REPORT OF SUBSURFACE EXPLORATION AND GEOTECHNICAL EVALUATION

STILWELL RUNNER'S ADDITION
STILWELL, OKLAHOMA
WALLACE PROJECT NUMBER: 2240472
BUILDING & EARTH PROJECT NO.: TU230035

PREPARED FOR:
Wallace Design Collective

MARCH 15, 2023

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

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1403 South 70th East Avenue
Tulsa, OK 74112
Ph: (918) 439-9005
www.BuildingAndEarth.com

March 15, 2023

Wallace Design Collective
123 North Martin Luther King Jr. Boulevard
Tulsa, Oklahoma 74103

Attention: Mr. Lance Woolsey, P.E., RA
Associate

Subject: Report of Subsurface Exploration and Geotechnical Evaluation
Stilwell Runner's Addition
Stilwell, Oklahoma
Wallace Project No.: 2240472
Building & Earth Project No: TU230035

Dear Mr. Woolsey:

Building & Earth Sciences, Inc. has completed the authorized subsurface exploration and geotechnical engineering evaluation for the above referenced project in Stilwell, Oklahoma.

The purpose of this exploration and evaluation was to determine general subsurface conditions at the site and to address applicable geotechnical aspects of the proposed construction and site development. The recommendations in this report are based on a physical reconnaissance of the site and observation and classification of samples obtained from eleven (11) test borings conducted at the site. Confirmation of the anticipated subsurface conditions during construction is an essential part of geotechnical services.

We appreciate the opportunity to provide consultation services for the proposed project. If you have any questions regarding the information in this report or need any additional information, please call us.

Respectfully Submitted,
BUILDING & EARTH SCIENCES, INC.
Certificate of Authorization #3975, Expires 6/30/2024

3/15/2023
JOSEPH D. VISTAD
30303

M. Dharmateja

Dharmateja Maganti, E.I.
Project Manager

Joseph D. Vistad, P.E.
Senior Engineering Review
OK: 303033

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1.0 PROJECT & SITE DESCRIPTION

The project site is located approximately 0.25 mile east from the South 4700 Road and Young Avenue intersection in Stilwell, Oklahoma. General information relative to the proposed site and the proposed development is listed in Table 1 below. Google Earth satellite imagery of the site and photographs depicting the current site conditions are presented on the following pages.

Development Item	Detail	Description
General Site	Size (Ac.)	Approx. 5
	Existing Development	An existing residential dwelling was noted within the central portion of the planned construction area. The remaining portions of the project site is currently an undeveloped tract of land. A gravel road runs through the property, running north to south
	Vegetation	Most of the site was covered with grass, and scattered trees
	Slopes	The project site gently slopes down to the north with a grade differential of approximately 10 feet across the planned development area
	Drainage	Natural surface drainage to the north. Ponding water was noted within portions of the project area (primarily within the gravel drive area). The site does not appear to be poorly drained
	Proposed Cuts & Fills [1]	See note 1
Proposed Buildings	No. of structures	Eight (8) residential lots New residential street with cul-de-sac and detention pond
	Square Ft.	Housing units ranging between 1,800 and 2,000 sq ft
	Stories	All units are single-story
	Construction	Wood framed residential dwellings (assumed)
	Column Loads [2]	<20 kips (assumed)
	Wall Loads [2]	1 to 2 kips per linear foot (assumed)
	Preferred Foundation	Post-tensioned slab foundation
	Preferred Slab	Post-tension reinforced slab-on-grade
Pavements	Traffic	Not provided, assumed to be minor residential street with design ESAL of 400,000

Table 1: Project and Site Description

Table 1 References:

- Site Plan with Boring Locations, prepared by Wallace Design Collective, undated
- Grading Plan, prepared by Wallace Design Collective, undated

Table 1 Notes:

1. Based on review of the provided grading plan, we understand that existing grades within the planned construction area range between 1165 on the south end to 1153 on the north end. Based on the provided finished floor elevations, we estimate cut depths of up to 4 feet and fill heights of about 2 feet will be required to achieve design grades. If changes are made to the provided grading plan, Building & Earth should be allowed to review the updated plan and its effects on our recommendations.
2. If actual loading conditions exceed our assumed loads, Building & Earth should be allowed to review the proposed structural design and its effects on our recommendations for foundation design.

At the time of our subsurface exploration and site reconnaissance, most of the project site was covered with grass and topsoil. Within the northern portion of the planned construction area, what appears to be future building pad areas, was cleared of vegetation and chert gravel material was exposed at four (4) locations. A gravel drive was noted on the north side of the project area, running north to south, and terminated just north of the existing building.

Figure 1: Google Earth aerial image, dated November 2022

Overhead power lines were noted within the portions of the site and underground water and sewer markings were noted along the north property boundary. Stockpiles of chert gravel were noted on the north side of the property at two (2) locations, on either side of the existing gravel drive.

Figure 2: View looking south, towards the existing building

Figure 3: View looking east, looking towards stockpiled material

Figure 4: Ponding water within the existing gravel drive area

Figure 5: Chert gravel exposed within northern portion of planned construction area

2.0 SCOPE OF SERVICES

The authorized subsurface exploration was performed on February 28, 2023, in conformance with our proposal TU25054 dated February 14, 2023 . Notice to proceed was provided by signing our proposal document on February 15, 2023.

The purpose of the geotechnical exploration was to determine general subsurface conditions at specific boring locations and to gather data on which to base a geotechnical evaluation with respect to the proposed construction. The subsurface exploration for this project consisted of eleven (11) test borings.

The site was drilled using a Geoprobe 7822DT track mounted drill rig equipped with hollow stem augers and an automatic hammer for performing Standard Penetration Tests (SPT) to help evaluate the relative soil strength. Refer to the Appendix for a description of the drilling and sampling procedures.

Boring locations were determined in the field by a representative of our staff using a handheld GPS device. As such, the boring locations shown on the Boring Location Plan attached to this report should be considered approximate.

The soil/rock samples recovered during our site investigation were visually classified and specific samples were selected by the project engineer for laboratory analysis. The laboratory analysis consisted of:

Test	ASTM	No. of Tests
Natural Moisture Content	D2216	41
Atterberg Limits	D4318	7
Material Finer Than No. 200 Sieve by Washing	D1140	2

Table 2: Scope of Laboratory Tests

The results of the laboratory analysis are presented on the enclosed Boring Logs and in tabular form in the Appendix of this report. Descriptions of the laboratory tests that were performed are also included in the Appendix.

The information gathered from the exploration was evaluated to determine a suitable foundation type for the proposed structures. The information was also evaluated to help determine if any special subgrade preparation procedures will be required during the earthwork phase of the project.

The results of the work are presented within this report that addresses:

- General site geology.
- Summary of existing surface conditions.
- A description of the subsurface conditions encountered at the boring locations.
- A description of the groundwater conditions observed in the boreholes during drilling. Long-term monitoring was not included in our scope of work.
- Presentation of laboratory test results.
- Site preparation considerations including material types to be expected at the site, treatment of any encountered unsuitable soils, excavation considerations, and surface drainage.
- Presentation of expected total and differential settlements.
- Recommendations to be used for design of slabs-on-grade, including modulus of subgrade reaction. Post-tension slab design recommendations will be included following the latest PTI slab design methodology.
- Compaction requirements and recommended criteria to establish suitable material for structural backfill.
- Recommended typical minimum flexible and rigid pavement sections for the residential street based on assumed traffic loading conditions.

3.0 GEOTECHNICAL SITE CHARACTERIZATION

The following discussion is intended to create a general understanding of the site from a geotechnical engineering perspective. It is not intended to be a discussion of every potential geotechnical issue that may arise, nor to provide every possible interpretation of the conditions identified. The following conditions and subsequent recommendations assume that significant changes in subsurface conditions do not occur between boreholes. However, anomalous conditions can occur due to variations in existing fill that may be present at the site, or the geologic conditions at the site, and it will be necessary to evaluate the assumed conditions during site grading and foundation installation.

3.1 GENERAL SITE GEOLOGY

According to the Oklahoma State Geologic Map published by the United States Geological Survey (USGS), the subject property is underlain by Early Mississippian age, Keokuk and Reed Spring Formations. These formations are described to comprise of chert and limestone. The subsurface conditions encountered at the project site generally correlate with the published geologic references.

3.2 EXISTING SURFACE CONDITIONS

At the time of our subsurface exploration, most of the project site was covered with grass and topsoil that had a thickness of about 2 to 4.5 inches in six (6) of the eleven (11) borings. It should be noted that topsoil thicknesses likely vary at unexplored locations of the project site, especially in heavily wooded areas. No testing has been performed to verify that soils meet the requirements of "topsoil". For this report, topsoil is defined as the soil horizon which contains the root mat of the noted light vegetation (grass and weeds).

In areas of borings P-02 and P-03, the ground surface was covered with aggregate base, that was approximately 2 to 3 inches in thickness. At borings B-04 and B-08, possible fill materials consisting of clayey chert gravel was exposed at the ground surface. Additionally, the topsoil had been stripped and residual lean clay was exposed at boring location B-06.

3.3 SUBSURFACE CONDITIONS

A generalized stratification summary has been prepared using data from the test borings and is presented in the table below. The stratification depicts the general soil conditions and stratum types encountered during our field investigation.

Stratum No.	Typical Thickness	Description	Consistency/Relative Density	Lab Test Data [(1)]
1	2 to 2.5' (Encountered in borings B-04 and B-08 only)	**Possible Fill Materials:** Clayey Chert Gravel (GC) Various shades and combinations of yellow, brown, red, and white	Loose to medium 3dense	Moisture Contents: 24 and 30%
2	0.7 to 9' (Not encountered in B-01, B-07, and P-01)	**Clay Residuum:** Lean Clays (CL) and some Fat Clays (CH) with chert fragments Various shades and combinations of brown, yellow, gray, and red	Typically, exhibited stiff consistencies Soft to medium clays soils were encountered within the upper 1 to 2.5 feet	***Lean Clays*** Atterberg Limits: LL = 29 to 30, PI = 12 to 13 Moisture Contents: 19 to 24% ***Fat Clays*** (Atterberg Limits) LL = 55, PI = 29 Moisture Content: 27%
3	Termination Layer	**Gravel Residuum:** Clayey Chert Gravel (GC), and some Silty Chert Gravel (GM) with chert cobbles, and clay seams and layers Various shades and combinations of brown, gray, and red	Medium dense to very dense	Atterberg Limits: LL = 25 to 28, PI = 3 to 11 Passing #200 Sieve: 20 and 53% Moisture Contents: 8 to 25%

Table 3: Stratification Summary

Table 3 Notes:

(1) For Atterberg limits, LL = Liquid Limit, and PI = Plasticity Index

A subsurface profile has been prepared based on the data obtained at the specific boring locations. The subsurface profile is presented in the Appendix. For specific details on the information obtained from individual borings, refer to the Boring Logs included in the Appendix.

The ground surface elevations at the boring locations indicated in this report were estimated from the contours shown on the provided grading plan, prepared by Wallace Design Collective .

3.3.1 GROUNDWATER

Groundwater was not encountered in the borings during drilling, and each was dry upon completion and prior to backfilling of the boreholes.

Fluctuations in the water level can occur due to seasonal rainfall. Water levels as observed during drilling are accurate for only the time and date that the boring was drilled. Short term groundwater level readings may not accurately reflect the actual groundwater levels at the borings.

4.0 SITE DEVELOPMENT CONSIDERATIONS

Based on review of the provided grading plan, we understand that existing grades within the planned construction area range between 1165 on the south end to 1153 on the north end. Based on the provided finished floor elevations, we estimate cut depths of up to 4 feet and fill heights of about 2 feet will be required to achieve design grades. If changes are made to the provided grading plan, Building & Earth should be allowed to review the updated plan and its effects on our recommendations.

Based on our evaluation of the subsurface conditions, and the planned residential housing units, it appears that construction of each structure with a post-tensioned slab foundation can be used for the planned development. The site development recommendations outlined below are intended for development of the site to support construction with a post-tensioned slab foundation.

If a different type of foundation system is preferred, Building & Earth should be allowed to review the site development recommendations to verify that they are appropriate for the preferred foundation system.

The primary geotechnical considerations for this project are:

- Possible fill materials comprised of clayey chert gravel were encountered in borings B-04 and B-08, extending to depths of about 2 to 2.5 feet below current grades.
- The near surface fill materials and residuum generally exhibited soft to medium stiff consistencies and loose relative densities, extending to depths of about 1 to 2.5 feet. These soils are prone to losing strength and stability with slight increases in soil moisture contents and when subjected to repeat traffic loading.
- Portions of onsite clay soils exhibited higher plasticity characteristics that have a high shrink/swell potential with moisture fluctuations.
- Although groundwater seepage was not encountered during drilling or prior to backfilling the boreholes, near-surface soils in most of the borings generally exhibited moist to wet conditions.

Recommendations addressing the site conditions are presented in the following sections.

4.1 INITIAL SITE PREPARATION

The initial site preparation should commence with demolition of existing structures and the gravel drive. In areas of borings P-02 and P-03, the ground surface was covered with aggregate base, that was approximately 2 to 3 inches in thickness. The aggregate thickness is only representative for the boring locations and likely differs in unexplored areas of the drive.

Any slabs, footings, below grade walls (if any), equipment, underground utility lines, gravel surfacing materials, etc. associated with the existing development should be removed from the proposed construction areas prior to any fill placement or new construction. Soils disturbed during the process should be undercut to undisturbed material and replaced with structural fill.

All trees, vegetation, roots, topsoil, and any other deleterious materials, should be removed from the proposed construction areas. Approximately 2 to 4.5 inches of topsoil were observed in most of the borings. The thickness of topsoil base could extend to greater depths in unexplored areas of the site.

Grubbing of trees should include removal of the tree stumps and the root systems. Desiccated clay soils may be present in the zone surrounding the trees. Desiccated clay soils should be undercut and replaced with structural fill.

Soils disturbed during demolition, and stripping operations should be undercut to undisturbed material and replaced with structural fill. The geotechnical engineer or their designated representative should observe demolition, and stripping operations to evaluate that all unsuitable materials are removed from locations proposed for construction. Materials disturbed during demolition and clearing operations should be stabilized in place or, if necessary, undercut to undisturbed materials and backfilled with properly compacted, approved structural fill.

Existing underground utility line markings are anticipated within the proposed construction area. All abandoned utility lines should be removed and existing utility lines that will remain in use should be rerouted outside the proposed structure areas. The trench excavations, following removal or rerouting of the existing utility lines, should be properly backfilled in accordance with requirements outlined in the *Structural Fill* section of this report.

During site preparation activities, the contractor should identify borrow source materials that will be used as structural fill and provide samples to the testing laboratory so that conformance to the structural fill requirements outlined below and appropriate moisture-density relationship curves can be determined.

4.2 PONDING WATER WITHIN PORTIONS OF PROJECT AREA

Ponding water was noted at the surface within the portions of project area, especially within the gravel drive areas. Moist to wet, soft/loose soils are commonly present within and adjacent to these areas.

The lateral extent and depth of soft/unstable and wet soils associated with the noted areas of the site were not determined as part of the scope of work presented in this report. Site development concerns include the presence of soft, unstable, and wet soils.

4.3 FULL-DEPTH REMOVAL OF LOW CONSISTENCY SOILS

At the time of drilling, most of the near-surface soils encountered in borings typically exhibited soft to medium stiff consistencies or loose relative densities. These near-surface, low consistency soils pose a concern for low bearing capacity and high risk for foundation settlement. These soils will not provide a stable platform for fill placement and construction of pavements.

Following initial site preparation and prior to any fill placement, we recommend the low consistency soils be undercut full depth to expose a stable, suitable subgrade and they should be replaced with properly compacted and approved structural fill.

For construction budget estimate purposes, an average undercut depth of 1.5 feet below existing grades is to be anticipated within proposed building and pavement areas that are close to grade or require fill to achieve design grade. Actual undercut depths will be dependent on the soil conditions during construction, and they could extend to depths greater than 1.5 feet within parts of the site.

The placement procedure, compaction, and composition of the structural fill should meet the requirements of the *Structural Fill* section of this report. The undercutting should be conducted under the observation of the geotechnical engineer or their designated representative. Once the undercut is complete, the areas planned for construction should be proofrolled to identify any additional soft soils requiring further removal.

4.4 EVALUATION OF POSSIBLE FILL MATERIALS

Possible fill materials comprised of clayey chert gravel were encountered in borings B-04 and B-08, extending to depths of about 2 to 2.5 feet below current grades. The owner and design team need to understand that there is a risk the fill may contain soft soils, organics, debris, over-sized rock fragments, or other unsuitable materials that could not be reasonably deduced from the widely spaced borings.

The presence of unforeseen conditions, such as those described above, could result in variable and unpredictable settlement of grade supported slabs and shallow footings. Although the risks cannot be eliminated unless removed full depth and replaced with new structural fill, they can be reduced by evaluation of the existing fill materials.

As a minimum, we recommend the exposed fill materials be thoroughly evaluated by the geotechnical engineer or their designated representative. We recommend the exposed subgrade be evaluated by means of proofrolling with a loaded tandem-axle dump truck (20- to 25-ton).

The proofrolling will aid in identifying unstable/soft areas, which should be delineated and further evaluated. Test pits should be excavated within the delineated areas of concern to evaluate the conditions of the fill below exposed subgrade.

If any soft soils, organics, construction debris, or any other unsuitable materials are encountered within the test pits, these unsuitable materials should be removed from the proposed building areas and replaced with structural fill.

4.5 GENERAL UNDERCUTTING RECOMMENDATIONS

All undercutting should be conducted under the observation of the geotechnical engineer or their designated representative and should extend a minimum of 5 feet outside the perimeter of any building footprint and its appurtenances, and 3 feet beyond the back of curb in any pavement areas. *Weather conditions at the time of construction can affect the undercutting depths and quantities*. Some instability may exist during construction, depending on climatic and other factors immediately preceding and during construction.

The placement procedure, compaction, and composition of the structural fill should meet the composition and placement requirements of the *Structural Fill* section of this report.

4.6 SUBGRADE EVALUATION AND PREPARATION

Following any undercutting and prior to start of fill placement, the exposed subgrade should be scarified to a minimum depth of 12 inches, moisture conditioned within range of 2 percent below to 2 percent above the optimum moisture content, and recompacted to at least 95 percent of the standard Proctor maximum dry density.

We recommend that the project geotechnical engineer or a qualified representative evaluate the subgrade after the site is prepared. Some unsuitable or unstable areas may be present in unexplored areas of the site. All areas that will require fill or that will support structures should be carefully proofrolled with a heavy (20- to 25-ton), loaded tandem axle dump truck at the following times.

- After an area has been stripped, and undercut as needed, prior to the placement of any fill.
- After grading an area to the finished subgrade elevation in building and pavement areas.
- After areas have been exposed to any precipitation, and/or have been exposed for more than 48 hours.

Some instability may exist during construction, depending on climatic and other factors immediately preceding and during construction. If any soft or otherwise unsuitable soils are identified during the proofrolling process, they should be undercut or stabilized prior to fill placement, floor slab, or pavement construction. All unsuitable material identified during the construction should be removed and replaced in accordance with the *Structural Fill* section of this report.

4.7 STRUCTURAL FILL

Requirements for structural fill on this project are as follows:

Soil Type	USCS Classification	Property Requirements	Placement Location
Imported Lean Clay, Clayey Sand, or Shale	CL, SC	LL<40, PI<20, P200>30%, Maximum 3" particle size in any dimension	**Low Plasticity Structural Fill** to be used for construction of building pad and below pavements as needed
Onsite Residuum Lean Clays and Clayey Chert Gravel	CL, GC	Same as above	***Suitable*** for placement as low plasticity structural fill

Soil Type	USCS Classification	Property Requirements	Placement Location
<u>Onsite Residuum</u> Fat Clays	CH	Not Applicable	***Not suitable*** for placement in building and pavement areas due to higher plasticity characteristics

Table 4: Structural Fill Requirements

Notes:

1. All structural fill should be free of vegetation, topsoil, and any other deleterious materials. The organic content of materials to be used for fill should be less than 3 percent.
2. LL indicates the soil Liquid Limit; PI indicates the soil Plasticity Index.
3. Representative bulk samples for any onsite and imported offsite materials are to be collected for soil classification and moisture-density relationship determination purposes as part of evaluating suitability for their intended use.
4. Material native to the region that may not meet the above structural fill criteria may be used if it contains more than 70% cherty sand and gravel retained on a No. 200 sieve (with maximum particle size of 3 inches) and is approved by the geotechnical engineer. Bulk samples of such material should be provided for, but not necessarily limited to, particle size analysis, Atterberg limits, and moisture-density relationship testing.
5. Cobble- and boulder-sized chert and intact chert lenses were observed in the gravelly residuum. Materials placed within depth of 24 inches below finished subgrade should have maximum particle size of 3 inches in any dimension. Below depth of 24 inches, a maximum particle-size up to 6 inches in any dimension is allowed.

Placement requirements for structural fill are as follows:

Specification	Requirement
Lift Thickness	Maximum loose lift thickness of 8 to 12 inches, depending on type of compaction equipment used.
Density	At least 95% of the standard Proctor (ASTM D698) maximum dry density
Moisture	±2% of the optimum moisture content as determined by ASTM D698
Density Testing Frequency	**<u>Building and foundation areas</u>**: One test per 2,500 square feet (SF) per lift with a minimum of three tests performed per lift **<u>Pavement areas and utility trenches</u>**: One test per 150 linear feet per lift with a minimum of three tests performed per lift The testing frequency can be increased or decreased by the Geotechnical Engineer of Record in the field based on uniformity of material being placed and compactive effort used.

Table 5: Structural Fill Placement Requirements

4.8 EXCAVATION CONSIDERATIONS

All excavations performed at the site should follow OSHA guidelines for temporary excavations. Excavated soils should be stockpiled according to OSHA regulations to limit the potential cave-in of soils.

4.8.1 PERCHED WATER

Although groundwater seepage was not encountered during drilling or prior to backfilling the boreholes, near-surface soils in most of the borings generally exhibited moist to wet conditions. Perched water may be encountered during construction in foundation or utility trench excavations.

It should be noted that fluctuations in the water level could occur due to seasonal variations in rainfall. The contractor should be prepared to remove groundwater seepage from excavations if encountered during construction. Excavations extending below groundwater levels will require dewatering systems (such as sump pumps or trench drains). The contractor should evaluate the most economical and practical dewatering method based on the conditions encountered at the time of construction.

4.9 UTILITY TRENCH BACKFILL

All utility trenches should be backfilled and compacted in the manner specified above for structural fill. It may be necessary to reduce the lift thickness to 4 to 6 inches to achieve compaction using hand-operated equipment.

At the perimeter wall crossings, we recommend that clay soils or a flowable fill be used to backfill the utility trench. The clay or flowable fill will act as a relatively impermeable plug reducing the risk of water migration from the outside into the interior of the building. The plug should be at least 36 inches wide and should extend below the perimeter walls to provide for a proper seal.

4.10 LANDSCAPING AND DRAINAGE CONSIDERATION

The potential for moisture fluctuations within building areas should be lessened to reduce the potential of subgrade movement. Site grading should include positive drainage away from buildings. Ponding of water adjacent to buildings and pavements could result in moisture increases and swelling of higher plasticity clay soils and softening of low plasticity clay soils. Landscaping and irrigation immediately adjacent to buildings and pavements should be limited. Excessive irrigation of landscaping poses a risk of saturating and softening soils below footings and pavements, which could result in settlement of footings and premature failure of pavements.

4.11 WET WEATHER CONSTRUCTION

Excessive movement of construction equipment across the site during wet weather may result in ruts, which will collect rainwater, prolonging the time required to dry the subgrade soils.

During rainy periods, additional effort will be required to properly prepare the site and establish/maintain an acceptable subgrade. The difficulty will increase in areas where clay or silty soils are exposed at the subgrade elevation, as is seen throughout this project site. Grading contractors typically postpone grading operations during wet weather to wait for conditions that are more favorable. Contractors can typically disk or aerate the upper soils to promote drying during intermittent periods of favorable weather. When deadlines restrict postponement of grading operations, additional measures such as undercutting and replacing saturated soils or stabilization can be utilized to facilitate placement of additional fill material.

5.0 FOUNDATION RECOMMENDATIONS

Specific structural loading conditions were not known at the time of this report. For this report, we have assumed the individual column loads will be less than 20 kips and wall loads will be between 1 and 2 kips per linear foot. ***When final structural loading information is available, our office should be contacted, such that our recommendations can be reviewed and revised if needed.***

5.1 POST-TENSIONED SLAB FOUNDATION

The planned construction may be supported on a post tensioned slab foundation with turndown edges or perimeter footings extending at least 2 feet below the finished exterior grade.

Perimeter footings, edge turndowns and stiffening beams of post-tensioned slab foundations are anticipated to be founded in properly moisture conditioned and recompacted onsite clay soils, structural fill, or a combination of the materials. Turndowns and stiffening beams can be dimensioned using a maximum net allowable bearing pressure of 2,000 pounds per square foot (psf).

Post-tensioned foundation systems may be designed using the procedures detailed in "Design of Post-Tensioned Slabs-on-Ground", Post Tensioning Institute publication PTI DC10.1-08 (3rd edition with 2008 Supplement), using the design parameter values presented in the following table.

Design Parameter	Parameter Value
Thornthwaite Moisture Index (Stilwell, OK)	+40
Moisture Active Zone Depth	8 feet
Equilibrium Soil Suction	3.25 pF
Wettest Soil Suction	3.0 pF
Driest Soil Suction	4.5 pF
Edge Moisture Variation Distance (e_m), Center Lift	9.0 feet
Edge Moisture Variation Distance (e_m), Edge Lift	5.3 feet
Differential Soil Movement (y_m), Center Lift	-0.7 inches
Differential Soil Movement (y_m), Edge Lift	0.1 inches

Table 6: Post-tensioned Slab-on-Ground Design Parameter Values

The estimated y_m and e_m values provided above are based on soil moisture conditions that are controlled by climate alone. Differential swell can be influenced by other non-climatic conditions that are unpredictable, such as pre-construction and post-construction vegetation cover, drainage conditions, local water sources (downspouts, irrigation, plumbing leaks, etc.) The PT slab designer should provide additional comments relative to the influence of non-climatic moisture conditions on PT slab performance.

5.2 SHEAR RESISTANCE

Passive earth pressures of materials adjacent to the footings as well as bearing material friction at the base may be used to resist shear.

The following table presents recommended friction coefficient and passive earth pressure values for new structural fill or onsite terrace deposits. The structural engineer should use a factor of safety of at least 1.5 when sizing the foundations to resist shear loads using the below ultimate soil parameter values.

Material	Friction Coefficient	Equivalent Fluid Unit Weight for Passive Condition Lateral Earth Pressures (pcf)
New Structural Fill or Residual Soils	0.30	200

Table 7: Soil Parameter Values Resisting Shear

5.3 GENERAL CONSIDERATIONS

The following items should be considered during the preparation of construction documents and foundation installation:

- The geotechnical engineer of record should observe the exposed foundation bearing surfaces prior to concrete placement to verify that the conditions anticipated during the subsurface exploration are encountered.
- All bearing surfaces must be free of soft or loose soil and debris prior to placing concrete.
- The bottom surface of all footings should be level.
- Water should not be allowed to pond in foundation excavations prior to concrete placement or above the concrete after the foundation is completed.
- Concrete should be placed the same day the excavations are completed and bearing materials verified by the engineer. If the excavations are left open for an extended period, or if the bearing surfaces are disturbed after the initial observation, then the bearing surfaces should be re-evaluated prior to concrete placement.
- Wherever possible, the foundation concrete should be placed "neat", using the sides of the excavations as forms. Where this is not possible, the excavations created by forming the foundations must be backfilled with suitable structural fill and properly compacted.
- Grades around the building pad should be sloped to drain away from the building foundations.
- Roof drains should be routed away from the foundation soils.

6.0 FLOOR SLABS

Site development recommendations presented in this report should be followed to provide for subgrade conditions suitable for support of grade supported slabs.

We recommend floor slabs for the proposed structure be supported on a minimum four-inch layer of ½-inch up to 1½-inch, free-draining, gap-graded gravel, such as No. 57 stone, with no more than 5 percent passing the ASTM No. 200 sieve. The purpose of this layer is to help distribute concentrated loads and act as a capillary break for moisture migration through the subgrade soil.

The open graded stone should be consolidated in-place with vibratory equipment. The surface of these bases should be choked off with finer material. A clean fine-graded material with a least 10 to 30 percent of particles passing a No. 100 sieve but not contaminated with clay, silt or organic material is recommended.

The open graded stone should be consolidated in-place with vibratory equipment. The surface of these bases should be choked off with finer material. A clean fine-graded material with a least 10 to 30 percent of particles passing a No. 100 sieve but not contaminated with clay, silt or organic material is recommended.

We recommend a minimum 10-mil thick vapor retarder meeting ASTM E 1745, Class C requirements be placed directly below the slab-on-grade floors. A higher quality vapor retarder (Class A or B) may be used if desired to further inhibit the migration of moisture through the slab-on-grade and should be evaluated based on the floor covering and use. The vapor retarder should extend to the edge of the slab-on-grade floors and should be sealed at all seams and penetrations.

An effective modulus of subgrade of 150 pci can be used for slabs supported on the recommended base stone. The slab should be appropriately reinforced (if required) to support anticipated floor loads.

7.0 PAVEMENT CONSIDERATIONS

We assume that proposed streets classify as minor residential. Specific traffic information was not provided. For this report we assumed that pavements will be subjected to passenger cars, pick-up trucks, occasional light delivery box trucks, and occasional delivery trucks and trash collection trucks. Pavements should have adequate capacity to support wheel loads and out riggers of an 80,000-pound fire truck. The following equivalent 18-kip single-axle load (ESAL) is assumed for this project:

Type	Design Structural Number	Estimated ESAL Capacity
Residential Street, Low Density	3.30	320,000

Table 8: Assumed ESAL Capacity

In addition, we have assumed the following design parameters:

Design Criteria	Value
Design life (Years)	20
Terminal Serviceability	2.0
Reliability	85%
Initial Serviceability	4.2 (Flexible) 4.5 (Rigid)
Standard Deviation	0.45 (Flexible) 0.35 (Rigid)

Table 9: Assumed Design Parameters

All subgrade, base and pavement construction operations should meet minimum requirements of the Oklahoma Department of Transportation (ODOT), Standard Specifications for Highway Construction, dated 2019. The applicable sections of the specifications are identified as follows:

Material	Specification Section
Portland Cement Concrete Pavement	414 & 701
Bituminous Asphalt Wearing Layer	411 & 708
Bituminous Asphalt Binder Layer	411 & 708
Mineral Aggregate Base Materials	303 & 703

Table 10: ODOT Specification Sections

7.1 FLEXIBLE PAVEMENT

The asphalt pavement sections described herein were designed using the "AASHTO Guide for Design of Pavement Structures, 1993". Alternative pavement sections were designed by establishing the structural numbers used for the AASHTO design system and substituting materials based upon structural equivalency as follows:

Material	Structural No.
Asphalt Concrete	0.44
Crushed Stone Base	0.14

Table 11: Structural Equivalent Coefficient

Based on the materials encountered at the boring locations and after our recommendations for site preparation are implemented, flexible pavements at the subject site may be designed based on an estimated California Bearing Ratio (CBR) of 3. The following flexible pavement sections are based on the design parameters presented above:

Minimum Recommended Thickness (in)	Material
2.0	HMAC Surface Course (Superpave "S4")
3.5	HMAC Binder Course (Superpave "S3")
6.0	Crushed Aggregate Base (ODOT Type "A")

Table 12: Asphalt Pavement Recommendations

In accordance with the ODOT specifications, asphaltic concrete should be compacted within 92 to 97 percent of the theoretical maximum specific gravity of the asphaltic concrete mix. The underlying aggregate base course should be compacted to at least 98 percent of the material's standard Proctor maximum dry density with a moisture content range of ± 2 percent of the optimum moisture content at the time of placement.

7.2 RIGID PAVEMENT

The following rigid pavement section is based on the design parameters presented above. We assume a modulus of subgrade reaction (k) of 100 pci. We have assumed concrete elastic modulus (E_c) of 3.1 X 10^6 psi, and a concrete modulus of rupture (S'_c) of 600 psi.

Minimum Recommended Thickness (in)	Material
6.0	Portland Cement Concrete, f'_c=3,500 psi
4.0	Crushed Aggregate Base (ODOT Type "A")

Table 13: Reinforced Rigid Pavement Recommendations

For entrance approaches that are frequently subject to high traffic loads with frequent braking and turning of wheels, consideration should be given to using a reinforced rigid pavement section comprised of seven (7) inches of Portland cement concrete and 6 inches ODOT Type "A" crushed aggregate base course.

The recommended aggregate base course will serve as a leveling course, improve the subgrade support properties, and reduce the risk of pumping of fine-grained subgrade soils through the joints.

The concrete should be protected against moisture loss, rapid temperature fluctuations, and construction traffic for several days after placement. All pavements should be sloped for positive drainage. We suggest that a curing compound be applied after the concrete has been finished.

Although not referenced in the ODOT specifications, based on our experience with project sites in this region and anticipated traffic loads, we recommend Portland cement concrete should have a minimum 28-day compressive strength of 3,500 psi, maximum lump of 4 inches, and air content of 5 to 7 percent.

For rigid pavements, we recommend a jointing plan be developed to control cracking and help preclude surficial migration of water into the base course and subgrade. If a jointing plan includes a widely spaced pattern (spacing typically greater than 30 times the slab thickness), consideration should be given to include steel reinforcement in rigid pavements, per Section 3.4 of the American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures 1993, and Section 3.8 of the American Concrete Institute (ACI) Guide for the Design and Construction of Concrete Parking Lots. Additionally, we recommend the joints be sealed to further preclude surficial moisture migration into the underlying supporting soils.

7.3 GENERAL PAVEMENT DESIGN CONSIDERATIONS

With the use of aggregate base course, the aggregate should have uniform thickness and the subgrade graded such as to provide positive drainage from the granular base. The aggregate base section should grade toward a storm sewer or drainage ditch to provide drainage from the aggregate base.

Pavements should be sloped, approximately ¼ inch per foot, to provide rapid surface drainage. Water allowed to pond on or adjacent to the pavement could saturate the subgrade and cause premature deterioration of the pavements due to loss of strength and stability.

Periodic maintenance of the pavement should be anticipated. This should include sealing of cracks and joints and maintaining proper surface drainage to avoid ponding of water on or near the pavement areas.

8.0 SUBGRADE REHABILITATION

The subgrade soils often become disturbed during the period between initial site grading and construction of surface improvements. The amount and depth of disturbance will vary with soil type, weather conditions, construction traffic, and drainage.

The engineer should evaluate the subgrade soil during final grading to verify that the subgrade is suitable to receive pavement and/or concrete slab base materials. The final evaluation may include proofrolling or density tests.

Subgrade rehabilitation can become a point of controversy when different contractors are responsible for site grading and building construction. The construction documents should specifically state which contractor will be responsible for maintaining and rehabilitating the subgrade. Rehabilitation may include moisture conditioning and re-compacting soils. When deadlines or weather restrict grading operations, additional measures such as undercutting and replacing saturated soils or chemical stabilization can often be utilized.

9.0 CONSTRUCTION MONITORING

Field verification of site conditions is an essential part of the services provided by the geotechnical consultant. To confirm our recommendations, it will be necessary for Building & Earth personnel to make periodic visits to the site during site grading. Typical construction monitoring services are listed below.

- Periodic observations and consultations by a member of our engineering staff during site grading
- Field density tests during structural fill placement on a continuous basis
- Observation and verification of the bearing surfaces exposed after foundation excavation
- Reinforcing steel inspections
- Post-tension reinforcement inspections, including elongation of tendons.
- Molding and testing of concrete cylinders
- Continuous monitoring and testing during pavement installation

10.0 CLOSING AND LIMITATIONS

This report was prepared for Wallace Design Collective for specific application to the subject project located in Stilwell, Oklahoma. The information in this report is not transferable. This report should not be used for a different development on the same property without first being evaluated by the engineer.

The recommendations in this report were based on the information obtained from our field exploration and laboratory analysis. The data collected is representative of the locations tested. Variations are likely to occur at other locations throughout the site. Engineering judgment was applied in regard to conditions between borings. It will be necessary to confirm the anticipated subsurface conditions during construction.

This report has been prepared in accordance with generally accepted standards of geotechnical engineering practice. No other warranty is expressed or implied. In the event that changes are made, or anticipated to be made, to the nature, design, or location of the project as outlined in this report, Building & Earth must be informed of the changes and given the opportunity to either verify or modify the conclusions of this report in writing, or the recommendations of this report will no longer be valid.

The scope of services for this project did not include any environmental assessment of the site or identification of pollutants or hazardous materials or conditions. If the owner is concerned about environmental issues Building & Earth would be happy to provide an additional scope of services to address those concerns.

This report is intended for use during design and preparation of specifications and may not address all conditions at the site during construction. Contractors reviewing this information should acknowledge that this document is for design information only.

An article published by the Geoprofessional Business Association (GBA), titled *Important Information About Your Geotechnical Report*, has been included in the Appendix. We encourage all individuals to become familiar with the article to help manage risk.

Appendix Table of Contents

GEOTECHNICAL INVESTIGATION METHODOLOGIES

The subsurface exploration, which is the basis of the recommendations of this report, has been performed in accordance with industry standards. Detailed methodologies employed in the investigation are presented in the following sections.

DRILLING PROCEDURES – STANDARD PENETRATION TEST (ASTM D1586)

At each boring location, soil samples were obtained at standard sampling intervals with a split-spoon sampler. The borehole was first advanced to the sample depth by augering and the sampling tools were placed in the open hole. The sampler was then driven 18 inches into the ground with a 140-pound automatic hammer free-falling 30 inches. The number of blows required to drive the sampler each 6-inch increment was recorded. The initial increment is considered the "seating" blows, where the sampler penetrates loose or disturbed soil in the bottom of the borehole.

The blows required to penetrate the final two (2) increments are added together and are referred to as the Standard Penetration Test (SPT) N-value. The N-value, when properly evaluated, gives an indication of the soil's strength and ability to support structural loads. Many factors can affect the SPT N-value, so this result cannot be used exclusively to evaluate soil conditions.

The SPT testing was performed using a drill rig equipped with an automatic hammer. Automatic hammers mechanically control the height of the hammer drop, and doing so, deliver higher energy efficiency (90 to 99 % efficiency) than manual hammers (60 % efficiency) which are dropped using a manually operated rope and cathead system. Because historic data correlations were developed based on use of a manual hammer, it is necessary to adjust the N-values obtained using an automatic hammer to make these correlations valid. Therefore, an energy correction factor of 1.3 was applied to the recorded field N-values from the automatic hammer for the purpose of our evaluation. The N-values discussed or mentioned in this report and shown on the boring logs are recorded field values.

Samples retrieved from the boring locations were labeled and stored in plastic bags at the jobsite before being transported to our laboratory for analysis. The project engineer prepared Boring Logs summarizing the subsurface conditions at the boring locations.

BORING LOG DESCRIPTION

Building & Earth Sciences, Inc. used the gINT software program to prepare the attached boring logs. The gINT program provides the flexibility to custom design the boring logs to include the pertinent information from the subsurface exploration and results of our laboratory analysis. The soil and laboratory information included on our logs is summarized below:

DEPTH AND ELEVATION

The depth below the ground surface and the corresponding elevation are shown in the first two columns.

SAMPLE TYPE

The method used to collect the sample is shown. The typical sampling methods include Split Spoon Sampling, Shelby Tube Sampling, Grab Samples, and Rock Core. A key is provided at the bottom of the log showing the graphic symbol for each sample type.

SAMPLE NUMBER

Each sample collected is numbered sequentially.

BLOWS PER INCREMENT, REC%, RQD%

When Standard Split Spoon sampling is used, the blows required to drive the sampler each 6-inch increment are recorded and shown in column 5. When rock core is obtained the recovery ration (REC%) and Rock Quality Designation (RQD%) is recorded.

SOIL DATA

Column 6 is a graphic representation of four different soil parameters. Each of the parameters use the same graph, however, the values of the graph subdivisions vary with each parameter. Each parameter presented on column 6 is summarized below:

- N-value- The Standard Penetration Test N-value, obtained by adding the number of blows required to drive the sampler the final 12 inches, is recorded . The graph labels range from 0 to 50.
- Qu – Unconfined Compressive Strength estimate from the Pocket Penetrometer test in tons per square foot (tsf). The graph labels range from 0 to 5 tsf.
- Atterberg Limits – The Atterberg Limits are plotted with the plastic limit to the left, and liquid limit to the right, connected by a horizontal line. The difference in the plastic and liquid limits is referred to as the Plasticity Index. The Atterberg Limits test results are also included in the Remarks column on the far right of the boring log. The Atterberg Limits graph labels range from 0 to 100%.
- Moisture – The Natural Moisture Content of the soil sample as determined in our laboratory.

SOIL DESCRIPTION

The soil description prepared in accordance with ASTM D2488, Visual Description of Soil Samples. The Munsel Color chart is used to determine the soil color. Strata changes are indicated by a solid line, with the depth of the change indicated on the left side of the line and the elevation of the change indicated on the right side of the line. If subtle changes within a soil type occur, a broken line is used. The Boring Termination or Auger Refusal depth is shown as a solid line at the bottom of the boring.

GRAPHIC

The graphic representation of the soil type is shown. The graphic used for each soil type is related to the Unified Soil Classification chart.   A chart showing the graphic associated with each soil classification is included.

REMARKS

Remarks regarding borehole observations, and additional information regarding the laboratory results and groundwater observations.

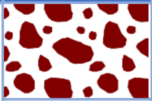
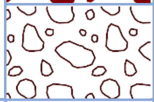
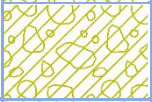
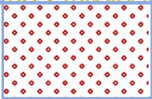
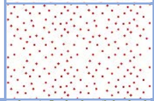
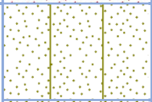
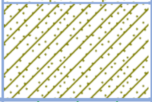
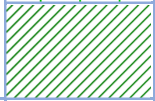
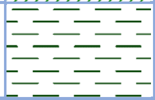
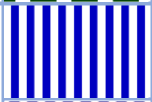
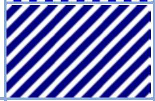
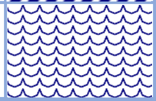
Major Divisions			***Symbols***		***Group Name & Typical Description***
			Lithology	***Group***	
Coarse Grained Soils *More than 50% of material is larger than No. 200 sieve size*	***Gravel and Gravelly Soils*** *More than 50% of coarse fraction is larger than No. 4 sieve*	***Clean Gravels*** *(Less than 5% fines)*		***GW***	*Well-graded gravels, gravel – sand mixtures, little or no fines*
				***GP***	*Poorly-graded gravels, gravel – sand mixtures, little or no fines*
		Gravels with Fines *(More than 12% fines)*		***GM***	*Silty gravels, gravel – sand – silt mixtures*
				***GC***	*Clayey gravels, gravel – sand – clay mixtures*
	Sand and Sandy Soils *More than 50% of coarse fraction is smaller than No. 4 sieve*	***Clean Sands*** *(Less than 5% fines)*		***SW***	*Well-graded sands, gravelly sands, little or no fines*
				***SP***	*Poorly-graded sands, gravelly sands, little or no fines*
		Sands with Fines *(More than 12% fines)*		***SM***	*Silty sands, sand – silt mixtures*
				***SC***	*Clayey sands, sand – clay mixtures*
Fine Grained Soils *More than 50% of material is smaller than No. 200 sieve size*	***Silts and Clays*** *Liquid Limit less than 50*	***Inorganic***		***ML***	*Inorganic silts and very find sands, rock flour, silty or clayey fine sands or clayey silt with slight plasticity*
				***CL***	*Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays*
		Organic		***OL***	*Organic silts and organic silty clays of low plasticity*
	Silts and Clays *Liquid Limit greater than 50*	***Inorganic***		***MH***	*Inorganic silts, micaceous or diatomaceous fine sand, or silty soils*
				***CH***	*Inorganic clays of high plasticity*
		Organic		***OH***	*Organic clays of medium to high plasticity, organic silts*
Highly Organic Soils				***PT***	*Peat, humus, swamp soils with high organic contents*

Table 1: Soil Classification Chart (based on ASTM D2487)

SOIL CLASSIFICATION METHODOLOGY

Building & Earth Sciences classifies soil in general accordance with the Unified Soil Classification System (USCS) presented in ASTM D2487. Table 1 and Figure 1 exemplify the general guidance of the USCS. Soil consistencies and relative densities are presented in general accordance with Terzaghi, Peck, & Mesri's (1996) method, as shown on Table 2, when quantitative field and/or laboratory data is available. Table 2 includes Consistency and Relative Density correlations with N-values obtained using either a manual hammer (60 percent efficiency) or automatic hammer (90 percent efficiency). The *Blows Per Increment* and *SPT N-values* displayed on the boring logs are the unaltered values measured in the field. When field and/or laboratory data is not available, we may classify soil in general accordance with the Visual Manual Procedure presented in ASTM D2488.

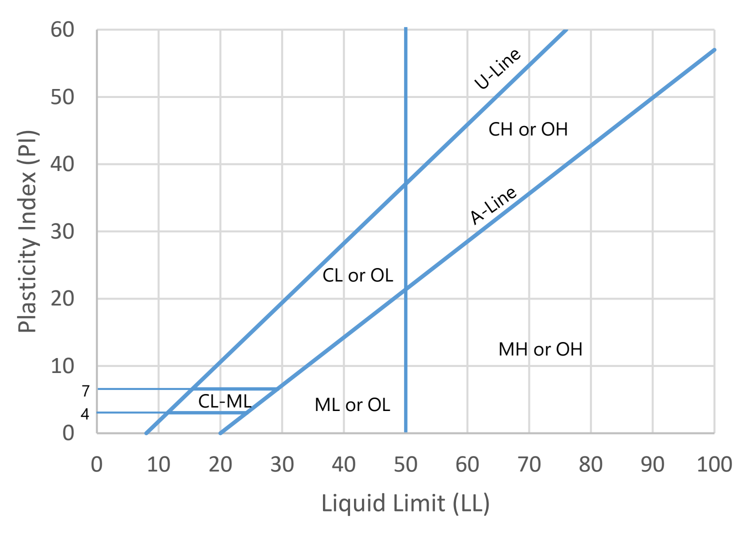


Figure 1: Plasticity Chart (based on ASTM D2487)

Non-cohesive: Coarse-Grained Soil			Cohesive: Fine-Grained Soil			
SPT Penetration (blows/foot)		Relative Density	SPT Penetration (blows/foot)		Consistency	Estimated Range of Unconfined Compressive Strength (tsf)
			Automatic Hammer*	Manual Hammer		
Automatic Hammer*	Manual Hammer		< 2	< 2	Very Soft	< 0.25
0 - 3	0 - 4	Very Loose	2 - 3	2 - 4	Soft	0.25 – 0.50
3 - 8	4 - 10	Loose	3 - 6	4 - 8	Medium Stiff	0.50 – 1.00
8 - 23	10 - 30	Medium Dense	6 - 12	8 - 15	Stiff	1.00 – 2.00
23 - 38	30 - 50	Dense	12 - 23	15 - 30	Very Stiff	2.00 – 4.00
> 38	> 50	Very Dense	> 23	> 30	Hard	> 4.00

Table 2: Soil Consistency and Relative Density (based on Terzaghi, Peck & Mesri, 1996)

* - Modified based on 80% hammer efficiency

KEY TO LOGS

☒	Standard Penetration Test ASTM D1586 or AASHTO T-206	⬇	Dynamic Cone Penetrometer (Sower DCP) ASTM STP-399
■	Shelby Tube Sampler ASTM D1587	○	No Sample Recovery
▨	Rock Core Sample ASTM D2113	▽	Groundwater at Time of Drilling
▮	Auger Cuttings	▼	Groundwater as Indicated

Table 1: Symbol Legend

Soil	Particle Size	U.S. Standard
Boulders	Larger than 300 mm	N.A.
Cobbles	300 mm to 75 mm	N.A.
Gravel	75 mm to 4.75 mm	3-inch to #4 sieve
Coarse	75 mm to 19 mm	3-inch to ¾-inch sieve
Fine	19 mm to 4.75 mm	¾-inch to #4 sieve
Sand	4.75 mm to 0.075 mm	#4 to #200 Sieve
Coarse	4.75 mm to 2 mm	#4 to #10 Sieve
Medium	2 mm to 0.425 mm	#10 to #40 Sieve
Fine	0.425 mm to 0.075 mm	#40 to #200 Sieve
Fines	Less than 0.075 mm	Passing #200 Sieve
Silt	Less than 5 μm	N.A.
Clay	Less than 2 μm	N.A.

Table 2: Standard Sieve Sizes

N-Value ☐	Standard Penetration Test Resistance calculated using ASTM D1586 or AASHTO T-206. Calculated as sum of original, field recorded values.	Atterberg Limits |—| PL LL	A measure of a soil's plasticity characteristics in general accordance with ASTM D4318. The soil Plasticity Index (PI) is representative of this characteristic and is bracketed by the Liquid Limit (LL) and the Plastic Limit (PL).
Qu ▲	Unconfined compressive strength, typically estimated from a pocket penetrometer. Results are presented in tons per square foot (tsf).	% Moisture ●	Percent natural moisture content in general accordance with ASTM D2216.

Table 3: Soil Data

Hollow Stem Auger	Flights on the outside of the shaft advance soil cuttings to the surface. The hollow stem allows sampling through the middle of the auger flights.
Mud Rotary / Wash Bore	A cutting head advances the boring and discharges a drilling fluid to support the borehole and circulate cuttings to the surface.
Solid Flight Auger	Flights on the outside bring soil cuttings to the surface. Solid stem requires removal from borehole during sampling.
Hand Auger	Cylindrical bucket (typically 3-inch diameter and 8 inches long) attached to a metal rod and turned by human force.

Table 4: Soil Drilling Methods

Descriptor	Meaning
Trace	Likely less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

Table 5: Descriptors

Manual Hammer	The operator tightens and loosens the rope around a rotating drum assembly to lift and drop a sliding, 140-pound hammer falling 30 inches.
Automatic Trip Hammer	An automatic mechanism is used to lift and drop a sliding, 140-pound hammer falling 30 inches.
Dynamic Cone Penetrometer (Sower DCP) ASTM STP-399	Uses a 15-pound steel mass falling 20 inches to strike an anvil and cause penetration of a 1.5-inch diameter cone seated in the bottom of a hand augered borehole. The blows required to drive the embedded cone a depth of 1-3/4 inches have been correlated by others to N-values derived from the Standard Penetration Test (SPT).

Table 6: Sampling Methods

Non-plastic	A 1/8-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Table 7: Plasticity

Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp but no visible water.
Wet	Visible free water, usually soil is below water table.

Table 8: Moisture Condition

Stratified	Alternating layers of varying material or color with layers at least ½ inch thick.
Laminated	Alternating layers of varying material or color with layers less than ¼ inch thick.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensides	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

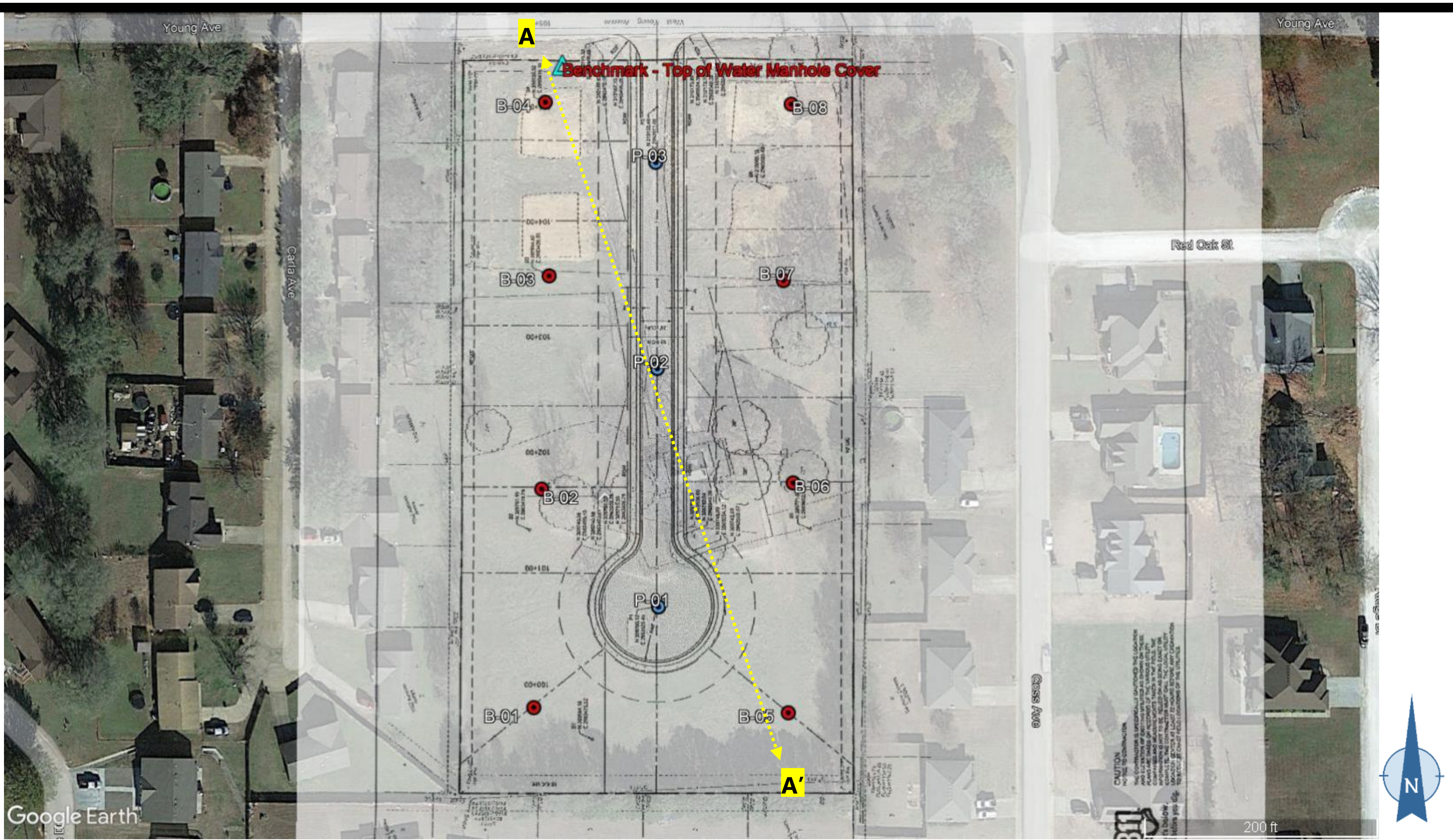
Table 9: Structure

KEY TO HATCHES

Hatch	Description	Hatch	Description	Hatch	Description
▨	***GW*** *- Well-graded gravels, gravel – sand mixtures, little or no fines*	■	*Asphalt*	▨	*Clay with Gravel*
▨	***GP*** *- Poorly-graded gravels, gravel – sand mixtures, little or no fines*	▨	*Aggregate Base*	▨	*Sand with Gravel*
▨	***GM*** *- Silty gravels, gravel – sand – silt mixtures*	▨	*Topsoil*	▨	*Silt with Gravel*
▨	***GC*** *- Clayey gravels, gravel – sand – clay mixtures*	▨	*Concrete*	▨	*Gravel with Sand*
▨	***SW*** *- Well-graded sands, gravelly sands, little or no fines*	■	*Coal*	▨	*Gravel with Clay*
▨	***SP*** *- Poorly-graded sands, gravelly sands, little or no fines*	▨	***CL-ML*** *- Silty Clay*	▨	*Gravel with Silt*
▨	***SM*** *- Silty sands, sand – silt mixtures*	▨	*Sandy Clay*	▨	*Limestone*
▨	***SC*** *- Clayey sands, sand – clay mixtures*	▨	*Clayey Chert*	▨	*Chalk*
▨	***ML*** *- Inorganic silts and very find sands, rock flour, silty or clayey fine sands or clayey silt with slight plasticity*	▨	*Low and High Plasticity Clay*	▨	*Siltstone*
▨	***CL*** *- Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays*	▨	*Low Plasticity Silt and Clay*	▨	*Till*
▨	***OL*** *- Organic silts and organic silty clays of low plasticity*	▨	*High Plasticity Silt and Clay*	▨	*Sandy Clay with Cobbles and Boulders*
▨	***MH*** *- Inorganic silts, micaceous or diatomaceous fine sand, or silty soils*	▨	*Fill*	▨	*Sandstone with Shale*
▨	***CH*** *- Inorganic clays of high plasticity*	▨	*Weathered Rock*	▨	*Coral*
▨	***OH*** *- Organic clays of medium to high plasticity, organic silts*	▨	*Sandstone*	▨	*Boulders and Cobbles*
▨	***PT*** *- Peat, humus, swamp soils with high organic contents*	▨	*Shale*	▨	*Soil and Weathered Rock*

Table 1: Key to Hatches Used for Boring Logs and Soil Profiles

BORING LOCATION PLAN



REFERENCE USED TO PRODUCE THIS DRAWING:

Google Earth Satellite Imagery dated November 2022 with overlay of Site Plan, prepared by Wallace Design Collective, undated

BORING LOCATION PLAN

DATE: 2/28/2023

PROJECT NO.

TU230035

PROJECT NAME / LOCATION:

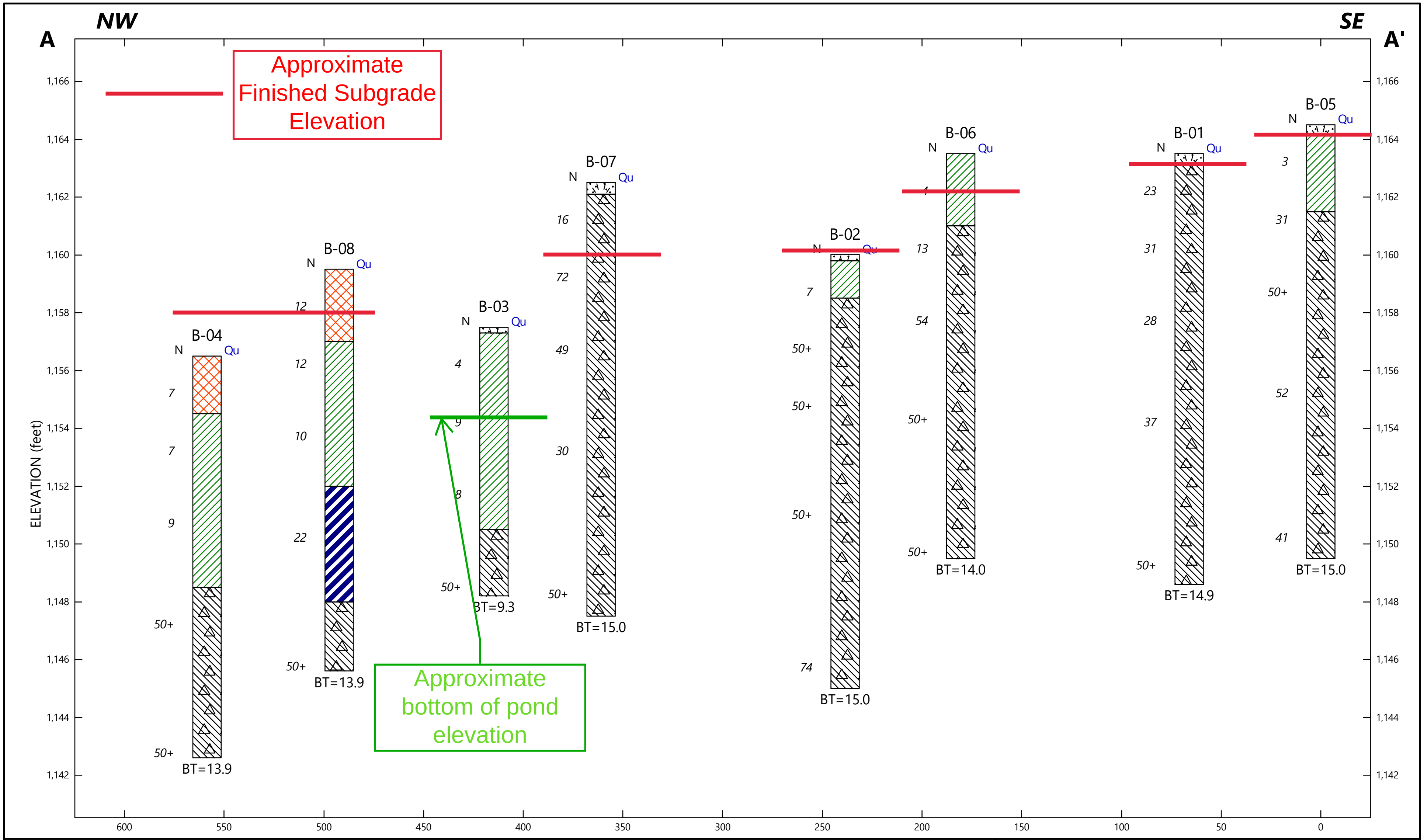
Stilwell Runner’s Addition
Stilwell, Oklahoma

SCALE:

As Shown

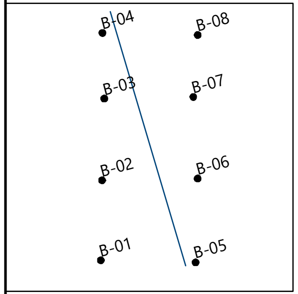
BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

SUBSURFACE PROFILE



Approximate Finished Subgrade Elevation

Approximate bottom of pond elevation



Site Map Scale 1 inch equals 435 feet

Key to Hatches

- ▨ Topsoil
- ▨ Clayey Chert
- 🟩 USCS Low Plasticity Clay
- 🟥 Fill
- ▨ USCS High Plasticity Clay

Legend

BT=Boring Termination, TPT=Test Pit Terminated
AR=Auger Refusal, ER=Excavation Refusal
N=Standard Penetration Test N-Value
Qu=Unconfined compressive strength estimate from pocket penetrometer test (tsf)
▽ Water Level Reading at time of drilling.
▼ Water Level Reading after drilling.

0 71
Horizontal Scale (feet)
Vertical Exaggeration: 14.5x

Building & Earth Sciences, Inc.
1403 South 70th East Avenue, Tulsa, OK 74112

Stilwell Runner's Addition
Tulsa, OK

A-A': Subsurface Profile

PROJECT NO: TU230035	PLATE NO: A-1	DATE: 3/15/23

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

BORING LOGS

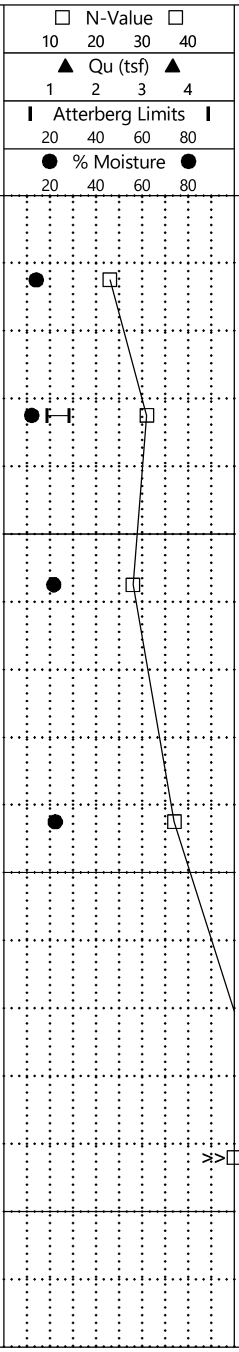
BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

LOG OF BORING
Designation: B-01
Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.803326, -94.644169

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1163.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



DEPTH (ft)	ELEVATION (ft)	SAMPLE TYPE	SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA	SOIL DESCRIPTION	REMARKS
0.4	1163.1					TOPSOIL: 4.5″	
		☒	1	4 10 13	Sample 1 M: 14.0%	CLAYEY CHERT GRAVEL (GC): medium dense to dense, brown, reddish brown, white, moist, (RESIDUAL)	
	1160	☒	2	10 15 16	Sample 2 LL: 28 PL: 18 PI: 10 M: 12.1% F: 53.3%	dense, yellow, yellowish red, white, with clay layers	
5		☒	3	8 12 16	Sample 3 M: 21.6%		
	1155	☒	4	18 17 20	Sample 4 M: 22.3%		
10							
	1150	☒	5	31 41 50/5″		very dense, with chert cobbles	Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.
14.9	1148.6					Boring Terminated at 14.9 feet.	
15							

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT	**M:**	NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT	**F:**	PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX		
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH				

Geotechnical, Environmental, and Materials Engineers

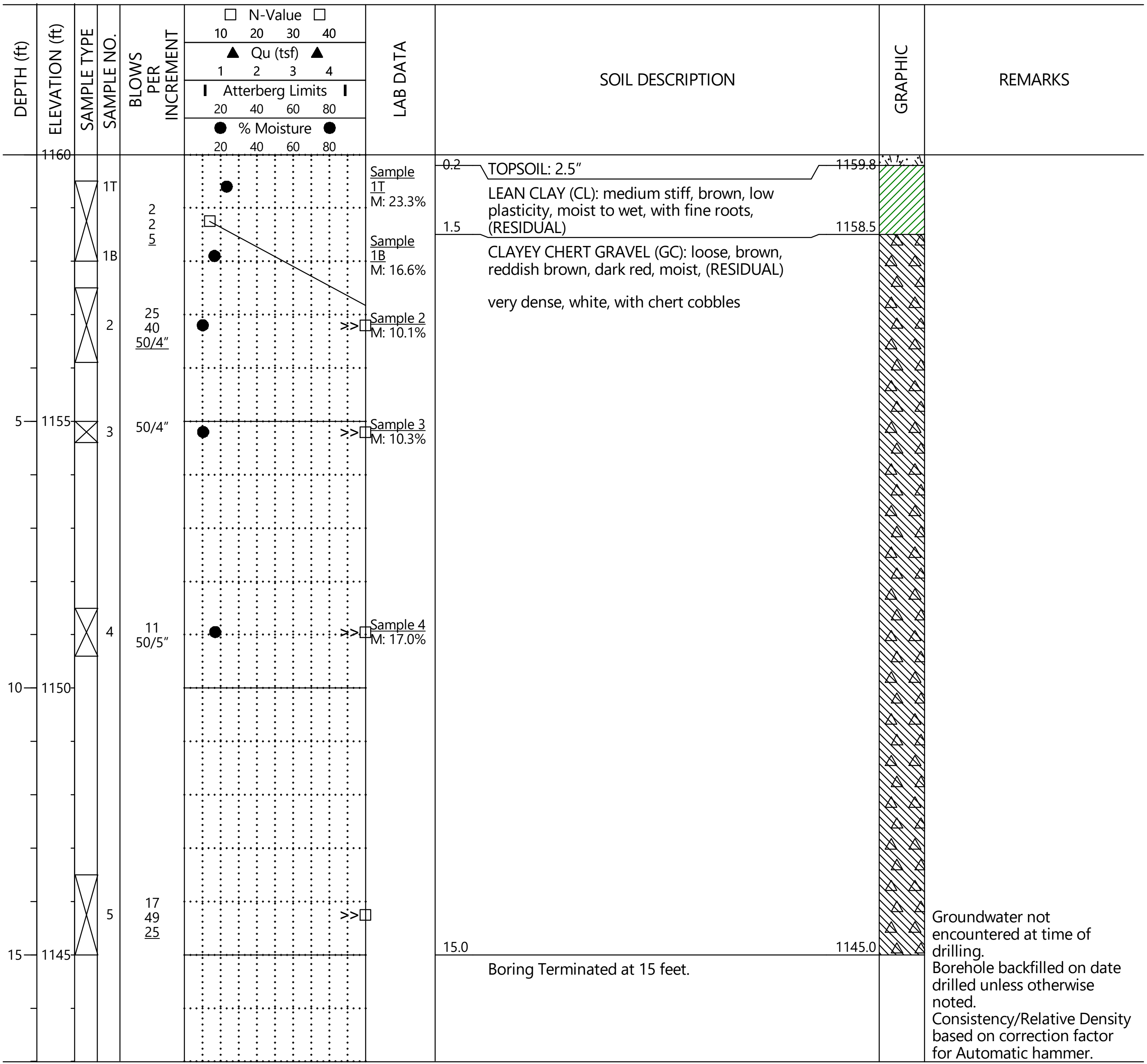
1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

LOG OF BORING

Designation: B-02

Sheet 1 of 1

PROJECT NAME:	Stilwell Runner's Addition	LOCATION:	Tulsa, OK
PROJECT NUMBER:	TU230035	DATE DRILLED:	2/28/23
DRILLING METHOD:	Hollow Stem Auger	WEATHER:	Sunny
EQUIPMENT USED:	GeoProbe 7822DT	ELEVATION:	1160
HAMMER TYPE:	Automatic	DRILL CREW:	Building & Earth
BORING LOCATION:	35.803835, -94.644149	LOGGED BY:	Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1T	2 2 5	Sample 1T M: 23.3%
1B		Sample 1B M: 16.6%
2	25 40 50/4"	Sample 2 M: 10.1%
3	50/4"	Sample 3 M: 10.3%
4	11 50/5"	Sample 4 M: 17.0%
5	17 49 25	

DEPTH (ft)	SOIL DESCRIPTION	ELEVATION (ft)
0.2	TOPSOIL: 2.5"	1159.8
1.5	LEAN CLAY (CL): medium stiff, brown, low plasticity, moist to wet, with fine roots, (RESIDUAL)	1158.5
15.0	CLAYEY CHERT GRAVEL (GC): loose, brown, reddish brown, dark red, moist, (RESIDUAL) very dense, white, with chert cobbles	1145.0
	Boring Terminated at 15 feet.	

REMARKS: Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT **M:** NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT **F:** PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

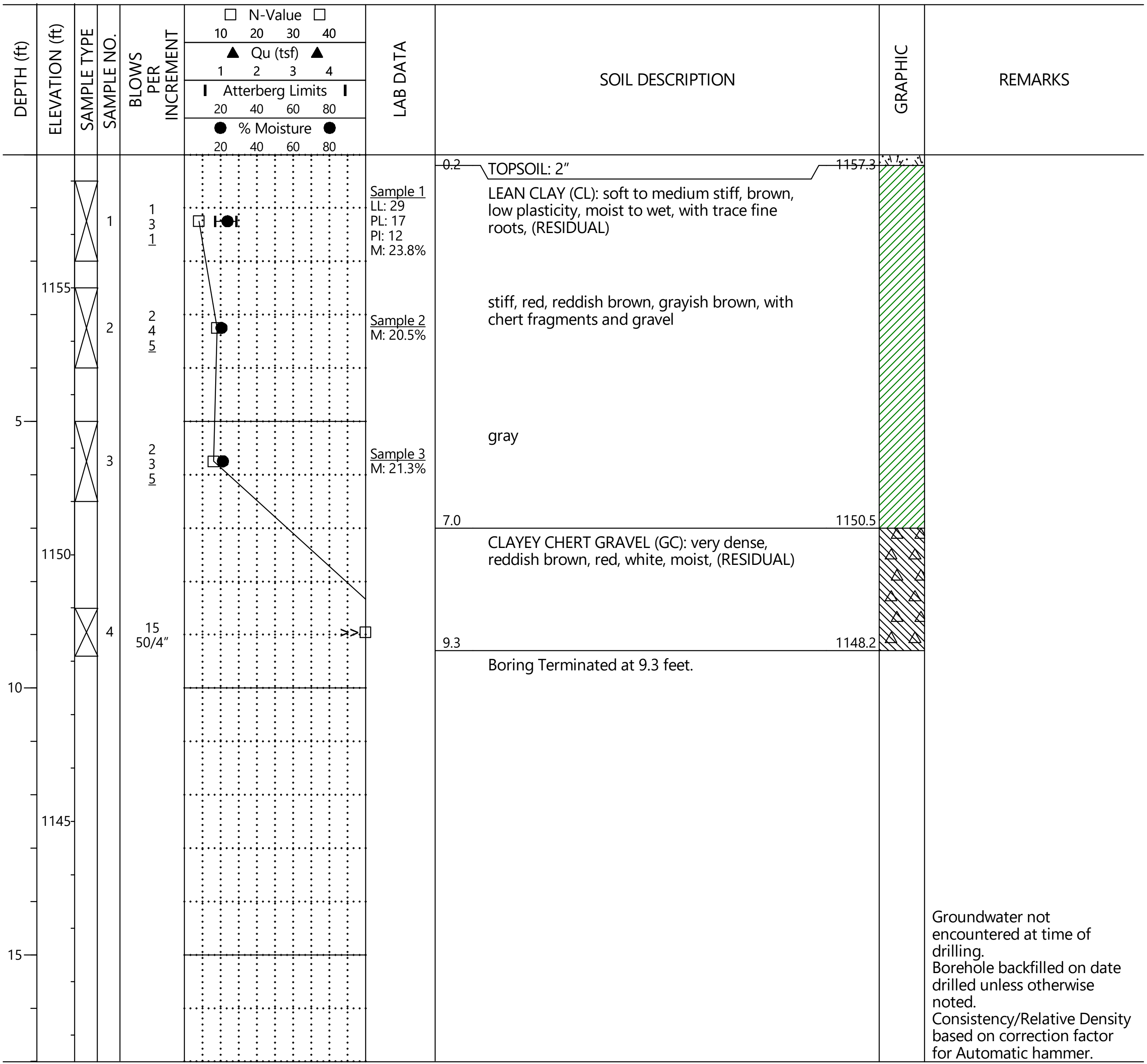
LOG OF BORING

Designation: B-03

Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.804337, -94.644129
LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1157.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1	1 3 1	Sample 1 LL: 29 PL: 17 PI: 12 M: 23.8%
2	2 4 5	Sample 2 M: 20.5%
3	2 3 5	Sample 3 M: 21.3%
4	15 50/4"	

DEPTH (ft)	SOIL DESCRIPTION	ELEVATION (ft)
0.2	TOPSOIL: 2"	1157.3
	LEAN CLAY (CL): soft to medium stiff, brown, low plasticity, moist to wet, with trace fine roots, (RESIDUAL) stiff, red, reddish brown, grayish brown, with chert fragments and gravel gray	
7.0		1150.5
	CLAYEY CHERT GRAVEL (GC): very dense, reddish brown, red, white, moist, (RESIDUAL)	
9.3		1148.2
	Boring Terminated at 9.3 feet.	

REMARKS: Groundwater not encountered at time of drilling.
Borehole backfilled on date drilled unless otherwise noted.
Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:** LIQUID LIMIT	**M:** NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:** PLASTIC LIMIT	**F:** PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:** PLASTICITY INDEX	
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

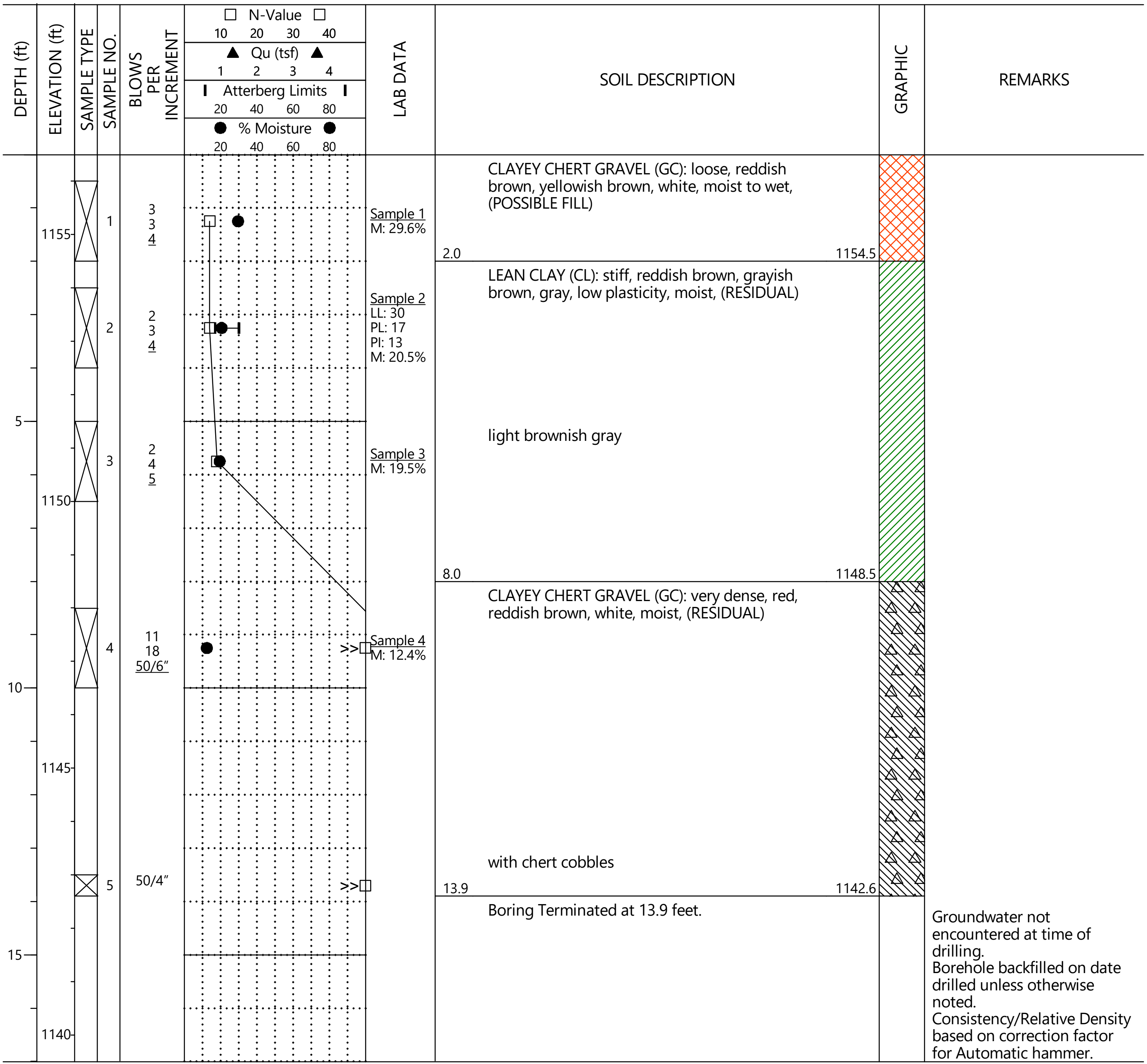
LOG OF BORING

Designation: B-04

Sheet 1 of 1

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.804746, -94.644140

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1156.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1	3 3 4	Sample 1 M: 29.6%
2	2 3 4	Sample 2 LL: 30 PL: 17 PI: 13 M: 20.5%
3	2 4 5	Sample 3 M: 19.5%
4	11 18 50/6"	Sample 4 M: 12.4%
5	50/4"	

CLAYEY CHERT GRAVEL (GC): loose, reddish brown, yellowish brown, white, moist to wet, (POSSIBLE FILL)

2.0 — 1154.5

LEAN CLAY (CL): stiff, reddish brown, grayish brown, gray, low plasticity, moist, (RESIDUAL)

light brownish gray

8.0 — 1148.5

CLAYEY CHERT GRAVEL (GC): very dense, red, reddish brown, white, moist, (RESIDUAL)

with chert cobbles

13.9 — 1142.6

Boring Terminated at 13.9 feet.

Groundwater not encountered at time of drilling.
Borehole backfilled on date drilled unless otherwise noted.
Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE STANDARD PENETRATION RESISTANCE (AASHTO T-206)
% MOISTURE PERCENT NATURAL MOISTURE CONTENT
∇ GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING
▼ STABILIZED GROUNDWATER LEVEL
REC RECOVERY
RQD ROCK QUALITY DESIGNATION
UD UNDISTURBED
Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH
LL: LIQUID LIMIT
PL: PLASTIC LIMIT
PI: PLASTICITY INDEX
M: NATURAL MOISTURE CONTENT
F: PERCENT PASSING NO. 200 SIEVE

BUILDING & EARTH
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LOG OF BORING

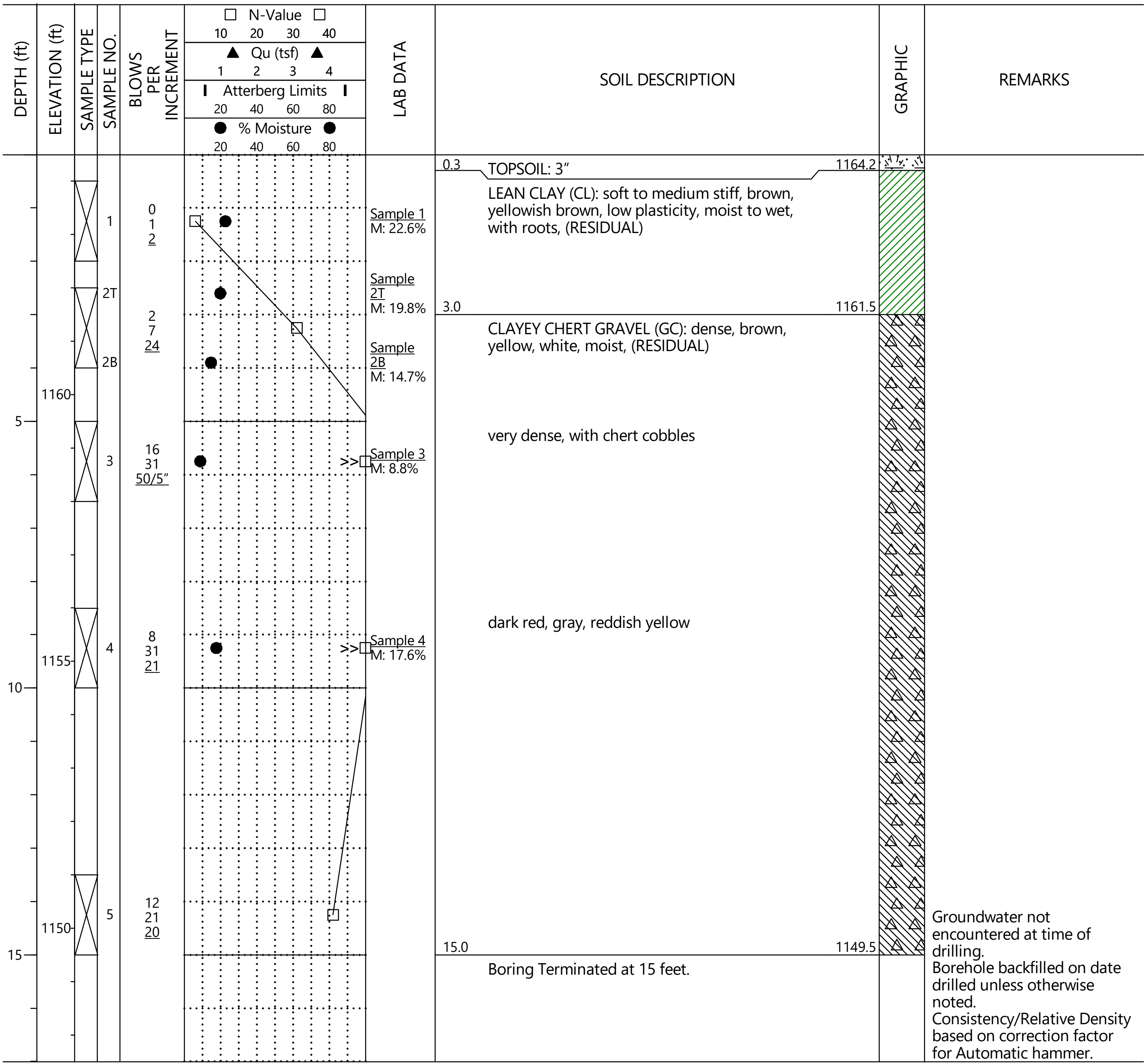
Designation: B-05

Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.803314, -94.643436

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1164.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1	0 1 2	Sample 1 M: 22.6%
2T	2 7 24	Sample 2T M: 19.8%
2B		Sample 2B M: 14.7%
3	16 31 50/5"	Sample 3 M: 8.8%
4	8 31 21	Sample 4 M: 17.6%
5	12 21 20	

0.3	TOPSOIL: 3"	1164.2
	LEAN CLAY (CL): soft to medium stiff, brown, yellowish brown, low plasticity, moist to wet, with roots, (RESIDUAL)	
3.0		1161.5
	CLAYEY CHERT GRAVEL (GC): dense, brown, yellow, white, moist, (RESIDUAL)	
	very dense, with chert cobbles	
	dark red, gray, reddish yellow	
15.0		1149.5
	Boring Terminated at 15 feet.	

Groundwater not encountered at time of drilling.
Borehole backfilled on date drilled unless otherwise noted.
Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

M: NATURAL MOISTURE CONTENT
F: PERCENT PASSING NO. 200 SIEVE

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

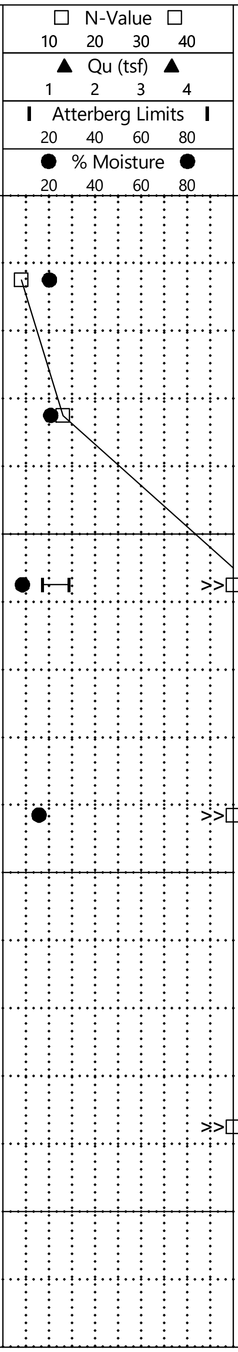
LOG OF BORING

Designation: B-06

Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME:	Stilwell Runner's Addition	LOCATION:	Tulsa, OK
PROJECT NUMBER:	TU230035	DATE DRILLED:	2/28/23
DRILLING METHOD:	Hollow Stem Auger	WEATHER:	Sunny
EQUIPMENT USED:	GeoProbe 7822DT	ELEVATION:	1163.5
HAMMER TYPE:	Automatic	DRILL CREW:	Building & Earth
BORING LOCATION:	35.803850, -94.643421	LOGGED BY:	Q. Mann



DEPTH (ft)	ELEVATION (ft)	SAMPLE TYPE	SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA	SOIL DESCRIPTION	GRAPHIC	REMARKS
		☒	1	1 2 2	Sample 1 M: 20.2%	LEAN CLAY (CL): medium stiff, brown, reddish brown, low plasticity, moist, with trace roots, chert fragments, (RESIDUAL)	▨	Soft to about 1 foot
2.5	1161.0							
		☒	2	11 6 7	Sample 2 M: 20.7%	CLAYEY CHERT GRAVEL (GC): medium dense, dark brown, brownish yellow, white, moist, (RESIDUAL)	▨	
		☒	3	9 22 32	Sample 3 LL: 28 PL: 17 PI: 11 M: 8.4% F: 19.5%	very dense, reddish yellow	▨	
		☒	4	18 28 50/3"	Sample 4 M: 15.7%		▨	
		☒	5	50/6"			▨	
14.0	1149.5					Boring Terminated at 14 feet.		Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT	**M:**	NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT	**F:**	PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX		
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH				

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

LOG OF BORING

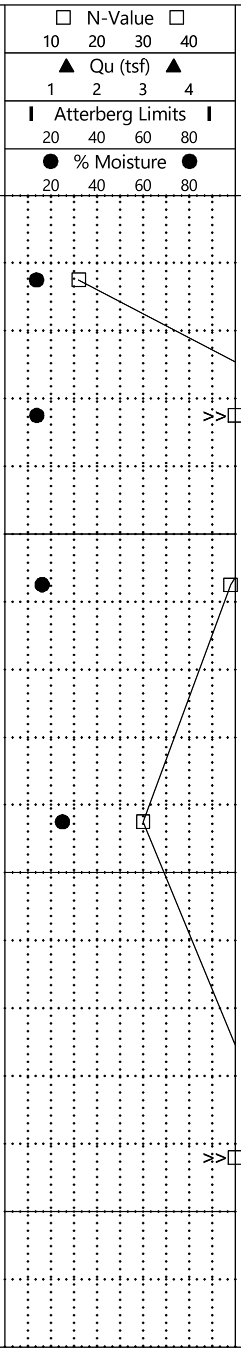
Designation: B-07

Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.804323, -94.643450

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1162.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



DEPTH (ft)	ELEVATION (ft)	SAMPLE TYPE	SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA	SOIL DESCRIPTION	GRAPHIC	REMARKS
0.4	1162.1					TOPSOIL: 4”		
		☒	1	2 9 7	Sample 1 M: 13.7%	CLAYEY CHERT GRAVEL (GC): medium dense, reddish brown, brown, white, moist, (RESIDUAL)		
	1160	☒	2	10 30 42	Sample 2 M: 13.9%	very dense		
5		☒	3	21 21 28	Sample 3 M: 16.2%	dark red		
	1155	☒	4	8 15 15	Sample 4 M: 25.0%	dense, with clay layers		
10	1150							
		☒	5	27 24 50/4”		very dense, with chert cobbles		Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.
15.0	1147.5					Boring Terminated at 15 feet.		

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

M: NATURAL MOISTURE CONTENT
F: PERCENT PASSING NO. 200 SIEVE

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

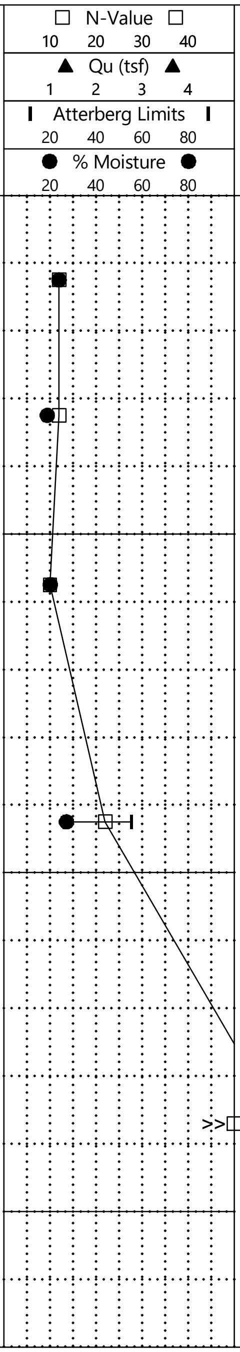
LOG OF BORING
Designation: B-08
Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.804739, -94.643426

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1159.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann

DEPTH (ft)	ELEVATION (ft)	SAMPLE TYPE	SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA	SOIL DESCRIPTION	GRAPHIC	REMARKS
		☒	1	1 4 8	Sample 1 M: 23.9%	CLAYEY CHERT GRAVEL (GC): medium dense, brownish yellow, brown, white, moist to wet, (POSSIBLE FILL)		Loose to about 1 foot
2.5	1157.0	☒	2	3 4 8	Sample 2 M: 18.8%	LEAN CLAY (CL): stiff to very stiff, brown, reddish brown, brownish yellow, low plasticity, moist, with chert fragments and gravel, (RESIDUAL)		
5	1155	☒	3	6 5 5	Sample 3 M: 20.1%	stiff, gray, dark red		
7.5	1152.0	☒	4	8 10 12	Sample 4 LL: 55 PL: 26 PI: 29 M: 27.2%	FAT CLAY (CH): very stiff, dark red, gray, reddish yellow, high plasticity, moist, (RESIDUAL)		
10	1150							
11.5	1148.0	☒	5	50/4"		CLAYEY CHERT GRAVEL (GC): very dense, white, dark red, moist, (RESIDUAL)		
13.9	1145.6					Boring Terminated at 13.9 feet.		Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.
15	1145							



SAMPLE TYPE ☒ Split Spoon

N-VALUE STANDARD PENETRATION RESISTANCE (AASHTO T-206)
% MOISTURE PERCENT NATURAL MOISTURE CONTENT
∇ GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING
▼ STABILIZED GROUNDWATER LEVEL

REC RECOVERY
RQD ROCK QUALITY DESIGNATION
UD UNDISTURBED
Qu POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH

LL: LIQUID LIMIT
PL: PLASTIC LIMIT
PI: PLASTICITY INDEX

M: NATURAL MOISTURE CONTENT
F: PERCENT PASSING NO. 200 SIEVE

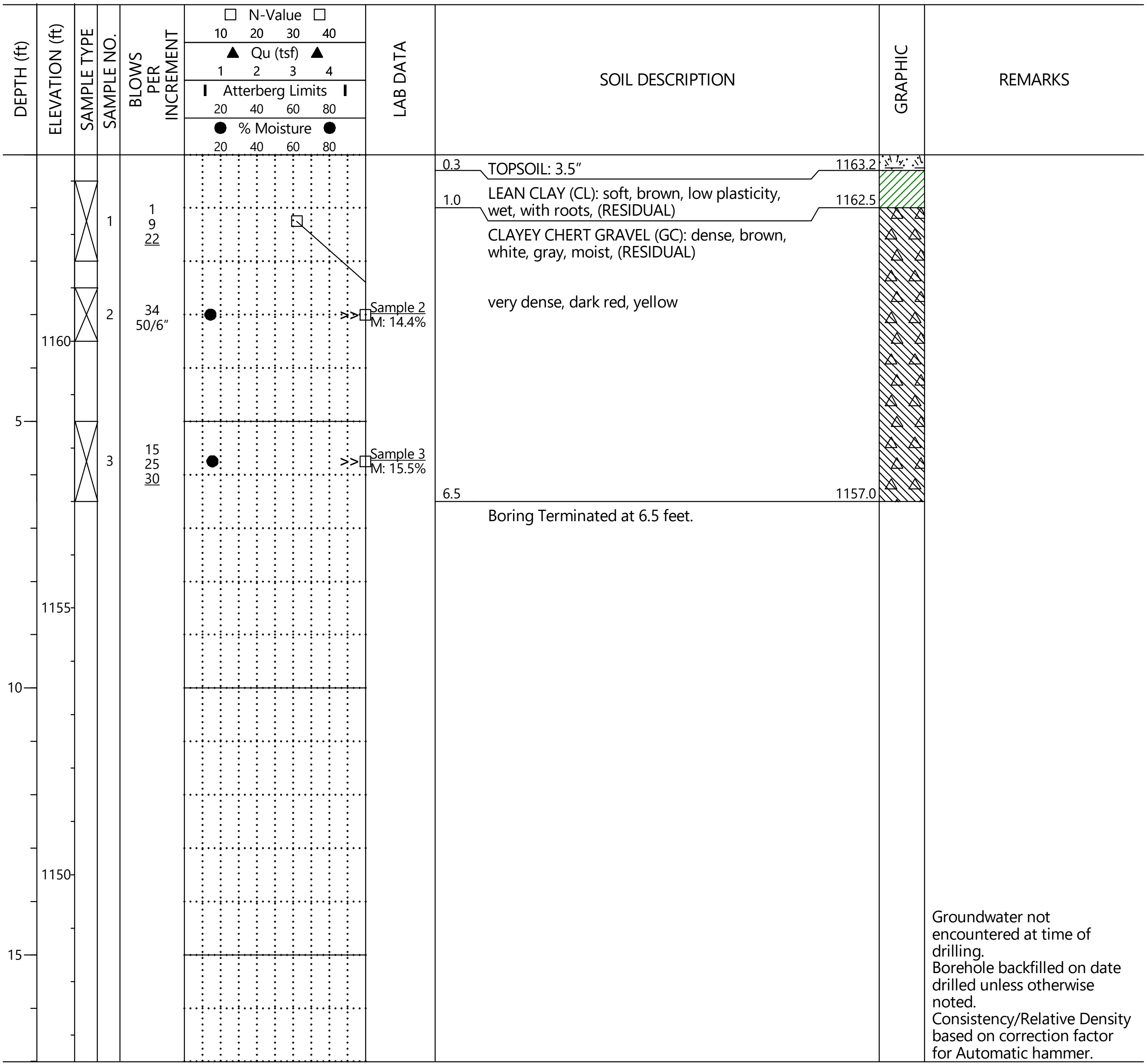
BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

LOG OF BORING
Designation: P-01
Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME: Stilwell Runner's Addition
PROJECT NUMBER: TU230035
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT USED: GeoProbe 7822DT
HAMMER TYPE: Automatic
BORING LOCATION: 35.803561, -94.643810

LOCATION: Tulsa, OK
DATE DRILLED: 2/28/23
WEATHER: Sunny
ELEVATION: 1163.5
DRILL CREW: Building & Earth
LOGGED BY: Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1	1 9 22	
2	34 50/6"	Sample 2 M: 14.4%
3	15 25 30	Sample 3 M: 15.5%

Depth	SOIL DESCRIPTION	Elevation
0.3	TOPSOIL: 3.5"	1163.2
1.0	LEAN CLAY (CL): soft, brown, low plasticity, wet, with roots, (RESIDUAL)	1162.5
	CLAYEY CHERT GRAVEL (GC): dense, brown, white, gray, moist, (RESIDUAL) very dense, dark red, yellow	
6.5	Boring Terminated at 6.5 feet.	1157.0

REMARKS:
Groundwater not encountered at time of drilling.
Borehole backfilled on date drilled unless otherwise noted.
Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:** LIQUID LIMIT	**M:** NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:** PLASTIC LIMIT	**F:** PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:** PLASTICITY INDEX	
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

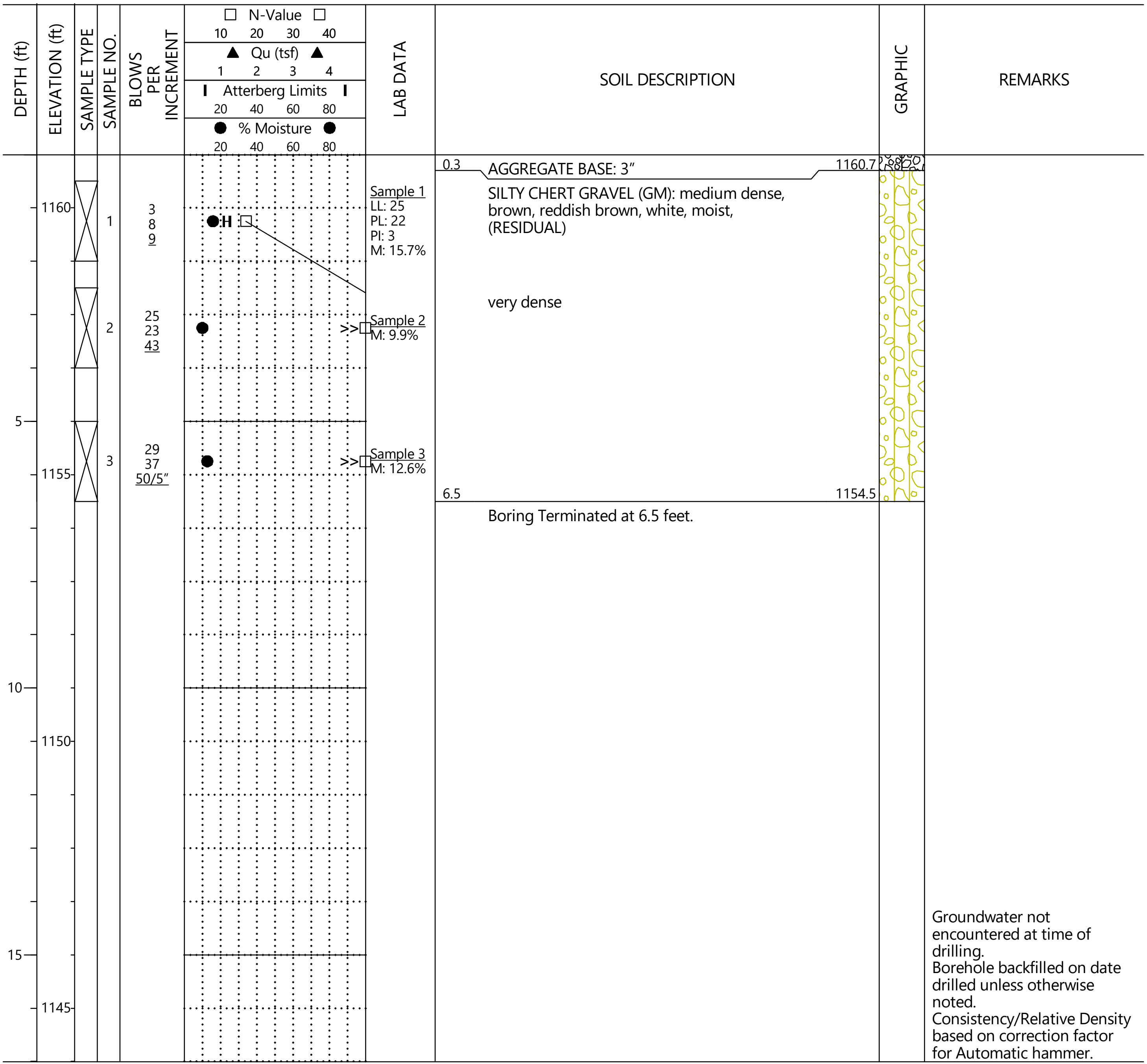
LOG OF BORING

Designation: P-02

Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME:	Stilwell Runner's Addition	LOCATION:	Tulsa, OK
PROJECT NUMBER:	TU230035	DATE DRILLED:	2/28/23
DRILLING METHOD:	Hollow Stem Auger	WEATHER:	Sunny
EQUIPMENT USED:	GeoProbe 7822DT	ELEVATION:	1161
HAMMER TYPE:	Automatic	DRILL CREW:	Building & Earth
BORING LOCATION:	35.804118, -94.643814	LOGGED BY:	Q. Mann



DEPTH (ft)	ELEVATION (ft)	SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA	SOIL DESCRIPTION	REMARKS
0.3	1160.7				AGGREGATE BASE: 3"	
		1	3 8 9	Sample 1 LL: 25 PL: 22 PI: 3 M: 15.7%	SILTY CHERT GRAVEL (GM): medium dense, brown, reddish brown, white, moist, (RESIDUAL)	
		2	25 23 43	Sample 2 M: 9.9%	very dense	
		3	29 37 50/5"	Sample 3 M: 12.6%		
6.5	1154.5				Boring Terminated at 6.5 feet.	
						Groundwater not encountered at time of drilling. Borehole backfilled on date drilled unless otherwise noted. Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

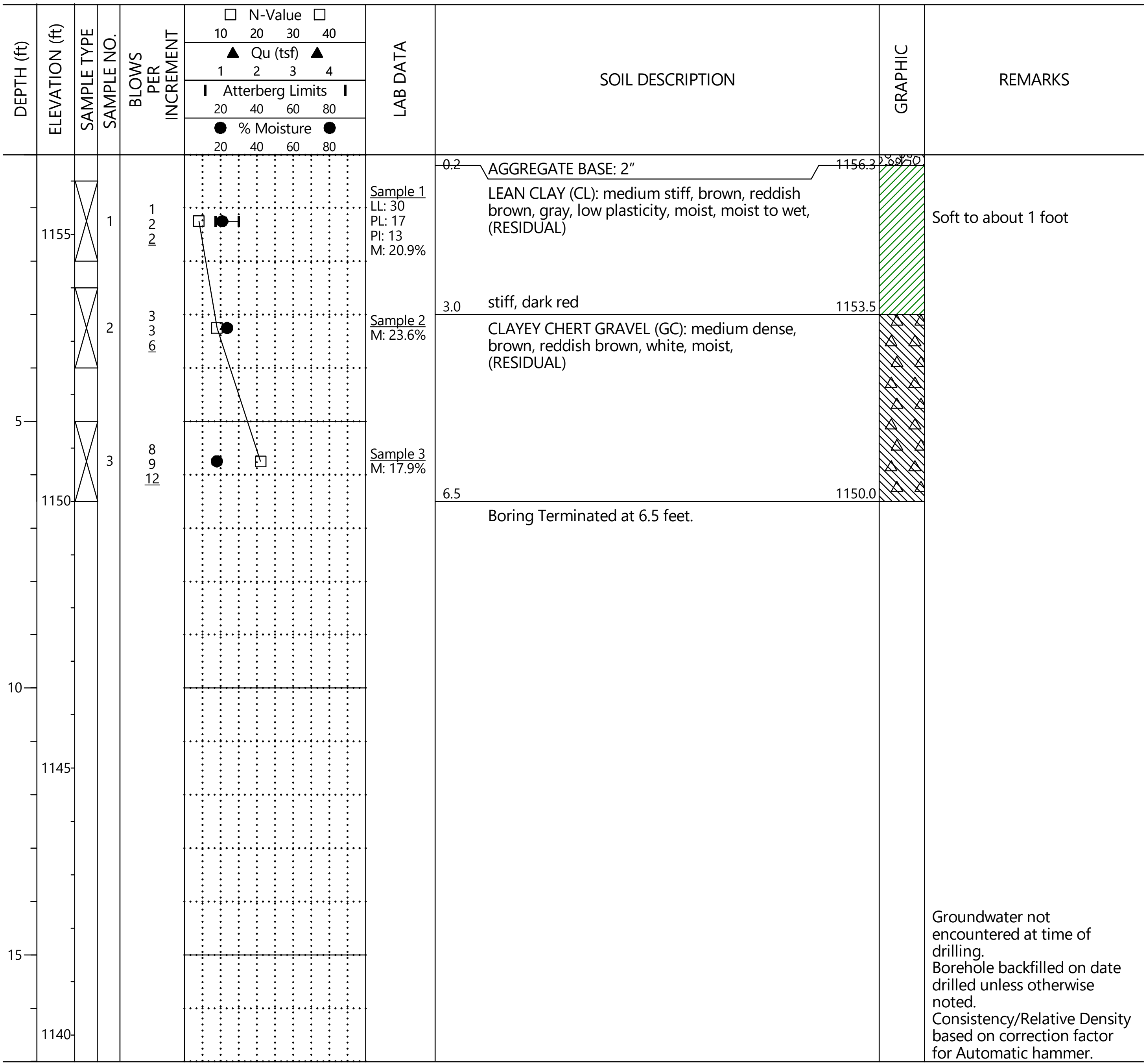
M: NATURAL MOISTURE CONTENT
F: PERCENT PASSING NO. 200 SIEVE

BUILDING & EARTH
Geotechnical, Environmental, and Materials Engineers

LOG OF BORING
Designation: P-03
Sheet 1 of 1

1403 South 70th East Avenue
Tulsa, OK 74112
Office: (918) 439-9005

PROJECT NAME:	Stilwell Runner's Addition	LOCATION:	Tulsa, OK
PROJECT NUMBER:	TU230035	DATE DRILLED:	2/28/23
DRILLING METHOD:	Hollow Stem Auger	WEATHER:	Sunny
EQUIPMENT USED:	GeoProbe 7822DT	ELEVATION:	1156.5
HAMMER TYPE:	Automatic	DRILL CREW:	Building & Earth
BORING LOCATION:	35.804604, -94.643819	LOGGED BY:	Q. Mann



SAMPLE NO.	BLOWS PER INCREMENT	LAB DATA
1	1 2 2	Sample 1 LL: 30 PL: 17 PI: 13 M: 20.9%
2	3 3 6	Sample 2 M: 23.6%
3	8 9 12	Sample 3 M: 17.9%

DEPTH (ft)	SOIL DESCRIPTION	ELEVATION (ft)	REMARKS
0.2	AGGREGATE BASE: 2”	1156.3	
	LEAN CLAY (CL): medium stiff, brown, reddish brown, gray, low plasticity, moist, moist to wet, (RESIDUAL) stiff, dark red		Soft to about 1 foot
3.0	CLAYEY CHERT GRAVEL (GC): medium dense, brown, reddish brown, white, moist, (RESIDUAL)	1153.5	
6.5	Boring Terminated at 6.5 feet.	1150.0	

Groundwater not encountered at time of drilling.
Borehole backfilled on date drilled unless otherwise noted.
Consistency/Relative Density based on correction factor for Automatic hammer.

SAMPLE TYPE ☒ Split Spoon

N-VALUE	STANDARD PENETRATION RESISTANCE (AASHTO T-206)	**REC**	RECOVERY	**LL:**	LIQUID LIMIT **M:** NATURAL MOISTURE CONTENT
% MOISTURE	PERCENT NATURAL MOISTURE CONTENT	**RQD**	ROCK QUALITY DESIGNATION	**PL:**	PLASTIC LIMIT **F:** PERCENT PASSING NO. 200 SIEVE
▽	GROUNDWATER LEVEL IN THE BOREHOLE AT TIME OF DRILLING	**UD**	UNDISTURBED	**PI:**	PLASTICITY INDEX
▼	STABILIZED GROUNDWATER LEVEL	**Qu**	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH		

LABORATORY TEST PROCEDURES

A brief description of the laboratory tests performed is provided in the following sections.

DESCRIPTION OF SOILS (VISUAL-MANUAL PROCEDURE) (ASTM D2488)

The soil samples were visually examined by our engineer and soil descriptions were provided. Representative samples were then selected and tested in accordance with the aforementioned laboratory-testing program to determine soil classifications and engineering properties. This data was used to correlate our visual descriptions with the Unified Soil Classification System (USCS).

NATURAL MOISTURE CONTENT (ASTM D2216)

Natural moisture contents (M%) were determined on selected samples. The natural moisture content is the ratio, expressed as a percentage, of the weight of water in a given amount of soil to the weight of solid particles.

ATTERBERG LIMITS (ASTM D4318)

The Atterberg Limits test was performed to evaluate the soil's plasticity characteristics. The soil Plasticity Index (PI) is representative of this characteristic and is bracketed by the Liquid Limit (LL) and the Plastic Limit (PL). The Liquid Limit is the moisture content at which the soil will flow as a heavy viscous fluid. The Plastic Limit is the moisture content at which the soil is between "plastic" and the semi-solid stage. The Plasticity Index (PI = LL - PL) is a frequently used indicator for a soil's potential for volume change. Typically, a soil's potential for volume change increases with higher plasticity indices.

MATERIAL FINER THAN NO. 200 SIEVE BY WASHING (ASTM D1140)

Grain-size tests were performed to determine the partial soil particle size distribution. The amount of material finer than the openings on the No. 200 sieve (0.075 mm) was determined by washing soil over the No. 200 sieve. The results of wash #200 tests are presented on the boring logs included in this report and in the table of laboratory test results.

LABORATORY TEST RESULTS

The results of the laboratory testing are presented in the following tables.

BORING NO.	DEPTH	MOISTURE CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	% PASSING #200 SIEVE	CLASSIFICATION
B-01	0.5 - 2.0	14.0					
B-01	2.5 - 4.0	12.1	28	18	10	53	
B-01	5.0 - 6.5	21.6					
B-01	8.5 - 10.0	22.3					
B-02	0.6	23.3					
B-02	1.9	16.6					
B-02	2.5 - 3.9	10.1					
B-02	5.0 - 5.4	10.3					
B-02	8.5 - 9.4	17.0					
B-03	0.5 - 2.0	23.8	29	17	12		
B-03	2.5 - 4.0	20.5					
B-03	5.0 - 6.5	21.3					
B-04	0.5 - 2.0	29.6					
B-04	2.5 - 4.0	20.5	30	17	13		
B-04	5.0 - 6.5	19.5					
B-04	8.5 - 10.0	12.4					
B-05	0.5 - 2.0	22.6					
B-05	2.6	19.8					
B-05	3.9	14.7					
B-05	5.0 - 6.5	8.8					
B-05	8.5 - 10.0	17.6					
B-06	0.5 - 2.0	20.2					
B-06	2.5 - 4.0	20.7					
B-06	5.0 - 6.5	8.4	28	17	11	19	
B-06	8.5 - 9.8	15.7					
B-07	0.5 - 2.0	13.7					
B-07	2.5 - 4.0	13.9					
B-07	5.0 - 6.5	16.2					
B-07	8.5 - 10.0	25.0					
B-08	0.5 - 2.0	23.9					
B-08	2.5 - 4.0	18.8					

TABLE L-1: General Soil Classification Test Results

Soils with a Liquid Limit (LL) greater than 50 and Plasticity Index (PI) greater than 25 usually exhibit significant volume change with varying moisture content and are considered to be highly plastic
(1) Indicates visual classification. WR indicates weathered rock.

LABORATORY TEST RESULTS

The results of the laboratory testing are presented in the following tables.

BORING NO.	DEPTH	MOISTURE CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	% PASSING #200 SIEVE	CLASSIFICATION
B-08	5.0 - 6.5	20.1					
B-08	8.5 - 10.0	27.2	55	26	29		
P-01	2.5 - 3.5	14.4					
P-01	5.0 - 6.5	15.5					
P-02	0.5 - 2.0	15.7	25	22	3		
P-02	2.5 - 4.0	9.9					
P-02	5.0 - 6.5	12.6					
P-03	0.5 - 2.0	20.9	30	17	13		
P-03	2.5 - 4.0	23.6					
P-03	5.0 - 6.5	17.9					

TABLE L-1: General Soil Classification Test Results

Soils with a Liquid Limit (LL) greater than 50 and Plasticity Index (PI) greater than 25 usually exhibit significant volume change with varying moisture content and are considered to be highly plastic

(1) Indicates visual classification. WR indicates weathered rock.

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a constructor — a construction contractor — or even another civil engineer. Because each geotechnical- engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. No one except you should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply this report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

Geotechnical Engineers Base Each Report on a Unique Set of Project-Specific Factors

Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical-engineering report that was:

- not prepared for you;
- not prepared for your project;
- not prepared for the specific site explored; or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical-engineering report is based on conditions that existed at the time the geotechnical engineer performed the study. *Do not rely on a geotechnical-engineering report whose adequacy may have been affected by*: the passage of time; man-made events, such as construction on or adjacent to the site; or natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. *Contact the geotechnical engineer before applying this report to determine if it is still reliable.* A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ — sometimes significantly — from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide geotechnical-construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are Not Final

Do not overrely on the confirmation-dependent recommendations included in your report. *Confirmation-dependent recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations *only* by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's confirmation-dependent recommendations if that engineer does not perform the geotechnical-construction observation required to confirm the recommendations' applicability.*

A Geotechnical-Engineering Report Is Subject to Misinterpretation

Other design-team members' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Constructors can also misinterpret a geotechnical-engineering report. Confront that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing geotechnical construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical-engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make constructors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give constructors the complete geotechnical-engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise constructors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure constructors have sufficient time* to perform additional study. Only then might you be in a position to give constructors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and constructors fail to recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Environmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform an *environmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold- prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical- engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; *none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.*

Rely, on Your GBC-Member Geotechnical Engineer for Additional Assistance

Membership in the Geotechnical Business Council of the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you GBC-Member geotechnical engineer for more information.

GBC GEOTECHNICAL BUSINESS COUNCIL
of the Geoprofessional Business Association

8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 Facsimile: 301/589-2017
e-mail: info@geoprofessional.org www.geoprofessional.org