RETAINING WALLS STUDY – WALLS D & E
GILCREASE MUSEUM ROAD WIDENING AND IMPROVEMENTS
CITY OF TULSA, OKLAHOMA
KLEINFELDER PROJECT NO.: 25003382.001A

JANUARY 28, 2025

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A Report Prepared for:

Ms. Cynthia Y. Lynn
President/CEO
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7224 E. 151st St., S.
Bixby, Oklahoma 74008

RETAINING WALLS STUDY – WALLS D & E
GILCREASE MUSEUM ROAD WIDENING AND IMPROVEMENTS
CITY OF TULSA, OKLAHOMA

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January 28, 2025
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Ms. Cynthia Y. Lynn
President/CEO
Thunderhead Testing, LLC
7224 E. 151st St., S.
Bixby, Oklahoma 74008

Subject: **Retaining Walls Study – Walls D & E**
Gilcrease Museum Road Widening and Improvements
City of Tulsa, Oklahoma

Dear Ms. Lynn:

Kleinfelder has completed the authorized subsurface exploration and geotechnical engineering evaluations for the above-referenced project. The purpose of this project was to explore and evaluate the subsurface conditions at/near the footprint of proposed retaining walls for the Gilcrease Museum Road widening as well as to develop geotechnical design and construction recommendations for the design and construction of the walls. The attached Kleinfelder report contains a description of the findings of our field exploration and laboratory testing program, our engineering interpretation of the results with respect to the project characteristics, and construction guidelines for the planned project.

Recommendations provided herein are contingent on the provisions outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report. The project owner should become familiar with these provisions in order to assess further involvement by Kleinfelder and other potential impacts to the proposed project.

We appreciate the opportunity to be of service to you on this project and are prepared to provide the recommended additional services. Please call us if you have any questions concerning this report.

Sincerely,
KLEINFELDER, INC.

John Thompson, PE (PA)
Staff Professional II

Bruce Stegman, PE
Principal Professional

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RETAINING WALL STUDY – WALLS D & E
GILCREASE MUSEUM ROAD WIDENING AND IMPROVEMENTS
CITY OF TULSA, OKLAHOMA

1. INTRODUCTION

1.1 GENERAL

Kleinfelder has completed the authorized subsurface explorations and geotechnical engineering evaluations for the proposed retaining walls; herein referred to as Walls D & E, associated with the roadway widening project along the Gilcrease Museum Road in Tulsa, Oklahoma. The services provided were in general accordance with the work order dated December 3, 2024.

This report has been prepared, and the corresponding work performed, in general accordance with the "State of Oklahoma Department of Transportation (ODOT) Geotechnical Specifications" dated August 2021.

This report includes our recommendations related to the geotechnical aspects of the project design and construction. Recommendations presented in the report are based on the subsurface information encountered at the locations of our exploration and the provisions and requirements outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report. In addition, an article prepared by The Geoprofessional Business Association (GBA), *Important Information About This Geotechnical Engineering Report*, has been included in Appendix D, we recommend that individuals reading this report review the LIMITATIONS along with the included GBA document.

1.2 PROPOSED CONSTRUCTION

We understand that the City of Tulsa (City) is planning to widen the existing Gilcrease Museum Road from Edison Street extending north approximately one mile to W. Pine Street. As part of the project, retaining walls are proposed on both sides of the roadway to limit the right of way acquisition.

Kleinfelder has previously completed a Geotechnical Engineering Report (Report Number TUL22R152034 dated March 31, 2023) for Retaining Walls A, B, and C. The Retaining Walls relevant to this

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geotechnical engineering report will be located at the northwest corner of the N. Gilcrease Museum Road and W. Independence Place intersection (Wall D) and at the southwest corner of the N. Gilcrease Museum Road and W. Pine Street intersection (Wall E).

Based on the preliminary retaining wall plans prepared by Poe & Associates Inc., Wall D will be approximately 300 feet long (Station 147+00 to Station 150+00). The wall will be constructed in cut sections and will have a maximum height of approximately 12 feet. Wall E will be approximately 120 feet long (Station 179+55 to Station 180+75). Wall E will be constructed in a fill section and will have a maximum wall height of approximately 20 feet.

Based on email correspondence between Poe & Associates (project designer) and Kleinfelder (Geotechnical Engineer of Record) we understand the preferred design options are soldier piles and lagging for Wall D, and a mechanically stabilized earth system (MSE) for Wall E.

The scope of the exploration and engineering evaluation for this study, as well as the recommendations in this report, were based on our understanding of the project as described above. If pertinent details of the project have changed or otherwise differ from our descriptions, we must be notified and engaged to review the changes and modify our recommendations, if needed.

2. SITE CONDITIONS

2.1 SITE DESCRIPTION

The general site location is shown on Figures 1 and 2. The existing Gilcrease Museum Road is a two lane two directional asphaltic concrete paved roadway with grass shoulders and residential properties on the east side. From Station 147+00 to 150+00 at the proposed Wall D location, the west shoulder is minimal with moderate increase in grade through wooded terrain. From Station 179+55 to 180+75 at the proposed Wall E location, the west shoulder contains a guiderail barrier followed by an existing rock wall with a toe slope decreasing in grade through wooded terrain.

2.2 GENERAL SITE GEOLOGY

According to the "Engineering Classification of Geological Materials – Division Eight" (1965) by ODOT, the project site appears to be located within the **Coffeyville Unit (Pcf)**. This unit consists predominantly of silty to sandy shale with many thick zones of tan sandstone. The sandstone generally is thin-bedded and moderately hard to soft. Locally, at the base of the unit, a black fissile shale about 15 feet thick is present. The sandstone zones are generally about 15 to 40 feet thick. The total thickness ranges from 175 feet in northern Division 8 to about 500 feet in the south. The Coffeyville Unit outcrops in Creek, Nowata, Rogers, Tulsa, and Washington Counties of Division 8. In Tulsa and Creek Counties, the thick sandstone zones cap prominent scarps.

2.3 SUBSURFACE EXPLORATION PROGRAM

Kleinfelder explored the subsurface conditions for the proposed retaining wall by performing four (4) borings (D-1 through D-4) for Wall D and two (2) boring (E-1 through E-2) for Wall E on December 19th, 2024. Supervision and monitoring of the field operation were provided by a representative of Kleinfelder, who field located the test locations utilizing a hand-held GPS. The approximate boring locations are shown on Figures 1 and 2 – Exploration Location, Plan and Vicinity Map with Reference Map.

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2.4 DESCRIPTION OF SUBSURFACE MATERIALS

The field exploration and laboratory testing programs are presented in Appendix A and Appendix B, respectively. The subsurface conditions encountered at the boring locations are shown on the boring logs in Appendix A. These logs should be consulted for boring-specific (detailed) stratigraphic information. It should be noted that the boring logs represent our interpretation of the subsurface conditions based on the field logs, visual examination of field samples by our geo-professionals, and laboratory test results of selected field samples.

Table 1 indicates the estimated ground surface elevations, overburden soils, and the approximate depth and elevation to the top of competent bedrock at the respective boring locations.

Table 1. Summary of Subsurface Strata

Boring No.	Ground Surface Elevation (ft)	Weathered Rock		Competent Bedrock*		Bedrock
		Depth BGS (ft)	Elevation (ft)	Depth BGS (ft)	Elevation (ft)	
D-1	763.0	1.0	762.0	11.0	752.0	Shale
D-2	768.0	1.0	767.0	9.5	758.5	Shale
D-3	772.0	1.0	771.0	6.0	766.0	Shale
D-4	775.0	1.0	774.0	6.0	769.0	Shale
E-1	822.0	19.0	803.0	21.0	801.0	Shale
E-2	824.0	-	-	13.5	810.5	Sandstone

BGS=Below ground surface
*Competent bedrock is characterized by ODOT (2021) as Standard Penetration test (SPT) refusal, or less than or equal to 6 inches of penetration per 50 blows.

The Subsurface Cross Section, Figures A-1 and A-3, depict the generalized subsurface profile across the project site based on the information obtained from the borings. The stratification lines shown on the logs and subsurface cross sections represent the approximate boundaries between material types; in-situ, the transitions may vary or be gradual.

2.4.1 Surface Materials

The test borings were covered by approximately 12 inches of asphaltic concrete.

2.4.2 Overburden

Overburden soils were encountered within the Wall E borings beneath the surficial materials. The overburden soils extended to depths of 13.5 to 19.0 feet beneath existing site grades, or elevations 803.0 and 810.5, respectively. The N-values recorded within this stratum generally ranged from 4 to 5 blows per foot (bpf), with one point of outlying data at 50/5.5 bpf, which indicates generally loose soils.

Laboratory testing of the overburden samples shows these soils to be generally non-plastic sands and gravels with varying amounts of silt and natural moisture contents ranging from 11.0% to 12.0%. The overburden soils are described under AASHTO as A-2-4 and A-4.

2.4.3 Bedrock

Bedrock was encountered within each test boring at depths ranging from 13.5 to 19.0 feet beneath existing site grades at the Wall E borings, and immediately beneath the pavement at 1.0 feet at the Wall D borings. Additionally, seismic refraction testing (Figure A-2) that took place along the Wall D alignment show that shallow competent bedrock is present aligning with the results from the borings. The bedrock was characterized as moderately strong to very strong.

2.5 GROUNDWATER OBSERVATIONS

Groundwater was observed withing boring E-1 at a depth of 11 feet below existing site grade, corresponding to elevation 811.

The materials encountered in the test borings have a wide range of permeabilities, and water level observations over an extended period of time through use of piezometers or cased borings would be required to better define groundwater levels. Fluctuations of groundwater levels can occur due to seasonal variations in the amount of rainfall, runoff, and other factors not evident at the time the borings were performed. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

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3. GEOTECHNICAL RECOMMENDATIONS

3.1 GENERAL

It is understood the desired wall type for Wall D is a soldier pile and lagging system, and a mechanically stabilized earth (MSE) system for Wall E. Based on the results of our field investigation and engineering evaluations, these wall types are adequate and viable design options for the proposed retaining walls. Our geotechnical recommendations are presented in the following sections.

The recommendations submitted here are based, in part, upon data obtained from our subsurface exploration. The nature and extent of subsurface variations that may exist at the proposed project site will not become evident until construction. If variations appear evident, then the recommendations presented in this report should be evaluated. In the event that any changes in the nature, design, or location of the proposed project are planned, the conclusions and recommendations contained in this report will not be considered valid unless the changes are reviewed, and our recommendations modified in writing.

3.2 MECHANICALLY STABILIZED EARTH RETAINING WALL DESIGN CRITERIA & CONSIDERATIONS

MSE retaining walls are gravity structures composed of facing panels and a reinforced soil zone (Figure 3-1). The wall should be considered to consist of the entire block defined as from the facing panel to the back of the reinforced zone.

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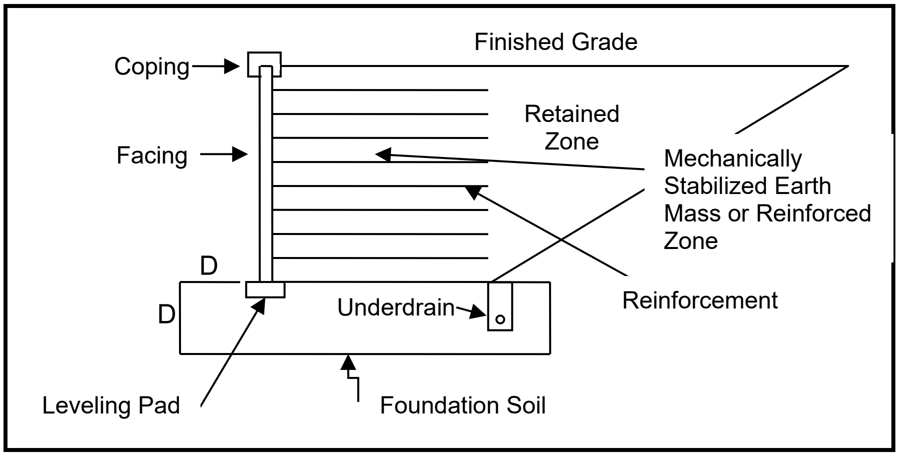

FIGURE 3-1. GENERALIZED MSE COMPONENTS

Based on the data obtained during our field investigation and experience in the design and construction of mechanically stabilized earth walls, we offer the following general design criteria for the proposed retaining walls.

- The retaining walls should be designed in accordance with the current editions of the AASHTO LRFD *Standard Specifications for Highway Bridges* and Oklahoma Department of Transportation *Standard Specifications for Highway Construction.*
- Provided the recommendations regarding structural fill placement and subgrade preparation are followed as outlined within this report, the overburden soils and/or properly placed structural fill can provide a factored bearing resistance of 3,000 psf while the underlying weathered bedrock surface can provide a factored bearing resistance of 6,000 psf.
- For resistance to sliding, we recommend an ultimate coefficient of friction of 0.37 be utilized for calculation of friction resistance along the bottom of MSE wall against the overburden soils, and 0.43 for friction resistance against the weathered bedrock surface.
- Structural fill placed behind the retaining walls should be placed in lifts not exceeding 8 inches in loose thickness and compacted to a minimum of 95% of the Modified Proctor maximum dry density per AASHTO T-180, with moisture content within the range provided in Table 4-1. Only lightweight hand-operated compaction equipment should be allowed within 3 feet of the back of retaining wall units. The optimum lift thickness and number of repetitive passes with compaction equipment necessary to achieve the required percentage compaction values should be determined in the field with test passes of the chosen compaction equipment.

- Material used in the reinforced zones of the proposed retaining walls should meet the following design criteria:
    - Internal friction angle of at least 34 degrees confirmed by the Standard Direct Shear Test (AASHTO T 236) prior to use. If at least 80 percent of the soil by weight is greater than the ¾ in sieve size, a Standard Direct Shear Test is not required.
    - A unit weight of at least 120 pounds per cubic foot (pcf).
    - Granular fill in accordance with Subsection 703.07 of the Oklahoma DOT *Standard Specifications for Highway Construction.*
    - Free of organic matter, ash, cinders, trash, demolition debris or other unsuitable materials
    - Cohesion of zero.
- Drainage aggregate (AASHTO No. 57) should be placed immediately behind the wall in accordance with the block manufacturer's guidelines and industry standard practice. Additional drainage considerations (chimney drains, heel drains, etc.) should be utilized in design where seeps occur and as necessary to minimize saturation of the reinforced zone of the walls.
- Based on laboratory testing results and in consideration of the guidelines outlined above, we offer the following guidance with respect to the reuse of the on-site soils within the reinforced zones of the proposed retaining walls:

  Overburden Soils – The overburden soils encountered at the site are considered not suitable for use as structural fill within the reinforced zones of the proposed retaining wall due to the amount of fines present.

  Processed Bedrock – A majority of the bedrock encountered is anticipated to be weathered shale. This material is also considered not suitable for use as structural fill within the reinforced zones of the proposed retaining wall due to the rock breaking down into a fine-grained material during construction handling.

- Based on the data collected, the retaining walls should be designed using the soil strength parameters outlined in the Lateral Earth Pressure Section below, as maximum values. Additional laboratory testing should be conducted during the design and construction phases of the project to further confirm these values and their consistency across the project site.

Geotechnical evaluations for the proposed MSE walls (including external global stability and settlement) are provided in the below sections. The internal stability of the walls is not discussed in this report and should be addressed separately by the contracted wall designer/ manufacturer for this project. We assume the MSE walls are stable internally.

3.2.1 GLOBAL STABILITY

The global stability of the MSE wall was analyzed at the maximum wall height anticipated. The existing and proposed surface elevations along the analyzed cross section were obtained from preliminary topographic plans provided by Poe & Associates, Inc*.* Shear strengths and cohesion values utilized for the soils were based on the lateral earth pressures as presented in Table 3-4.

Additional model inputs included: a 250 pound-per-square-foot (psf) live load surcharge for proposed drive lanes, and a 150 pound-per-square-foot (psf) live load surcharge for shoulder lanes.

Slide Software (Version 9.034) by Rocscience, which incorporates Bishop Simplified and Spencer Method of Slices, was used to evaluate the stability of the proposed wall against global failures. Based on our analyses and provided the engineering characteristics of the soils, materials and techniques used in construction are consistent with those utilized in our models, the proposed MSE wall will exhibit a satisfactory factor-of-safety of greater than 1.5. Note that Kleinfelder's analysis utilized the cross-sectional information available at the time for the soils and the retaining wall/slope geometry. Detailed cross-sectional information developed as the project plans and retaining wall shop drawings are developed should be reviewed by Kleinfelder to evaluate consistency with our analytical assumption.

The results of the model analyzed is summarized in the table below and a graphical depiction of the cross-section analyzed is included in Appendix C.

Table 3-3. Slope Stability Factor of Safety	
Cross-Section	**FS**
Station 1118+35	1.64

At the tallest wall section it is likely that internal stability of the wall will be the failure method controlling minimum reinforcing length. At areas of the wall where the wall does not bear on the weathered bedrock surface, global stability of the wall may control. To achieve an adequate factor of safety, we recommend a minimum reinforcing length to wall height ratio of 0.8.

3.2.2 SETTLEMENT

Based on the subsurface conditions encountered within the borings, Kleinfelder anticipates that the long-term structural settlement of the proposed MSE wall designed and constructed as outlined above should be one inch or less. Differential settlements of approximately one inch or less per 100 feet of wall length should be anticipated. Utility backfill within the wall footprint must be properly compacted to reduce the potential for localized differential settlement.

3.3 SOLDIER PILE WALL

Soldier pile walls are steel H-Piles that are vertically driven or drilled into the ground at regular intervals prior to excavation. As excavation progresses in stages, horizontal lagging (could be timber, steel, or precast concrete panels) is then installed behind the front flanges of H-Piles to retain soils as the excavation continues. The soldier pile walls can be designed as cantilever walls or anchors, or bracing could be installed to provide additional lateral support.

Pre-drilling will also be required for the construction of H-Piles. It should also be noted that cantilever soldier pile size increases dramatically for wall heights of 13 feet or greater. It is the sole responsibility of the wall contractor to design the soldier pile wall system.

Recommended geotechnical parameters for use in the evaluation of lateral load capacity and deflection of the proposed soldier piles are presented in Table 3-1. The parameters provided are based on input requirements of LPILE Plus 5.0 by Ensoft, Inc. We have included parameters including: the effective angle of internal friction (ϕ'), the effective unit weight (γ'), the soil modulus parameter (k), the undrained shear strength (S_u), and the strain at 50 percent of peak strength (E_{50}) value.

The values given in Table 3-1 are based on our analysis of the existing subsurface conditions and were estimated, or calculated, based on generally accepted engineering correlations. Design parameters for other methods of analysis can be provided, should a different method of analyzing lateral drilled shaft capacity be chosen for this design. As indicated in Table 3-1, we recommend that the weathered shale and shale bedrock be modelled as "1 - Stiff Clay without Free Water" due to the degree of weathering and low indicated strength of the bedrock materials.

Table 3-1. L-Pile Design Parameters

Boring (Ground Elevation Feet)	Depth (BEG) (ft)	Material Type*	Effective Angle of Internal Friction ϕ,' (degrees)	Undrained Cohesion C, (psf)	Strain Factor E_{50}	Soil Modulus Parameter *k,* (pci)	Effective Unit Weight γ,' (pcf)
D-1 (763.0)	0 to 4**	N/A	N/A	N/A	N/A	N/A	120
	4 to 11	1	N/A	3,000	0.005	N/A	130
	11+	1	N/A	8,000	0.004	N/A	135
D-2 (768.0)	0 to 4**	N/A	N/A	N/A	N/A	N/A	120
	4 to 9.5	1	N/A	3,000	0.005	N/A	130
	9.5+	1	N/A	8,000	0.004	N/A	135
D-3 (772.0)	0 to 4**	N/A	N/A	N/A	N/A	N/A	120
	4 to 6	1	N/A	3,000	0.005	N/A	130
	6+	1	N/A	8,000	0.004	N/A	135
D-4 (775.0)	0 to 4**	N/A	N/A	N/A	N/A	N/A	120
	4 to 6	1	N/A	3,000	0.005	N/A	130
	6+	1	N/A	8,000	0.004	N/A	135

BEG – Below existing ground
* 1-Stiff Clay without Free Water
** The strength of the upper 4 feet should not be included in the model due to seasonal moisture changes and frost; however, the effect of the overburden pressure may be included in the model.

3.4 LATERAL EARTH PRESSURE

The following data is recommended for the design of the proposed retaining walls to be constructed on the project site. The data presented is based on the use of structural fill placed under engineering control for backfill of the retaining walls. Should different soil be used, design data should be re-evaluated and changed based on the specific material. Table 3-2 below provides the Earth Pressure Design Data for the use of the above referenced soils.

Table 3-2. Summary of Lateral Earth Pressures				
Parameter	**Reinforced Zone Fill**	**Overburden Soils**	**Weathered Rock**	**Bedrock**
Unit Weight of Soil (pcf)	120	110	130	135
Submerged Unit Weight of Soil (pcf)	57.6	47.6	67.6	72.6
Angle of Internal Friction (degrees)	34*	30	0	0
Cohesion (psf)	0	0	3000	8000
Earth Pressure Coefficient, Active Condition	0.28	0.33	N/A	N/A
Earth Pressure Coefficient, Passive Condition	3.53	3.00	N/A	N/A
Earth Pressure Coefficient, At-Rest Condition	0.44	0.50	N/A	N/A

Notes: pcf – pounds per cubic foot
psf – pound per square foot
*Imported fill planned to be used as retained zone backfill of MSE walls should be tested prior to use to insure an internal friction angle of at least 34 degrees in accordance with AASHTO T 236.

Adequate drainage must be maintained adjacent to earth retaining walls to minimize the buildup of hydrostatic pressure on the structures. At a minimum, a drainage blanket consisting of clean, crushed aggregate should be placed behind the retaining wall. The drainage blanket should be connected to a drain at the base of the retaining wall with water directed to dedicated stormwater channels. Consideration may also be given to placing a non-woven geotextile filter fabric between the drainage blanket and on-site soil backfill to minimize potential clogging and sedimentation of the drainage blanket.

The parameters recommended above are based upon 1) adequate drainage to prevent the accumulation of water, 2) horizontal granular backfill capped with an impervious layer, 3) retaining walls that can rotate a sufficient amount to mobilize an active state of earth pressure. In developing the design lateral pressure, the lateral pressure due to traffic surcharge load should be added to the lateral earth pressure. Care should be exercised so that heavy compaction equipment does not damage the walls. Having foundation walls braced during backfilling may be prudent.

3.5 SETTLEMENTS

Based on the subsurface conditions encountered within the borings, Kleinfelder anticipates that the long-term structural settlement of the proposed retaining walls designed and constructed as outlined above should be one inch or less. Differential settlements of approximately one inch or less per 100 feet of wall length should be anticipated. Utility backfill within the wall footprint must be properly compacted to reduce the potential for localized differential settlement.

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3.6 SEISMIC HAZARDS DETERMINATION

We have evaluated the seismic hazards based on the 2020 AASHTO LRFD Bridge Design Specification, 9th Edition. Based on our subsurface information and evaluation of the data, we recommend a Site Class "C" be used in design.

4. SITE DEVELOPMENT

4.1 CLEARING AND GRUBBING

Clearing and grubbing should be performed in accordance with the more stringent of the procedures outlined in this section or as specified by the Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2019)", Section 201. We recommend that unsuitable materials be removed from the site prior to the select fill material being placed. We recommend that qualified engineering personnel monitor the stripping operations to observe that unsuitable materials have been removed. Soils removed during stripping operations could be wasted outside of the project site. Care should be exercised to separate these materials to avoid the incorporation of organic matter in structural fill sections.

Care should be taken during required tree excavations to thoroughly remove root systems from the proposed construction area. Materials disturbed during the removal of stumps should be undercut and replaced with structural fill.

4.2 UTILITIES, STORM DRAINS, AND CULVERTS

Relocation of any existing utility lines within or below the foundation and/or active zone should also be completed as part of the site preparation. The lines should be relocated to areas outside the footprint of the proposed retaining walls. We recommend the proposed relocation of the utilities, if any, be completed prior to beginning of the wall construction. Additionally, any temporary trench excavation for placement or maintenance of utilities within one wall height in front of the wall or two wall heights behind the face should be designed by an engineer who has reviewed this report and the final retaining wall design.

Excavations created by the removal of the existing lines or relocating new lines should be cut wide enough to allow for the use of heavy construction equipment to compact the backfill. As an alternative, the excavations could be backfilled with Controlled Low Strength Material (CLSM). In addition, the base of the excavations should be thoroughly evaluated by a geotechnical engineering technician prior to placement of backfill. Backfill should be placed in accordance with the recommendations presented in Section 4.5 of this report.

4.3 MOISTURE CONDITIONING AND COMPACTION

Prior to the placement of any required fill, the moisture content of the exposed subgrade should be evaluated. Depending on the in-situ moisture content of the subgrade exposed, moisture conditioning of the exposed grade may be required prior to proof rolling and/or fill placement. The moisture content of the exposed grade in these fill areas should be adjusted to within the range recommended for structural fill (provided in Table 4-1), to allow the exposed material to be compacted to a minimum of 95% of the Modified Proctor maximum dry density per AASHTO T-180.

Extremely wet or unstable areas that hamper the compaction of subgrade may require undercutting and replacement with structural fill or other stabilization techniques. Suitable structural fill should be placed to reach the design grade as soon as practical after reworking the subgrade to avoid moisture changes in the underlying soils.

4.4 EXCAVATIONS

4.4.1 General

It is anticipated that excavations will mostly be in native overburden sandy soils. Excavation of the native soils should be possible with conventional heavy equipment such as backhoes, loaders, etc. Excavation through weathered sandstone may require ripping and or hoe-rams.

4.4.2 Foundation and Utility Excavations and Slopes

Excavations should be cut to a stable slope or be temporarily braced, depending on the excavation depths and the subsurface conditions encountered. ***Temporary construction slopes should be designed in strict compliance with the most recent governing regulations.*** The contractor should also be aware that slope height, slope inclination, or excavation depths (including utility trench excavations) should in no case exceed those specified in local, State, and/or federal safety regulations, such as OSHA Health and Safety Standard for Excavations, 29 CFR Part 1926, or successor regulations.

Construction slopes should be closely observed for signs of mass movement: tension cracks at the crest, bulging at the toe, etc. If potential stability problems are observed, a geotechnical engineer should be contacted immediately. ***The responsibility for excavation safety and stability of temporary construction slopes lies solely with the contractor.*** Shoring, bracing, or underpinning may be required to provide structural stability and to protect personnel working within the excavation.

4.4.3 Construction Considerations/Temporary Excavations and Slopes

For planning purposes, excavations should be inclined no steeper than 1.5H:1V above the groundwater table and in the absence of seepage. Depending on soil and seepage conditions, excavations below the groundwater table or in areas of seepage may need to be inclined flatter than 2H:1V, shored, and/or dewatered with well points. Seepage from excavation sidewalls may cause sloughing and may need to be controlled with well points and/or by buttressing with coarse, crushed rock and controlled with sumps and pumps.

Heavy construction equipment, building materials, excavated soil, and vehicular traffic should not be allowed near the top of any excavation. Where the stability of other structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning may be required to provide structural stability and to protect personnel working within the excavation. Earth retention, bracing, or underpinning required for the project (if any) should be designed by a professional engineer registered in the state of Oklahoma. Raveling of native sand soils should be anticipated and could require flatter slopes.

Temporary excavations and slopes should be protected from the elements by covering with plastic sheeting or some other similar impermeable material. Sheeting sections should overlap by at least 3 feet and be tightly secured with sandbags, tires, staking, or other means to prevent wind from exposing the soil under the sheeting.

Excavations and slopes must comply with OSHA. Construction site safety is the responsibility of the Contractor, who shall also be solely responsible for the means, methods, and sequencing of construction operations. We are providing excavation sloping information solely as a service to our client for planning purposes. Under no circumstances should the information be interpreted to mean that Kleinfelder is assuming responsibility for construction site safety or the Contractor's activities; such responsibility is not being implied and should not be inferred.

4.4.4 Construction Dewatering

Groundwater was encountered within Boring E-1 at a depth of 11 feet corresponding to elevation 811. A dewatering specification should require the contractor to provide an adequate dewatering system capable of maintaining the groundwater table a minimum of 2 feet below subgrade elevations during earthwork and backfilling operations. The specifications should also require that the dewatering system be designed such that adjacent structures will not be impacted.

4.5 STRUCTURAL FILL

4.5.1 Materials

Our recommendations regarding suitable imported fill and the re-use of on-site soils as structural fill are provided below.

Imported Fill

- Free of organic matter, ash, cinders, trash, or other unsuitable or deleterious materials.
- Particle size distribution that is well-graded, per USCS guidelines.
- Liquid Limit (LL) less than 30 and Plasticity Index (PI) less than 10.
- Less than 15 percent by weight rock fragments larger than 3" with no particle size exceeding 6”, less than 30 percent by weight larger than the 3/4" and less than 30 percent smaller than the no. 200 sieve.

Alternate soils proposed for use which differ from those specified above should be evaluated by the Kleinfelder regarding their suitability prior to placement at the site.

Reuse of On-Site Soils

Topsoil – The topsoil will not be suitable for reuse as structural fill. However, the topsoil may be stockpiled for reuse within landscaping areas, non-structural areas, berms, etc.

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Overburden Soils – The overburden soils were found to be moderately well graded, generally non-plastic and comprised predominantly of Sand with secondary amounts of Silt and Clay. These soils are considered to be marginally suitable for use as structural fill. Based on the amount of fines (Silt) within this soil, this soil may be moisture sensitive and difficult to place in periods of adverse weather.

4.5.2 Compaction Criteria

Fill should be placed in lifts having a maximum loose lift thickness of 8 inches. The lift thickness may need to be reduced, depending upon the type/size of compaction equipment utilized at the site. Fill placed at the site should be compacted to a minimum of 95 percent of the material's Maximum Dry Density (MDD) as determined by AASHTO T-180 (Modified Proctor compaction). Moisture contents of the fill at the time of compaction should be maintained within the range specified in Table 4-1 until completion of the subgrade preparation.

Table 4-1. Compaction Criteria

Material	Required Moisture Content (%)	Percent Compaction (%) Modified Proctor
PI > 22	0% to 4% point above optimum	95% of MDD
PI < = 22	Within 2% point from optimum	95% of MDD

5. ADDITIONAL SERVICES

5.1 PLANS AND SPECIFICATIONS REVIEW

We recommend that Kleinfelder conduct a general review of the final plans and specifications to evaluate that our recommendations have been properly interpreted and implemented during design. In the event Kleinfelder is not retained to perform this recommended review, we will assume no responsibility for misinterpretation of our recommendations.

5.2 CONSTRUCTION OBSERVATION AND TESTING

We recommend that earthwork and retaining wall installation be monitored by a representative from Kleinfelder, including site preparation, excavation, and placement of engineered fill. The purpose of these services would be to provide Kleinfelder the opportunity to observe the subsurface conditions encountered during construction, evaluate the applicability of the recommendations presented in this report to the subsurface conditions encountered, and recommend appropriate changes in design or construction procedures if conditions differ from those described herein.

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6. LIMITATIONS

This work was performed in a manner consistent with that level of care and skill ordinarily exercised by other members of Kleinfelder's profession practicing in the same locality, under similar conditions, and at the date the services are provided. Our conclusions, opinions, and recommendations are based on a limited number of observations and data. It is possible that conditions could vary between or beyond the data evaluated. Kleinfelder makes no other representation, guarantee, or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided. The scope of our services did not include any environmental assessment or exploration for the presence of hazardous or toxic materials in the soil, surface water, groundwater, or air, on, below, or around this site.

This report may be used only by the Client and the registered design professional in responsible charge and only for the purposes stated for this specific engagement within a reasonable time from its issuance, but in no event later than two (2) years from the date of the report. Land use, site conditions (both on-site and off-site), regulations, or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify Kleinfelder of such intended use. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the Client or anyone else will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party and the client agrees to defend, indemnify, and hold harmless Kleinfelder from any claim or liability associated with such unauthorized or non-compliance.

The work performed was based on project information provided by the Client. If the Client does not retain Kleinfelder to review any plans and specifications, including any revisions or modifications to the plans and specifications, Kleinfelder assumes no responsibility for the suitability of our recommendations. In addition, if there are any changes in the field to the plans and specifications, the Client must obtain written approval from Kleinfelder's engineer that such changes do not affect our recommendations. Failure to do so will vitiate Kleinfelder's recommendations

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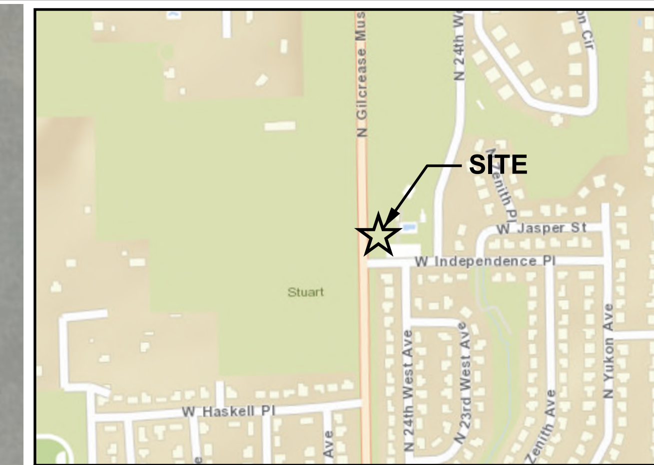
Figures



VICINITY MAP

NOT TO SCALE

NOTES:
1. BASE MAPPING AND VICINITY MAP CREATED FROM LAYERS COMPILED BY ESRI PRODUCTS.
COORDINATE SYSTEM: NAD 1983 2011 STATEPLANE OKLAHOMA NORTH FIPS 3501
2. REFERENCED BASE MAP WAS PROVIDED BY ___________, DATED ______________.

LEGEND

⬢ SOIL BORING

N

0 40 80

1" = 40 SCALE IN FEET

GIS FILE PATH: \\azrgisstorp03\working_clients_Automated_Exploration Plans\25003382.001A_RoadwayWideningandImprovements_20250106_sbhandari\APRX\
GIS FILE NAME: gINT_20250106_1536_sb
PLOTTED: 1/6/2025 3:51 PM BY: SBHANDARI

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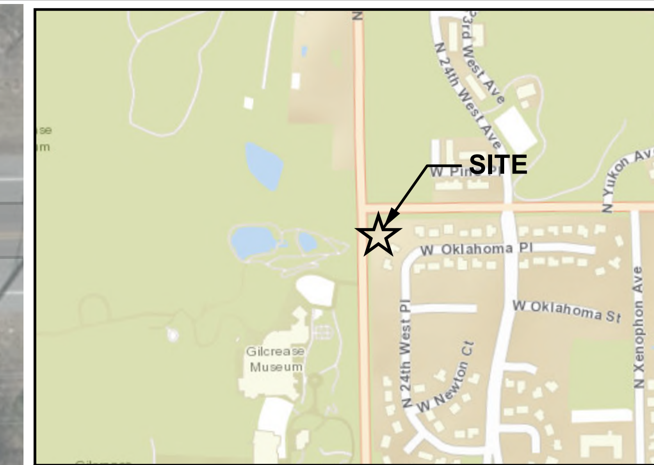
PROJECT NO. 25003382.001A		EXPLORATION LOCATION PLAN AND VICINITY MAP WITH REFERENCE MAP	FIGURE
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	1
CHECKED BY:	SYW		
DATE:	01-06-2025		



VICINITY MAP

NOT TO SCALE

NOTES:
1. BASE MAPPING AND VICINITY MAP CREATED FROM LAYERS COMPILED BY ESRI PRODUCTS. COORDINATE SYSTEM: NAD 1983 2011 STATEPLANE OKLAHOMA NORTH FIPS 3501
2. REFERENCED BASE MAP WAS PROVIDED BY ___________, DATED _____________.

LEGEND

⬢	SOIL BORING

N

0 40 80

1" = 40 SCALE IN FEET

GIS FILE PATH: \\azrgisstorp03\working_clients_Automated_Exploration Plans\25003382.001A_RoadwayWideningandImprovements_20250106_sbhandari\APRX\
GIS FILE NAME: gINT_20250106_1508_sb
PLOTTED: 1/6/2025 3:32 PM BY: SBHANDARI

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PROJECT NO. 25003382.001A		EXPLORATION LOCATION PLAN AND VICINITY MAP WITH REFERENCE MAP	FIGURE
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	2
CHECKED BY:	SYW		
DATE:	01-06-2025		

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Appendix A

FIELD EXPLORATION PROGRAM

Kleinfelder explored the subsurface conditions for the proposed retaining wall at/near the footprint of the proposed alignments by performing a total of 4 borings (D-1 through D-4) for Wall D and 2 borings (E-1 through E-2) for Wall E on December 19th, 2024. The ground elevations at the borings were assumed based on topographic plans provided by Poe and Associates, LLC. The approximate boring locations are shown on Figures 1 and 2. Subsurface cross sections are presented as Figures A-1 and A-2, and depicts the generalized subsurface conditions encountered at the boring locations.

Boring locations were established in the field by a representative of Kleinfelder by using an GPS with an accuracy of approximately 15 feet and existing nearby landmarks/bridge features. Locations and elevations of the borings should be considered accurate only to the degree implied by the methods used.

Borings were drilled with a CMe-45B rotary drill rig using hollow stem augers to advance the boreholes. Representative samples were obtained by split-barrel sampling procedures in accordance with AASHTO T-206. The split-barrel sampling procedure utilizes a standard 2-inch O.D. split-barrel sampler that is driven into the bottom of the boring with a 140-pound auto-hammer (with energy transfer efficiencies of 80.3 percent) falling 30 inches. The number of blows required to advance the sampler the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) Resistance Value (N). The "N" values are indicated on the boring logs at their depth of occurrence and provide an indication of the relative density/consistency of the material.

Boring logs included in Appendix A present soil and rock descriptions, consistency, relative density and relative hardness evaluations, depths, sampling intervals, and observed groundwater conditions. Conditions encountered in the borings were monitored and recorded by Kleinfelder field engineer(s). Field logs included visual classification of the materials encountered during drilling, as well as drilling characteristics. Our final boring logs represent the engineer's interpretation of the field logs combined with laboratory observation and testing of the samples.

Visual classifications were made in accordance with the Unified Soil Classification System (USCS) presented on the Graphics Key, Soil Description Key, and Rock Description Key that are also presented in

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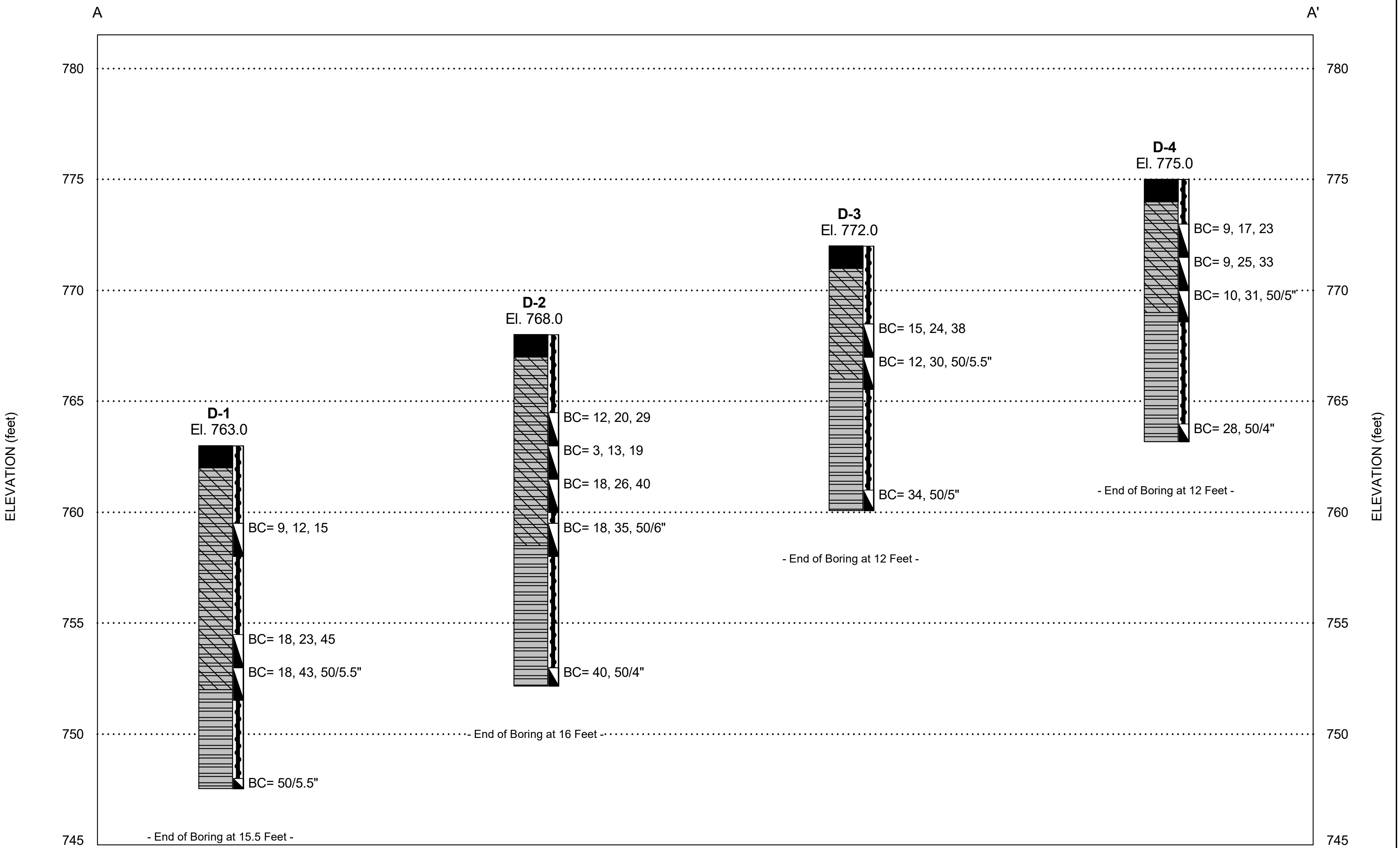
Figures A-2 through A-4, respectively, in this appendix. Stratification boundaries indicated on the boring logs and cross section (Figure A-1) were based on observations during our fieldwork, an extrapolation of information obtained by examining samples from the borings, and comparisons of soils with similar engineering characteristics. Locations of these boundaries are approximate, and the transitions between material types may be gradual rather than clearly defined.



NOTE:
REFER TO INDIVIDUAL LOGS FOR DETAILED INFORMATION AND THE GRAPHIC LEGEND KEYS FOR GRAPHICAL SYMBOL INFORMATION.

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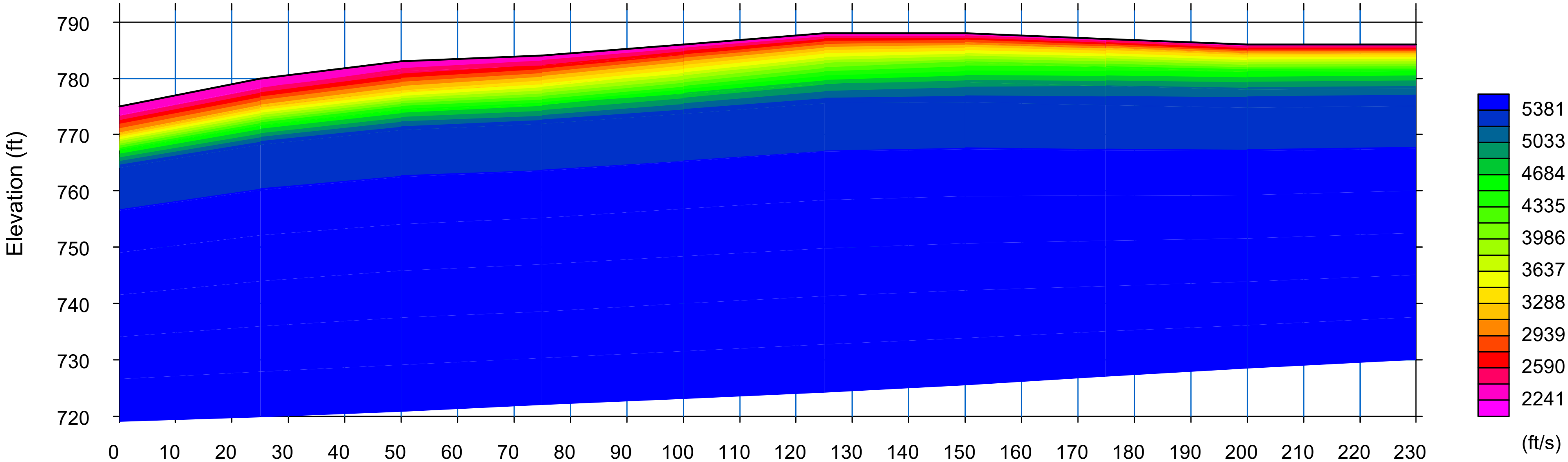
SUBSURFACE CROSS-SECTION

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

FIGURE

A-1



Scale = 1 / 1100

Final_Velocity.vs

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PROJECT NO.: 25003382.001A

DRAWN BY: SB

CHECKED BY: BGS

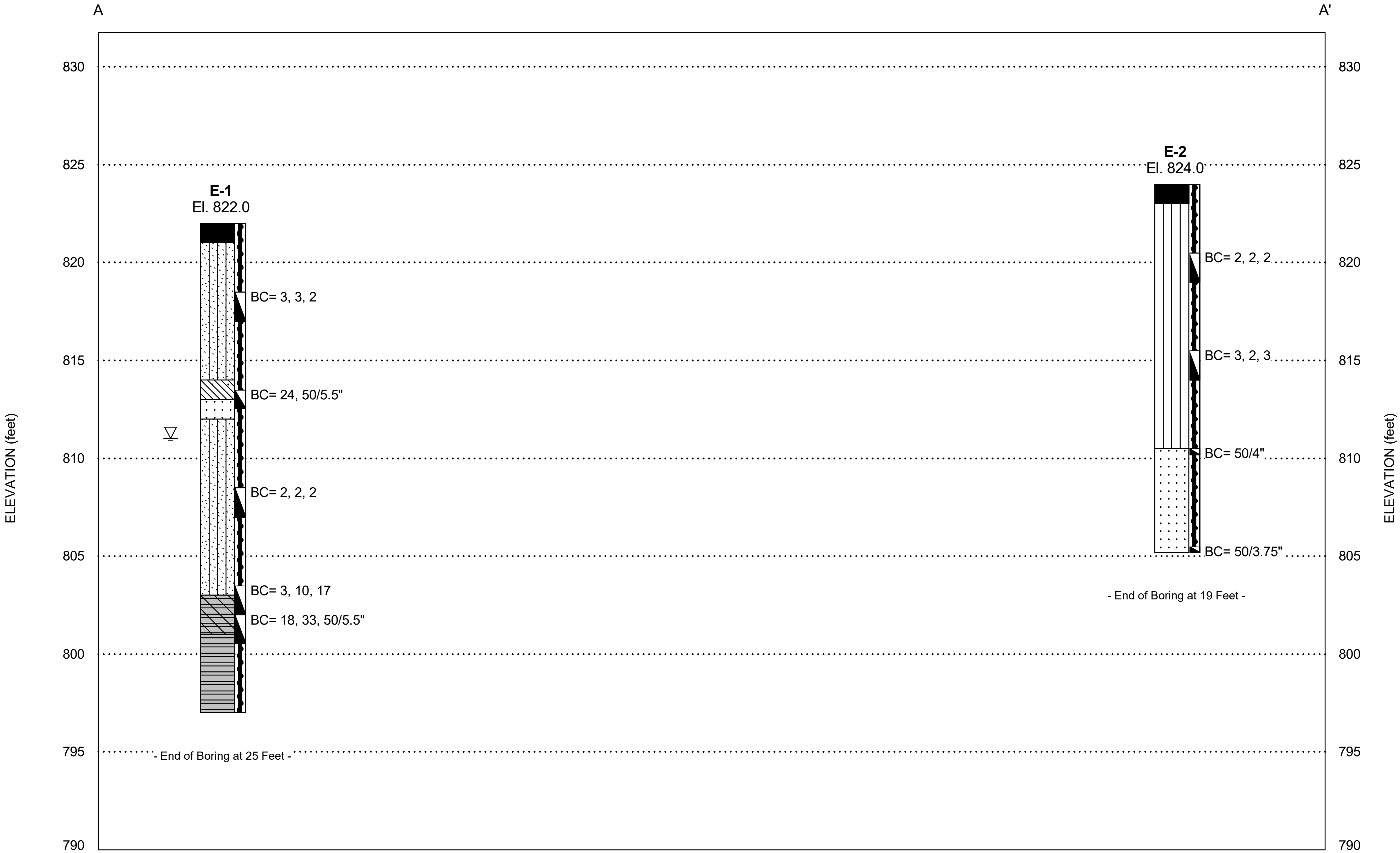
DATE: 1/23/2025

SEISMIC REFRACTION CROSS-SECTION

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

FIGURE

A-2



NOTE:
REFER TO INDIVIDUAL LOGS FOR DETAILED INFORMATION AND THE GRAPHIC LEGEND KEYS FOR GRAPHICAL SYMBOL INFORMATION.

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PROJECT NO.: 25003382.001A		SUBSURFACE CROSS-SECTION	FIGURE
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	A-3
CHECKED BY:	BGS		
DATE:	1/23/2025		

AASHTO CLASSIFICATION OF SOILS AND SOIL AGGREGATE MIXTURES

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (more than 35% passing No. 200)			
Group Classification	A-1			A-2							A-7*
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve Analysis: Percent Passing											
No. 10 (2.00 mm)	50 max.	---	---	---	---	---	---	---	---	---	---
No. 40 (0.425 mm)	30 max.	50 max.	51 min.	---	---	---	---	---	---	---	---
No. 200 (0.075 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of Fraction:											
Passing No. 40 (0.425 mm)											
Liquid Limit	---		Non-Plastic	40 max.	41 min.	40 max.	40 min.	40 max.	41 min.	40 max.	41 max.
Plasticity Index	6 max.			10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments, gravels, and sand		Fine Sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating of subgrade	Excellent to good							Fair to poor			

* Plasticity Index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

DRILLING METHOD/SAMPLER TYPE GRAPHICS

SOLID STEM AUGER

STANDARD PENETRATION SPLIT SPOON SAMPLER
(2 in. (50.8 mm.) outer diameter and 1-3/8 in. (34.9 mm.) inner diameter)

GROUND WATER GRAPHICS

WATER LEVEL (level where first observed)

WATER LEVEL (level after stabilizing period)

WATER LEVEL (additional levels after exploration)

OBSERVED SEEPAGE

NOTES

- The report and graphics key are an integral part of these logs. All data and interpretations in this log are subject to the explanations and limitations stated in the report.
- Solid lines separating strata on the logs represent approximate boundaries only, dashed lines are inferred or extrapolated boundaries. Actual transitions may be gradual or differ from those represented.
- No warranty is provided as to the continuity of soil or rock conditions between individual sample locations.
- Logs represent general soil or rock conditions observed at the point of exploration on the date indicated.
- In general, American Association of State Highway and Transportation Officials (AASHTO M 145) designations presented on the logs were based on visual classification in the field and were modified where appropriate based on gradation and index property testing.
- If sampler is not able to be driven at least 6 inches then 50/X indicates number of blows required to drive the identified sampler X inches with a 140 pound hammer falling 30 inches.

ABBREVIATIONS

C_u - Coefficients of Uniformity
C_c - Coefficients of Curvature
WOH - Weight of Hammer
WOR - Weight of Rod

REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 1991, AASHTO M 145: Classification of Soils and Soil Aggregate Mixtures for Highway Construction Purposes.

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	DRAWN BY: SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	A-4
	CHECKED BY: BGS		
	DATE: 1/23/2025		

GRAIN SIZE[1]

DESCRIPTION		SIEVE SIZE	GRAIN SIZE
Boulders		>12 in.	>12 in. (304.8 mm.)
Cobbles		3 - 12 in.	3 - 12 in. (76.2 - 304.8 mm.)
Gravel	coarse	3/4 -3 in.	3/4 -3 in. (19 - 76.2 mm.)
	fine	#4 - 3/4 in.	0.19 - 0.75 in. (4.8 - 19 mm.)
Sand	coarse	#10 - #4	0.079 - 0.19 in. (2 - 4.9 mm.)
	medium	#40 - #10	0.017 - 0.079 in. (0.43 - 2 mm.)
	fine	#200 - #40	0.0029 - 0.017 in. (0.07 - 0.43 mm.)
Fines		Passing #200	<0.0029 in. (<0.07 mm.)

SECONDARY CONSTITUENT[1]

Term of Use	AMOUNT	
	Secondary Constituent is Fine Grained	Secondary Constituent is Coarse Grained
Trace	<5%	<15%
With	≥5 to <15%	≥15 to <30%
Modifier	≥15%	≥30%

PLASTICITY[1]

DESCRIPTION	CRITERIA
Non-Plastic	A 1/8 in. (3 mm) 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 rerolled 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 rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

MOISTURE CONTENT[1]

DESCRIPTION	FIELD TEST
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

CONSISTENCY - FINE-GRAINED SOIL[2, 3]

CONSISTENCY	SPT - N (# blows / ft)	Pocket Pen (tsf)	UNCONFINED COMPRESSIVE STRENGTH (Q_u)(psf)	VISUAL / MANUAL CRITERIA
Very Soft	<2	PP < 0.25	<500	Easily penetrated several inches by fist
Soft	2 - 4	0.25 ≤ PP <0.5	500 - 1,000	Easily penetrated several inches by thumb
Medium Stiff	4 - 8	0.5 ≤ PP <1	1,000 - 2,000	Can be penetrated several inches by thumb with moderate effort
Stiff	8 - 15	1 ≤ PP <2	2,000 - 4,000	Readily indented by thumb but penetrated only with great effort
Very Stiff	15 - 30	2 ≤ PP <4	4,000 - 8,000	Readily indented by thumbnail
Hard	>30	4 ≤ PP	>8,000	Indented by thumbnail with difficulty

APPARENT DENSITY - COARSE-GRAINED SOIL[2]

APPARENT DENSITY	SPT-N (# blows / ft)
Very Loose	<4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

STRUCTURE[1]

DESCRIPTION	CRITERIA
Stratified	Alternating layers of varying material or color with layers at least 1/4-in. (6mm) thick, note thickness.
Laminated	Alternating layers of varying material or color with the layers less than 1/4-in. (6 mm) thick, note thickness.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	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; note thickness.
Homogeneous	Same color and appearance throughout

ANGULARITY[1]

DESCRIPTION	CRITERIA
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

REFERENCES

1. American Society for Materials and Testing (ASTM), 2017, ASTM D2488: Standard Practice for Description and Identification of Soils (Visual Manual Procedures).
2. Terzaghi, K and Peck, R., 1948, Soil Mechanics in Engineering Practice, John Wiley & Sons, New York.
3. United States Department of the Interior Bureau of Reclamation (USBR), 1998, Earth Manual, Part I.

REACTION WITH HYDROCHLORIC ACID[1]

DESCRIPTION	FIELD TEST
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

CEMENTATION[1]

DESCRIPTION	FIELD TEST
Weakly	Crumbles or breaks with handling or little finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

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PROJECT NO.: 25003382.001A	SOIL DESCRIPTION KEY (For additional tables, see ASTM D2488)	FIGURE
DRAWN BY: SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	A-5
CHECKED BY: BGS		
DATE: 1/23/2025		

INFILLING TYPE

NAME	ABBR	NAME	ABBR
Albite	Al	Muscovite	Mus
Apatite	Ap	None	No
Biotite	Bi	Pyrite	Py
Clay	Cl	Quartz	Qz
Calcite	Ca	Sand	Sd
Chlorite	Ch	Sericite	Ser
Epidote	Ep	Silt	Si
Iron Oxide	Fe	Talc	Ta
Manganese	Mn	Unknown	Uk

Kleinfelder modified from (FHWA, 2002)

DENSITY/SPACING OF DISCONTINUITIES

DESCRIPTION	SPACING CRITERIA
Unfractured	> 6 ft. (> 1.83 meters)
Slightly Fractured	2 - 6 ft. (.061 - 1.83 meters)
Moderately Fractured	8 in - 2 ft. (203.20 - 609.60 mm.)
Highly Fractured	2 - 8 in. (50.80 - 203.30 mm.)
Intensely Fractured	< 2 in. (< 50.80 mm.)

(USACE, 1994)

BEDDING CHARACTERISTICS

TERM	Thickness (in.)	Thickness (mm.)
Very Thick Bedded	> 36	> 915
Thick Bedded	12 - 36	305 - 915
Moderately Bedded	4 - 12	102 - 305
Thin Bedded	1 - 4	25 - 102
Very Thin Bedded	0.4 - 1	10 - 25
Laminated	0.1 - 0.4	2.5 - 10
Thinly Laminated	< 0.1	< 2.5

Kleinfelder modified from (USBR, 1998)

Bedding Planes	Planes dividing the individual layers, beds, or stratigraphy of rocks.
Joint	Fracture in rock, generally more or less vertical or traverse to bedding.
Seam	Applies to bedding plane with unspecified degree of weather.

APERTURE

DESCRIPTION	CRITERIA [in.(mm.)]
Tight	< 0.04 (< 1)
Open	0.04 - 0.20 (1 - 5)
Wide	> 0.20 (> 5)

Kleinfelder modified from Rock Mass Rating Classification (Bieniawski, 1989)

ADDITIONAL TEXTURAL ADJECTIVES

DESCRIPTION	RECOGNITION
Pit (Pitted)	Pinhole to 0.03 ft. (3/8 in.) (>1 to 10 mm.) openings
Vug (Vuggy)	Small openings (usually lined with crystals) ranging in diameter from 0.03 ft. (3/8 in.) to 0.33 ft. (4 in.) (10 to 100 mm.)
Cavity	An opening larger than 0.33 ft. (4 in.) (100 mm.), size descriptions are required, and adjectives such as small, large, etc., may be used
Honeycombed	If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form
Vesicle (Vesicular)	Small openings in volcanic rocks of variable shape and size formed by entrapped gas bubbles during solidification

(USBR, 1994)

DISCONTINUITY TYPE

DESCRIPTION
Fault
Joint
Shear
Foliation
Vein
Bedding

INFILLING AMOUNT

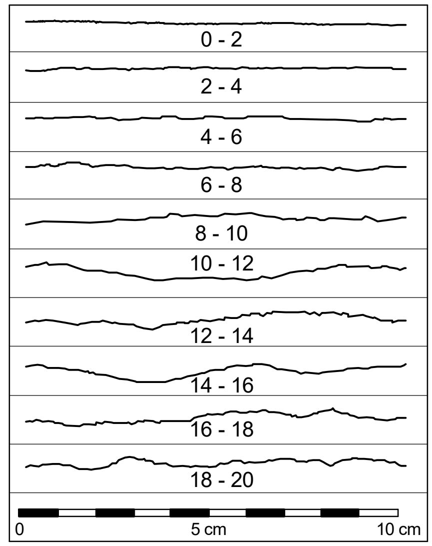
DESCRIPTION
Surface Stain
Spotty
Partially Filled
Filled
None

ROCK QUALITY DESIGNATION (RQD)

DESCRIPTION	RQD (%)
Very Poor	0 - 25
Poor	25 - 50
Fair	50 - 75
Good	75 - 90
Excellent	90 - 100

(Deere and Deere, 1989; ASTM D 6032)

JOINT ROUGHNESS COEFFICIENT (JRC)



(ISRM, 1978; Barton and Choubey, 1977)

RQD Rock-quality designation (RQD) Rough measure of the degree of jointing or fracture in a rock mass, measured as a percentage of the drill core in lengths of 10 cm. or more.

DEGREES OF WEATHERING (USACE, 1994)

DESCRIPTION	CRITERIA
Unweathered	No evidence of chemical/mechanical alternation; rings with hammer blow.
Slightly Weathered	Slight discoloration on surface; slight alteration along discontinuities; <10% rock volume altered.
Moderately Weathered	Discoloring evident; surface pitted and alteration penetration well below surface; Weathering "halos" evident; 10-50% rock altered.
Highly Weathered	Entire mass discolored; Alteration pervading most rock, some slight weathering pockets; some minerals may be leached out.
Decomposed	Rock reduced to soil with relic rock texture/structure; Generally molded and crumbled by hand.

RELATIVE HARDNESS / STRENGTH DESCRIPTIONS - FOR WEAKER SEDIMENTARY ROCKS IN COLORADO (USACE, 1994)

SPT N_{60}	HARDNESS
< 20	Very Weak to Weathered
20 - 39	Weak
40 - 49	Moderately Strong
50 - 50/6"	Strong
> 50/6"	Very Strong

This table was developed by Kleinfelder based on project experience in Colorado for shale, claystone, siltstone, poorly cemented sandstone, and other weaker sedimentary rocks.

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 25003382.001A	ROCK DESCRIPTION KEY	FIGURE
	DRAWN BY: SB CHECKED BY: BGS DATE: 1/23/2025	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	A-6

Date Begin - End:	12/19/2024	**Drilling Company:**	Hinderliter		**BORING LOG D-1**
Logged By:	V. Kasaraneni	**Drill Crew:**	H. Morril		
Hor.-Vert. Datum:	NAD83	**Drilling Equipment:**	CME-45B	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Flight Auger	**Hammer Efficiency:**	71.3%
Weather:	58° P. Cloudy	**Auger Diameter:**	6 in. O.D.	**Hammer Cal. Date:**	8/02/2024

FIELD EXPLORATION / LABORATORY RESULTS

Latitude: 36.16713°
Longitude: -96.01988°
Approximate Ground Surface Elevation (ft.): 763.00
Surface Condition: Asphalt

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE (blows/ft) / Water Content Plot (%)	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
	0–1	**ASPHALT**: 12 inches								
760	1–10.5	**Decomposed SHALE**: olive, yellow, and gray, fissured, weak to moderately strong	SS-1	BC=9 12 15	27	18"				**Passing #200=** 85 **Atterberg Limits=** Liquid Limits: 44 Plasticity Index: 17
755			SS-2	BC=18 23 45	68; ▲ 12.1	18"		12.1		
	10		SS-3	BC=18 43 50/5.5"	50/5.5"	17"				
750	10.5–15.5	**SHALE**: gray, highly weathered, fissured, very strong								
	15		SS-4	BC=50/5.5"	50/5.5"	5"				
745										

The boring was terminated at approximately 15.5 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not observed during drilling or after completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 25003382.001A	BORING LOG D-1	BORING
	DRAWN BY: SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	D-1
	CHECKED BY: BGS		
	DATE: 1/23/2025		PAGE: 1 of 1

Date Begin - End: 12/19/2024	**Drilling Company:** Hinderliter		**BORING LOG D-2**
Logged By: V. Kasaraneni	**Drill Crew:** H. Morril		
Hor.-Vert. Datum: NAD83	**Drilling Equipment:** CME-45B	**Hammer Type - Drop:** 140 lb. Auto - 30 in.	
Plunge: -90 degrees	**Drilling Method:** Solid Flight Auger	**Hammer Efficiency:** 71.3%	
Weather: 50° P. Cloudy	**Auger Diameter:** 6 in. O.D.	**Hammer Cal. Date:** 8/02/2024	

Latitude: 36.16734°
Longitude: -96.01987°
Approximate Ground Surface Elevation (ft.): 768.00
Surface Condition: Asphalt

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE (blows/ft) / Water Content Plot (%)	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
		ASPHALT: 12 inches									
765		**Decomposed SHALE**: olive, yellow, and gray, weak to moderately strong									
			SS-1		BC=12 20 29	11.0 ▲; 49 ●	18"		11.0		**Passing #200=** 85 **Atterberg Limits=** Liquid Limits: 43 Plasticity Index: 15
	5		SS-2		BC=3 13 19	32 ●	18"				
		- weak below 6.5 feet	SS-3		BC=18 26 40	66 ●	18"				
760		- moderately strong below 7.5 feet									
			SS-4		BC=18 35 50/6"	50/6" ●	18"				
	10	**SHALE**: gray, highly weathered, fissured, very strong									
755											
	15		SS-5		BC=40 50/4"	50/4" ●	10"				
750											

The boring was terminated at approximately 16 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not observed during drilling or after completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 25003382.001A	BORING LOG D-2	BORING
	DRAWN BY: SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	D-2
	CHECKED BY: BGS		
	DATE: 1/23/2025		PAGE: 1 of 1

Date Begin - End:	12/19/2024	**Drilling Company:**	Hinderliter		**BORING LOG D-3**
Logged By:	V. Kasaraneni	**Drill Crew:**	H. Morril		
Hor.-Vert. Datum:	NAD83	**Drilling Equipment:**	CME-45B	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Flight Auger	**Hammer Efficiency:**	71.3%
Weather:	45° Sunny	**Auger Diameter:**	6 in. O.D.	**Hammer Cal. Date:**	8/02/2024

FIELD EXPLORATION / LABORATORY RESULTS

Latitude: 36.16758°
Longitude: -96.01988°
Approximate Ground Surface Elevation (ft.): 772.00
Surface Condition: Asphalt

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE (blows/ft)	Water Content Plot (%)	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
772	0	**ASPHALT**: 12 inches									
	1	**Decomposed SHALE**: olive, yellow, and gray, weak to moderately strong									
770											
	3.5	- moderately strong below 4 feet	SS-1	BC=15 24 38	62	11.0	18"		11.0		**Passing #200=** 82 **Atterberg Limits=** Liquid Limits: 43 Plasticity Index: 15
	5		SS-2	BC=12 30 50/5.5"	50/5.5"		17"				
	6	**SHALE**: gray, highly weathered, fissured, moderately to very strong									
765											
762	10										
	11		SS-3	BC=34 50/5"	50/5"		10"				
760											
755	15										

The boring was terminated at approximately 12 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not observed during drilling or after completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.

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PROJECT NO.: 25003382.001A		BORING LOG D-3	BORING
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	D-3
CHECKED BY:	BGS		
DATE:	1/23/2025		PAGE: 1 of 1

BORING LOG D-4

Date Begin - End:	12/19/2024	**Drilling Company:**	Hinderliter		
Logged By:	V. Kasaraneni	**Drill Crew:**	H. Morril		
Hor.-Vert. Datum:	NAD83	**Drilling Equipment:**	CME-45B	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Flight Auger	**Hammer Efficiency:**	71.3%
Weather:	37° P. Cloudy	**Auger Diameter:**	6 in. O.D.	**Hammer Cal. Date:**	8/02/2024

FIELD EXPLORATION / LABORATORY RESULTS

Latitude: 36.16774°
Longitude: -96.01987°
Approximate Ground Surface Elevation (ft.): 775.00
Surface Condition: Asphalt

● Uncorrected N-VALUE (blows/ft)
▲ Water Content Plot (%)

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
		ASPHALT: 12 inches								
		Decomposed SHALE: olive, yellow, and gray, weak to moderately strong								
			SS-1	BC=9 17 23	40 (▲13.9)	18"		13.9		**Passing #200=** 88 **Atterberg Limits=** Liquid Limits: 46 Plasticity Index: 20
		- moderately strong below 3 feet	SS-2	BC=9 25 33	58	18"				
770	5		SS-3	BC=10 31 50/5"	50/5"	16"				
		SHALE: gray, highly weathered, fissured, very strong								
765	10									
			SS-4	BC=28 50/4"	50/4"	9"				
760	15									

The boring was terminated at approximately 12 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not observed during drilling or after completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.

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PROJECT NO.: 25003382.001A		BORING LOG D-4	BORING
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	D-4
CHECKED BY:	BGS		
DATE:	1/23/2025		PAGE: 1 of 1

Date Begin - End:	12/19/2024	**Drilling Company:**	Hinderliter		**BORING LOG E-1**
Logged By:	V. Kasaraneni	**Drill Crew:**	H. Morril		
Hor.-Vert. Datum:	NAD83	**Drilling Equipment:**	CME-45B	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Flight Auger	**Hammer Efficiency:**	71.3%
Weather:	53° P. Cloudy	**Auger Diameter:**	6 in. O.D.	**Hammer Cal. Date:**	8/02/2024

FIELD EXPLORATION / LABORATORY RESULTS

Latitude: 36.17604°
Longitude: -96.01979°
Approximate Ground Surface Elevation (ft.): 822.00
Surface Condition: Asphalt

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE (blows/ft) / Water Content Plot (%)	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
822	0	**ASPHALT**: 12 inches								
821	1	**Silty GRAVEL with Sand (A-2-4)**: brown, moist, loose, trace sandstone fragments								
	3.5		SS-1	BC=3 3 2	5; 11.0	12"	GM	11.0		**Passing #200=** 29 **Atterberg Limits=** Liquid Limits: NP Plasticity Index: NP
	8	**Decomposed SANDSTONE**: yellowish brown, weakly cemented, weak	SS-2	BC=24 50/5.5"	50/5.5"	8"				
	9	**SANDSTONE**: yellowish brown, highly weathered, weakly cemented, very strong								
	10	**Silty SAND with Gravel (A-2-4)**: brown, moist to wet, very loose, with sandstone fragments - wet below 11 feet								
	13.5		SS-3	BC=2 2 2	4	18"	SM			**Passing #200=** 29 **Atterberg Limits=** Liquid Limits: NP Plasticity Index: NP
	18.5		SS-4	BC=3 10 17	27	18"				
	19	**Decomposed SHALE**: gray, weak to moderately strong	SS-5	BC=18 33 50/5.5"	50/5.5"	17"				
	21	**SHALE**: gray, highly weathered, very strong								

The boring was terminated at approximately 25 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
▽ Groundwater was observed at approximately 11 ft. below ground surface during drilling.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.
Caving was observed at a depth of 13 ft. below ground surface during drilling operation.

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PROJECT NO.: 25003382.001A
DRAWN BY: SB
CHECKED BY: BGS
DATE: 1/23/2025

BORING LOG E-1

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

BORING E-1

BORING LOG E-2

Date Begin - End:	12/19/2024	**Drilling Company:**	Hinderliter		
Logged By:	V. Kasaraneni	**Drill Crew:**	H. Morril		
Hor.-Vert. Datum:	NAD83	**Drilling Equipment:**	CME-45B	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Flight Auger	**Hammer Efficiency:**	71.3%
Weather:	58° P. Cloudy	**Auger Diameter:**	6 in. O.D.	**Hammer Cal. Date:**	8/02/2024

FIELD EXPLORATION / LABORATORY RESULTS

Latitude: 36.17629°
Longitude: -96.01978°
Approximate Ground Surface Elevation (ft.): 824.00
Surface Condition: Asphalt

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. blows/6 in	Uncorrected N-VALUE (blows/ft)	Water Content Plot (%)	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Additional Tests/ Remarks
824	0	**ASPHALT**: 12 inches									
	1	**Silty SAND (A-4)**: brown, moist, loose, with sandstone fragments									
820			SS-1	BC=2 2 2	4	12.0	18"	SM	12.0		**Passing #200=** 42 **Atterberg Limits=** Liquid Limits: NP Plasticity Index: NP
815			SS-2	BC=3 2 3	5		18"	SM			**Passing #200=** 20 **Atterberg Limits=** Liquid Limits: NP Plasticity Index: NP
810		**SANDSTONE**: yellowish brown, highly weathered, moderately cemented, very strong	SS-3	BC=50/4"	50/4"		4"				
805			SS-4	BC=50/3.75"	50/3.75"		3"				

The boring was terminated at approximately 19 ft. below ground surface. The boring was backfilled with auger cuttings, bentonite and patched at surface on December 19, 2024.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not observed during drilling or after completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.
A handheld GPS unit was used to locate the exploration with an accuracy of 15 feet.

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PROJECT NO.: 25003382.001A		BORING LOG E-2	BORING
DRAWN BY:	SB	Roadway Widening and Improvements Retaining Walls D & E Gilcrease Museum Road Tulsa, OK	E-2
CHECKED BY:	BGS		
DATE:	1/23/2025		PAGE: 1 of 1

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Appendix B

LABORATORY TESTING PROGRAM

Laboratory tests were performed on select, representative samples to evaluate pertinent engineering properties of these materials. We directed our laboratory testing program primarily toward classifying the subsurface materials and measuring index values of the on-site materials. Laboratory tests were performed in general accordance with applicable standards. The results of the laboratory tests are presented on the respective boring logs. The laboratory testing program consisted of the following:

- **Moisture content tests**, AASHTO T-265, Standard Test Method for Laboratory Determination of Moisture Content of Soils.
- **Soil Classification**, AASHTO T-87, T-88, T-89 and T-90, Standard Method for Test For Dry preparation of Disturbed Soil and Soil Aggregate Samples of Test, Standard Method for Test For Particle Size Analysis of Soils, Standard Method for Test For Determining the Liquid Limit of Soils, and Standard Method for Test For Determining the Plastic Limit and Plasticity Index of Soils, respectively.
- **Visual classification,** ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

KLEINFELDER 12727 East 61st Street, Suite A, Tulsa, OK 74146 **p**| 918.627.6161 **f**| 918.627.6262

Exploration ID	Depth (ft.)	Sample No.	Sample Description	USCS	AASHTO	OKLAHOMA SOIL INDEX (OSI)	Water Content (%)	Atterberg Limits			Sieve Analysis (%)				
								Liquid Limits	Plastic Limits	Plasticity Index	Passing #4	Passing #10	Passing #40	Passing #100	Passing #200
D-1	3.5 - 5.0	SS-1	SILT WITH SAND					44	27	17	100	97	93		85
D-1	8.5	SS-2					12.1								
D-2	3.5	SS-1	SILT WITH SAND				11.0	43	28	15	100	96	88		85
D-3	3.5	SS-1	SILT WITH SAND				11.0	43	28	15	96	92	86		82
D-4	2.0	SS-1	LEAN CLAY				13.9	46	26	20	100	99	93		88
E-1	3.5	SS-1	SILTY GRAVEL WITH SAND	GM	A-2-4		11.0	NP	NP	NP	48	43	39		29
E-1	13.5	SS-3	SILTY SAND WITH GRAVEL	SM	A-2-4			NP	NP	NP	84	81	77		29
E-2	3.5	SS-1	SILTY SAND WITH GRAVEL	SM	A-4		12.0	NP	NP	NP	77	68	61		42
E-2	8.5	SS-2	SILTY SAND WITH GRAVEL	SM	A-2-4			NP	NP	NP	77	70	65		20

Refer to the Geotechnical Evaluation Report or the supplemental plates for the method used for the testing performed above.
NP = Nonplastic
NA = Not Available

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PROJECT NO.: 25003382.001A
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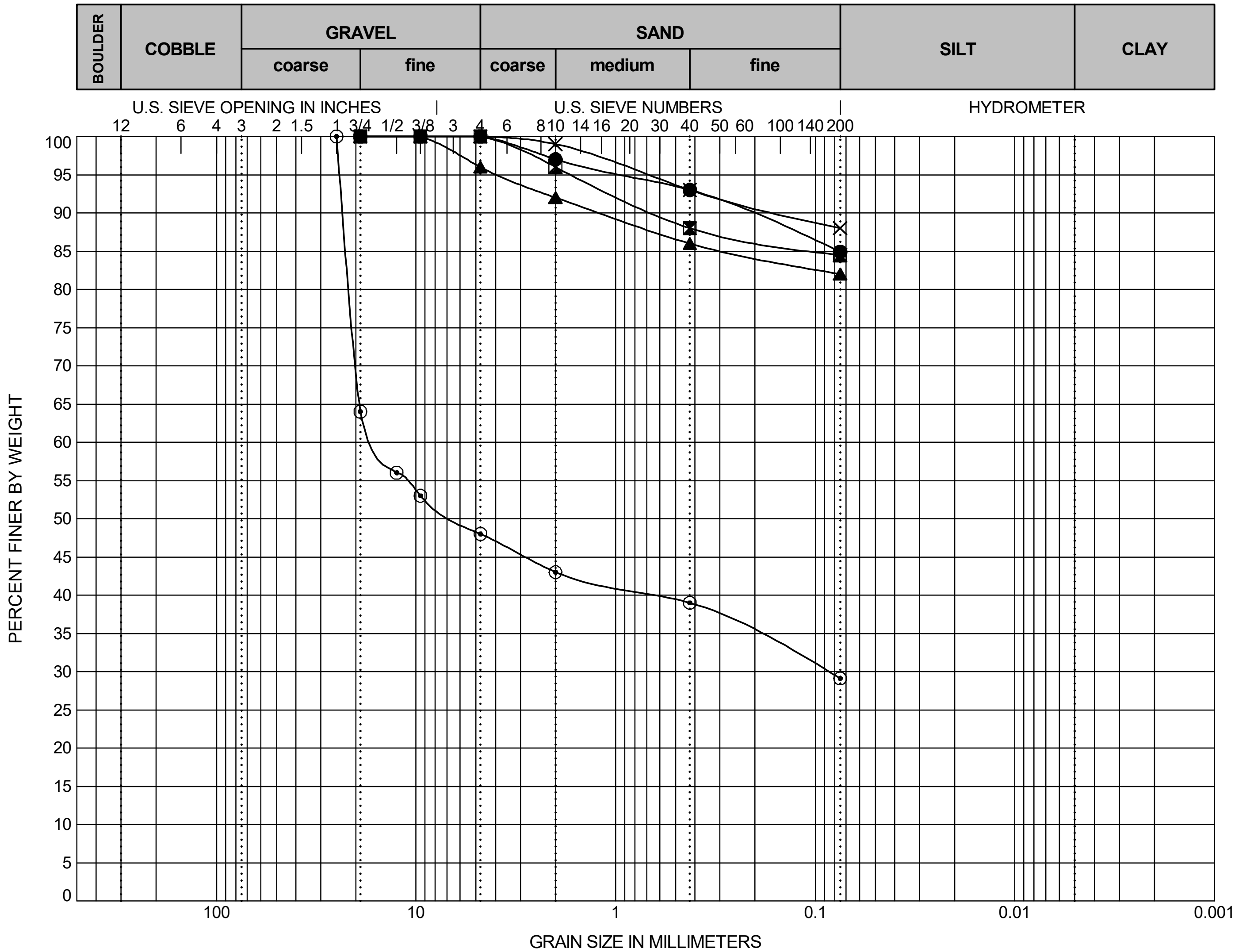
DATE: 1/23/2025

LABORATORY TEST RESULT SUMMARY

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

TABLE B-1



Exploration ID		Depth (ft.)	Sample Number	Sample Description	LL	PL	PI
●	D-1	3.5 - 5	SS-1	SILT with SAND (ML) (A-7-6)	44	27	17
⧗	D-2	3.5	SS-1	SILT with SAND (ML) (A-7-6)	43	28	15
▲	D-3	3.5	SS-1	SILT with SAND (ML) (A-7-6)	43	28	15
×	D-4	2	SS-1	LEAN CLAY (CL) (A-7-6)	46	26	20
⊙	E-1	3.5	SS-1	SILTY GRAVEL with SAND (GM) (A-2-4)	NP	NP	NP

Exploration ID		Depth (ft.)	D_{100}	D_{60}	D_{30}	D_{10}	Cc	Cu	Passing 3/4"	Passing #4	Passing #200	%Silt	%Clay
●	D-1	3.5 - 5	19	NM	NM	NM	NM	NM	100	100	85	NM	NM
⧗	D-2	3.5	19	NM	NM	NM	NM	NM	100	100	85	NM	NM
▲	D-3	3.5	19	NM	NM	NM	NM	NM	100	96	82	NM	NM
×	D-4	2	19	NM	NM	NM	NM	NM	100	100	88	NM	NM
⊙	E-1	3.5	25	15.411	0.088	NM	NM	NM	64	48	29	NM	NM

Sieve Analysis and Hydrometer Analysis testing performed in general accordance with ASTM D422.
NP = Nonplastic
NA = Not Available
NM = Not Measured

Coefficients of Uniformity - $C_u = D_{60} / D_{10}$
Coefficients of Curvature - $C_C = (D_{30})^2 / D_{60} D_{10}$
D_{60} = Grain diameter at 60% passing
D_{30} = Grain diameter at 30% passing
D_{10} = Grain diameter at 10% passing

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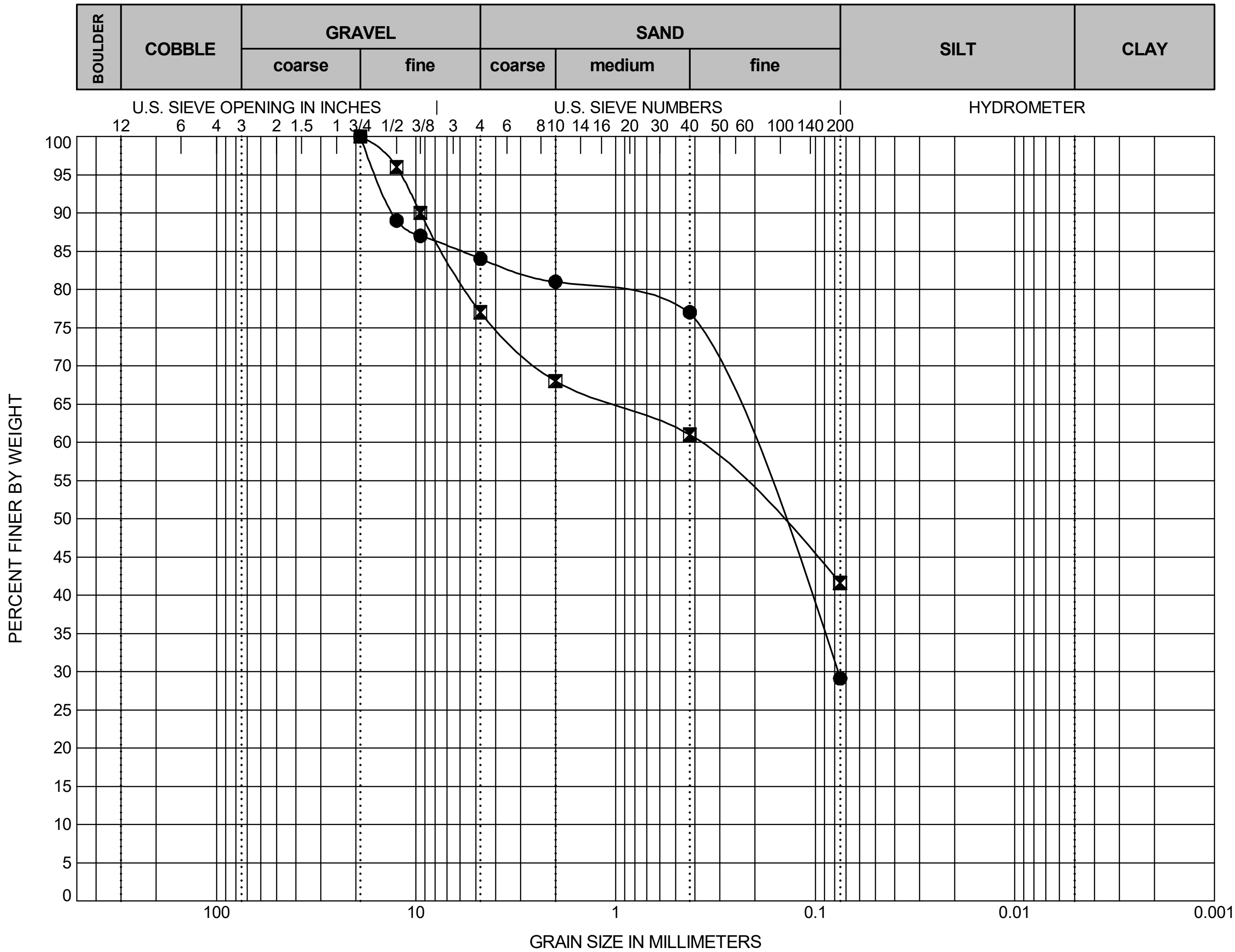
PROJECT NO.: 25003382.001A
DRAWN BY: SB
CHECKED BY: BGS
DATE: 1/23/2025

SIEVE ANALYSIS

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

TABLE
B-2



Exploration ID		Depth (ft.)	Sample Number	Sample Description	LL	PL	PI
●	E-1	13.5	SS-3	SILTY SAND with GRAVEL (SM) (A-2-4)	NP	NP	NP
⧗	E-2	3.5	SS-1	SILTY SAND with GRAVEL (SM) (A-4)	NP	NP	NP

Exploration ID		Depth (ft.)	D_{100}	D_{60}	D_{30}	D_{10}	Cc	Cu	Passing 3/4"	Passing #4	Passing #200	%Silt	%Clay
●	E-1	13.5	19	0.23	0.077	NM	NM	NM	100	84	29	NM	NM
⧗	E-2	3.5	19	0.389	NM	NM	NM	NM	100	77	42	NM	NM

Sieve Analysis and Hydrometer Analysis testing performed in general accordance with ASTM D422.
NP = Nonplastic
NA = Not Available
NM = Not Measured

Coefficients of Uniformity - $C_u = D_{60} / D_{10}$
Coefficients of Curvature - $C_C = (D_{30})^2 / D_{60}\, D_{10}$
D_{60} = Grain diameter at 60% passing
D_{30} = Grain diameter at 30% passing
D_{10} = Grain diameter at 10% passing

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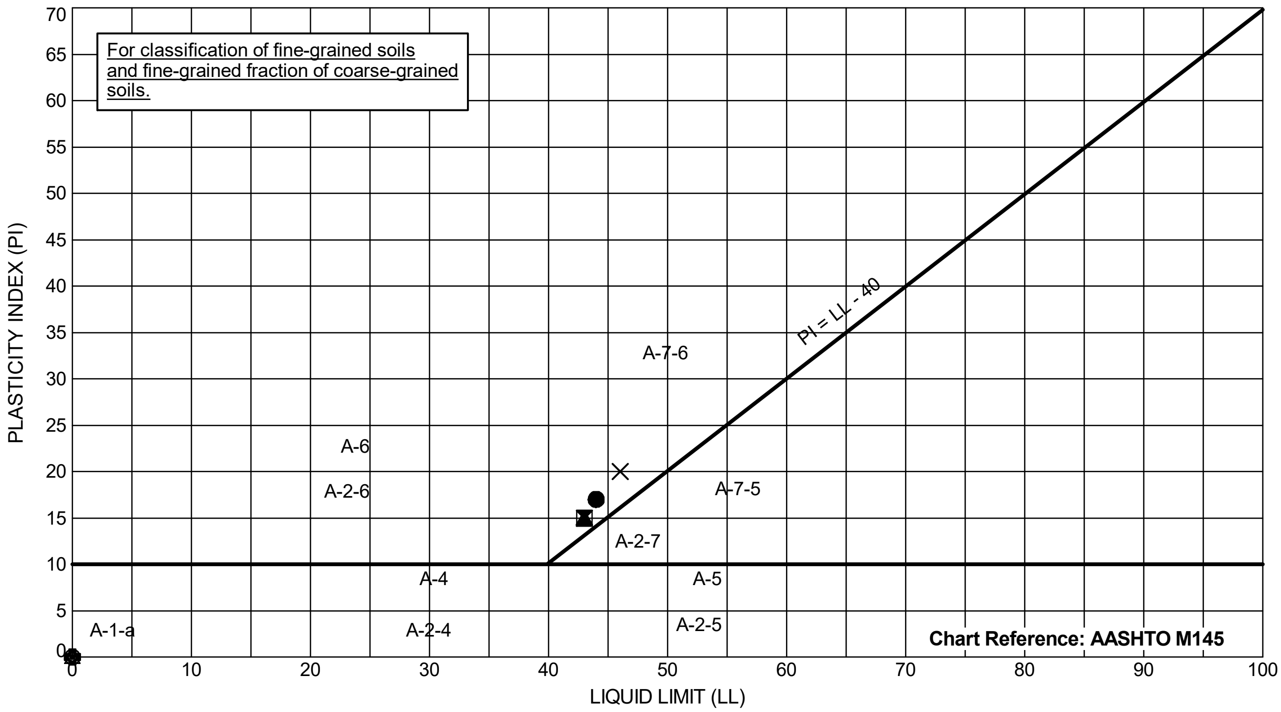
PROJECT NO.: 25003382.001A
DRAWN BY: SB
CHECKED BY: BGS
DATE: 1/23/2025

SIEVE ANALYSIS

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

TABLE
B-3



	Exploration ID	Depth (ft.)	Sample Number	Sample Description	Passing #200	LL	PL	PI
●	D-1	3.5 - 5	SS-1	SILT with SAND (A-7-6)	85	44	27	17
⧗	D-2	3.5	SS-1	SILT with SAND (A-7-6)	85	43	28	15
▲	D-3	3.5	SS-1	SILT with SAND (A-7-6)	82	43	28	15
×	D-4	2	SS-1	LEAN CLAY (A-7-6)	88	46	26	20
⊙	E-1	3.5	SS-1	SILTY GRAVEL with SAND (A-2-4)	29	NP	NP	NP
✿	E-1	13.5	SS-3	SILTY SAND with GRAVEL (A-2-4)	29	NP	NP	NP
○	E-2	3.5	SS-1	SILTY SAND with GRAVEL (A-4)	42	NP	NP	NP
△	E-2	8.5	SS-2		NM	NP	NP	NP

Testing performed in general accordance with AASHTO M145.
NP = Nonplastic
NA = Not Available
NM = Not Measured

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PROJECT NO.: 25003382.001A

DRAWN BY: SB

CHECKED BY: BGS

DATE: 1/23/2025

ATTERBERG LIMITS

Roadway Widening and Improvements
Retaining Walls D & E
Gilcrease Museum Road
Tulsa, OK

TABLE B-4

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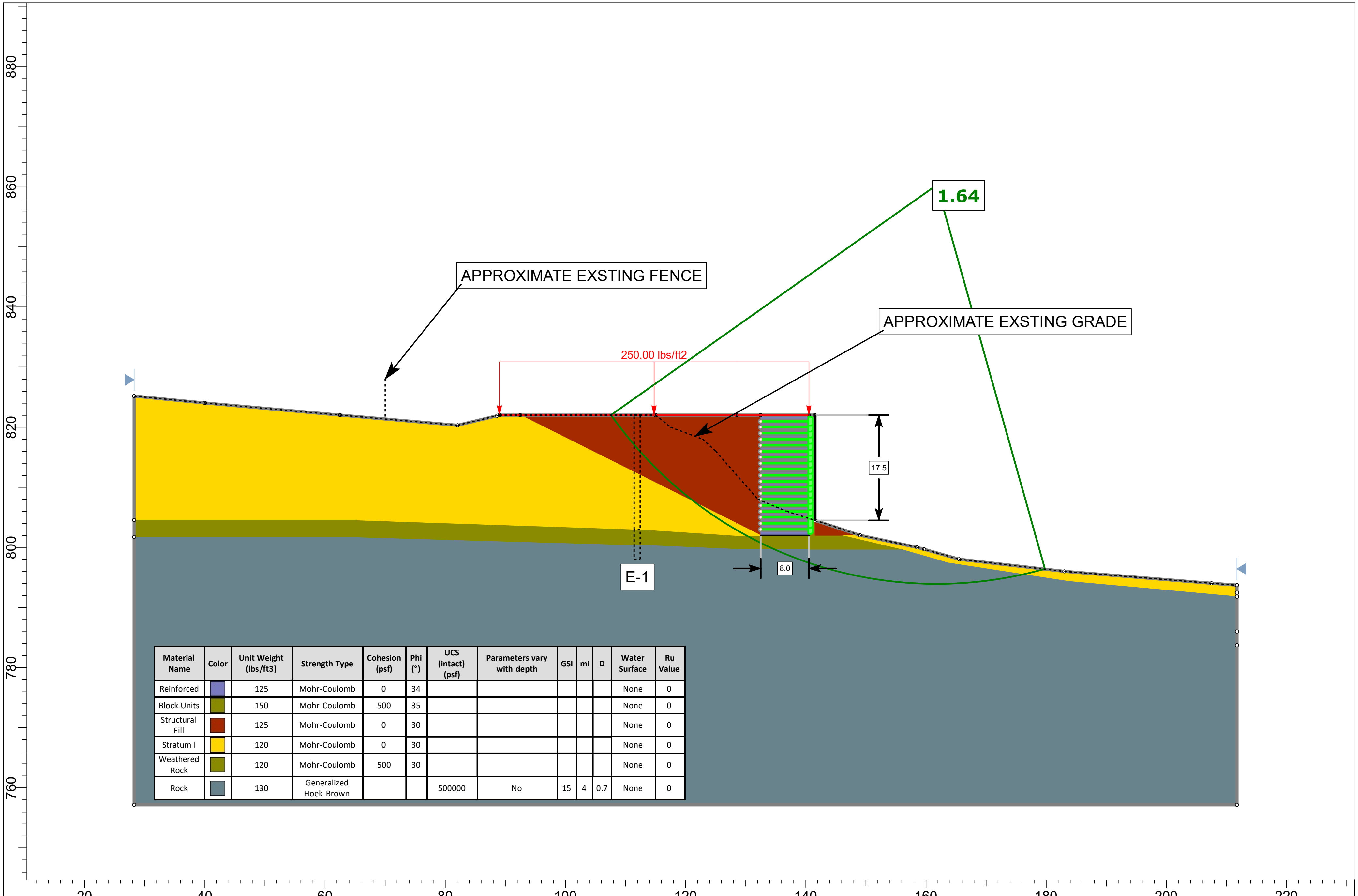
Appendix C



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (°)	UCS (intact) (psf)	Parameters vary with depth	GSI	mi	D	Water Surface	Ru Value
Reinforced		125	Mohr-Coulomb	0	34						None	0
Block Units		150	Mohr-Coulomb	500	35						None	0
Structural Fill		125	Mohr-Coulomb	0	30						None	0
Stratum I		120	Mohr-Coulomb	0	30						None	0
Weathered Rock		120	Mohr-Coulomb	500	30						None	0
Rock		130	Generalized Hoek-Brown			500000	No	15	4	0.7	None	0

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Project	Retaining Walls Study - Walls D & E - Gilcrease Museum Road
Analysis Description	Global Stability - Proposed MSE Wall E - Sta 179+80
Drawn By	J. Thompson
Scale	1:250
Company	Thunderhead Testing, LLC
Date	1/22/2025
File Name	Wall E Global Stability.slmd

SLIDEINTERPRET 9.037

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Appendix D

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.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

Do not rely on this report if your geotechnical engineer prepared it:
- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. *Read and refer to the report in full.*

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:
- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept* *responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are <u>not</u> final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include 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.

Geoenvironmental Concerns Are <u>Not</u> Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will <u>not</u> of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are <u>not</u> building-envelope or mold specialists.***

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