ATTACHMENT 4 TO RFP 30-14

Geotechnical Engineering Report

Clay County Self-Support Tower
McGinnis Road and Highway 33
Kearney, MO

April 4, 2014
Terracon Project No. 02145055

Prepared for:
Selective Site Consultants, Inc.
Overland Park, KS

Prepared by:
Terracon Consultants, Inc.
Lenexa, KS

April 4, 2014

Selective Site Consultants, Inc.
9900 W. 109th Street, Suite 300
Overland Park, KS 66210

Attn: Ms. Emily Roseberry
P: [913] 438-7700
E: ERoseberry@ssc.us.com

Re: Geotechnical Engineering Report
Clay County Self-Support Tower
McGinnis Road and Highway 33
Kearney, MO
Terracon Project Number: 02145055

Dear Ms. Roseberry:

Terracon Consultants, Inc. (Terracon) has completed the Geotechnical Engineering Services for the referenced project. This report presents the findings of the subsurface exploration and provides geotechnical recommendations regarding the design and construction of foundations and earthwork for the project.

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

Sincerely,
Terracon Consultants, Inc.

Daniel A. Barnett, P.G.
Project Geologist
Missouri: 2007035892

Craig K. Denny, Ph.D., P.E.
Senior Principal / Senior Consultant
Missouri: E-19174

4/4/14

STATE OF MISSOURI
CRAIG K. DENNY
NUMBER E-19174
REGISTERED PROFESSIONAL ENGINEER

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EXECUTIVE SUMMARY

Geotechnical Services have been performed for Clay County Self-Support Tower. Three (3) borings were performed at the site. Samples recovered from the borings have been tested. Professional opinions and recommendations presented in this report are summarized below.

- The proposed self-support tower may be supported on drilled shaft foundations bearing within slightly weathered limestone bedrock.
- The proposed equipment shelter may be supported on footing foundations bearing within native stiff to very stiff clay soils or engineered fill.
- On-site soils generally appear suitable for use as engineered fill.
- Based on the 2012 International Building Code (IBC), in our opinion, seismic site classification for this site is C.

The professional opinions and recommendations presented in this report are based on evaluation of data developed by testing discrete samples obtained from three (3) borings. Site subsurface conditions have been inferred from available data, but actual subsurface conditions will only be revealed by excavation. So that variations in subsurface conditions which may affect the design can be addressed as they are encountered, we recommend a qualified geotechnical engineer be retained to observe excavation and perform tests during the site preparation, earthwork and foundation construction phases of the project.

This executive summary should not be separated from or used apart from this report. This report presents recommendations and opinions based on our understanding of the project at the time the report was prepared. The report limitations are described in section **5.0 GENERAL COMMENTS**.

GEOTECHNICAL ENGINEERING REPORT
CLAY COUNTY SELF-SUPPORT TOWER
MCGINNIS ROAD AND HIGHWAY 33
KEARNEY, MO

Terracon Project No. 02145055
April 4, 2014

1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) has completed the Geotechnical Engineering Services for Clay County Self-Support Tower. Three (3) borings were performed to depths ranging from about 25.5 to 29.5 feet below the existing ground surface. An exploration plan and boring logs are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations and/or professional opinions relative to:

- subsurface soil conditions
- groundwater conditions
- earthwork
- foundation design and construction
- seismic site class

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Exhibit A-1: Exploration Plan
Tower type and height	Self-support tower with three (3) legs and a height of approximately 180 feet
Maximum tower loads (estimated by Terracon)	Vertical: 600 kips Shear: 60 kips Overturning moment: 3,000 ft-kips
Equipment shelter	An equipment shelter will be constructed adjacent to the proposed tower. We estimate maximum equipment shelter wall loads will be 1.5 klf.
Site Grading	A site grading plan was not provided. We considered maximum cuts/fills of approximately 5 feet of fill will be required to develop design grades.

2.2 Site Location and Description

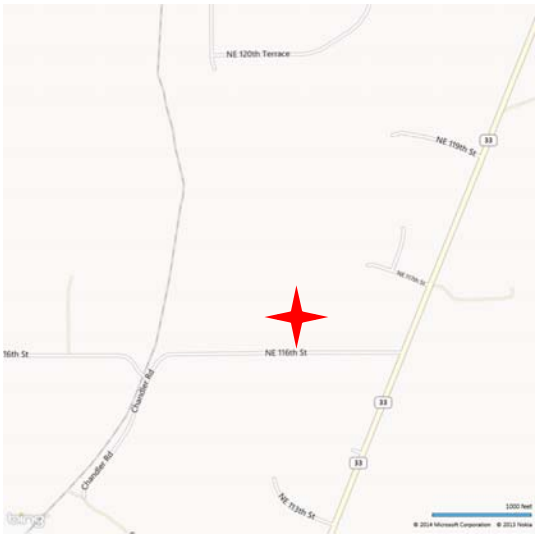


Figure 1. Site Location

Figure 2. Aerial Photo of Site

Item	Description
Location	McGinnis Road and Highway 33, Kearney, MO Latitude: 39° 18' 17.010" N Longitude: 94° 22' 40.784" W
Existing Improvements	An existing shelter building is located in the center of a circle drive southeast of the proposed tower.
Current Ground Cover	Bare ground
Existing Topography	Based on the provided topographic site plan, site grades within the lease area slope down to the northwest.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Subsurface Profile

Subsurface conditions at the borings can be generalized as follows:

Stratum No.	Approximate Depth to Bottom of Stratum (bgs)	Material Description	Comments
1	13 to 16 feet	Native fat clay	Medium stiff to very stiff
2	25 feet	Shale bedrock	Severely to moderately weathered, light brown to gray brown

Stratum No.	Approximate Depth to Bottom of Stratum (bgs)	Material Description	Comments
3	Not determined	Limestone bedrock	Practical auger refusal occurred in limestone at depths ranging from about 24.5 to 26.5 feet. Boring B-1 was extended below the depth of auger refusal by core drilling.

Conditions encountered at the boring locations are indicated on the boring logs. 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 Water Level Observations

The borings were observed while drilling and upon drilling completion, but prior to rock coring, for the presence and level of groundwater. Groundwater was not observed in the borings at these times. 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 conditions could be different than indicated on the boring logs at other times. The potential presence of groundwater should be considered when developing the design and construction plans for the project.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

We understand drilled shaft foundations are the preferred foundation type for self-support towers. In our opinion, the self-support telecommunication tower can be supported on drilled shaft foundations and the equipment shelter can be supported on footing foundations. Foundation design and earthwork recommendations are presented in the following sections.

4.2 Earthwork

A site grading plan was not provided. We expect some cuts/fills will be required to develop design grades. Earthwork on this project should be observed and evaluated by Terracon. Recommendations for site preparation, excavation, subgrade preparation, and placement of engineered fill for the project are provided in the following sections.

4.2.1 Site Preparation

Site preparation should begin with removal of any vegetation, topsoil, and loose, soft or otherwise unsuitable material from the construction area. The soils exposed following stripping and cutting should be proofrolled. A Terracon representative should observe proofrolling of the

exposed soils. Proofrolling can be accomplished using a loaded tandem-axle dump truck with a gross weight of at least 25 tons, or similarly loaded equipment. Areas that display excessive deflection (pumping) or rutting during proofroll operations should be improved by scarification/compaction or by removal and replacement with engineered fill.

4.2.2 Engineered Fill Material Requirements

Engineered fill should meet the following material property requirements:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Clay soils	CL, ML, CH	All locations and elevation except where free-draining backfill is required [3]
Granular materials	GM [2], GW, GP, SW, SP	All locations and elevations except where free-draining backfill is required [3]

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade.
2. Similar to MoDOT Type 5 crushed limestone aggregate.
3. Free-draining backfill should be granular materials with less than 15% low plasticity fines.

4.2.3 Fill Placement and Compaction Requirements

Item	Description
Fill Lift Thickness [1]	9-inches or less in loose thickness
Compaction Requirements [2]	95% of the material's maximum dry density [3]
Moisture Content Clay Soils	Optimum moisture content to +4% of optimum moisture content value [3]
Moisture Content Granular Material	Sufficient to achieve compaction without pumping when proofrolled

1. Reduced lift thicknesses are recommended in confined areas (e.g., utility trenches, foundation excavations, and foundation backfill) and when hand-operated compaction equipment is used.
2. We recommend that engineered fill 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.
3. As determined by the standard Proctor test (ASTM D 698).

4.2.4 Grading and Drainage

During construction, grades should be developed to direct surface water flow away from or around the tower site. Exposed subgrades should be sloped to provide positive drainage so that saturation of subgrades is avoided. Surface water should not be permitted to accumulate on the site. Final grades should promote rapid surface drainage away from the structures. Accumulation of water adjacent to the equipment shelter could contribute to significant moisture increases in

the subgrade soils and subsequent softening/settlement or expansion/heave. Roof drains should discharge into a storm sewer or at least 10 feet away from the shelter.

4.2.5 Earthwork Construction Considerations

Care should be taken to avoid disturbance of prepared subgrades. Unstable subgrade conditions could develop during general construction operations, particularly if the soils are wetted and/or subjected to repetitive construction traffic. New fill compacted above optimum moisture content or that accumulates water during construction can also become disturbed under construction equipment. Construction traffic over the completed subgrade should be avoided to the extent practical. If the subgrade becomes saturated, desiccated, or disturbed, the affected materials should either be scarified and compacted or be removed and replaced. Subgrades should be observed and tested by Terracon prior to construction of the slab and pavements.

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, state, and federal safety regulations. The contractor should be aware that slope height, slope inclination, and excavation depth should in no instance exceed those specified by these safety regulations. Flatter slopes than those dictated by these regulations may be required depending upon the soil conditions encountered and other external factors. These regulations are strictly enforced and if they are not followed, the owner, contractor, and/or earthwork and utility subcontractor could be liable and subject to substantial penalties. Under no circumstances should the information provided in this report be interpreted to mean that Terracon is responsible for construction site safety or the contractor’s activities. Construction site safety is the sole responsibility of the contractor who shall also be solely responsible for the means, methods, and sequencing of the construction operations.

4.3 Foundations

In our opinion, the self-support telecommunication tower can be supported on drilled shaft foundations and the equipment shelter can be supported on footing foundations. Foundation design recommendations are presented in the table on page 6.

4.3.1 Drilled Shaft Foundation Design Recommendations for Tower

Stratum	Fat clay	Fat clay	Shale bedrock	Limestone bedrock
Depth (feet)	0 – 3	3 – 13	13 – 18	Below 18
Material Type [1]	3	3	3	9
Allowable Skin Friction (psf) [2]	Ignore	250	1,000	1,000
Allowable End Bearing Pressure (psf) [2]	Ignore	Ignore	Ignore	40,000
Effective Unit Weight (pcf)	120	120	130	140
Undrained Shear Strength, c_u (psf)	Ignore	1,500	N/A	N/A
Static Soil Modulus Parameter, k (pci) [3]	Ignore	500	N/A	N/A
Strain, ε_{50} (in/in)	Ignore	0.005	N/A	N/A
Unconfined Compressive Strength for Rock (psi)	N/A	N/A	100	1,000
Rock Quality Designation (RQD), %	N/A	N/A	25	45
Parameter k_{rm} for Weak Rock	N/A	N/A	0.0005	0.0005
Elastic Modulus for Weak Rock (psi)	N/A	N/A	250,000	500,000

1. Material Type for LPILE: 3=Stiff Clay without Free Water, 9=Weak Rock
2. Minimum pier length of three diameters required. Terracon should be contacted if the pier length is less than three times the pier diameter as modifications to our design parameters may be warranted.
3. Static soil modulus parameter estimated from correlation in LPILE user manual.

4.3.2 Drilled Shaft Foundation Construction Considerations

Drilled shaft excavations should be observed by a representative of Terracon to evaluate the suitability of the bearing materials. Temporary steel casing should be installed if personnel will enter shaft excavations. The base of the drilled shaft excavations should be free of water and loose material prior to placement of concrete. Conventional excavating and drilling equipment should be able to penetrate the clay soils. A rock auger or core barrel will likely be required to advance the excavation into slightly weathered shale and limestone bedrock.

We recommend the concrete mixture be designed to have a slump in the range of 5 to 7 inches to facilitate temporary casing removal, if required. While removing the casing from a shaft excavation during concrete placement, the concrete inside the casing should be maintained at a sufficient level to prevent intrusion of overburden materials into the shaft excavation and resist any earth pressures outside the casing during the entire casing removal procedure.

Provided drilled shafts are designed and constructed in accordance with recommendations presented in this report, we estimate total settlement of the drilled shafts on the order of 1 inch or less. Differential settlement would be less than half the total settlement.

4.3.3 Shallow Foundation Design Recommendations for Equipment Shelter

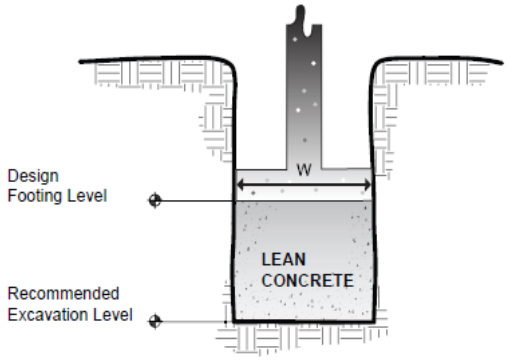
Description	Wall
Net allowable bearing pressure [1]	2,000 psf
Minimum footing width	12 inches
Minimum embedment below finished grade [2]	36 inches
Estimated total post construction settlement [3, 4]	1 inch or less
Estimated differential settlement [3, 4]	¾ inch over 40 feet
Allowable passive pressure [5]	1,000 psf
Allowable coefficient of sliding friction [5]	0.30

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. These values assume unsuitable materials or soft soils, if encountered, will be undercut and replaced with engineered fill.
2. This embedment depth is for perimeter footings and footings beneath unheated areas to provide frost protection and to reduce the effects of seasonal moisture variations in the subgrade soils. The interior footings may be supported at shallower depths in heated areas.
3. The foundation settlement 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, and the quality of the earthwork operations.
4. The sides of the excavation for shallow foundations must be nearly vertical and the concrete should be placed neat against these vertical faces for the passive earth pressure values to be valid. If the loaded side is sloped or benched, and then backfilled, the allowable passive pressure will be significantly reduced. Passive resistance in the upper 3 feet of the soil profile should be neglected unless covered/protected by pavements. If passive resistance is used to resist lateral loads, the base friction should be neglected.

4.3.4 Shallow Foundation Construction Considerations

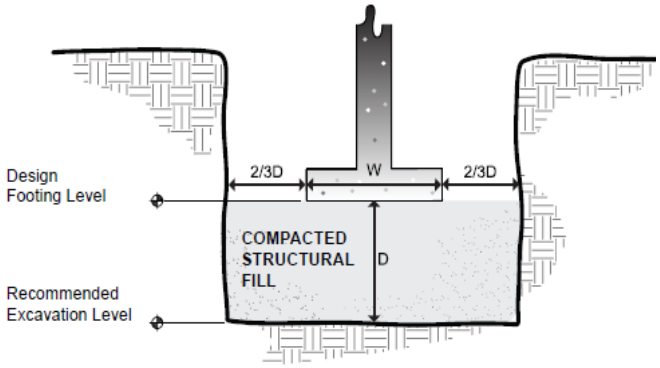
The base of foundation excavations should be free of water and loose or soft soil prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. If the soils at bearing level become excessively dry, disturbed, saturated, or frozen, the affected soil should be removed prior to placing concrete. Placement of a lean concrete mud-mat over the bearing soils should be considered if the excavations must remain open overnight or for an extended period of time.

All footing bearing surfaces should be observed and tested by Terracon. Footing excavations should be extended deeper if unsuitable conditions are encountered. Footings can bear directly on suitable soils at the lower level or on lean concrete backfill placed in the excavations as shown in Figure 3. The footings could also bear on properly compacted backfill extending down to the suitable soils as shown in Figure 4. 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 well graded granular material placed and compacted as recommended in section **4.2.3**.



Lean Concrete Backfill

Figure 3



Overexcavation / Backfill

Figure 4

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

4.4 Seismic Considerations

Code	Site Classification
2012 International Building Code (IBC)	C [1]

1. IBC Site Class determination is based on average properties of the subsurface profile within 100 feet of the ground surface. Exploratory borings extended to a maximum depth of about 30 feet. Terracon's opinion of Site Class is based on boring data and our knowledge of geotechnical and geologic conditions in this locale.

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, recommendations and professional opinions 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 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 geotechnical services for this project 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.

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

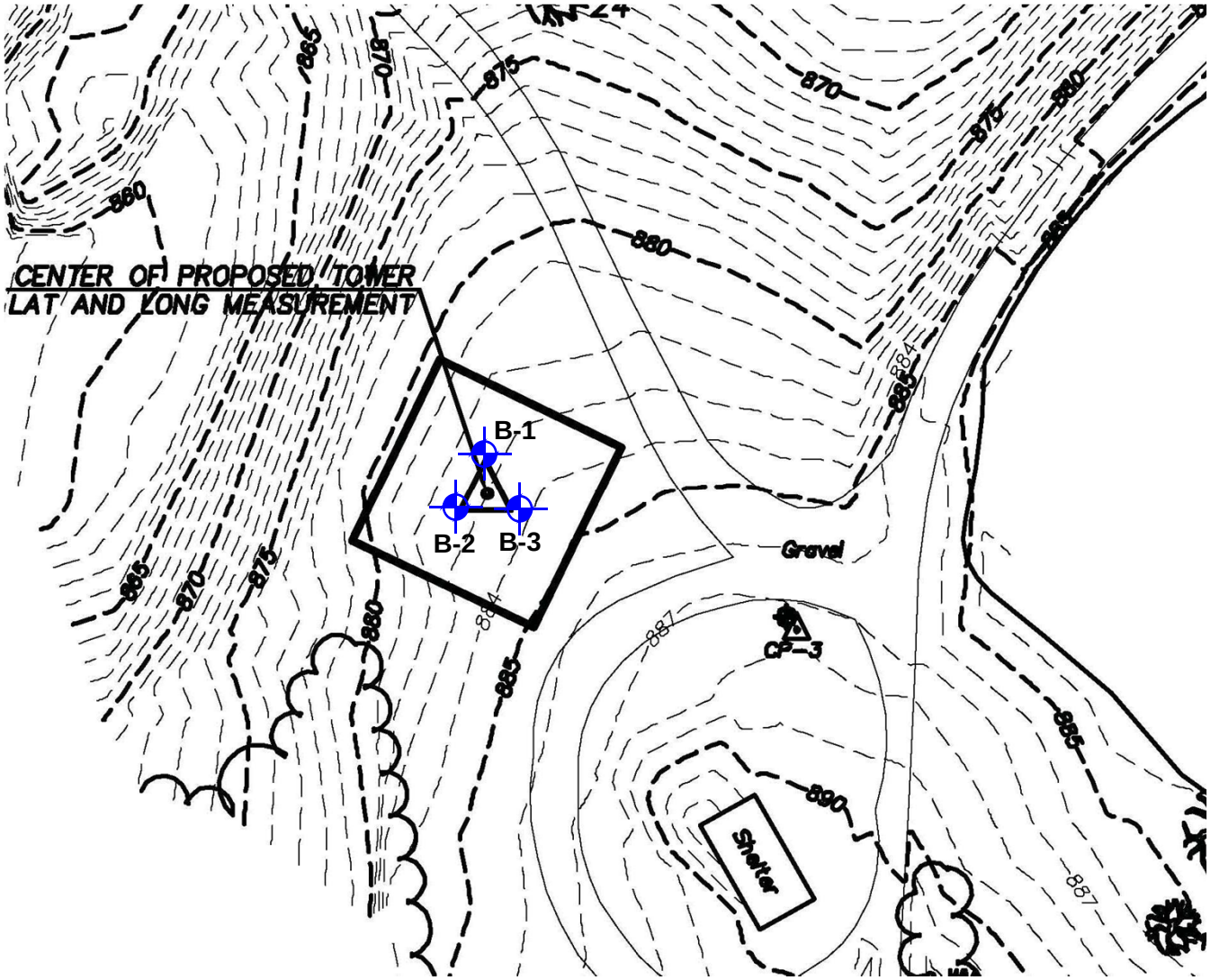


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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Manager: DAB	Project No. 02145055	Terracon Consulting Engineers & Scientists	EXPLORATION PLAN	Exhibit
Drawn By: DAB	Scale: NTS.		Clay County Self-Support Tower	A-1
Checked By: CKD	File Name:		McGinnis Road and Highway 33	
Approved By: DAB	Date: 04/03/2014	13910 West 96th Terrace Lenexa, KS 66215 PH. (913) 492-7777 FAX. (913) 492-7443	Kearney, MO	

BORING LOG NO. B-1

PROJECT: Clay County Self-Support Tower

CLIENT: Selective Site Consultants, Inc. Overland Park, KS

SITE: McGinnis Road and Highway 33 Kearney, MO

LOCATION See Exhibit A-1

Approximate Surface Elev: 882 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description
		FAT CLAY (CH), brown
13.0	869+/-	
		SHALE, light brown to gray brown, severely to moderately weathered
25.1	857+/-	
		LIMESTONE, gray, slightly weathered, thinly bedded - 5" gray shale seam at 26.9 feet - 4" gray shale seam at 28.2 feet
29.5	852.5+/-	- nodular limestone below 28.2 feet
		Boring Terminated at 29.5 Feet

DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY TORVANE/HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
		23			1270	28	90
		8			3220	28	92
5							
		11			3020	26	99
10							
		23			7730	19	111
15							
		10	13-25-35 N=60			17	
20							
		10	15-50/5"			18	
25			REC: 94% RQD: 48%				

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

Hammer Type: Automatic SPT Hammer

Advancement Method:
Continuous flight solid-stem augers and core drilling

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-5 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.

Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
13910 West 96th Terrace
Lenexa, Kansas

Boring Started: 3/19/2014	Boring Completed: 3/19/2014
Drill Rig: CME-55	Driller: SSS
Project No.: 02145055	Exhibit: A-2

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 02145055.GPJ TERRACON2012.GDT 4/2/14

BORING LOG NO. B-2

PROJECT: Clay County Self-Support Tower

CLIENT: Selective Site Consultants, Inc. Overland Park, KS

SITE: McGinnis Road and Highway 33 Kearney, MO

LOCATION See Exhibit A-1

Approximate Surface Elev: 882 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description
		FAT CLAY (CH), brown
15.0	867+/-	
		SHALE, light brown to gray brown
24.0	858+/-	
24.5	857.5+/-	**LIMESTONE**, gray
		Auger Refusal at 25.5 Feet

GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
	5, 10, 15, 20, 25								

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

Hammer Type: Automatic SPT Hammer

Advancement Method:
Continuous flight solid-stem augers

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-5 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.

Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
13910 West 96th Terrace
Lenexa, Kansas

Boring Started: 3/19/2014	Boring Completed: 3/19/2014
Drill Rig: CME-55	Driller: SSS
Project No.: 02145055	Exhibit: A-3

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 02145055.GPJ TERRACON2012.GDT 4/2/14

BORING LOG NO. B-3

PROJECT: Clay County Self-Support Tower

CLIENT: Selective Site Consultants, Inc. Overland Park, KS

SITE: McGinnis Road and Highway 33 Kearney, MO

LOCATION See Exhibit A-1

Approximate Surface Elev: 884 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description
		FAT CLAY (CH), brown
16.0	868+/-	
		SHALE, light brown to gray brown
26.0	858+/-	
26.5	857.5+/-	**LIMESTONE**, gray
		Auger Refusal at 26.5 Feet

GRAPHIC LOG	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
	5, 10, 15, 20, 25								

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

Hammer Type: Automatic SPT Hammer

Advancement Method:
Continuous flight solid-stem augers

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-5 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.

Elevations were interpolated from a topographic site plan.

Notes:

WATER LEVEL OBSERVATIONS

Groundwater not encountered

Terracon
13910 West 96th Terrace
Lenexa, Kansas

Boring Started: 3/19/2014	Boring Completed: 3/19/2014
Drill Rig: CME-55	Driller: SSS
Project No.: 02145055	Exhibit: A-4

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 02145055.GPJ TERRACON2012.GDT 4/2/14

Field Exploration Description

The boring locations were laid out at the site by Terracon utilizing a site plan provided by the client. Distances from existing site features were measured and right angles were estimated. Ground surface elevations (rounded to the nearest 1-foot) indicated on the log was obtained by plotting the boring locations on a topographic site plan an interpolating between elevation contours. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were drilled with a rotary drill rig using continuous flight augers to advance the boreholes. Samples of the soils encountered at Boring B-1were obtained using thin-walled tube sampling procedures. In the thin-walled tube sampling procedure, a thin-walled, seamless steel tube with a sharp cutting edge is pushed hydraulically into the soil to obtain a relatively undisturbed sample. At B-1 below 18.5 feet, split-barrel samples were obtained. In this procedure, the number of blows required to advance a standard 2-inch O.D. split-barrel sampler the last 12 inches of the typical total 18-inch penetration by means of a 140-pound automatic hammer with a free fall of 30 inches is the standard penetration resistance value (SPT-N). The samples were sealed and transported to the laboratory for testing and classification. At Borings B-2 and B-3, conditions encountered at these borings were determined by visual/tactual examination of disturbed auger cuttings.

The drill crew prepared a field log of each boring to record data including visual classifications of the materials encountered during drilling and the driller's interpretation of the subsurface conditions between samples. The boring logs included with this report represent our interpretation of the subsurface conditions at each boring based on field and laboratory data and observation of the samples.

APPENDIX B
LABORATORY TESTS

Laboratory Tests

Representative samples obtained from the borings were tested in the laboratory to measure their natural water contents. Dry unit weight tests were performed on samples extruded from thin-walled tubes. A hand penetrometer was used to estimate the approximate unconfined compressive strength of the cohesive samples. The test results are provided on the boring logs in Appendix A.

The soil samples were classified in the laboratory based on visual observation, texture, plasticity, and the laboratory tests described above. The soil descriptions presented on the boring log for native soils are in accordance with the enclosed General Notes and Unified Soil Classification System (USCS). The estimated USCS group symbols for native soils are shown on the boring logs, and a brief description of the USCS is included in this report.

APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

Auger	Split Spoon
Shelby Tube	Macro Core
Ring Sampler	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

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

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UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]		GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [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" 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	< 0.75	OL	Organic clay [K,L,M,N]
			Liquid limit - not dried			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	< 0.75	OH	Organic clay [K,L,M,P]
			Liquid limit - not dried			Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

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

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

[F] If soil contains ≥ 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.

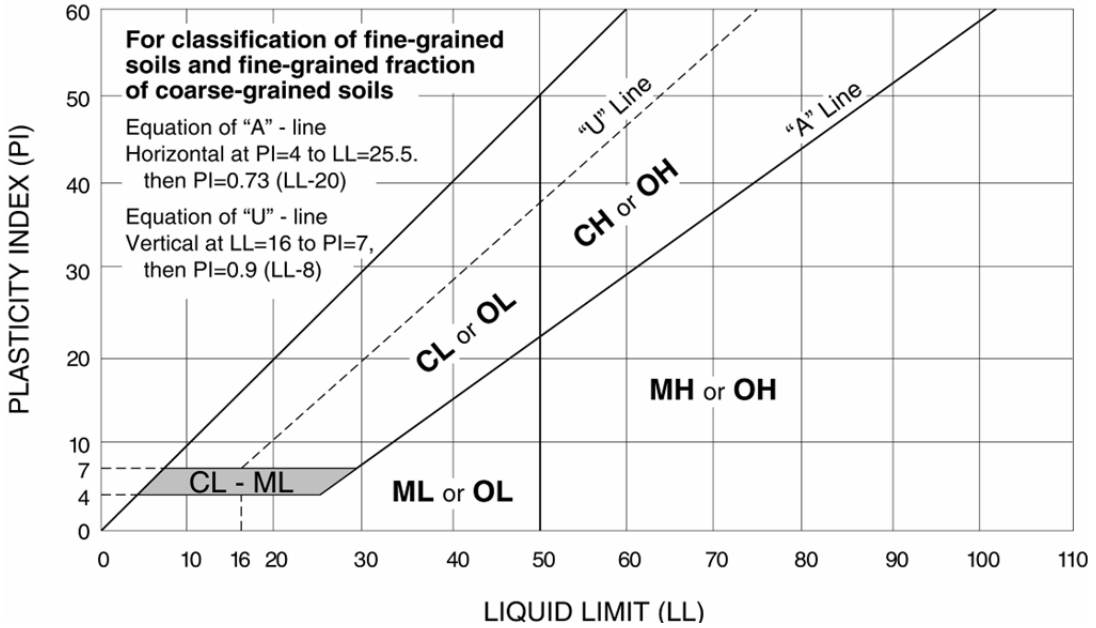

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Exhibit C-2

DESCRIPTION OF ROCK PROPERTIES

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" not 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 [a]

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

a. 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) a

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

a. RQD (given as a percentage) = length of core in pieces 4 in. 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.