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Banner Associates, Inc.
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Attn: Adam Hanson, PE

Subj: Geotechnical Exploration
Proposed Ground Storage Reservoir
Lewis & Clark Regional Water System
459th Avenue & 234th Street
Near Madison, South Dakota
GeoTek #17-297

This correspondence presents our written report of the geotechnical exploration program for the referenced project. Our work was performed in accordance with the authorization of Tim Conner with Banner Associates, Inc. We are transmitting an electronic copy of our report for your use.

We thank you for the opportunity of providing our services on this project and look forward to continued participation during the design and construction phases. If you have any questions regarding this report, please contact our office at (605) 335-5512.

Respectfully Submitted,
GeoTek Engineering & Testing Services, Inc.

Jared Haskins

Jared Haskins, PE
Geotechnical Manager

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INTRODUCTION

Project Information

This report presents the results of the recent geotechnical exploration program for the proposed ground storage reservoir for Lewis & Clark Regional Water System near Madison, South Dakota.

Scope of Services

Our work was performed in accordance with the authorization of Tim Conner with Banner Associates, Inc. The scope of work as presented in this report is limited to the following:

1. To perform 4 standard penetration test (SPT) borings to gather data on the subsurface conditions at the site.

2. To perform laboratory tests that include moisture content, dry density, sieve analysis (#200 sieve wash), Atterberg limits (liquid and plastic limits) and unconfined compressive strength. In 2017, our scope of work did not include performing laboratory tests to determine the soil resistivity, pH, chloride content or sulfate content of the soils at the site.

3. To prepare an engineering report that includes the results of the field and laboratory tests as well as our earthwork and foundation recommendations for design and construction.

The scope of our work was intended for geotechnical purposes only. This scope of work did not include determining the presence or extent of environmental contamination at the site or to characterize the site relative to wetlands status.

SITE & SUBSURFACE CONDITIONS

Site Location & Description

The site is located northeast of the intersection of 459th Avenue and 234th Street in Lake County, South Dakota. The city of Madison is located about 3 miles west of the site. The topography of the site is generally flat. A slough is located north of the area designated for the proposed ground storage reservoir.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were estimated from a drawing provided by Banner Associates, Inc. Based on our estimates, the ground surface elevations at the test boring locations were 1,732.0 feet at test boring 1, 1,731.8 feet at test boring 2, 1,732.2 feet at test boring 3 and 1,732.0 feet at test boring 4. A site map (Figure 1) is attached showing the relative location of the test borings.

Subsurface Conditions

Four (4) test borings were performed at the site on April 24, 2017. The subsurface conditions encountered at the test boring locations are illustrated by means of the boring logs included in Appendix A. A subsurface diagram (Figure 2) is attached showing a cross-sectional view of the subsurface conditions encountered at the test boring locations (west to east direction across the ground storage reservoir).

The subsurface profile at the test boring locations consisted of the following soil types: topsoil materials, fine alluvium soils and glacial till soils. The topsoil materials were encountered at all of the test borings and extended to a depth of 1 foot. The fine alluvium soils were encountered beneath the topsoil materials and extended to a depth of 7 feet. The glacial till soils were encountered beneath the fine alluvium soils and extended to the termination depth of the test borings.

The consistency or relative density of the soils is indicated by the standard penetration resistance (“N”) values as shown on the boring log. A description of the soil consistency or relative density based on the "N" values can be found on the attached Soil Boring Symbols and Descriptive Terminology data sheet.

We wish to point out that the subsurface conditions at other times and locations at the site may differ from those found at our test boring locations. If different conditions are encountered during construction, then it is important that you contact us so that our recommendations can be reviewed.

Soil Types

Topsoil Materials

The topsoil materials consisted of lean clay (CL). The moisture condition of the topsoil materials was moist.

Fine Alluvium Soils

Fine alluvium soils are soils with more than 50 percent by weight passing the #200 sieve that have been deposited by moving water. The fine alluvium soils consisted of fat clay (CH). "N" values within the fine alluvium soils ranged from 6 to 8 (consistency of firm). The moisture condition of the fine alluvium soils moist.

Glacial Till Soils

Glacial till soils are soils with more than 50 percent by weight passing the #200 sieve that have been deposited by a glacier. The glacial till soils consisted of lean clay with sand (CL) and sandy lean clay (CL). "N" values within the glacial till soils ranged from 8 to 17 (consistency of firm, stiff and very stiff). The moisture condition of the glacial till soils was moist.

Water Levels

Measurements to record the groundwater levels were made at test borings 1, 2 and 3 (not at test boring 4). A groundwater measurement was not made at test boring 4 because drilling fluid was used to advance the deep test boring. The time and level of the groundwater readings are recorded on the boring logs. Also, a summary of the groundwater levels is shown in Table 1.

Table 1. Groundwater Levels

Test Boring	Ground Surface Elevation, ft	Groundwater Level, ft	Elevation of Groundwater, ft
1	1,732.0	5	1,727.0
2	1,731.8	5 1/2	1,726.3
3	1,732.2	5	1,727.2
4	1,732.0	Rotary Mud	N/A

Notes: Again, the ground surface elevations at the test boring locations were estimated from a drawing provided by Banner Associates, Inc. Also, the groundwater readings were taken in 2017.

ENGINEERING REVIEW & RECOMMENDATIONS

Project Design Data

We understand that the project will consist of constructing a ground storage reservoir for the Lewis & Clark Regional Water System near Madison, South Dakota. The proposed ground storage reservoir will likely have a diameter of 78 feet, an approximate wall height of 28 feet and a capacity of approximately 1.0 million gallons. The finished floor elevation of the ground storage reservoir will likely be near elevation 1,735.0 feet (about 3 feet above the existing grades). We understand that the ground storage reservoir will be supported by a floor slab with a thickened edge (perimeter footing). The perimeter footing will likely rest near elevation 1,733.5 feet. The contact pressure beneath the perimeter footing may be approximately 2,500 pounds per square foot (psf) and the contact pressure beneath the floor slab may be approximately 1,800 psf. We expect that an earthen berm (height of about 5 feet) will be placed against the exterior of the ground storage reservoir. The ground storage reservoir has the following settlement criteria: total settlement of 2 1/4 inches or less at the center of the ground storage reservoir and differential settlement of 1 1/8 inches or less between the center and edge of the ground storage reservoir.

The information/assumptions detailed in the project design data section are important factors in our review and recommendations. If there are any corrections or additions to the information detailed in this section, then it is important that you contact us so that we can review our recommendations with regards to the revised plans.

Discussion

In our opinion, 2 options could be considered for support of the proposed ground storage reservoir. The first option consists of an excavate/refill system. This option would consist of excavating down to suitable soils, followed by placing and compacting granular structural fill up to the design elevations. The second option consists of an intermediate foundation system of rammed aggregate piers or aggregate piers. Specific recommendations for the 2 options are discussed in the following sections.

Support Option 1 – Excavate/Refill System

Site Preparation

For this option, we recommend that the site preparation for the entire footprint of the ground storage reservoir consist of excavating to elevation 1,724.0 feet or deeper. At elevation 1,724.0 feet, we expect that suitable glacial till soils will be encountered. If suitable glacial till soils are not encountered at elevation 1,724.0 feet, then we recommend further excavating down to suitable glacial till soils. Based on the ground surface elevations at the test boring locations and a proposed bottom-of-excavation elevation of 1,724.0 feet, an excavation depth of about 8 feet should be expected. The anticipated excavation depths are also shown on the boring logs. We recommend that observations and hand auger borings be performed at the bottom of the excavation. Following the removals, we recommend placing and compacting granular structural fill up to the design elevations. At a minimum, the final 6 inches of granular structural fill beneath the floor slab and perimeter footing should consist of select granular fill.

Foundation Loads

If our recommendations are followed during site preparations (excavate/refill system), then it is our opinion that the floor slab and perimeter footing of the ground storage reservoir can be designed using a net allowable soil bearing pressure of up to 4,000 psf. It is also our opinion that the recommended bearing pressure should provide a minimum safety factor of 3.0 against shear or base failure. The net allowable soil bearing pressure may be increased by 1/3 for transient wind or seismic loads.

Settlement

With the excavate/refill system, we estimate the total settlement at the center of the ground storage reservoir to be on the order of 1 3/4 inches. Regarding settlement at the edge of the ground storage reservoir, we estimate it to be on the order of 1 1/4 inches. Based on our estimates, differential settlement between the center of the ground storage reservoir and the edge of the ground storage reservoir should be on the order of 1/2 inch. Unknown soil conditions at the site that are different from those depicted at the test boring locations could increase the amount of expected settlement.

Support Option 2 – Rammed Aggregate Piers & Aggregate Piers

Site Preparation

Prior to the installation of the rammed aggregate piers or aggregate piers, we recommend removing the vegetation and topsoil materials from the footprint of the ground storage reservoir. Following the removal of the vegetation and topsoil materials, we recommend further excavating to a minimum depth of 3 feet below the bottom-of-footing/bottom-of-floor elevation. The overexcavated areas should be backfilled with a minimum of 3 feet of modified granular structural fill. At a minimum, the final 6 inches of modified granular structural fill beneath the floor slab and perimeter footing should consist of select granular fill.

Design & Installation

We recommend that the rammed aggregate piers or aggregate piers be designed by a licensed professional engineer specializing in the design of rammed aggregate piers or aggregate piers. The designer will typically provide a net allowable soil bearing pressure (for the perimeter footing and floor slab) and estimated settlements. The rammed aggregate piers or aggregate piers should be installed by an experienced licensed rammed aggregate pier or aggregate pier contractor. Testing of the rammed aggregate piers and aggregate piers should be performed at the beginning of the work and during production to confirm the design parameters.

Rammed aggregate piers and aggregate piers are installed using 2 methods, the displacement method and the replacement method. The displacement method consists of probing equipment into the ground without removing soil (no "pre-drilling"). With the displacement method, excess pore pressures develop in soft/saturated clay soils that are displaced, which can decrease the strength and supporting characteristics of the surrounding soils and cause additional settlement. The replacement method consists of "pre-drilling" a hole, followed by replacing the removed soils with aggregate to construct the pier. With the replacement method, minimum disturbance occurs to the surrounding soils. With the soils encountered at the site, we recommend that the replacement method be used to construct the piers. Some casing may be needed with the replacement method.

Protection of the rammed aggregate piers and aggregate piers will need to be considered before, during and after installation. The tops of the rammed aggregate piers and aggregate piers should be protected from construction traffic. Excavations performed within close proximity of a rammed aggregate pier or aggregate pier can affect the integrity of the rammed aggregate pier or aggregate pier. With that said, excavation work for underground utility installation, maintenance or future repair should be considered prior to the installation of the rammed aggregate piers or aggregate piers. Excavation work for future construction, maintenance or repairs should also take into account any risks that may affect the integrity of any rammed aggregate piers and aggregate piers. Ground vibrations should be expected during the installation of the rammed aggregate piers and aggregate piers.

We would like to point out that not all applications/systems are equivalent and each submitted design should be reviewed. In addition, the designer and installation contractor should have appropriate experience (e.g., at least 5 years of experience and at least 15 or more successfully completed similar projects).

Excavation

All excavations within the footprint of the ground storage reservoir should be performed with a track backhoe with a smooth edge bucket. The subgrade should not be exposed to heavy construction traffic from rubber tire vehicles.

Water or Saturated Soils

If water or saturated soils are encountered at the bottom of the excavation, then we recommend placing a layer (6 inches to 12 inches) of drainage rock at the bottom of the excavation prior to the placement of the granular structural fill or modified granular structural fill. Based on the groundwater levels at the test boring locations, we expect that some drainage rock will be needed during construction with the excavate/refill system.

Laterally Oversized Excavation

The bottom of the excavation should be laterally oversized 1 foot beyond the edges of the foundation for each vertical foot of granular structural fill, modified granular structural fill or drainage rock required below the foundation (1 horizontal : 1 vertical).

Dewatering

Dewatering may be needed during construction, especially with the excavate/refill system. It will likely be possible to remove and control water entering the excavation using normal sump pumping techniques due to the low permeable characteristics of the predominant clayey soils encountered at the test boring locations. More extensive dewatering techniques will be needed if waterbearing sand soils are encountered.

Soil Modulus of Subgrade Reaction – Floor Slab

With the excavate/refill system, it is our opinion that a k value (soil modulus of subgrade reaction) of 200 psi/inch could be used for the design of the floor slab of the ground storage reservoir. If rammed aggregate piers or aggregate piers are used, then the designer of the rammed aggregate piers or aggregate piers should be able to provide a k value.

Coefficient of Friction

It is our opinion that a friction factor of 0.45 can be used between the granular structural fill, modified granular structural fill and the bottom of the concrete. The friction value is considered an ultimate value. We recommend applying a theoretical safety factor of at least 2.0.

Potential Vertical Rise

With the excavate/refill system, it is our opinion that the potential vertical rise of the ground storage reservoir will be minimal. Our opinion of this is based on the thickness of the granular structural fill beneath the ground storage reservoir with the excavate/refill system.

With the rammed aggregate piers or aggregate piers, a minimum of 3 feet of modified granular structural fill will be provided between the fat clay (CH) and the perimeter footing and floor slab of the ground storage reservoir. In our opinion, the 3 feet of modified granular structural fill will help minimize the potential vertical rise of the ground storage reservoir (due to potential swelling of the fat clay (CH)).

With both support options, we expect that the potential vertical rise of the ground storage reservoir will be less than 1 inch.

Drainage System

Due to shallow groundwater at the test boring locations (see Table 1 on page 7) and as a precaution, we recommend that a drainage system be installed along the outside edge of the perimeter footing of the ground storage reservoir. The drainage system should consist of a drainage pipe that is surrounded by properly graded rock. The rock should be wrapped with a geotextile fabric to minimize clogging. The geotextile filter fabric should consist of Mirafi FW402, US 120NW, US 205NW or an approved equivalent. The drainage pipe should be connected to a suitable means of discharge or daylighted. The drainage pipe should be installed at a level that is below the bottom-of-footing elevation.

Buoyancy Forces

As long as the drainage system is working properly, then it is our opinion that the ground storage reservoir does not need to be designed to resist hydrostatic pressures. However, regular maintenance/inspection would be needed to ensure that the drainage system is working properly. If it is difficult to perform regular maintenance/inspection, then, as a precaution, the ground storage reservoir should be designed to resist hydrostatic pressures.

Frost Protection – Footing

We recommend that the footing be placed at a sufficient depth for frost protection. Footings for heated structures should be placed such that the bottom of the footing is a minimum of 4 feet below the finished exterior grade. Footings for unheated structures should be placed such that the bottom of the footing is a minimum of 5 feet below the finished exterior grade. As previously stated, we expect that an earthen berm (height of about 5 feet) will be placed against the exterior of the ground storage reservoir. The earthen berm will help provide frost protection.

Frost Protection – Floor Slab

With the excavate/refill system, a significant amount of granular structural fill will be provided beneath the floor slab. In our opinion, this layer of granular structural fill will provide adequate frost protection for the floor slab. With the rammed aggregate piers or aggregate piers, 3 feet of modified granular structural fill will be provided beneath the floor slab. The 3 feet of modified granular structural fill will provide some frost protection.

Lateral Pressures

The lateral earth pressures used for the design of below-grade walls or retaining walls at the site will depend on the material used to backfill the walls. The active and passive lateral earth coefficients may be employed only if movement of the walls can be tolerated to reach the active state. A horizontal movement of approximately 1/500 of the height of the wall would be required to develop the active state for granular materials, while a horizontal movement of approximately 1/50 of the height of the wall would be required to develop the active state for cohesive soils. If the movements above cannot be tolerated, then we recommend using the at-rest lateral earth coefficients to design the walls. Table 2 shows the lateral earth coefficients and Table 3 shows the equivalent fluid unit weight values for the various soil types anticipated for this project.

Table 2. Lateral Earth Coefficients

Soil Type	Wet Unit Weight, pcf*	Effective Unit Weight, pcf**	Friction Angle, Degrees	Active Earth Pressure (Ka)	At-Rest Earth Pressure (Ko)	Passive Earth Pressure (Kp)
On-Site Glacial Till	130	68	22	0.45	0.63	2.20
Imported Free-Draining Sand	125	63	35	0.27	0.43	3.69

Notes: *The wet unit weight is the weight above the water table. **The effective unit weight is the weight below the water table.

Table 3. Equivalent Fluid Unit Weight Values

Soil Type	At-Rest, pcf		Active, pcf		Passive, pcf	
	Drained	Submerged*	Drained	Submerged*	Drained	Submerged*
On-Site Glacial Till	82	105	59	93	286**	150**
Imported Free-Draining Sand	53	89	34	79	461**	231**

Notes: *If clay soils are used as backfill, then a submerged or high groundwater condition should be considered for the design of the walls. **These values can be used below the frost depth – 0 pcf should be used above the frost depth.

Prior to backfilling the below-grade walls or retaining walls, the contractor should verify what soil type could be used to backfill the walls. If clay soils can be used to backfill the below-grade walls and retaining walls, then the clay backfill should consist of the on-site glacial till soils. The granular backfill should consist of the an imported free-draining granular material. If granular materials are selected as backfill, then the zone of the granular backfill should extend a minimum of 2 feet outside the bottom of the foundation and then extend upward and outward at a slope no steeper than 1:1 (horizontal to vertical). With the granular materials, we recommend capping the granular backfill section with a 2-foot layer of clayey soil in areas that will not have concrete surfacing to minimize infiltration of surface waters.

During compaction efforts, only hand-operated compaction equipment should be used directly adjacent to the walls.

Seismic Site Classification

Based on the 2018 International Building Code (IBC), it is our opinion that the site, as a whole, corresponds to a Site Class D (stiff soil). Also, the acceleration parameters are as follows: S_S = 0.099 g, S_1 = 0.028 g, S_{MS} = 0.158 g, S_{M1} = 0.067 g, S_{DS} = 0.105 g, S_{D1} = 0.045 g, F_a = 1.6, F_v = 2.4. Therefore, the seismic design category is “A”. The ground acceleration values are based on the ASCE 7-16 (referenced standard for 2018 IBC) with Risk Category II/III. If needed, we can provide ground acceleration values for a different design code.

Shrinkage Factors

Table 4 summarizes the estimated shrinkage factors for the various soils encountered at the test boring locations.

Table 4. Summary of the Shrinkage Factors of the Soils

Soil Type	Estimated Shrinkage Factors (%)
Topsoil Materials & Fine Alluvium Soils	25
Glacial Till Soils	20

Gravel Surfaced Areas

Discussion

We assume that gravel surfaced areas will be constructed as part of the project. Based on the test borings, fine alluvium soils will be encountered at subgrade soils. In general, the fine alluvium soils are prone to instability/strength loss during freeze-thaw cycles. With that said, it would be beneficial to incorporate geotextile fabric into the project. The geotextile fabric will provide additional support to the gravel section. Without the geotextile fabric, aggregate loss and additional maintenance could be expected.

Subgrade Preparation & Gravel Section Thickness

We recommend that the subgrade preparation in the gravel surfaced areas consist of removing the vegetation and highly organic materials. A removal depth of approximately 12 inches should be expected. Following the removals, the subgrade should be prepared by cutting or placing subgrade fill to the design elevations. Once the design elevations have been achieved, we recommend that the exposed subgrade be scarified (with a disc harrow) to a minimum depth of 8 inches and adjusted to a moisture level that is within plus or minus 2 percent of the optimum moisture content as determined by standard Proctor (ASTM:D698). The moisture-conditioned soils should then be compacted.

Additional corrections will likely be needed if unstable areas are encountered during construction. The additional corrections may include the following: moisture conditioning the soils (e.g. drying the soils by scarification), mixing cement with the subgrade soils, an overexcavation to remove and replace the unstable subgrade soils, the placement of a woven geotextile fabric at the subgrade surface, and/or the placement of granular subbase at the subgrade surface. The type of correction performed should be determined after observing the condition of the subgrade. We expect that stable conditions will be encountered during drier periods of the year, while some unstable conditions could be encountered during wetter periods of the year.

For the thickness of the gravel section, we recommend at least 4 inches of gravel surfacing over 6 inches of aggregate base course. Again, it would be beneficial to incorporate geotextile fabric into the project. Regarding the geotextile fabric, we recommend using Mirafi HP 370, Propex Geotex 3x3 HF, Huesker Comtrac P 45/45 or approved alternative. Without the geotextile fabric, aggregate loss and additional maintenance should be expected.

Water Pipes

Subgrade Soils

The subgrade soils anticipated at the invert depths of the water pipes will likely consist of clay soils. Where soils having moderate moisture and density values are encountered at the bottom of the trench excavations, it is our opinion that the soils are considered suitable for support of the water pipes, provided they are adequately dewatered, and are not disturbed by construction traffic. Localized areas of wet or soft soils may be encountered at the bottom of some of the trench excavations. These areas will require subexcavation and trench stabilization methods and materials. Appropriate bedding materials should be used for the water pipes.

Water Control

Water may enter some of the trench excavations as a result of subsurface water, precipitation or surface run off. Dewatering procedures may be required in order to control and remove water entering the trench excavations. Where clay soils are encountered, it will likely be possible to remove and control water entering the excavations using normal sump pumping techniques. However, if waterbearing sand soils are encountered, then extensive dewatering techniques will likely be required due to the potentially large volumes of water. The contractor should provide appropriate dewatering methods and equipment. Any water that accumulates at the bottom of the excavations should be immediately removed and surface drainage away from the excavations should be provided during construction.

Trench Backfill

In our opinion, the majority of the glacial till soils and some of the fine alluvium soils can likely be reused as trench backfill. Some moisture adjustment should be expected with the majority of the fine alluvium soils. The topsoil materials should not be used as trench backfill. The topsoil materials should be used as "topping" material.

Water Pipes – Beneath & Just Outside of the Ground Storage Reservoir

We expect that the water pipes beneath the ground storage reservoir will be able to withstand the potential settlement of the ground storage reservoir. With that said, it is our opinion that the water pipes beneath the ground storage reservoir do not need to be encased in concrete. Granular structural fill or modified granular structural fill should be used as trench backfill below the ground storage reservoir.

In order to absorb some of the settlement of the ground storage reservoir beneath the water pipes that are just outside of the ground storage reservoir, we recommend placing a pea rock material beneath the water pipes. The pea rock material should have a minimum thickness of 2 feet (below the pipes) and should extend approximately 15 feet from the edge of the ground storage reservoir. The pea rock material should not be compacted. Flexible connections should also be incorporated into the design where applicable.

Material Types & Compaction Levels

Granular Structural Fill – The granular structural fill should consist of a pit-run or processed sand or gravel having a maximum particle size of 3 inches with less than 10 percent by weight passing the #200 sieve. The granular structural fill should be placed in lifts of up to 1 foot in thickness.

Modified Granular Structural Fill – To reduce the potential for caving of the granular material during the installation of the rammed aggregate piers or aggregate piers, we recommend that the modified granular structural fill consist of a pit-run or processed sand or gravel having a maximum particle size of 3 inches with 15 percent to 25 percent by weight passing the #200 sieve. The modified granular structural fill should be placed in lifts of up to 1 foot in thickness.

Select Granular Fill – The select granular fill should consist of a medium to coarse grained, free-draining sand or rock having a maximum particle size of 1 inch with less than 5 percent by weight passing the #200 sieve. The select granular fill should be placed in lifts of up to 1 foot in thickness.

Drainage Rock – The drainage rock should be crushed, washed and meet the gradation specifications shown in Table 5.

Table 5. Drainage Rock Gradation Specifications

Sieve Size	Percent Passing
1 ½-inch	100
1-inch	70 – 90
3/4-inch	25 – 50
3/8-inch	0 – 5

Free-Draining Sand – The free-draining sand should have a maximum particle size of 3 inch with less than 5 percent by weight passing the #200 sieve. The free-draining sand should be placed in lifts of up to 1 foot in thickness.

Exterior Backfill (Earthen Embankment) for the Ground Storage Reservoir – The exterior backfill for the ground storage reservoir could consist of either a granular or clay material. Debris, organic material, or over-sized material should not be used as exterior backfill. If a granular material is used, then it should consist of a pit-run or processed sand or gravel having a maximum particle size of 3 inches. If granular soils are used, then we recommend capping the granular soils with approximately 2 feet of clayey soils to minimize infiltration of surface water.

If a clay material is selected, then it should consist of a non-organic lean clay. Scrutiny on the clay material's moisture content should be made prior to the acceptance and use. The exterior backfill should be placed in lifts of up to 1 foot in thickness. A portion of the on-site soils can be used as exterior backfill.

Pea Rock Material – The pea rock material should consist of a rounded rock having a maximum particle size of ½ inch and less than 5 percent by weight passing the #8 sieve.

Subgrade Fill – The subgrade fill should consist of a similar material as discussed for the exterior backfill (earthen embankment) for the ground storage reservoir.

Granular Subbase – The granular subbase should consist of crushed quartzite, recycled concrete or a crushed pit-run material meeting the gradation specifications shown in Table 6.

Table 6. Granular Subbase Gradation Specifications

Sieve Size	Percent Passing
4-inch	100
3-inch	70 – 90
2-inch	60 – 80
1-inch	40 – 70
#4	10 – 50
#40	5 – 20
#200	0 – 8

Aggregate Base Course Material – We recommend that the aggregate base course materials meet the requirements of Sections 260 and 882 of the SDDOT Standard Specifications.

Gravel Surfacing Material – We recommend that the gravel surfacing meet the requirements of Sections 260 and 882 of the SDDOT Standard Specifications. In our opinion, it is important to provide a gravel surfacing material that meets the plasticity index requirement that ranges from 4 to 12.

Recommended Compaction Levels – The recommended compaction levels listed in Table 7 are based on a material's maximum dry density value, as determined by a standard Proctor (ASTM: D698) test.

Table 7. Recommended Compaction Levels

Placement Location	Compaction Specifications
Below the Ground Storage Reservoir	100%
Exterior Backfill – Ground Storage Reservoir	95%
Behind Below-Grade & Retaining Walls	95% - 98%
Subgrade Fill	95%
Aggregate Base Course	97%
Gravel Surfacing	97%
Trench Backfill	95%
Non-Structural Areas	90%

Notes: Compaction specifications are not applicable with the drainage rock. Compaction testing may not be practical for the granular subbase due to the large aggregate.

Recommended Moisture Levels – The moisture content of the clay materials should be maintained within a range of plus 2 percent to minus 2 percent of the materials' optimum moisture content. The optimum moisture content should be determined using a standard Proctor (ASTM: D698) test. The moisture content of the granular materials should be maintained at a level that will be conducive for vibratory compaction.

Corrosive Potential

As previously stated, our scope of work in 2017 did not include performing laboratory tests to determine the soil resistivity, pH, chloride content or sulfate content of the soils at the site. However, we performed numerous test borings and laboratory tests for a treated water pipeline in 2021 for (Madison Segments 2, 3 and 4). Test borings 4-7 (located southwest of SD Highway 34 and 461st Avenue) and 4-8 (located southwest of SD Highway 34 and 460th Avenue) are located about 2 miles southeast of the site for the ground storage reservoir. The laboratory results from test borings 4-7 and 4-8 are shown in Table 8. Additional sampling and testing would be needed to determine the soil resistivity, pH, chloride content or sulfate content of the soils at the site.

Table 8. Laboratory Test Results

Test Boring	Depth (ft)	Soil Type	Resistivity (ohm-cm) (as-received)	Resistivity (ohm-cm) (saturated)	pH	Chloride (mg/kg)	Sulfate (mg/kg)
4-7	7 to 8 ½	Lean Clay w/ Sand (GT)	1,474	1,407	8.2	22	83
4-8	9 ½ to 11	Lean Clay w/ Sand (GT)	1,340	1,273	8.3	13	146

Drainage

Proper drainage should be maintained during and after construction. The general site grading should direct surface run-off waters away from the excavations. Water which accumulates in the excavations should be removed in a timely manner. Finished grades around the perimeter of the structure should be sloped such that positive drainage away from the structure is provided.

CONSTRUCTION CONSIDERATIONS

Groundwater & Surface Water

Water may enter the excavations due to subsurface water, precipitation or surface run off. Any water that accumulates in the bottom of the excavations should be immediately removed and surface drainage away from the excavations should be provided during construction.

Disturbance of Soils

The soils encountered at the test boring locations are susceptible to disturbance and can experience strength loss caused by construction traffic and/or additional moisture. Precautions will be required during earthwork activities in order to reduce the risk of soil disturbance.

Cold Weather Precautions

If site preparation and construction is anticipated during cold weather, then we recommend all foundations, slabs and other improvements that may be affected by frost movements be insulated from frost penetration during freezing temperatures. If filling is performed during freezing temperatures, then all frozen soils, snow and ice should be removed from the areas to be filled prior to placing the new fill. The new fill should not be allowed to freeze during transit, placement and compaction. Concrete should not be placed on frozen subgrades. Frost should not be allowed to penetrate below the foundations. If floor subgrades freeze, then we recommend the frozen soils be removed and replaced, or completely thawed, prior to placement of the floor. The subgrade soils will likely require reworking and recompacting due to the loss of density caused by the freeze/thaw process.

Excavation Sideslopes

The excavations must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, “Excavations and Trenches”. This document states that the excavation safety is the responsibility of the contractor. Reference to this OSHA requirement should be included in the project specifications.

Observations & Testing

This report was prepared using a limited amount of information for the project and a number of assumptions were necessary to help us develop our conclusions and recommendations. It is recommended that our firm be retained to review the geotechnical aspects of the final design plans and specifications to check that our recommendations have been properly incorporated into the design documents.

The recommendations submitted in this report have been made based on the subsurface conditions encountered at the test boring locations. It is possible that there are subsurface conditions at the site that are different from those represented by the test borings. As a result, on-site observation during construction is considered integral to the successful implementation of the recommendations. We believe that qualified field personnel need to be on-site at the following times to observe the site conditions and effectiveness of the construction.

Excavation

We recommend that a geotechnical engineer or geotechnical engineering technician working under the direct supervision of a geotechnical engineer observe all excavations for foundations, slabs and pavements. These observations are recommended to determine if the exposed soils are similar to those encountered at the test boring locations, if unsuitable soils have been adequately removed and if the exposed soils are suitable for support of the proposed construction. These observations should be performed prior to placement of fill or foundations.

Testing

After the subgrade is observed by a geotechnical engineer/technician and approved, we recommend a representative number of compaction tests be taken during the placement of the structural fill and backfill placed below foundations, slabs and pavements, beside foundation walls and behind retaining walls. The tests should be performed to determine if the required compaction has been achieved. As a general guideline, we recommend at least 1 test be taken for every 2,000 square feet of structural fill placed in building and pavement areas, at least 1 test for every 75 feet to 100 feet in trench fill, and for every 2-foot thickness of fill or backfill placed. The actual number of tests should be left to the discretion of the geotechnical engineer. Samples of proposed fill and backfill materials should be submitted to our laboratory for testing to determine their compliance with our recommendations and project specifications.

SUBSURFACE EXPLORATION PROCEDURES

Test Borings

We performed 4 SPT borings on April 24, 2017 with a truck rig equipped with hollow-stem auger. Soil sampling was performed in accordance with the procedures described in ASTM:D1586. Using this procedure, a 2-inch O.D. split barrel sampler is driven into the soil by a 140-pound weight falling 30 inches. After an initial set of 6 inches, the number of blows required to drive the sampler an additional 12 inches is known as the penetration resistance, or “N” value. The “N” value is an index of the relative density of cohesionless soils and the consistency of cohesive soils. In addition, thin walled tube samples were obtained according to ASTM:D1587, where indicated by the appropriate symbol on the boring logs.

The test borings were backfilled with on-site materials and some settlement of these materials can be expected to occur. Final closure of the holes is the responsibility of the client or property owner. The soil samples were discarded in 2017.

Soil Classification

As the samples were obtained in the field, they were visually and manually classified by the crew chief according to ASTM:D2488. Representative portions of all samples were then sealed and returned to the laboratory for further examination and for verification of the field classification. In addition, select samples were then submitted to a program of laboratory tests. Where laboratory classification tests (sieve analysis and Atterberg limits) have been performed, classifications according to ASTM:D2487 are possible. Logs of the test borings indicating the depth and identification of the various strata, the "N" value, the laboratory test data, water level information and pertinent information regarding the method of maintaining and advancing the drill holes are also attached in Appendix A. Charts illustrating the soil classification procedures, the descriptive terminology and the symbols used on the boring logs are also attached in Appendix A.

Water Level Measurements

Subsurface groundwater levels should be expected to fluctuate seasonally and yearly from the groundwater readings recorded at the test boring locations. Fluctuations occur due to varying seasonal and yearly rainfall amounts and snowmelt, as well as other factors. It is possible that the subsurface groundwater levels during or after construction could be significantly different than the time the test borings were performed.

Laboratory Tests

Laboratory tests were performed on select samples to aid in determining the index and strength properties of the soils. The index tests consisted of moisture content, dry density, sieve analysis (#200 sieve wash) and Atterberg limits (liquid and plastic limits). The strength tests consisted of unconfined compressive strength. The laboratory tests were performed in accordance with the appropriate ASTM procedures. The results of the laboratory tests are shown on the boring logs opposite the samples upon which the tests were performed or on the data sheets included in the Appendix.

LIMITATIONS

The recommendations and professional opinions submitted in this report were based upon the data obtained through the sampling and testing program at the test boring locations. We wish to point out that because no exploration program can totally reveal the exact subsurface conditions for the entire site, conditions between test borings and between samples and at other times may differ from those described in our report. Our exploration program identified subsurface conditions only at those points where samples were retrieved or where water was observed. It is not standard engineering practice to continuously retrieve samples for the full depth of the borings. Therefore, strata boundaries and thicknesses must be inferred to some extent. Additionally, some soils layers present in the ground may not be observed between sampling intervals. If the subsurface conditions encountered at the time of construction differ from those represented by our test borings, it is necessary to contact us so that our recommendations can be reviewed. The variations may result in altering our conclusions or recommendations regarding site preparation or construction procedures, thus, potentially affecting construction costs.

This report is for the exclusive use of the addressee and its representatives for use in design of the proposed project described herein and preparation of construction documents. Without written approval, we assume no responsibility to other parties regarding this report. Our conclusions, opinions and recommendations may not be appropriate for other parties or projects.

STANDARD OF CARE

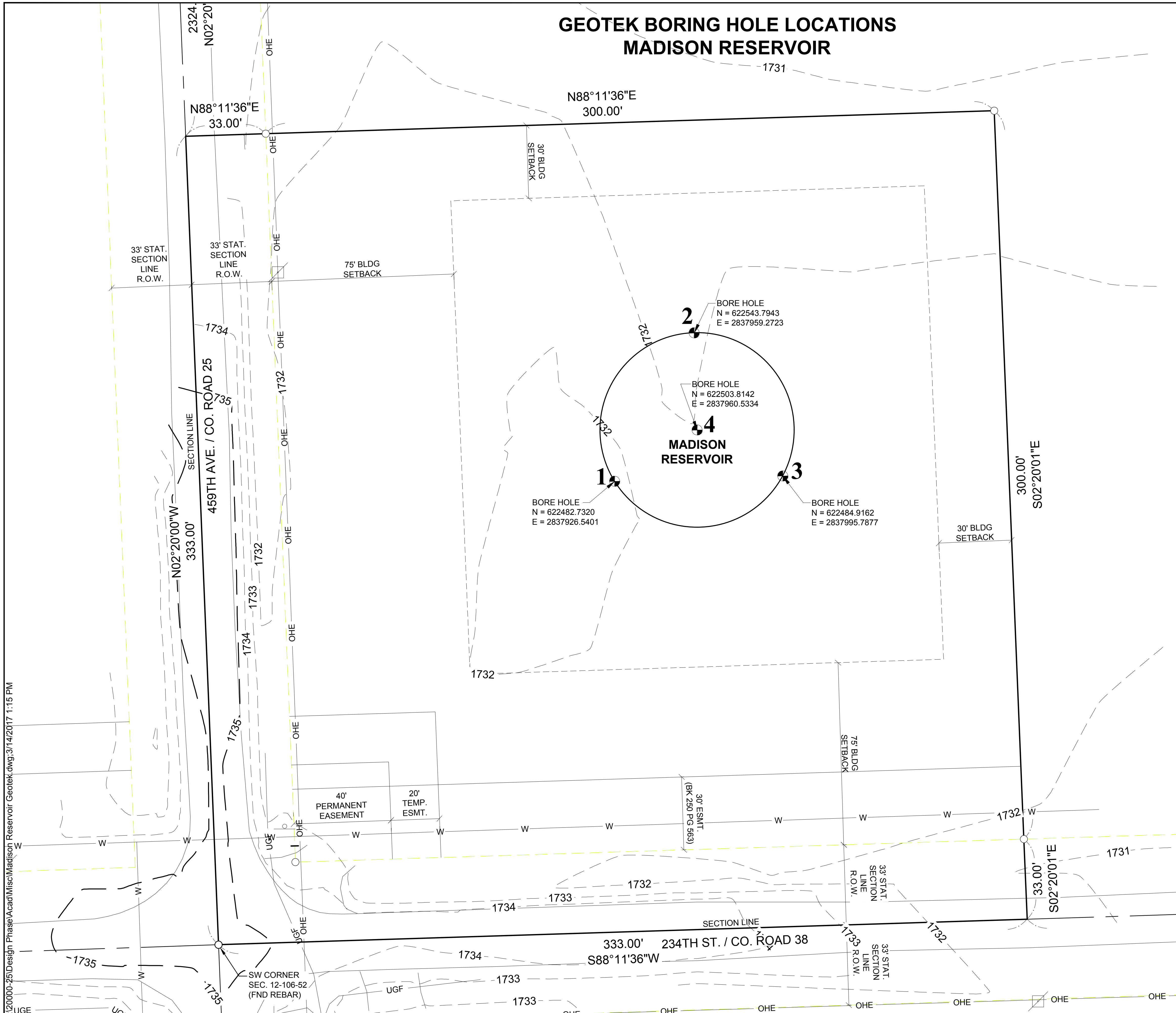
The recommendations submitted in this report represent our professional opinions. Our services for your project were performed in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering profession currently practicing at this time and area.

This report was prepared by:
GeoTek Engineering & Testing Services, Inc.

Jared Haskins, PE
Geotechnical Manager

REGISTERED PROFESSIONAL ENGINEER
REG. NO. 10971
JARED E. HASKINS
SOUTH DAKOTA
3-23-22

GEOTEK BORING HOLE LOCATIONS
MADISON RESERVOIR



GRID BEARING

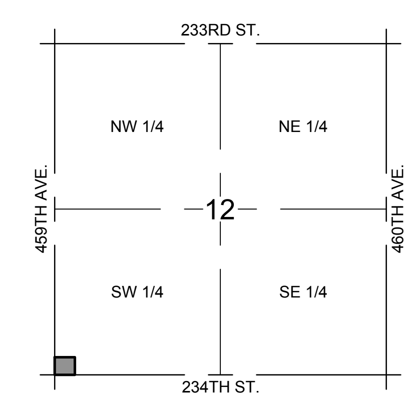
20' 10' 0 20' 40'

HORIZONTAL DATUM:
- NAD 83
- PROJECTION: SOUTH DAKOTA STATE PLANE COORDINATES SOUTH ZONE (4002)

VERTICAL DATUM:
- NAVD 88
- GEOID 09

BASIS OF BEARING: GEODETIC NORTH

ALL DIMENSIONS SHOWN ARE IN TERMS OF U.S. SURVEY FEET



VICINITY MAP
SEC. 12-T106N-R52W

PROJECT / SHEET TITLE:
LEWIS & CLARK REGIONAL WATER SYTEM
GEOTEK BORING HOLE LOCATIONS
MADISON, SOUTH DAKOTA

REV.	DATE	DESCRIPTION

FOR REVIEW ONLY
NOT FOR CONSTRUCTION

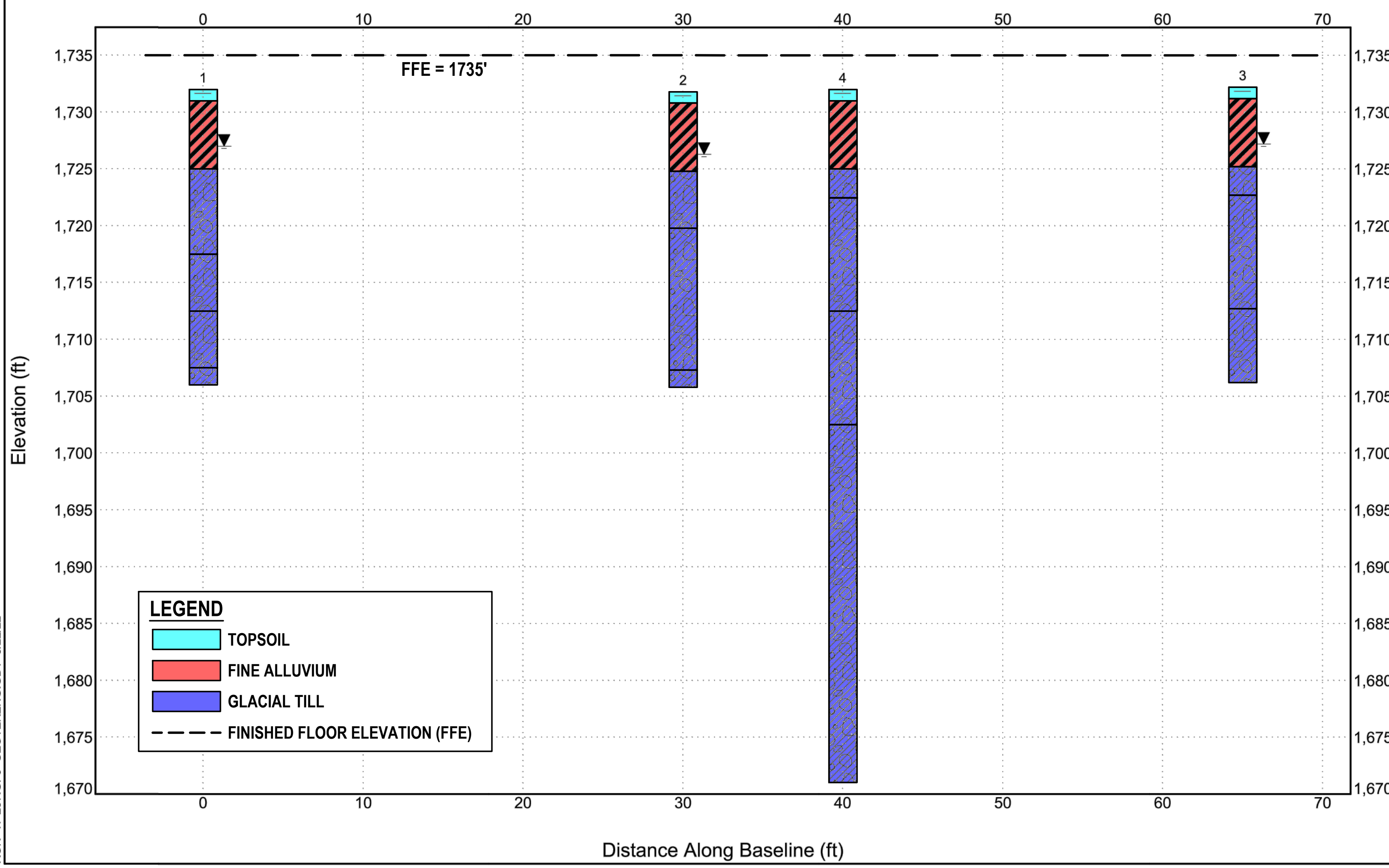
JOB No.:	20000.39.00
DATE:	MARCH 2017
DESIGNED BY:	C.E.B.
CHECKED BY:	C.E.B.
DRAWN BY:	S.A.N.

SCALE REDUCTION BAR 0 1/2" 1"

SHEET No.: 1

SUBSURFACE DIAGRAM
FIGURE 2

CLIENT Banner Associates, Inc.
PROJECT NUMBER 17-297
PROJECT NAME Proposed Ground Storage Reservoir
PROJECT LOCATION Lewis & Clark Regional Water System



RON 17-297.GPJ GEOTEKENG.GDT 3/22/22

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
909 E 50th St N
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605-335-5512 Fax
jhaskins@geotekeng.com

GEOTECHNICAL TEST BORING LOG

GEOTEK # **17-297**

BORING NO. **1 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir, Lewis & Clark Regional Water System, 459th Avenue & 234th Street, Near Madison, SD**

SURFACE ELEVATION 1732.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL									
	FAT CLAY: mottled brown and gray, moist, firm, (CH)	FINE ALLUVIUM			1	HSA					
			6		2	SPT					
7			8	▼	3	SPT	27	98	54	19	3600
	LEAN CLAY WITH SAND: a little gravel, ~~brown,~~ moist, firm to stiff, percent passing the #200 sieve = 84% (at 10') (CL) Excavation Depth (8.0') Option 1	GLACIAL TILL	8		4	SPT	22				
			12		5	SPT	23	104			
14½			12		6	SPT					
19½	**LEAN CLAY WITH SAND**: a little gravel, dark brown, moist, stiff, (CL)	GLACIAL TILL	13		7	SPT					
24½	**SANDY LEAN CLAY**: a little gravel, dark brown and gray, moist, stiff, (CL)	GLACIAL TILL	16		8	SPT					
26	**SANDY LEAN CLAY**: a little gravel, gray, moist, stiff, (CL)	GLACIAL TILL	9		9	SPT					
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-25-17	8:05 am	26	--	18	▼ 5
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-24-17 COMPLETE 4-24-17 2:47 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **17-297**

BORING NO. **2 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir, Lewis & Clark Regional Water System, 459th Avenue & 234th Street, Near Madison, SD**

SURFACE ELEVATION 1731.8 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL
7	**FAT CLAY**: mottled brown and gray, moist, firm, with a few lenses of lean clay (CH)	FINE ALLUVIUM
12	**SANDY LEAN CLAY**: a little gravel, brown, moist, stiff, percent passing the #200 sieve = 64% (at 10') (CL)	GLACIAL TILL
24½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL
26	**LEAN CLAY WITH SAND**: a little gravel, dark grayish brown, moist, very stiff, (CL)	GLACIAL TILL
	Bottom of borehole at 26 feet.	

Excavation Depth (7.8')
Option 1

N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
		1	HSA					
8		2	SPT					
8	▼	3	SPT	27	99			
9		4	SPT					
9		5	SPT	22	105			
10		6	SPT					
14		7	SPT					
12		8	SPT					
16		9	SPT					

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-25-17	8:05 am	26	--	18	▼ 5.5
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-24-17 COMPLETE 4-24-17 1:29 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **17-297** BORING NO. **3 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir, Lewis & Clark Regional Water System, 459th Avenue & 234th Street, Near Madison, SD**

SURFACE ELEVATION 1732.2 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	FAT CLAY: mottled brown and gray, moist, firm, with a few lenses of lean clay (CH)	FINE ALLUVIUM	6		2	SPT					
			7	▼	3	SPT	27	97			1800
7	**SANDY LEAN CLAY**: a trace of gravel, brown, moist, stiff, (CL)	GLACIAL TILL	13		4	SPT	22	105			
9½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	11		5	SPT	20	110			5100
			10		6	SPT					
			9		7	SPT					
19½	**LEAN CLAY WITH SAND**: a little gravel, dark grayish brown, moist, very stiff, (CL)	GLACIAL TILL	17		8	SPT					
			17		9	SPT					
26	Bottom of borehole at 26 feet.										

Excavation Depth (8.2')
Option 1

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-25-17	8:05 am	26	--	12	▼ 5
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-24-17 COMPLETE 4-24-17 3:42 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **17-297** BORING NO. **4 (1 of 2)**

PROJECT **Proposed Ground Storage Reservoir, Lewis & Clark Regional Water System, 459th Avenue & 234th Street, Near Madison, SD**

SURFACE ELEVATION 1732.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL									
	FAT CLAY: mottled brown and gray, moist, firm, (CH)	FINE ALLUVIUM			1	FA					
			6		2	SPT					
7			8		3	SPT					
	SANDY LEAN CLAY: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	9		4	SPT	22	105			
9½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	9		5	SPT	22	106			3000
			11		6	SPT					
19½	**LEAN CLAY WITH SAND**: a little gravel, dark brown, moist, stiff, (CL)	GLACIAL TILL	13		7	SPT					
			11		8	SPT					
29½	**SANDY LEAN CLAY**: a little gravel, gray, moist, stiff, (CL)	GLACIAL TILL	13		9	SPT					

Excavation Depth (8.0')
Option 1

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-24-17 COMPLETE 4-24-17 12:24 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

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& TESTING SERVICES, INC.
909 E 50th St N
Sioux Falls, South Dakota, 57104
605-335-5512 Fax
jhaskins@geotekeng.com

GEOTECHNICAL TEST BORING LOG

GEOTEK # **17-297**

BORING NO. **4 (2 of 2)**

PROJECT **Proposed Ground Storage Reservoir, Lewis & Clark Regional Water System, 459th Avenue & 234th Street, Near Madison, SD**

SURFACE ELEVATION 1732.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	SANDY LEAN CLAY: a little gravel, gray, moist, stiff, (CL) *(Continued from previous page)*	GLACIAL TILL									
			12		10	SPT	20	110			2800
			11		11	SPT					
			12		12	SPT					
			14		13	SPT					
			14		14	SPT					
			14		15	SPT					
61	Bottom of borehole at 61 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-24-17 COMPLETE 4-24-17 12:24 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY 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 AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

BORING LOG SYMBOLS AND DESCRIPTIVE TERMINOLOGY

SYMBOLS FOR DRILLING AND SAMPLING

Symbol	Definition
Bag	Bag sample
CS	Continuous split-spoon sampling
DM	Drilling mud
FA	Flight auger; number indicates outside diameter in inches
HA	Hand auger; number indicates outside diameter in inches
HSA	Hollow stem auger; number indicates inside diameter in inches
LS	Liner sample; number indicates outside diameter of liner sample
N	Standard penetration resistance (N-value) in blows per foot
NMR	No water level measurement recorded, primarily due to presence of drilling fluid
NSR	No sample retrieved; classification is based on action of drilling equipment and/or material noted in drilling fluid or on sampling bit
SH	Shelby tube sample; 3-inch outside diameter
SPT	Standard penetration test (N-value) using standard split-spoon sampler
SS	Split-spoon sample; 2-inch outside diameter unless otherwise noted
WL	Water level directly measured in boring
▼	Water level symbol

SYMBOLS FOR LABORATORY TESTS

Symbol	Definition
WC	Water content, percent of dry weight; ASTM:D2216
D	Dry density, pounds per cubic foot
LL	Liquid limit; ASTM:D4318
PL	Plastic limit; ASTM:D4318
QU	Unconfined compressive strength, pounds per square foot; ASTM:D2166

DENSITY/CONSISTENCY TERMINOLOGY

Density Term	N-Value	Consistency Term
Very Loose	0-4	Soft
Loose	5-8	Firm
Medium Dense	9-15	Stiff
Dense	16-30	Very Stiff
Very Dense	Over 30	Hard

DESCRIPTIVE TERMINOLOGY

Term	Definition
Dry	Absence of moisture, powdery
Frozen	Frozen soil
Moist	Damp, below saturation
Waterbearing	Pervious soil below water
Wet	Saturated, above liquid limit
Lamination	Up to ½” thick stratum
Layer	½” to 6” thick stratum
Lens	½” to 6” discontinuous stratum

PARTICLE SIZES

Term	Particle Size
Boulder	Over 12”
Cobble	3” – 12”
Gravel	#4 – 3”
Coarse Sand	#10 – #4
Medium Sand	#40 – #10
Fine Sand	#200 – #40
Silt and Clay	passes #200 sieve

GRAVEL PERCENTAGES

Term	Range
A trace of gravel	2-4%
A little gravel	5-15%
With gravel	16-50%