

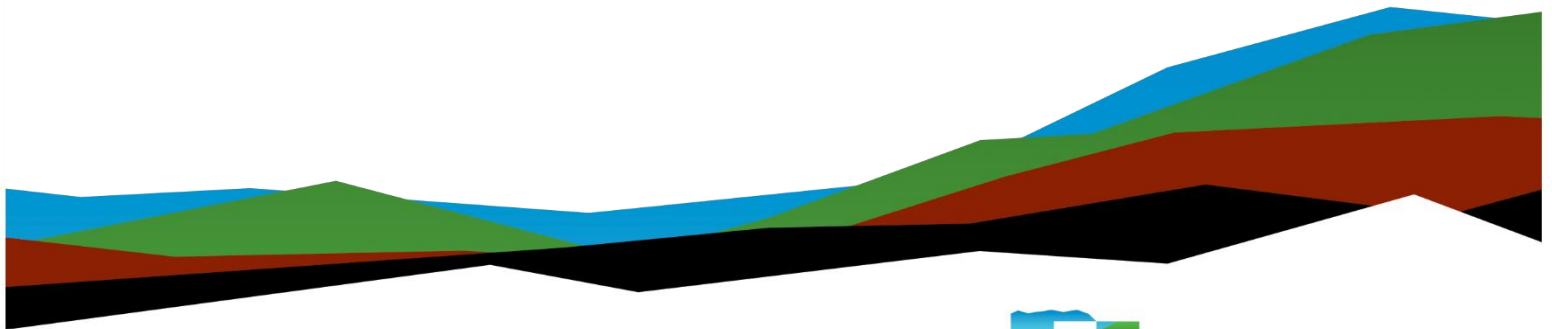
WYCO Lake Retaining Wall Improvements

Geotechnical Engineering Report

January 26, 2023 | Terracon Project No. 02235265

Prepared for:

Unified Government of Wyandotte-
County, Kansas City, KS – Parks
and Recreation Department
Kansas City, Kansas 66101



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January 26, 2023

Unified Government of Wyandotte-County, Kansas City, KS – Parks and Recreation
Department
701 N 7th Street Suite 712
Kansas City, Kansas 66101

Attn: Angel Ferrara, CPRP - Director
P: (913) 573-8354
E: aferrara@wycokck.org

Re: Geotechnical Engineering Report
WYCO Lake Retaining Wall Improvements
3862 West Drive
Kansas City, Kansas
Terracon Project No. 02235265

Dear Ms. Ferrara:

We have completed a subsurface exploration and geotechnical engineering evaluation for the referenced project in general accordance with Terracon Proposal No. P02235265 dated September 21, 2023. This report presents the findings of the subsurface exploration and provides geotechnical analysis and opinions concerning the retaining wall failure.

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

David Gudino-Chausse, EI
Staff Engineer

Mohamad (Mo) Ibrawish, P.E.
Geotechnical Department Manager
Kansas: PE 23575


Reviewed by: Kole Berg, P.E.

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Attachments

- Exploration and Testing Procedures**
- Site Location and Exploration Plans**
- Exploration and Laboratory Results**
- Supporting Information**

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.

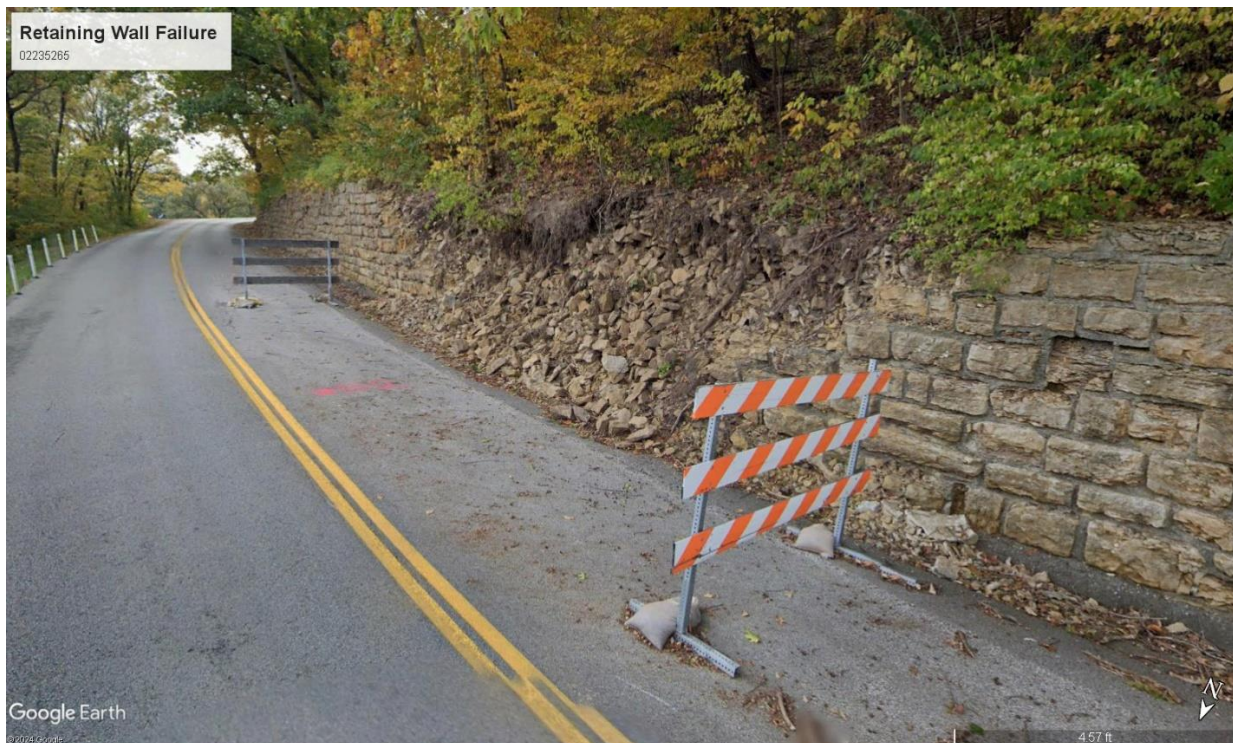
Introduction

This report presents the results of our subsurface exploration and Geotechnical Engineering and Geophysical evaluation performed for the retaining wall failure at Wyandotte County Lake in Kansas City, Kansas. Three exploratory borings and two seismic lines were performed at the site.

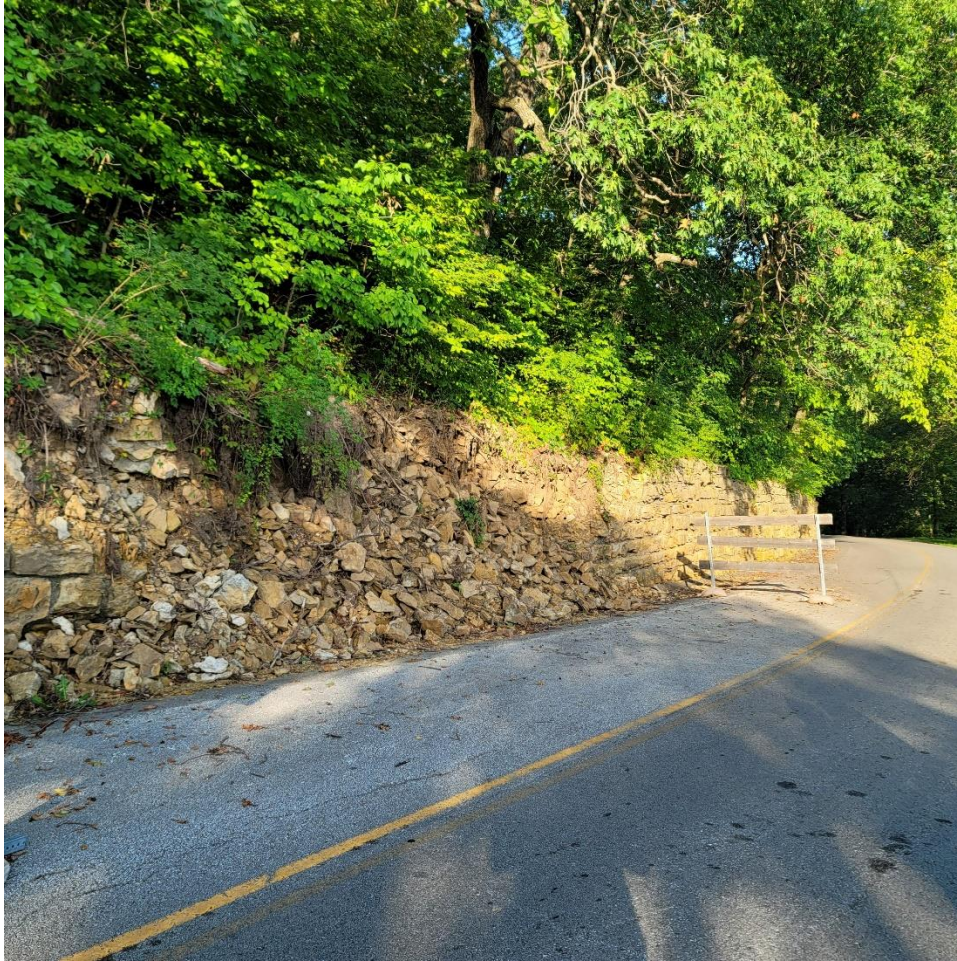
Drawings showing the site and boring locations are shown on the attached [Site Location Plan](#) and [Exploration Plan](#). The results of the laboratory testing performed on soil samples obtained from the site during our field exploration are included on the boring logs and/or as separate graphs in [Exploration Results](#).

Project Description

Terracon was contacted by WYCO Parks and Recreation (WYCOPR), in August 2023 to evaluate a retaining wall failure and possible slope failure (See Pictures 1 & 2) on the southwest side of Wyandotte County Lake in Kansas City, Kansas. Approximate Latitude/Longitude: 39.1593, -94.7930



Picture 1



Picture 2

Based on conversations with the client during the initial site meeting we understand the wall collapsed in February of 2023. It is believed the wall itself is approximately 75 to 85 years old, the lake and park are approximately 85 years old. We understand the lake was constructed on the location of a rock mine area where bedrock used to be mined for construction purposes. Based on conversations and recollections the client team, some cracks were noticed within the wall prior to the collapse.

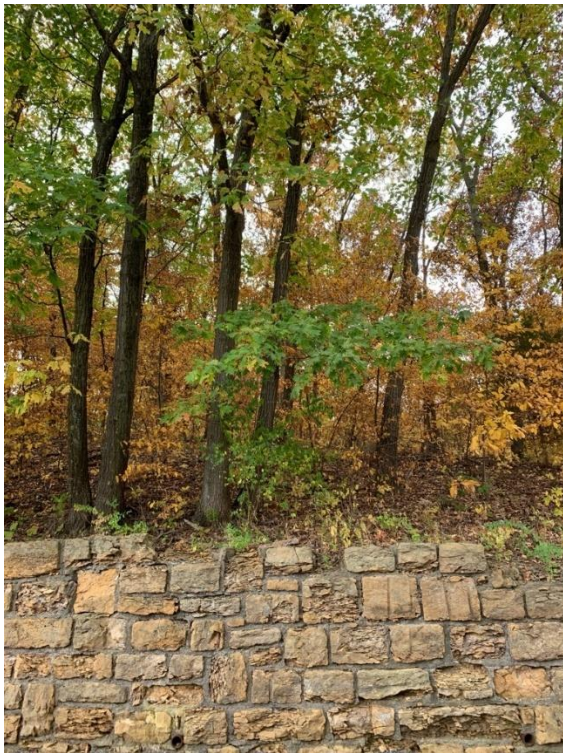
Site Conditions

The following observations and information are derived from our site visits in association with the field exploration as well as local knowledge of site history.

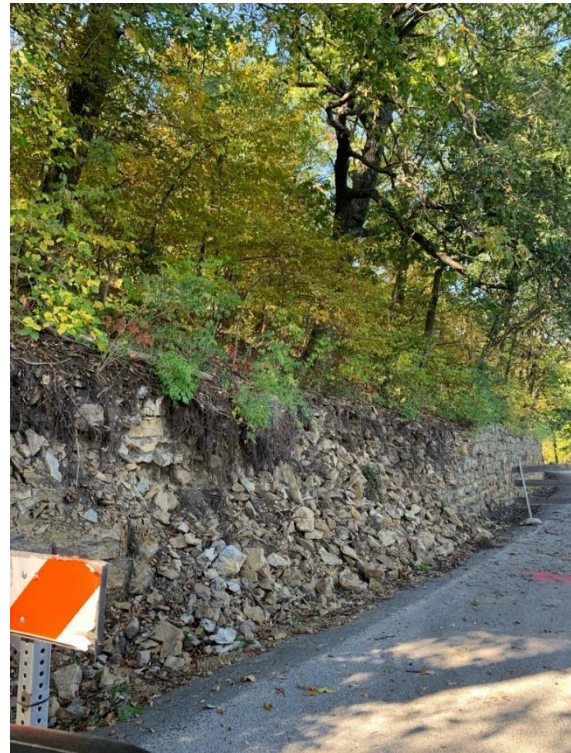
The observed wall/slope failure is located along an existing roadway that cuts through a slope that sloped down from south to north. The slope is approximately 200 feet in length and 60 feet in elevation change. The areas surrounding the failure are currently

heavily wooded to the east, west, and south. Grass areas with a manmade lake are located to the north. The lake area was previously a rock quarry. Some areas of the quarry were brought back to elevation using various types of fill and other areas were left open to create the lake and park.

The retaining wall is comprised of limestone and sandstone blocks and has a maximum height of approximately 8 feet. As seen in the images below, the rock pieces used to construct the wall show evidence of weathering and fracturing. Existing trees in the slope area above the wall have been observed to be leaning in the direction of the wall, but no obvious signs of slope sloughing were observed. Further inspection of the wall revealed that several of the weep holes were obstructed/clogged with soil and rock, and it appeared that the backfill material behind the wall consisted of limestone fragments of various sizes.



Picture 3



Picture 4

Geotechnical Characterization

We have developed a general characterization of the subsurface conditions based on the subsurface exploration, laboratory data, geologic setting, and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical evaluation. Conditions observed at each boring location are indicated on the individual

logs. The individual logs are in the [Exploration Results](#) and the GeoModel is 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	Existing Fill	Loess (wind-deposited) lean clays and Glacial Till lean to fat clays
2	Bedrock	Highly to moderately weathered limestone, moderately weathered sandstone, and moderately weathered shale

The borings were observed during drilling and shortly after completion of drilling for the presence and level of water. Groundwater was not encountered in the other borings at these times. A longer period of time may be required for groundwater to develop and stabilize in a borehole. Longer term observations in piezometers or observation wells, sealed from the influence of surface water, are often required to define groundwater levels.

Groundwater levels may fluctuate due to seasonal variations in the amount of rainfall, runoff, and other factors not evident at the time the borings were performed. “Perched” water could occur above lower permeability soil layers and/or near the soil/bedrock interface, and “trapped” water could be present within existing fill materials. Therefore, groundwater conditions at other times may be different than the conditions encountered in our exploratory borings. The potential for water level fluctuations and perched water should be considered when developing design and construction plans and specifications for the project.

Geophysical Analysis

P-Wave Seismic Analysis: P-Wave Seismic Analysis: Terracon performed compression wave (p-wave) seismic refraction surveys at two locations as shown on the [Exploration Plan](#). A p-wave is the first motion recorded on a seismogram; thus, has been given the designation “p” for the Latin word “primus”. Our method utilized a seismograph and a linear array of twenty-four 4.5 Hz geophones spaced 5 feet apart. Seismic source shots were initiated at nine locations along each array. A shot location is where the energy source, in this case a sledgehammer and source plate, was activated to create the p-waves. A single shot consisted of a blow from the source. At each shot location, at least nine hammer swings were recorded and stacked to make one shot. The geophones were triggered by the source, and a 0.5 second data set with a 0.125 millisecond sample interval was recorded for each shot.

Using Pickwin developed by Geometrics and RayFract developed by Intelligent Resources Inc., the first-arrival travel times were selected, and the survey geometry was entered to perform forward modeling using a non-linear optimization technique called adaptive simulated annealing. This algorithm determines the compressive wave velocity model for a corresponding depth and resolution, with the minimum travel-time error, without searching through every possible model. The resulting model provides a p-wave velocity depth profile.

The following figures present the interpretations of the data from the geophysical field exploration. The velocity at which a p-wave travels through a material is mainly influenced by the density of the material. In general, lower velocity materials (violet) are interpreted to represent overburden and fill materials (relatively less dense); whereas, higher velocity materials (blue to red) are interpreted to represent bedrock (relatively more dense). The borings were overlayed on the seismic cross sections to constrain our interpretations of the geophysical models. Both the borings and the geophysical models were used to develop the global stability model described in the section below.

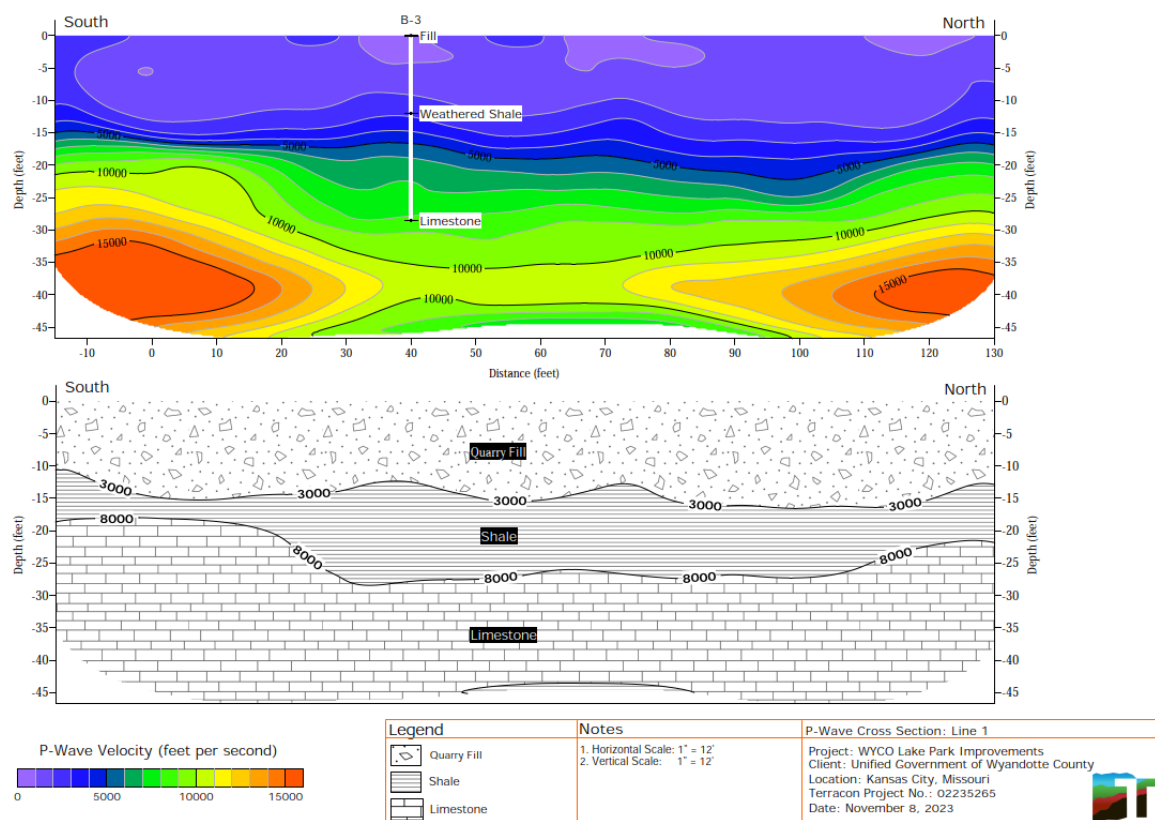


Figure 1: P-Wave Cross Section: Line 1

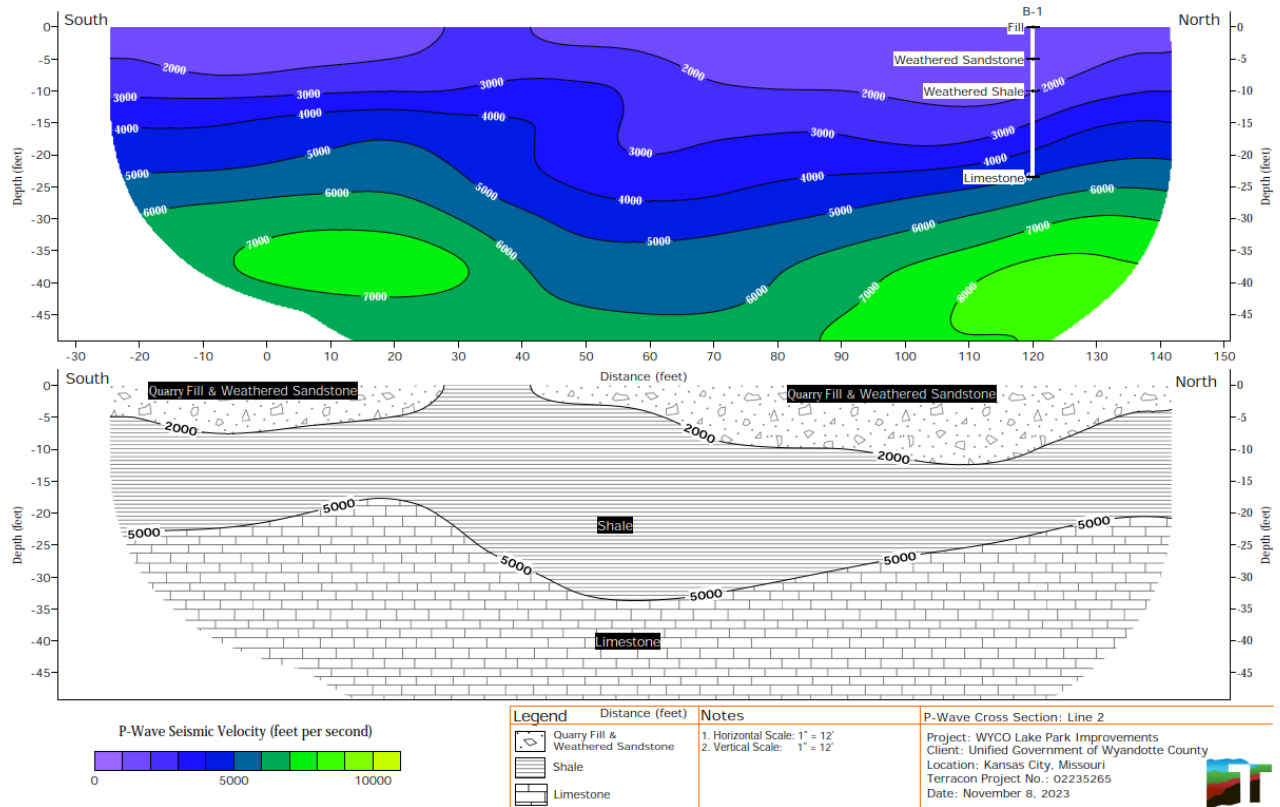


Figure 2: P-Wave Cross Section: Line 2

Global Stability Analyses

Slope stability analyses were performed for impacted area of the wall. Parameters for the analyses were derived from our exploratory borings, experience with local soil and rock materials, and laboratory tests. Stability analyses were conducted using the computer program Slope/W developed by Geo-Slope International. Based on the analyses, the factor-of-safety for global stability at the analyzed cross sections was at least 1.5. Due to the nature of the slope we selected to run the analyses based on a block slope failure.

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WYCO Lake Retaining Wall Improvements | Kansas City, Kansas

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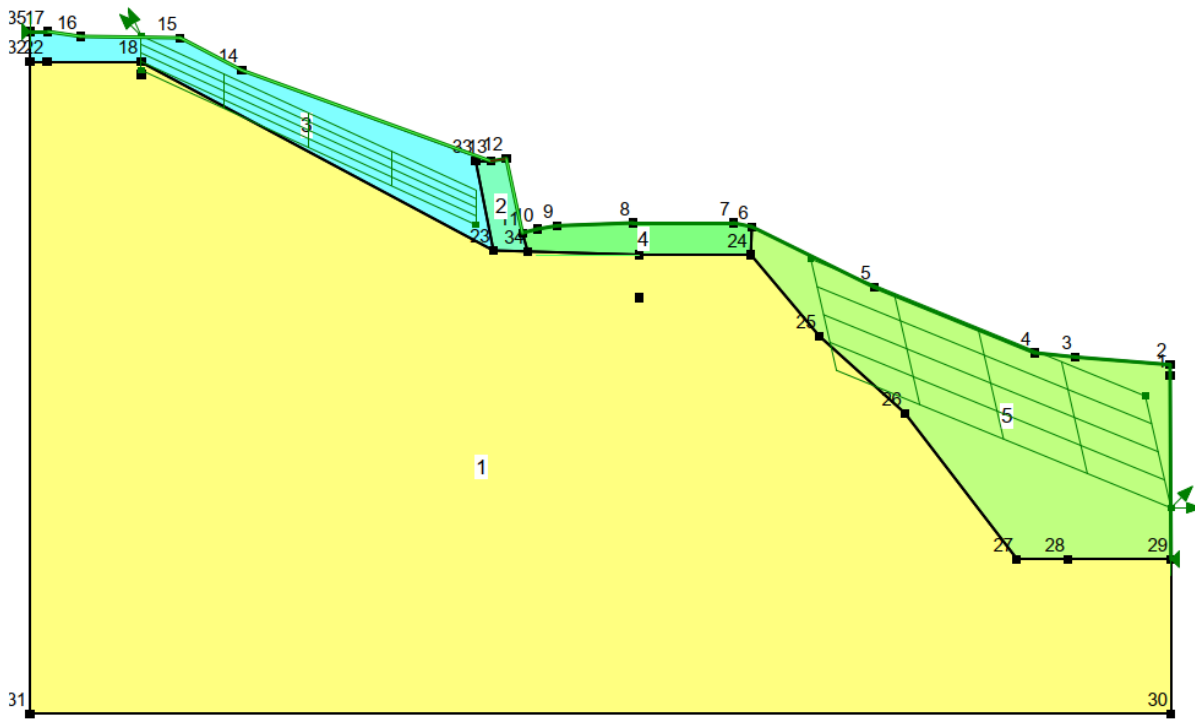


Figure 3 – Slope Configuration

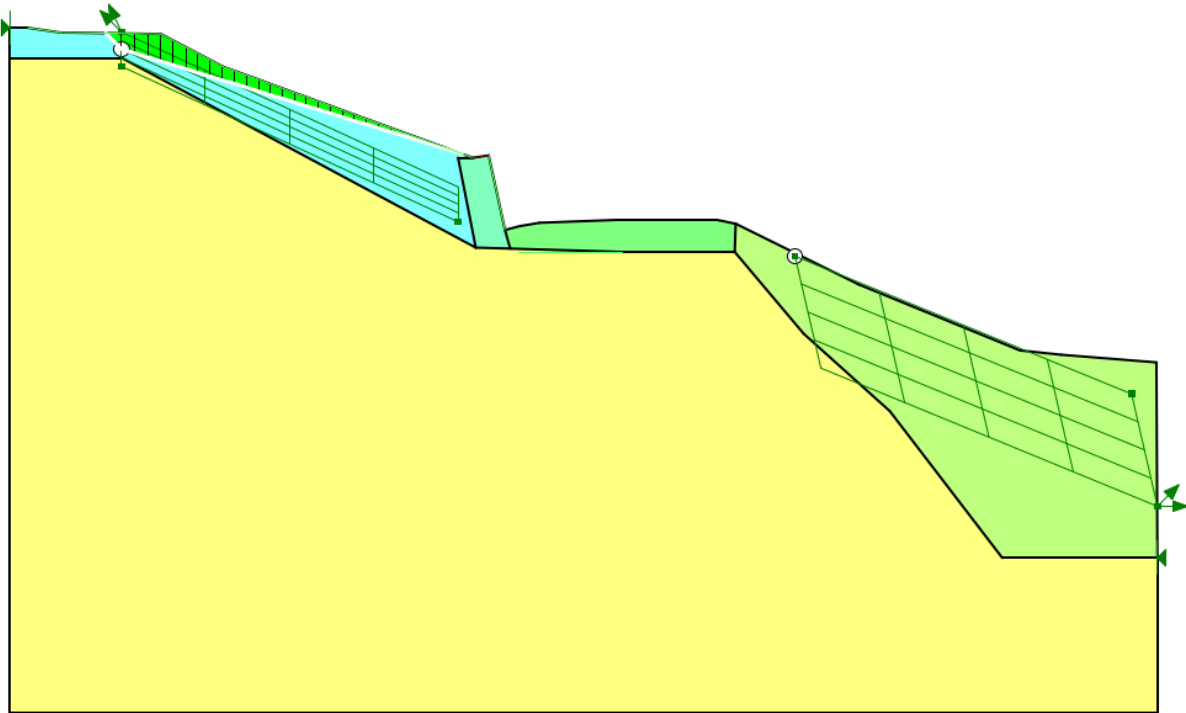


Figure 4 – Slope Analysis Cross-Section

Professional Opinions and Observations

The global stability analysis performed indicated that the in general the slope is in stable condition. The failure of the wall appears to be a localized failure of the retaining wall. The reason the retaining wall collapsed was not determined and is outside of the scope of our investigation. However, based on our observations and experience the following causes may have contributed individually or as a group in its collapse:

- Wall is old: the wall is approximately 75 years old. This is beyond the expected service period of similar retaining wall structures in this area. We observed deterioration of the building blocks and cementing materials of the wall itself. The limestone and sandstone blocks used in the wall appear to have weathered and deteriorated over time and that may impact the stability of the wall structure.
- Hydrostatic pressure behind the wall: weep holes that allow water to seep from the backfill materials outside the wall to reduce the hydrostatic pressure appear to have become blocked. This causes the hydrostatic pressure behind the wall to

increase to a point above the design capability of the wall and may have contributed to the failure.

- **Roots:** Root systems of mature trees that are in near proximity to the wall may have caused deterioration along the back of the wall.

Solutions to the collapsed wall vary in price and degree of disturbance to the current landscape. The following section provides a discussion of recommended options:

- **Construct a new wall**
 - The entire wall will need to be demolished and reconstructed. The type of new wall can be selected by the client based on the available budget, performance requirements, constructability, and other factors.
 - Partial construction of only the damaged/collapsed portions of the wall is not recommended. The remaining portions of the existing wall show signs of deterioration, and vibrations from construction equipment could cause the remaining portions of the wall to collapse.
 - Weep holes are clogged and not functioning.
- **Terrace the slope or cut it back on a 3:1 (Horizontal:Vertical) slope**
 - Care must be taken to ensure during design and construction that runoff water is diverted away from the slope face and the toe of the slope.
 - This option will require significant excavation of rock, since bedrock is present at relatively shallow depths in the slope.
 - The tree cover will be lost if the slope is flattened or terraced.
- **Level a portion between the road and the slope and create a vertical cut directly into the rock face**
 - The cut could extended approximately 10 feet off the side of the road.
 - Appropriate drainage of surface water should also be considered.

The above suggestions should be considered after consulting with a team of geotechnical and civil engineers.

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.

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. If variations appear, we can provide further 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 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, cost estimating, 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.

Geotechnical Engineering Report

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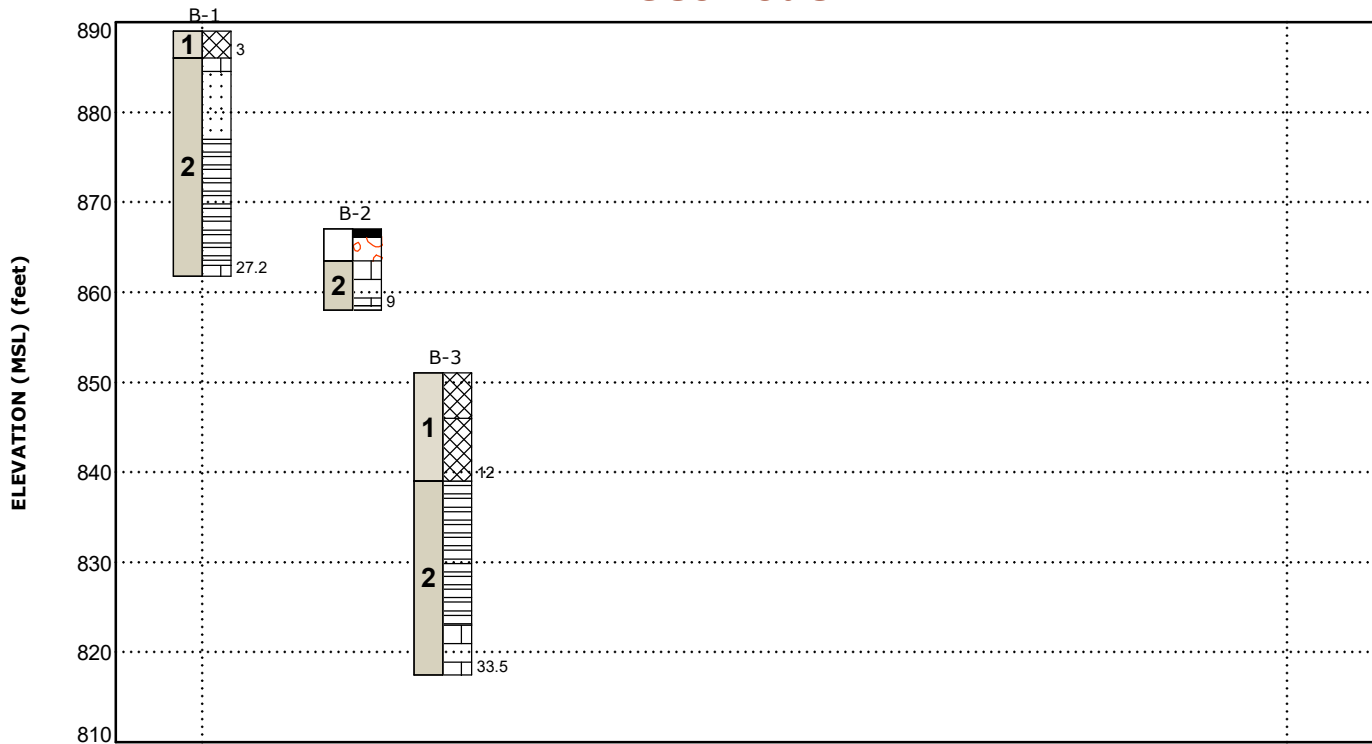


Figures

Contents:

GeoModel

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	Legend	
1	Existing Fill	Loess clays and Glacial Till lean to fat clays	Fill	Limestone
2	Bedrock	Highly to moderately weathered limestone, Moderately weathered sandstone, and Moderately weathered shale	Sandstone	Shale
			Asphalt	Aggregate Base Course

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.

Geotechnical Engineering Report

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Attachments

Exploration and Testing Procedures

Field Exploration

Number of Borings	Approximate Boring Depth (feet)	Location
3	9 to 33.5	Along the suspected slope failure

Boring Layout and Elevations: Terracon personnel provided the boring layout using handheld GPS equipment (estimated horizontal precision of about ±10 feet) and referencing existing site features. Approximate ground surface elevations were obtained by a site-specific topographic survey that was completed at the time of the exploration.

Subsurface Exploration Procedures: We advanced the borings with a track-mounted rotary drill rig using continuous flight augers. Samples were obtained from the borings using thin-walled tube and split-barrel sampling procedures. In the thin-walled tube sampling procedure, a thin-walled, seamless steel tube with a sharp cutting edge was pushed hydraulically into the soil to obtain a relatively undisturbed sample. 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. The borings were backfilled with auger cuttings after their completion. The upper few inches of the borehole penetration through pavement were surface patched with cold-mix asphalt.

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

Our exploration team prepared field boring logs to record the sampling depths, penetration distances, other sampling information, visual classifications of the materials observed during drilling, and our interpretation of the subsurface conditions between samples. The samples were placed in appropriate containers and taken to our laboratory for testing and classification. The final boring logs provided with this report include modifications based on the results of the laboratory tests and observations of the recovered samples.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests. The laboratory testing program included the following tests on selected samples:

- Moisture Content
- Dry Unit Weight
- Unconfined Compression
- Grain Size Analyses
- Atterberg Limits

The laboratory testing program 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 general accordance with the Unified Soil Classification System.

Rock classification was conducted using locally accepted practices for engineering purposes; core samples and petrographic analysis may indicate other rock types. The rock classifications on the boring logs were determined using the attached Rock Classification Notes.

Site Location and Exploration Plans

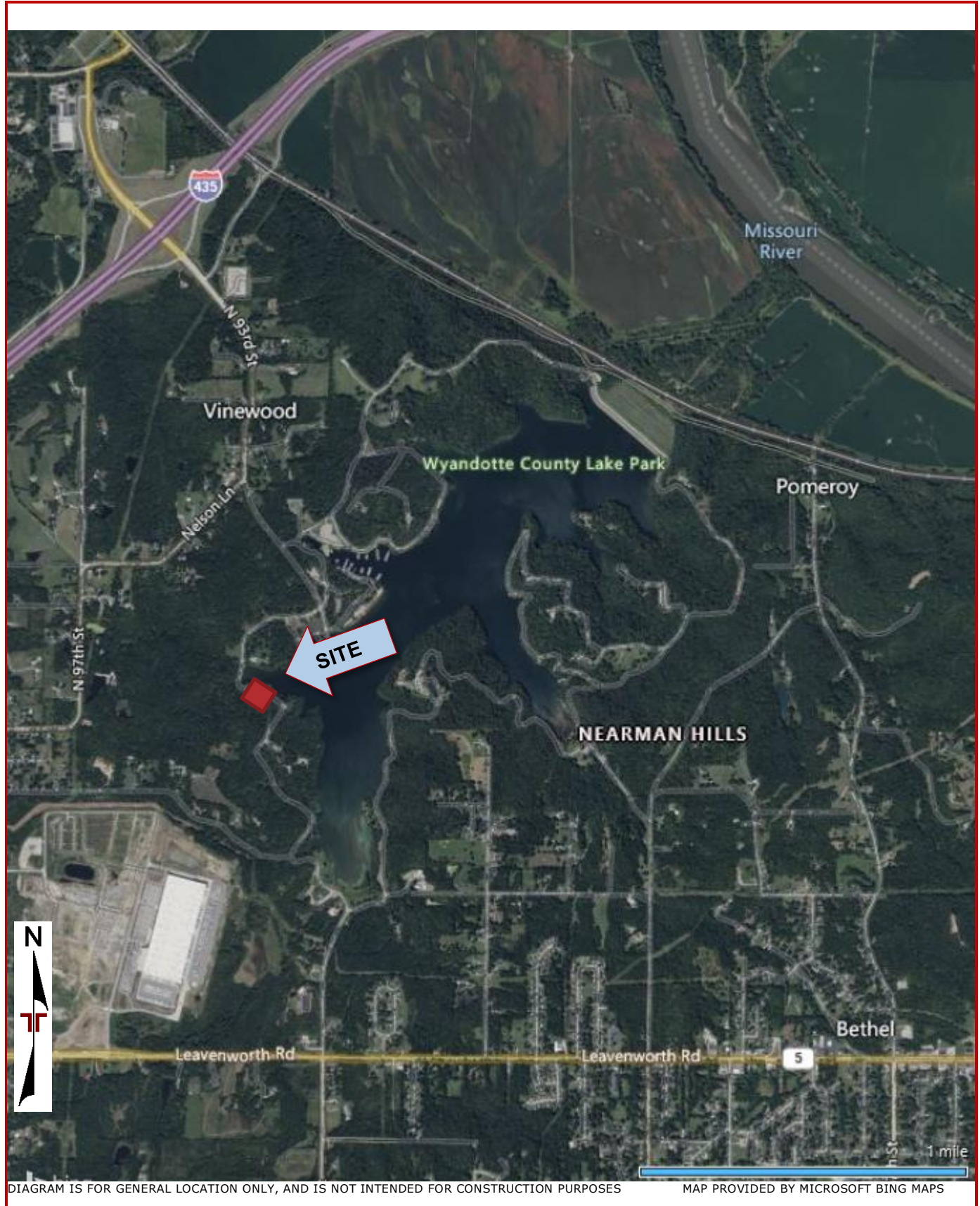
Contents:

Site Location Plan
Exploration Plan

Topographic Survey of Site

Note: All attachments are one page unless noted above.

Site Location



Geotechnical Engineering Report

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Exploration Plan



Exploration and Laboratory Results

Contents:

Boring Logs (B-1 through B-3)

Note: All attachments are one page unless noted above.

Boring Log No. B-1

Model Layer	Graphic Log	Location: See Exploration Plan		Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits		
		Latitude: 39.1592° Longitude: -94.7930°	Elevation.: 889 (Ft.)								LL-PL-PI		
1		Depth (Ft.)											
		FILL - LEAN CLAY WITH SILT , light brown, residual loess fill		3.0	886	█	14		10.2	103	37-20-17		
2		LIMESTONE , gray, highly weathered, caprock		4.5	884.5								
		SANDSTONE , light brown, moderately weathered				5							
						█	10		5.0				
						█	10						
						X	18	13-29-31 N=60	14.8				
		SHALE , light brown to gray, moderately weathered, sandy from 12-20 ft		12.0	877								
						15							
						X	8	15-50/5"	13.5				

<p>See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).</p> <p>See Supporting Information for explanation of symbols and abbreviations.</p>	<p>Water Level Observations</p>	<p>Drill Rig CME-55</p> <p>Hammer Type Automatic</p> <p>Driller LN</p> <p>Logged by DGC</p> <p>Boring Started 10-23-2023</p> <p>Boring Completed 10-23-2023</p>
<p>Notes</p> <p>Elevation Reference: Elevations were sureveyed</p>	<p>Advancement Method HSA</p> <p>Abandonment Method Boring backfilled with Auger Cuttings and/or Bentonite</p>	

Boring Log No. B-1

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 39.1592° Longitude: -94.7930° Depth (Ft.) _____ Elevation.: 889 (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
										LL-PL-PI	
2		SHALE , light brown to gray, moderately weathered, sandy from 12-20 ft (<i>continued</i>)	20		X	8	12-50/5"	12.6			
			25		X	12	14-39-50/4"	13.6			
			26.0	863							
		LIMESTONE , gray, moderately weathered									
		Auger Refusal at 27.2 Feet									
		27.2	861.8								

<p>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.</p> <p>Notes Elevation Reference: Elevations were sureveyed</p>	<p>Water Level Observations</p> <p>Advancement Method HSA</p> <p>Abandonment Method Boring backfilled with Auger Cuttings and/or Bentonite</p>	<p>Drill Rig CME-55</p> <p>Hammer Type Automatic</p> <p>Driller LN</p> <p>Logged by DGC</p> <p>Boring Started 10-23-2023</p> <p>Boring Completed 10-23-2023</p>
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Boring Log No. B-2

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 39.1593° Longitude: -94.7929°	Depth (Ft.)	Elevation.: 867 (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits		
												LL-PL-PI		
	8" ASPHALT		0.8	866.2										
	FILL - CRUSHED LIMESTONE WITH CLAY													
	LIMESTONE , gray, moderately weathered, with sandstone seams		3.5	863.5			12		4-4-4 N=8					
2	LIMESTONE , gray, moderately weathered, with sandstone seams				5				REC: 100% RQD: 55%					
	SHALE , trace sand, gray		8.5	858.5					REC: 69% RQD: 33%	23.5				
	SHALE , trace sand, gray		9.0	858										
	Boring Terminated at 9 Feet													

<p>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.</p> <p>Notes Elevation Reference: Elevations were sureveyed</p>	<p>Water Level Observations</p> <p>Drill Rig CME-55</p> <p>Hammer Type Automatic</p> <p>Driller LN</p> <p>Logged by DGC</p> <p>Boring Started 10-23-2023</p> <p>Boring Completed 10-23-2023</p>	<p>Advancement Method 0-3.5 HSA 3.5-9 NQ Core</p> <p>Abandonment Method Boring backfilled with Auger Cuttings and/or Bentonite</p>
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Boring Log No. B-3

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 39.1594° Longitude: -94.7929°	Depth (Ft.)	Elevation.: 851 (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
											LL-PL-PI	
1		Depth (Ft.) Elevation.: 851 (Ft.) FILL - LEAN CLAY/FAT CLAY , brown and gray, glacial till										
			5.0	846	5	8	2-3-3 N=6	19.8				
						15			22.5	106	48-17-31	
						17		23.9	99			
		FILL - FAT CLAY , dark gray, with organic debris limestone fragments from 9.5-12 ft										
			10		15	2-3-25 N=28	22.0					
2		SHALE , gray brown to gray, highly weathered, with completely weathered seams										
			12.0	839		15	2-8-9 N=17	15.5				
			15									

<p>See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).</p> <p>See Supporting Information for explanation of symbols and abbreviations.</p>	<p>Water Level Observations</p>
<p>Notes</p> <p>Elevation Reference: Elevations were sureveyed</p>	<p>Drill Rig CME-55</p> <p>Hammer Type Automatic</p> <p>Driller LN</p> <p>Logged by DGC</p> <p>Boring Started 10-23-2023</p> <p>Boring Completed 10-23-2023</p>
	<p>Advancement Method 0-28.5 HSA 28.5-33.5 NQ Core</p> <p>Abandonment Method Boring backfilled with Auger Cuttings and/or Bentonite</p>

Boring Log No. B-3

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 39.1594° Longitude: -94.7929°	Depth (Ft.)	Elevation.: 851 (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Dry Unit Weight (pcf)	Atterberg Limits	
											LL-PL-PI	
2		SHALE , gray brown to gray, highly weathered, with completely weathered seams (<i>continued</i>)	18		X	18	4-4-7 N=11	17.5				
			25		X	18	6-4-5 N=9	22.3				
		LIMESTONE , gray, slightly weathered, with shaley seams	30	823	0	50/1"	REC: 100% RQD: 78%					
			33.5	817.5			REC: 100% RQD: 64%					
Boring Terminated at 33.5 Feet												

<p>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.</p> <p>Notes Elevation Reference: Elevations were sureveyed</p>	<p>Water Level Observations</p> <p>Drill Rig CME-55</p> <p>Hammer Type Automatic</p> <p>Driller LN</p> <p>Logged by DGC</p> <p>Boring Started 10-23-2023</p> <p>Boring Completed 10-23-2023</p>	
<p>Advancement Method 0-28.5 HSA 28.5-33.5 NQ Core</p> <p>Abandonment Method Boring backfilled with Auger Cuttings and/or Bentonite</p>		









Supporting Information

Contents:

General Notes
Unified Soil Classification System
Rock Classification Notes

Note: All attachments are one page unless noted above.

General Notes

Sampling	Water Level	Field Tests
 Rock Core  Grab Sample  Shelby Tube  Split Spoon	 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.

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	$Cu \geq 4$ and $1 \leq Cc \leq 3$ ^E	GW	Well-graded gravel ^F
		Gravels with Fines: More than 12% fines ^C	$Cu < 4$ and/or $[Cc < 1$ or $Cc > 3.0]$ ^E	GP	Poorly graded gravel ^F
			Fines classify as ML or MH	GM	Silty gravel ^{F, G, H}
		Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands: Less than 5% fines ^D	Fines classify as CL or CH	GC
	$Cu \geq 6$ and $1 \leq Cc \leq 3$ ^E			SW	Well-graded sand ^I
	Sands with Fines: More than 12% fines ^D		$Cu < 6$ and/or $[Cc < 1$ or $Cc > 3.0]$ ^E	SP	Poorly graded sand ^I
			Fines classify as ML or MH	SM	Silty 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
PI < 4 or plots below "A" line ^J				ML	Silt ^{K, L, M}
Organic:			$\frac{LL \text{ oven dried}}{LL \text{ not dried}} < 0.75$	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
PI plots below "A" line		MH			Elastic silt ^{K, L, M}
Organic:		$\frac{LL \text{ oven dried}}{LL \text{ not dried}} < 0.75$		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	

^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 $\geq 15\%$ 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 $\geq 15\%$ 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 $\geq 30\%$ plus No. 200 predominantly sand, add "sandy" to group name.

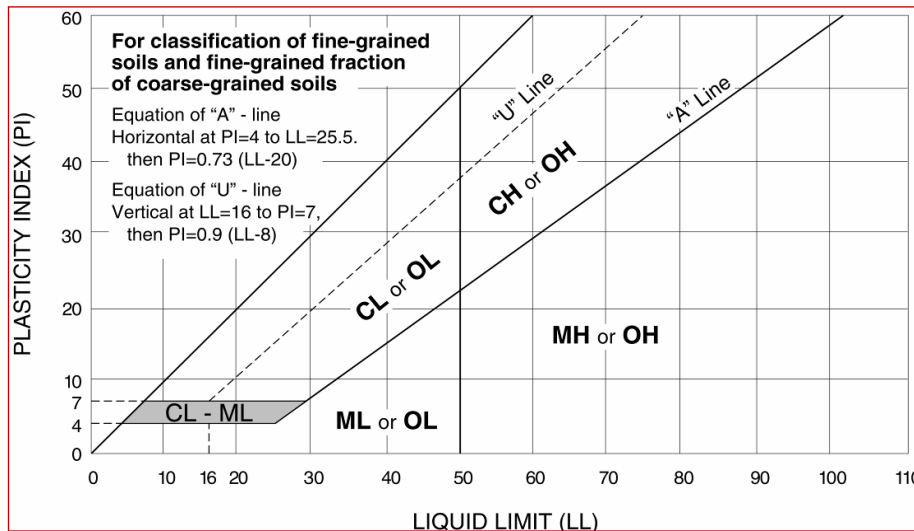
^M If soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

^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.



Rock Classification Notes

WEATHERING			
Term	Description		
Fresh	Mineral crystals appear bright; show no discoloration. Features show little or now staining on surfaces. Discoloration does not extend into intact rock.		
Slightly weathered	Rock generally fresh except along fractures. Some fractures stained and discoloration may extend <0.5 inches into rock.		
Moderately weathered	Significant portions of rock are dull and discolored. Rock may be significantly weaker than in fresh state near fractures. Soil zones of limited extent may occur along some fractures.		
Highly weathered	Rock dull and discolored throughout. Majority of rock mass is significantly weaker and has decomposed and/or disintegrated; isolated zones of stronger rock and/or soil may occur throughout.		
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The rock mass or fabric is still evident and largely intact. Isolated zones of stronger rock may occur locally.		
STRENGTH OR HARDNESS			
Description	Field Identification		Uniaxial Compressive Strength, psi
Extremely strong	Can only be chipped with geological hammer. Rock rings on hammer blows. Cannot be scratched with a sharp pick. Hand specimens require several hard hammer blows to break.		>36,000
Very strong	Several blows of a geological hammer to fracture. Cannot be scratched with a 20d common steel nail. Can be scratched with a geologist's pick only with difficulty.		15,000-36,000
Strong	More than one blow of a geological hammer needed to fracture. Can be scratched with a 20d nail or geologist's pick. Gouges or grooves to ¼ inch deep can be excavated by a hard blow of a geologist's pick. Hand specimens can be detached by a moderate blow.		7,500-15,000
Medium strong	One blow of geological hammer needed to fracture. Can be distinctly scratched with 20d nail. Can be grooved or gouged 1/16 in. deep by firm pressure with a geologist's pick point. Can be fractured with single firm blow of geological hammer. Can be excavated in small chips (about 1-in. maximum size) by hard blows of the point of a geologist's pick;		3,500-7,500
Weak	Shallow indent by firm blow with geological hammer point. Can be gouged or grooved readily with geologist's pick point. Can be excavated in pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.		700-3,500
Very weak	Crumbles under firm blow with geological hammer point. Can be excavated readily with the point of a geologist's pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.		150-700
DISCONTINUITY DESCRIPTION			
Fracture Spacing (Joints, Faults, Other Fractures)		Bedding Spacing (May Include Foliation or Banding)	
Description	Spacing	Description	Spacing
Intensely fractured	< 2.5 inches	Laminated	< ½-inch
Highly fractured	2.5 – 8 inches	Very thin	½ – 2 inches
Moderately fractured	8 inches to 2 feet	Thin	2 inches – 1 foot
Slightly fractured	2 to 6.5 feet	Medium	1 – 3 feet
Very slightly fractured	> 6.5 feet	Thick	3 – 10 feet
		Massive	> 10 feet
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.