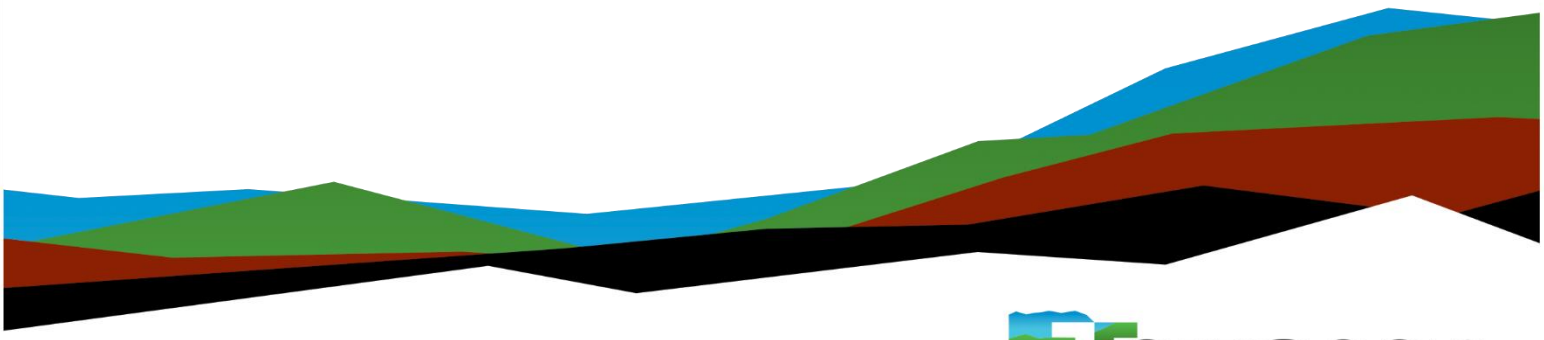
MACA - Kentucky

Revised Preliminary Geotechnical Engineering Report

March 13, 2025 | Terracon Project No. 18245139

Prepared for:

DJ&A
6221 E Silver Maple Circle, Ste 1
Sioux Falls, SD 57110



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March 13, 2025

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Attn: Mr. Chris Brandriet
P: 605-937-6160
E: chrisb@djanda.com

Re: Revised Preliminary Geotechnical Engineering Report
MACA - Kentucky
Mammoth Cave National Park
Mammoth Cave National Park, Kentucky
Terracon Project No. 18245139

Dear Chris:

We have completed the scope of our Revised Preliminary Geotechnical Engineering services for the above referenced project in general accordance with Terracon Proposal No. P18245139 dated May 14, 2024. This revised report presents the findings of the subsurface exploration and provides preliminary geotechnical recommendations concerning earthwork and the design and construction of foundations, slabs and pavement for the proposed project. It also incorporates updates and comments provided to Terracon on March 4, 2025.

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

Sincerely,

Terracon

for

Tim Thomson, P.E.
Senior Engineer

03/13/2025

William E.S. McCloy, P.E.
Geotechnical Department Manager

STATE OF KENTUCKY
WILLIAM E. S. MCCLOY
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LICENSED
PROFESSIONAL ENGINEER

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Note: This report was originally delivered in a web-based format. **Blue Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the Terracon logo will bring you back to this page. For more interactive features, please view your project online at **client.terracon.com**.

Refer to each individual Attachment for a listing of contents.

Introduction

This report presents the results of our subsurface exploration and Revised Preliminary Geotechnical Engineering services performed for the proposed development to be located at Mammoth Cave National Park in Mammoth Cave National Park, Kentucky. The purpose of these services was to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Seismic site classification per IBC
- Site preparation and earthwork
- Demolition considerations
- Dewatering considerations
- Foundation design and construction
- Floor slab design and construction
- Pavement design and construction

The geotechnical engineering Scope of Services for this project included the advancement of test borings, laboratory testing, engineering analysis, and preparation of this report.

Drawings showing the site and boring locations are shown on the **Site Location** and **Exploration Plan**, respectively. The results of the laboratory testing performed on soil samples obtained from the site during our field exploration are included on the boring logs in the **Exploration Results** section.

Project Description

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Based on telephone and email conversations between March 4 and 10, 2025, Terracon understands that the project will now be designed under the IBC 2024. Therefore, this report has been updated to reflect this change as appropriate.

Item	Description
Information Provided	Terracon received a Request for Proposal (RFP) on May 3, 2024 from Mr. Chris Brandriet, with DJ&A. Site plans, details of construction and the project team, and the RFP were included. Multiple meeting and discussions have occurred since the original RFP that has refined the original scope.
Project Description	The project will include construction of two seasonal housing buildings, a storge/multi-purpose building and an outdoor pavilion, as well as pavements for additional parking. **Due to the amount of existing trees and vegetation present on the northern portion of the site, the proposed geotechnical exploration around "Housing Building 2" and the "Storage/Multi-purpose building" could not be performed. Terracon recommends that additional subsurface exploration be performed within the footprint of these structures once clearing and site access can be provided as additional geotechnical recommendations for these structures may be warranted. Terracon can provide a quote for these services upon request.**
Proposed Structure	Based upon a review of a Site Plan dated 11/15/2024 the following structures are anticipated to be part of the development. ▪ Two housing buildings ▪ One Storage/Multi-Purpose Facility ▪ Outdoor Pavilion ▪ Paved parking areas
Building Construction	The project will consist of demolition of existing apartment buildings 97, 98, and 99 and construction of new two-three level, wood-framed structures. Due to site topography, the Housing structures are to have a raised slab with up to 4-feet between finish grade and finished floor elevation. The Storage/Multipurpose Facility is to have a slab on grade ground floor.
Finished Floor Elevation	Based upon a review of Grading Plan dated 11/15/2024 the finished floor elevation of the structures will be as follows: • Housing Building 1 – 774.47 • Housing Building 2 – 774.80 • Storage/Multi-purpose Facility – 774.84 • Outdoor Pavilion – 777.00

Item	Description
Maximum Loads	Anticipated structural loads were provided in an email dated 1/17/25 by Ammon Groesbeck of DJ&A. We will use the following provided loads in estimating settlement. ■ Columns: 20 kips ■ Walls: 3.2 kips per linear foot (klf) ■ Slabs: 120 pounds per square foot (psf)
Grading/Slopes	Based upon a review of the grading plan dated 11/15/2024, up to 5 feet of fill may be required to develop final grades. Final slopes are anticipated with a maximum height of 3 feet and an inclination of 3H:1V (Horizontal: Vertical) or flatter.
Below-Grade Structures	None anticipated nor indicated on the site plan
Free-Standing Retaining Walls	Retaining walls are not expected to be constructed as part of site development to achieve final grades. Sloping or benching is anticipated to facilitate remedial site grade changes.
Pavements	A preferred pavement surfacing has not been identified to us as part of the preliminary information. Asphalt surfacing is common in the area for projects of this nature and is the assumed preference. Anticipated traffic is as follows: ■ Autos/light pickup trucks: 500 vehicles per day ■ Light delivery vehicles: 5 vehicles per day ■ Trash collection trucks: 2 vehicle per week The pavement design period is 20 years.
Building Code	2024 IBC

Terracon should be notified if any of the above information is inconsistent with the planned construction, especially the grading limits, as modifications to our recommendations may be necessary.

Site Conditions

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project is located within a portion of the Mammoth Cave National Park, Kentucky. Approximate GPS Coordinates of center of the site are 37.1845° N and 86.0880° W (See Exhibit D)
Existing Improvements	The area of the proposed development consists of an existing parking lot along the southern portion of the development. The remainder of the proposed development is vacant undeveloped land consisting of a grass field or wooded area.
Current Ground Cover	The site is covered with a mixture of asphalt, grass and vegetation. The northern portion of the development is heavily wooded.
Existing Topography	Based on a Grading Plan dated 11/15/2024, the site slopes downward around the perimeter of the site; approximate maximum grades within the proposed area of disturbance vary from about 768 feet to 785 feet, MSL.

We also collected photographs at the time of our field exploration program(s) and select samples. Representative photos are provided in our **Photography Log**.

Geotechnical Characterization

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of the site. Conditions observed at each exploration point are indicated on the individual logs. The individual logs can be found in the **Exploration Results** and the GeoModel can be found in the **Figures** attachment of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	**Surface Cover**	8 to 12 inches of topsoil
2	**Lean Clay**	Low plasticity clay with variable amounts of silts and sand, some mineral nodules, generally medium stiff to

		very stiff but occasionally soft and very soft at the surface
3	**Fat Clay**	High plasticity clay with variable amounts of silts and sand, stiff, typically encountered below 5 feet

Borings B-1 and B-2 were drilled within the footprint of the Housing Building 1. Borings B-7 and B-8 were performed in the approximate footprint of the Outdoor Pavilion. Borings P-1 through P-4 were performed for the proposed parking lot addition. Due to the presence of trees, Borings B-3 through B-6 could not be performed. Once the trees have been cleared, additional subsurface exploration will be required to for the structures in this area (Housing Building 2 and Storage/Multi-purpose Facility).

The borings typically encountered about 8 to 12 inches of topsoil cover at the surface. Underlying the topsoil cover, the borings encountered lean clay with variable amounts of silt and sand. Natural fat clay was encountered beneath the lean clay and extended to termination depth or auger refusal on apparent limestone bedrock at depths ranging from about 8 to 17 ½ feet below existing grade. The natural clay is typically stiff to very stiff but occasionally very soft to medium stiff near the surface based on Standard Penetration Test (SPT) N-values varying from 1 blow per foot (bpf) to 50+ bpf.

Groundwater Conditions

Groundwater was not observed in the borings while drilling, or for the short duration the borings could remain open. This does not necessarily mean the borings terminated above groundwater, or the water levels summarized above are stable groundwater levels. Due to the low permeability of the soils encountered in the borings, a relatively long period may be necessary for a groundwater level to develop and stabilize in a borehole. Long term observations in piezometers or observation wells sealed from the influence of surface water are often required to define groundwater levels in materials of this type.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. Perched water can also develop on top of bedrock or within the porous fill material. The possibility of groundwater level fluctuations and perched water should be considered when developing the design and construction plans for the project.

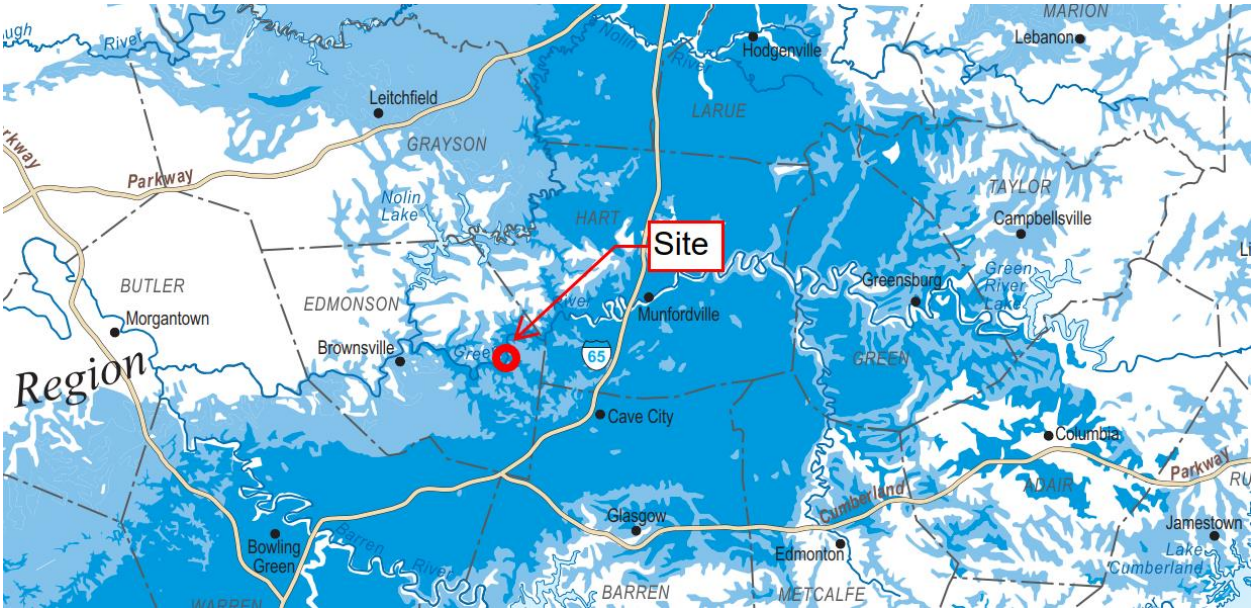
Geologic Hazards

Based upon a review of local geologic maps, the geology of this site is composed of the following geologic formations.

Formation [1]	Description
Big Clifty Sandstone Member Formation	**Big Clifty Sandstone** – Sandstone, shale and interbedded sandstone and shale: Sandstone, grayish-white, light-yellowish-brown, tan, and buff, very fine to medium-grained quartz, subangular to rounded. Thickness 50 to 120 feet
Girkin Formation	**Girkin** – Limestone, shale and siltstone: Limestone, medium-light-gray, brownish-gray, and medium gray. Finley to Medium-crystalline, thin bedded to massive.

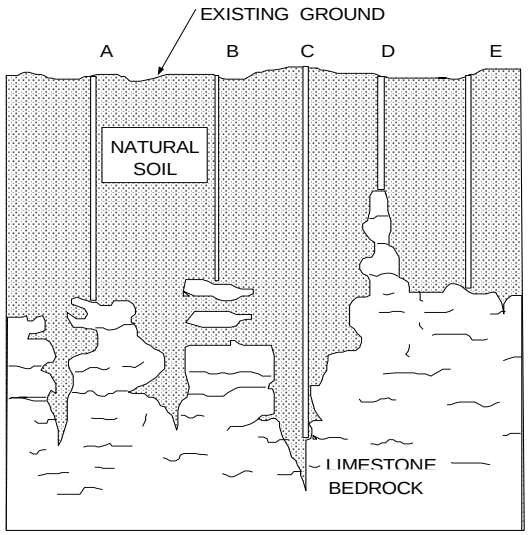
1. Geology of the Mammoth Cave Quadrangle, Kentucky published by the Department of the Interior, United States Geological Survey, (1964).

The project site is in an area of significant karst potential. A portion of the Karst Potential Maps by the Kentucky Geological Survey is shown below. Karst is a distinctive landscape that commonly occurs where carbonate bedrock strata (i.e. limestone and dolostone) are subjected to dissolution weathering by even slightly acidic surface and groundwater. Rainwater picks up carbon dioxide from the atmosphere and as it infiltrates down through the soil profile. The weathering is typified by a chemical solutioning process that progresses along joints, fractures and bedding planes in the bedrock. This process often results in a highly irregular rock profile that contains deep weathered slots filled with soft soils. Voids are created as the bedrock dissolves and over time widened fractures, solution cavities, and caves form. This may progress to ground subsidence and/or sinkholes as soil overburden ravels into or is eroded by groundwater into the subsurface voids.



AUGER REFUSAL ILLUSTRATION

In an area of limestone bedrock, auger refusal can result on slabs of unweathered limestone suspended in the residual soil matrix ("floaters"), on rock "pinnacles" rising above the surrounding bedrock surface, in widened joints that may extend well below the surrounding bedrock surface, or on the upper surface of continuous bedrock. Several of these possible auger refusal conditions are illustrated in the adjacent figure.



THIS FIGURE IS FOR ILLUSTRATIVE PURPOSES ONLY AND DOES NOT NECESSARILY DEPICT THE SPECIFIC BEDROCK CONDITIONS AT THIS SITE

Seismic Site Class

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Previously, Terracon based the seismic site classification on the soil properties observed at the site and as described on the exploration logs and results per IBC 2018 which rendered in our professional opinion a Seismic Site Classification of C be considered for the project. **However, based on the**

project being designed under IBC 2024 criteria, ASCE 7-22, and in the absence of performing additional scope to obtain shear wave velocity data, it is our professional opinion that a Seismic Site Classification of CD be considered for this project. Subsurface explorations at this site were extended to a maximum depth of 17 ½ feet. The site properties below the boring or shear wave test depth and extending to 100 feet below the lowest planned building elevation were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring or test depth.

Geotechnical Overview

Due to the presence and amount of mature trees on the northern portion of the site in the areas of Housing Building 2 and the Storage/Multi-purpose Facility, Terracon's proposed Borings B-3 through B-6 could not be performed. Once the trees and brush have been cleared, additional subsurface exploration will be required to confirm and/or provide geotechnical recommendations for these structures. At a minimum, the level of additional exploration could consist of test pits with backhoe/trackhoe equipment or additional soil test borings under the supervision of the geotechnical engineer of record.

Based on the information obtained from our subsurface explorations in the remaining areas, Housing Building 1 and the site infrastructure can be developed as proposed. However, due to the presence of low strength natural clay in some of the upper soils, subgrade remediation will be required to achieve suitable bearing for buildings support and to control settlements to tolerable limits. During our study, the following geotechnical considerations were identified.

Some low strength natural soils with high moisture content were encountered at the site, such as noted in borings B-1, B-2 and P-3. Softer soils at these boring locations extended to depths of about 3 feet below existing grade. Prior to placing new fill and any construction, some undercutting/replacement and/or recompaction will be required to achieve subgrade stability. The extent of subgrade remediation and near surface subgrade instability will also be dependent upon prevailing weather conditions at the time of grading. Depending upon the amount of new fill to be placed, it may be possible to bridge low strength soils beneath roadway/pavement areas, but we do not recommend bridging of softer soils within the building pads. The lateral extent of these soils can be delineated in the field via proofrolling. The undercut soils can be reused as engineered fill if moisture conditioned to near optimum and if the material meets our fill criteria outlined herein.

The site is underlain by carbonate limestone that is highly susceptible to dissolution along joints and bedding planes in the rock mass. This results in voids and solution channels within the rock strata and a highly irregular bedrock surface. The weathering of

the bedrock and subsequent collapse or erosion of the overburden into these openings results in what is referred to as karst topography. Any construction in karst topography is accompanied by some degree of risk for future internal soil erosion and ground subsidence that could affect the stability of the soil supported structures.

The near surface cohesive soils appear to be moisture sensitive and could become unstable during wet weather and under repetitive construction traffic. Therefore, effective drainage should be implemented early in the construction sequence and maintained after construction to avoid potential subgrade instability issues. We recommend the grading be performed during the warmer and drier times of the year. If grading is performed during the wet season, widespread subgrade instability issues may arise that may require undercutting and replacement of unstable subgrade. Additional recommendations

Our opinion of pavement section thickness design has been developed based on our understanding of the intended use, assumed traffic, and subgrade preparation recommended herein using methodology contained in AASHTO and adjusted with consideration to local practice or local/state design manual. The **Pavements** section includes minimum pavement component thickness.

The **Shallow Foundations** section addresses support of the building directly bearing on native stiff to hard lean/fat clay or engineered fill. We do not expect significant dead load on the floors and recommend either overexcavation of near-surface high plasticity clays to reduce the heave potential or use of suspended slabs to accommodate potential ground heave. The **Floor Slabs** section addresses slab-on-grade support of the building using overexcavation techniques.

Additional site preparation recommendations, including subgrade improvement and fill placement, are provided in the **Earthwork** section.

The recommendations contained in this report are based upon the results of field and laboratory testing (presented in the **Exploration Results**), engineering analyses, and our current understanding of the proposed project. The **General Comments** section provides an understanding of the report limitations.

Earthwork

Earthwork is anticipated to include clearing and grubbing, excavations, and engineered fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria, as necessary, to render the site in the state considered in our geotechnical engineering evaluation for foundations and pavements.

Site Preparation

Prior to placing new fill, existing vegetation, topsoil, trees including stumps and root mats should be removed. Complete stripping of the topsoil should be performed in the proposed building and parking/driveway areas.

Mature trees are located within or near the footprint of some of the proposed buildings, which will require removal at the onset of construction. Tree root systems can remove substantial moisture from surrounding soils. Where trees are removed, the full root ball and all associated dry and desiccated soils should be removed. The soil materials which contain less than 5 percent organics can be reused as engineered fill provided the material is moisture conditioned and properly compacted.

Where fill is placed on existing slopes steeper than 5H:1V, benches should be cut into the existing slopes prior to fill placement. The benches should have a minimum vertical face height of 1 foot and a maximum vertical face height of 3 feet and should be cut wide enough to accommodate the compaction equipment. This benching will help provide a positive bond between the fill and natural soils and reduce the possibility of failure along the fill/natural soil interface.

Although no evidence of fill or underground structures (such as septic tanks, cesspools, basements, and utilities) was observed during the exploration and site reconnaissance, such features could be encountered during construction. If unexpected fills or underground facilities are encountered, such features should be removed, and the excavation thoroughly cleaned prior to backfill placement and/or construction.

Subgrade Preparation

The subgrade should be proofrolled with an adequately loaded vehicle such as a fully-loaded tandem-axle dump truck. The proofrolling should be performed under the observation of the Geotechnical Engineer or representative. Areas excessively deflecting under proofroll should be delineated and subsequently addressed by the Geotechnical Engineer. Excessively wet or dry material should either be removed or moisture conditioned and recompacted.

All exposed areas which will receive new fill, once properly cleared and benched where necessary, should be scarified to a minimum depth of 10 inches, moisture conditioned as necessary, and compacted per the compaction requirements in this report. Compacted engineered fill soils should then be placed to the proposed design grade and the moisture content and compaction of subgrade soils should be maintained until foundation or pavement construction.

Based upon the subsurface conditions determined from the geotechnical exploration, subgrade soils exposed during construction are anticipated to be relatively workable;

however, the workability of the subgrade may be affected by precipitation, repetitive construction traffic or other factors. If unworkable conditions develop, workability may be improved by scarifying and drying.

Excavation

We anticipate that excavations for the proposed construction can be accomplished with conventional earth moving equipment. The bottom of excavations should be thoroughly cleaned of loose soils and disturbed materials prior to backfill placement and/or construction.

Soil Stabilization

Methods of subgrade improvement, as described below, could include scarification, moisture conditioning and recompaction, removal of unstable materials and replacement with granular fill (with or without geosynthetics), and chemical stabilization. The appropriate method of improvement, if required, would be dependent on factors such as schedule, weather, the size of area to be stabilized, and the nature of the instability. More detailed recommendations can be provided during construction as the need for subgrade stabilization occurs. Performing site grading operations during warm seasons and dry periods would help reduce the amount of subgrade stabilization required.

If the exposed subgrade is unstable during proofrolling operations, it could be stabilized using one of the methods outlined below.

- **Scarification and Recompaction -** It may be feasible to scarify, dry, and recompact the exposed soils. The success of this procedure would depend primarily upon favorable weather and sufficient time to dry the soils. Stable subgrades likely would not be achievable if the thickness of the unstable soil is greater than about 1 foot, if the unstable soil is at or near groundwater levels, or if construction is performed during a period of wet or cool weather when drying is difficult.
- **Crushed Stone** - The use of crushed stone or crushed gravel is a common procedure to improve subgrade stability. Typical undercut depths would be expected to range from about 18 to 24 inches below finished subgrade elevation. The use of high modulus geotextiles (i.e., engineering fabric or geogrid) could also be considered after underground work such as utility construction is completed. Prior to placing the fabric or geogrid, we recommend that all below grade construction, such as utility line installation, be completed to avoid damaging the fabric or geogrid. Equipment should not be operated above the fabric or geogrid until one full lift of crushed stone fill is placed above it. The maximum particle size of granular material placed over geotextile fabric or geogrid should not exceed 1-1/2 inches.

- **Chemical Modification** - Improvement of subgrades with portland cement or class C fly ash could be considered for improving unstable soils. Chemical modification should be performed by a pre-qualified contractor having experience with successfully stabilizing subgrades in the project area on similar sized projects with similar soil conditions. Results of chemical analysis of the additive materials should be provided to the geotechnical engineer prior to use. The hazards of chemicals blowing across the site or onto adjacent property should also be considered. Additional testing would be needed to develop specific recommendations to improve subgrade stability by blending chemicals with the site soils. Additional testing could include, but not be limited to, determining the most suitable stabilizing agent, the optimum amounts required, the presence of sulfates in the soil, and freeze-thaw durability of the subgrade.

Further evaluation of the need and recommendations for subgrade stabilization can be provided during construction as the geotechnical conditions are exposed.

Fill Material Types

Fill required to achieve design grade should be classified as engineered fill and general fill. Engineered fill is material used below, or within 10 feet of structures, and pavements, concrete slabs or constructed slopes. General fill is material used to achieve grade outside of these areas.

Fill materials should meet the following material property requirements. Regardless of its source, compacted fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade.

Excavated on-site soil may be selectively reused as fill below, or within 10 feet of structure, pavement, concrete slabs, and any compacted slopes. Material property requirements for on-site soil and offsite borrow material for use as engineered fill and general fill are noted in the table below:

Soil Type [1]	USCS Classification	Acceptable Parameters (for Engineered Fill)	Acceptable Parameters (for General Fill)
Low Plasticity Cohesive	CL, CL-ML[2], ML[2]	Liquid Limit ≥ 45 Plasticity index ≤ 25 Can be used in all areas except where confined footing undercut prevents compactive efforts using larger equipment	Can be used in all areas

Soil Type [1]	USCS Classification	Acceptable Parameters (for Engineered Fill)	Acceptable Parameters (for General Fill)
High Plasticity Cohesive	CH	Liquid limit ≥ 45 but ≤ 60 Plasticity index ≤ 30 Not recommended within upper 2 feet of building slab or foundation or 1 feet of finished pavement.	Can be used in all areas
Granular	GW[3]	Can be used in all areas	Can be used in all areas
Clean well graded processed rock, "shot rock", or surge stone	--	Max. rock size 8 (surge) to 12 inches (shot or processed) Can be used in all areas except in confined footing undercut areas or trenches where large compactor cannot be used	Maximum rock size 2/3 of the lift thickness

1. Engineered and general fill should consist of approved materials free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to use on this site. Additional geotechnical consultation should be provided prior to use of uniformly graded gravel on the site.
2. High silt content soils (CL-ML, ML) are extremely sensitive to variations in moisture content and can lose strength rapidly with increases in moisture. It should be noted that the moisture content of the silt must be closely controlled to achieve the desired degree of compaction. Drying of soils excavated from deeper cut areas of the site should be anticipated prior to use as engineered fill.
3. Similar to Kentucky Transportation Cabinet (KYTC) "Standard Specifications for Road and Bridge Construction", 2019 Edition Section 805 – Coarse Aggregate.

Fill Placement and Compaction Requirements

Engineered and general fill should meet the following compaction requirements.

Item	Engineered Fill	General Fill
Maximum Lift Thickness	8 inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used 12 to 18 inches for surge and "shot rock"[4]	Same as engineered fill
Minimum Compaction Requirements [1,2,3]	98% of max. below foundations, floor slabs, and pavements Surge and "shot rock" to be compacted with heavy-duty vibratory smooth drum roller or D-6 class dozer making ten passes (five in one direction and 5 at right angle to initial passes) or until the material is not yielding under the load.	92% of max.
Water Content Range [1]	Low plasticity cohesive: -1% to +3% of optimum High plasticity cohesive: 0 to +3% of optimum Granular: -2% to +2% of optimum	As required to achieve min. compaction requirements

1. Maximum density and optimum water content as determined by the standard Proctor test (ASTM D 698).
2. High plasticity cohesive fill should not be compacted to more than 100% of standard Proctor maximum dry density.
3. If the granular material is a coarse sand or gravel, or of a uniform size, or has a low fines content, compaction comparison to relative density may be more appropriate. In this case, granular materials should be compacted to at least 70% relative density (ASTM D 4253 and D 4254). Materials not amenable to density testing should be placed and compacted to a stable condition observed by the Geotechnical Engineer or representative.
4. Approval of surge and "shot rock" should be made prior to placement. Any rock fill containing more than 5% clay fines should not be used as engineered fill.

Utility Trench Backfill

Any soft or unsuitable materials encountered at the bottom of utility trench excavations should be removed and replaced with engineered fill or bedding material in accordance with public works specifications for the utility be supported. This recommendation is particularly applicable to utility work requiring grade control and/or in areas where

subsequent grade raising could cause settlement in the subgrade supporting the utility. Trench excavation should not be conducted below a downward 1:1 projection from existing foundations without engineering review of shoring requirements and geotechnical observation during construction.

On-site materials are considered suitable for backfill of utility and pipe trenches from 1 foot above the top of the pipe to the final ground surface, provided the material is free of organic matter and deleterious substances.

Trench backfill should be mechanically placed and compacted as discussed earlier in this report. Compaction of initial lifts should be accomplished with hand-operated tampers or other lightweight compactors. Where trenches are placed beneath slabs or footings, the backfill should satisfy the gradation and expansion index requirements of engineered fill discussed in this report. Flooding or jetting for placement and compaction of backfill is not recommended.

For low permeability subgrades, utility trenches are a common source of water infiltration and migration. Utility trenches penetrating beneath the building should be effectively sealed to restrict water intrusion and flow through the trenches, which could migrate below the building. The trench should provide an effective trench plug that extends at least 5 feet from the face of the building exterior. The plug material should consist of cementitious flowable fill or low permeability clay. The trench plug material should be placed to surround the utility line. If used, the clay trench plug material should be placed and compacted to comply with the water content and compaction recommendations for engineered fill stated previously in this report.

Grading and Drainage

All grades must provide effective drainage away from the building during and after construction and should be maintained throughout the life of the structure. Water retained next to the building can result in soil movements greater than those discussed in this report. Greater movements can result in unacceptable differential floor slab and/or foundation movements, cracked slabs and walls, and roof leaks. The roof should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet from the building.

Exposed ground should be sloped and maintained at a minimum 5% away from the building for at least 10 feet beyond the perimeter of the building. Locally, flatter grades may be necessary to transition ADA access requirements for flatwork. After building construction and landscaping have been completed, final grades should be verified to document effective drainage has been achieved. Grades around the structure should also be periodically inspected and adjusted, as necessary, as part of the structure's maintenance program. Where paving or flatwork abuts the structure, a maintenance

program should be established to effectively seal and maintain joints and prevent surface water infiltration.

Earthwork Construction Considerations

Shallow excavations for the proposed structure are anticipated to be accomplished with conventional construction equipment. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of soil-supported improvements such as floor slabs and pavements. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety or the contractor's activities; such responsibility shall neither be implied nor inferred.

Construction Observation and Testing

The earthwork efforts should be observed by the Geotechnical Engineer (or others under their direction). Observation should include documentation of adequate removal of surficial materials (vegetation, topsoil, and pavements), evaluation and remediation of existing fill materials, as well as proofrolling and mitigation of unsuitable areas delineated by the proofroll.

Each lift of compacted fill should be tested, evaluated, and reworked, as necessary, as recommended by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 2,500 square feet of compacted fill in the building areas and 5,000 square feet in pavement areas. Where not specified by local ordinance, one density and water content test should be performed for every 100 linear feet of compacted utility trench backfill and a minimum of one test performed for every 10 vertical inches of compacted backfill.

In areas of foundation excavations, the bearing subgrade should be evaluated by the Geotechnical Engineer. If unanticipated conditions are observed, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

Karst Mitigation Techniques

The risks associated with development in karst prone geology can be reduced by careful attention during site preparation activities. Site design should include provisions for positive drainage, and water should not be allowed to pond on the site, both during and after construction. Surface runoff including roof drain discharge should be captured in a storm water system and conveyed off property.

The grading contractor should be alert during construction to any indication of possible incipient sinkholes within the subsurface. Given the risk for karst related problems in the local geology, it is essential that stripping and proofrolling operations be observed by the geotechnical engineer or their representatives to detect the presence of near surface karst features that may require remediation. Sinkhole features encountered during the site grading, or during later stages of construction, should be reviewed by the geotechnical engineer. Further assessment of specific, unusual features such as areas of unusually thick topsoil or silt, where natural processes have filled older sinkholes, open throats, or other features such as fresh or old soil dropouts, may be warranted if discovered during site development.

While the anticipated construction on this site may not be different from other developments in the surrounding area or already developed in this similar geology, the karst mitigation measures provided below are intended to be a general guide.

Avoidance

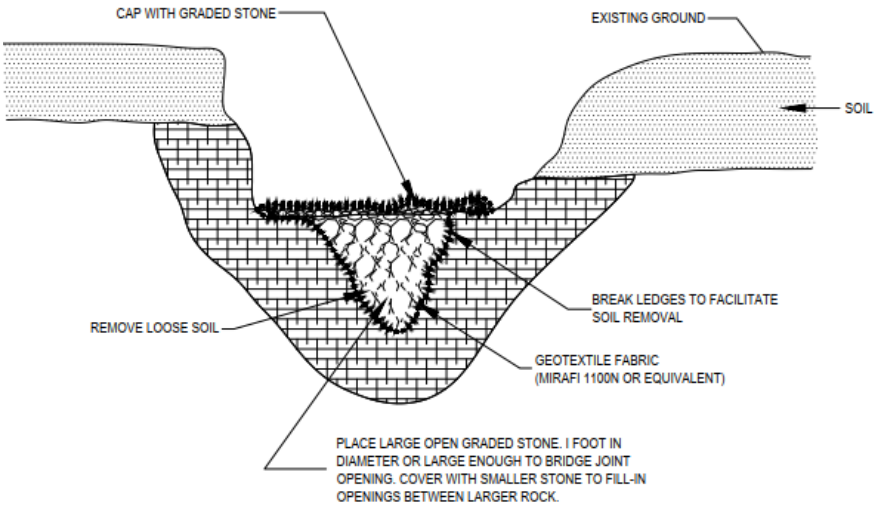
Avoidance (i.e., moving to areas of the site where karst activity is not incipient or occurring to a limited extent) is often the least costly option but the risk for future karst related problems would need to be weighed against the availability of space to construct the development. To the extent possible, buildings and other critical structures should be located away from known karst features or located in areas where more economical methods of mitigation can be employed. We also recommend that detention/retention ponds be located outside of areas with known karst features. Removal of soil overburden, introduction of water into the subsurface, and fluctuations in the water level are catalysts in allowing subsurface voids to migrate to the ground surface and

ultimately form a sinkhole. Fluctuation of water levels cause a saturation in the soil forming an arch over the cavity. When water levels drop, buoyancy is no longer supplied by the water and the saturated soil collapses into the void where it is carried away. Consideration should be given to lining ponds with geomembranes or geosynthetic clay liners to limit water infiltration into the subsurface.

Sinkhole Remediation via Inverted Rock Filter

In karst geology, during site grading and construction, the potential for a surface collapse is elevated due to vibrations, water intrusion, and potentially excavating stiff bridging soils from above a weakened soil or void. The below image depicts a conventional shallow collapse remediation referred to as an inverted rock filter. This method of remediation may prove more economical for project budget and will be easier to implement prior to construction. The collapse area is excavated to the throat or smallest entrance of the sinkhole where bedrock is surrounding the void on all sides with the slopes graded at an angle. The area is lined with a geotextile fabric to allow water to pass into the feature without the erosion of soil fines. The fabric lengths should extend outside the sinkhole so that it can extend or fold back over the top of the repair. Large rip-rap stone is then placed to cover the opening. The size and amount of rip-rap stone will depend on the opening size. After the large stone has been placed, smaller open-graded stone, such as No. 57 or No. 2 stone, can be placed and compacted to cap the large stone. The geotextile fabric can then be folded over the top enclosing the repair. The remaining fill can consist of available fill material found on-site.

This method is suitable for pavement and slab areas. Any collapses that occur below foundations should be evaluated and may require the use of a concrete backfill versus this inverted filter backfill.



Shallow Foundations

If the site has been prepared in accordance with the requirements noted in **Earthwork**, the following design parameters are applicable for shallow foundations for the Housing Building 1.

Design Parameters – Compressive Loads

Item	Description
Maximum Net Allowable Bearing Pressure [1, 2]	2,500 psf - foundations bearing upon engineered fill or stiff (or better) native soils
Minimum Foundation Dimensions	Per IBC 1809.7
Ultimate Passive Resistance [4] **(equivalent fluid pressures)**	295 pcf (cohesive backfill) 350 pcf (granular backfill)
Coefficient of Sliding Resistance [5]	0.35 (native soils/engineered fills)
Minimum Embedment below Finished Grade [6]	Footings: 24 inches
Estimated Total Settlement from Structural Loads [2]	Less than about 1 inch
Estimated Differential Settlement [2, 7]	About ¾ of total settlement

1. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. Values assume that exterior grades are no steeper than 20% within 10 feet of structure.
2. Values provided are for maximum loads noted in **Project Description**. Additional geotechnical consultation will be necessary if higher loads are anticipated.
3. Unsuitable or soft soils should be overexcavated and replaced per the recommendations presented in **Earthwork**.
4. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted engineered fill be placed against the vertical footing face. Assumes no hydrostatic pressure.
5. Can be used to compute sliding resistance where foundations are placed on suitable soil/materials. Frictional resistance for granular materials is dependent on the bearing pressure which may vary due to load combinations. For fine-

Item	Description

grained materials, lateral resistance using cohesion should not exceed ½ the dead load.

6. Embedment necessary to minimize the effects of frost and/or seasonal water content variations. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.
7. Differential settlements are noted for equivalent-loaded foundations and bearing elevation as measured over a span of 50 feet.

Design Parameters – Overturning and Uplift Loads

Shallow foundations subjected to overturning loads should be proportioned such that the resultant eccentricity is maintained in the center-third of the foundation (e.g., e < b/6, where b is the foundation width). This requirement is intended to keep the entire foundation area in compression during the extreme lateral/overturning load event. Foundation oversizing may be required to satisfy this condition.

Uplift resistance of spread footings can be developed from the effective weight of the footing and the overlying soils with consideration to the IBC basic load combinations.

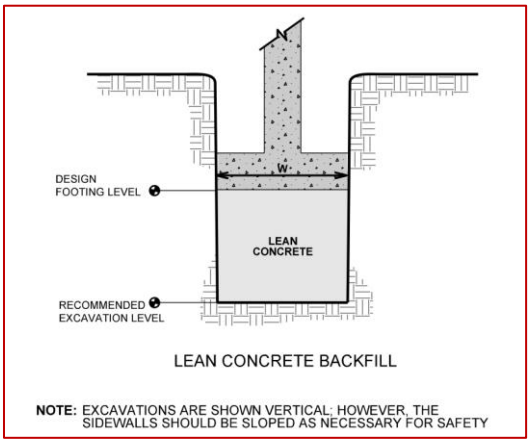
Item	Description
Soil Moist Unit Weight	110 pcf
Soil Effective Unit Weight[1]	40 pcf
Soil weight included in uplift resistance	Soil included within the prism extending up from the top perimeter of the footing at an angle of 20 degrees from vertical to ground surface

1. Effective (or buoyant) unit weight should be used for soil above the foundation level and below a water level. The high groundwater level should be used in uplift design as applicable.

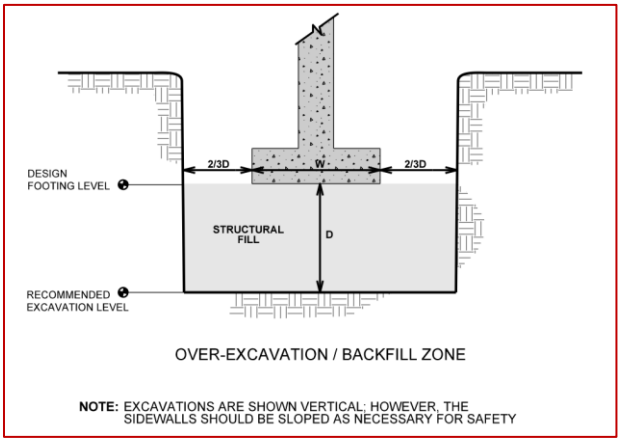
Foundation Construction Considerations

As noted in **Earthwork**, the footing excavations should be evaluated under the observation of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil/rock, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the footing excavations should be removed/reconditioned before foundation concrete is placed.

If unsuitable bearing soils are observed at the base of the planned footing excavation, the excavation should be extended deeper to suitable soils, and the footings could bear directly on these soils or on lean concrete backfill placed in the excavations. The lean concrete replacement zone is illustrated on the sketch below.



Overexcavation for engineered fill placement below footings should be conducted as shown below. The overexcavation should be backfilled up to the footing base elevation, with lean clay placed, as recommended in the **Earthwork** section.



Floor Slabs

Design parameters for floor slabs assume the requirements for **Earthwork** have been followed. Specific attention should be given to positive drainage away from the structure and positive drainage of the aggregate base beneath the floor slab.

Floor Slab Design Parameters

Item	Description
Floor Slab Support[1]	Use minimum 4 inches base course meeting material specifications of ACI 302and compacted to at least 98% of ASTM D698
Estimated Modulus of Subgrade Reaction [2]	110 pounds per square inch per inch (psi/in) for point loads

1. Floor slabs should be structurally independent of building footings or walls to reduce the possibility of floor slab cracking caused by differential movements between the slab and foundation.
2. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in **Earthwork**, and the floor slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.

The use of a vapor retarder should be considered beneath concrete slabs on grade covered with wood, tile, carpet, or other moisture sensitive or impervious coverings, when the project includes humidity-controlled areas, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

Saw-cut contraction joints should be placed in the slab to help control the location and extent of cracking. For additional recommendations, refer to the ACI Design Manual. Joints or cracks should be sealed with a waterproof, non-extruding compressible compound specifically recommended for heavy duty concrete pavement and wet environments.

Where floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or floor slab cracks beyond the length of the structural dowels. The Structural Engineer should account for potential differential settlement through use of sufficient control joints, appropriate reinforcing or other means.

Floor Slab Construction Considerations

Finished subgrade, within and for at least 10 feet beyond the floor slab, should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or

desiccated prior to construction of floor slabs, the affected material should be removed, and engineered fill should be added to replace the resulting excavation. Final conditioning of the finished subgrade should be performed immediately prior to placement of the floor slab support course.

Prior to construction of grade supported slabs, varying levels of remediation may be required to reestablish stable subgrades within slab areas due to construction traffic, rainfall, disturbance, desiccation, etc. As a minimum, the following measures are recommended.

- Confirm that interior trench backfill placed beneath slabs is compacted in accordance with recommendations outlined in this report.
- All floor slab subgrade areas should be moisture-conditioned and properly compacted to the recommendations in this report immediately prior to placement of the stone base and concrete.

The Geotechnical Engineer should observe the condition of the floor slab subgrades immediately prior to placement of the floor slab support course, reinforcing steel, and concrete. Attention should be paid to high traffic areas that were rutted and disturbed earlier, and to areas where backfilled trenches are located.

Pavements

Pavement Subgrade Support Characteristics

On most project sites, the site grading is accomplished relatively early in the construction phase. Fills are placed and compacted in a uniform manner. However, as construction proceeds, excavations are made into these areas, rainfall and surface water saturates some areas, heavy traffic from concrete trucks and other delivery vehicles disturbs the subgrade and many surface irregularities are filled in with loose soils to improve trafficability temporarily. As a result, the pavement subgrades, initially prepared early in the project, should be carefully evaluated as the time for pavement construction approaches.

General Pavement Comments

Pavement designs are provided for the traffic conditions and pavement life conditions as noted in **Project Description** and in the following sections of this report. A critical aspect of pavement performance is site preparation. Pavement designs noted in this section must be applied to the site which has been prepared as recommended in the **Earthwork** section. The section thicknesses and traffic conditions in this report do not account for construction traffic, incomplete placement of the full pavement section, or

loads beyond what was assumed or provided. If the contractor or owners are aware or require additional sections or traffic count considerations, Terracon should be provided that information for our review.

Pavement Design Parameters

A California Bearing Ratio (CBR) of 3 was used for the subgrade for the asphaltic concrete (AC) pavement designs. A modulus of subgrade reaction of 110 pci was used for the Portland cement concrete (PCC) pavement designs. The value was empirically derived based upon our experience with the lean clay subgrade soils and our expectation of the quality of the subgrade as prescribed by the **Site Preparation** conditions as outlined in **Earthwork**. A modulus of rupture of 580 psi was used in design for the concrete (based on correlations with a minimum 28-day compressive strength of 4,000 psi).

Pavement Section Thicknesses

The following table provides our estimated minimum thickness of PCC pavements.

Layer	Asphaltic Concrete Design Thickness (inches)	
	Light Duty [1]	Heavy Duty [1]
AC Surface [2]	1 ½	1 ½
AC Binder [2]	1 ½	2
Aggregate Base [2]	6	8

1. See **Project Description** and design parameters discussed in the previous section for more specifics regarding Light Duty and Heavy-Duty traffic.
2. Asphalt concrete aggregates and base course materials should conform to the Kentucky Transportation Cabinet (KYTC) "Standard Specifications for Road and Bridge Construction", 2019 Edition, Section 805 for Dense Graded Aggregate Base (DGA) and Section 804 for Asphalt Base and Surface Course.

The following table provides our estimated minimum thickness of PCC pavements.

Layer	Portland Cement Concrete Design		
	Thickness (inches)		
	Light Duty [1]	Heavy Duty [1]	Dumpster Approach/Apron [3]
PCC [2,4]	5	6½	7
Aggregate Base [2]	4	4	4

1. See **Project Description** and design parameters discussed in the previous section for more specifics regarding traffic classifications.
2. All materials should meet the current Kentucky Transportation Cabinet (KYTC) "Standard Specifications for Road and Bridge Construction", 2019 Edition.
3. In areas of anticipated heavy traffic, fire trucks, delivery trucks, or concentrated loads (e.g., dumpster approach/apron), and areas with repeated turning or maneuvering of heavy vehicles. Additional steel reinforcement within aprons is not common but the use of dowels at the connection of aprons to dumpster pads may help alleviate potential cracking from concentrated wheel loads.
4. Portland cement concrete should be 4,000 psi compressive strength at 28 days. PCC pavements are recommended for trash container pads and in any other areas subjected to heavy wheel loads and/or turning traffic such as entrance aprons.

Areas for parking of heavy vehicles, concentrated turn areas, and start/stop maneuvers could require thicker pavement sections. Edge restraints (i.e. concrete curbs or aggregate shoulders) should be planned along curves and areas of maneuvering vehicles.

A minimum 4-inch thick base course layer is recommended to help reduce potential for slab curl, shrinkage cracking, and subgrade pumping through joints. Proper joint spacing will also be required to prevent excessive slab curling and shrinkage cracking. Joints should be sealed to prevent entry of foreign material and doweled where necessary for load transfer. PCC pavement details for joint spacing, joint reinforcement, and joint sealing should be prepared in accordance with ACI 330 and ACI 325.

Where practical, we recommend early-entry cutting of crack-control joints in PCC pavements. Cutting of the concrete in its "green" state typically reduces the potential for micro-cracking of the pavements prior to the crack control joints being formed, compared to cutting the joints after the concrete has fully set. Micro-cracking of pavements may lead to crack formation in locations other than the sawed joints, and/or reduction of fatigue life of the pavement.

Openings in pavements, such as decorative landscaped areas, are sources for water infiltration into surrounding pavement systems. Water can collect in the islands and migrate into the surrounding subgrade soils thereby degrading support of the pavement. Islands with raised concrete curbs, irrigated foliage, and low permeability near-surface soils are particular areas of concern. The civil design for the pavements with these conditions should include features to restrict or collect and discharge excess water from the islands. Examples of features are edge drains connected to the stormwater collection system, longitudinal subdrains, or other suitable outlets and impermeable barriers preventing lateral migration of water such as a cutoff wall installed to a depth below the pavement structure.

Pavement Drainage

Pavements should be sloped to provide rapid drainage of surface water. Water allowed to pond on or adjacent to the pavements could saturate the subgrade and contribute to premature pavement deterioration. In addition, the pavement subgrade should be graded to provide positive drainage within the granular base section. Appropriate sub-drainage or connection to a suitable daylight outlet should be provided to remove water from the granular subbase.

Pavement Maintenance

The pavement sections represent minimum recommended thicknesses and, as such, periodic upkeep should be anticipated. Preventive maintenance should be planned and provided for through an on-going pavement management program. Maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Pavement care consists of both localized (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Additional engineering consultation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur, and repairs may be required.

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope down from the edges at a minimum 2%.
- Subgrade and pavement surfaces should have a minimum 2% slope to promote proper surface drainage.
- Install pavement drainage systems surrounding areas anticipated for frequent wetting.
- Install joint sealant and seal cracks immediately.

- Seal all landscaped areas in or adjacent to pavements to reduce moisture migration to subgrade soils.
- Place compacted, low permeability backfill against the exterior side of curb and gutter.
- Place curb, gutter and/or sidewalk directly on clay subgrade soils rather than on unbound granular base course materials.

General Comments

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly affect excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety and cost estimating including excavation support and dewatering requirements/design are the responsibility of others. Construction and site development have the potential to affect adjacent properties. Such

impacts can include damages due to vibration, modification of groundwater/surface water flow during construction, foundation movement due to undermining or subsidence from excavation, as well as noise or air quality concerns. Evaluation of these items on nearby properties are commonly associated with contractor means and methods and are not addressed in this report. The owner and contractor should consider a preconstruction/precondition survey of surrounding development. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

Figures

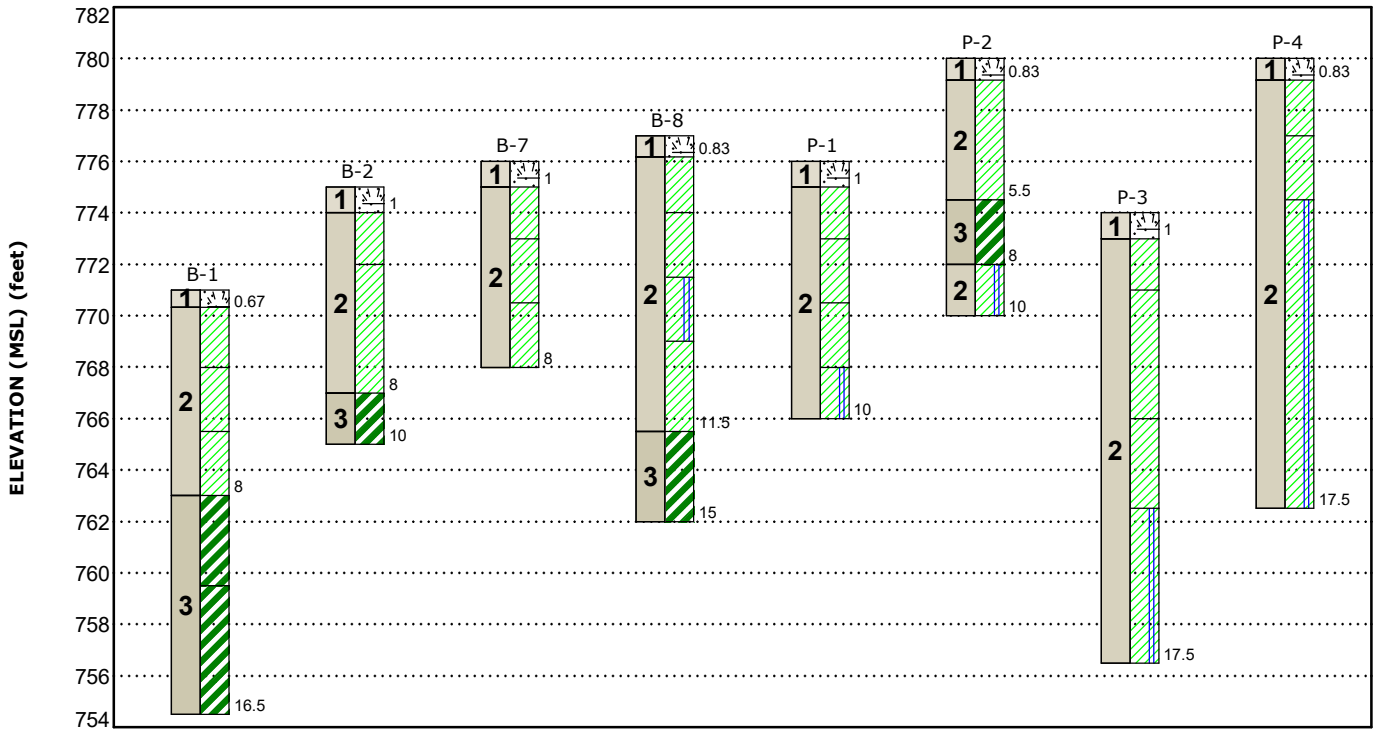
Contents:

GeoModel

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike
Ste 905
Nashville, TN

GeoModel



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description
1	Surface Cover	8 to 12 inches of topsoil
2	Lean Clay	Low plasticity clay with variable amounts of silts and sand, some mineral nodules, generally medium stiff to very stiff but occasionally soft and very soft at the surface
3	Fat Clay	High plasticity clay with variable amounts of silts and sand, stiff, typically encountered below 5 feet

Legend

Topsoil
Lean Clay
Fat Clay
Lean Clay with Silt

NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.
Numbers adjacent to soil column indicate depth below ground surface.

Exploration and Testing Procedures

Field Exploration

Number of Exploration Points[1]	Approximate Exploration Depth (feet)	Location
2 (B-1 & B-2)	10 to 16 ½	Housing Building 1
2 (B-7 & B-8)	8 to 15	Outdoor Pavilion
4 (P-1 through P-4)	10 to 17 ½	Parking Lot

[1] Due to the presence and number of mature trees on the northern portion of the site in the areas of Housing Building 2 and the Storage/Multi-purpose Facility, Terracon's proposed Borings B-3 through B-6 could not be performed.

Boring Layout and Elevations: Terracon personnel provided the boring layout using handheld GPS equipment (estimated horizontal accuracy of about ±10 feet) and referencing existing site features. Approximate ground surface elevations were obtained by interpolation from the provided grading plan dated 11/15/2024. If elevations and a more precise boring layout are desired, we recommend borings be surveyed.

Subsurface Exploration Procedures: We advanced the borings with a track-mounted rotary drill rig using continuous flight augers (solid stem and/or hollow stem, as necessary, depending on soil conditions). Four samples were obtained in the upper 10 feet of each boring and at intervals of 5 feet thereafter. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. For safety purposes, all borings were backfilled with auger cuttings after their completion.

We also observed the boreholes while drilling and at the completion of drilling for the presence of groundwater. Groundwater was not observed at these times in the boreholes.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials observed during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests. The laboratory testing program included the following types of tests:

- Water content
- Atterberg limits
- Grain size analysis

The laboratory testing program often included examination of soil samples by an engineer. Based on the results of our field and laboratory programs, we described and classified the soil samples in accordance with the Unified Soil Classification System.

Photography Log

Photo 1 – View looking North, vicinity of P-2

Photo 2 – Northern Grass Field

Photo 3 – View Looking Northeast

Photo 4 – View Looking Northwest along Maintenance Road

Photo 5 – Wooded Area on Northern Portion of the Site

Photo 6 - Wooded Area on Northern Portion of the Site

Site Location and Exploration Plans

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted above.

Site Location

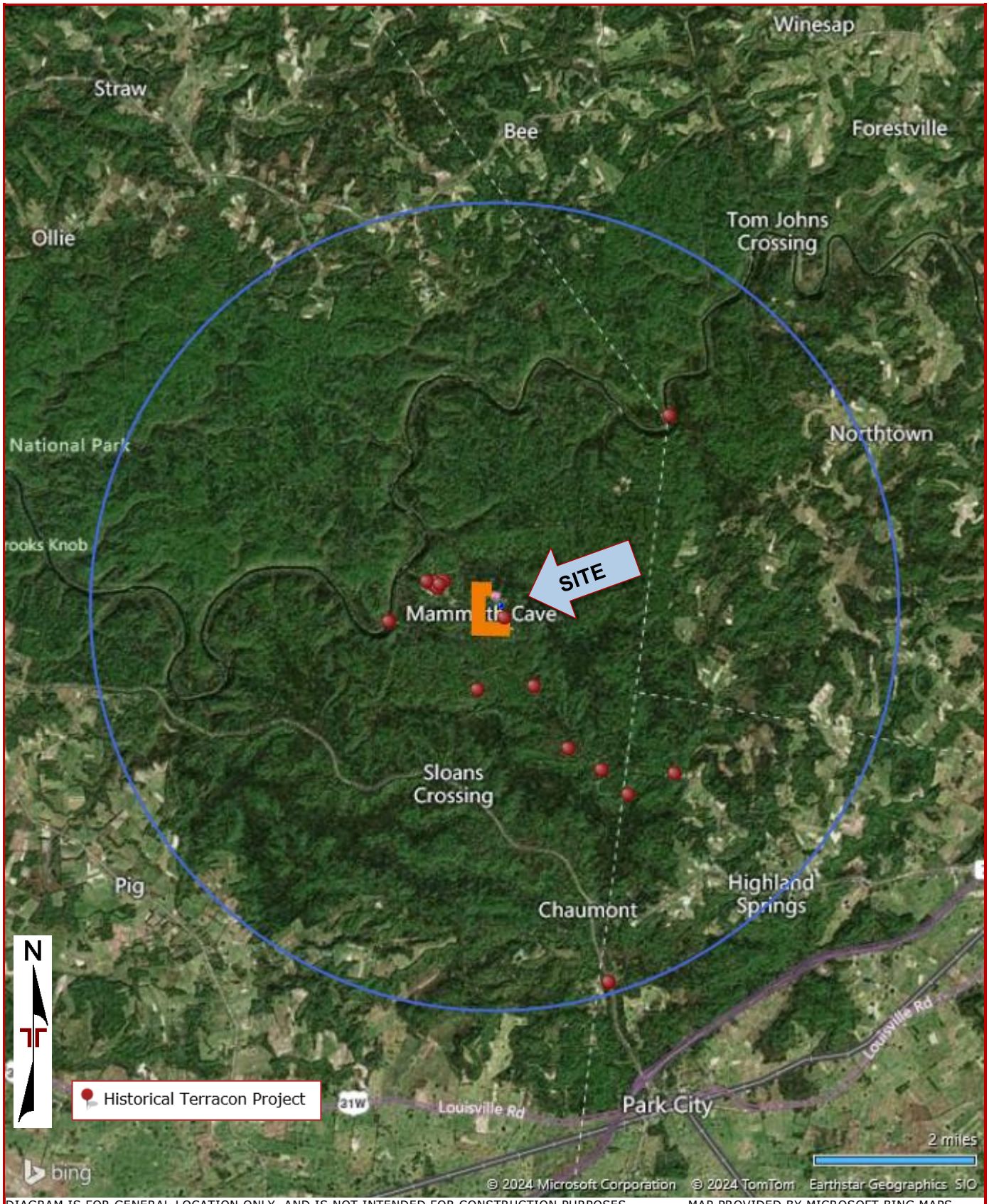


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plan with Overlay

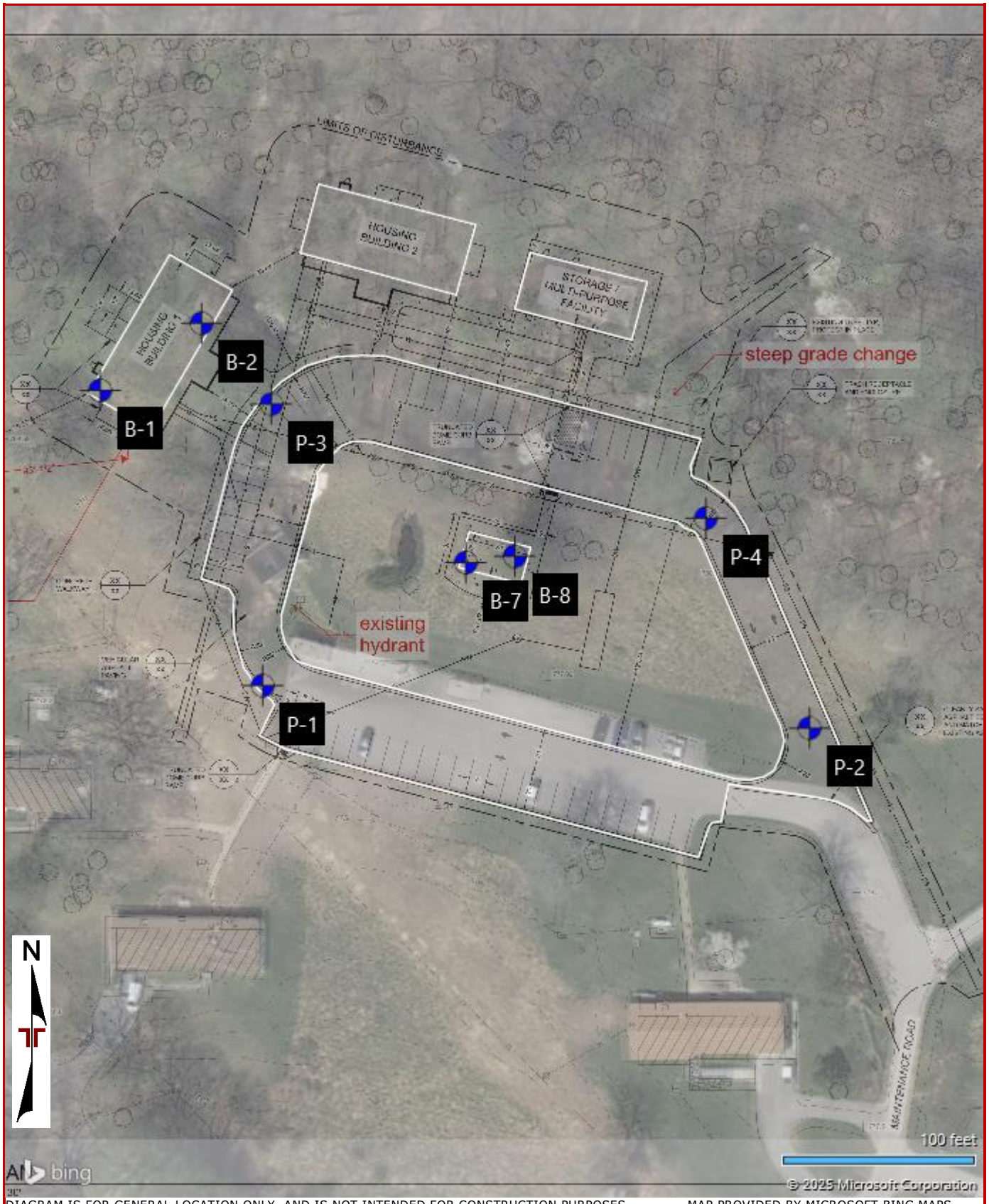


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plan without Overlay

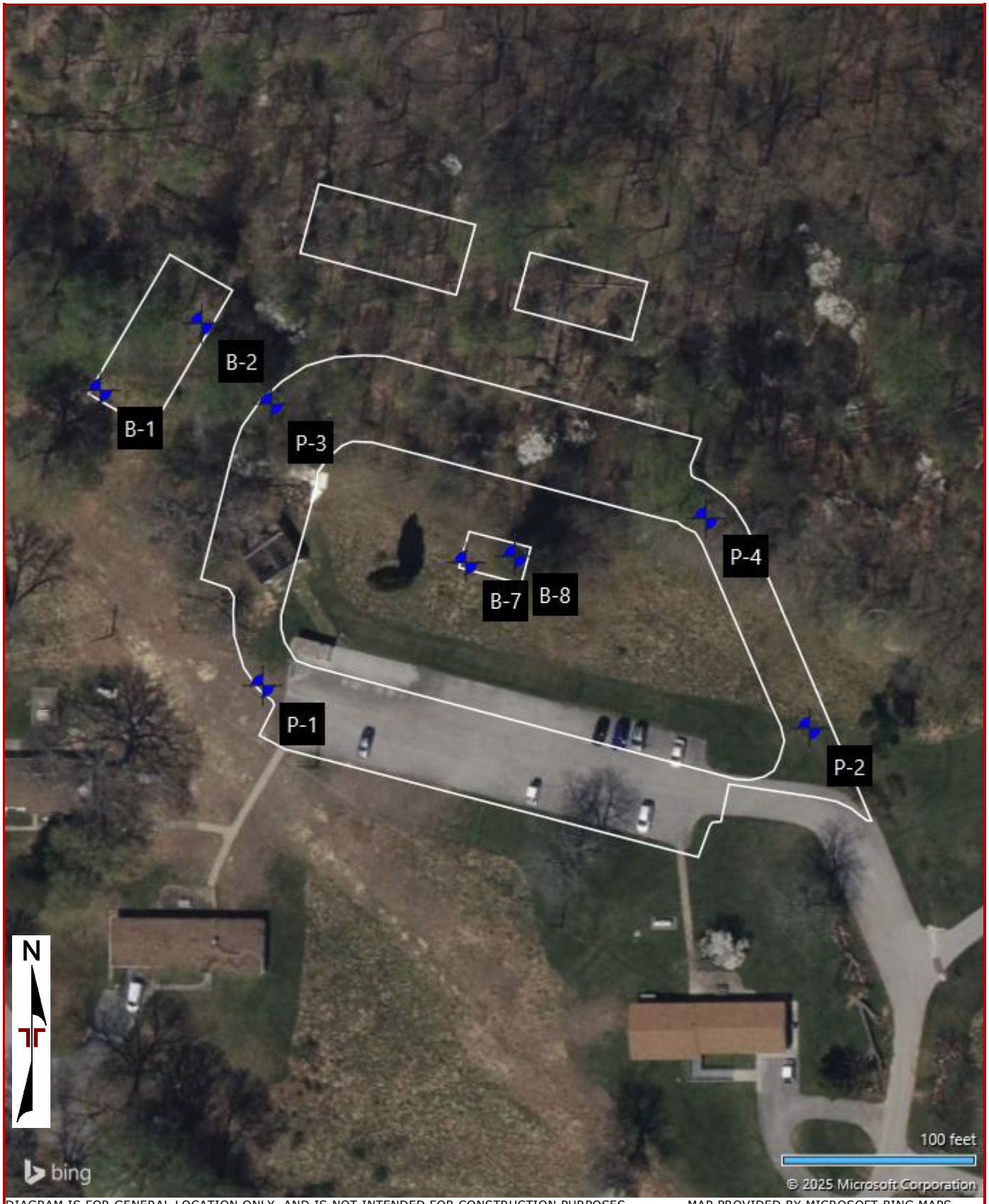


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration and Laboratory Results

Contents:

Boring Logs (B-1, B-2, B-7, B-8 and P-1 through P-4)
Atterberg Limits

Note: All attachments are one page unless noted above.

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. B-1

Location: See Exploration Plan

Latitude: 37.1846° Longitude: -86.0884°

Model Layer	Graphic Log	Depth (Ft.)	Elevation: 771 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		0.7	**8" TOPSOIL** 770.33						
2		3.0	**LEAN CLAY (CL)**, trace mineral nodules and silt, yellowish brown, medium stiff 768				WOH-2-6 N=8	18.8	
		5.5	**LEAN CLAY (CL)**, trace silt, yellowish brown, very stiff 765.5	5			5-8-11 N=19	21.4	
		8.0	**LEAN CLAY (CL)**, silty clay, reddish brown with gray mottling, very stiff 763				9-8-10 N=18	20.6	
3		11.5	**FAT CLAY (CH)**, trace silt, yellowish red with gray mottling, stiff 759.5	10			4-5-7 N=12	32.6	
		16.5	**FAT CLAY (CH)**, trace fine sand, yellowish brown with gray mottling, very stiff 754.5	15			4-3-20 N=23	22.4	
			Auger Refusal at 16.5 Feet						

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-16-2024

Boring Completed
12-16-2024

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. B-2

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 37.1847° Longitude: -86.0882° Depth (Ft.) — Elevation: 775 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**12" TOPSOIL** 1.0 — 774						
2		**LEAN CLAY (CL)**, trace mineral nodules and roots, yellowish brown, very soft 3.0 — 772				WOH-WOH-1 N=1	27.7	33-19-14
2		**LEAN CLAY (CL)**, trace mineral nodules, yellowish brown with gray mottling, medium stiff to stiff	5			3-3-4 N=7	20.4	
2		8.0 — 767				3-5-8 N=13	22.2	
3		**FAT CLAY (CH)**, trace mineral nodules, red with gray mottling, stiff 10.0 — 765				3-7-50/4"	27.9	
		Auger Refusal at 10 Feet	10					

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-17-2024

Boring Completed
12-17-2024

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. B-7

Location: See Exploration Plan

Latitude: 37.1843° Longitude: -86.0878°

Model Layer	Graphic Log	Depth (Ft.) / Elevation: 776 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**12" TOPSOIL** 1.0 / 775						
2		**LEAN CLAY (CL)**, trace roots and mineral nodules, yellowish brown with gray mottling, medium stiff 3.0 / 773				1-2-4 N=6	19.2	
		LEAN CLAY (CL), with sand, trace mineral nodules, yellowish brown with gray mottling, stiff 5.5 / 770.5	5			3-5-7 N=12	19.2	33-17-16
		LEAN CLAY (CL), trace mineral nodules, reddish brown with gray mottling, stiff 8.0 / 768				2-5-6 N=11	21.8	
		Auger Refusal at 8 Feet						

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-17-2024

Boring Completed
12-17-2024

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. B-8

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 37.1843° Longitude: -86.0877° Depth (Ft.) / Elevation: 777 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**10" TOPSOIL** 0.8 / 776.17						
2		**LEAN CLAY (CL)**, trace roots and mineral nodules, brown, very stiff 3.0 / 774				4-10-12 N=22	14.0	
		LEAN CLAY (CL), trace mineral nodules and silt, yellowish red, very stiff 5.5 / 771.5	5			4-12-16 N=28	16.2	
		LEAN CLAY (CL), with silt, yellowish red with gray mottling, very stiff 8.0 / 769				6-12-11 N=23	17.8	
		LEAN CLAY (CL), trace silt and mineral nodules, reddish brown with gray mottling, very stiff 11.5 / 765.5	10			5-9-11 N=20	19.9	
3		**FAT CLAY (CH)**, with find sand, few mineral nodules, dark brown 15.0 / 762				4-5-30/2"	27.8	
		Auger Refusal at 15 Feet	15					

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-17-2024

Boring Completed
12-17-2024

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. P-1

Location: See Exploration Plan

Latitude: 37.1841° Longitude: -86.0881°

Model Layer	Graphic Log	Depth (Ft.)	Elevation: 776 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		1.0	**12" TOPSOIL** 775						
2		3.0	**LEAN CLAY (CL)**, trace mineral nodules, yellowish brown, stiff 773				1-2-8 N=10	19.1	
		5.5	**LEAN CLAY (CL)**, trace mineral nodules, yellowish red, stiff 770.5	5			2-7-8 N=15	18.5	
		8.0	**LEAN CLAY (CL)**, trace mineral nodules, yellowish red with gray mottling, stiff 768				3-6-8 N=14	21.3	
		10.0	**LEAN CLAY (CL)**, with silt, reddish brown with gray mottling, very stiff 766				3-7-12 N=19	19.0	
			Boring Terminated at 10 Feet	10					

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-16-2024

Boring Completed
12-16-2024

MACA - Kentucky
Mammoth Cave National Park | Mammoth Cave, KY
Terracon Project No. 18245139

1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. P-2

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 37.1841° Longitude: -86.0872° Depth (Ft.) / Elevation: 780 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**10" TOPSOIL** 0.8 / 779.17						
2		**LEAN CLAY (CL)**, trace mineral nodules and silt, yellowish brown with gray mottling, stiff 5.5 / 774.5	5			3-5-9 N=14	15.5	
						3-5-8 N=13	16.7	
3		**FAT CLAY (CH)**, trace mineral nodules and silt, reddish brown with gray mottling, stiff 8.0 / 772				5-6-9 N=15	29.3	
2		**LEAN CLAY (CL)**, with silt and trace mineral nodules, reddish brown with gray mottling, stiff 10.0 / 770	10			3-5-8 N=13	24.9	
		Boring Terminated at 10 Feet						

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-17-2024

Boring Completed
12-17-2024

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. P-3

Location: See Exploration Plan

Latitude: 37.1845° Longitude: -86.0881°

Model Layer	Graphic Log	Depth (Ft.) / Elevation: 774 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**12" TOPSOIL** 1.0 / 773						
2		**LEAN CLAY (CL)**, trace mineral nodules and roots, yellowish brown with gray mottling, soft 3.0 / 771				WOH/12"-2 N=2	25.9	26-18-8
		LEAN CLAY (CL), trace mineral nodules, yellowish red with gray mottling, very stiff 8.0 / 766	5			4-7-10 N=17	22.7	
						3-6-12 N=18	22.3	
		LEAN CLAY (CL), trace silt and sand, reddish brown with gray mottling, very stiff 11.5 / 762.5	10			3-6-13 N=19	27.5	
		LEAN CLAY (CL), with silt and trace mineral nodules, gray to reddish brown, hard 17.5 / 756.5	15			3-13-22 N=35	10.7	
		Auger Refusal at 17.5 Feet						

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

Boring Started
12-17-2024

Boring Completed
12-17-2024

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Terracon Project No. 18245139

Terracon
1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Boring Log No. P-4

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 37.1844° Longitude: -86.0873° Depth (Ft.) / Elevation: 780 (Ft.) +/-	Depth (Ft.)	Water Level Observations	Sample Type	Field Test Results	Water Content (%)	Atterberg Limits LL-PL-PI
1		**10" TOPSOIL** 0.8 / 779.17						
2		**LEAN CLAY (CL)**, trace mineral nodules, yellowish brown, stiff 3.0 / 777				1-3-7 N=10	23.8	
		LEAN CLAY (CL), trace silt, yellowish brown with gray mottling, stiff 5.5 / 774.5	5			3-6-9 N=15	20.1	
		LEAN CLAY (CL), with silt, yellowish red with gray mottling, very stiff				3-6-10 N=16	18.8	
						4-12-17 N=29	19.2	
			10					
						5-7-9 N=16	16.3	
			15					
		17.5 / 762.5						
		Auger Refusal at 17.5 Feet						

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevation Reference: Elevations were interpolated from the Project Grading Plan dated 11-15-2024

Water Level Observations
Groundwater not encountered

Drill Rig
Track

Hammer Type
Automatic

Driller
Earth Science Engineering

Notes

Advancement Method
Hollow Stem Auger

Abandonment Method
Boring backfilled with auger cuttings upon completion.

Logged by
JV

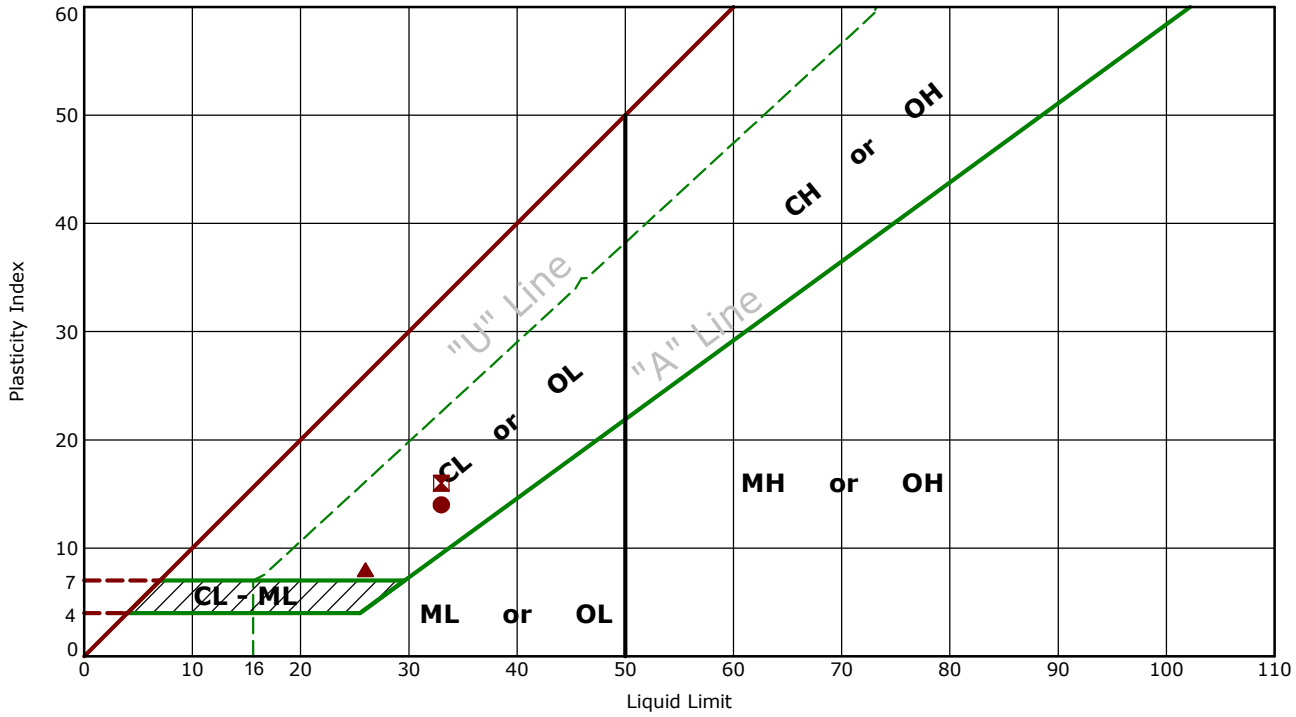
Boring Started
12-17-2024

Boring Completed
12-17-2024

1922 Old Murfreesboro Pike Ste 905
Nashville, TN

Atterberg Limit Results

ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	B-2	1 - 2.5	33	19	14	98.4	CL	LEAN CLAY
⊠	B-7	3.5 - 5	33	17	16	75.1	CL	LEAN CLAY with SAND
▲	P-3	1 - 2.5	26	18	8	89.0	CL	LEAN CLAY

Supporting Information

Contents:

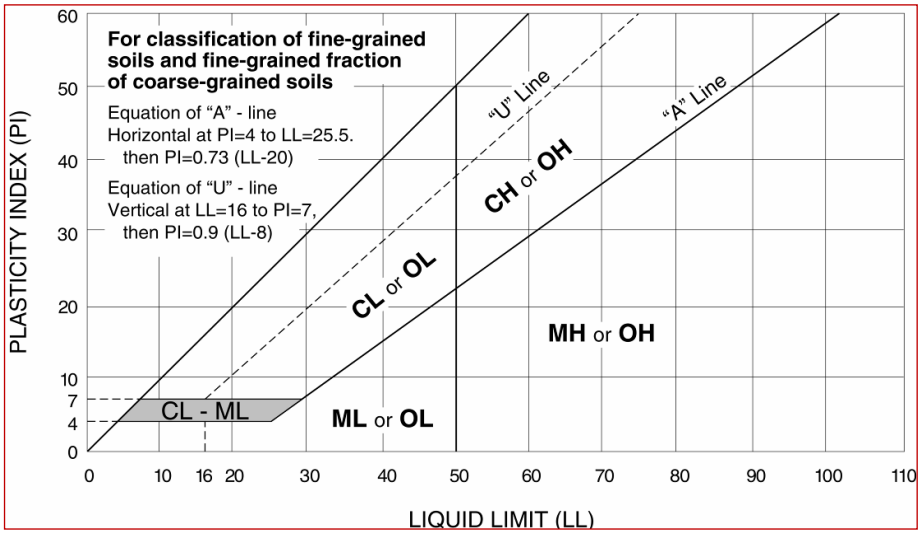
General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted above.

Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu≥4 and 1≤Cc≤3 [E]	GW	Well-graded gravel [F]
			Cu<4 and/or [Cc<1 or Cc>3.0] [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu≥6 and 1≤Cc≤3 [E]	SW	Well-graded sand [I]
			Cu<6 and/or [Cc<1 or Cc>3.0] [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots above "A" line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried} < 0.75$	OL	Organic clay [K, L, M, N]
					Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried} < 0.75$	OH	Organic clay [K, L, M, P]
					Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.
[E] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[F] If soil contains ≥ 15% sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.



Terracon
1922 Old Murfreesboro Pike
Ste 905
Nashville, TN

General Notes

Sampling	Water Level	Field Tests
Standard Penetration Test	Water Initially Encountered Water Level After a Specified Period of Time Water Level After a Specified Period of Time Cave In Encountered Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	N Standard Penetration Test Resistance (Blows/Ft.) (HP) Hand Penetrometer (T) Torvane (DCP) Dynamic Cone Penetrometer UC Unconfined Compressive Strength (PID) Photo-Ionization Detector (OVA) Organic Vapor Analyzer

Descriptive Soil Classification

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

Location And Elevation Notes

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

Strength Terms

Relative Density of Coarse-Grained Soils (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		Consistency of Fine-Grained Soils (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Relative Density	**Standard Penetration or N-Value (Blows/Ft.)**	**Consistency**	**Unconfined Compressive Strength Qu (tsf)**	**Standard Penetration or N-Value (Blows/Ft.)**
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	4 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	8 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
		Hard	> 4.00	> 30

Relevance of Exploration and Laboratory Test Results

Exploration/field results and/or laboratory test data contained within this document are intended for application to the project as described in this document. Use of such exploration/field results and/or laboratory test data should not be used independently of this document.