Geotechnical Engineering Report

Slope Stabilization and Pedestrian Access
Bellbrook, Greene County, Ohio
May 17, 2021
Terracon Project No. N1205425

Prepared for:
City of Bellbrook
Bellbrook, Ohio

Prepared by:
Terracon Consultants, Inc.
Cincinnati, Ohio

May 17, 2021

City of Bellbrook
15 East Franklin Street
Bellbrook, Ohio 45305

Attn: Ms. Melissa Dodd – City Manager
P: (937) 310-3222
E: M.Dodd@cityofbellbrook.org

Re: Geotechnical Engineering Report
Slope Stabilization and Pedestrian Access
Little Sugarcreek Road
Bellbrook, Greene County, Ohio
Terracon Project No. N1205425

Dear Ms. Dodd:

We have completed the Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with revised Terracon Proposal No. PN1205425 dated March 9, 2021 and authorized on March 11, 2021. This report presents the findings of the subsurface exploration and provides a conceptual discussion regarding options for the pedestrian facilities and slope stabilization as well as preliminary designs for drilled shaft retaining walls.

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

Sincerely,
Terracon Consultants, Inc.

STATE OF OHIO
RUSSELL M. GATERMANN
E-81833
REGISTERED PROFESSIONAL ENGINEER

Russ Gatermann, P.E.
Project Engineer

FOR: Craig M .Davis, P.E., CPESC
Geotechnical Department Manager

Terracon Consultants, Inc. 611 Lunken Park Drive Cincinnati, Ohio 45226
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REPORT TOPICS

ATTACHMENTS

Geotechnical Engineering Report
Slope Stabilization and Pedestrian Access
Little Sugarcreek Road
Bellbrook, Greene County, Ohio
Terracon Project No. N1205425
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INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for slope stabilization and pedestrian access along Little Sugarcreek Road in Bellbrook, Greene County, Ohio. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil and rock conditions
- short-term groundwater conditions
- Conceptual discussion regarding options for the pedestrian facilities and slope stabilization
- Preliminary pier wall design for various subsurface conditions

The geotechnical engineering Scope of Services for this project included the advancement of ten (10) test boring to approximate depths of 17.4 to 30 feet below the existing road grade. The test borings were performed in the northbound lane of Little Sugarcreek Road starting about 175 feet north of West Franklin Street and ending about 2,100 feet north of West Franklin Street. The test borings were spaced about 190 feet to 360 feet from one another.

In addition to the test borings, geophysical exploration services, consisting of a refraction seismic survey using the Multi-Channel Analysis of Surface Waves (MASW) method, were performed. The primary survey (Line 1) was performed in the northbound lane of Little Sugarcreek Road starting near Test Boring B-1 and extending to about Test Boring B-10. Two additional, shorter surveys were performed east, off of the road in the unpaved shoulder near Test Borings B-3 and B-8.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs in the **Exploration Results** section. Graphical outputs from the MASW surveys are provided in **Figures**.

The **General Comments** section provides an understanding of the report limitations

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the staking of borings (performed on March 24, 2021), field exploration and our review of select publicly-available geologic and topographic maps.

Item	Description
Parcel Information	§ The project site is located along the east side of Little Sugarcreek Road in Bellbrook, Greene County, Ohio. The project alignment starts at W. Franklin Street (Sta. 10+60) and ends near Magee Park (Sta. 32+40). § Start: Latitude: 39.6362, Longitude: -84.0757 (approx.) § End: Latitude: 39.6412, Longitude: -84.0801 (approx.) § **Site Location**
Existing Improvements	Little Sugarcreek Road is an existing asphalt-paved road with one approximately 11-feet-wide lane and approximately 1-foot-wide paved shoulder in each direction. A sanitary sewer runs along Little Sugar Creek. There are overhead utilities along the west side of Little Sugarcreek Road from approximately Sta. 12+00 to Sta. 18+50.
Existing Topography (from Google Earth Pro)	Elevations along Little Sugarcreek Road generally increase from about El. 790 to about El. 810 from south to north. Grades slope from the road down to Little Sugar Creek on the east side of the road with slopes ranging from about 1H:1V to 2H:1V. Little Sugar Creek is about 15 to 20 feet below the road. Near Sta. 28+00, Little Sugar Creek meanders away from Little Sugarcreek Road and Magee Park is located between Little Sugarcreek Road and Little Sugarcreek.
Geology	Based on the review of SSURGO database of the USDA-NCRS Soil Survey Map of Greene County, the surficial soils at the site belong to the Casco and Miamian Soil Series. The Casco Series consists of sandy outwash and the Miamian Series consists of glacial till. Bedrock at the site is mapped as belonging to the Waynesville and Arnheim Formation, which consists of interbedded shale and limestone.

PROJECT DESCRIPTION

Our understanding of the project is described in this section. The following information was provided:

- Geotechnical Report – Little Sugarcreek Road Landslide (Geotechnology Report No. J033975, July 9, 2019)
- Little Sugarcreek Road – Pedestrian Access and Slope Stability Feasibility Study (LJB, July 31, 2019)
- Topographic data and project stationing provided by LJB via email
- Various information provided by Mr. Dan Hoying via email and in phone conversations

We understand there have been slope stability issues on the downslope (east) side of Little Sugarcreek Road for a number of years. Stability issues affecting the road have been typically repaired at the surface by building back up the subgrade as necessary and re-paving/patching the asphalt. We understand a landslide occurred on the east side of Little Sugarcreek Road in February 2019, approximately 1,400 feet north of W. Franklin Road (approximately Sta. 24+00 to 25+00). This area had undergone movement in the past, but the additional movement in February 2019 displaced the guardrail. A head scarp (differential vertical movement, often at the top/crest of a landslide) formed about 2 to 3 feet away from the pavement edge.

LJB and Geotechnology were retained by the City of Bellbrook to perform a feasibility study for remediation of the landslide in conjunction with providing pedestrian facilities along Little Sugarcreek Road. Geotechnology performed four (4) test borings along the approximately 100-feet-long landslide area. The feasibility study recommended a drilled pier wall consisting of structural piers and plug piers to remediate the landslide and support the pedestrian facilities. Three Alternatives were proposed (all including a drilled pier wall):

- Alternate A: curb and gutter along Little Sugarcreek Road, 7-feet-wide sidewalk, and concrete barrier constructed above the wall
- Alternate B: guardrail only with no curb or pedestrian facilities
- Alternate C: curb and gutter along Little Sugarcreek Road, 7-feet-wide sidewalk, and a railing above the wall (face of wall set back farther from road than in Alternative A).

Cost estimates were provided to the City of Bellbrook as part of the feasibility study. Total costs for the alternates (both phases) ranged from about $6.5 million to $9.0 million. Alternate C was recommended in the feasibility study.

We understand the City of Bellbrook intends to construct the stabilization and pedestrian access project in segments as funding becomes available. The City of Bellbrook would like to prioritize areas that are most vulnerable to slope movement, ultimately stabilizing the entire corridor. Accommodations for the sidewalk would be implemented into each segment of the project and the sidewalk would be constructed after the stabilization methods have been implemented along the entire corridor.

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. Conditions encountered at the exploration points are indicated on the boring log in the **Exploration Results** section of this report. The GeoModel can be found in the **Figures** section 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.

Surficial materials encountered in the test borings include asphalt pavement and granular base. The encountered asphalt pavement thickness ranged from about 4 to 18 inches thick. Where encountered, the encountered granular base thickness ranged from about 3 to 20 inches thick.

Model Layer	Layer Name	General Description
1	**Existing Fill**	Well-graded gravel with sand, lean clay, clayey sand, clayey sand with gravel, and sandy lean clay; encountered in all test borings to depths ranging from 3.5 to 13.5 feet below existing road grades
2	**Natural Cohesive**	Lean clay and sandy lean clay; encountered in all test borings except B-2; consistency ranges from medium stiff to hard
3	**Natural Granular**	Well-graded gravel; only encountered in B-3; dense
4	**Weathered Bedrock**	Brown to brown and gray shale with limestone fragments and layers; shale: very weak (in terms of rock strength)
5	**Bedrock**	Interbedded gray shale and limestone: Shale: gray: slightly weathered to weathered, weak, very thin to thin bedded, 80% to 90% of the rock matrix (as encountered in rock cores) Limestone: gray, unweathered, strong, very thin bedded, 10% 5o 20% of the rock matrix (as encountered in rock cores)

Groundwater Conditions

The boreholes were observed while drilling and immediately after their completion for the presence and level of groundwater. The short-term water levels observed in the boreholes are noted on the test boring logs and are summarized below.

Boring	Approximate depth to groundwater while drilling, feet	Approximate depth to groundwater after drilling, feet
B-1	20	18.7
B-2	Not encountered	Not encountered
B-3	Not encountered	-- [1]
B-4	Not encountered	16
B-5	Not encountered	Not encountered
B-6	Not encountered	-- [1]
B-7	Not encountered	Not encountered
B-8	Not encountered	Not encountered
B-9	20	-- [1]
B-10	20	20.7

1. Water added to borehole for rock coring purposes. Recorded water levels not representative of actual groundwater conditions.

Short-term groundwater observations are inadequate to characterize long-term groundwater conditions over the design life of the structure(s). Long-term observations in piezometers or observation wells sealed from the influence of surface water are required to characterize groundwater levels. From experience, seepage is commonly encountered within existing fill (trapped/perched water), along the fill/natural soil interface, within granular strata of glacial profiles such as those at this site, and at the soil/bedrock interface.

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 test boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

Geophysical Surveys

Terracon Consultants, Inc. (Terracon) performed geophysical exploration services consisting of a refraction seismic survey using the Multi-Channel Analysis of Surface Waves (MASW) method. The primary goal of this survey was to characterize the site subsurface conditions, particularly the depth to bedrock. The primary survey (Line 1) was performed in the northbound lane of Little Sugarcreek Road starting near Test Boring B-1 and extending to about Test Boring B-10. Two additional, shorter surveys were performed east, off of the road in the unpaved shoulder near Test Borings B-3 and B-8.

The shear wave velocity cross-sections are provided in **MASW Cross-Sections** in **Figures**. The different seismic velocities, combined with the boring logs, were used to identify subsurface strata, top of weathered bedrock, and top of bedrock. Based on corroboration with the test borings, the top of weathered bedrock (brown shale) was identified at a shear wave velocity of 1,200 ft/sec. Interbedded gray shale and limestone bedrock was identified at a shear wave velocity of about 1,500 ft/sec. The approximate top of weathered bedrock and top of bedrock are identified by dashed lines on the exhibit. The top of bedrock elevations should be considered approximate. Actual depths may vary from those identified.

In general, the top of brown shale ranged from about 8 to 20 feet below existing grades. The top of interbedded limestone and gray shale ranged from about 10 to 25 feet below existing grades.

The depth to interbedded gray shale and limestone bedrock was about 20 feet at B-3 in Line 1. It was also about 20 feet deep in Line 2, performed off the road near B-3. The depth to weathered brown shale bedrock was about 15 feet and the depth to interbedded gray shale and limestone bedrock was about 20 feet at B-8 in Line 1. The depths to bedrock were similar in Line 3, which was performed east of the road near B-8. This indicates bedrock is relatively level moving from west to east perpendicular to the road.

GEOTECHNICAL CONSIDERATIONS

The test borings encountered variable depths of existing fill underlain by natural cohesive and granular soils. All test borings terminated in interbedded gray shale and limestone bedrock. Existing fill was encountered to depths ranging from about 3.5 to 13.5 feet below road grades. The existing fill included both cohesive and granular materials. We anticipate the existing fill was placed during construction of Little Sugarcreek Road, which would have been common to typical historic balanced-cut-and-fill construction techniques. We have interpreted the existing fill to be undocumented/uncontrolled, or at-least significantly weathered.

Natural cohesive soils consisting of lean clay and sandy lean clay were encountered underlying the existing fill with consistencies ranging from medium stiff to hard. Some layers were identified as glacial till and residuum. Glacial till is material deposited by glaciers and typically consists of material of various sizes mixed together. It classifies as sandy lean clay at this site. Residuum is soil formed from the in-place weathering of the parent bedrock and classifies as lean clay with limestone fragments.

Bedrock consists of weathered brown shale with limestone layers that transitions into interbedded gray shale and limestone with depth. The weathered brown shale layer was not encountered in all test borings. However, it may be present but did not fall within the sampling interval depths of the test borings. Five feet of rock coring of the interbedded gray shale and limestone was performed in three test borings, B-3, B-6, and B-9. The rock quality designation (RQD) of the rock core samples ranged from 30% to 95%. Shale comprised about 80% to 90% of the retrieved rock cores with limestone comprised the remaining portion.

We understand a landslide occurred on the east side of Little Sugarcreek Road in February 2019 approximately 1,400 feet north of W. Franklin Road (approximately Sta. 24+00 to 25+00). We understand there have been additional areas of instability along the downslope side of Little Sugarcreek Road. Evidence of landslides/slope movement was observed in three areas during the reconnaissance performed on March 24, 2021. Head scarps (differential vertical ground movement, often at the top of a landslide) were observed between Test Borings B-2 and B-3 (approximately 150 feet long), between Test Borings B-6 and B-7 (February 2019 slide), and near Test Boring B-8 (approximately 100 feet long).

Slope movement along roadsides constructed along hillsides are common in the region. Slope movement is particularly common along the downslope side of roads that are constructed by excavating into the upslope side and placing fill on the downslope side – such as the construction of Little Sugarcreek Road. Slope movement, which is the condition where the driving forces exceed the resisting forces, can occur for a number of reasons, including:

- Weak fill soils due to inadequate compaction effort and moisture control during fill placement, or long-term weathering
- Fill soils placed on the downslope sides of roads are placed too steep (generally steeper than about 3H:1V), or not properly benched onto stable soils

- The roads are constructed on natural soils that are already weak or inclined
- The soil and underlying bedrock weather over time due to environmental weathering, such as freeze/thaw and wet/dry cycles, or the permeation of the roots of vegetation
- Water is not shed properly, and pore water pressures build up in the soil, which can weaken the soil

The distance from the edge of the existing pavement to the crest of the slope is variable along Little Sugarcreek Road, ranging from zero (crest of the slope is immediately adjacent to the road) to about 30 feet. While it may be possible to construct a sidewalk in some areas along the east side of the road with minimal new fill placement, fill will primarily be required to facilitate sidewalk construction. Placing fill to accommodate sidewalk construction can trigger or accelerate slope movement by increasing the driving forces. The following approaches should be considered to address slope stabilization and sidewalk construction.

- **Do-Nothing Approach**: No stabilization measures could be implemented. In areas where feasible, the sidewalk could be constructed at/near existing grade with little to no new fill placement. This would leave both the roadway and new sidewalk susceptible to future slope movement. It is very difficult to predict timing, location, and rate of future slope movement.
- **"Short" Retaining Structures**: Relatively short retaining walls (such as cast-in-place concrete or reinforced block walls) could be constructed to accommodate sidewalk construction. However, these types of retaining walls would not stabilize deeper slope instability and would not protect the sidewalk against deep-seated failures. It is our opinion that these walls would not be worth the investment to construct as they, along with the sidewalk, would be susceptible to slope movement.
- **Earthwork Solutions**: Earthwork solutions could be implemented to both stabilize existing slopes in conjunction with providing room to construct the sidewalk. Final, permanent slopes (without other reinforcement) would generally need to be at least 2.5H:1V or flatter. An earthwork approach would likely take a significant amount of earthwork and fill placement. In areas where Little Sugar Creek is close to Little Sugarcreek Road, an earthwork approach would likely not be feasible due to space constraints toward constructing new slopes. Right-of-way would also need to be considered. Erosion control measured would need to be implemented to protect any slopes from erosion from Little Sugar Creek. In addition, final slopes would need to be designed to an appropriate factor of safety and consider existing failure planes, which may dictate slopes flatter than 3H:1V, benches, toe keys, rock toes, or other measures to improve the factor of safety. Generally speaking, an earthwork solution would be a "significant" undertaking in both design and construction. We also anticipate it would be difficult to implement an earthwork solution in a segmented fashion. One area where an earthwork solution may be feasible is at the north end of the alignment where Magee Park is below Little Sugarcreek Road, the height of the slope is less, and Little Sugar Creek is not immediately below Little Sugarcreek Road.
- **Soil Nail Stabilization**: A soil nail remediation could stabilize the slope by removing some of the slide mass and launching and/or drilling soil nails into the slope. The process begins

by excavating some of the slide mass on the face of the slope. After the excavation, the soil nails are launched and/or drilled into the slope face and pressure grouted. The soil nail installation can likely be performed from the crest of the slope. The pressure grouting increases the bond between the soil nails and the surrounding soil. The slope face is then lined with mesh and shotcrete is placed. The slope face can also be lined with vegetation. Some clearing of trees near the crest of the slope would likely be required. Soil nail systems are usually designed and installed by specialty contractors. In our experience, soil nail systems are typically comparable in cost to drilled pier retaining walls. Soil nail systems are suited to remediate existing slope failures but may be difficult to implement with the need for sidewalk construction. It is our opinion that soil nail stabilization is not the best remediation option for this project.

- **Drilled Pier Retaining Wall**: A drilled-pier-and-plug-pier retaining wall consists of drilled concrete structural and plug piers. The structural piers would be drilled to bedrock and would be reinforced with steel beams or a reinforcing steel cage. Unreinforced plug piers would be drilled behind the structural piers to fill in the gap between the structural piers. There are typically two plug piers in each gap. The drilled shaft and plug pier wall could be installed from the crest of the slope. The piers are typically excavated by a tracked excavator with an auger. Minimal earthwork may be need after the piers are installed to clean up and re-grade the slope. Little to no clearing of trees on the slope would be required. A drilled pier retaining wall would provide stabilization for Little Sugarcreek Road and could be constructed to allow fill placement for sidewalk construction. It is our opinion that a drilled pier retaining wall is well-suited for the project goals.

We understand the City of Bellbrook intends to construct the project in segments and would like to target areas most prone to landslide movement first. Note that it will likely be more expensive to construct intermittent repairs than to perform all construction at one time. It is very difficult to predict landslide movements – including where they will occur, when they will occur, and rate of movement. However, the following are general recommendations on how to prioritize the work:

- Areas that have moved in the past are likely to move in the future. Evidence of landslide movement was observed at three locations: between Test Borings B-2 and B-3, between Test Borings B-6 and B-7 (February 2019 slide), and near Test Boring B-8. It is our opinion that these areas are the best place to start with stabilization measures.
- Areas where the crest of the existing slope is closest to the edge of the roadway. If the crest of the slope is adjacent to the roadway and movement occurs, there is no buffer between the slope movement and the roadway and the roadway will be directly impacted. In areas where the crest of the slope is way from the edge of the roadway, there is time to react if slope movement occurs due to the buffer between the edge of pavement and crest of the slope.
- Steeper slopes are generally more prone to movement than less steep slopes. Targeting areas with the steepest slopes is a recommended approach.
- Areas of existing fill are likely more susceptible to slope movement. Deeper existing fills were encountered in Test Borings B-1, B-2 and B-3.

DRILLED PIER WALL PRELIMINARY DESIGNS

The following table includes preliminary design information for a plug and pier lagging wall along Little Sugarcreek Road. The preliminary designs consider no passive soil resistance above weathered bedrock. The analysis is based on the retaining wall being constructed about 24 feet from the centerline of the existing road. The analysis is based on bedrock depths encountered in the test borings and identified in the MASW survey and considers a rock slope of about 6H:1V. Therefore, the depth of bedrock considered in the evaluation below is about 3 feet deeper than encountered in the test borings and MASW survey in the road. The preliminary designs consider the top of the drilled shaft retaining wall will be near the elevations of Little Sugarcreek Road to create a level shoulder and sidewalk.

The information below should be considered preliminary and for budgeting purposes only. Final, detailed design would be required for construction purposes. Note that additional wall configurations (alternate combinations of pier spacing, pier diameters, reinforcing options, etc.) may also be suitable.

Relevant Test Borings	Type [2]	Depth to Top of Bedrock (feet) [1]	Structural Shaft Diameter (inches)	Structural Shaft Center-to-Center Spacing (feet)	Total Shaft Length (feet)	Reinforcing – Steel Beam Option	Reinforcing – Reinforcing Cage Option – Longitudinal Reinforcing
B-5, B-6	Type 1	up to 13	30	6	25	W21x62	(5) #9 bars upslope (2) #9 bars downslope
B-2, B-4, B-7, B-8	Type 2	up to 18	36	6	36	W27x114	(8) #10 bars upslope (2) #10 bars downslope
B-1, B-3	Type 3	up to 23	36	6	44	W24x207	(10) #14 bars upslope (2) #14 bars downslope
B-9, B-10	Type 4	greater than 23	(see discussion below)				

1. Top of bedrock is considered weathered brown shale for this evaluation
2. Type 1 approximate stations: 20+95 to 22+45, 23+45 to 25+45, 26+20 to 27+20
   Type 2 approximate stations: 14+20 to 15+70, 17+20 to 18+45, 19+70 to 20+95, 27+95 to 28+95
   Type 3 approximate stations: 12+70 to 14+20, 15+70 to 17+20, 18+45 to 19+70, 22+45 to 23+45, 25+45 to 26+20, 27+20 to 27+95
   Type 4 approximate stations: 28+95 to 31+70

Cantilevers greater than about 20 to 25 feet become increasingly expensive to construct due to the significant reinforcement that is required. Additional study in these areas is recommended. Passive resistance above the top of bedrock may be considered. In addition, this is the area above Magee Park and an alternate solution to a drilled shaft wall, such as an earthwork solution, may be viable.

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. Natural variations will occur away from exploration point location 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 the final 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, ecological, cultural or biological 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, impact or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system 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 impact 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. 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.

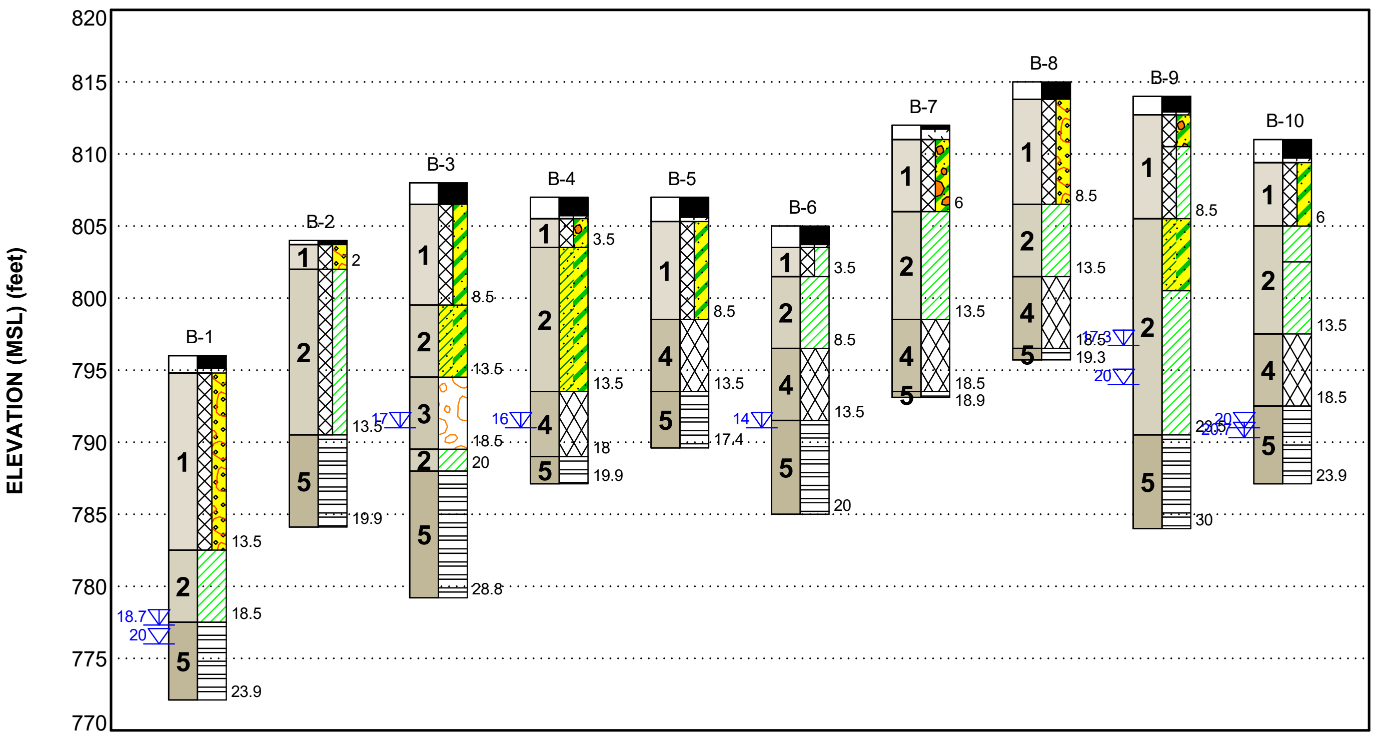
FIGURES

Contents:

GEOMODEL

Little Sugarcreek Road Stabilization and Pedestrian Access ■ Bellbrook, OH
Terracon Project No. N1205425

Terracon GeoReport



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	**Existing Fill**	Cohesive and granular materials; encountered in all test borings to depths ranging from 3.5 to 13.5 feet below existing road grades
2	**Natural Cohesive**	Lean clay and sandy lean clay; encountered in all test borings except B-2; consistency ranges from medium stiff to hard
3	**Natural Granular**	Well-graded gravel; only encountered in B-3; dense
4	**Weathered Bedrock**	Brown to brown and gray shale with limestone fragments and layers; shale: very weak (in terms of rock strength)
5	**Bedrock**	Interbedded gray shale (about 80% to 90% of rock matrix) and limestone (about 10% to 20% of rock matrix)

LEGEND

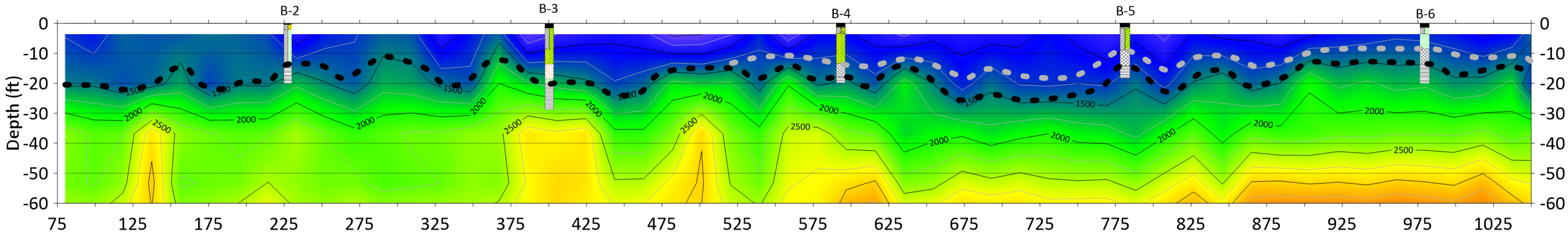
- Asphalt
- Base
- Well-graded Gravel w/sand
- Lean Clay
- Shale
- Clayey Sand
- Sandy Lean Clay/Clayey Sand
- Well-graded Gravel
- Clayey Sand with Gravel
- Highly Weathered Shale

- First Water Observation
- Second Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time. Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

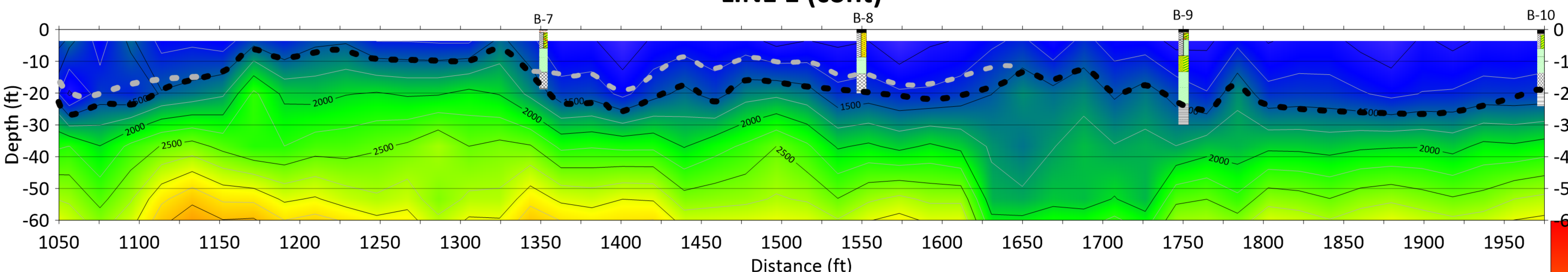
NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project. Numbers adjacent to soil column indicate depth below ground surface.

LINE 1

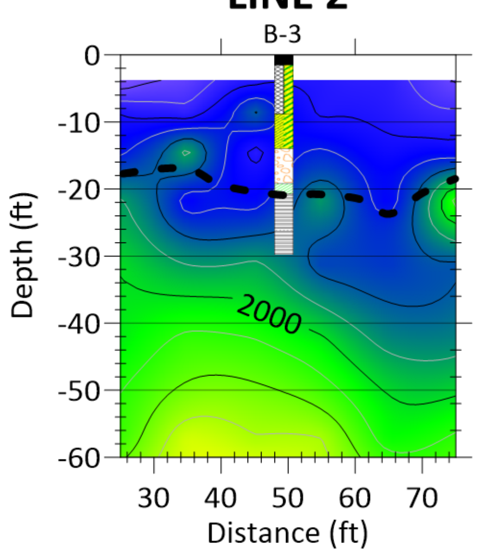


Note: x=0 set at B-1 (Sta. 11+95)

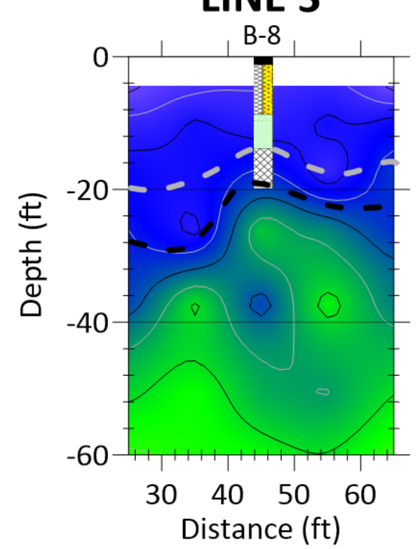
LINE 1 (cont)

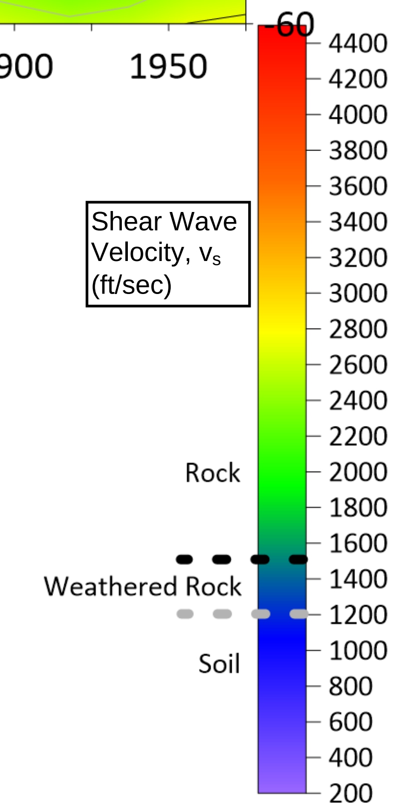


LINE 2



LINE 3





Project Manager: RMG	Project No. N1205425	Terracon Consulting Engineers & Scientists 611 Lunken Park Drive Cincinnati, Ohio 45226	**MASW CROSS-SECTIONS**
Drawn by: JCT	Scale: As Shown		Pedestrian Access and Slope Stabilization
Checked by: KJS	File Name: map		Little Sugarcreek Road
Approved by: CMD	Date: 04/27/2021		Bellbrook, Greene County, Ohio

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet) [1]	Drilled Location
10	45	Northbound lane of Little Sugarcreek Road

1. Below ground surface

Boring Layout and Elevation: Terracon personnel provided the boring layout. Coordinates and elevations were obtained with a survey-grade Zeno GPS unit. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

Subsurface Exploration Procedures: We advanced the borings with a track-mounted rotary drill rig using continuous-flight-hollow-stem augers. Four samples were obtained in the upper 10 feet of the 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 log at the test depths. Thin-walled samples (Shelby tubes) were pushed at select depths in some test borings to obtain relatively undisturbed soil sample. Upon encountering bedrock, five feet of rock coring was performed using NQ2-size rock coring tools in three test borings – B-3, B-6, and B-9. Water was used as a drilling fluid to aid in the coring of the bedrock. In test borings where rock coring was not performed, rock samples were collected by overdriving the split-barrel sampler and the borings were terminated.

In addition, we observed and recorded short-term groundwater levels during drilling and sampling. Groundwater was not observed in the test boring during the short-term observation. For safety purposes, the boring was backfilled with auger cuttings immediately upon its completion. Asphalt cold patch was placed at the surface of the test borings.

The sampling depths, penetration distances, and other sampling information were recorded on the field boring log. 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 log as part of the drilling operations. The field log included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring log, prepared from the field log, represents the Geotechnical Engineer's interpretation of the field log 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 to understand the engineering properties of the various soil and rock strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

The laboratory testing program included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System.

Rock classification was conducted using locally-accepted practices for engineering purposes. Boring log rock classification was determined using Terracon's **Description of Rock Properties**, attached to this report.

Geophysical Methods

The investigation used a roll along MASW method and involved a vehicle to pull a land-streamer geophysical array along linear paths. The array consisted of 24 4.5Hz geophones, spaced approximately 5 feet apart along the land-streamer for a total line length 115 feet. The array was pulled at ten-foot intervals and a source strike was completed with a sledge hammer at each interval while recording the seismic response. Two additional stationary MASW lines were also performed at borings B-3 and B-8 on the east side of the guard rail.

The data was then processed using dispersion analysis software (SurfSeis, engineered by the Kansas Geological Survey) that extracts the fundamental-mode dispersion curve(s). The curves are inverted and modeled to yield a 1D shear-wave velocity profile along the array for a corresponding depth. At each strike source, the 1D profiles are created and then combined to yield a 2D profile. These 2D profiles are then examined for changes in shear wave velocities to indicate the top of bedrock.

Limitations: All geophysical testing methods rely on instrument signals to indicate physical conditions in the field. Signal information can be affected by on-site conditions beyond the control of the operator, such as, but not limited to, cultural features, standing water, ground water, buried objects, and cultural noise (e.g. traffic). Interpretation of those signals is based on a combination of known factors combined with the experience of the operator and geophysical scientist evaluating the results. The provided depth measurements are estimations based on an estimation of the electrical properties of the subsurface material. This report has been prepared for the application discussed and in accordance with generally accepted geophysical practices. No warranties, expressed or implied, are intended or made. The findings presented in this report are based upon the data obtained from the geophysical surveys and from other information discussed in this report. This report does not reflect variations that may occur in areas not tested or inaccessible to the geophysical equipment, across the site, or due to the modifying effects of construction or weather.

SITE LOCATION AND EXPLORATION PLAN

Contents:

SITE LOCATION

Slope Stabilization and Pedestrian Access ■ Bellbrook, Greene County, Ohio
May 17, 2021 ■ Terracon Project No. N1205425

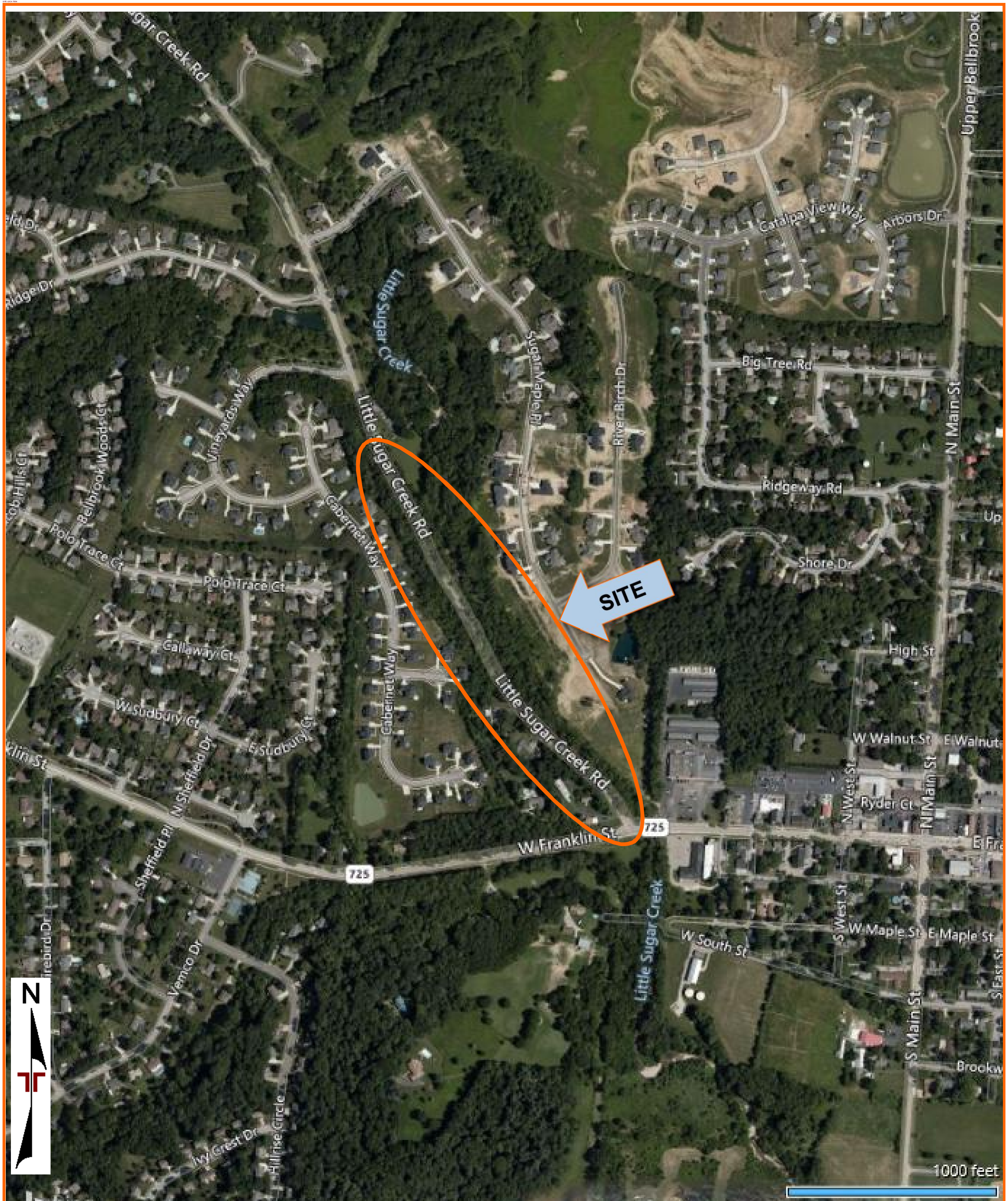


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

Slope Stabilization and Pedestrian Access ■ Bellbrook, Greene County, Ohio
May 17, 2021 ■ Terracon Project No. N1205425

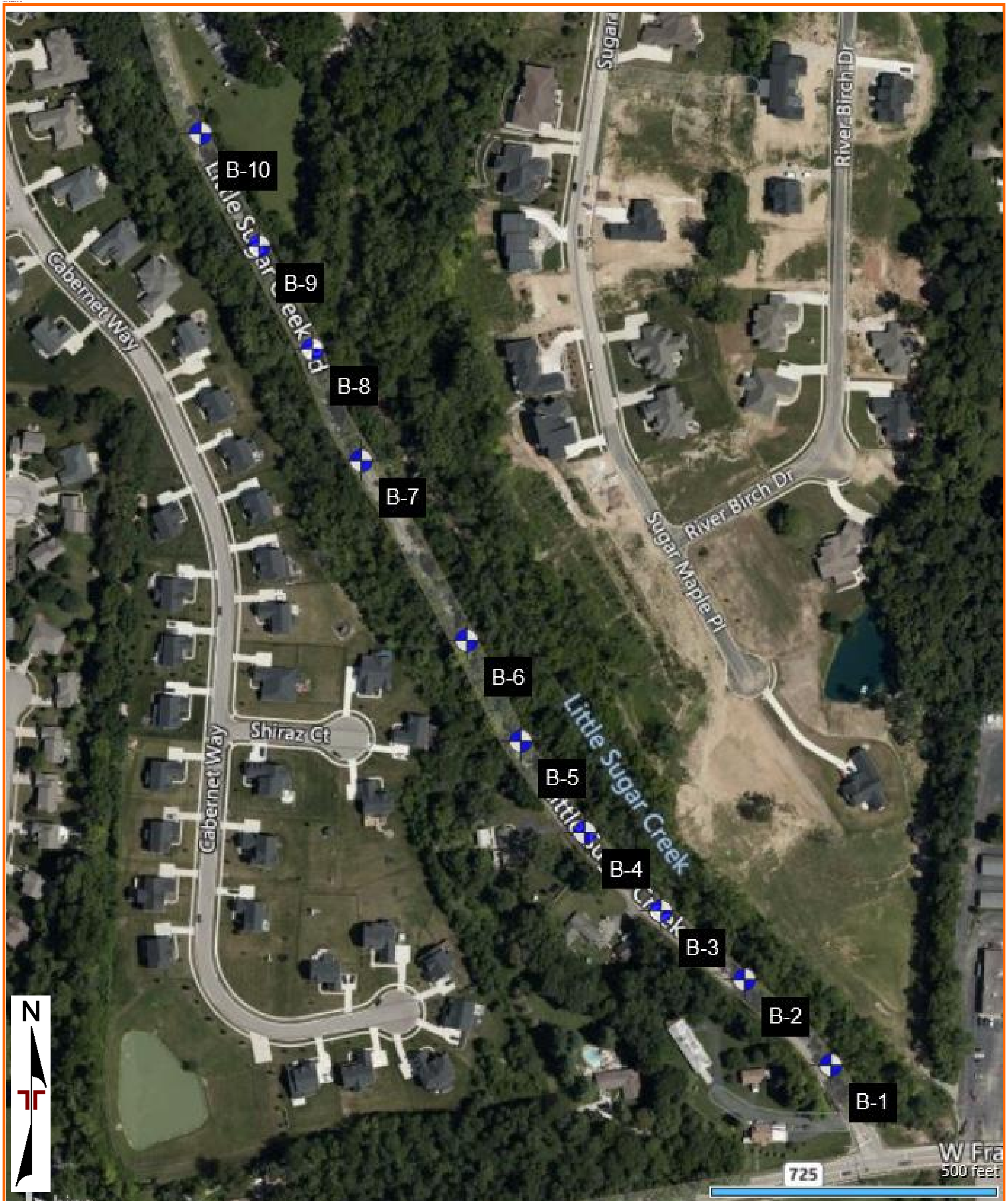


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

BORING LOG NO. B-1

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH
Bellbrook, OH

SITE: Little Sugarcreek Road
Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6366° Longitude: -84.0761°

Station: 11+95 Offset: 9' R

Approximate Surface Elev.: 796 (Ft.) +/-

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)
	0.9	**ASPHALT (11")**	795+/-
	1.2	**GRANULAR BASE (3")**	795+/-
1	13.5	**FILL - WELL GRADED GRAVEL WITH SAND (GW)**, trace clay, brown	782.5+/-
2	18.5	**LEAN CLAY (CL)**, trace sand, trace gravel, brown, hard, (GLACIAL TILL)	777.5+/-
5	23.9	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	772+/-
		Split Spoon Refusal and Boring Terminated at 23.9 Feet	

SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
Split spoon	44	8-6-4 N=10						
Split spoon	44	4-3-3 N=6				8.3		
Split spoon	67	4-5-6 N=11						
Split spoon	67	8-9-10 N=19						
Split spoon	100	10-15-50/5"		4.5+ (HP)		20.8		
Split spoon	83	12-10-13 N=23				14.7		
Split spoon	100	50/4"						

Water level observations: water observed at approx. 18.7 ft and 20 ft; wet cave-in at 22 ft.

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey.
Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

- Water observed at 20' during drilling
- Water observed at 18.7 after drilling
- Wet cave-in encountered at 22'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-2

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH, Bellbrook, OH

SITE: Little Sugarcreek Road, Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6370° Longitude: -84.0766°

Station: 14+05 Offset: 9' R

Approximate Surface Elev.: 804 (Ft.) +/-

MODEL LAYER	DEPTH	MATERIAL DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	0.3	**ASPHALT (4")**	803.5+/-											
1	2.0	**FILL - WELL GRADED GRAVEL WITH SAND (GW)**, trace fines, gray, (AGGREGATE BASE)	802+/-			Split spoon	67	8-4-3 N=7						
2		**FILL - LEAN CLAY (CL)**, with gravel, trace sand, dark brown to gray, trace asphalt fragments				Split spoon	67	3-1-2 N=3		0.5 (HP)		15.4		
		-clay drain tile fragments at 6 feet		5		Split spoon	22	3-2-3 N=5		0.75 (HP)		15.1		
						Shelby tube	50	PUSH 2.0'						28-15-13
	13.5		790.5+/-	10										
5		**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong				Split spoon	78	12-16-13 N=29				11.9		
				15	Cave-in (16.5')									
	19.9		784+/-			Split spoon	88	24-38-50/5"				10.1		
		Split Spoon Refusal and Boring Terminated at 19.9 Feet												

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

No water observed after drilling

Wet cave-in encountered at 16.5'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-3

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH
Bellbrook, OH

SITE: Little Sugarcreek Road
Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6374° Longitude: -84.0771°

Station: 15+95 Offset: 9' R

Approximate Surface Elev.: 808 (Ft.) +/-

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	1.5	**ASPHALT (18")**	806.5+/-											
1	8.5	**FILL - CLAYEY SAND (SC)**, with gravel, brown to dark brown	799.5+/-			X	89	4-4-3 N=7				8.7		
				5		X	44	1-1-1 N=2				10.3		
						X	44	1-0-2 N=2				13.4		
2	13.5	**SANDY LEAN CLAY (CL)**, with gravel, brown, medium stiff, (possible fill)	794.5+/-	10		X	67	1-3-6 N=9		0.5 (HP)		11.3		
3	18.5	**WELL GRADED GRAVEL (GW)**, trace sand, trace fines, brown to reddish brown, dense, (possible fill)	789.5+/-	15	▽	X	78	18-12-23 N=35						
2	20.0	**LEAN CLAY (CL)**, brown, hard, with limestone fragments and layers, trace bedding planes, (RESIDUUM)	788+/-	20		X	67	14-16-8 N=24				15.3		
5	28.8	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE (85%)**, gray, very thin to thin bedding, slightly weathered to unweathered, very weak **LIMESTONE (15%)**, gray, very thin bedding, unweathered, strong	779+/-		cave-in	X	100	50/4"				9.4		
				25		Core	94		30					
		Boring Terminated at 28.8 Feet												

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey.
Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

▽ *Water observed at 17' after drilling*

Wet cave-in encountered at 21.5'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-4

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH Bellbrook, OH

SITE: Little Sugarcreek Road Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6377° Longitude: -84.0776°

Station: 17+85 Offset: 9' R

Approximate Surface Elev.: 807 (Ft.) +/-

MODEL LAYER	DEPTH	MATERIAL DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	1.3	**ASPHALT (15")**	805.5+/-											
1	1.5	**AGGREGATE BASE (3")**	805.5+/-				67	7-4-3 N=7				6.4		
1	3.5	**FILL - CLAYEY SAND WITH GRAVEL (SC)**, brown	803.5+/-											
2		**SANDY LEAN CLAY (CL)**, with gravel, brown, medium stiff					33	2-1-2 N=3		1.0 (HP)		12.5		
2				5			87	PUSH 2.0'			0.96	12.1	124	
2	13.5	-dark brown at 8.5 feet	793.5+/-	10			78	2-2-3 N=5		1.0 (HP)		21.5		
4	18.0	**SHALE**, brown with some gray, highly weathered, very weak, trace limestone fragments and layers	789+/-	15	Water observed at 16' after drilling; Wet cave-in at 17.6'		78	7-9-8 N=17		4.5 (HP)		21.2		
5	19.9	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	787+/-				94	24-28-50/5"				9.1		

Split Spoon Refusal and Boring Terminated at 19.9 Feet

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

Water observed at 16' after drilling

Wet cave-in encountered at 17.6'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-5

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH
Bellbrook, OH

SITE: Little Sugarcreek Road
Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6382° Longitude: -84.0780°

Station: 19+80 Offset: 9' R

Approximate Surface Elev.: 807 (Ft.) +/-

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)
	1.4	**ASPHALT (17")**	805.5+/-
	1.7	**AGGREGATE BASE (3")**	805.5+/-
1	8.5	**FILL - SANDY LEAN CLAY (CL)**, with gravel, dark brown to gray	798.5+/-
4	13.5	**SHALE**, brown and gray, highly weathered, very weak, trace limestone fragments and layers	793.5+/-
5	17.4	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	789.5+/-
		Split Spoon Refusal and Boring Terminated at 17.4 Feet	

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
1-2.5		X	78	2-1-2 N=3		0.5 (HP)		12.7		
3.5-5		X	44	2-1-1 N=2		1.0 (HP)		15.2		
6-7.5		X	78	2-1-4 N=5		1.5 (HP)		23.3		
8.5-10		X	67	7-7-10 N=17		4.5+ (HP)		17.8		
13.5-15		X	89	29-28-50 N=78				13.4		
15.8	Dry cave-in									
16-17.4		X	100	20-49-50/5"				9.8		

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

No water observed after drilling

Dry cave-in encountered at 15.8'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021 | Boring Completed: 03-29-2021

Drill Rig: CME55 | Driller: CK

Project No.: N1205425

BORING LOG NO. B-6

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH, Bellbrook, OH

SITE: Little Sugarcreek Road, Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6387° Longitude: -84.0783°

Station: 21+75 Offset: 9' R

Approximate Surface Elev.: 805 (Ft.) +/-

MODEL LAYER	DEPTH	MATERIAL DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	1.3	**ASPHALT (15")**	803.5+/-											
	1.5	**AGGREGATE BASE (3")**	803.5+/-											
1	3.5	**FILL - LEAN CLAY (CL)**, with sand, with gravel, dark brown to gray	801.5+/-			Split spoon	89	2-2-2 N=4		0.75 (HP)		21.8		
2	8.5	**LEAN CLAY (CL)**, brown and gray, trace bedding planes, trace limestone fragments and layers, (RESIDUUM)	796.5+/-	5		Split spoon	78	3-12-9 N=21		3.0 (HP)		27.7		
						Split spoon	67	14-9-7 N=16		4.0 (HP)		19.8		45-22-23
4	13.5	**SHALE**, brown and gray, highly weathered, very weak, trace limestone fragments and layers	791.5+/-	10		Split spoon	78	4-7-13 N=20		4.5 (HP)		20.5		
5	20.0	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE (90%)**, gray, very thin to thin bedding, slightly weathered to unweathered, very weak **LIMESTONE (10%)**, gray, very thin bedding, unweathered, strong	785+/-	15	▽ (14')	Split spoon	94	14-24-50/5"				10.5		
					Wet cave-in (17.6')	Rock core	100		94					
		Boring Terminated at 20 Feet		20										

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

▽ *Water observed at 14' after drilling*

Wet cave-in encountered at 17.6'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-7

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH
Bellbrook, OH

SITE: Little Sugarcreek Road
Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6395° Longitude: -84.0790°

Station: 25+35 Offset: 9' R

Approximate Surface Elev.: 812 (Ft.) +/-

MODEL LAYER	DEPTH	MATERIAL DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	0.3	**ASPHALT (4")**	811.5+/-											
	1.0	**AGGREGATE BASE (8")**	811+/-											
1		**FILL - CLAYEY SAND WITH GRAVEL (SC)**, brown, trace asphalt fragments				X	67	8-4-4 N=8				7.3		
						X	53	3-2-3 N=5				8.6		
	6.0		806+/-	5										
2		**LEAN CLAY (CL)**, trace sand, trace gravel, brown, stiff				X	78	1-2-3 N=5		1.5 (HP)		21.1		44-18-26
						X	78	2-3-4 N=7		2.0 (HP)		16.0		
	13.5		798.5+/-	10										
4		**SHALE**, brown and gray, highly weathered, very weak, trace limestone fragments and layers				X	78	30-14-24 N=38				15.4		
				15	Cave-in									
	18.5		793.5+/-											
5	18.9	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	793+/-			X	100	50/4"				4.8		
		Split Spoon Refusal and Boring Terminated at 18.9 Feet												

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

No water observed after drilling

Dry cave-in encountered at 16.9'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-8

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH, Bellbrook, OH

SITE: Little Sugarcreek Road, Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6400° Longitude: -84.0793°

Station: 27+50 Offset: 9' R

Approximate Surface Elev.: 815 (Ft.) +/-

MODEL LAYER	DEPTH	MATERIAL DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	1.2	**ASPHALT (14")**	814+/-											
1		**FILL - WELL GRADED GRAVEL WITH SAND (GW)**, brown and gray				X	67	6-5-5 N=10						
				5		X	16	4-3-2 N=5						
	8.5	-mostly gravel/rock fragments recovered at 3.5 and 6 feet	806.5+/-			X	16	4-4-4 N=8						
2		**LEAN CLAY (CL)**, with gravel, trace sand, brown, stiff		10		X	100	4-4-7 N=11		1.5 (HP)		17.3		
	13.5		801.5+/-											
4		**SHALE**, brown and gray, highly weathered, very weak, trace limestone fragments and layers		15	Dry cave-in (16.5')	X	78	6-12-14 N=26		4.5 (HP)		18.2		
	18.5		796.5+/-											
5	19.3	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	795.5+/-			X	100	48-50/4"				3.9		

Split Spoon Refusal and Boring Terminated at 19.3 Feet

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey. Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

No water observed during drilling

No water observed after drilling

Dry cave-in encountered at 16.5'

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-9

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH, Bellbrook, OH

SITE: Little Sugarcreek Road, Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6405° Longitude: -84.0796°

Station: 29+45 Offset: 9' R

Approximate Surface Elev.: 814 (Ft.) +/-

MODEL LAYER	DEPTH (Ft.)	DESCRIPTION	ELEVATION (Ft.)
	1.1	**ASPHALT (13")**	813+/-
1	1.3	**AGGREGATE BASE (3")**	812.5+/-
1	3.5	**FILL - CLAYEY SAND WITH GRAVEL (SC)**, dark brown to gray	810.5+/-
1	8.5	**FILL - LEAN CLAY (CL)**, trace sand, trace gravel, dark brown to gray	805.5+/-
2	13.5	**SANDY LEAN CLAY (CL)**, with gravel, brown, very stiff, (possible fill)	800.5+/-
2	23.5	**LEAN CLAY (CL)**, olive brown and gray, very stiff to hard, trace bedding planes, trace limestone fragments and layers, (RESIDUUM)	790.5+/-
5	30.0	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE (80%)**, gray, very thin to thin bedding, slightly weathered to unweathered, very weak **LIMESTONE (20%)**, gray, very thin bedding, unweathered, strong	784+/-
		Boring Terminated at 30 Feet	

SAMPLE DEPTH (approx. Ft.)	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
1–2.5	78	6-5-2 N=7				7.2		
3.5–5	78	1-2-2 N=4		0.5 (HP)		19.8		
6–8	100	PUSH 2.0'			1.03	22.3	103	
8.5–10	89	3-5-3 N=8		2.5 (HP)		12.6		
13.5–15	89	6-6-7 N=13		4.5 (HP)		20.8		
18.5–19.7	75	23-13-50/2"		2.5 (HP)		25.0		
23.5–23.8	100	50/4"						
25–30	100		50					

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey.
Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS
- *Water observed at 20' during drilling*
- *Water observed at 17.3' after drilling*
- *Wet cave-in encountered at 22.3'*

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

BORING LOG NO. B-10

PROJECT: Little Sugarcreek Road Stabilization and Pedestrian Access

CLIENT: City of Bellbrook OH Bellbrook, OH

SITE: Little Sugarcreek Road Bellbrook, OH

LOCATION See Exploration Plan

Latitude: 39.6411° Longitude: -84.0799°

Station: 31+70 Offset: 9' R

Approximate Surface Elev.: 811 (Ft.) +/-

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (%)	FIELD TEST RESULTS	RQD%	LABORATORY HP (tsf)	UNCONFINED COMPRESSIVE STRENGTH (tsf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI
	1.3	**ASPHALT (16")**	809.5+/-											
	1.6	**AGGREGATE BASE (3")**	809.5+/-											
1	6.0	**FILL - SANDY LEAN CLAY WITH GRAVEL (CL)**, grayish brown	805+/-			X	67	5-4-4 N=8		1.0 (HP)		12.7		
				5		X	53	5-0-1 N=1				10.7		
2	8.5	**LEAN CLAY (CL)**, trace sand, trace gravel, dark brown, stiff	802.5+/-			X	67	3-1-3 N=4		1.5 (HP)		23.0		
	13.5	**LEAN CLAY (CL)**, with sand, trace gravel, brown, very stiff, (GLACIAL TILL)	797.5+/-	10		X	67	2-4-3 N=7		3.5 (HP)		15.7		
4	18.5	**SHALE**, brown and gray, highly weathered, very weak, trace limestone fragments and layers	792.5+/-	15		X	89	10-12-16 N=28		4.5 (HP)		21.1		
5	23.9	**INTERBEDDED GRAY SHALE AND LIMESTONE** **SHALE**, gray, slightly weathered to unweathered, very weak **LIMESTONE**, gray, unweathered, strong	787+/-	20	▽ ▽ cave-in	X	89	32-42-45 N=87						
							100	50/4"						

Split Spoon Refusal and Boring Terminated at 23.9 Feet

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

Hammer Type: Automatic

Advancement Method:
3.25-inch Continuous-Flight Hollow-Stem Augers
2-inch Split-Barrel Sampler

Abandonment Method:
Boring backfilled with Auger Cuttings
Surface capped with asphalt

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.

Coordinates from Terracon Leica Zeno survey.
Elevation interpolated from LJB survey.

Notes:

WATER LEVEL OBSERVATIONS

- ▽ *Water observed at 20' during drilling*
- ▽ *Water observed at 20.7' after drilling*
- *Wet cave-in encountered at 21.4'*

Terracon
611 Lunken Park Dr
Cincinnati, OH

Boring Started: 03-29-2021	Boring Completed: 03-29-2021
Drill Rig: CME55	Driller: CK
Project No.: N1205425	

SUPPORTING INFORMATION

Contents:

.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Little Sugarcreek Road Stabilization and Pedestrian Access ■ Bellbrook, OH

Terracon Project No. N1205425

Terracon GeoReport

SAMPLING	WATER LEVEL	FIELD TESTS
Rock Core Shelby Tube 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		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (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 SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification: Group Symbol	Soil Classification: 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 ³ 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 ³ 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 on or above “A” line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below “A” line [J]	ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried / Liquid limit - 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:	Liquid limit - oven dried / Liquid limit - 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] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ³ 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 ³ 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 ³ 30% plus No. 200 predominantly sand, add “sandy” to group name.

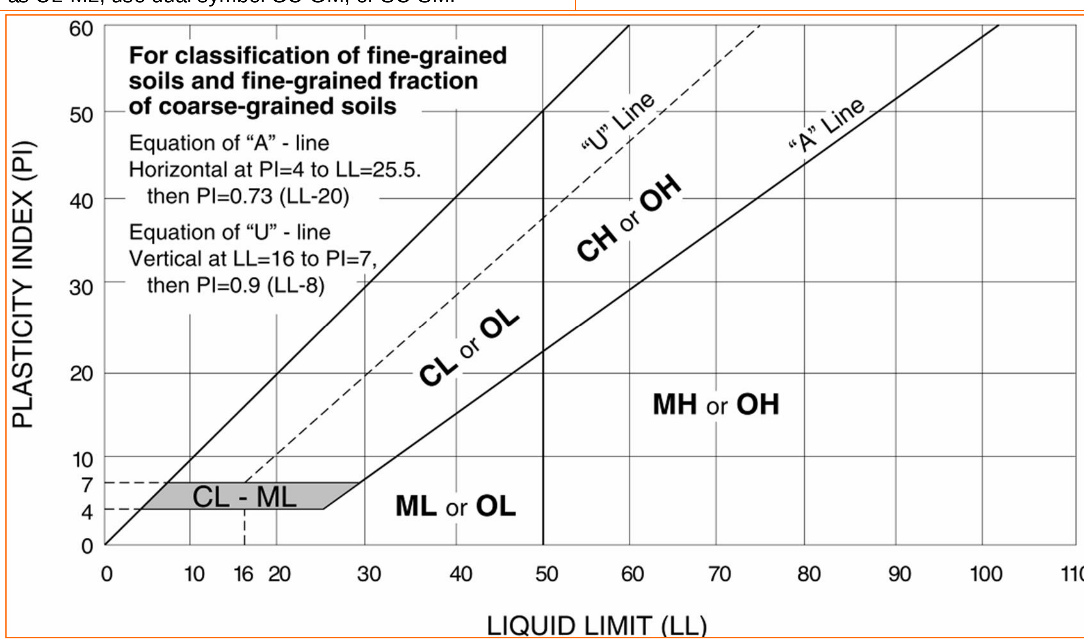
[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[N] PI ³ 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.



DESCRIPTION OF ROCK PROPERTIES

WEATHERING	
Term	**Description**
Unweathered	No visible sign of rock material weathering, perhaps slight discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

STRENGTH OR HARDNESS		
Description	**Field Identification**	**Uniaxial Compressive Strength, psi (MPa)**
Extremely weak	Indented by thumbnail	40-150 (0.3-1)
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	150-700 (1-5)
Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	700-4,000 (5-30)
Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	4,000-7,000 (30-50)
Strong rock	Specimen requires more than one blow of geological hammer to fracture it	7,000-15,000 (50-100)
Very strong	Specimen requires many blows of geological hammer to fracture it	15,000-36,000 (100-250)
Extremely strong	Specimen can only be chipped with geological hammer	>36,000 (>250)

DISCONTINUITY DESCRIPTION			
Fracture Spacing (Joints, Faults, Other Fractures)		**Bedding Spacing (May Include Foliation or Banding)**	
Description	**Spacing**	**Description**	**Spacing**
Extremely close	< ¾ in (<19 mm)	**Laminated**	< ½ in (<12 mm)
Very close	¾ in – 2-1/2 in (19 - 60 mm)	**Very thin**	½ in – 2 in (12 – 50 mm)
Close	2-1/2 in – 8 in (60 – 200 mm)	**Thin**	2 in – 1 ft. (50 – 300 mm)
Moderate	8 in – 2 ft. (200 – 600 mm)	**Medium**	1 ft. – 3 ft. (300 – 900 mm)
Wide	2 ft. – 6 ft. (600 mm – 2.0 m)	**Thick**	3 ft. – 10 ft. (900 mm – 3 m)
Very Wide	6 ft. – 20 ft. (2.0 – 6 m)	**Massive**	> 10 ft. (3 m)

Discontinuity Orientation (Angle): Measure the angle of discontinuity relative to a plane perpendicular to the longitudinal axis of the core. (For most cases, the core axis is vertical; therefore, the plane perpendicular to the core axis is horizontal.) For example, a horizontal bedding plane would have a 0-degree angle.

ROCK QUALITY DESIGNATION (RQD) [1]	
Description	**RQD Value (%)**
Very Poor	0 - 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 - 100

1. The combined length of all sound and intact core segments equal to or greater than 4 inches in length, expressed as a percentage of the total core run length.

Reference: U.S. Department of Transportation, Federal Highway Administration, Publication No FHWA-NHI-10-034, December 2009
Technical Manual for Design and Construction of Road Tunnels – Civil Elements