



PUBLIC WORKS
Engineering

TO: E-mail Distribution

RE: GEOTECHNICAL REPORT TRANSMITTAL

The City of Tulsa provides the attached document(s) with the following conditions:

- A. The Geotechnical Report is not part of the construction documents. The Geotechnical Report is provided for informational purposes only, to assist the Contractor in understanding the general subsurface conditions at the site. The report presents the data and findings of the geotechnical engineer at the specific boring locations and times of the investigation.
- B. The Contractor is solely responsible for all interpretations, conclusions, and deductions drawn from the Geotechnical Report concerning the conditions at the site affecting the execution of the Work, including, but not limited to, the subsurface conditions, the scope of work, means, methods, sequencing, and pricing.
- C. The City makes no warranty or representation, express or implied, as to the accuracy, completeness, or interpretations of the data, information, and representations contained in the Geotechnical Report. The information provided is not a substitute for the Contractor's own independent investigation, judgment, and expertise.
- D. The Contractor shall visit the site and make their own investigations. This will include any borings, additional borings, and/or testing to determine actual subsurface conditions and the conditions under which the Bid is to be prepared, and the Work is to be performed.

1836 * 1898

TUL * USA

Yahola Reservoir Project

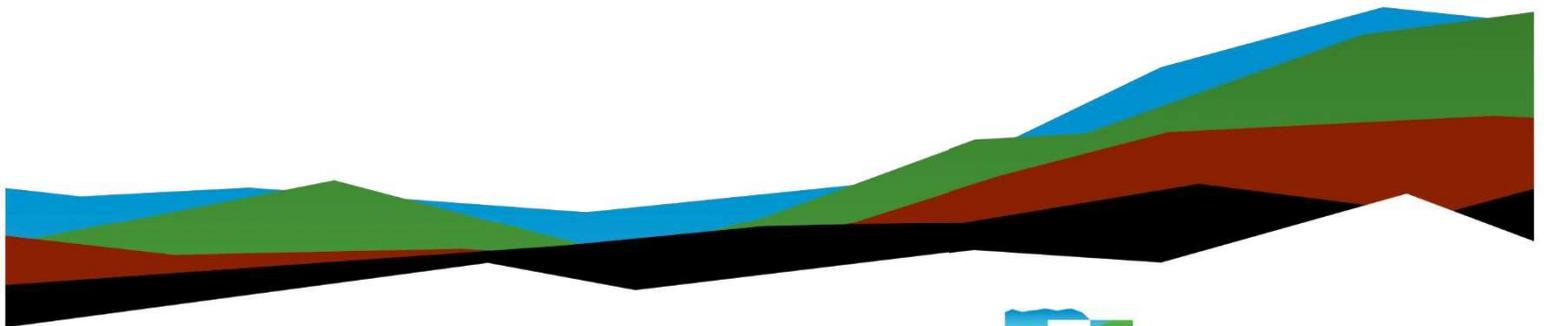
Geotechnical Exploration Report

Tulsa County, Oklahoma

March 10, 2026 | Terracon Project No. 04245197 Revision No. 1

Prepared for:

Keithline Engineering Group, PLLC
8556 East 101st Street, Suite C
Tulsa, Oklahoma 74133



Nationwide
[Terracon.com](https://www.terracon.com)

- Facilities
- Environmental
- Geotechnical
- Materials



9134 East 46th Street
Tulsa, Oklahoma 74145
P (918) 250-0461
Terracon.com

March 10, 2026

Keithline Engineering Group, PLLC
8556 East 101st Street, Suite C
Tulsa, Oklahoma 74133

Attn: Dan Keithline, P.E., S.E.
P: (918) 369-7911
E: dan@kengineering-us.com

Re: Geotechnical Exploration Services
Yahola Reservoir Project
Tulsa, Oklahoma
Terracon Project No. 04245197 Revision No. 1

Dear Mr. Keithline:

We have completed the scope of Geotechnical Exploration services for the above referenced project in general accordance with Terracon Proposal No. 04245197 Rev1, dated February 20, 2025. This report presents the findings of the subsurface exploration and provides geotechnical recommendations for the proposed project.

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

Cert. Of Auth. #CA-4531 exp. 6/30/27

Ali Vafaei, P.E.
Project Engineer

David Williams, P.E.
Regional Technical Consultant



Table of Contents

Introduction	2
Project Description	2
Site Conditions	3
Geotechnical Characterization	3
Subsurface Profile	3
Groundwater Conditions.....	4
Findings	4
General Comments	5

Figures

GeoModel

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  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 Geotechnical Exploration services performed for the proposed Yahola Reservoir Project north of the Mohawk Water Treatment Plant in Tulsa, Oklahoma. The purpose of these services was to provide information and geotechnical recommendations related to:

- Subsurface soil and rock conditions
- Groundwater conditions

The geotechnical exploration Scope of Services for this project included the advancement of soil borings, laboratory testing, and preparation of this data report.

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

Project Description

Our initial understanding of the project was provided in our proposal and was discussed during project planning. Our final understanding of the project conditions is as follows:

Item	Description
Information Provided	An email request for a proposal was provided by Mr. Dan Keithline, P.E., S.E., with Keithline Engineering on September 25, 2024. The email included a Site Map with proposed boring locations.
Project Description	We understand the project involves the evaluation of the subsurface conditions of the dike around Yahola Reservoir. The plan is to construct 2 control gate towers to allow for full depth conveyance of water between the three reservoir cells.

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

Site Conditions

The following description of site conditions is derived from our site visit in association with the field exploration.

Item	Description
Parcel Information	The project is located in Tulsa, Oklahoma. Latitude/Longitude (approximate) 36.2204, -95.927 See Site Location
Existing Improvements	Existing dike
Current Ground Cover	Gravel road on top of dike
Existing Topography	Relatively flat. The dike is approximately 20 feet tall.

Geotechnical Characterization

Subsurface Profile

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

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 and the individual boring logs.

Model Layer	Layer Name	General Description
1	Native Soils	Lean Clay, Lean Clay with sand, (CL); Fat Clay (CH)
2	Bedrock	Weathered Shale

Groundwater Conditions

The boreholes were observed while drilling and immediately after completion for the presence and level of groundwater. The water levels observed in the boreholes can be found on the boring logs in [Exploration Results](#) and are summarized below.

Boring	Approximate Depth to Groundwater while Drilling ¹ (feet)	Approximate Depth to Groundwater after Drilling ¹ (feet)
B-1	18.5	Not encountered
B-2	Not encountered	30
B-3	Not encountered	30

1. Below ground surface.

Due to the low permeability of the soil encountered in the borings, a relatively long period may be necessary for a groundwater level to develop and stabilize in a borehole. Long term observations in piezometers or observation wells sealed from the influence of surface water are often required to define groundwater levels in materials of this type.

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

Findings

In **Boring B-1**, the subsurface profile consisted entirely of medium stiff to stiff fat clay to the termination depth of 25 feet.

In **Boring B-2**, the upper 6.5 feet consisted of medium stiff to stiff lean clay, underlain by a thick deposit of very soft to very stiff fat clay extending from 6.5 feet to the termination depth of 50 feet. A zone of very soft saturated soil was encountered between 43.5 feet and 49.5 feet bgs.

In **Boring B-3**, the upper 18.5 feet consisted of medium stiff to very stiff lean clay, followed by lean clay with sand from 18.5 feet to 48.5 feet, and underlain by weathered shale from 48.5 feet to the termination depth of 54.7 feet. A zone of very soft saturated soil was encountered starting at a depth of approximately 32 feet bgs, extending to the top of weathered shale at 48.5 feet bgs.

Based on the field exploration and laboratory testing, the following falling head permeability results were obtained:

Boring	Depth (feet)	Soil Classification	Permeability (cm/s)
B-1	3.5-5	Fat Clay (CH)	9.2E-09
B-2	11-12.5	Fat Clay (CH)	8.2E-09
B-3	8-9.5	Lean Clay (CL)	6.6E-09

Earthwork

The site appears suitable for the proposed construction based upon geotechnical conditions encountered in the soil borings, provided that the recommendations provided in this report are implemented in the design and construction phases of this project.

Due to the presence of soils with high moisture content and relatively low strength, some means of subgrade stabilization may be required to facilitate construction, especially if wet/soft soils are encountered during foundation excavation.

In general (weather permitting), scarifying, drying and compacting the exposed subgrades is expected to be the most economical means of improving these soils. However, this option is typically less effective where soft/wet soils are more than about one foot thick. The use of crushed stone or crushed gravel is also a common procedure to improve subgrade stability. Typical undercut depths would be expected to range from about 1 to 3 feet below finished subgrade elevation. The use of high modulus geotextiles (i.e., engineering fabric or geogrid) should also be considered after underground work such as utility construction is completed to reduce the migration of cohesive soils into the subgrade stabilization zone. Prior to placing the fabric or geogrid, we recommend that all below grade construction, such as utility line installation, be completed to avoid damaging the fabric or geogrid. Equipment should not be operated above the fabric or geogrid until one full lift of crushed stone fill is placed above it.

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

Foundation Recommendations

Terracon recommends construction of a shallow foundation system to support the proposed structures. Construction of a deep foundation bearing in the bedrock would likely be cost prohibitive due to the depth of the bedrock.

Based on conversations with Mr. Dan Keithline, P.E., S.E., the proposed bearing elevation is around elevation 586 feet supported on 18 inches of Oklahoma Department of Transportation (ODOT) Type A aggregate base with a separation fabric. The allowable bearing pressure of the medium stiff to very stiff clay at that elevation for the two structure locations is 2,000 psf. However, we understand current bearing pressures are anticipated to be about 1,000 psf. Understanding the planned bearing pressures, depth of foundation bearing below existing grade, we estimate total settlements on the order of 1 inch, with differential settlement about 1/2 to 2/3 of the total settlement could occur. If additional bearing capacity is needed, helical piles, precast driven piles, or similar can be installed for added support.

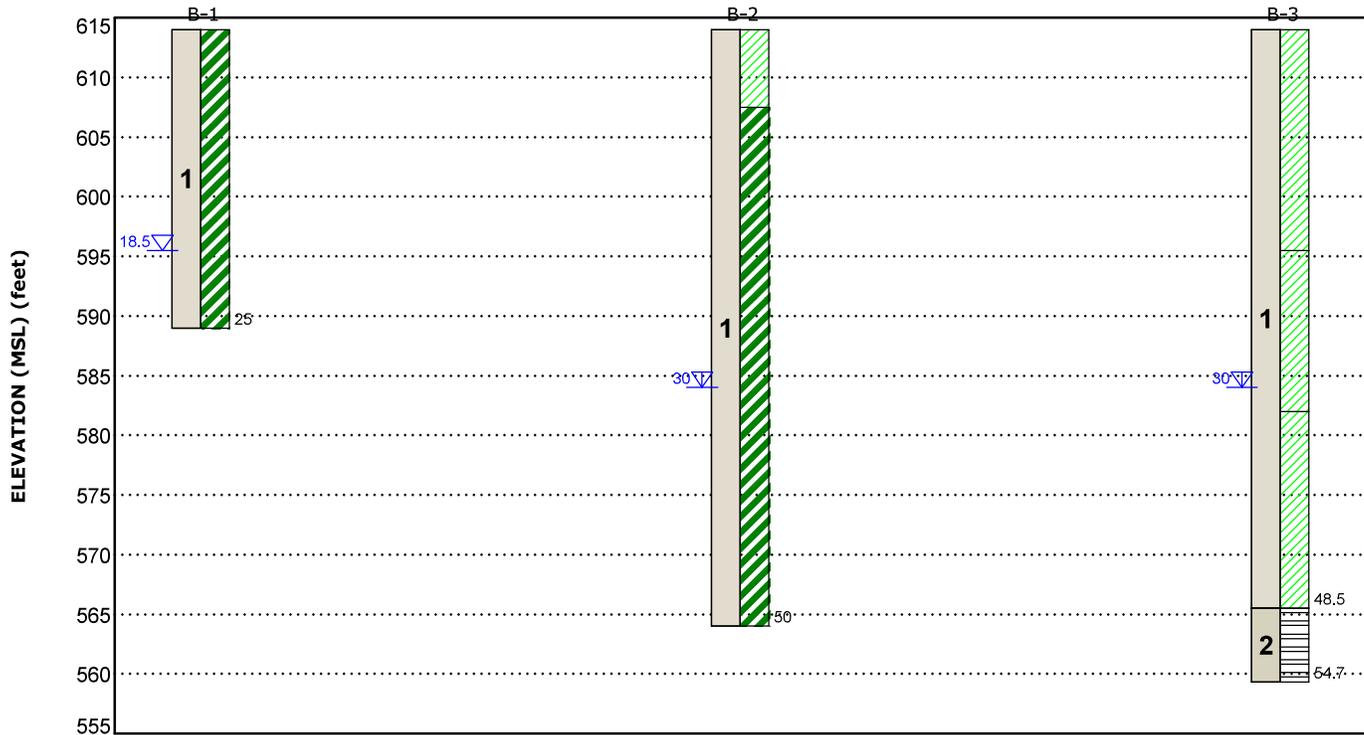
General Comments

Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during, or after construction.

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 exploration 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 information provided by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

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	Native Soils	Lean Clay, Lean Clay with sand (CL); Fat Clay (CH)	Fat Clay	Lean Clay
2	Bedrock	Weathered Shale	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.

Geotechnical Exploration Report

Yahola Reservoir Project | Tulsa, Oklahoma

March 10, 2026 | Terracon Project No. 04245197 Revision No. 1



Figures

Contents:

GeoModel

Geotechnical Exploration Report

Yahola Reservoir Project | Tulsa, Oklahoma

March 10, 2026 | Terracon Project No. 04245197 Revision No. 1



Attachments

Exploration and Testing Procedures

Field Exploration

Number of Borings	Approximate Boring Depth (feet)	Location ¹
1 (B-1)	25	Through the Dike Embankment and Foundation Soils
1 (B-2)	50	Through the Dike Embankment and Foundation Soils
1 (B-3)	55	Through the Dike Embankment and Foundation Soils

1. The boring locations are shown on the attached **Exploration Plan**.

Boring Layout and Elevations: The borings were laid out using handheld GPS equipment (estimated horizontal accuracy of about ±10 feet) and referencing existing site features. Approximate ground surface elevations were estimated using Google Earth. We rounded the elevations on the boring log to the nearest foot. Consider the location and elevation of the boring accurate only to the degree implied by the methods used to make these measurements.

Subsurface Exploration Procedures: We advanced the borings with an ATV-mounted rotary drill rig using continuous flight hollow stem augers. Thirteen samples were obtained in the upper 20 feet of each boring and at intervals of 5 feet thereafter. In the split barrel sampling procedure, a standard 2-inch outer diameter split barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling 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. Also, soil sampling was performed using thin walled (Shelby) tube sampling procedures. One Shelby tube sample was obtained in each boring. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, all borings were backfilled with bentonite grout after their completion.

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

prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

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

- Moisture Content
- Atterberg Limits
- Grain Size Distribution
- Falling Head Permeability

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 accordance with the Unified Soil Classification System.

Rock classification was conducted using locally accepted practices for engineering purposes; petrographic analysis may reveal other rock types. Rock core samples typically provide an improved specimen for this classification. Boring log rock classification was determined using the Description of Rock Properties.

Geotechnical Exploration Report

Yahola Reservoir Project | Tulsa, Oklahoma

March 10, 2026 | Terracon Project No. 04245197 Revision No. 1



Site Location and Exploration Plans

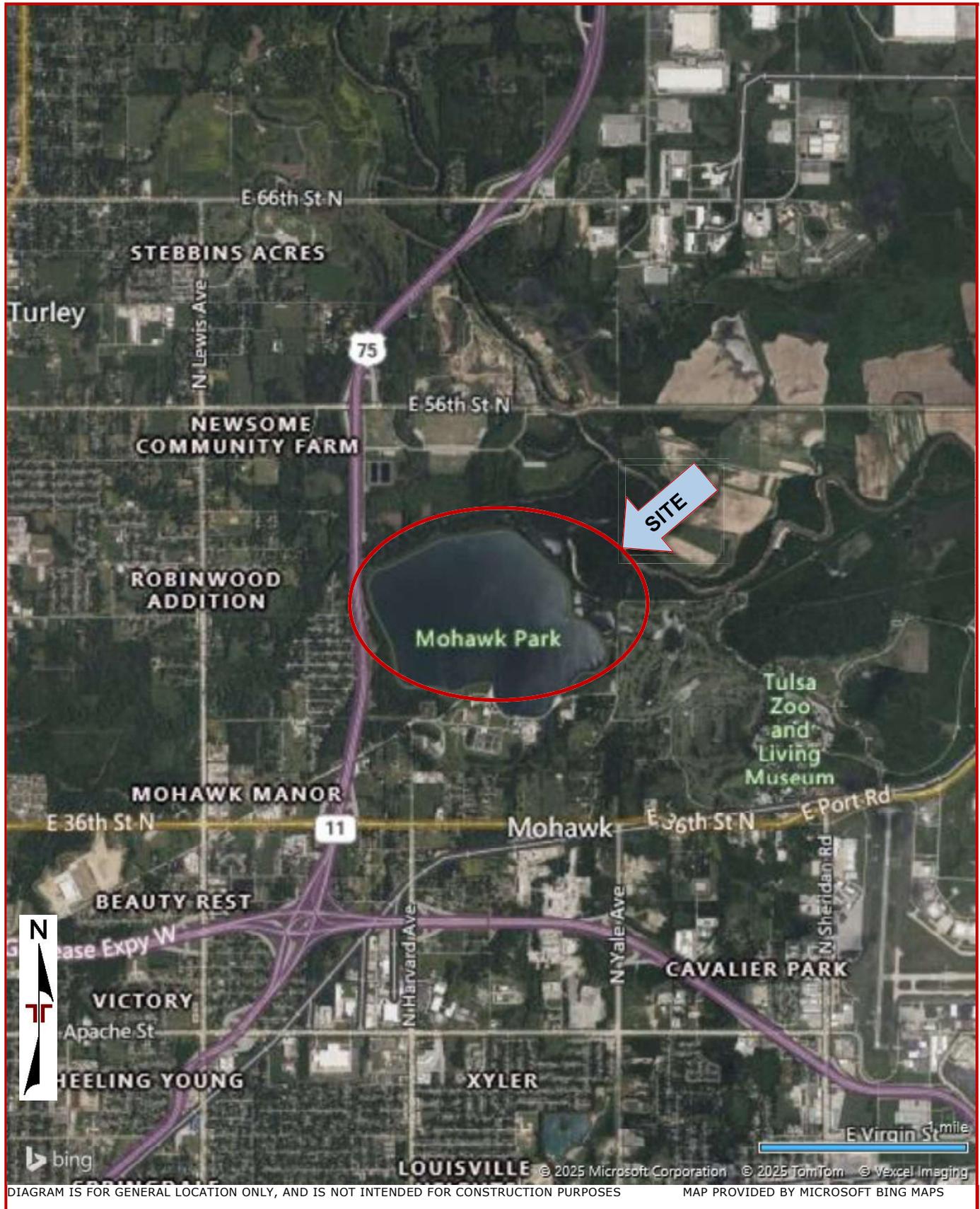
Contents:

Site Location Plan

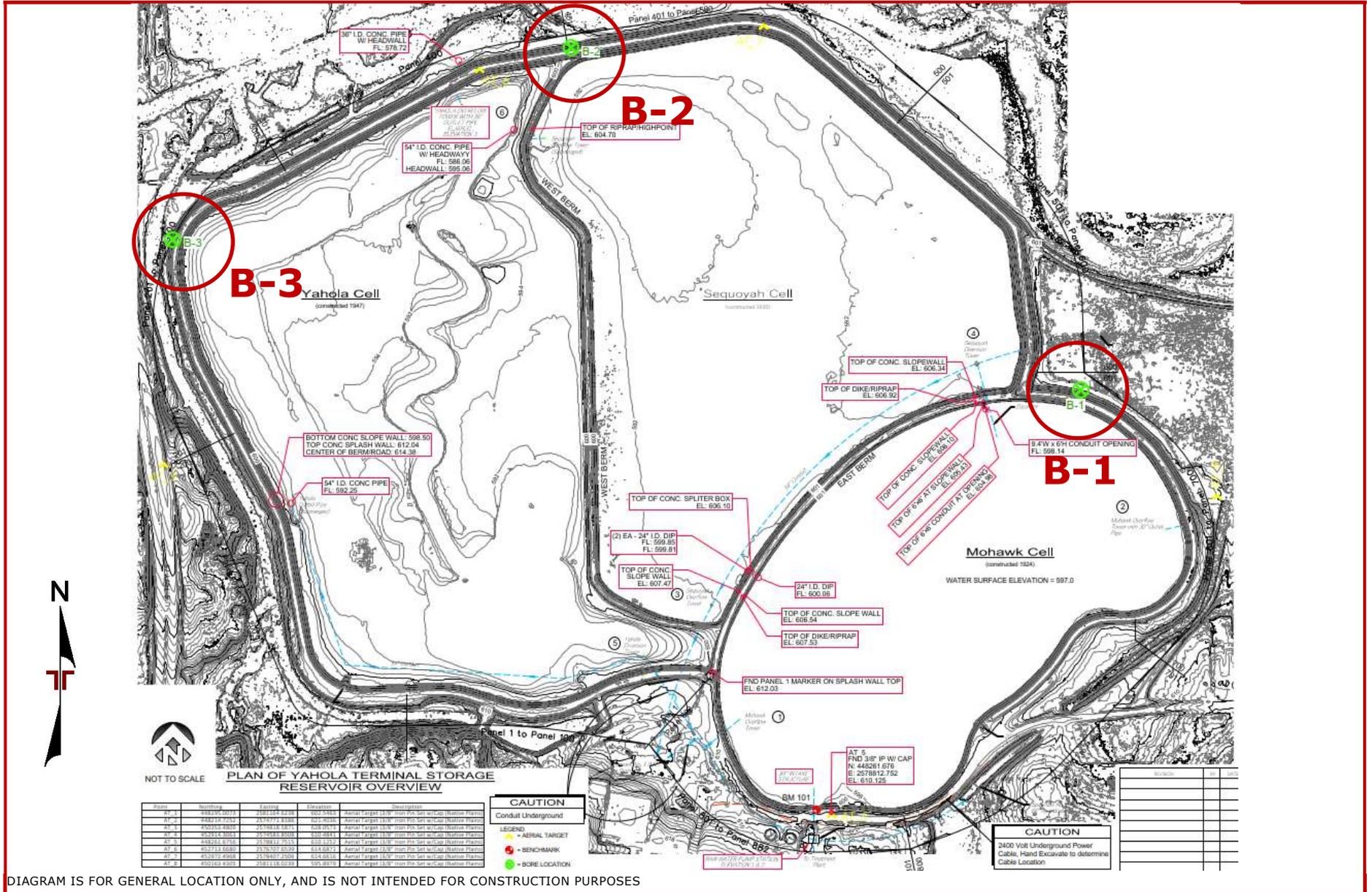
Exploration Plan

Note: All attachments are one page unless noted above.

Site Location



Exploration Plan



Exploration and Laboratory Results

Contents:

- Boring Logs (B-1 to B-3) (6 pages)
- Atterberg Limit Results (1 page)
- Grain Size Distribution (2 pages)
- Falling Head Permeability Results (3 pages)

Note: All attachments are one page unless noted above.

Boring Log No. B-2

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 36.2202° Longitude: -95.9257° Depth (Ft.) Approximate Elevation: 614.0 (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Atterberg Limits				
									LL-PL-PI	Percent Fines			
1	6.5	Approximately 6" Topsoil LEAN CLAY (CL) , brown, gray and reddish brown, medium stiff to stiff FAT CLAY (CH) , brown, gray and reddish brown, very soft to very stiff	607.5		X	18	4-4-4 N=8	20.1	41-22-19	87.9			
					X	18	3-4-5 N=9	20.6					
					23			27.4					
						5		X	18		3-5-5 N=10	19.2	
								X	6		2-4-4 N=8	31.9	54-25-29
								X	18		2-3-3 N=6	20.4	
						10		X	18		3-4-5 N=9	25.6	
								X	18		3-4-5 N=9	20.2	
								X	18		3-2-4 N=6	21.8	
						15		X	18		4-5-5 N=10	24.0	
								X	18		2-4-5 N=9	29.5	
								X	18		4-6-6 N=12	25.2	
						20		X	18		4-6-6 N=12	27.5	
								X	18		1-2-3 N=5	25.8	97.6
						30	▽	X	18		4-7-8 N=15	21.9	
					X	18	5-8-10 N=18	21.4					
			40		X	18	4-5-4 N=9	21.4					
					X	18	0-0-0 N=0	26.6					
			50		X	18	0-1-4 N=5	25.1					
Boring Terminated at 50 Feet			564										

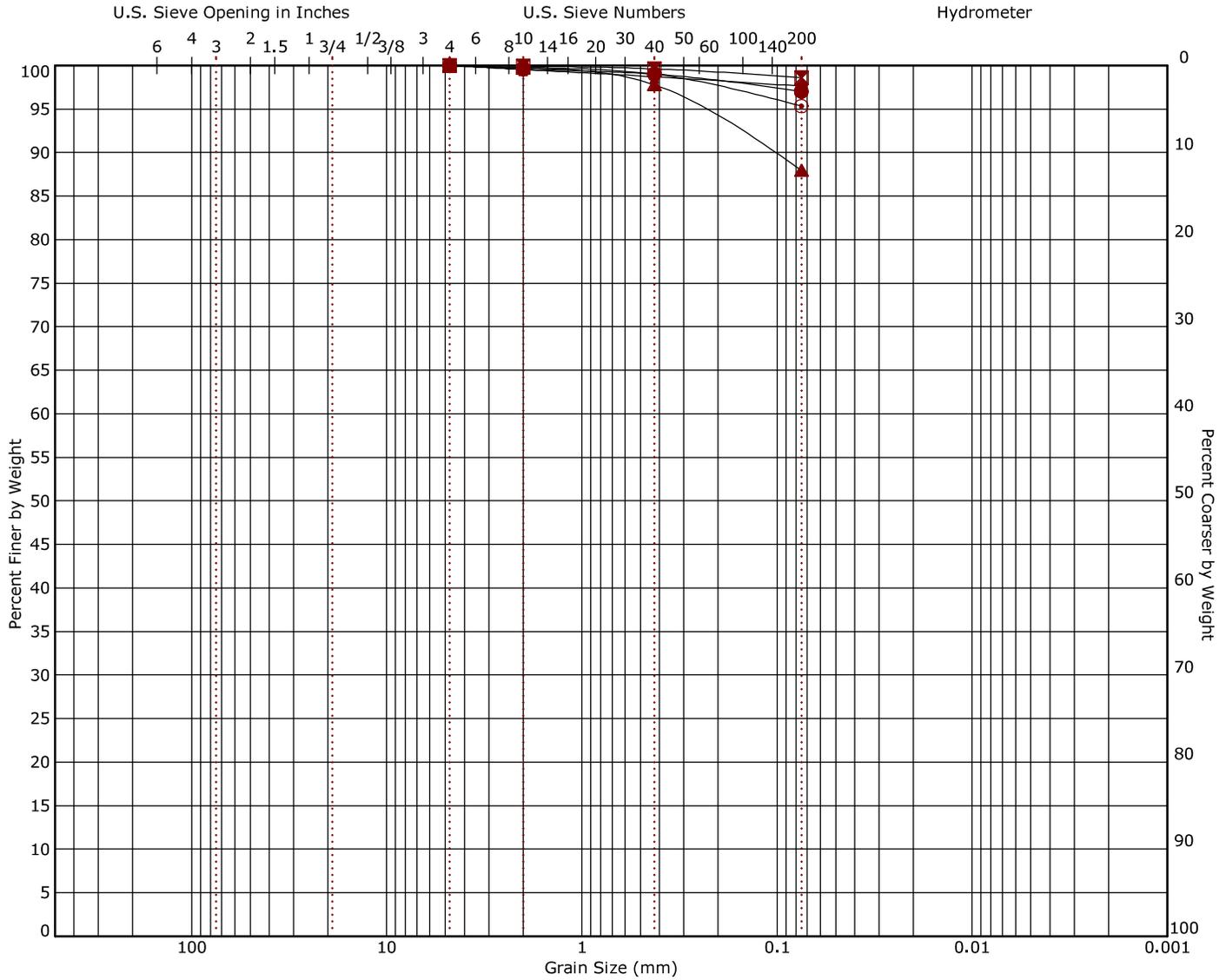
<p>See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).</p> <p>See Supporting Information for explanation of symbols and abbreviations.</p> <p>+Classification estimated from disturbed samples</p>	<p>Water Level Observations Not encountered while drilling</p> <p style="color: blue;">▽</p> <p>30 feet after drilling</p>	<p>Drill Rig CME550/ATV</p> <p>Hammer Type Automatic</p> <p>Driller TS</p>
<p>Notes</p>	<p>Advancement Method Hollow Stem Auger</p> <p>Abandonment Method Boring backfilled with grout and bentonite chips upon completion.</p>	<p>Logged by WA</p> <p>Boring Started 03-25-2025</p> <p>Boring Completed 03-25-2025</p>

Boring Log No. B-3

Model Layer	Graphic Log	Location: See Exploration Plan Latitude: 36.2239° Longitude: -95.9426°	Depth (Ft.)	Approximate Elevation: 614 (Ft.)	Depth (Ft.)	Water Level Observations	Sample Type	Recovery (In.)	Field Test Results	Water Content (%)	Atterberg Limits																																																																				
											LL-PL-PI	Percent Fines																																																																			
1		Approximately 6" Topsoil LEAN CLAY (CL) , brown, gray and reddish brown, medium stiff to very stiff	5	595.5	5		18	12	3-3-3 N=6	17.4	37-18-19	95.3																																																																			
													18	18	3-3-4 N=7	22.2	34-17-17																																																														
																		18	18	3-4-5 N=9	22.5	40-21-19																																																									
																							18	18	5-5-6 N=11	23.4	91.7																																																				
																												18	18	3-4-5 N=9	18.3																																																
																																10	11	5-7-10 N=17	18.3																																												
																																				18	18	6-8-9 N=17	22.4																																								
																																								15	5	3-4-6 N=10	17.2																																				
																																												18	18	5-5-7 N=12	19.7																																
																																																18	18	6-7-8 N=15	17.7																												
																																																				18	18	7-9-9 N=18	14.4																								
																																																								20	11	7-7-8 N=15	20.6																				
																																																												18	18	9-7-7 N=14	18.6																
																																																																18	18	3-3-3 N=6	24.9												
																																																																				18	18	3-3-4 N=7	22.2								
																																																																								25	18	3-3-4 N=6	22.3				
																																																																												30	18	3-3-3 N=6	22.3
40	18	35-40-50/2"	76.6																																																																												
				45	18	35-40-50/2"	76.6																																																																								
								50	18	35-40-50/2"	76.6																																																																				
												54.7	14	35-40-50/2"	76.6																																																																
																54.7	14	35-40-50/2"	76.6																																																												
																				54.7	14	35-40-50/2"	76.6																																																								
																								54.7	14	35-40-50/2"	76.6																																																				
																												54.7	14	35-40-50/2"	76.6																																																
																																54.7	14	35-40-50/2"	76.6																																												
																																				54.7	14	35-40-50/2"	76.6																																								
																																								54.7	14	35-40-50/2"	76.6																																				
																																												54.7	14	35-40-50/2"	76.6																																
																																																54.7	14	35-40-50/2"	76.6																												
																																																				54.7	14	35-40-50/2"	76.6																								
																																																								54.7	14	35-40-50/2"	76.6																				
																																																												54.7	14	35-40-50/2"	76.6																
																																																																54.7	14	35-40-50/2"	76.6												
																																																																				54.7	14	35-40-50/2"	76.6								
54.7	14	35-40-50/2"	76.6																																																																												
				54.7	14	35-40-50/2"	76.6																																																																								
								54.7	14	35-40-50/2"	76.6																																																																				
												54.7	14	35-40-50/2"	76.6																																																																
																54.7	14	35-40-50/2"	76.6																																																												
																				54.7	14	35-40-50/2"	76.6																																																								
																								54.7	14	35-40-50/2"	76.6																																																				
																												54.7	14	35-40-50/2"	76.6																																																
																																54.7	14	35-40-50/2"	76.6																																												
																																				54.7	14	35-40-50/2"	76.6																																								
																																								54.7	14	35-40-50/2"	76.6																																				
																																												54.7	14	35-40-50/2"	76.6																																
																																																54.7	14	35-40-50/2"	76.6																												
																																																				54.7	14	35-40-50/2"	76.6																								
																																																								54.7	14	35-40-50/2"	76.6																				
																																																												54.7	14	35-40-50/2"	76.6																
																																																																54.7	14	35-40-50/2"	76.6												
																																																																				54.7	14	35-40-50/2"	76.6								
54.7	14	35-40-50/2"	76.6																																																																												
				54.7	14	35-40-50/2"	76.6																																																																								
								54.7	14	35-40-50/2"	76.6																																																																				
												54.7	14	35-40-50/2"	76.6																																																																
																54.7	14	35-40-50/2"	76.6																																																												
																				54.7	14	35-40-50/2"	76.6																																																								
																								54.7	14	35-40-50/2"	76.6																																																				
																												54.7	14	35-40-50/2"	76.6																																																
																																54.7	14	35-40-50/2"	76.6																																												
																																				54.7	14	35-40-50/2"	76.6																																								
																																								54.7	14	35-40-50/2"	76.6																																				
																																												54.7	14	35-40-50/2"	76.6																																
																																																54.7	14	35-40-50/2"	76.6																												
																																																				54.7	14	35-40-50/2"	76.6																								
																																																								54.7	14	35-40-50/2"	76.6																				
																																																												54.7	14	35-40-50/2"	76.6																
																																																																54.7	14	35-40-50/2"	76.6												
																																																																				54.7	14	35-40-50/2"	76.6								
54.7	14	35-40-50/2"	76.6																																																																												
				54.7	14	35-40-50/2"	76.6																																																																								
								54.7	14	35-40-50/2"	76.6																																																																				
												54.7	14	35-40-50/2"	76.6																																																																
																54.7	14	35-40-50/2"	76.6																																																												
																				54.7	14	35-40-50/2"	76.6																																																								
																								54.7	14	35-40-50/2"	76.6																																																				
																												54.7	14	35-40-50/2"	76.6																																																
																																54.7	14	35-40-50/2"	76.6																																												
																																				54.7	14	35-40-50/2"	76.6																																								
																																								54.7	14	35-40-50/2"	76.6																																				
																																												54.7	14	35-40-50/2"	76.6																																
																																																54.7	14	35-40-50/2"	76.6																												
																																																				54.7	14	35-40-50/2"	76.6																								
																																																								54.7	14	35-40-50/2"	76.6																				
																																																												54.7	14	35-40-50/2"	76.6																
																																																																54.7	14	35-40-50/2"	76.6												
																																																																				54.7	14	35-40-50/2"	76.6								
54.7	14	35-40-50/2"	76.6																																																																												
				54.7	14	35-40-50/2"	76.6																																																																								
								54.7	14	35-40-50/2"	76.6																																																																				
												54.7	14	35-40-50/2"	76.6																																																																
																54.7	14	35-40-50/2"	76.6																																																												
																				54.7	14	35-40-50/2"	76.6																																																								
																								54.7	14	35-40-50/2"	76.6																																																				
																												54.7	14	35-40-50/2"	76.6																																																
																																54.7	14	35-40-50/2"	76.6																																												
																																				54.7	14	35-40-50/2"	76.6																																								
																																								54.7	14	35-40-50/2"	76.6																																				

Grain Size Distribution

ASTM D422 / ASTM C136



Cobbles |
 Gravel |
 Sand |
 Silt or Clay

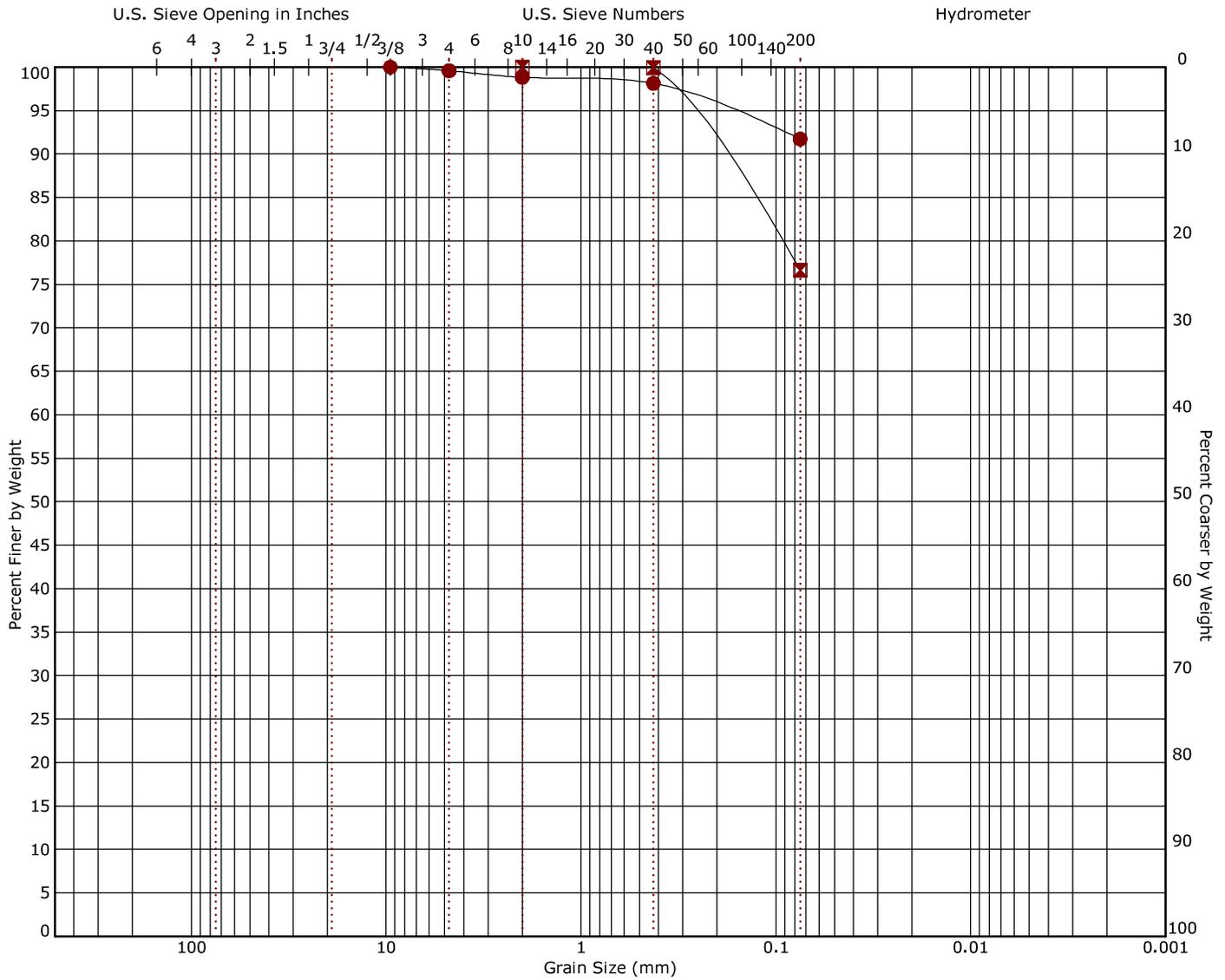
coarse | fine | coarse | medium | fine

Boring ID	Depth (Ft)	USCS Classification	USCS	AASHTO	LL	PL	PI	Cc	Cu
● B-1	2 - 3.5								
☒ B-1	8 - 9.5								
▲ B-2	8 - 9.5								
★ B-2	23.5 - 25								
⊙ B-3	5 - 6.5								

Boring ID	Depth (Ft)	D ₁₀₀	D ₆₀	D ₃₀	D ₁₀	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● B-1	2 - 3.5	4.75				0.0	0.0	3.0	97.0		
☒ B-1	8 - 9.5	4.75				0.0	0.0	1.4	98.6		
▲ B-2	8 - 9.5	4.75				0.0	0.0	12.1	87.9		
★ B-2	23.5 - 25	4.75				0.0	0.0	2.4	97.6		
⊙ B-3	5 - 6.5	4.75				0.0	0.0	4.7	95.3		

Grain Size Distribution

ASTM D422 / ASTM C136



Boring ID	Depth (Ft)	USCS Classification	USCS	AASHTO	LL	PL	PI	Cc	Cu
● B-3	9.5 - 11								
✕ B-3	20 - 21.5								

Boring ID	Depth (Ft)	D ₁₀₀	D ₆₀	D ₃₀	D ₁₀	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● B-3	9.5 - 11	9.5				0.0	0.4	7.8	91.7		
✕ B-3	20 - 21.5	2				0.0	0.0	23.4	76.6		

HYDRAULIC CONDUCTIVITY DETERMINATION

Report Number 04245197
Service Date: 4/8/2025
Report Date: 4/16/2025



4701 N. Stiles Ave.
Oklahoma City, Oklahoma 73105

Client

Keithline Engineering Group
8556 E 101st St Ste C
Tulsa, OK 74133-7036

Project

Yahola Reservoir - Keithline

Project No. 04245197

Summary of Test Results

Boring No. B-1

Sample No. n/a

Depth: 3.5' - 5.0'

Classification: Fat Clay, Brown, Gray, and Reddish Brown

Remolding
Parameters: n/a

	<u>INITIAL</u>	<u>FINAL</u>
DRY UNIT WEIGHT (pcf)	105.1	105.0
CONTENT (%)	21.4	22.7
DIAMETER (cm)	7.140	7.150
LENGTH (cm)	9.228	9.177
B VALUE PARAMETER:	96	
HYDRAULIC GRADIENT (MAXIMUM)	7.56	
TEMPERATURE (°C)	24.4	
PERCENT SATURATION	98.4	(Percent saturation calculation is based on final measurements and an estimated specific gravity.)

HYDRAULIC CONDUCTIVITY
k (cm/sec)

9.0E-09

Deaired water was used as the liquid permeant.



HYDRAULIC CONDUCTIVITY DETERMINATION

Report Number 04245197
Service Date: 4/8/2025
Report Date: 4/16/2025



4701 N. Stiles Ave.
Oklahoma City, Oklahoma 73105

Client

Keithline Engineering Group
8556 E 101st St Ste C
Tulsa, OK 74133-7036

Project

Yahola Reservoir - Keithline

Project No. 04245197

Summary of Test Results

Boring No. B-2

Sample No. n/a

Depth: 11.0' -12.5'

Classification: Fat Clay, Brown, Gray and Reddish Brown

Remolding
Parameters: n/a

	<u>INITIAL</u>	<u>FINAL</u>
DRY UNIT WEIGHT (pcf)	99.6	97.1
CONTENT (%)	27.1	27.9
DIAMETER (cm)	7.079	7.160
LENGTH (cm)	8.753	8.768
B VALUE PARAMETER:	96	
HYDRAULIC GRADIENT (MAXIMUM)	7.66	
TEMPERATURE (°C)	24.4	
PERCENT SATURATION	99.8	(Percent saturation calculation is based on final measurements and an estimated specific gravity.)



HYDRAULIC CONDUCTIVITY
k (cm/sec)

8.2E-09

Deaired water was used as the liquid permeant.

HYDRAULIC CONDUCTIVITY DETERMINATION

Report Number 04245197
Service Date: 4/8/2025
Report Date: 4/16/2025



4701 N. Stiles Ave.
Oklahoma City, Oklahoma 73105

Client

Keithline Engineering Group
8556 E 101st St Ste C
Tulsa, OK 74133-7036

Project

Yahola Reservoir - Keithline

Project No. 04245197

Summary of Test Results

Boring No. B-3

Sample No. n/a

Depth: 8.0' -9.5'

Classification: Lean Clay, Brown, Gray, and Reddish Brown

Remolding
Parameters: n/a

	<u>INITIAL</u>	<u>FINAL</u>
DRY UNIT WEIGHT (pcf)	104.7	105.7
CONTENT (%)	25.9	22.2
DIAMETER (cm)	7.155	7.262
LENGTH (cm)	8.473	8.484

B VALUE PARAMETER: 94

HYDRAULIC GRADIENT (MAXIMUM) 8.44

TEMPERATURE (°C) 24.4

PERCENT SATURATION 97.9 (Percent saturation calculation is based on final measurements and an estimated specific gravity.)

HYDRAULIC CONDUCTIVITY k (cm/sec) **6.6E-09**

Deaired water was used as the liquid permeant.



Geotechnical Exploration Report

Yahola Reservoir Project | Tulsa, Oklahoma

March 10, 2026 | Terracon Project No. 04245197 Revision No. 1



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
 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 (psf)	Standard Penetration or N-Value (Blows/Ft.)
Very Loose	0 - 3	Very Soft	less than 500	0 - 1
Loose	4 - 9	Soft	500 to 1,000	2 - 4
Medium Dense	10 - 29	Medium Stiff	1,000 to 2,000	5 - 8
Dense	30 - 50	Stiff	2,000 to 4,000	9 - 15
Very Dense	> 50	Very Stiff	4,000 to 8,000	16 - 30
		Hard	> 8,000	> 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 ≥ 4 and 1 ≤ Cc ≤ 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 ≥ 6 and 1 ≤ Cc ≤ 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 ≥ 15% sand, add "with sand" to group name.

^G If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^H If fines are organic, add "with organic fines" to group name.

^I If soil contains ≥ 15% gravel, add "with gravel" to group name.

^J If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

^K If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^L If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

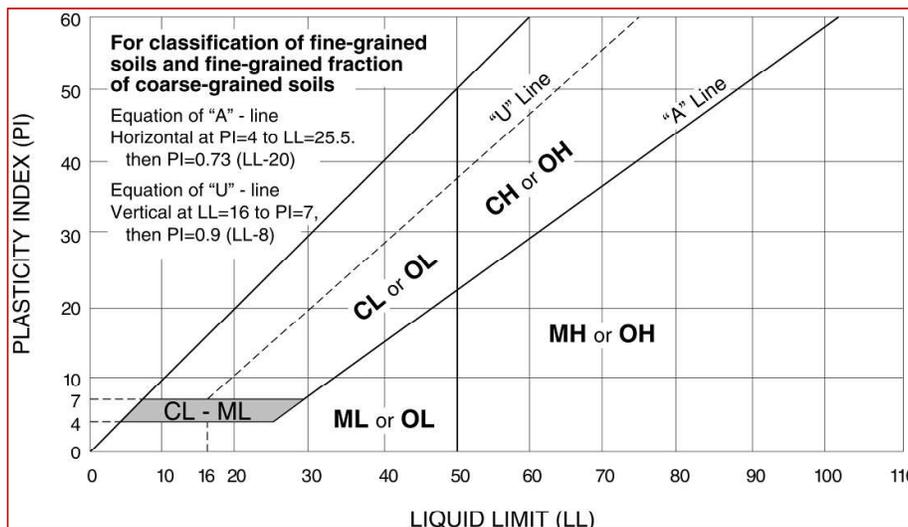
^M If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

^N PI ≥ 4 and plots on or above "A" line.

^O PI < 4 or plots below "A" line.

^P PI plots on or above "A" line.

^Q PI plots below "A" line.



Rock Classification Notes

DESCRIPTIVE ROCK CLASSIFICATION

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaley, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

Limestone	Light to dark colored, crystalline to fine-grained texture, composed of CaCO ₃ , reacts readily with HCl.
Dolomite	Light to dark colored, crystalline to fine-grained texture, composed of CaMg(CO ₃) ₂ , harder than limestone, reacts with HCl when powdered.
Chert	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz (SiO ₂), brittle, breaks into angular fragments, will scratch glass.
Shale	Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
Sandstone	Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
Conglomerate	Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (1/2 inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

PHYSICAL PROPERTIES

Degree of Weathering		Bedding and Joint Characteristics ¹		
		Bed Thickness	Joint Spacing	Dimensions
Slight	Slight decomposition of parent material on joints. May be color change.	Laminated	---	.1 in. – .4 in.
Moderate	Some decomposition and color change throughout.	Very thin	Very close	.4 in. – 2 in.
		Thin	Close	2 in. – 1 ft.
High	Rock highly decomposed, may be extremely broken.	Medium	Moderately close	1 ft. – 3 ft.
		Thick	Wide	3 ft. – 10 ft.
		Very thick	Very wide	More than 10 ft.
Hardness and Degree of Cementation				
Limestone and Dolomite				
Hard	Difficult to scratch with a knife.	Bedding Plane	A plane dividing sedimentary rocks of the same or different lithology.	
Moderately Hard	Can be scratched easily with a knife, cannot be scratched with a fingernail.			
Soft	Can be scratched with a fingernail.			
Shale, Siltstone and Claystone				
Hard	Can be scratched easily with a knife, cannot be scratched with a fingernail.	Joint	Fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.	
Moderately Hard	Can be scratched with a fingernail.	Seam	Generally applies to bedding plane with an unspecified degree of weathering.	
Soft	Can easily be dented but not molded with fingers.	Solution and Void Conditions		
Sandstone and Conglomerate				
Well Cemented	Capable of scratching a knife blade.	Solid	Contains no voids.	
Cemented	Difficult to scratch with a knife.	Vuggy (Pitted)	Rock having small solution pits or cavities up to 1/2 inch diameter, frequently with a mineral lining.	
Poorly Cemented	Can be broken apart easily with fingers.	Porous	Containing numerous voids, pores, or other openings, which may or may not interconnect.	
		Cavernous	Containing cavities or caverns, sometimes quite large.	

1. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.