Date: **May 17, 2023**

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Subject: Subsurface Exploration Report

Vertical Bridge Designation:	***Site Number:***	*US-WA-7023*
	Site Name:	*Tolt Highlands*
Engineering Firm Designation:	***TEP Project Number:***	*331175.849418*

Site Data: ***33284 Tolt River Road NE, Carnation, WA 98014 (King County)***
Latitude N47° 38' 56.2", Longitude W121° 53' 46.5"
155 Foot – Proposed Monopole Tower

Justin Owen,

Tower Engineering Professionals, Inc. (TEP) is pleased to submit this **"Subsurface Exploration Report"** to evaluate subsurface conditions in the tower area as they pertain to providing support for the tower foundation.

This report has been prepared in accordance with generally accepted geotechnical engineering practice for specific application to this project. The conclusions in this report are based on the applicable standards of TEP's practice in this geographic area at the time this report was prepared. No other warranty, expressed or implied, is made.

TEP assumes the current ground surface elevation, tower location and subsequent centerline provided are correct and are consistent with the elevation and centerline to be used for construction of the structure. Should the ground surface elevation be altered and/or the tower location be moved or shifted TEP should be contacted to determine if additional borings are necessary.

The analyses and recommendations submitted herein are based, in part, upon the data obtained from the subsurface exploration. The soil conditions may vary from what is represented in the boring log. While some transitions may be gradual, subsurface conditions in other areas may be quite different. Should actual site conditions vary from those presented in this report, TEP should be provided the opportunity to amend its recommendations, as necessary.

We at *Tower Engineering Professionals, Inc.* appreciate the opportunity of providing our continuing professional services to you and Vertical Bridge. If you have any questions or need further assistance on this or any other project, please give us a call.

Report Prepared/Reviewed by: Zeke A. Buchta, G.I.T. / John D. Longest, P.E.

Respectfully submitted by:

Graham M. Andres, P.E.

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5/17/23

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1) PROJECT DESCRIPTION

It is understood a monopole communications tower is being planned for construction at the above referenced site. The structure loads can be obtained from the tower manufacturer.

2) SITE EXPLORATION

The field exploration included the performance of one soil test boring (B-1). The boring was advanced to the auger refusal depth of 42 feet below ground surface (bgs) at the approximate location of the proposed monopole tower. The boring was performed by a track mounted drill rig using continuous flight hollow stem augers to advance the hole. Split-spoon samples and Standard Penetration Test (SPT) resistance values (N-values) were obtained in accordance with ASTM D1586 at a frequency of four samples in the top 10 feet and two samples in every 10 feet thereafter.

The Split-spoon samples were transported to the TEP laboratory where they were classified by a qualified representative of the Geotechnical Engineer in general accordance with the Unified Soil Classification System (USCS), using visual-manual identification procedures (ASTM D2488).

A boring location plan showing the approximate boring location and the boring log presenting the subsurface information obtained, accompanied with a brief guide to interpreting the boring log, are included in Appendix A and B, respectively.

3) SITE CONDITIONS

The site is located at 33284 Tolt River Road NE in Carnation, King County, Washington. The proposed tower and compound are to be located at the base of a slope in a wooded area. The ground topography is slightly sloping.

4) SUBSURFACE CONDITIONS

The following description of subsurface conditions is brief and general. For more detailed information, the individual boring log contained in Appendix B may be consulted.

4.1) Soil

The USCS classification of the soils encountered in the boring include SM, ML, and SP. The Standard Penetration Resistance (“N” Values) recorded in the subsurface materials range from 4 to 35 blows per foot of penetration.

4.2) Rock

Rock was not encountered in the boring. Refusal of auger advancement was encountered at a depth of 42 feet (bgs) in the boring. Drillers noted that refusal was on cobbles.

4.3) Subsurface Water

Subsurface water was not encountered in the boring at the time of drilling. It should be noted the subsurface water level will fluctuate during the year due to seasonal variations, precipitation events and construction activity in the area.

4.4) Frost

The Telecommunications Industry Association (TIA) frost depth for King County, Washington is 10 inches.

5) TOWER FOUNDATION ANALYSIS

Based on the boring data, it is the opinion of TEP that a pier extending to a single large mat foundation or a single drilled shaft can be used to support the new tower. If the drilled shaft foundation option is utilized, design of the foundation should ensure termination in a known material. The following presents TEP's conclusions and recommendations regarding the foundation types.

5.1) Shallow Foundation

Based on preliminary site information, the site is located on lightly sloping ground. It is recommended that foundation designs account for site grades being raised with excavation spoils or that foundation drawings specify minimum embedment depths based on existing site elevations and factor in ground slopes.

The following values may be used for design of a shallow foundation. The foundation should bear a minimum of 10 inches below the ground surface to penetrate the frost depth and with sufficient depth to withstand overturning of the tower. To resist the overturning moment, the weight of the concrete and any soil directly above the foundation can be used. The values provided in Table 1 consider ground surface elevation at the time of the subsurface exploration and undisturbed, native materials. Due to the construction process disturbing the in-situ soils and reducing the soil densities above the new foundation from those provided in Table 1, TEP recommends that the foundation designer specify a minimum depth and unit weight for compacted backfill to resist overturning of the new shallow foundation.

Table 1 – Shallow Foundation Design Parameters

Depth		Soil	Gross Ultimate Bearing[1,2] (psf)	Cohesion[1] (psf)	Friction Angle[1] (degrees)	Effective Unit Weight (pcf)	Friction Factor
Top	Bottom						
0	0.8	SM[3]	7725	-	28	104	0.34
0.8	2.5	SM	7950	-	30	104	0.36
2.5	7.5	SM	6850	-	33	113	0.40
7.5	10	ML	6325	1050	-	108	0.30
10	15	ML	6325	825	-	108	0.30

Notes:
1) These values should be considered ultimate soil parameters.
2) Bearing values consider a foundation width ranging from 12 to 35 feet and less than 1 inch of total settlement. Slope effects have been applied considering a maximum estimated slope of 5 degrees at and below the tower foundation.
3) Values have been modified to account for strength losses due to freeze/thaw cycles.

Bearing above the seasonal frost depth may lead to settlement and rotation, settlement of the base, and potential and progressive movement downhill. Foundations bearing above the frost depth may experience fluctuations in vertical movements with the annual frost/thaw. If tower foundation bears above frost depth, more frequent maintenance visits should be made.

5.2) Drilled Shaft Foundation

The following values may be used for design of a drilled shaft foundation. TEP recommends the side frictional and lateral resistance values developed in the top section of the caisson for a depth equal to half the diameter of the caisson or the frost depth, whichever is greater, be neglected in design calculations. The values presented in Table 2 are based on the ground surface elevation at the time of the subsurface exploration.

Table 2 – Drilled Shaft Foundation Design Parameters

Depth		Soil	Gross Ultimate Bearing[1] (psf)	Ultimate Side Frictional Resistance[1] (psf)	Cohesion[1] (psf)	Friction Angle[1] (degrees)	Effective Unit Weight (pcf)
Top	Bottom						
0	0.8	SM[2]	650	10	-	28	104
0.8	2.5	SM	1800	70	-	30	104
2.5	7.5	SM	5300	250	-	33	113
7.5	10	ML	8275	570	1050	-	108
10	15	ML	6900	450	825	-	108
15	20	SM	18800	820	-	31	113
20	25	SP	36675	1180	-	34	113
25	30	SP	50775	1500	-	35	113
30	35	SP	54925	1720	-	34	113
35	40	SP	78075	2120	-	36	114
40	42	SP	65575	2110	-	33	113

Notes:
1) These values should be considered ultimate soil parameters.
2) Values have been modified to account for strength losses due to freeze/thaw cycles.

Relying on soil strengths above the seasonal frost depth may lead to settlement and rotation, and settlement of the base. Where analysis of foundations relies on strengths of soils above the frost depth, more frequent maintenance visits should be made to check plumb and verify vertical movements of the foundation have not occurred.

5.3) Modulus of Subgrade Reaction

A vertical modulus of subgrade reaction and a horizontal modulus of subgrade reaction may be derived using the following equations and soil parameters for analysis of foundations.

$$k_{s-v} = 12 \cdot SF \cdot q_a$$

$$k_{s-h} = k_{s-v} \cdot B$$

Where;

q_a = Allowable Bearing Capacity (ksf)
SF = Factor of Safety
B = Base width (ft), use 1 if B < 1ft.
k_{s-v} = Vertical Modulus of Subgrade Reaction (kcf)
k_{s-h} = Horizontal Modulus of Subgrade Reaction (ksf)

6) SEISMIC SITE CLASS

The Site Class, per Section 1613.2.2 of the 2018 International Building Code (2018 IBC) and Chapter 20 of ASCE 7 (2016), based on the site soil conditions is Site Class D.

7) SOIL RESISTIVITY

A soil resistivity test was performed at the TEP laboratory in accordance with ASTM G57 (Standard Test Method for Measurement of Soil Resistivity Using the Four Electrode Soil Box Method). The test result indicates a resistivity of 47,000 ohms-cm. It should be noted that soil resistivity will fluctuate during the year due to seasonal variations, precipitation events and depth below surface.

8) CONSTRUCTION CONSIDERATIONS - SHALLOW FOUNDATION

The following recommendations pertain to the newly proposed tower foundation only. Should additional recommendations be required for lightly loaded support structures, such as the equipment shelter, TEP can provide these, at the client's request, for an additional fee.

8.1) Excavation

The boring data indicates excavation to the expected subgrade level for the shallow foundation will extend through sand and silt. A large tracked excavator should be able to remove the materials with moderate difficulty. Boulders and bedrock outcroppings are common to this geographic region and may also be encountered in the excavation area.

Excavations should be sloped or shored in accordance with local, state and federal regulations, including OSHA (29 CFR Part 1926) excavation trench safety standards. It is the responsibility of the contractor for site safety. This information is provided as a service and under no circumstance should TEP be assumed responsible for construction site safety.

8.2) Dewatering/Foundation Evaluation/Subgrade Preparation

As subsurface water was not encountered during the subsurface exploration, dewatering will not likely be required. However, should subsurface water be encountered during construction, it can likely be controlled with the use of a sump and pump system and/or trenches. Dewatering components should be placed to not interfere with the placement of backfill materials and/or concrete foundations and should be utilized to keep the localized water table below the bottom of any excavation.

After dewatering and excavation to the design elevation for the footing, the materials should be evaluated by a Geotechnical Engineer or a representative of the Geotechnical Engineer prior to reinforcement and concrete placement. This evaluation should include probing, shallow hand auger borings and dynamic cone penetrometer testing (ASTM STP 399) to help verify that suitable residual material lies directly under the foundation and to determine the need for any undercut and replacement of unsuitable materials. Loose surficial material should be compacted in the excavation prior to reinforcement and concrete placement to stabilize surface soil that may have become loose during the excavation process. TEP recommends a 6-inch layer of compacted dense-graded stone be placed just after excavation to aid in surface stability.

8.3) Fill Placement and Compaction

Backfill materials placed above the shallow foundation to the design subgrade elevation should not contain more than 5 percent by weight of organic matter, waste, debris or any otherwise deleterious materials. To be considered for use, backfill materials should have a maximum dry density of at least 100 pounds per cubic foot as determined by standard Proctor (ASTM D 698), a Liquid Limit no greater than 40, a Plasticity Index no greater than 20, a maximum particle size of 4 inches, and 20 percent or less of the material having a particle size between 2 and 4 inches. Because small handheld or walk-behind compaction equipment will most likely be used, backfill should be placed in thin horizontal lifts not exceeding 6 inches (loose).

Fill placement should be monitored by a qualified Materials Technician working under the direction of a Geotechnical Engineer. In addition to the visual evaluation, a sufficient amount of in-place field density tests should be conducted to confirm the required compaction is being attained.

8.4) Reuse of Excavated Soil

The sand and silt that meets the above referenced criteria can be utilized as backfill based on dry soil and site conditions at the time of construction.

9) CONSTRUCTION CONSIDERATIONS - DRILLED SHAFTS

Based on TEP's experience, a conventional drilled shaft rig (Hughes Tool LDH, or equivalent) can be used to excavate to the auger refusal depth of TEP's boring. An earth auger can typically penetrate the materials encountered to the auger refusal depth of the boring with moderate difficulty. Boulders and bedrock outcroppings are sometimes encountered in this geographic region and may be encountered outside of the boring location. Special excavation equipment may be necessary for a shaft greater that 60-inches in diameter. Augers designed for the removal of cobbles and boulders may be necessary for advancing holes deeper than 15 feet (bgs).

The following are general procedure recommendations in drilled shaft construction using the "dry" method:

1) Drilling equipment should have cutting teeth to result in a hole with little or no soil smeared or caked on the sides; a spiral like corrugated side should be produced. The shaft diameter should be at least equal to the design diameter for the full depth.

2) The drilled shaft should be drilled to satisfy a plumbness tolerance of 1.5 to 2 percent of the length and an eccentricity tolerance of 2 to 3 inches from plan location.

3) Refer to Section 4.3) for subsurface water information. Water will fluctuate during the year and during rain events. Any subsurface water should be removed by pumping, leaving no more than 3 inches in the bottom of the shaft excavation.

4) A removable steel casing may be installed in the shaft to prevent caving of the excavation sides due to soil relaxation. Loose soils in the bottom of the shaft should be removed.

5) The drilled shaft should be evaluated by the Geotechnical Engineer or their representative to confirm suitable end bearing conditions and to verify the proper diameter and bottom cleanliness. The shaft should be evaluated immediately prior to and during concrete operations.

6) The drilled shaft should be concreted as soon as practical after excavation to reduce the deterioration of the supporting soils due to caving and subsurface water intrusion.

7) The slump of the concrete is critical for the development of side shear resistance. TEP recommends a concrete mix having a slump of 6 to 8 inches be used with the minimum compressive strength specified by the structural engineer. A mix design incorporating super plasticizer will likely be required to obtain this slump.

8) The concrete may be allowed to fall freely through the open area in the reinforcing steel cage provided it is not allowed to strike the reinforcing steel or the casing prior to reaching the bottom of the shaft excavation.

9) The protective steel casing should be extracted as concrete is placed. A head of concrete should be maintained above the bottom of the casing to prevent soil and water intrusion into the concrete below the casing.

Due to the subsurface water and the sandy soil, the contractor may elect to utilize the “slurry” method for shaft construction. The following are general procedure recommendations in drilled shaft construction using the “slurry” method:

1) Slurry drilled shafts are constructed by conventional caisson drill rigs excavating beneath a drilling mud slurry. Typically, the slurry is introduced into the excavation after the water table has been penetrated and/or the soils on the sides of the excavation are observed to be caving-in. When the design shaft depth is reached, fluid concrete is placed through a tremie pipe at the bottom of the excavation.

2) The slurry level should be maintained at a minimum of 5 feet or one shaft diameter, whichever is greater, above the subsurface water level.

3) Inspection during excavation should include verification of plumbness, maintenance of sufficient slurry head, monitoring the specific gravity, pH and sand content of the drilling slurry, and monitoring any changes in the depth of the excavation between initial approval and prior to concreting.

4) A removable steel casing may be installed in the shaft to prevent caving of the excavation sides due to excavation disturbance and soil relaxation. Loose soils in the bottom of the shaft should be removed.

5) The specific gravity or relative density of the drilling mud slurry should be monitored from the initial mixing to the completion of the excavation. An increase in the specific gravity or density of the drilling slurry by as much as 10 percent is indicative of soil particles settling out of the slurry onto the bottom of the excavation. This settling will result in a reduction of the allowable bearing capacity of the bottom of the drilled shaft.

6) After approval, the drilled shaft should be concreted as soon as practical using a tremie pipe.

7) For slurry drilled shafts, the concrete should have a 6- to 8-inch slump prior to discharge into the tremie. The bottom of the tremie should be set at about one tremie pipe diameter above the excavation. A closure flap at the bottom of the tremie should be used, or a sliding plug introduced into the tremie before the concrete, to reduce the potential for the concrete being contaminated by the slurry. The bottom of the tremie must be maintained in concrete during placement, which should be continuous.

8) The protective steel casing should be extracted as concrete is placed. A head of concrete should be maintained above the bottom of the casing to prevent soil and water intrusion into the concrete below the casing.

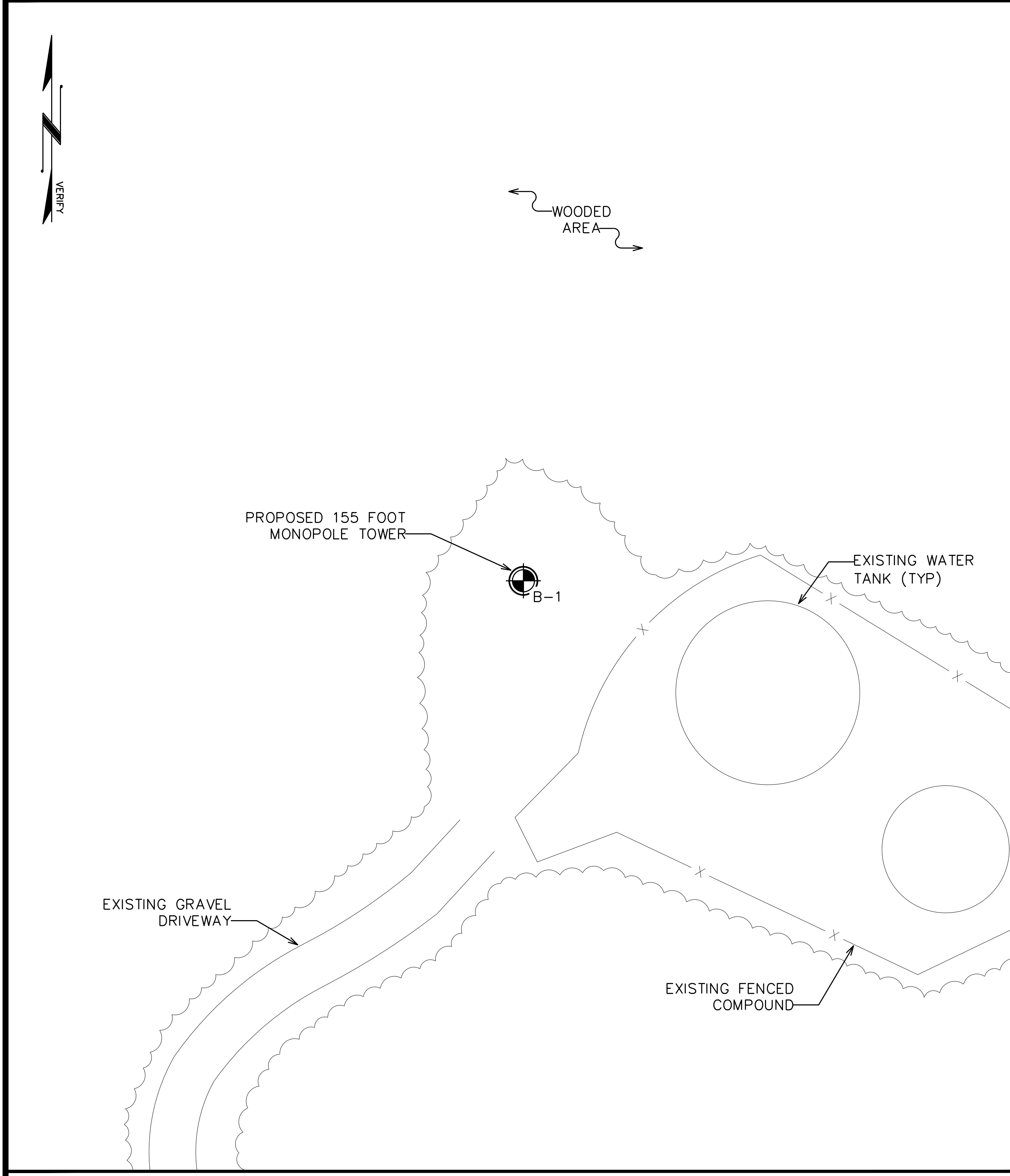
If variability in the subsurface materials is encountered, a representative of the Geotechnical Engineer should verify that the design parameters are valid during construction. Modification to the design values presented above may be required in the field.

10) SITE PHOTOGRAPHS

	Boring During Drilling
	Borehole After Drilling

APPENDIX A

BORING LAYOUT



BORING LAYOUT

SCALE: N.T.S.

PREPARED BY:

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PREPARED FOR:

vertical bridge
750 PARK OF COMMERCE DRIVE
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PROJECT INFORMATION:

TOLT HIGHLANDS
SITE #: US-WA-7023

33284 TOLT RIVER ROAD
CARNATION, WA 98014
(KING COUNTY)

REVISION: 0
TEP JOB #:331175.849418
SHEET NUMBER:
C-1

APPENDIX B

BORING LOG

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LOG OF BORING B-1

PROJECT	SITE ID:	TEP NO.:
Tolt Highlands	US-WA-7023	331175

DATE STARTED	DRILLING METHOD	HOLE SIZE	CITY, STATE
5/11/2023	Hollow Stem Auger	8.0 in O.D.	Carnation, Washington

DATE COMPLETE	HAMMER WEIGHT/FALL	HAMMER TYPE	TOTAL DEPTH	DRILL RIG TYPE
5/11/2023	140lbs / 30in	Auto Hammer	42.0 FT	CME 55

GROUND EL.	LOGGED BY	CHECKED BY	BACKFILL	DEPTH/EL. GROUNDWATER
	KWG	JDL	Cuttings	Not Encountered

BORING LOCATION: At the approximate location of the proposed tower

SAMPLE NUMBER	SAMPLE LENGTH (INCHES)	BLOW COUNTS (N) / REC% / RQD%	POCKET PEN TSF	UNCONFINED STRENGTH, PSF	UNIT WEIGHT PCF
S1	18	1-2-2 (4)			
S2	18	5-6-5 (11)			
S3	18	2-2-4 (6)	2.2		
S4	18	3-4-4 (8)	1.1		
S5	18	3-5-5 (10)			
S6	18	4-9-11 (20)			
S7	18	4-10-16 (26)			
S8	18	5-10-13 (23)			
S9	18	9-14-21 (35)			
S10	18	6-11-12 (23)			

DEPTH (FEET): 5, 10, 15, 20, 25, 30, 35, 40, 45

DESCRIPTION AND CLASSIFICATION	REMARKS
0.0-0.8: 8"- Topsoil	
0.8-2.5: Very loose, brown, fine to coarse, silty SAND (SM), trace organics, moist 2.5-7.5: to medium dense, no organics -2" clay lens	Driller Note: Sand from 2 feet to 15 feet bgs
7.5-15.0: Medium stiff, dark brown, SILT (ML), with sand, trace rootlets, moist	
15.0-20.0: Loose, brown, fine to medium, silty SAND (SM), trace clay, moist	Driller Note: Sand with cobbles from 15 feet bgs to the end of the boring
20.0-35.0: Medium dense, gray, fine to coarse, poorly graded SAND (SP), with gravel, moist	
35.0-40.0: to dense	
40.0-42.0: to medium dense	
42.0: Boring Terminated	Driller Note: Refusal on cobbles

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Key to Soil Symbols and Terms

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE-GRAINED SOILS (major portions retained on No. 200 sieve): includes (1) clean gravel and sands and (2) silty or clayey gravels and sands. Condition is rated according to relative density as determined by laboratory tests or standard penetration resistance tests.

Descriptive Terms	SPT Blow Count
Very Loose	< 4
Loose	4 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	> 50

FINE-GRAINED SOILS (major portions passing on No. 200 sieve): includes (1) inorganic and organic silts and clays (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings, SPT blow count, or unconfined compression tests.

Descriptive Terms	SPT Blow Count
Very Soft	< 2
Soft	2 to 4
Medium Stiff	5 to 8
Stiff	9 to 15
Very Stiff	16 to 30
Hard	> 30

GENERAL NOTES

1. Classifications are bases on the Unified Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.

2. Surface elevations are based on topographic maps and estimated locations and should be considered approximate.

3. Descriptions on these boring logs apply only at the specific boring locations and at the time the borings were made. They are not guaranteed to be representative of subsurface condition at other locations or times.

	Group Symbols	Typical Names
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, little or no fines/sands
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-silt mixtures
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly-graded sands, little or no fines/sands/gravels
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
	ML	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
	MH	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
	PT	Peat and other highly organic soils

Sampler Symbols

- Split Spoon
- Standard Penetration Test (SPT)
- Pushed Shelby Tube
- Auger Cuttings
- Grab Sample
- Dynamic Cone Penetrometer
- Hand Auger
- Rock Core

Log Abbreviations

ATD - At Time of Drilling
AD - After Drilling
EOD - End of Drilling
RMR - Rock Mass Rating
WOH - Weight of Hammer
WOR - Weight of Rod
REC - Rock Core Recovery
RQD - Rock Quality Designation

Information Regarding This Subsurface Exploration Report

The information contained in this report has been specifically tailored to the needs of the client at the time the report was provided, for the specific purpose of the project named in this report. The attached report may not address the needs of contractors, civil engineers, or structural engineers. Anyone other than the named client should consult with the geotechnical engineer prior to utilizing the information contained in the report.

It is always recommended that the full report be read. While certain aspects of the report may seem unnecessary or irrelevant; just as each project and site are unique, so are the subsurface investigation reports and the information contained in them. Several factors can influence the contents of these reports, and the geotechnical engineer has taken into consideration the specific project, the project location, the client's objectives, potential future improvements, etc. If there is any question about whether the attached report pertains to your specific project or if you would like to verify that certain factors were considered in the preparation of this report, it is recommended that you contact the geotechnical engineer.

Geotechnical subsurface investigations often are prepared during the preliminary stages of a project and aspects of the project may change later on. Some changes may require a report revision or additional exploration. Some changes that often need to be brought to the attention of the geotechnical engineer include changes in location, size and/or type of structure, modifications to existing structures, grading around the project site, etc. Some naturally occurring changes can also develop that impact the information contained in this geotechnical report such as earthquakes, landslides, floods, subsurface water levels changing, etc. It is always recommended that the geotechnical be informed of known changes at the project site.

Subsurface exploration reports are generated based on the analysis and professional opinions of a geotechnical engineer based on the results of field and laboratory data. Often subsurface conditions can vary – sometimes significantly – across a site and over short distances. It often is helpful to retain the geotechnical engineer's services during the construction process. Otherwise, the geotechnical cannot assume responsibility or liability for report recommendations which may have needed to change based on changing site conditions or misinterpretation of recommendations.

Geotechnical engineers assemble testing and/or boring logs based on their interpretation of field and laboratory data. Testing and/or boring logs should always be coupled with the subsurface exploration report. The geotechnical engineer and Tower Engineering Professionals cannot be held reliable for interpretations, analyses, or recommendations based solely on the testing and/or boring log if it is independent of the prepared report.

The scope of the subsurface exploration report does not include an assessment or analysis of environmental conditions, determination of the presence or absence of wetlands or hazardous or toxic materials on or below the ground surface. Any notes regarding odors, fill, debris, or anything of that nature are offered as general information for the client, often to help identify or delineate natural soil boundaries.

For additional information, please contact the geotechnical engineer named in the attached report.

TOWER ENGINEERING PROFESSIONALS