Lewis and Clark Caverns Water System Improvements Geotechnical Report

May 2025

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Lewis and Clark Caverns Water System Improvements Geotechnical Report

Jefferson County, Montana

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REVISION NO.	AUTHOR	VERSION	DESCRIPTION	DATE
Rev 0	Adam Fetherston	Draft	Internal Review	May 2025
Rev 1	Mike Browne	Final	Client Submittal	May 27, 2025

1 INTRODUCTION

Larson Civil Engineering contracted Pioneer Technical Services, Inc. (Pioneer) to complete a geotechnical investigation for the proposed Lewis and Clark Caverns State Park Water System Improvements project. The purpose of the geotechnical investigation was to explore subsurface conditions at the site and provide information on soil characteristics, soil bearing capacity, lateral earth loads, soil corrosivity concerns, seismic zone, groundwater conditions, material specifications, and discussion of any unusual conditions. This report provides conclusions of the investigation, results of laboratory testing and analyses, and design recommendations.

2 INVESTIGATION

2.1 Site Description

Lewis and Clark Caverns State Park is located at 25 Lewis and Clark Caverns Road near Cardwell, Montana. The project location will begin near the existing campground pump building and continue towards the lower visitor's center and follow Lewis and Clark Caverns Road to the upper visitor's center water treatment building. The project is located in Sections 16 and 21, Township 1 North, Range 2 West.

2.2 Geotechnical Investigation

The geotechnical investigation was conducted in two phases. The first phase consisted of drilling boreholes along the upper alignment. Eight boreholes were drilled (BH-01 through BH-08) to depths between 2 and 16.5 feet below the ground surface at locations shown on Figure 1. The drilling work was performed by Pioneer on March 28, 2025. The boreholes were drilled using a Geoprobe 7822DT track-mounted drill rig. An engineer from Pioneer logged the borehole lithology and collected samples for laboratory testing.

The second phase consisted of excavating test pits along the lower alignment. Five test pits were excavated (TP-01 through TP-05) to depths between 6.4 and 9.5 feet below the ground surface at locations shown on Figure 1. The excavation work was performed by Karnath Contracting, Inc. on April 4, 2025. The test pits were excavated using a Wacker Neuson 6003 mini-excavator. An engineer from Pioneer logged the test pit lithology and collected samples for laboratory testing.

During drilling operations, *in situ* strengths were collected via Standard Penetration Tests (SPTs) using a 2-inch outside diameter split-spoon sampler, which was driven into the soil using a standard 140-pound safety hammer falling from a height of 30 inches. Geotechnical samples were collected from each SPT interval and test pit and field classified in general accordance with ASTM International D2488 (Standard Practice for Description and Identification of Soils [Visual – Manual Procedure]).

2.2.1 Soil Lithology

Geologically, the project is located in alluvial deposits (Q_{alo} and Q_{af}) overlying bedrock. The Jefferson Canyon Fault runs east to west and bisects the alignment just north of the proposed pump building and water storage tank. South of the fault, the bedrock consists of Elkhorn Mountain Volcanics (K_{em}). North of the fault, the bedrock consists of the Lahood Formation (Y_{la}) (MBMG, 2006).

Soil encountered during the investigation was generally consistent with the mapped geology as sand with varying amounts of silt, clay, gravel and cobbles was encountered in each borehole and test pit. In TP-02, frequent boulders were encountered at 5.5 feet to the bottom of the test pit at 6.4 feet, where excavator refusal occurred. Pioneer speculates that a larger machine could excavate deeper.

In BH-05, bedrock was encountered at 3.5 feet. The bedrock was able to be drilled through to the bottom of the borehole at 5 feet, but drilling was very difficult. In BH-06, bedrock was encountered at 2 feet resulting in drill rig refusal. The drill rig was moved multiple times and encountered refusal at 2 feet during each attempt.

Appendix A contains the detailed borehole and test pit logs, while Appendix B presents photographs of the investigation. The stratification lines shown on the logs represent the approximate boundary between soil types as observed within the boreholes and test pits. The actual *in situ* transition is variable because of the nature and depositional characteristics of natural soil and bedrock. Interpolation of subsurface conditions beyond the location of the boreholes and test pits may be unreliable as soil conditions can change rapidly in both lateral and vertical directions.

2.2.2 Groundwater Conditions

Groundwater was not encountered in any of the boreholes or test pits during the investigation. Review of local well logs on the Montana Bureau of Mines and Geology (MBMG) *Ground Water Information Center* website (MBMG, 2025) showed groundwater depths in nearby wells varied from 25 to 70 feet below the ground surface.

2.3 Laboratory Testing

Collected soil samples were transported and analyzed at Pioneer's materials testing laboratory. The samples were collected from select depths and were tested for their index (physical) and chemical properties.

2.3.1 Index Properties

A summary of the laboratory testing results is presented in Table 1. Appendix C provides the complete laboratory testing results.

Table 1: Laboratory Index Data

INVESTIGATION NO.	DEPTH (feet)	USCS SYMBOL	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	GRADATION ANALYSIS		
						GRAVEL (%)	SAND (%)	FINES (%)
BH-08	10-15	SM	NV	NP	NP	21	54	25
TP-01	5-5.5	SW-SM	NV	NP	NP	35	57	8
TP-02	4-5	GP	NV	NP	NP	56	41	3
TP-05	6-7	SM	NV	NP	NP	10	72	18

NP: non-plastic. NV: non-viscous. USCS: Unified Soil Classification System.

Moisture contents ranged from 2% to 6% with an average moisture content of 3%.

2.3.2 Chemical Properties

Corrosivity testing (soluble sulfate, pH, and resistivity) was conducted to determine if the on-site soil may potentially be corrosive to buried concrete or metal associated with the proposed construction. The pH and soluble sulfate testing were subcontracted to Alpine Analytical, Inc. A summary of corrosivity testing results is presented in Table 2.

Table 2: Corrosivity Testing

INVESTIGATION NO.	DEPTH (feet)	SOLUBLE SULFATE (%)
TP-02	4-5	0.0200

ohm-cm: ohm-centimeter. s.u.: standard unit

Criteria from the Portland Cement Association (PCA, 2007) were used to evaluate soil corrosiveness. Based on the sulfate testing results, the on-site soil has negligible exposure to concrete sulfate attack. Type I, Type I/II, or Type IL cement are acceptable for all cast-in-place structural concrete exposed to the on-site soil.

3 ANALYSIS AND RECOMMENDATIONS

3.1 Proposed Construction

The proposed project will consist of the following components:

1. Water Storage Tank: The new steel-reinforced high-density polyethylene (HDPE) water storage tank will be 14,500 gallons. It will have a diameter of 8 feet and will be 40 feet long. There will be 2 feet of cover soil over the tank, and it will be buried 9 feet deep. TP-01 and BH-08 were completed at the water storage tank location.
2. Pump Building: A new booster pump station will be constructed. The pump building will have spread footings and a slab-on-grade. TP-02 was completed at the pump building location.

3. Chlorination Room Addition: An addition to the existing campground pump building will be constructed. The addition will have spread footings and a slab-on-grade. TP-05 was completed at the addition location.
4. Water Line Replacement: The existing water line will be replaced from the existing campground pump building to the upper visitor's center water treatment building. The remaining test pits and boreholes were completed along the water line alignment to provide information on bedrock depth.

3.2 Site Grading

Due to the sloping site topography at the new pump building, the civil design may require cut and fill operations to level the site. Pioneer recommends the following measures related to site grading earthwork:

1. Excavate and remove topsoil and vegetation from the building footprint.
2. Excavate to design grade. Excavated soil may be stockpiled for reuse as fill assuming it is free of organics and particles larger than 4 inches in diameter are removed.
    a. Any permanent cuts should be designed to have slopes of 3 horizontal to 1 vertical (3H:1V) or flatter.
3. Moisture condition excavated surface to plus or minus 2% of optimum moisture content. Compact the excavation surface to a standard relative compaction (ASTM D698) of at least 95%. Footing locations should be compacted to a standard relative compaction of at least 98% per Section 3.3.
4. If needed, place fill to design grade in 8-inch (maximum) loose lifts and compact to a standard relative compaction of at least 95%. Footing locations should be compacted to a standard relative compaction of at least 98% per Section 3.3.

Ensure there is positive drainage away from all open project excavations to keep surface water from draining into the excavations. This recommendation also applies to final grading, where positive drainage should be in place around the entire structure perimeters per the International Building Code (IBC, 2021).

3.3 Spread Footings

The Pump Building and Chlorination Room Addition spread footings can be founded directly on the native sand. For the spread footings, Pioneer recommends the following:

1. Bottom of exterior footings should be located at least 42 inches below final grade to mitigate frost potential.
2. Excavate and remove topsoil and vegetation from the building footprint.
3. Excavate to design grade.
    a. At the Chlorination Room Addition, ensure any uncontrolled fill from backfilling around the existing campground pump building is removed entirely.
4. Moisture condition excavated surface to plus or minus 2% of optimum moisture content. Compact the excavation surface to a standard relative compaction of at least 98%.

5. If needed at the Chlorination Room Addition, place fill to design grade in 8-inch (maximum) loose lifts and compact to a standard relative compaction of at least 98%.
    a. Excavated soil may be reused as fill assuming it is free of organics, particles larger than 4 inches in diameter are removed, and there is a maximum of 40% fines. If needed, imported base course meeting the gradation requirements listed in Table 3 can be used as fill.

Table 3: Base Course
(MPWSS 3/4-inch Minus Base Course)

SIEVE SIZE	PERCENT PASSING
3/4-inch	100
No. 4	40 - 70
No. 10	25 – 55
No. 200	2 – 10

Provided recommendations listed above are followed, Pioneer recommends an allowable soil bearing capacity of 2,500 pounds per square foot (psf). The friction coefficient (μ) can be taken as 0.40 for sliding against the native sandy soil. Based on theory of elasticity, total and differential settlement are anticipated to be less than 1 inch and ½ inch, respectively.

3.4 Foundation Walls

The on-site soil is suitable for backfill provided it is free of organics and particles larger than 4 inches in diameter are removed. Place the backfill in 8-inch (maximum) loose lifts and compact each lift to a standard relative compaction of at least 95%.

Reinforced concrete wall design can use the following list of lateral pressure loading values based on conservatively assumed strength values for an internal angle of friction (ϕ) equal to 32 degrees, a cohesion (c) value of 0 psf, a moist unit weight of 125 pounds per cubic foot (pcf), and an equivalent fluid weight of 38 pcf. Lateral earth coefficients (based on level backfill) are listed in Table 4.

Table 4: Lateral Earth Coefficients and Pressures

LATERAL EARTH PRESSURE	COEFFICIENT (K)
Active	0.31
Passive	3.26
At-Rest	0.47

These values can also be used for any potential retaining walls planned for the project provided similar backfill is used.

3.5 Slab-On-Grade

For a slab-on-grade floor system, Pioneer recommends the following:

1. Over-excavate a minimum of 6 inches below the bottom of the slab-on-grade elevation.
2. Moisture condition excavated surface to plus or minus 2% of optimum moisture content. Compact the excavation surface to a standard relative compaction of at least 95%.
3. Place and compact imported base course to design grade. Place base course in 8-inch (maximum) loose lifts and compact to a standard relative compaction of at least 95%. Base course should meet gradation requirements listed in Table 3.
4. From a geotechnical perspective, a vapor barrier is not required. Vapor barriers are used to prevent moisture and gas vapors (typically radon) from migrating through the floor slab. Some floor coverings are moisture-sensitive and are intended for use with vapor barriers. The project design team should determine the need for a vapor barrier based on floor coverings and moisture and gas vapor control requirements. If a vapor barrier is to be installed, Pioneer recommends a 15-mil polyolefin vapor barrier be placed over the base course prior to pouring the concrete slab.

For structural design of the concrete slab, Pioneer recommends using a subgrade modulus of 200 pounds per square inch per inch (pci).

3.6 Water Storage Tank

For the Water Storage Tank, Pioneer recommends the following:

1. Over-excavate a minimum of 12 inches below the bottom of the tank.
2. Moisture condition excavated surface to plus or minus 2% of optimum moisture content. Compact the excavation surface to a standard relative compaction of at least 95%.
3. Place tank bedding and primary backfill material per project drawings/specifications and manufacture recommendations.
    a. Pioneer recommends placing the primary backfill in 8-inch (maximum) loose lifts and compacting with a minimum of four passes of vibratory compaction equipment. Density testing is not required.
4. Place a layer of Propex Geotex 601 Nonwoven Geotextile or approved equivalent across the primary backfill per project drawings/specifications.
5. Place secondary backfill material per project drawings/specifications and tank manufacture recommendations.
    a. The on-site soil has particle sizes greater than 1 inch and will likely not be suitable to use as secondary backfill without processing.
    b. Imported base course, meeting gradation requirements listed in Table 3, is a suitable alternative for secondary backfill.

3.7 Seismic Considerations

The seismic coefficients were estimated using ASCE7-16 and Risk Category II (ASCE7-16 is based on the 2021 IBC [IBC, 2021]). The seismic coefficients are summarized in Table 5 and the data sheets are included in Appendix D.

Table 5: Seismic Coefficients

Site Soil Class Definition	D
Seismic Design Category	D
Mapped Spectral Response Acceleration Parameter, S_S for 0.2 second	0.753g
Mapped Spectral Response Acceleration Parameter, S_1 for 1.0 second	0.232g
Adjusted Maximum Considered Earthquake Spectral Response Acceleration Parameter, S_{MS}	0.903g
Adjusted Maximum Considered Earthquake Spectral Response Acceleration Parameter, S_{M1}	N/A
Design Spectral Response Acceleration Parameter, S_{DS}	0.602g
Design Spectral Response Acceleration Parameter, S_{D1}	N/A

3.8 Underground Utilities and Trench Stability

For utility trench excavations, trench soil meets the Occupational Safety and Health Administration's 29 Code of Federal Regulations Part 1926 requirements for Type C soil. The steepest unsupported slope within Type C soil is set at 1.5H:1V.

Use Type I bedding soil beneath and up to 6 inches above the top of the pipe. Type I bedding soil is ¾-inch minus granular soil having a soluble sulfate content less than 0.1% and a resistivity greater than 3,000 ohm-centimeters. The on-site soil can be reused as trench backfill above the bedding soil.

Soil compaction in utility trenches deeper than 5 feet should be performed using a remote trench compactor or a Felco-style bucket on an excavator and observed by an inspector. Perform compaction testing on each lift from a depth of 5 feet to the top of the trench. Place the trench soil in 8-inch (maximum) loose lifts and compact to a standard relative compaction of at least 95%.

3.9 Shrink/Swell Characteristics

The volume change potential of the site granular soil is considered 'low' based on the physical properties of the soil. Regardless, Pioneer recommends the following be incorporated into the design:

1. Roof runoff water should be collected in a gutter/downspout system and routed away from any foundations.
2. Grades should be designed and constructed per the 2021 IBC (IBC, 2021) to promote positive drainage away from the structure perimeters.
3. Avoid placing plantings and irrigation systems immediately adjacent to any structures.

4 EARTHWORK TESTING

Pioneer recommends that a qualified inspector perform compaction testing for subgrade, base course, and backfill. Table 6 lists the suggested minimum compaction testing frequency.

Table 6: Compaction Testing Frequency

LOCATION	FREQUENCY
Beneath Strip Footings	1 test per 25 linear feet of footing per lift
Foundation Wall Backfill	1 test per 50 linear feet per lift
Beneath Slab-On-Grade	1 test per 400 square feet per lift
Beneath Water Storage Tank	1 test per 400 square feet per lift
Water Storage Tank Backfill	1 test per 400 square feet per lift

Table 7 summarizes the material compaction specifications presented in other sections of this report. Compaction testing should be performed on subgrade, base course, and backfill. Frozen soil, ice particles, and soil with organics, debris, or deleterious materials are not suitable for use as fill. Appropriate winter construction techniques must be used, as warranted, to protect subgrade, fill, and cast concrete from frost. Fill shall not be placed on top of frozen soil. The maximum loose lift thickness is 8 inches.

Table 7: Required Relative Compaction

LOCATION	REQUIRED MINIMUM RELATIVE COMPACTION	STANDARD
Beneath Foundation Footings	98%	ASTM D698
Foundation Wall Backfill	95%	ASTM D698
Beneath Slab-On-Grade	95%	ASTM D698
Beneath Water Storage Tank	95%	ASTM D698
Water Storage Tank Primary Backfill	Not Required	-
Water Storage Tank Secondary Backfill	95%	ASTM D698

Concrete testing frequency should be performed according to project specifications and/or structural engineer requirements.

5 BASIS OF RECOMMENDATIONS

The analyses and recommendations submitted in this report are based upon the boreholes and test pits completed during the subsurface investigation and with general site familiarity. Often, variations occur within the subgrade, the nature and extent of which do not become evident until additional exploration or construction is conducted. Pioneer recommends geotechnical involvement be continued throughout the project to ascertain the recommendations presented herein (Geotechnical Report) have been properly interpreted both during design and construction. These services will reduce potential for misinterpretation of geotechnical design recommendations. Pioneer also recommends a geotechnical engineer be notified during the construction phase to evaluate the foundation soil and verify its resemblance to those encountered during the site investigation.

This report is based on Pioneer's understanding of the preliminary design associated with the proposed Lewis and Clark Caverns State Park Water System Improvements project. If the location or proposed elevation profiles change, please consult Pioneer to verify that these recommendations are still applicable.

This report is for the exclusive use of Larson Civil Engineering and their design team. In the absence of Pioneer's written approval, Pioneer makes no representation and assumes no responsibility to other parties regarding this report. The data, analyses, and recommendations may not be appropriate for other structures or purposes. Other parties contemplating other structures or purposes should contact Pioneer. If you are not a designated or authorized recipient, further review, dissemination, distribution, or copying of this report is strictly prohibited.

Services performed by Pioneer's personnel for this project have been conducted with the level of care and skill ordinarily exercised by members of the profession currently practicing in this area under similar budget and time restraints. No warranty, expressed or implied, is made.

Professional Certification
I hereby certify that this report was prepared by me and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

Digitally signed by Michael Browne
Date: 2025.05.27 12:23:40 -06'00'

Mike Browne, P.E.
Geotechnical Engineer

Adam Fetherston, P.E.
Geotechnical Engineer

6 REFERENCES

IBC, 2021. International Building Code, Chapter 18 Soils and Foundation, Section 1804.4 Site Grading, 2018.

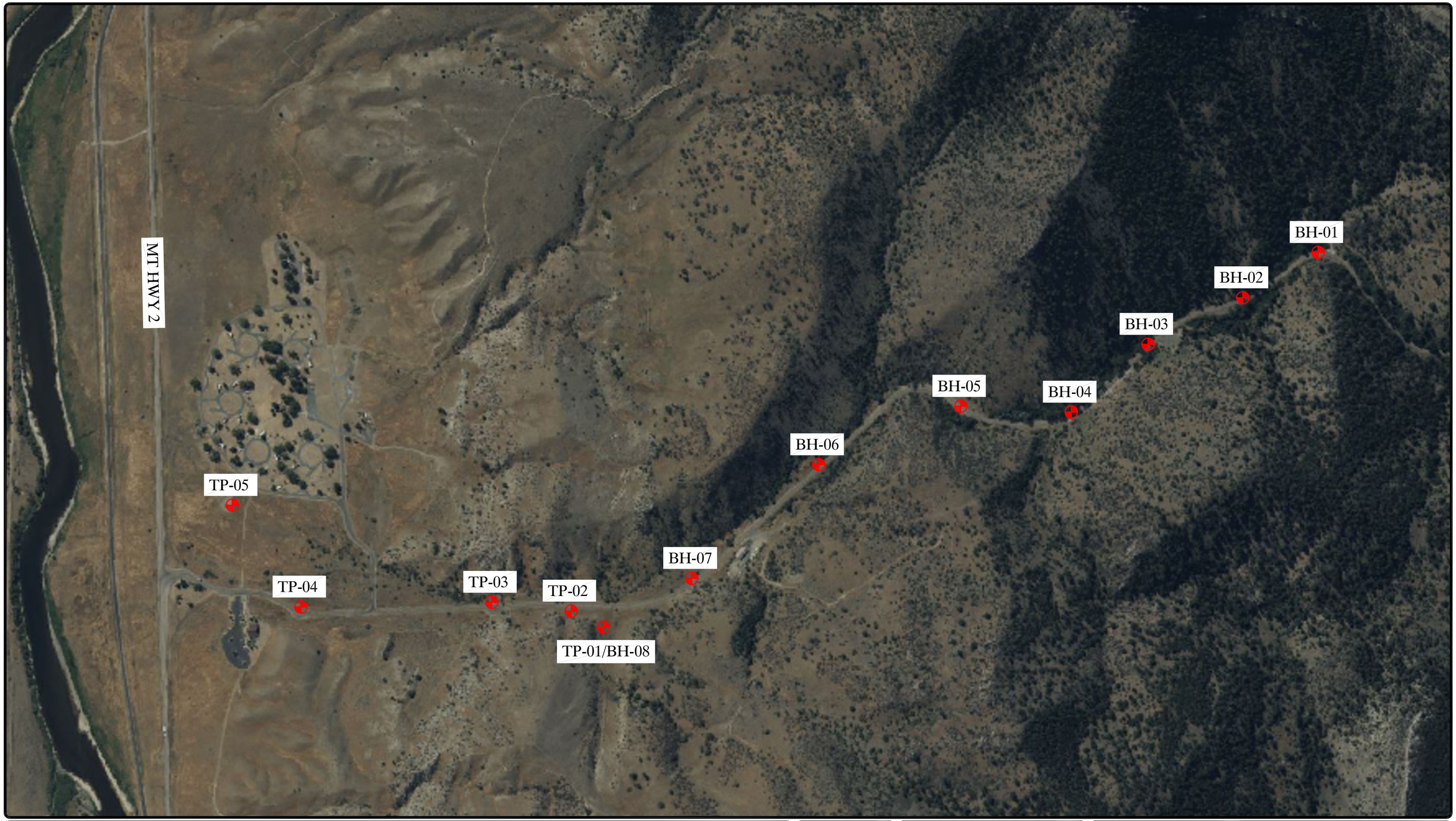
MBMG, 2006. Geologic Map of the Cenozoic Deposits of the Lower Jefferson Valley, Southwestern Montana, Montana Bureau of Mines and Geology Open File Report 537, Susan M. Vuke, 2006.

MBMG, 2025. Montana Bureau of Mines and Geology Ground Water Information Center. Montana's Ground Water Information Center 2025 (mtech.edu). May 2025.

PCA, 2007. Concrete Technology, Effects of Substances on Concrete and Guide to Protective Treatments.

Figures

Figure 1. Site Map



INVESTIGATION LOCATION MARKER

N

DISPLAYED AS:
COORD SYS/ZONE: MSP
DATUM: NAD83
UNITS: US Survey Feet
SOURCE: Pioneer

SCALE IN FEET
0 250 500

FIGURE 1

LEWIS AND CLARK CAVERNS WATER SYSTEM IMPROVEMENTS

PIONEER TECHNICAL SERVICES, INC.
3241 COLONIAL DRIVE
HELENA, MT 59601
(406) 443-6053

DATE: MAY 2025

Appendix A
Investigation Logs

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1-3/8" I.D., 2" O.D., unless otherwise noted	CA:	Casing Advancer
ST:	Thin-Walled Tube - 3" O.D., unless otherwise noted	DA:	Drill Auger
CB:	California Sampler - 2" I.D., 2.5" O.D., unless otherwise	HA:	Hand Auger
DB:	noted Diamond Bit Coring - 4", NX, unless otherwise noted	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	GS:	Grab Sample

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value". The field blow counts are reported for each 6-inch interval, or portion thereof if greater than 50 blows are required to advance the full 6-inch interval. For over-sized split spoon samplers, non-standard hammers, or non-standard drop heights, the field penetration values are reported on the bore log. The values must be corrected to obtain the N-value.

WL:	Water Level	WS:	While Sampling	NE:	Not Encountered
WCl:	Wet Cave in	WD:	While Drilling		
DCI:	Dry Cave in	BCR:	Before Casing Removal		
AB:	After Boring	ACR:	After Casing Removal		

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Soil Classification System, Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: gravel or sand. Cobbles and boulders are not part of the USCS system but are included, when present, as percentages. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; depending on their plasticity, they are described as clays or silts. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	< 2	Very Soft
500 - 1,000	2 - 4	Soft
1,001 - 2,000	5 - 8	Medium Stiff
2,001 - 4,000	9 - 15	Stiff
4,001 - 8,000	16 - 30	Very Stiff
8,000 +	30 +	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	California Barrel (CB) Blows/Ft.	Relative Density
0 - 4	0 - 6	Very Loose
5 - 10	7 - 18	Loose
11 - 30	19 - 58	Medium Dense
31 - 50	59 - 98	Dense
50 +	99 +	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

USCS* GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

*For AASHTO grain size the #4 sieve is replaced with the #10 sieve

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifiers	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-Plastic	0
Slightly	1 - 5
Low	6 - 10
Medium	11 - 20
High	21 - 40
Very Highly	> 40

PIONEER TECHNICAL SERVICES, INC.

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	$Cu \geq 4$ and $1 \leq Cc \leq 3$		GW	Well-graded Gravel [F]
			$Cu <$ and/or $1 > Cc > 3$		GP	Poorly graded gravel [F]
		Gravels with Fines More than 12% fines	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	$Cu \geq 6$ and $1 \leq Cc \leq 3$		SW	Well-graded Sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$		SP	Poorly graded Sand [I]
		Sands with Fines More than 12% fines	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		CL	Lean Clay [K,L,M]
			PI < 4 or plots below "A" line		ML	Silt [K,L,M]
		organic	Liquid limit - oven dried	< 0.75	OL	Organic Clay [K,L,M,N]
			Liquid limit - not dried			Organic Silt [K,L,M,Q]
	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	< 0.75	OH	Organic Clay [K,L,M,P]
			Liquid limit - not dried			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-in. (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] $Cu = D_{60} / D_{10} \quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[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.

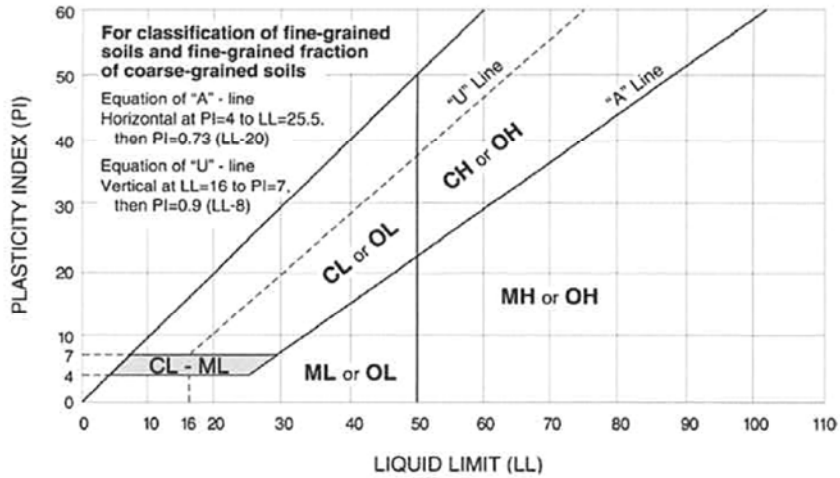
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



PIONEER TECHNICAL SERVICES, INC.

307 E. Park Ave., Suite 421
Anaconda, MT 59711
Phone: (406) 723-1948

LOG OF BORING

Boring BH-01

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 / **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25 / **Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2			65		4 - 6 - 6		Clayey SAND with gravel (SC), medium dense, moist, gray brown, fine to coarse grained, subrounded to subangular.							Road embankment fill.
4			30		3 - 5 - 6									
6			50		4 - 3 - 1			6.5						

Boring Depth: 6.5 ft, *Elevation:*

Water Level Observations		
After Drilling:	During Drilling: **Not Encountered**	Remarks:
	After Drilling:	

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LOG OF BORING

Boring BH-02

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 / **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25 / **Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2			90		4 - 5 - 8		TOPSOIL, Clayey SAND (SC), moist, brown, fine to coarse grained. Organics.	0.3						
4			90		5 - 9 - 17		Clayey SAND with gravel (SC), medium dense, moist, brown, fine to coarse grained.							
6			90		6 - 6 - 16			6.5						

Boring Depth: 6.5 ft, *Elevation:*

Water Level Observations		
After Drilling:	During Drilling: **Not Encountered**	Remarks:
	After Drilling:	

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LOG OF BORING

Boring BH-03

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns		**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018	**UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25	**Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein		**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2			70		2 - 4 - 5		TOPSOIL, Clayey SAND (SC), loose to medium dense, moist, brown, fine to coarse grained.	0.3						
4			60		3 - 4 - 5		Clayey SAND with gravel (SC), loose to medium dense, moist, brown, fine to coarse grained, subrounded to subangular.							
6			70		1 - 3 - 13			6.5						

Boring Depth: 6.5 ft, *Elevation:*

Water Level Observations		Remarks:
After Drilling:	During Drilling: **Not Encountered**	
	After Drilling:	

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LOG OF BORING

Boring BH-04

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns		**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018	**UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25	**Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein		**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							TOPSOIL.	0.2						
2			60		2 - 2 - 1		Clayey SAND with gravel (SC), loose to very loose, moist, brown, fine to coarse grained, subangular.							
4			80		1 - 2 - 3									
6			80		2 - 2 - 1			6.0						
							Silty SAND (SM), moist, brown, fine grained. Non-plastic.	6.5						

Boring Depth: 6.5 ft, *Elevation:*

Water Level Observations

During Drilling: **Not Encountered**	Remarks:
After Drilling:	After Drilling:

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LOG OF BORING

Boring BH-05

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 / **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25 / **Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2			70		4 - 7 - 4		Clayey SAND with gravel (SC), medium dense, moist, brown, fine to coarse grained, subangular to angular.							
			60		21 - 50/0.4ft									
4							Lahood Formation bedrock.	3.5						Driller noted hard drilling and gray dust.
			50		20 - 50/0.3ft			5.8						Can drill bedrock but very slowly. Moved north 5' and encountered bedrock at same depth.

Boring Depth: 5.8 ft, *Elevation:*

Water Level Observations		Remarks:
After Drilling:	During Drilling: **Not Encountered**	
	After Drilling:	

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LOG OF BORING

Boring BH-06

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 / **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25 / **Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2			100		2 - 50/0.4ft		TOPSOIL, Clayey SAND (SC). Clayey SAND (SC), dense, moist, brown, fine to coarse grained.	0.3 2.0						

Boring Depth: 2.0 ft, *Elevation:*

Auger refusal at 2' depth on 3 boreholes 5' apart.

Water Level Observations		Remarks:
During Drilling: **Not Encountered**		
After Drilling:	After Drilling:	

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LOG OF BORING

Boring BH-07

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns		**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018	**UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25	**Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein		**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / *Elev. (ft)*	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
			85		2 - 3 - 4		TOPSOIL, Clayey SAND (SC), moist, brown. Trace organics.	0.3						
2							Clayey SAND with gravel (SC), medium dense, moist, brown, fine to coarse grained, subrounded to subangular.							
4			85		1 - 2 - 9									
6			70		8 - 11 - 12			6.5						

Boring Depth: 6.5 ft, *Elevation:*

Water Level Observations	During Drilling: Not Encountered	Remarks:
After Drilling:	After Drilling:	

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LOG OF BORING

Boring BH-08

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** Geo 7822 DT **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 3/28/25 **Date Finished:** 3/28/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Pioneer **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
0							TOPSOIL, Clayey SAND (SC), moist, brown, fine to coarse grained.	0.3						
2			70		2 - 5 - 3		Silty SAND with gravel (SM), medium dense to loose, moist, brown, fine to coarse grained, subrounded to subangular.							
4			70		5 - 5 - 7									
6			60		6 - 8 - 5				2					
8			65		5 - 3 - 4									
10			65		6 - 9 - 9				6					
12											NP	25		Increase in gravel in cuttings.
14														
16			65		8 - 12 - 10				3					
								16.5						

Boring Depth: 16.5 ft, *Elevation:*

Water Level Observations		Remarks:
▽ After Drilling:	▽ During Drilling: **Not Encountered**	
	▼ After Drilling:	

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LOG OF BORING

Boring TP-01

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** WN 6003 **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 4/4/25 **Date Finished:** 4/4/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Vern Karmath **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2 4 6 8							TOPSOIL, Clayey SAND (SC), moist, brown, fine to coarse grained. Trace gravels and organics. Well-Graded SAND with silt and gravel (SW-SM), moist to dry, brown to tan, fine to coarse grained, subangular to subrounded. Trace cobbles.	0.7 8.3			NP	8		

Boring Depth: 8.3 ft, *Elevation:*

Water Level Observations

▽ During Drilling: **Not Encountered**

▼ After Drilling:

▽ After Drilling:

Remarks:

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LOG OF BORING

Boring TP-02

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** WN 6003 **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 4/4/25 **Date Finished:** 4/4/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Vern Karmath **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							TOPSOIL, Clayey SAND with gravel (SC), moist, brown, fine to coarse grained. Trace organics.							
							Clayey SAND with gravel (SC), Cobbles, moist to dry, brown to tan, fine to coarse grained, subrounded to subangular. Trace boulders.	0.9						
2														
4							Poorly-Graded GRAVEL with sand (GP), Boulders, dry, brown to tan, fine to coarse grained, subrounded to subangular.	4.0	2		NP	3		Frequent boulders; transitioning to bedrock.
6								6.4						

Boring Depth: 6.4 ft, *Elevation:*

Excavator refusal; could possibly excavate deeper with larger excavator and larger excavation.

Water Level Observations		Remarks:
During Drilling: **Not Encountered**		
After Drilling:	After Drilling:	

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LOG OF BORING

Boring TP-03

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** WN 6003 **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 4/4/25 **Date Finished:** 4/4/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Vern Karmath **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							TOPSOIL, Clayey SAND with gravel (SC).							
							Clayey SAND with gravel (SC), Cobbles, moist, brown, fine to coarse grained.	0.5						
2														
4														
							Poorly-Graded SAND with gravel (SP), Cobbles, moist, brown, fine to coarse grained. Non-plastic.	5.0						
6														
								7.2						Ended test pit at 7.2' due to space constraints.

Boring Depth: 7.2 ft, *Elevation:*

Water Level Observations		Remarks:
After Drilling:	During Drilling: **Not Encountered**	
	After Drilling:	

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LOG OF BORING

Boring TP-04

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** WN 6003 **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 4/4/25 **Date Finished:** 4/4/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Vern Karmath **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
							TOPSOIL, Clayey SAND with gravel (SC), moist, brown, fine to coarse grained. Trace organics.							
							Clayey SAND with gravel (SC), Cobbles, moist, brown, fine to coarse grained, subangular to subrounded. Trace of boulders.	1.0						
2														
4														
							Silty SAND with gravel (SM), moist, light brown, fine to coarse grained. Non-plastic; trace boulders.	5.5						
6														
8								8.8						

Boring Depth: 8.8 ft, *Elevation:*

Water Level Observations		
▽ During Drilling: **Not Encountered**		Remarks:
▼ After Drilling:	▼ After Drilling:	

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LOG OF BORING

Boring TP-05

PIONEER TECHNICAL SERVICES, INC.

Project: L&C Caverns	**Rig:** WN 6003 **Hammer:** Auto	**Boring Location Coordinates:**	**Station:** **Offset:**
Project Number: 2025018 **UPN:**	**Boring Diameter:**	**System:** MT S.P. (E) **Datum:** NAD83	**Top of Boring Elevation:** ft
Date Started: 4/4/25 **Date Finished:** 4/4/25	**Drilling Fluid:** None	**Location Source:**	**Elevation Source:**
Driller: Vern Karmath **Logger:** A. Klein	**Abandonment Method:** Backfilled with Cuttings	**Township Range and Section:**	

Depth (ft) / Elev. (ft)	Operation	Sample Type	Recovery (%)	RQD (%)	Blow Count	Lithology	Material Description	Depth (ft)	MC (%)	LL	PL	-200 (%)	DD	Remarks and Other Tests
2 4 6 8							TOPSOIL, Silty SAND (SM), moist, brown, fine to coarse grained. Non-plastic.	1.0						
							Silty SAND (SM), moist, brown, fine to coarse grained, subangular to subrounded. Non-plastic; trace cobbles.				NP	18		
								9.5						

Boring Depth: 9.5 ft, *Elevation:*

Water Level Observations		
After Drilling:	During Drilling: **Not Encountered**	Remarks:
	After Drilling:	

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Appendix B
Photograph Log

Picture #: 1	Description: TP-01 location

Picture #: 2	Description: TP-01

Picture #: 3	Description: TP-01 spoils pile

Picture #: 4	Description: TP-02 location

Picture #: 5	Description: TP-02

Picture #: 6	Description: TP-03 location

Picture #: 7	Description: TP-03

Picture #: 8	Description: TP-04 location

Picture #: 9	Description: TP-04

Picture #: 10	Description: TP-04 spoils pile

Picture #: 11	Description: TP-05 location

Picture #: 12	Description: TP-05

Appendix C
Laboratory Data

PIONEER TECHNICAL SERVICES

Moisture Analysis - AASHTO T265; ASTM D2216

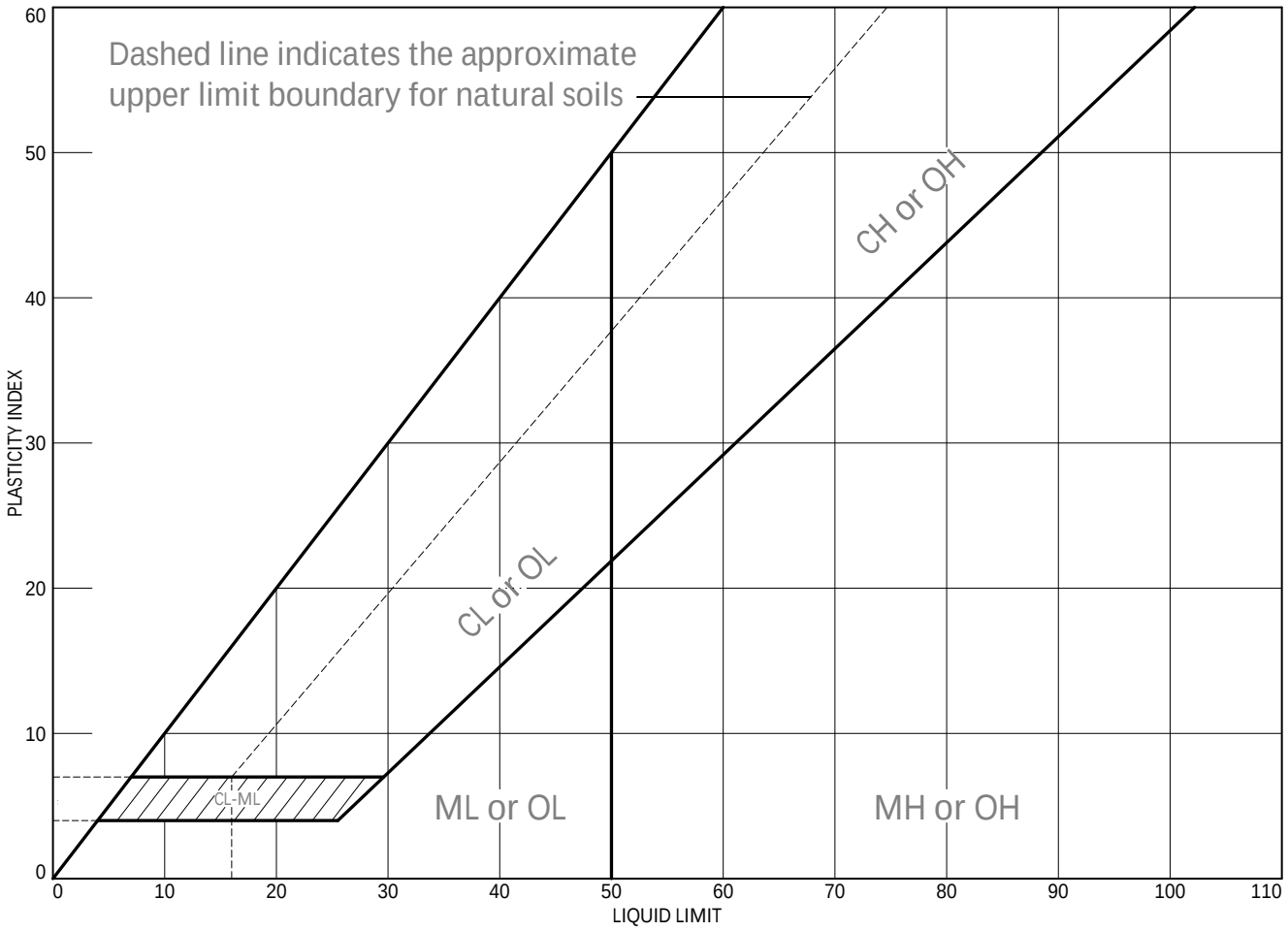
Project Name: L&C Caverns Water System Improvements **Project Number:**

Lab No:	31397	31399	31400	31404						
BH or Loc:	BH-08	BH-08	BH-08	TP-02						
Depth:	5-6.5'	10-11.5'	15-16.5'	4-5'						
Date Tested:	5/5/2025	5/5/2025	5/5/2025	5/5/2025						
Pan No:										
Wet Wt, & Pan (g):	544.9	430.3	518.2	544						
Dry Wt, & Pan (g):	536.5	411.4	505.6	535.9						
Loss of Moisture	8.4	18.9	12.6	8.1						
Wt. of Pan (g):	82.3	85.2	81.6	82.1						
Wt. of Dry Soil (g):	454.2	326.2	424	453.8						
M. Content (%):	**1.8**	**5.8**	**3.0**	**1.8**						

Lab No:										
BH or Loc:										
Depth:										
Date Tested:										
Pan No:										
Wet Wt, & Pan (g):										
Dry Wt, & Pan (g):										
Loss of Moisture										
Wt. of Pan (g):										
Wt. of Dry Soil (g):										
M. Content (%):										

Revised 06-17-24

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand with gravel	NV	NP	NP	49	25	SM
■	well-graded sand with silt and gravel	NV	NP	NP	26	8	SW-SM
▲	poorly graded gravel with sand	NV	NP	NP	13	3	GP
◆	silty sand	NV	NP	NP	52	18	SM

Project No. 2025018 Client: Larson Civil Engineering, LLC

Project: L&C Caverns Waterline

●Location: BH-08 Depth: 10-15' Sample Number: 31401
■Location: TP-01 Depth: 5-5.5' Sample Number: 31403
▲Location: TP-02 Depth: 4-5' Sample Number: 31404
◆Location: TP-05 Depth: 6-7' Sample Number: 31409

Remarks:

PIONEER TECHNICAL SERVICES, INC.

Figure

Tested By: DZ

Particle Size Distribution Report

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	1	20	5	25	24	25	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5"	100		
1"	100		
3/4"	99		
1/2"	95		
3/8"	90		
#4	79		
#10	74		
#20	62		
#40	49		
#60	40		
#100	33		
#200	25		

* (no specification provided)

Soil Description

silty sand with gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 9.7722 D_{85}= 7.1750 D_{60}= 0.7742
D_{50}= 0.4445 D_{30}= 0.1136 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

F.M.=2.57

Location: BH-08
Sample Number: 31401 Depth: 10-15' Date: 5/6/25

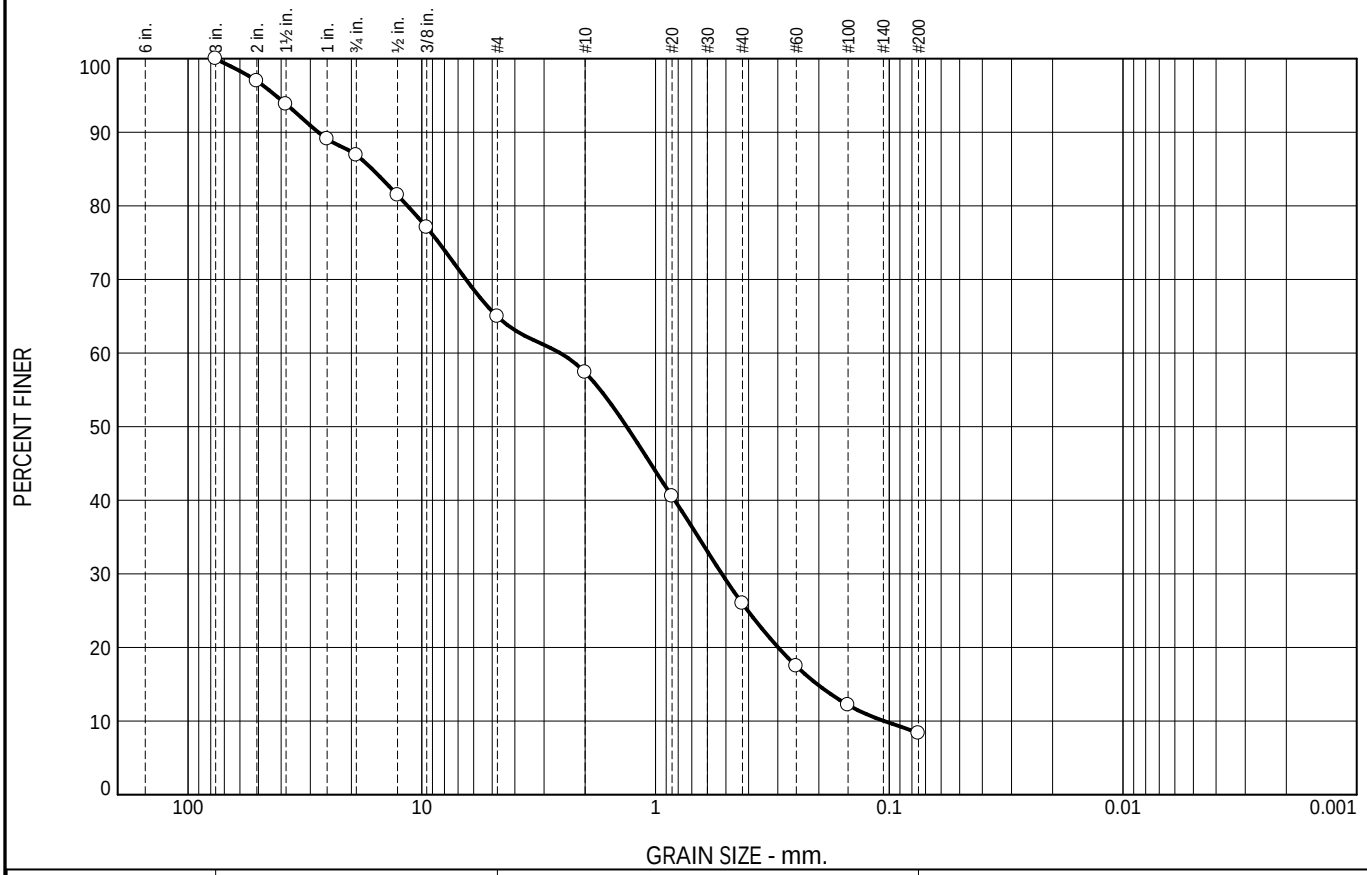
PIONEER TECHNICAL SERVICES, INC.

Client: Larson Civil Engineering, LLC
Project: L&C Caverns Waterline

Project No: 2025018 Figure

Tested By: TJ

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	13	22	8	31	18	8	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3"	100		
2"	97		
1.5"	94		
1"	89		
3/4"	87		
1/2"	81		
3/8"	77		
#4	65		
#10	57		
#20	41		
#40	26		
#60	17		
#100	12		
#200	8		

* (no specification provided)

Soil Description

well-graded sand with silt and gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 27.7408 D_{85}= 16.2852 D_{60}= 2.5587
D_{50}= 1.3285 D_{30}= 0.5206 D_{15}= 0.2034
D_{10}= 0.1050 C_u= 24.38 C_c= 1.01

Classification

USCS= SW-SM AASHTO= A-1-b

Remarks

F.M.=4.05

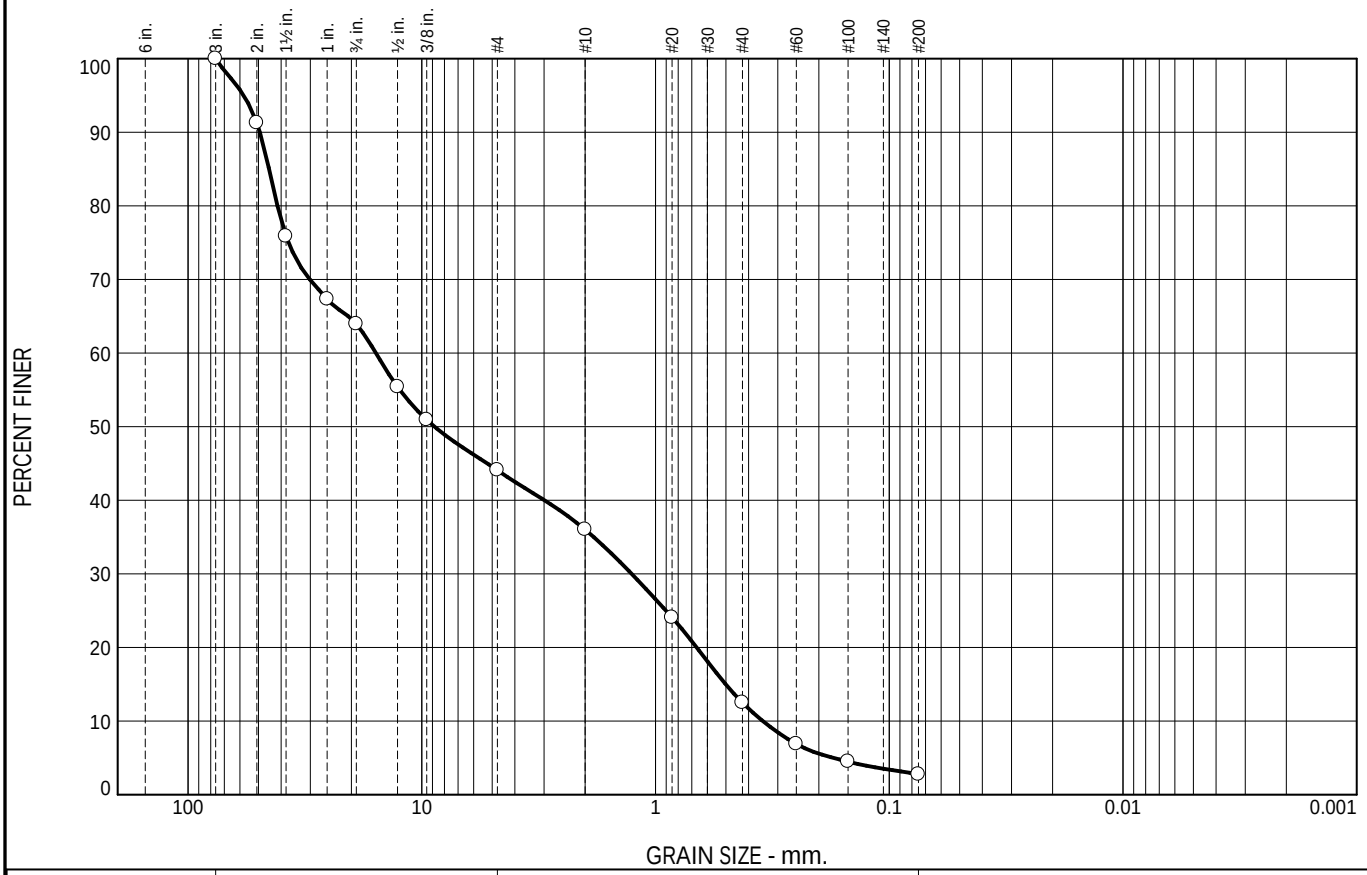
Location: TP-01
Sample Number: 31403 Depth: 5-5.5' Date: 5/14/25

PIONEER TECHNICAL SERVICES, INC.

Client: Larson Civil Engineering, LLC
Project: L&C Caverns Waterline

Project No: 2025018 Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	36	20	8	23	10	3	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3"	100		
2"	91		
1.5"	76		
1"	67		
3/4"	64		
1/2"	55		
3/8"	51		
#4	44		
#10	36		
#20	24		
#40	13		
#60	7		
#100	4		
#200	3		

* (no specification provided)

Soil Description

poorly graded gravel with sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 49.3030 D_{85}= 45.0399 D_{60}= 15.7091
D_{50}= 8.8284 D_{30}= 1.2650 D_{15}= 0.5011
D_{10}= 0.3477 C_u= 45.18 C_c= 0.29

Classification

USCS= GP AASHTO= A-1-a

Remarks

F.M.=5.67

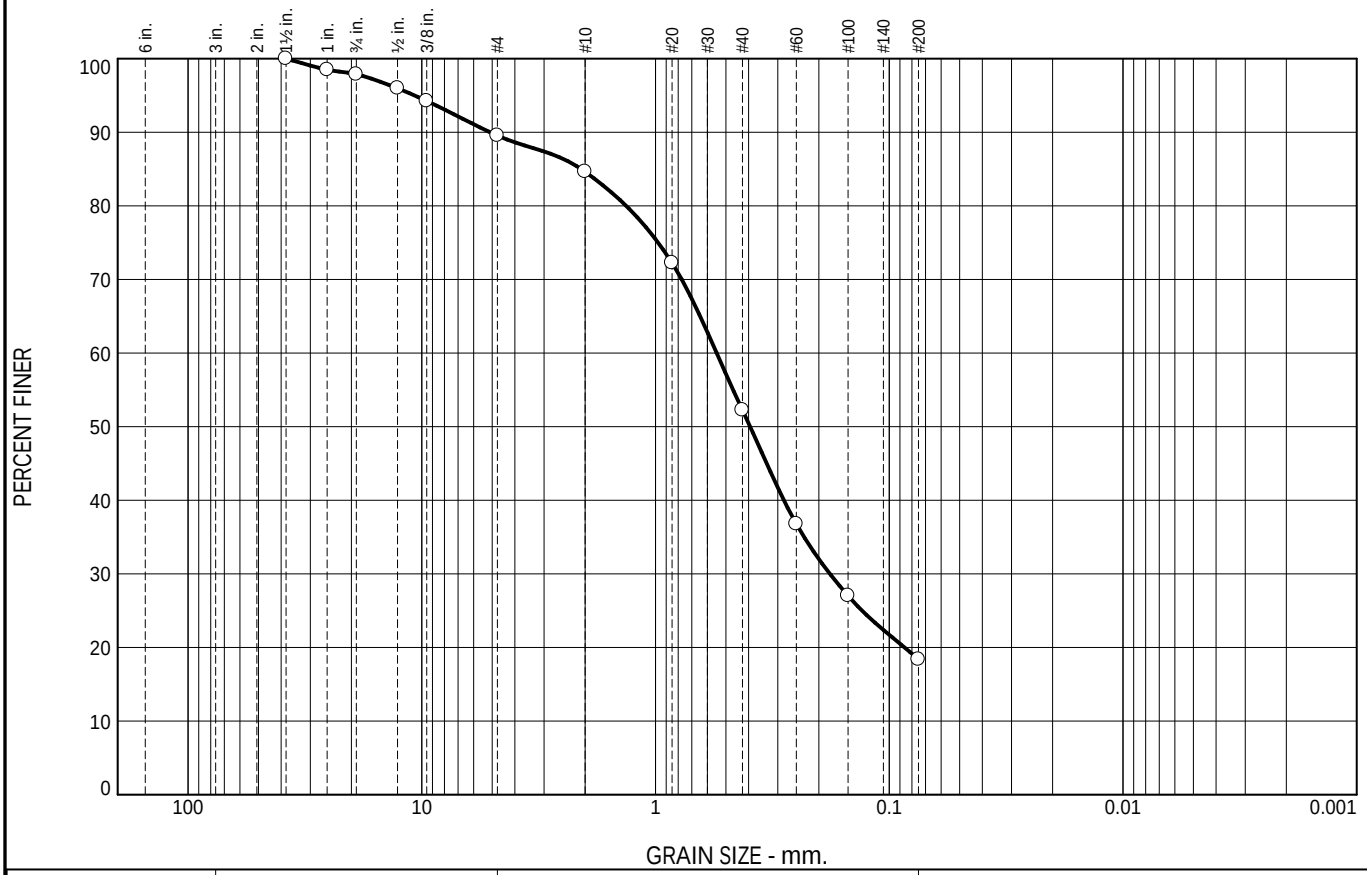
Location: TP-02
Sample Number: 31404 Depth: 4-5' Date: 5/6/25

PIONEER TECHNICAL SERVICES, INC.

Client: Larson Civil Engineering, LLC
Project: L&C Caverns Waterline

Project No: 2025018 Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	2	8	5	33	34	18	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5"	100		
1"	98		
3/4"	98		
1/2"	96		
3/8"	94		
#4	90		
#10	85		
#20	72		
#40	52		
#60	37		
#100	27		
#200	18		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 5.1001 D_{85}= 2.0778 D_{60}= 0.5476
D_{50}= 0.3939 D_{30}= 0.1795 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

F.M.=2.23

Location: TP-05
Sample Number: 31409 Depth: 6-7' Date: 5/14/25

PIONEER TECHNICAL SERVICES, INC.

Client: Larson Civil Engineering, LLC
Project: L&C Caverns Waterline

Project No: 2025018 Figure

Alpine Analytical Laboratory

1315 Cherry, Helena, MT 59601
(406)449-6282

Client: **Pioneer Technical Services**

Date Reported: 22-May-25

Sample ID: TP-02 4-5'
Project ID: L & C Caverns

Chain of Custody #: 83

Laboratory ID: 07F191
Sample Matrix: Soil

Date / Time Sampled: 08-May-25
Date / Time Received: 08-May-25 @ 14:05

Parameter	Result	PQL	Analyzed Date/Time	By	Method Reference
Soluble Sulfate, %	0.0200	0.00005	22-May-25 @ 14:00	CE	EPA 300.0

Comments:

PQL - Practical Quantitation Limit

References:

Methods for Chemical Analysis of Water and Wastes, US EPA, 600/4-79-020
Method of Sampling and Testing MT232-04, *Soil Corrosion Test* (Montana Method).

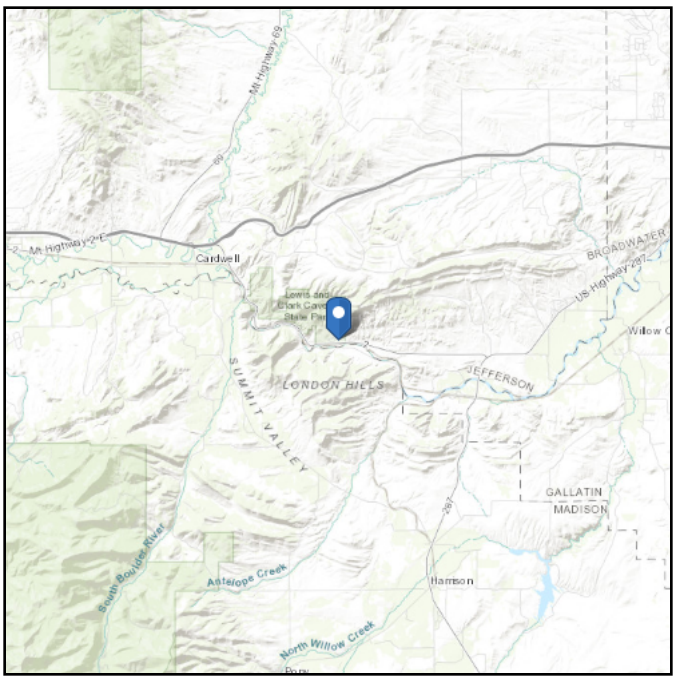
Reviewed by: CE

Appendix D
Seismic Data

ASCE Hazards Report

Address:
No Address at This Location

Standard:	ASCE/SEI 7-16	**Latitude:**	45.822924
Risk Category:	II	**Longitude:**	-111.851571
Soil Class:	D - Stiff Soil	**Elevation:**	4282.438960909433 ft (NAVD 88)



Seismic

Site Soil Class: D - Stiff Soil

Results:

S_S :	0.753	S_{D1} :	N/A
S_1 :	0.232	T_L :	6
F_a :	1.199	PGA :	0.33
F_v :	N/A	PGA_M :	0.419
S_{MS} :	0.903	F_{PGA} :	1.27
S_{M1} :	N/A	I_e :	1
S_{DS} :	0.602	C_v :	1.177

Ground motion hazard analysis may be required. See ASCE/SEI 7-16 Section 11.4.8.

Data Accessed: Wed May 14 2025

Date Source: USGS Seismic Design Maps

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