GEOTECHNICAL INVESTIGATION REPORT

Prepared for:

Central Iron County Water Conservancy District
Paul Monroe
88 E. Fiddlers Canyon Road, Ste A
Cedar City, UT 84721

November 3, 2022

Cedar Highlands Water Tank – Site 2

Prepared by:

LANDMARK
TESTING & ENGINEERING

795 East Factory Drive
St. George, UT 84790

Landmark Project No: 220353

November 3, 2022

Central Iron County Water Conservancy District
Paul Monroe
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Subject: Geotechnical Investigation Report
Cedar Highlands Water Tank – Site 2
Iron County, Utah
Landmark Project No.: 220353

Paul,

As requested, we have completed our Geotechnical Investigation for the above noted project. Our geotechnical recommendations, along with our field and laboratory data are presented in this report.

Our field investigation consisted of the drilling of 4 borings on 2 sites. Upon review of the field data, the lower site was chosen, and this report was prepared. Spread footings established on structurally placed soils are recommended for structural support of the proposed culinary water tank. Over-excavation and recompaction, as detailed in Section 5.0 of this report, will be required. The existing silty sands, free from organics and other debris are suitable for use as structural fill.

Landmark has great interest in providing materials testing and special inspection services during the construction phase of this project. If you advise us of the appropriate time to discuss these engineering services, we will be pleased to meet with you at your convenience.

Please feel free to contact our office at (435) 986-0566 if you have any questions.

Sincerely,
LANDMARK TESTING AND ENGINEERING

Steven Wells, P.E.
Geotechnical Manager

CC: Justin Christensen, PE, Ensign Engineering

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1.0 INTRODUCTION

This report presents the results of Landmark Testing & Engineering's geotechnical investigation for the proposed Cedar Highlands Culinary Water Tank to be construction in Iron County, Utah. Figure A-1 is a Vicinity Map showing the project location relative to surrounding features. Figure A-2 is a Site Map showing the proposed project layout and the approximate locations of the borings completed for this investigation.

We have previously completed field and laboratory testing, along with analysis for the initial site for the tank, which was to be located approximately 850 feet south of the current location. The previous site showed evidence of landsliding, and soft, compressible soils. Therefore, it was decided to investigate two additional sites in the area. Upon completion of our field and laboratory testing, the lower site was chosen for final analysis and the preparation of this report.

This investigation was completed to assist in developing opinions and recommendations concerning site earthwork and foundation design.

2.0 PROPOSED CONSTRUCTION

We understand that a reinforced concrete culinary water tank is planned for construction on the site. The tank will be 65 feet in diameter, and approximately 20 feet in height.

Loading for the structure was not provided; however, we have estimated the following loads based on similar tanks:

- Exterior Wall Footing: 6.0 klf
- Interior Spot Footings: 100 kips
- Tank Water Load: 3.0 ksf

Any significant changes to the anticipated development should be reviewed by Landmark to evaluate the continued applicability of the recommendations contained in this report.

3.0 SITE SETTING

3.1 SURFACE CONDITIONS

The tank site is located in a high mountain meadow. The ground surface slopes down to the west, with an elevation change of approximately 5 feet across the width of the tank. The ground surface has a relatively uniform grade, and was covered with field grasses.

The site is bound by a public gravel road to the north, and by open meadow to the south, east and west.

3.2 GEOLOGIC SETTING

According to the Utah Geological Survey,[1] the project site is mapped as located on:

Qac Alluvium and colluvium (Holocene to upper Pleistocene) – Poorly to moderately sorted, clay- to boulder-size, locally derived sediment deposited in swales and small drainages by fluvial,

1 Interactive Geologic Map Portal, Retrieved October 26, 2022, from Utah Geological Survey, https://geology.utah.gov/apps/intgeomap.

slopewash, and creep processes; gradational with alluvial and colluvial deposits; generally less than 20 feet thick.

These deposits line in a shallow bowl formed by the surrounding mass movement deposits which are comprised of:

Qms **Landslides (Historical to middle[?] Pleistocene)** – Very poorly sorted, locally derived material deposited by rotational and translational movement; composed of clay- to boulder-size debris as well as large, partly intact, bedrock blocks; characterized by hummocky topography, numerous internal scarps, chaotic bedding attitudes, and small ponds, marshy depressions, and meadows; the largest landslide complexes involve the Tropic Shale and Dakota Formation (Ktd) and are several square miles in size; undivided as to inferred age because even landslides having subdued morphology (suggesting that they are older, weathered, and have not experienced recent large-scale movement) may continue to exhibit slow creep or are capable of renewed movement if stability thresholds are exceeded; age and stability determinations require detailed geotechnical investigations.

The surface deposits found on the site all correlate well with this formation. The underlying formations shown in the vicinity of the site, which are buried by the landslide deposits, consisted of:

Ktd **Tropic Shale and Dakota Formation, undivided (Upper Cretaceous)** – Interbedded, slope- and ledge-forming sandstone, siltstone, mudstone, claystone, carbonaceous shale, coal, and marl; sandstone is yellowish brown, thin to very thick bedded, fine to medium grained; mudstone and claystone are gray to reddish brown and commonly smectitic; oyster coquina beds, clams, and gastropods are common; 5 to 12 feet of dark gray and yellowish-brown sandy mudstone, coal, and shale near the top of the map unit represent a thin (0 to 8 feet thick) Tropic Shale and underlying Upper Culver coal zone; Tropic and Dakota strata are typically poorly exposed and involved in large landslide complexes; deposited in marginal-marine environments including floodplain, river, estuarine, lagoonal, and swamp environments for the Dakota Formation and a shallow-marine environment dominated by fine-grained clastic sediment for the Tropic Shale; the Dakota Formation is about 950 feet thick in Cedar Canyon.

Kcm **Cedar Mountain Formation (Cretaceous)** – Grayish-brown, poorly cemented, basal conglomerate overlain by brightly colored variegated mudstone; conglomerate ranges from 0 to 10 feet (0–3 m) thick and contains subrounded to rounded, pebble- to small-cobble-size quartzite, chert, and limestone clasts; mudstone is variegated gray, purplish red, and reddish brown; clay is smectitic and weathers to "popcorn-like" soils; upper contact is poorly exposed and corresponds to a color and lithologic change, from comparatively brightly colored smectitic mudstone below to gray and light-yellowish-brown mudstone.

The geologic map package includes a cross section which crosses the vicinity of the site. The bedrock formations in the area are bent and deformed due to the presence of the Hurricane fault. The layers are curved, with a dip angle of approximately 45 degrees where the formation layers surface.

3.3 GEOLOGIC HAZARDS

Cedar City lies within the transitional zone between the Colorado Plateau to the east and the Basin and Range Province to the west. Southwestern Utah is located on a structural block proximate to the southern segment of the Intermountain Seismic belt, which is characterized by high-angle normal faults that tend to step down to the west. The Hurricane fault with an offset of 6,000 to 8,000 feet forms the eastern edge of the transition zone. The Grand Wash-Reef Reservoir-Gunlock fault system with displacement of about 1,500 to 3,000 feet forms the western edge.

Fault Rupture

The trace of the Hurricane fault is located approximately 2 miles northwest of the site. Higgins and Willis (1995),[2] indicate that the Hurricane fault displaces late Quaternary sediments and is considered active. Strong ground motion associated with movement along the Hurricane or other faults associated with the Intermountain Seismic Belt is possible, however, the potential for surface fault rupture is considered low.

Liquefaction

Liquefaction is the sudden loss of shear strength in the soil due to the build-up of excess pore water pressure.[3] This can occur when the soil is subjected to intense shaking such as during a seismic event. The soils that are most susceptible to liquefaction are loose, saturated sandy soils with a low fines content (material passing the #200 sieve).

Soils encountered in the borings were soft to medium stiff clays. These types of soils are generally not considered susceptible to liquefaction in the presence of shallow ground water. A defined groundwater table was not encountered in our borings during our investigation and therefore liquefaction potential may be considered low. A liquefaction study does not appear to be warranted.

Rockfall

Rockfall is generally not considered to be hazard if the slope from the source area is shallower than 22 degrees. The slope angle of the steepest portion of the site was approximately 18 degrees. Based on the lack of a defined source zone, and the shallowness of the slope, it does not appear that rockfall is a significant hazard on this site.

Landslides

The site is shown on the UGS geologic map as being located partially within landslide deposits, as shown on the Geologic Map, Figure A-3. Geologic units that crop out on the slopes above a determined critical angle of 14 degrees are considered to have a moderate landslide hazard.

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2 Higgins, J.M. and Willis, G.C., 1995, Interim Geologic Map of the St. George Quadrangle, Washington County, Utah; Utah Geological Survey Open-File Report 323

3 Coduto, Donald P. (1999), Geotechnical Engineering: Principles and Practices, Prentice Hall, Upper Saddle River, NJ

Expansive soils

Expansive soils are clays and claystone which changes volume due to moisture content changes. Expansive soils were encountered in our borings, and recommendations for to mitigate this hazard are included in this geotechnical investigation report.

3.4 SEISMICITY

Seismicity at the site was determined using the Seismic Maps Tool from seismicmaps.org website. The following values are presented to assist with seismic design:

- Latitude = 37.63503° North, Longitude = 113.03577° West
- Risk Category = IV (public water supply)
- Site Class = D – Stiff Soils, based on ASCE 7 as referenced in 2018 IBC

Period (sec)	Sa (g)	Site Class
0.2	S_S = 0.749	B/C
1.0	S_1 = 0.242	B/C
0.2	S_{DS} = 0.599	D
1.0	S_{D1} = Null*	D
PGA	0.328	
F_{PGA}	1.272	

* See ASCE Section 11.4.8. S_{D1} is dependent upon the fundamental period of the structure

As per Section 20.1 of ASCE 7-16, "The soil shall be classified in accordance with Table 20.3-1 and Section 20.3 based on the upper 100 feet of the site profile." However, Section 20.1 continues, "Where site specific data are not available to a depth of 100 feet, appropriate soil properties are permitted to be estimated by the registered design professional preparing the soil investigation report based on known geologic conditions." Based on our engineering experience in the area, mapped geology and the soils encountered in the borings, it is the opinion of Landmark Testing and Engineering that the soils on site classify as Site Class D.

4.0 INVESTIGATION

4.1 FIELD INVESTIGATION

Two (2) borings were completed to a maximum depth of 50.0 feet within the anticipated tank site footprint in order to characterize subsurface conditions at the site for the structure. The borings were drilled with a CME 55 drill rig utilizing 8.0-inch O.D. hollow-stem augers. Samples were obtained with a 3.0- inch O.D., split barrel, sampler driven with a 140-lb auto hammer dropping 30 inches. Depending on subsurface conditions, bag or block samples of soil were obtained from the borings. When bedrock was encountered, the upper 10 feet of the bedrock was cored with an HX core barrel. A Landmark geologist, Mr. Greg Kaiser, supervised drilling and sampling operations. Approximate boring locations are shown on Figure A-2.

Groundwater was not encountered in the borings at the time of investigation, however, the soils had relatively high moisture contents. The borings were not piped to monitor the long-term groundwater elevation.

One boring was drilled on the upper and lower sides of the tank. The soils encountered in the borings were similar, and consisted of an upper layer of silty sand with gravel (SM) which extended to between, 10 and 14 feet below the existing grade. The sands were underlain by a layer of stiff to very hard underlain by stiff to very stiff medium to high plastic clays (CL and CH) which was between 3 and 5 feet in thickness, followed by a second layer of silty sand with gravel (SM) to 17 to 25 feet. The sands were underlain by stiff to hard sandy lean clay (CL) and claystone to the maximum depth of exploration, 50.0 feet.

The Logs of Borings are presented on Figures A-4 and A-5. A key to the soil classifications used on the logs is presented on Figure A-6.

4.2 LABORATORY TESTING

Soil samples from the test pits were taken to our St. George, Utah laboratory for testing. Tests performed on the samples included:

- Moisture content and unit weight for density determination
- Sieve analysis and Atterberg Limits for soil classification
- One-Dimension Consolidation for earthwork design
- Modified Proctor for relative density comparison
- Unconfined Compressive Strength for strength analysis

The soils on the site generally fall into 2 categories. The upper soil layers consisted of silty sands. The sample tested contained 14.0 percent gravel and 32.3 percent non-plastic fines. The lower layers consisted of medium to high plastic clays. The Atterberg Limits of the clayey soils ranged from a liquid limit of 32 to 50 and plasticity indexes of 12 to 34, indicating medium to high plasticity.

The soils were mildly moisture sensitive. Samples tested collapsed between 2.1 and 2.7 percent when saturated under constant loads of 1,000 and 1,150 psf. A sample of the clays from Boring 1 at 25.2 feet swelled 0.8 percent when saturated under a constant load of 2,000 psf. The swell pressure of the clay was 3,400 psf. This test result indicates a low to moderate swell potential.

Three samples of the clays were selected for unconfined compressive strength testing. The samples had unconfined compressive strengths ranging from 8,340 to 18,980 psf.

The results of the laboratory tests are shown on the Boring Logs on Figures A-4 and A-5 and on the Summary of Laboratory Test Results on Table B-1. Individual test results are also included in Appendix B.

4.3 ANALYSIS AND CONCLUSIONS

Our field and laboratory test results indicate the soils on site consisted of predominately loose to medium dense silty sands over stiff clays. The clays had a moderate plasticity, and were moist. The high plasticity clays were slightly expansive.

Based on known and expected material properties, we anticipate settlement on the order of 1.7 inches in the center of the tank and 1.2 inches at the edge. Settlement was calculated using the elastic half-space method. To reduce and equalize the amount of settlement, and to provide for a higher bearing capacity below the tank, we recommend 2 feet of imported, granular fill below the bottom of the tank.

General recommendations for the earthwork and the foundation system are outlined in Sections 5.0 and 6.0 of the report.

5.0 SITE GRADING AND EARTHWORK

5.1 GENERAL GRADING

Site preparation should initially consist of grubbing and removal of vegetation. Grubbing is expected to extend from 6 to 18 inches. These soils may be stockpiled for use as topsoil, but should not be used as structural fill. We understand that the tank will be buried approximately 10 to 15 feet, approximately half the height of the tank.

On-site soils below the tank consisted of silty sands over stiff clays with a low swell potential. The area below the tank should be over-excavated to remove the layer of fat clay. The depth of removal is expected to be approximately 5 feet below the bottom of the tank.

Following over-excavation, a Landmark engineer or geologist should observe the excavation to document the depth of over-excavation, and determine if subsurface conditions match those found in our field investigation. Alterations to our recommendations may be required if substantially different conditions are encountered.

Following over-excavation, the exposed subgrade should be scarified 8 inches, moisture conditioned to within 2 percent of the optimum for compaction, and compacted to a minimum of 90 percent of the modified proctor dry density.

5.2 FILL PLACEMENT AND COMPACTION

All fill to be placed for support of footings and slabs-on-grade should be considered structural fill. On-site silty sands are suitable for use as structural fill. The upper 2 feet of structural fill, directly below the bottom of the tank, should consist of imported, granular fill.

The onsite clayey soils are not suitable for use as structural fill below the bottom of the tank. Clayey soils may be mixed with the silty sands and used a backfill around the tank

Imported, granular fill, should be well-graded, non-expansive, and free of organics and all deleterious materials. Soils used for imported, granular fill should meet the following specifications and preferably would classify as gravel.

GRADATION	PERCENT PASSING
3- inch	100
1.5-inch	80-100
No. 200 sieve	5-15

ATTERBERG LIMITS	
Liquid Limit	30 or less
Plasticity Index	9 or less

Material not meeting the above requirements may be suitable for use as structural fill at the discretion of the geotechnical engineer. Samples of structural fill should be submitted for testing prior to transporting to the site.

Any on-site soils used as structural fill or imported, granular fill should be compacted to the following specifications.

FILL PLACEMENT AND COMPACTION	
Maximum lift thickness	8-inch (loose)
Minimum compaction	95% ASTM D-1557
Compacted Moisture Content	within 2% of optimum

Compaction of structural fill should be completed with equipment suitable for the conditions encountered in the field such that compaction requirements are met, including those areas that may be inaccessible to large rolling compactors. All structural fill should be evenly spread on a horizontal plane in eight-inch loose lifts. Each eight-inch lift of structural fill material placed at the site should be tested for compliance with the required relative compaction and moisture content prior to proceeding with additional lifts.

5.3 CUT AND FILL SLOPES

It is recommended that permanent cut or fill slopes be maintained at a slope of two horizontal to one vertical (2H:1V) or flatter unless structurally retained.

Grading of both cut and fill slopes should be such that surface water is directed away from the slopes and not concentrated on slopes or in unprotected channels. Construction procedures should ensure adequate compaction of slope faces. All excavations should conform to OSHA standards.

6.0 FOUNDATION & CONSTRUCTION CONSIDERATIONS

The proposed tank may be supported on conventional spread and continuous footings established on imported, granular fill. Foundation excavations should be visually observed and tested by qualified personnel prior to placement of reinforcing steel or concrete. Additional foundation recommendations are subsequently presented.

DESCRIPTION	VALUE
Foundation Type	Continuous or spread footings
Bearing Material	Imported, granular fill
Allowable Bearing Capacity	3,000 psf on imported granular fill
Minimum embedment depth below finished grade	12 inches (for frost and confinement)

Minimum footing width	24 inches (continuous) 24-inches (isolated spread)
Total estimated settlement	1-inch
Total differential settlement	1-inch

The allowable bearing capacity is based upon dead load plus long-term live load. A one-third increase in allowable bearing capacity for short duration loads such as wind or seismic loads is permitted with the alternative load combinations given in Section 1605.3.2 of the IBC.

7.0 LATERAL EARTH PRESSURES

7.1 LATERAL EARTH PRESSURES

Lateral loads imposed on footings may be resisted by the development of passive earth pressures against the sides of footings and friction between the base of the footing and the supporting soils. Lateral earth pressure values are presented in the following table.

Case Evaluated	Soil Type	Value
Active	Onsite Silty Sands	40 psf/ft
		71 psf/ft (with seismic)
At-Rest	Onsite Silty Sands	61 psf/ft
Passive	Onsite Silty Sands	423 psf/ft
		341 psf/ft (with seismic)
Seismic Coefficient	IBC 1610.1.1	0.240
Coefficient of friction tan(φ*0.6) where φ = 34°	Imported, Granular Fill	0.37

The lateral earth pressures presented do not include any safety factors except where the friction angle (φ) used to determine the coefficient of friction has been multiplied by 0.6 to account for smooth contact conditions. The pressures also assume horizontal backfill and that the backfill is in a drained condition with no build-up of hydrostatic pressure. The additional effects of sloping backfill, surcharge, structural loads and groundwater conditions should be included in calculating lateral earth pressures. Backfill should be placed in accordance with the requirements of structural fill except that backfill in landscape and areas that will not be subject to structural loadings may be reduced to 90 percent of the maximum dry density as determined by ASTM D-1557.

7.2 BEHIND WALL DRAINAGE

The portion of the tank which is backfilled should have a drainage system installed as part of the backfill of the tank. A moisture barrier should be installed on the tank. This barrier should meet AWWA/APWA standards for the type of tank planned. The drain should consist of free-draining gravel, as described in Section 5.2, and separated from the tank backfill by a minimum 4-oz, non-woven filter fabric. The free-draining rock should extend to the drainpipe for the base of the tank. If groundwater seepage is encountered, the pipe size may need to be increased. A detail of the proposed drain is included in Appendix C.

7.3 BACKFILL

The tank wall should be designed to resist the lateral earth pressured listed above. Backfill should be placed subsequent to roof construction. Otherwise, the walls should be braced to prevent lateral movement and cracking. Backfill should be placed in accordance with the requirements of structural fill except that the compaction requirement for the backfill may be reduced to 90 percent of the maximum dry density as determined by ASTM D-1557. It is recommended that relatively light, manually propelled compactors be used within 5 feet of the walls and that compactors used beyond 5 feet be limited in weight to 3,000 pounds.

8.0 SOIL CORROSIVITY

Soils from the project site were tested for water-soluble sulfates content. The percent of water-soluble sulfates in the soil is 30 ppm, which is considered negligible according to ACI 318. We recommend that concrete mixes used on the project be designed in accordance with ACI 318 Table 4.3.1 for Sulfate Exposure Class S1.

9.0 FOUNDATION REVIEW AND TESTING

This report has been prepared to assist in project design and construction. Variations from the conditions portrayed in the exploratory investigations may occur which are sometimes sufficient to require modifications to the design. In order to incorporate recommendations provided into actual field conditions and to confirm that the project specifications are implemented, we recommend that observation and testing be performed during construction to monitor over-excavation, grading, and preparation of soils upon which foundations elements or structural loads may be established.

10.0 LIMITATIONS

The exploratory data presented in this report were collected to provide geotechnical design recommendations for this project and subsurface site descriptions represent conditions observed at the time and at the locations explored. The investigations may not be indicative of subsurface conditions beyond the investigation location and conditions may change with passage of time. If subsurface conditions are encountered that are significantly different than those reported herein, Landmark should be contacted immediately for the continued applicability of the recommendations. In the event changes to the project are made that differ from those presented in this report, Landmark should be made aware of the changes. Landmark will provide written verification that the recommendations and conclusions remain valid or that modifications are required.

This report has been prepared to assist in project design and construction. We respectfully request the opportunity to review the final design drawings and specifications in order to determine whether the assumptions and recommendations presented herein are applicable to the anticipated designs.

This report is not intended to be used as the sole bid document. Any information concerning the environmental conditions of the site is beyond the scope of this geotechnical study. This geotechnical report has been prepared to meet the specific needs of our client and may not be appropriate to satisfy the needs of other users.

Site conditions and standards of practice change, therefore, we should be notified to review and update the report and its recommendations if construction is not commenced within 3 years of the date it was issued.

LANDMARK TESTING & ENGINEERING

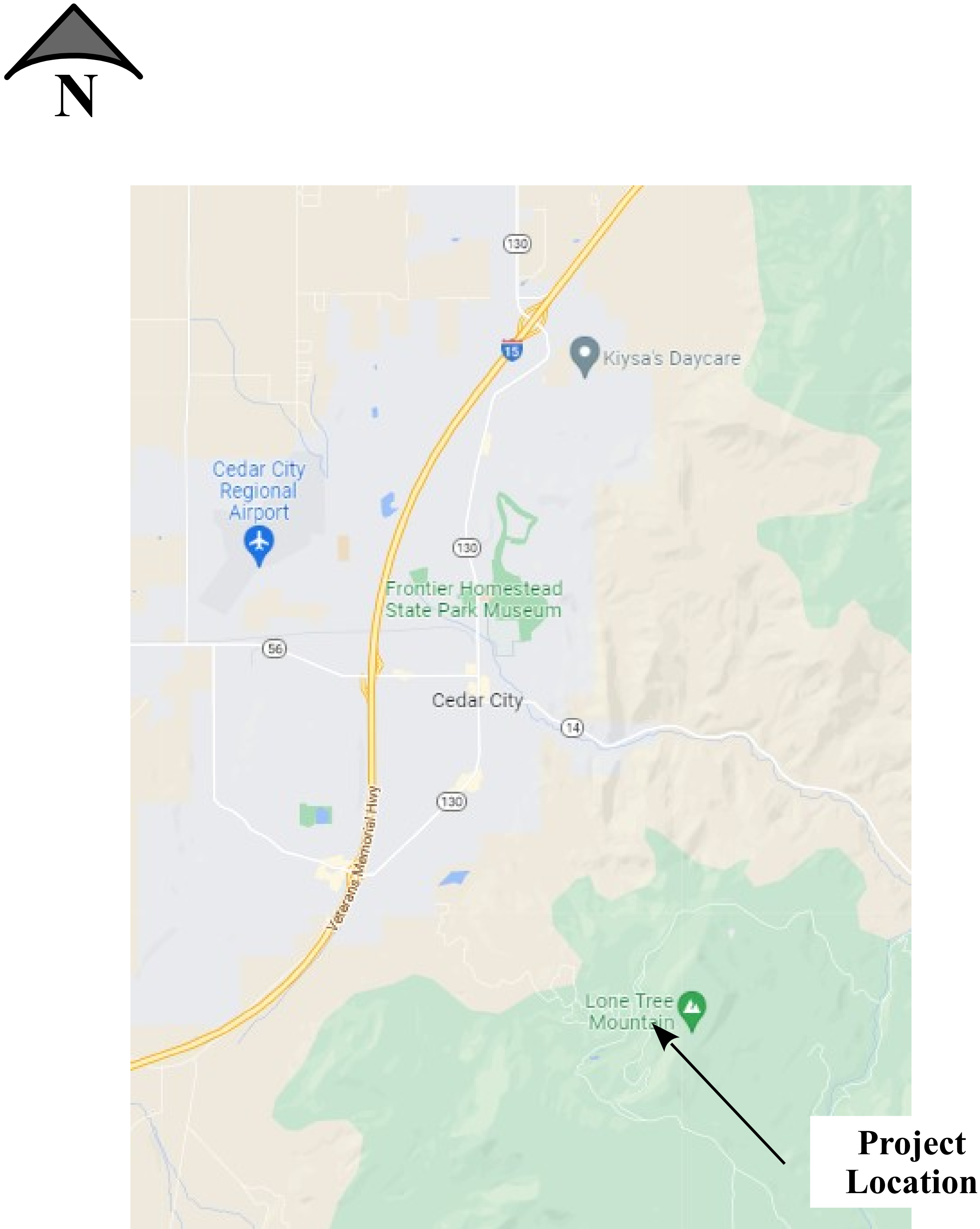
John M. Anderson, P.E.
Project Engineer

Reviewed by:

Steven Wells, P.E.
Geotechnical Manager

APPENDIX A

Field Investigation

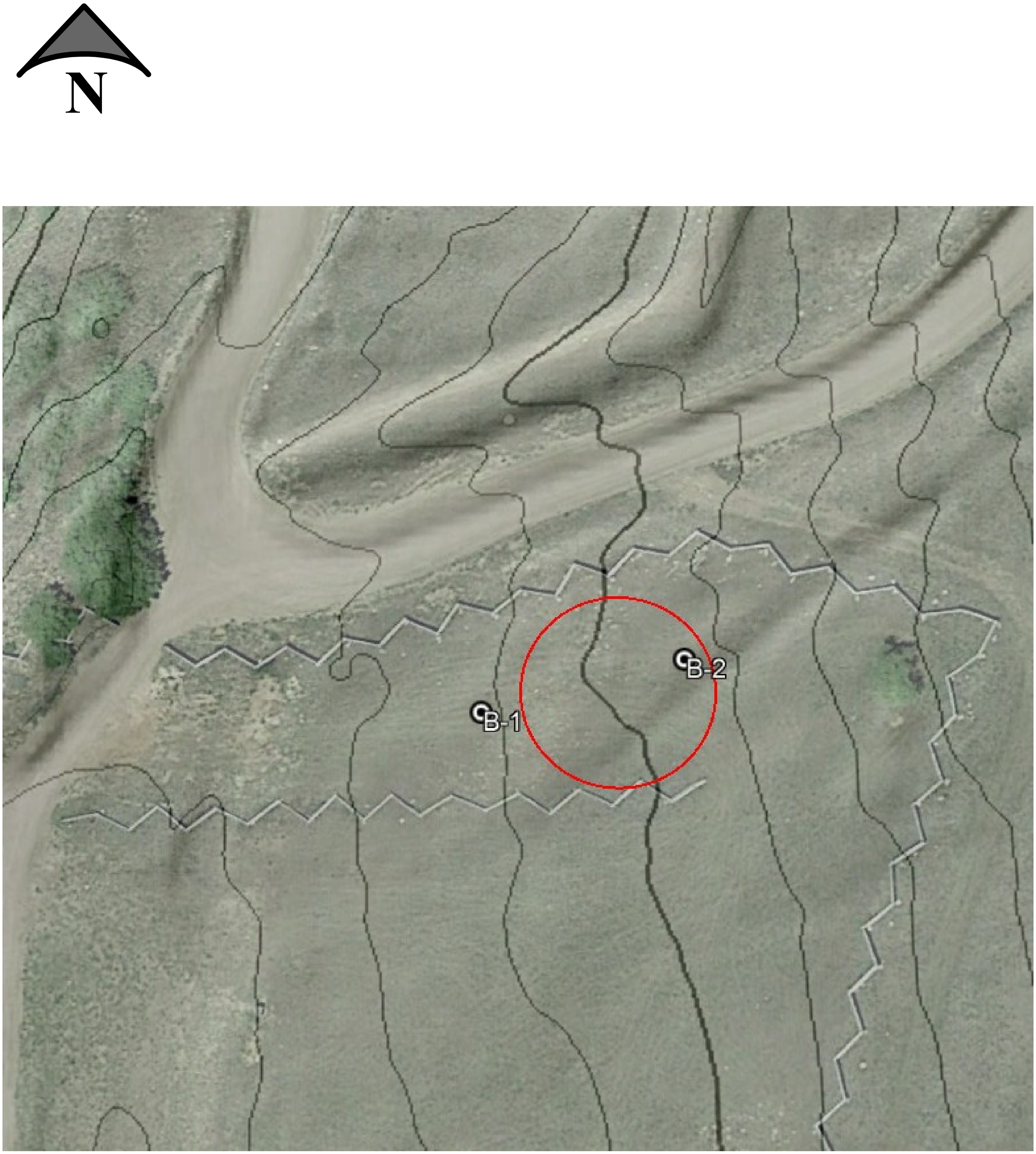


LANDMARK TESTING & ENGINEERING

Vicinity Map

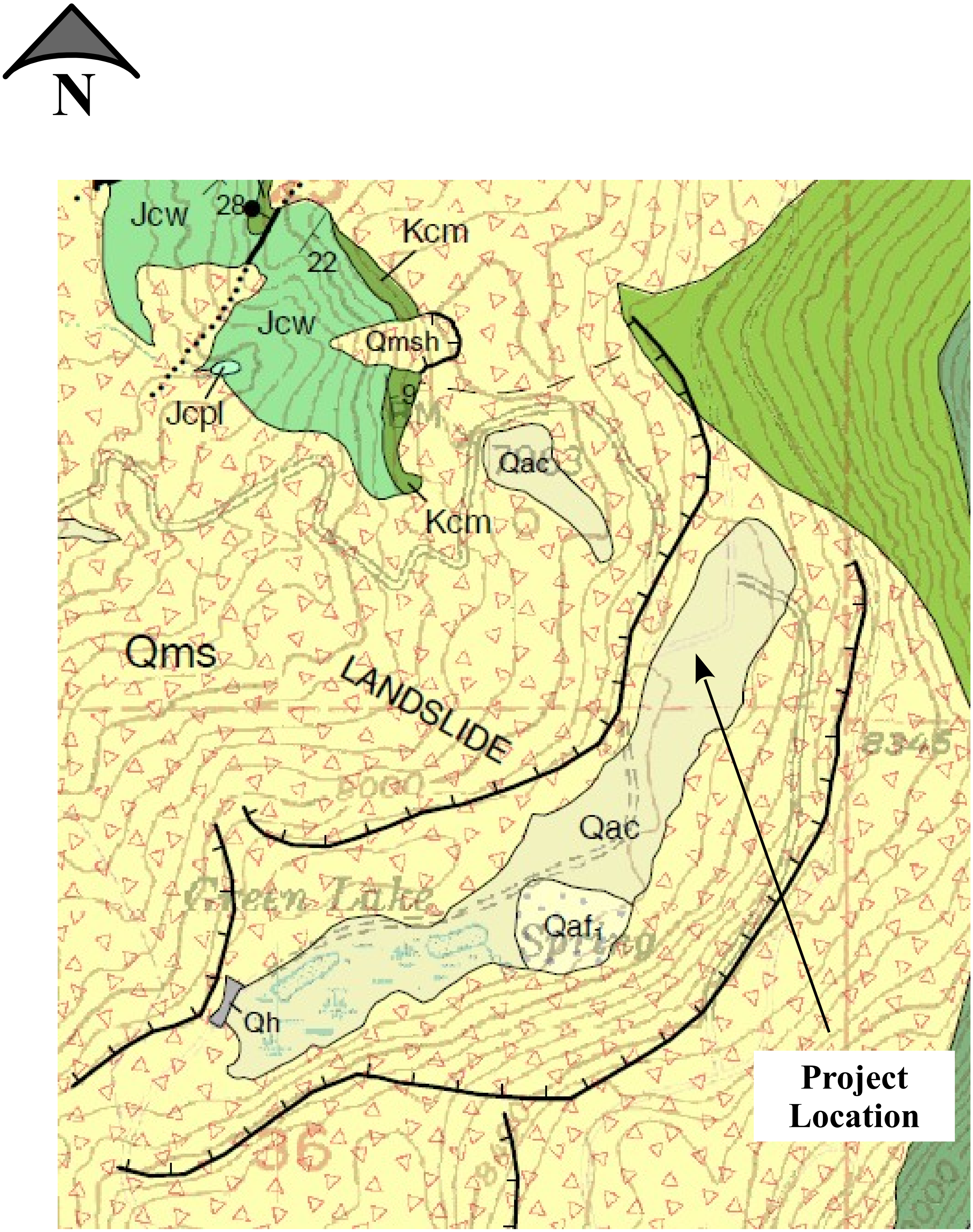
Landmark Project No 220353

Figure A-1



Site Map
Landmark Project No 220353

Figure A-2



Geologic Map
Landmark Project No 220353

Figure A-3

BORING NUMBER LST - B1

DATE STARTED 9/19/22 **COMPLETED** 9/19/22 **DRILLING COMPANY** South Slopes Drilling **ELEVATION** 8146

DRILLING METHOD: CME 55, 8-inch hollow-stem auger **GROUND WATER LEVEL AT TIME OF DRILLING**

LOGGED BY Greg Kaiser **CHECKED BY** John Anderson **GROUND WATER LEVEL ON** ---

NOTES Lower side of tank **LATITUDE:** 37.635026 **LONGITUDE:** -113.035774

DEPTH (ft)	SAMPLE TYPE NUMBER	BLOWCOUNTS	MATERIAL DESCRIPTION	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	MECHANICAL GRADATION: GRAVEL (%)	MECHANICAL GRADATION: SAND (%)	MECHANICAL GRADATION: FINES (%)	Other Tests
0			SILTY SAND (SM), with some gravel, loose to medium dense, dry, fine to medium grain, subrounded to subangular gravel, light brown.								
			slightly moist to dry, brown.								
10	1 2 3 4	31	FAT CLAY WITH SAND (CH), with some gravel, medium stiff, slightly moist to dry, fine to medium grained sand, dark brown to gray.	106.1	10.6						0.6% Collapse @ 1140 psf
	5 6 7 8	52	SILTY SAND WITH GRAVEL (SM), with some gravel, loose to medium dense, dry, fine to medium grained sand, subrounded to subangular gravel, light brown.	101.7	8.6 7.9	NP	NP	14	54	32	2.7% Collapse @ 1000 psf
			SANDY LEAN CLAY (CL), medium stiff to hard, fine to medium grained sand, slightly moist to dry, dark brown to black.								
20	9 10 11	102/8"			20.4						Unconfined Compressive Strength = 8.5 ksf
	12 13 14 15 16	57		113.1	11.2 13.1						Unconfined Compressive Strength = 19 ksf 0.8% Swell @ 2000 psf Swell Pressure = 3,400 psf

Bottom of borehole at 26.5 feet.

LANDMARK TESTING & ENGINEERING

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PROJECT NAME Cedar Highlands Tank

CLIENT Central Iron County Water Conservancy District

PROJECT NUMBER 220353

PROJECT LOCATION Iron County, Utah

Figure No. A-4

BORING NUMBER LST - B2

DATE STARTED 9/16/22 **COMPLETED** 9/19/22 **DRILLING COMPANY** South Slopes Drilling **ELEVATION** 8150

DRILLING METHOD: CME 55, 8-inch hollow-stem auger **GROUND WATER LEVEL AT TIME OF DRILLING**

LOGGED BY Greg Kaiser **CHECKED BY** John Anderson **GROUND WATER LEVEL ON** ---

NOTES Upper side of tank **LATITUDE:** 37.635073 **LONGITUDE:** -113.035538

DEPTH (ft)	SAMPLE TYPE NUMBER	BLOWCOUNTS	MATERIAL DESCRIPTION	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	MECHANICAL GRADATION: GRAVEL (%)	MECHANICAL GRADATION: SAND (%)	MECHANICAL GRADATION: FINES (%)	Other Tests
0			SILTY SAND (SM), with some gravel, loose to medium dense, dry, fine to medium grain, subrounded to subangular gravel, light brown.								
			slightly moist to dry, brown.								
10											
	1 2 3	28	FAT CLAY WITH SAND (CH), medium stiff to stiff, slightly moist, fine to medium grained sand, dark brown to gray.		16.1	50	34	1	21	78	
			SILTY SAND (SM), with some gravel, loose to medium dense, dry, fine to medium grain, subrounded to subangular gravel, light brown.								
20	4 5 6 7	79		98.5	7.6						2.1% Collapse @ 1000 psf
	8 9 10	44	LEAN CLAY (CL), medium stiff to stiff, fine to medium grain, slightly moist to dry, dark brown to black.		19.2 17.3			0	16	84	Unconfined Compressive Strength = 8.3 ksf
30	11 12 13	39			19.2	34	12	0	16	84	
	14	38									
40	15		LIMESTONE BOULDER.								
			LEAN CLAY (CL), medium stiff to stiff, fine to medium grain, slightly moist to dry, dark brown to black.								
50											

Bottom of borehole at 50.0 feet.

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PROJECT NAME Cedar Highlands Tank

CLIENT Central Iron County Water Conservancy District

PROJECT NUMBER 220353

PROJECT LOCATION Iron County, Utah

Figure No. A-5

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS		SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS (More than 50% of soil Retained on No. 200 sieve size)	GRAVELS More than 1/2 of coarse fraction > No.4 sieve size	GW	Well graded gravels or gravel-sand mixtures little or no fines.
		GP	Poorly graded gravels or gravel-sand mixtures little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 1/2 of coarse fraction < No.4 sieve size	SW	Well graded sands or gravelly sand mixtures little or no fines.
		SP	Poorly graded sands or gravelly sand mixtures little or no fines.
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (Less than 50% of soil Retained on No. 200 sieve size)	SILTS & CLAYS Liquid Limit < 50	ML	Inorganic silts and very fine sands, rock flour, silty fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS Liquid Limit > 50	MH	Inorganic silts, micaceous of diatomaceous fine sand or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

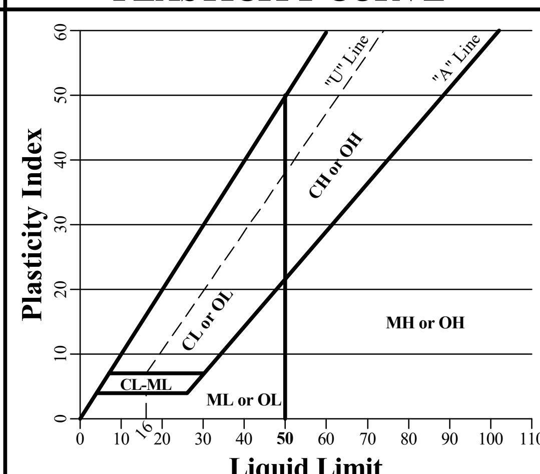
GRAIN SIZE CHART

CLASSIFICATION	Range of Grain Size: U.S. Standard Sieve Size	Range of Grain Size: Grain Size in Millimeters
BOULDERS	**Above 12"**	**Above 305**
COBBLES	**12" to 3"**	**305 to 76.2**
GRAVEL	**3" to No. 4**	**76.2 to 4.76**
Coarse	3" to 3/4"	76.2 to 19.1
Fine	3/4" to No. 4	19.1 to 4.76
SAND	**No. 4 to No. 200**	**4.76 to 0.074**
Coarse	No. 4 to No. 10	4.76 to 2.00
Medium	No. 10 to No. 40	2.00 to 0.42
Fine	No. 40 to No. 200	0.420 to 0.074
SILT & CLAY	Below No. 200	Below 0.074

SAMPLES

- Relatively Undisturbed Sample
- Block Sample
- Bag Sample
- Auger Cuttings
- Bucket Sample
- Core
- No Recovery

PLASTICITY CURVE



LANDMARK TESTING & ENGINEERING
Landmark Testing & Engineering
795 East Factory Drive
St. George, UT 84790
Telephone: 435-986-0566
Fax: 435-986-0568

PROJECT NAME Cedar Highlands Tank
CLIENT Central Iron County Water Conservancy District
PROJECT NUMBER 220353
PROJECT LOCATION Iron County, Utah

Figure No. A-6

USCS SUMMARY - LANDMARK NEW.GDT - 11/4/22 14:35 - P:\PROJECTS\22 PROJECTS\220353\GEOTECH\NEW PROPOSED LOCATION\220353 - CEDAR HIGLAND TANKS 2.GPJ

APPENDIX B

Laboratory Test Results

LANDMARK TESTING & ENGINEERING

SUMMARY OF LABORATORY TEST RESULTS

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 11/4/2022

Project: Cedar Highlands Tank

Project #: 220353

Location: Iron County, Utah

Boring / Test Pit Number	Depth Below Ground Surface (ft)	Moisture Content (%)	In-Place Dry Desnity (pcf)	Mechanical Gradation			Atterberg Limits		Swell-Consolidation Swell/Collapse @ Wetting Load (S/C @ psf)	Modified Proctor / CBR			Unconfined Compressive Strength (ksf)	Sooluble Sulfate Content (%)	USCS Group Symbol	AASHTO Soil Classification
				Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plasticity Index		Maximum Dry Density (pcf)	Optimum Moisture Content (%)	CBR Value				
B-1	11.0	10.6	106.1						0.6% C @ 1k						CH	A-7-6
	15.0	8.6	101.7						2.7% C @ 1k						SM	A-2-4
	16.0	7.9		14.0	53.7	32.3	NP	NP							SM	A-2-4
	20.2	20.4											8.5		CL	A-6
	24.3	11.2											19.0		CL	A-6
	25.3	13.1	113.1						0.8% C @ 2k						CL	A-6
B-2	14.0	16.1					50	34							CH	A-7-6
	20.0	7.6	98.5						2.1% C @ 1k						SM	A-2-4
	25.0	19.2		0.0	16.4	83.6									CL	A-6
	25.3	17.3											8.3		CL	A-6
	30.8	19.2		0.0	16.4	83.6	34	12							CL	A-6

TABLE B-1

CONSOLIDATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/4/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4760

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Sandy Fat Clay (CH) **Tested By:** J. Bracken **Date:** 9/27/2022
Location of Sample: LST Boring 1 at 11' **Authorized By:** Client **Date:** 9/20/2022

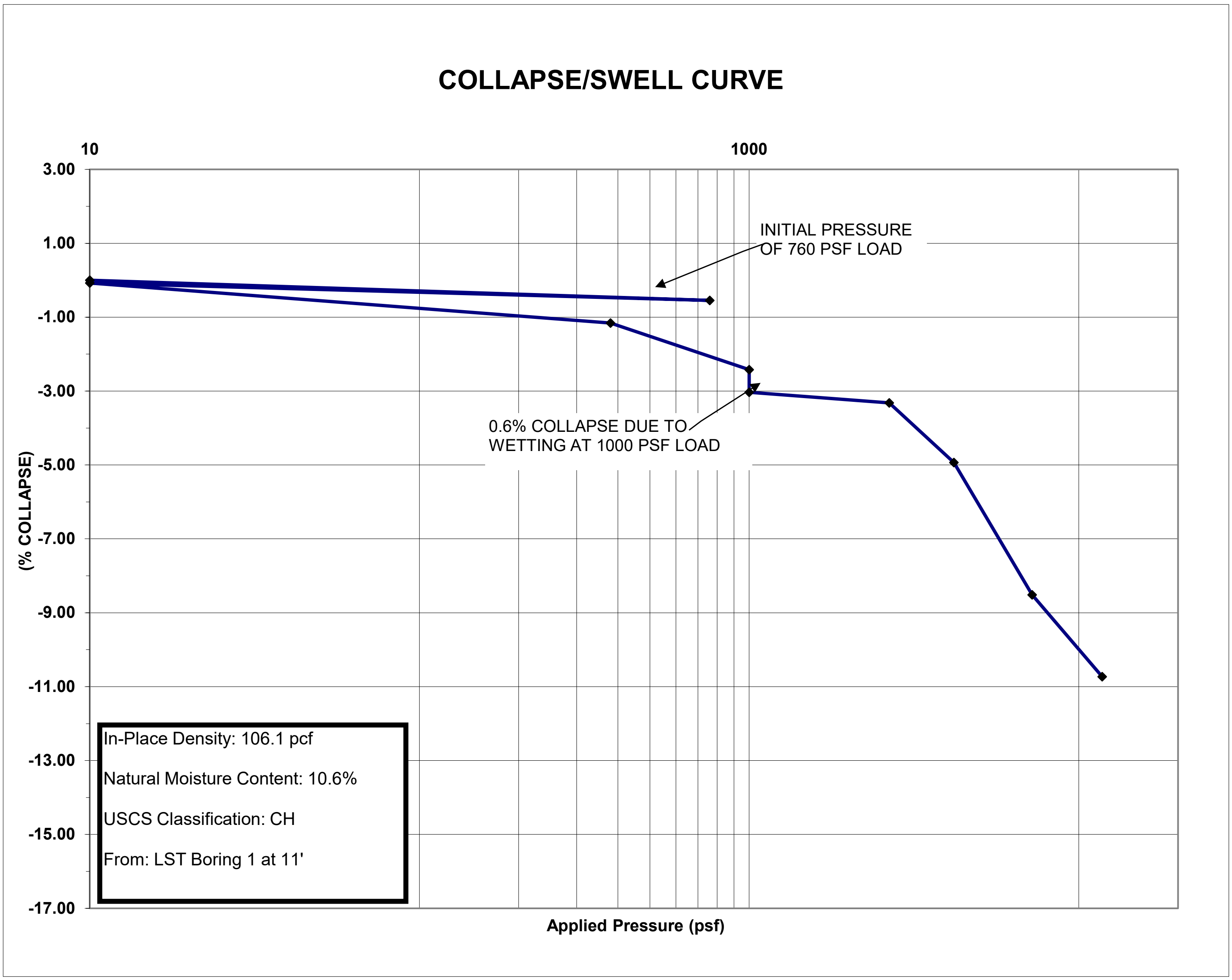


FIGURE B-1

CONSOLIDATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/4/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4761

Project:	Cedar Highlands Tank			**Project #:**	220353
Location:	Cedar City	**Sampled By:**	G. Kaiser	**Date:**	9/20/2022
Type of Sample:	Silty Sand with Gravel (SM)	**Tested By:**	J. Bracken	**Date:**	9/27/2022
Location of Sample:	LST Boring 1 at 15'	**Authorized By:**	Client	**Date:**	9/20/2022

COLLAPSE/SWELL CURVE

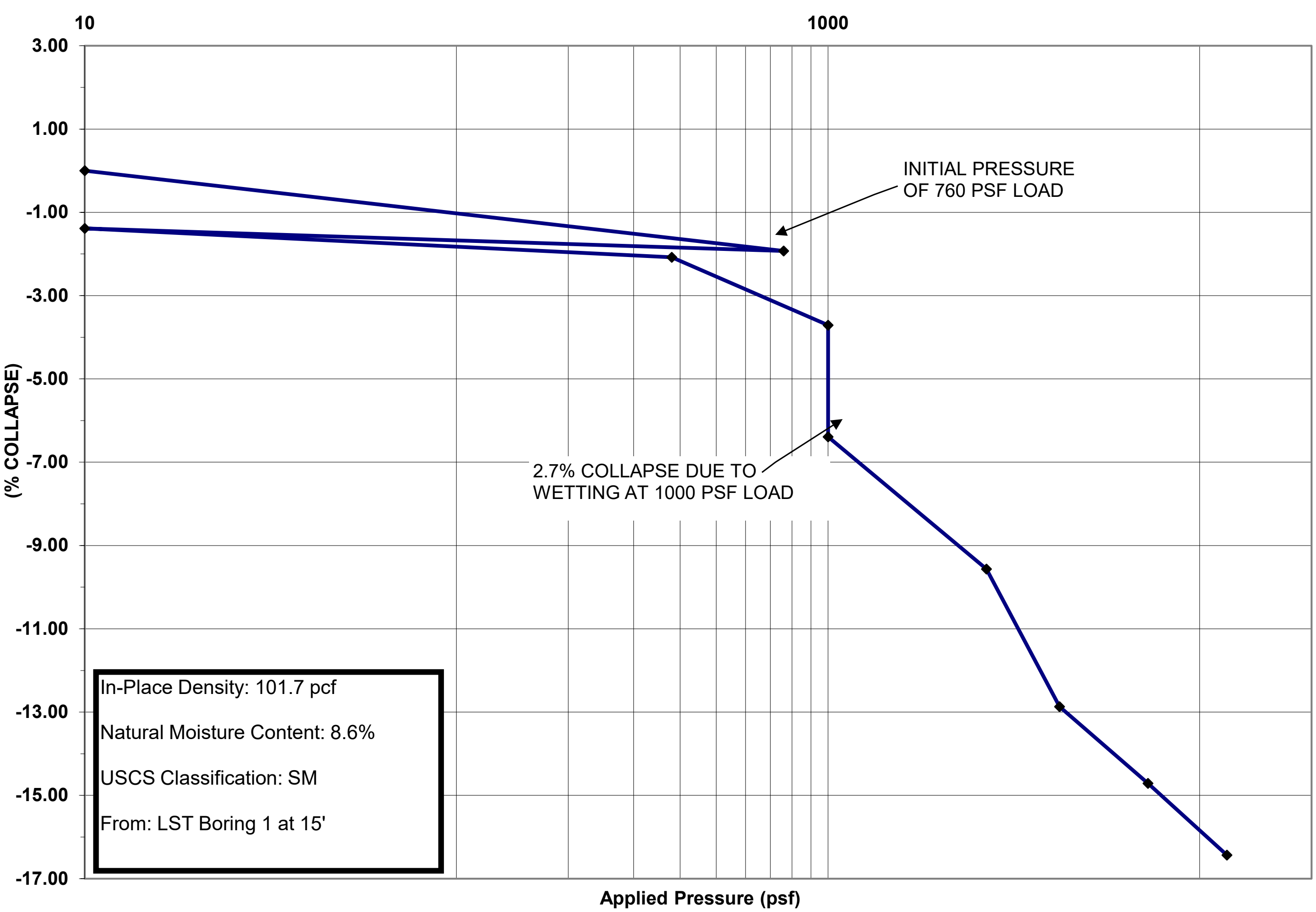


FIGURE B-2

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CONSOLIDATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/11/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4765

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Sandy Lean Clay (CL) **Tested By:** J. Bracken **Date:** 10/5/2022
Location of Sample: LST Boring 1 at 25.33 **Authorized By:** Client **Date:** 9/20/2022

COLLAPSE/SWELL CURVE

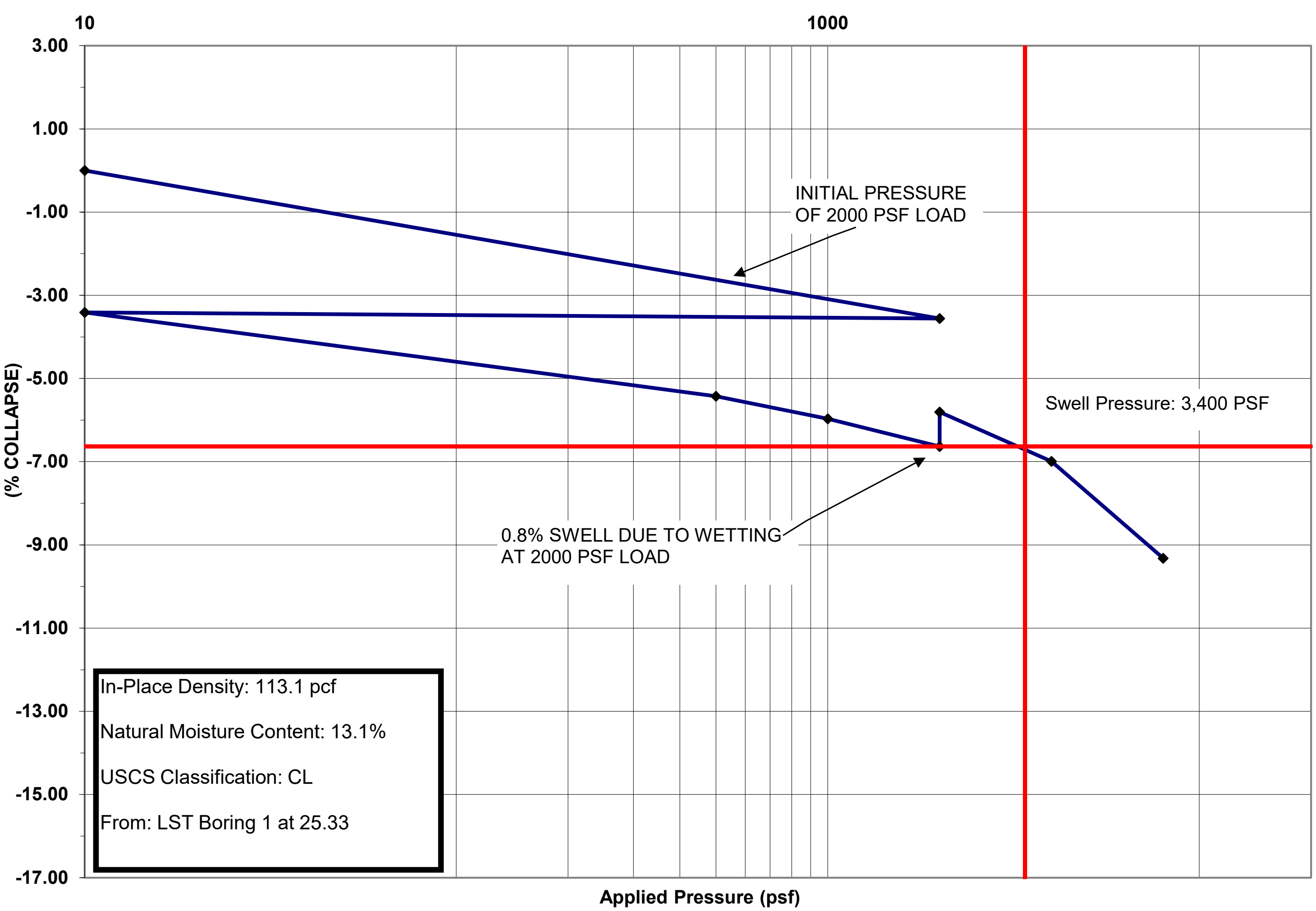


FIGURE B-3

CONSOLIDATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/10/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4767

Project: Cedar Highlands Tank
Project #: 220353
Location: Cedar City
Sampled By: G. Kaiser **Date:** 9/20/2022
Type of Sample: Silty Sand with Gravel (SM)
Tested By: J. Bracken **Date:** 10/4/2022
Location of Sample: LST Boring 2 at 20'
Authorized By: Client **Date:** 9/20/2022

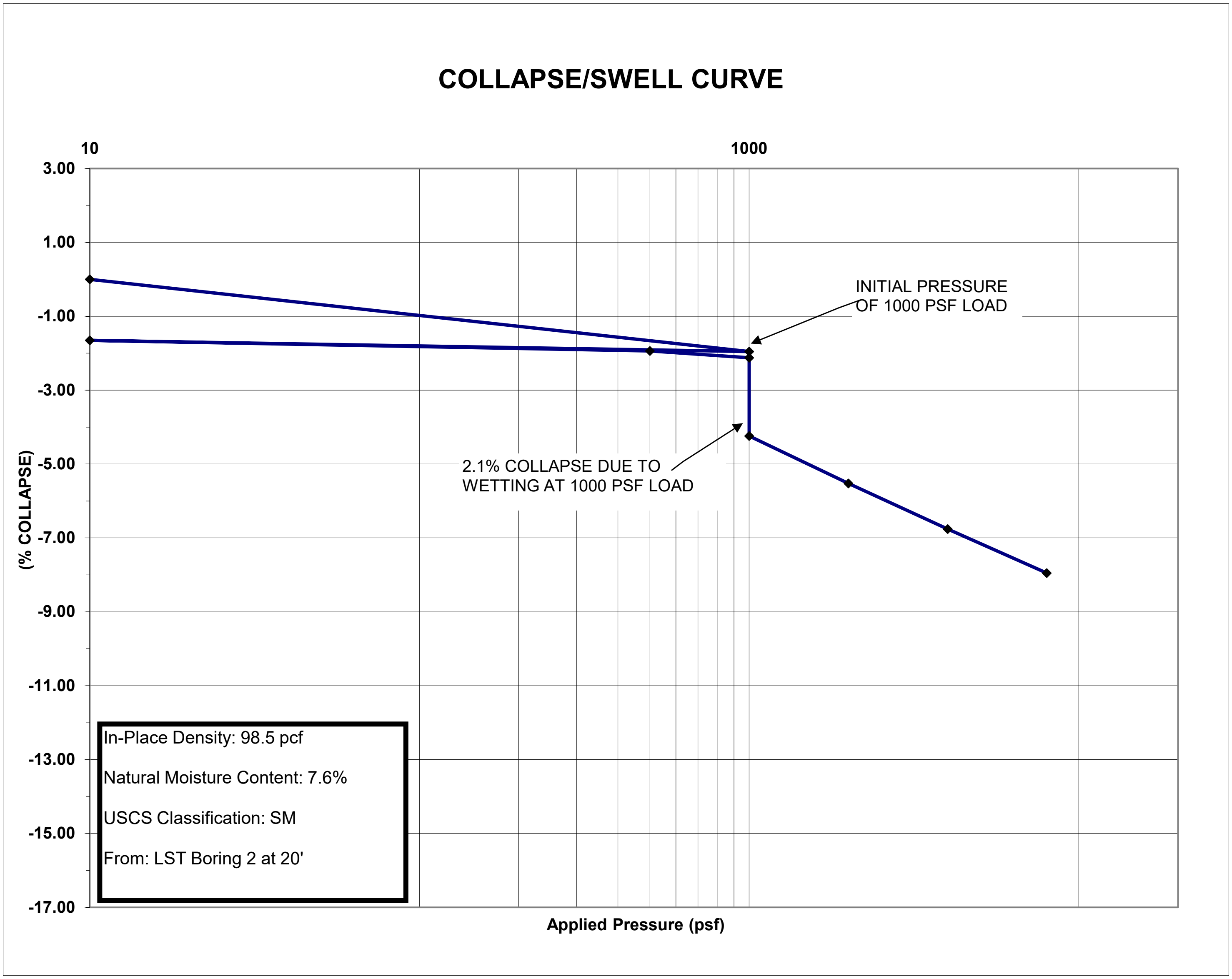


FIGURE B-4

Unconfined Compressive Strength

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/6/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4763

Project: Cedar Highlands Tank
Project #: 220353
Location: Cedar City
Sampled By: G. Kaiser **Date:** 9/20/2022
Type of Sample: Sandy Lean Clay
Tested By: J. Wells **Date:** 9/30/2022
Location of Sample: LST Boring 1 at 20.2'
Authorized By: Client **Date:** 9/20/2022

	Result
Initial Moisture %	20.4
Unconfined Compressive Strength (PSF)	8533.9
Average Height of Specimen (in)	3.69
Diameter of Specimen (in)	1.87
Height to Diameter Ratio	1.973
Average Rate of Strain to Failure, %	0.74
Strain at Failure (.001 in)	0.115
Type of Specimen	Intact

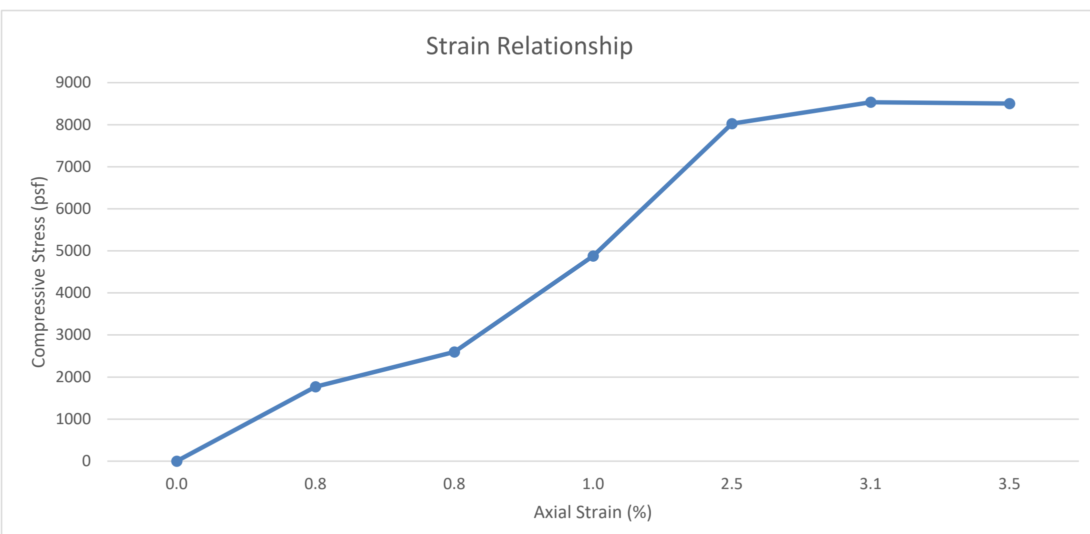


FIGURE B-5

Unconfined Compressive Strength

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/6/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4764

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Sandy Lean Clay (CL) **Tested By:** J. Wells **Date:** 9/30/2022
Location of Sample: LST Boring 1 at 24.25' **Authorized By:** Client **Date:** 9/20/2022

	Result
Initial Moisture %	11.2
Unconfined Compressive Strength (PSF)	18978.3
Average Height of Specimen (in)	3.85
Diameter of Specimen (in)	1.88
Height to Diameter Ratio	2.048
Average Rate of Strain to Failure, %	0.77
Strain at Failure (.001 in)	0.182
Type of Specimen	Intact

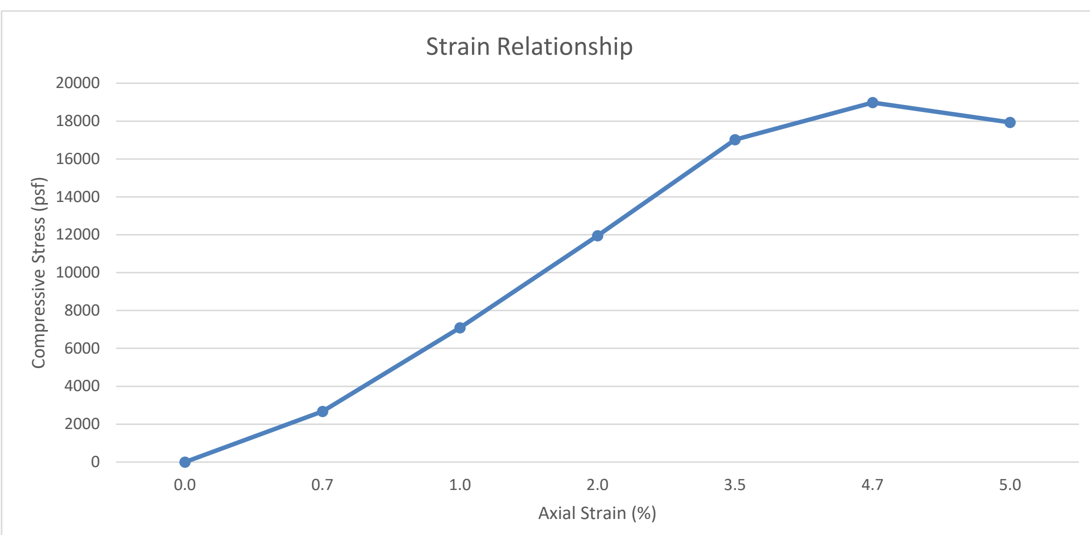


FIGURE B-6

Unconfined Compressive Strength

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/6/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4769

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Sandy Lean Clay (CL) **Tested By:** J. Wells **Date:** 9/30/2022
Location of Sample: LST Boring 2 at 25.33 **Authorized By:** Client **Date:** 9/20/2022

	Result
Initial Moisture %	17.3
Unconfined Compressive Strength (PSF)	8340.5
Average Height of Specimen (in)	3.6
Diameter of Specimen (in)	1.89
Height to Diameter Ratio	1.905
Average Rate of Strain to Failure, %	0.72
Strain at Failure (.001 in)	0.238
Type of Specimen	Intact

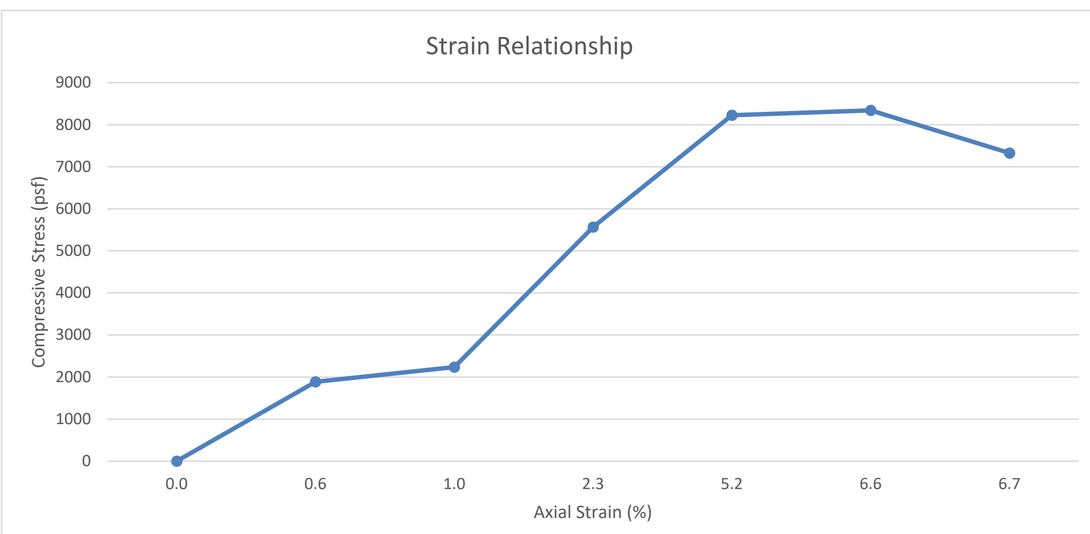


FIGURE B-7

SOIL CLASSIFICATION REPORT

LANDMARK TESTING & ENGINEERING

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 9/30/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4762

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Dark Brown Silty Sand **Tested By:** N. Klingonsmith **Date:** 9/26/2022
Location of Sample: LST-Boring 1 at 16' **Authorized By:** Client **Date:** 9/20/2022

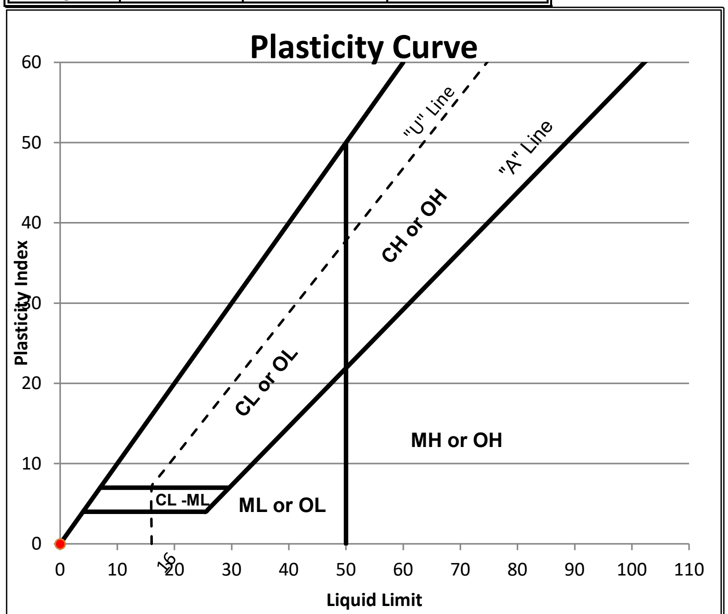
Sieve Analysis , ASTM C136 and C117

Sieve Size		% Passing Cumulative	Specification
150 mm	6"		
75 mm	3"		
50 mm	2"		
37.5 mm	1-1/2"		
25 mm	1"		
19 mm	3/4"	100	
12.5 mm	1/2"	99	
9.5 mm	3/8"	95	
4.75 mm	#4	86	
2.00 mm	#10	77	
1.18 mm	#16	73	
425 µm	#40	68	
300 µm	#50	65	
75 µm	#200	32.3	

Test	Result	Specification	Test Standard
Natural Moisture Content, %	7.9		ASTM D 2216
Liquid Limit	NP		ASTM D 4318
Plasticity Index	NP		ASTM D 4318
Unified Classification System	SM		ASTM D 2487
AASHTO Classification System	A-2-4(0)		AASHTO M145

% Cobble > 3"	% Gravel < 3" - #4	% Sand < #4 - #200	% Silt-Clay < #200
0.0	14.0	53.7	32.3

Diameter D_{60}	Diameter D_{30}	Diameter D_{10}	Coefficient of Uniformity, C_U	Coefficient of Concavity, C_C



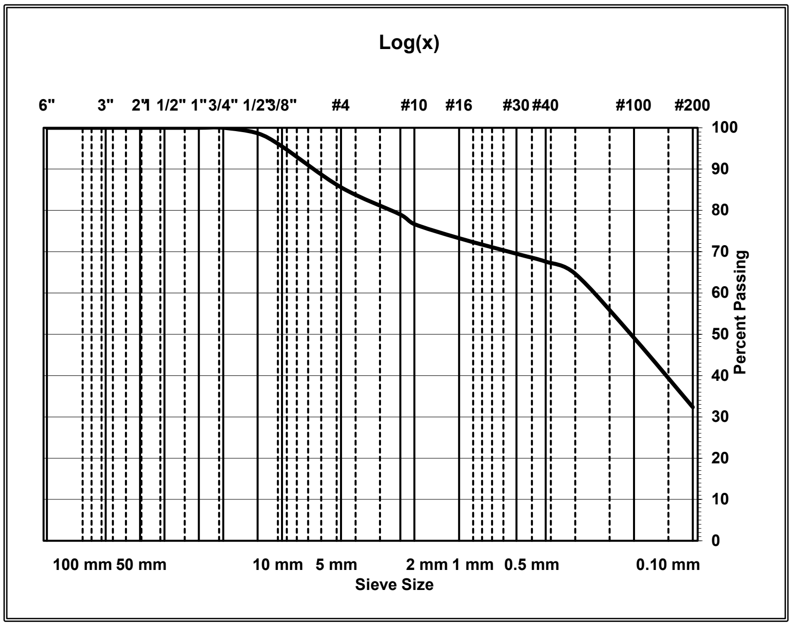


FIGURE B-8

LANDMARK TESTING & ENGINEERING

SOIL CLASSIFICATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 9/30/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4766

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Dark Brown Fat Clay with Sand **Tested By:** N. Klingonsmith **Date:** 9/26/2022
Location of Sample: LST Boring 2 at 14' **Authorized By:** Client **Date:** 9/20/2022

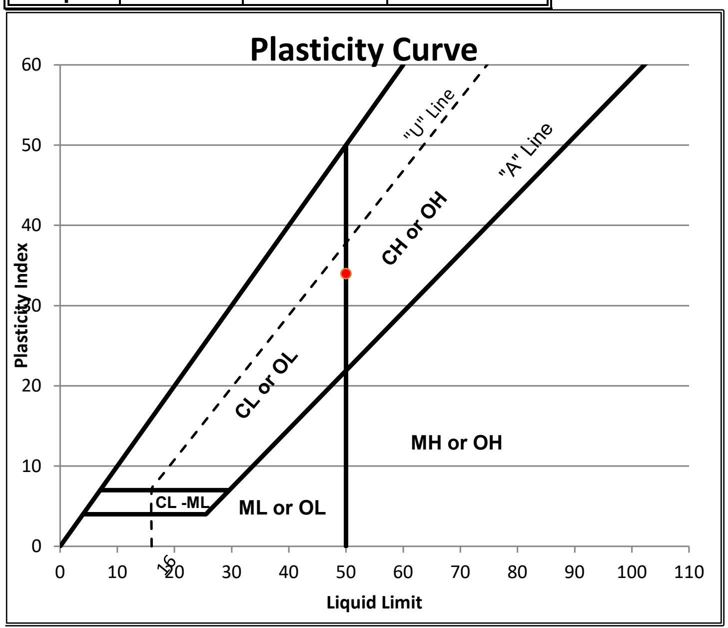
Sieve Analysis , ASTM C136 and C117

Sieve Size		% Passing Cumulative	Specification
150 mm	6"		
75 mm	3"		
50 mm	2"		
37.5 mm	1-1/2"		
25 mm	1"		
19 mm	3/4"		
12.5 mm	1/2"		
9.5 mm	3/8"	100	
4.75 mm	#4	99	
2.00 mm	#10	98	
1.18 mm	#16	97	
425 µm	#40	95	
300 µm	#50	93	
75 µm	#200	77.6	

Test	Result	Specification	Test Standard
Natural Moisture Content, %	16.1		ASTM D 2216
Liquid Limit	50		ASTM D 4318
Plasticity Index	34		ASTM D 4318
Unified Classification System	CH		ASTM D 2487
AASHTO Classification System	A-7-6(26)		AASHTO M145

% Cobble > 3"	% Gravel < 3" - #4	% Sand < #4 - #200	% Silt-Clay < #200
0.0	1.0	21.4	77.6

Diameter D_{60}	Diameter D_{30}	Diameter D_{10}	Coefficient of Uniformity, C_U	Coefficient of Concavity, C_C



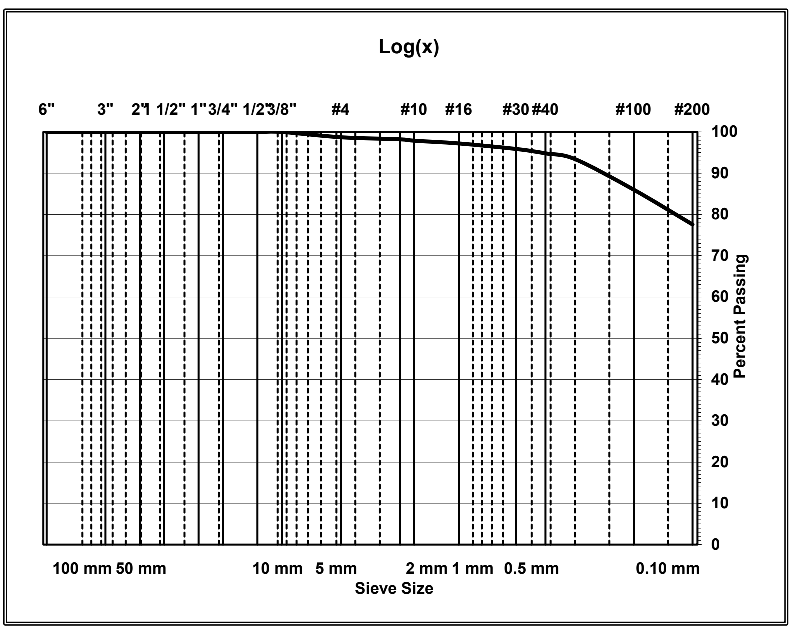


FIGURE B-9

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SOIL CLASSIFICATION REPORT

LANDMARK TESTING & ENGINEERING

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/3/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4768

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Dark Brown Lean Clay with Sand **Tested By:** N. Klingonsmith **Date:** 9/26/2022
Location of Sample: LST Boring 2 at 25' **Authorized By:** Client **Date:** 9/20/2022

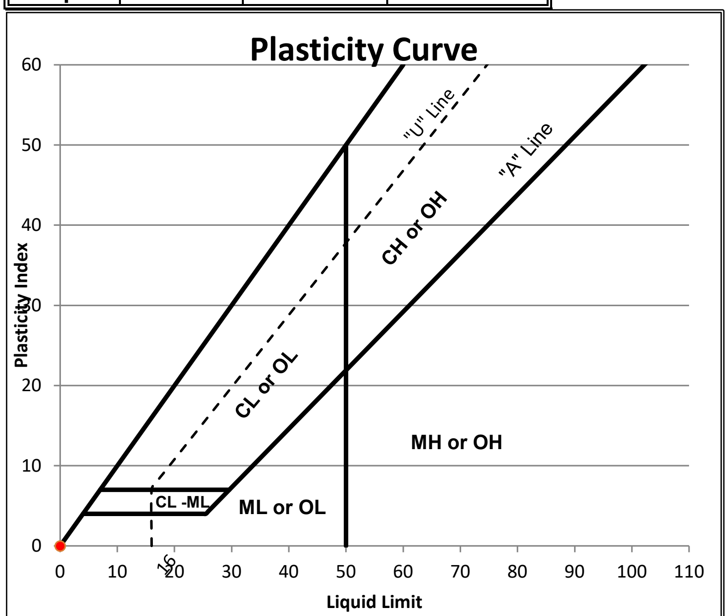
Sieve Analysis , ASTM C136 and C117

Sieve Size		% Passing Cumulative	Specification
150 mm	6"		
75 mm	3"		
50 mm	2"		
37.5 mm	1-1/2"		
25 mm	1"		
19 mm	3/4"		
12.5 mm	1/2"		
9.5 mm	3/8"		
4.75 mm	#4	100	
2.00 mm	#10	99	
1.18 mm	#16	98	
425 µm	#40	95	
300 µm	#50	94	
75 µm	#200	83.6	

Test	Result	Specification	Test Standard
Natural Moisture Content, %	19.2		ASTM D 2216
Liquid Limit			ASTM D 4318
Plasticity Index			ASTM D 4318
Unified Classification System	CL		ASTM D 2487
AASHTO Classification System	A-6		AASHTO M145

% Cobble > 3"	% Gravel < 3" - #4	% Sand < #4 - #200	% Silt-Clay < #200
0.0	0.0	16.4	83.6

Diameter D_{60}	Diameter D_{30}	Diameter D_{10}	Coefficient of Uniformity, C_U	Coefficient of Concavity, C_C



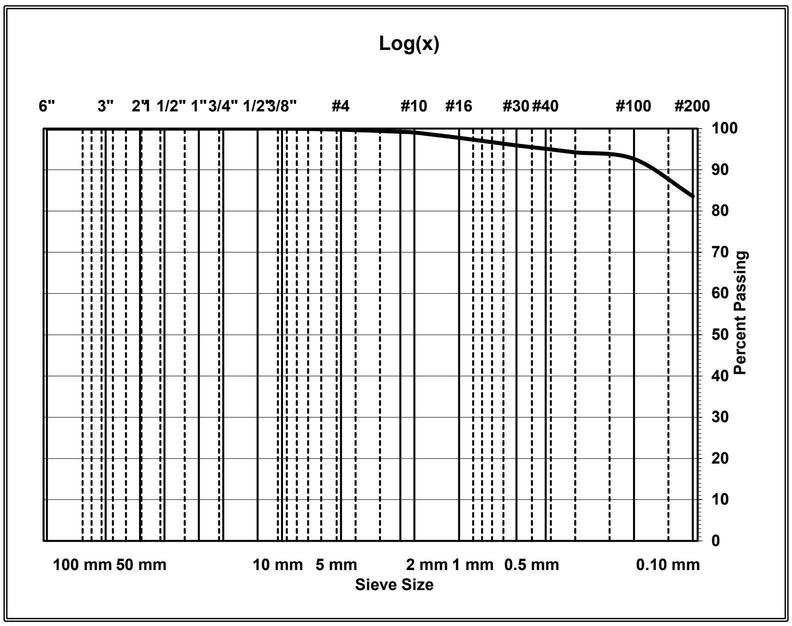


FIGURE B-10

SOIL CLASSIFICATION REPORT

Client: Central Iron County Water Conservancy District
88 E. Fiddlers Canyon Road, Suite A
Cedar City, UT 84721

Date of Report: 10/3/2022
Reviewed By: Z. Girsberger
Lab#: 22SG4771

Project: Cedar Highlands Tank **Project #:** 220353
Location: Cedar City **Sampled By:** G. Kaiser **Date:** 9/20/2022
Type of Sample: Dark Brown Lean Clay with Sand **Tested By:** N. Klingonsmith **Date:** 9/26/2022
Location of Sample: LST Boring 2 at 30'8" **Authorized By:** Client **Date:** 9/20/2022

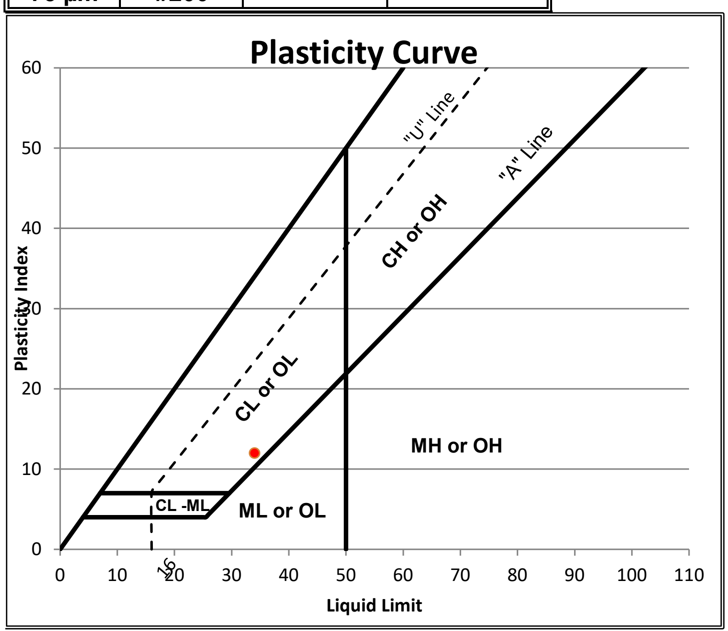
Sieve Analysis , ASTM C136 and C117

Sieve Size		% Passing Cumulative	Specification
150 mm	6"		
75 mm	3"		
50 mm	2"		
37.5 mm	1-1/2"		
25 mm	1"		
19 mm	3/4"		
12.5 mm	1/2"		
9.5 mm	3/8"		
4.75 mm	#4	100	
2.00 mm	#10	99	
1.18 mm	#16	98	
425 µm	#40	95	
300 µm	#50	94	
75 µm	#200	83.6	

Test	Result	Specification	Test Standard
Natural Moisture Content, %	19.2		ASTM D 2216
Liquid Limit	34		ASTM D 4318
Plasticity Index	12		ASTM D 4318
Unified Classification System	CL		ASTM D 2487
AASHTO Classification System	A-6(10)		AASHTO M145

% Cobble > 3"	% Gravel < 3" - #4	% Sand < #4 - #200	% Silt-Clay < #200
0.0	0.0	16.4	83.6

Diameter D_{60}	Diameter D_{30}	Diameter D_{10}	Coefficient of Uniformity, C_U	Coefficient of Concavity, C_C



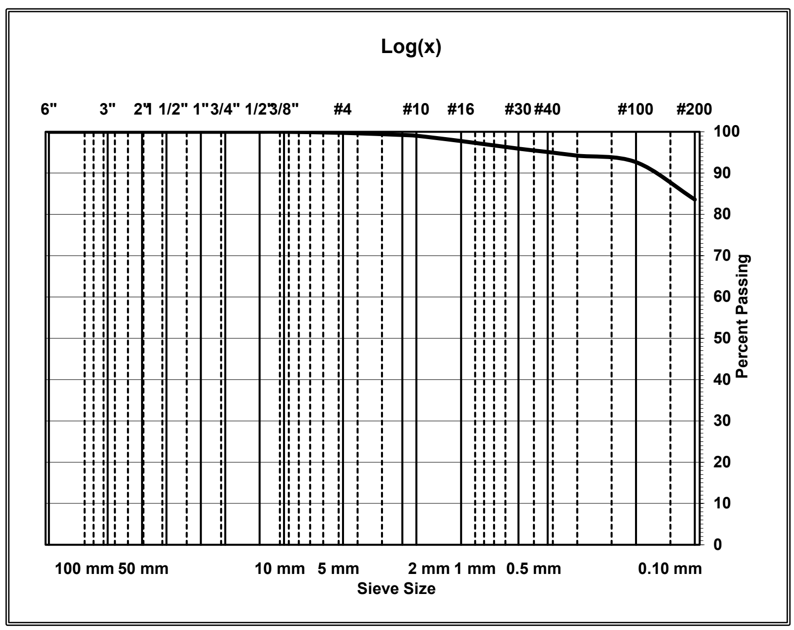
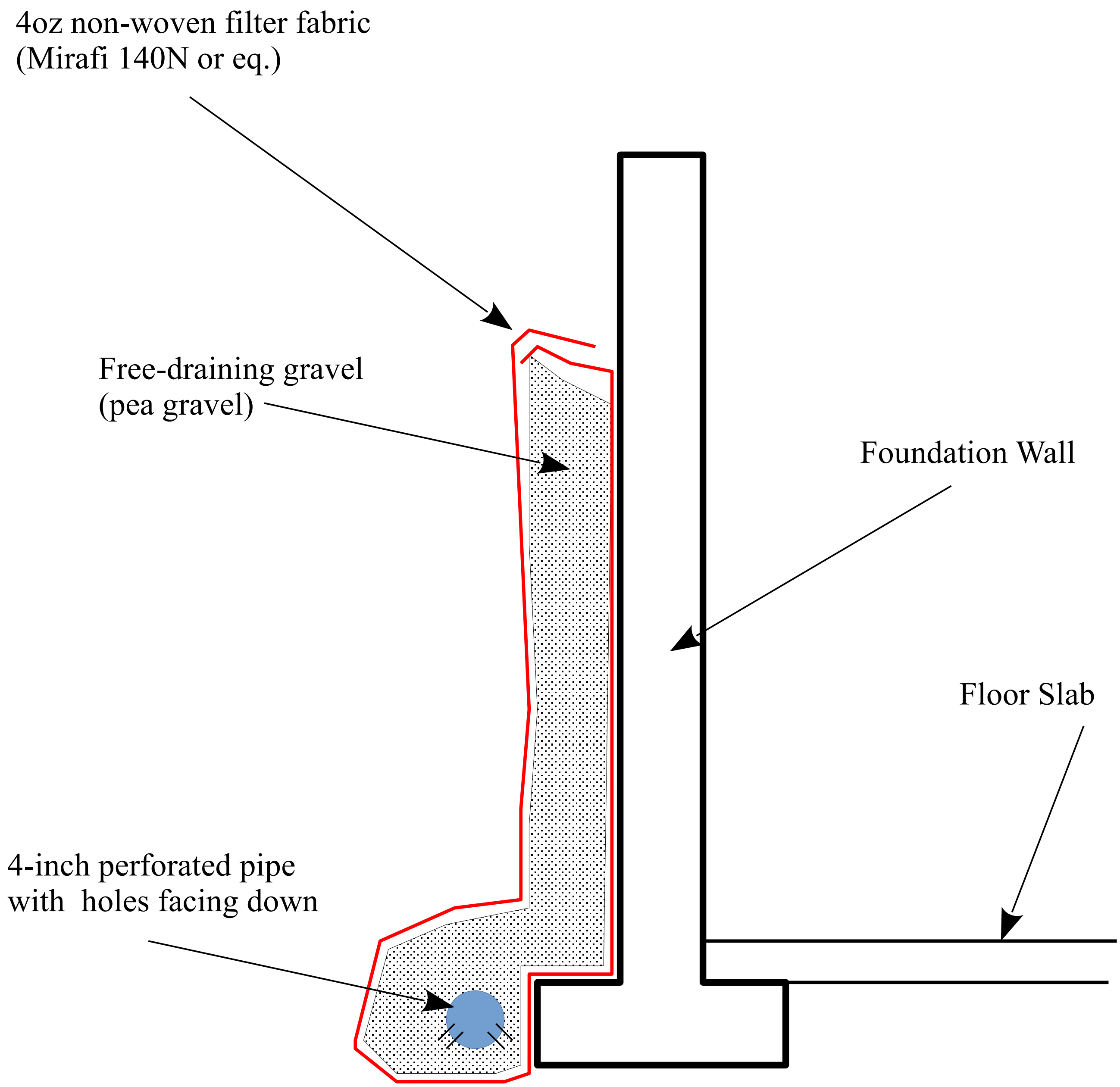


FIGURE B-11

APPENDIX C

Detail



1. Clean outs should be located at the major corners to allow for maintenance of the system.
2. The system should either daylight a minimum of 10 feet from the foundation, or to a sump to be pumped to a location a minimum of 10 feet from the foundation.

LANDMARK TESTING & ENGINEERING

Foundation Drain Detail
Landmark Project No 220353

Figure C-1