, and Caissons, Dayton, Ohio, February 1975, ASCE. (B) Schmertmann, J.H., "Static Cone to Compute Static Settlement over Sand", Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 96, No. SM3, May 1970, pp. 1011-1043.
3. Allowable rock/concrete bond strength has a factor of safety of about 2.

TABLE C.2

BORING B-3
MFAD 5.0/HFAD 5.0 ANALYSES
SOIL/ROCK PARAMETERS

Seven Clans Avenue Substation
Terracon Project No. 04185092
Tahlequah, Oklahoma

Soil/Rock Layer Number	Layer Type	Depth to Bottom of Layer (feet)	Effective Unit Weight [1] (pcf)	Deformation Modulus [2] (ksi)	Effective Friction Angle (degrees)	Undrained Shear Strength or Rock Effective Cohesion (ksf)	Allowable Rock/Concrete Bond Strength [3] (ksf)
1	Soil	2	110	1.7	28	0	---
2	Soil	7	110	5	40	0	---
3	Soil	32.5	110	1.4	0	2.2	---

Notes:

1. Design depth to groundwater is assumed to be greater than about 32.5 feet.
2. Deformation modulus determined based on the data in the following papers: (A) DiGioia, A.M., Donovan, T.D., and Cortese, F.J., “A Multi-Layered/Pressuremeter Approach to Laterally Loaded Rigid Caisson Design”, presented at the seminar on Lateral Pressures Related to Large Diameter Pipes, Piles, Tunnels, and Caissons, Dayton, Ohio, February 1975, ASCE. (B) Schmertmann, J.H., “Static Cone to Compute Static Settlement over Sand”, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 96, No. SM3, May 1970, pp. 1011-1043.
3. Allowable rock/concrete bond strength has a factor of safety of about 2.

APPENDIX D
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

Auger	Split Spoon
Shelby Tube	Pressure Meter
Texas Cone	Rock Core
Grab Sample	No Recovery

WATER LEVEL

- 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.

FIELD TESTS

(HP)	Hand Penetrometer
(T)	Torvane
(b/f)	Standard Penetration Test (blows per foot)
(PID)	Photo-Ionization Detector
(OVA)	Organic Vapor Analyzer
(TCP)	Texas Cone Penetrometer

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 Includes gravels, sands and silts.			CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance			
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength, Qu, psf**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**
Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3
Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4
Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	4 - 8	5 - 9
Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 15	10 - 18
Very Dense	> 50	≥ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42
			Hard	> 8,000	> 30	> 42

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

Terracon

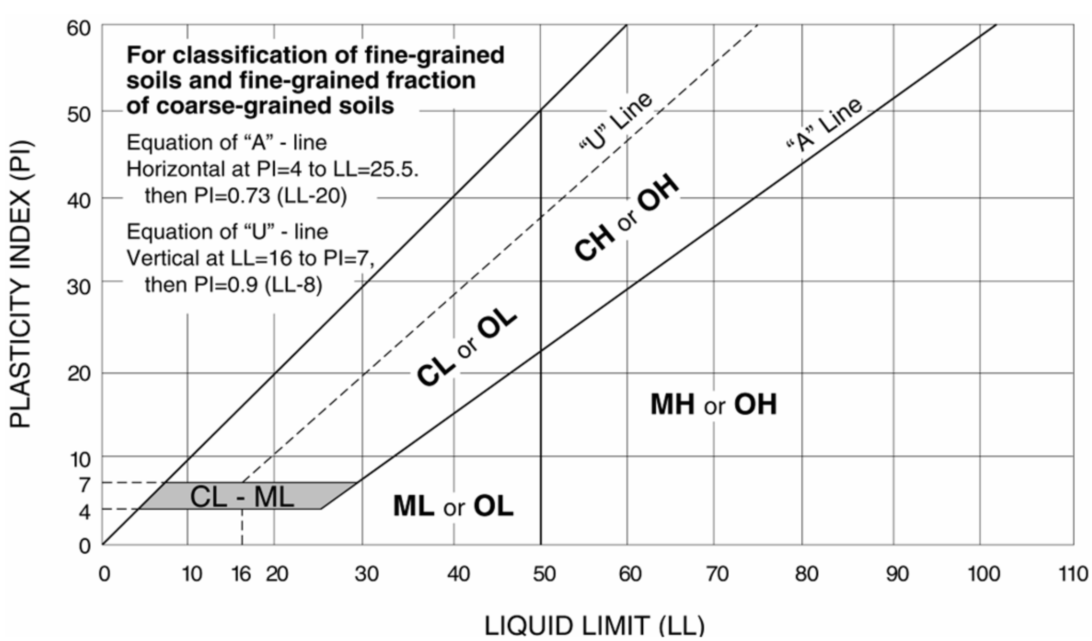
UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	**Group Name** [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ≥ 4 and 1 ≤ Cc ≤ 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 ≥ 6 and 1 ≤ Cc ≤ 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" line [J]	CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [K,L,M,N]
					Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K,L,M]
			PI plots below "A" line	MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [K,L,M,P]
					Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

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

[F] If soil contains ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 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.



Terracon

GENERAL NOTES

Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

LIMESTONE	Light to dark colored, crystalline to fine-grained texture, composed of $CaCo_3$, reacts readily with HCl.
DOLOMITE	Light to dark colored, crystalline to fine-grained texture, composed of $CaMg(CO_3)_2$, harder than limestone, reacts with HCl when powdered.
CHERT	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz (SiO_2), brittle, breaks into angular fragments, will scratch glass.
SHALE	Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
SANDSTONE	Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
CONGLOMERATE	Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

PHYSICAL PROPERTIES:

DEGREE OF WEATHERING

Slight	Slight decomposition of parent material on joints. May be color change.
Moderate	Some decomposition and color change throughout.
High	Rock highly decomposed, may be extremely broken.

HARDNESS AND DEGREE OF CEMENTATION

Limestone and Dolomite:

Hard	Difficult to scratch with knife.
Moderately Hard	Can be scratched easily with knife, cannot be scratched with fingernail.
Soft	Can be scratched with fingernail.

Shale, Siltstone and Claystone

Hard	Can be scratched easily with knife, cannot be scratched with fingernail.
Moderately Hard	Can be scratched with fingernail.
Soft	Can be easily dented but not molded with fingers.

Sandstone and Conglomerate

Well Cemented	Capable of scratching a knife blade.
Cemented	Can be scratched with knife.
Poorly Cemented	Can be broken apart easily with fingers.

BEDDING AND JOINT CHARACTERISTICS

Bed Thickness	Joint Spacing	Dimensions
Very Thick	Very Wide	>10′
Thick	Wide	3′ - 10′
Medium	Moderately Close	1′ - 3′
Thin	Close	2″ - 1′
Very Thin	Very Close	.4″ - 2″
Laminated	—	.1″ - .4″

Bedding Plane	A plane dividing sedimentary rocks of the same or different lithology.
Joint	Fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.
Seam	Generally applies to bedding plane with an unspecified degree of weathering.

SOLUTION AND VOID CONDITIONS

Solid	Contains no voids.
Vuggy (Pitted)	Rock having small solution pits or cavities up to ½ inch diameter, frequently with a mineral lining.
Porous	Containing numerous voids, pores, or other openings, which may or may not interconnect.
Cavernous	Containing cavities or caverns, sometimes quite large.

Terracon