GEOTECHNICAL EXPLORATION
PROPOSED GROUND STORAGE RESERVOIR & PUMP STATION
LEWIS & CLARK REGIONAL WATER SYSTEM
HARRISON AVENUE
NEAR HULL, IOWA
GEOTEK #22-971

LICENSED PROFESSIONAL ENGINEER
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6-27-22

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Daniel R. Hanson

License number 11557

My license renewal date is December 31, 2022.

Pages or sheets covered by this seal:
1-30 PLUS APPENDIX

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June 27, 2022

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Attn: Bryan Lipp, PE

Subj: Geotechnical Exploration
Proposed Ground Storage Reservoir & Pump Station
Lewis & Clark Regional Water System
Harrison Avenue
Near Hull, Iowa
GeoTek #22-971

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 Scott Vander Meulen with Banner Associates. 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

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INTRODUCTION

Project Information

This report presents the results of the recent geotechnical exploration program for the proposed ground storage reservoir and pump station for the Lewis & Clark Regional Water System near Hull, Iowa.

Scope of Services

Our work was performed in accordance with the authorization of Scott Vander Meulen with Banner Associates. The authorized scope of services included the following:

1. To perform 9 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), unconfined compressive strength, pH, sulfate content, chloride content, resistivity, redox potential and sulfide content.
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 along the east side of Harrison Avenue (south of 340th Street) in Sioux County, Iowa. A site location map (Figure 1) is attached showing the location of the site. The town of Hull is located about 2 miles north/northeast of the site. The site was previously used for agricultural purposes (farmland). The topography of the site slopes downward from the southeast corner of the site to the northwest corner of the site.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were provided by Banner Associates and were 1,478.3 feet at test boring 1, 1,479.6 feet at test boring 2, 1,478.4 feet at test boring 3, 1,478.6 feet at test boring 4, 1,479.8 feet at test boring 5, 1,479.8 feet at test boring 6, 1,479.3 feet at test boring 7, 1,480.3 feet at test boring 8 and 1,480.7 feet at test boring 9. A test boring location map (Figure 2) is attached at the conclusion of this report showing the relative location of the test borings.

Subsurface Conditions

Nine (9) test borings were performed at the site on June 13, 2022. Of the 9 test borings, 2 test borings (test borings 1 and 2) were performed in the concrete pavement areas, 2 test borings (test borings 3 and 4) were performed for the pump station and 5 test borings (test borings 5 through 9) were performed for the ground storage reservoir. The subsurface conditions encountered at the test boring locations are illustrated by means of the boring logs included in Appendix A.

The subsurface profile at the test boring locations consisted of the following soil types: topsoil materials, loess soils, coarse alluvium soils, glacial till soils and glacial outwash soils. The topsoil materials were encountered at all of the test borings and extended to depths of 2 feet and 2 ½ feet. The loess soils were encountered beneath the topsoil materials and extended to depths varying from 6 feet to 8 ½ feet. The coarse alluvium soils were encountered beneath the loess soils at test borings 1 and 3. The glacial till soils were encountered beneath the loess soils and coarse alluvium soils at the majority of the test borings (not at test boring 1). The glacial outwash soils were encountered within the glacial till soils at test boring 5.

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 dry and moist.

Loess Soils

Loess soils are soils with more than 50 percent by weight passing the #200 sieve that have been deposited by wind. The loess soils consisted of lean clay (CL). "N" values within the loess soils ranged from 4 to 9 (consistency of soft, firm and stiff). The moisture condition of the loess soils was moist and wet.

Coarse Alluvium Soils

Coarse alluvium soils are soils with less than 50 percent by weight passing the #200 sieve that have been deposited by moving water. The coarse alluvium soils consisted of clayey sand (SC) and sand with silt (SP-SM). "N" values within the coarse alluvium soils ranged from 8 to 11 (relative density of loose and medium dense). The moisture condition of the coarse alluvium soils was moist, wet and waterbearing.

Glacial Till Soils

Glacial till soils are soils with more than 50 percent by weight passing the #200 sieve that have been deposited and consolidated by a glacier. The glacial till soils consisted of lean clay with sand (CL). “N” values within the glacial till soils ranged from 7 to 32 (consistency of firm, stiff, very stiff and hard). The moisture condition of the glacial till soils was moist.

Glacial Outwash Soils

Glacial outwash soils are soils with less than 50 percent by weight passing the #200 sieve that deposited by running water from the melting ice of a glacier. The glacial outwash soils consisted of silty sand (SM). An “N” value of 36 (relative density of very dense) was measured within the glacial outwash soils at test boring 5. The moisture condition of the glacial outwash soils was waterbearing.

Water Levels

Measurements to record the groundwater levels were made at the majority of the test borings (not at test boring 5). A groundwater measurement was not made at test boring 5 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	1,478.3	Dry to the Cave-In Depth	N/A
2	1,479.6	Dry to the Cave-In Depth	N/A
3	1,478.4	10	1,468.4
4	1,478.6	10	1,468.6
5	1,479.8	Rotary Mud	N/A
6	1,479.8	Dry to the Cave-In Depth	N/A
7	1,479.3	Dry to the Cave-In Depth	N/A
8	1,480.3	10	1,470.3
9	1,480.7	Dry to the Cave-In Depth	N/A

ENGINEERING REVIEW & RECOMMENDATIONS

Overall Project Design Data

We understand that the project will consist of constructing a ground storage reservoir and pump station for the Lewis & Clark Regional Water System near Hull, Iowa. A new generator will be installed east of the pump station. New concrete pavement will also be constructed and new water pipes will also be installed at the site.

Ground Storage Reservoir

Design Data

The proposed ground storage reservoir will likely have a diameter of 94 feet, an approximate wall height of 30 feet and a capacity of approximately 1.5 million gallons. We assume that the finished floor of the ground storage reservoir will be near elevation 1,482.0 (about 1 foot to 2 feet above the existing grades). We understand that the ground storage reservoir will be supported by a concrete floor slab with a thickened edge (perimeter footing). We assume that the perimeter footing will rest near elevation 1,480.5 feet. We also assume that the contact pressure beneath the perimeter footing will be approximately 2,800 pounds per square foot (psf) and the contact pressure beneath the floor slab will be approximately 2,000 psf. We expect that an earthen berm (height of about 5 feet) will be placed against the exterior of the ground storage reservoir. We assume that the ground storage reservoir has the following settlement criteria: total settlement – 2 ½ inches or less at the center, edge settlement – 2 inches or less at the edge and differential settlement – ½ inch or less between the center and edge.

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

For this option, we recommend that the site preparation for the entire footprint of the ground storage reservoir consist of excavating to elevation 1,470.0 feet or deeper. At elevation 1,470.0 feet, we expect that suitable glacial till soils will be encountered. If suitable glacial till soils are not encountered at elevation 1,470.0 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 1,470.0 feet, excavation depths of about 9 feet to 11 feet should be expected. The anticipated excavation depths are also shown on the boring logs (test borings 5 through 9). 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.

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.

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. It is our opinion that a friction factor of 0.45 can be used between the 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.

With the excavate/refill system, we estimate that the total settlement at the center of the ground storage reservoir will be on the order of 1 ½ inches. Regarding settlement at the edge of the ground storage reservoir, we estimate that it will be on the order of 1 inch. 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 ½ 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.

Our settlement estimates are based on our assumptions for the design elevations and loads. With that said, we recommend that we be contacted to perform another settlement analysis when the design elevations and loads are known.

Support Option 2 – Rammed Aggregate Piers & Aggregate Piers

Prior to the installation of the rammed aggregate piers or aggregate piers, we recommend removing the topsoil materials from the footprint of the ground storage reservoir. Following the removal of the topsoil materials, we recommend achieving the design elevations within and around the ground storage reservoir by cutting or placing and compacting general structural fill up to the design elevations. Also, we recommend placing a minimum of 6 inches of select granular fill beneath the floor slab and perimeter footing of the ground storage reservoir (after the rammed aggregate piers or aggregate piers are installed).

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. Also, the designer of the rammed aggregate piers or aggregate piers should be able to provide a k value and a coefficient of friction. 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.

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).

Potential Vertical Rise

With both support options, we expect that the potential vertical rise of the ground storage reservoir will be less than ½ inch.

Drainage System

Due to 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 – Ground Storage Reservoir

We recommend that the footing be placed at a sufficient depth for frost protection. 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.

Pump Station & Generator

Design Data

The pump station will be a slab-on-grade structure with an approximate footprint area of 2,000 square feet. We understand that the finished floor of the pump station will be at elevation 1,481.0 feet (1 foot to 3 feet above the existing grades). We anticipate that foundation support for the pump station will be provided by perimeter footings resting below frost depth. Light to moderate foundation and floor loads are expected for the pump station. The generator will be located on the east side of the pump station. We expect that the generator will be supported by an on-grade slab.

Discussion

In our opinion, a spread footing foundation system can be used for support of the proposed pump station after the recommended site preparation has been performed. Also, an on-grade slab can be used for support of the generator.

It is our opinion that the topsoil materials are not suitable for support of the footings or floor slab of the pump station or the generator slab. Due to the low strength characteristics of the loess soils, we recommend that additional site preparation (overexcavation and backfill with drainage rock) be performed beneath the footings of the pump station. The additional site preparation will assist in providing uniform support over the low strength soils and provide a stable working surface for footing construction.

Site Preparation – Footing Areas

The initial site preparation in the footing areas of the pump station should consist of removing the topsoil materials in order to expose the loess soils, coarse alluvium soils or glacial till soils. Following the removals, we recommend that an overexcavation be performed to a minimum depth of 12 inches below the bottom-of-footing elevation. The overexcavated areas should be backfilled with a minimum of 12 inches of drainage rock. If the level of the drainage rock is below the bottom-of-footing elevation, then the remainder of the excavation could be backfilled with drainage rock or granular structural fill. The thickness of the granular material (drainage rock or granular structural fill) will exceed 12 inches in areas where the topsoil materials extend more than 12 inches below the bottom-of-footing elevation.

Site Preparation – Floor Slab Areas

The site preparation in the floor slab areas of the pump station should consist of removing the topsoil materials or excavating to a minimum depth of 6 inches below the bottom-of-slab elevation, whichever is greater. Once the subgrade is approved, granular structural fill should be placed and compacted up to the bottom-of-slab elevation. The thickness of the granular structural fill will exceed 6 inches in areas where the topsoil materials extend more than 6 inches below the bottom-of-slab elevation. We recommend that the final 6 inches of granular structural fill beneath the floor slab consist of select granular fill.

Site Preparation – Generator Slab

The site preparation for the generator slab should consist of removing the topsoil materials or excavating to a minimum depth of 6 inches below the bottom-of-slab elevation, whichever is greater. The thickness of the granular structural fill will exceed 6 inches in areas where the topsoil materials extend more than 6 inches below the bottom-of-slab elevation. Also, please see the section entitled *Frost Protection – Generator Slab* regarding frost protection for the generator slab.

Foundation Loads & Settlement

If our recommendations are followed during site preparations, then it is our opinion that the footings of the pump station can be sized for a net allowable soil bearing pressure of up to 2,000 psf. The net allowable soil bearing pressure may be increased by one-third for transient wind or seismic loads. With the expected loads, net allowable soil bearing pressure and our site preparation recommendations, total settlement of the footings should be less than 1 inch and differential settlement should be less than ½ inch over 50 feet. Unknown soil conditions at the site that are different from those depicted at the test boring location could increase the amount of expected settlement.

Floor Slab & Soil Modulus of Subgrade Reaction

If our recommendations are followed during site preparations, then it is our opinion that the floor slab of the pump station can be designed using a k value of 100 psi/inch.

Coefficient of Friction

It is our opinion that a friction factor of 0.45 can be used between the drainage rock or 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.

Frost Protection – Footings – Pump Station

We recommend that all footings be placed at a sufficient depth for frost protection. The perimeter footings for heated buildings should be placed such that the bottom of the footing is a minimum of 4 feet below the finished exterior grade. Interior footings in heated buildings can be placed beneath the floor slab. Footings for unheated areas and canopies, or footings that are not protected from frost during freezing temperatures, should be placed such that the bottom of the footing is a minimum of 5 feet below the finished exterior grade.

Frost Protection – Generator Slab

Based on the current grades at the location of the generator slab and our site preparation recommendations for the generator slab, about 2 feet of granular structural fill will be provided beneath the generator slab. In our opinion, this layer (2 feet) of granular structural fill will reduce (but not eliminate) the amount of potential frost heave of the slab. If it is desired to eliminate the amount of potential frost heave of the generator slab, then the granular structural fill should extend to a depth of 4 feet below the finished exterior grade.

General Recommendations for the Ground Storage Reservoir, Pump Station & Generator

Excavation

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

Water & Saturated Soils

If water or saturated soils are encountered at the bottom of an 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 any fill, footings or slabs. Based on the groundwater levels at the test boring locations, some drainage rock may be needed during construction with the excavate/refill system for the ground storage reservoir. We would like to point out that drainage rock is already recommended in the footing areas of the pump station.

Laterally Oversized Excavations – Granular Structural Fill & Drainage Rock

Where granular structural fill or drainage rock is needed below the footings or slabs, the bottom of the excavations should be laterally oversized 1 foot beyond the edges of the footings or slabs for each vertical foot of granular structural fill or drainage rock needed below the footings or slabs (1 horizontal : 1 vertical).

Dewatering

Dewatering may be needed during construction, especially with the excavate/refill system for the ground storage reservoir. It may be possible to remove and control water entering the excavations 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. Waterbearing sand soils were encountered at test boring 3.

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 Loess	120	53	17	0.55	0.71	1.83
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 Loess	85	103	66	94	219**	106**
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 could consist of the on-site loess soils or 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 2021 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 =

0.076 g, S_1 = 0.037 g, S_{MS} = 0.122 g, S_{M1} = 0.089 g, S_{DS} = 0.081 g, S_{D1} = 0.060 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 2021 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	25
Loess Soils	25
Glacial Till Soils	15

Concrete Pavement Areas

Discussion

Loess soils are expected to be encountered as subgrade soils in the pavement areas. In general, the loess soils have low strength characteristics and are prone to instability during freeze-thaw cycles. In addition, the loess soils are prone to instability from normal construction traffic and additional moisture. With that said, we recommend placing a geotextile fabric beneath the aggregate base course.

Subgrade Preparation

We recommend that the subgrade preparation in the pavement areas consist of removing any vegetation and highly organic materials. A removal depth of about 1 ½ feet should be expected. Following the removals, the subgrade should be prepared by cutting or placing and compacting subgrade fill up to the design subgrade 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 1 percent to 4 percent below the optimum moisture content as determined by standard Proctor (ASTM:D698). The moisture-conditioned soils should then be compacted.

Prior to the placement of the geotextile fabric, we recommend that a proof roll be performed on the exposed subgrade with a truck weighing 20 tons to 30 tons. During the proof roll, unstable areas in the subgrade should be delineated from stable areas. An unstable area would be considered a location with at least 1 inch of rutting or deflection. Unstable areas will need additional corrections to provide a uniform and stable subgrade condition. 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, and/or the placement of granular subbase at the subgrade surface. The type of correction performed should be determined after observing the performance of the subgrade during the proof roll test. 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 (late fall and the spring thaw).

Concrete Pavement Section Thickness

We expect that the vehicle traffic will vary from automobiles to occasional trucks. For the concrete pavement section, we recommend 6 inches concrete overlying 12 inches of aggregate base course. Again, a geotextile fabric should be placed beneath the aggregate base course. The concrete pavement should meet the requirements of the IADOT Standard Specifications.

It should be noted that routine maintenance such as crack filling and localized patching should be expected with our recommendations. The design section could be reduced if the owner is willing to assume additional maintenance costs or potentially shorter pavement life.

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 loess soils, coarse alluvium soils and glacial till soils can likely be reused as trench backfill. Some moisture adjustment should be expected with the majority of the loess 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 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 15 percent by weight passing the #200 sieve. The granular structural fill should be placed in lifts of up to 1 foot in thickness.

General Structural Fill – The general structural fill should consist of either a granular or clay material. 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. The granular material can be placed in lifts of up to 1 foot in thickness. If a clay material is selected, then it should consist of a non-organic clay having a liquid limit less than 45. Scrutiny on the clay material's moisture content should be made prior to the acceptance and use. The clay fill should be placed in lifts of up to 6 inches in thickness. The on-site loess soils, coarse alluvium soils and glacial till soils could be used as general structural fill. Drying, some excessive, will be needed with the loess soils. The on-site topsoil materials should not be used as general structural fill.

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

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.

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 & Exterior Foundation Wall Backfill for Slab-on-Grade Structures – The exterior backfill 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. The majority of the on-site soils can be used as exterior backfill.

Interior Foundation Wall Backfill for Slab-on-Grade Structures – We recommend that granular structural fill be used to backfill the interior side of the foundation walls. The interior backfill should be placed in lifts of up to 1 foot in thickness.

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 and the exterior foundation wall backfill for slab-on-grade structures.

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 either gradation 11 or 14 in the IADOT standard specifications for Highway and Bridge Construction manual.

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%
Below Footings – Pump Station	95%
Below Slabs – Pump Station & Generator	95%
Exterior Foundation Wall Backfill for Slab-on-Grade Structures	95%
Behind Below-Grade & Retaining Walls	95% - 98%
Subgrade Fill in Pavement Areas	95%
Aggregate Base Course in Pavement Areas	97%
Granular Subbase in Pavement Areas	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 backfill materials, when used as backfill around a foundation should be maintained within a range of plus or minus 2 percent of the materials' optimum moisture content. When the clay backfill materials are used below a vehicle area, or as site grading, the materials' moisture content should be maintained within a range of minus 1 percent to minus 4 percent of the materials' optimum moisture content. The moisture content of the trench backfill soils should be adjusted to a moisture level that is within plus or minus 2 percent of the optimum moisture content. The optimum moisture content should be determined using a standard Proctor (ASTM: D698) test.

The moisture content of the granular backfill materials should be maintained at a level that will be conducive for vibratory compaction.

Corrosive Potential of the Soils

Soil samples were collected from test borings 5 and 6 and were submitted for pH, sulfate content, chloride content, resistivity, redox potential and sulfide content testing. The results of the pH, resistivity, redox potential and sulfide content testing are shown in Table 8 and the results of the chloride content and sulfate content testing are shown in Table 10.

Table 8. pH, Resistivity, Redox Potential & Sulfide Content Results

Test Boring	Depth (ft)	Soil Classification	pH	Resistivity (ohm-cm)	Redox Potential (mV)	Sulfide (mg/kg)
5	2 to 7	CL (Loess)	8.5	1,742	129	<0.01
6	7 to 13 ½	CL (Glacial Till)	9.0	1,340	124	<0.01

Note: The resistivity values are minimum values (saturated condition).

Using the Ductile Iron Pipe Research Association's (DIPRA) 10-point system and the lab results shown in Table 8, we evaluated the corrosive potential of the tested soils. The 10-point system is based on resistivity, pH, redox potential, sulfides and moisture. An explanation of the point system is shown on Figure 3. The results of the evaluation are shown in Table 9. According to DIPRA, a value of 10 or more indicates that the soil is corrosive to underground piping and metals, while a value below 10 indicates that the soil is not corrosive to underground piping and metals. Based on Table 9, the loess soils and glacial till soils tested are considered corrosive. With that said, protective measures should be taken.

Table 9. Results of DIPRA 10-Point System Evaluation

Test Boring	Depth (ft)	Soil Classification	Total Value	Result
5	2 to 7	CL (Loess)	10	Corrosive
6	7 to 13 ½	CL (Glacial Till)	15	Corrosive

Note: A "poor drainage, continuously wet" was used for the moisture condition (2 points).

Table 10. Sulfate & Chloride Content Test Results

Test Boring	Depth (ft)	Soil Classification	Sulfate (mg/kg)	Chloride (mg/kg)
5	2 to 7	CL (Loess)	12	6
6	7 to 13 ½	CL (Glacial Till)	26	11

As shown in Table 10, the sulfate contents were 12 mg/kg and 26 mg/kg. Generally, the sulfate attack on concrete is considered mild if the sulfate content is below 150 mg/kg, moderate if the sulfate content is between 150 mg/kg and 1,500 mg/kg and severe if the sulfate content is above 1,500 mg/kg. Based on the test results, the potential sulfate attack on the concrete will be mild. Regarding the chloride content levels, a level below 250 mg/kg is considered mildly corrosive.

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 structures should be sloped such that positive drainage away from the structures is provided. Also, a system to collect and channel roof run-off waters away from the pump station is suggested.

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.

We recommend a geotechnical engineer or a geotechnical engineering technician working under the direct supervision of a geotechnical engineer monitor the installation of the rammed aggregate piers or aggregate piers. Detailed records should be kept during installation.

SUBSURFACE EXPLORATION PROCEDURES

Test Borings

We performed 9 SPT borings on June 13, 2022 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 collected from the test boring locations will be retained in our office for a period of 1 month after the date of this report and will then be discarded unless we are notified otherwise.

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), Atterberg limits (liquid and plastic limits), pH, sulfate content, chloride content, resistivity, redox potential and sulfide content. 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 attached data sheets.

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 (SD)
Geotechnical Manager

Daniel Hanson, PE (IA)
General Manager

LICENSED PROFESSIONAL ENGINEER
DANIEL R. HANSON
11577
6-27-22
IOWA

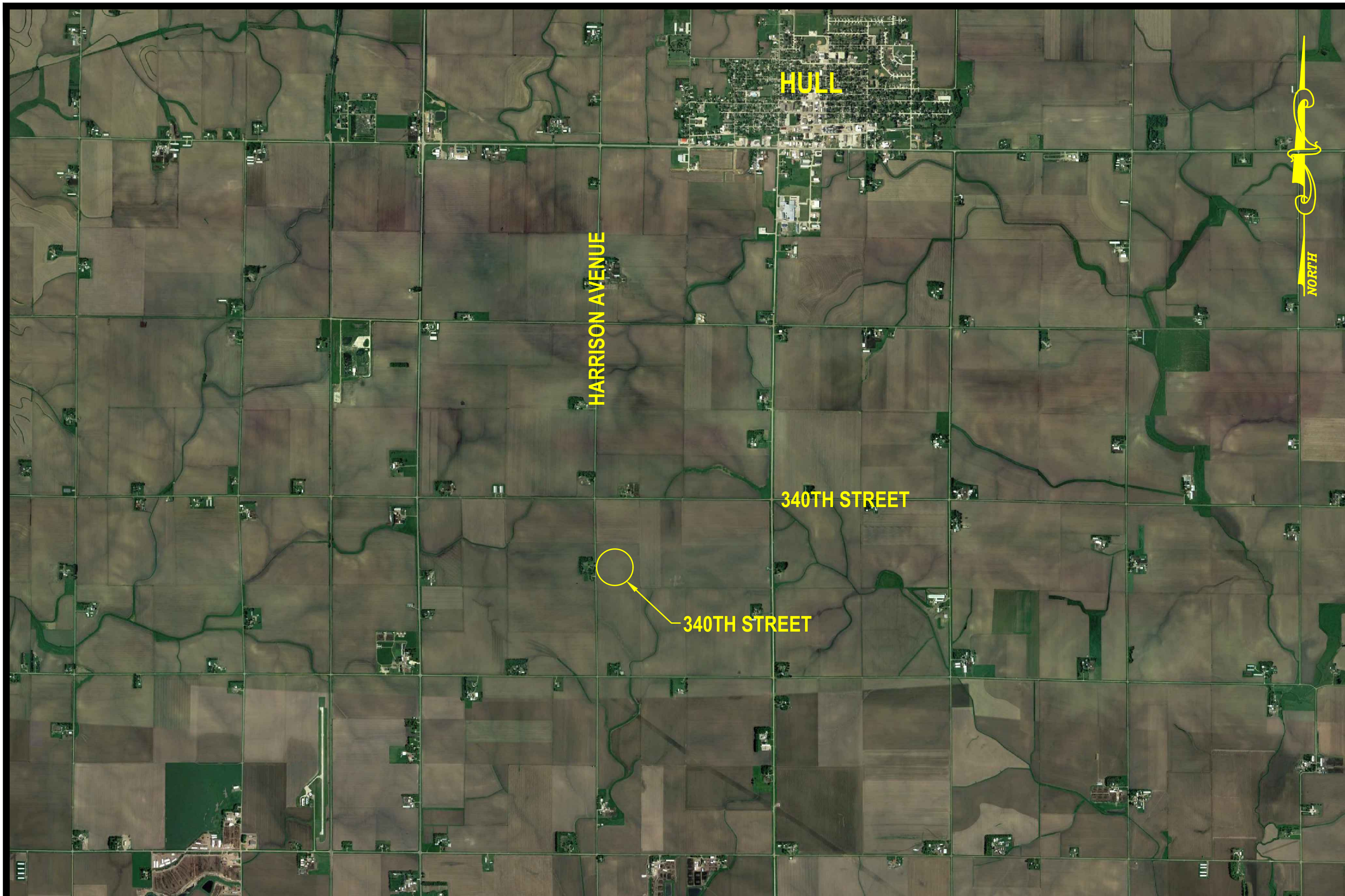

FIGURE 1
SITE LOCATION MAP
PROPOSED GROUND STORAGE RESEVOIR & PUMP STATION
LEWIS & CLARK REGIONAL WATER SYSTEM
HARRISON AVENUE
NEAR HULL, IA

ACAD/GEOTEK/JARED/22-971

PROJECT#: 22-971

DRAWN BY: DHP

GEOTEK ENGINEERING & TESTING SERVICES, INC.
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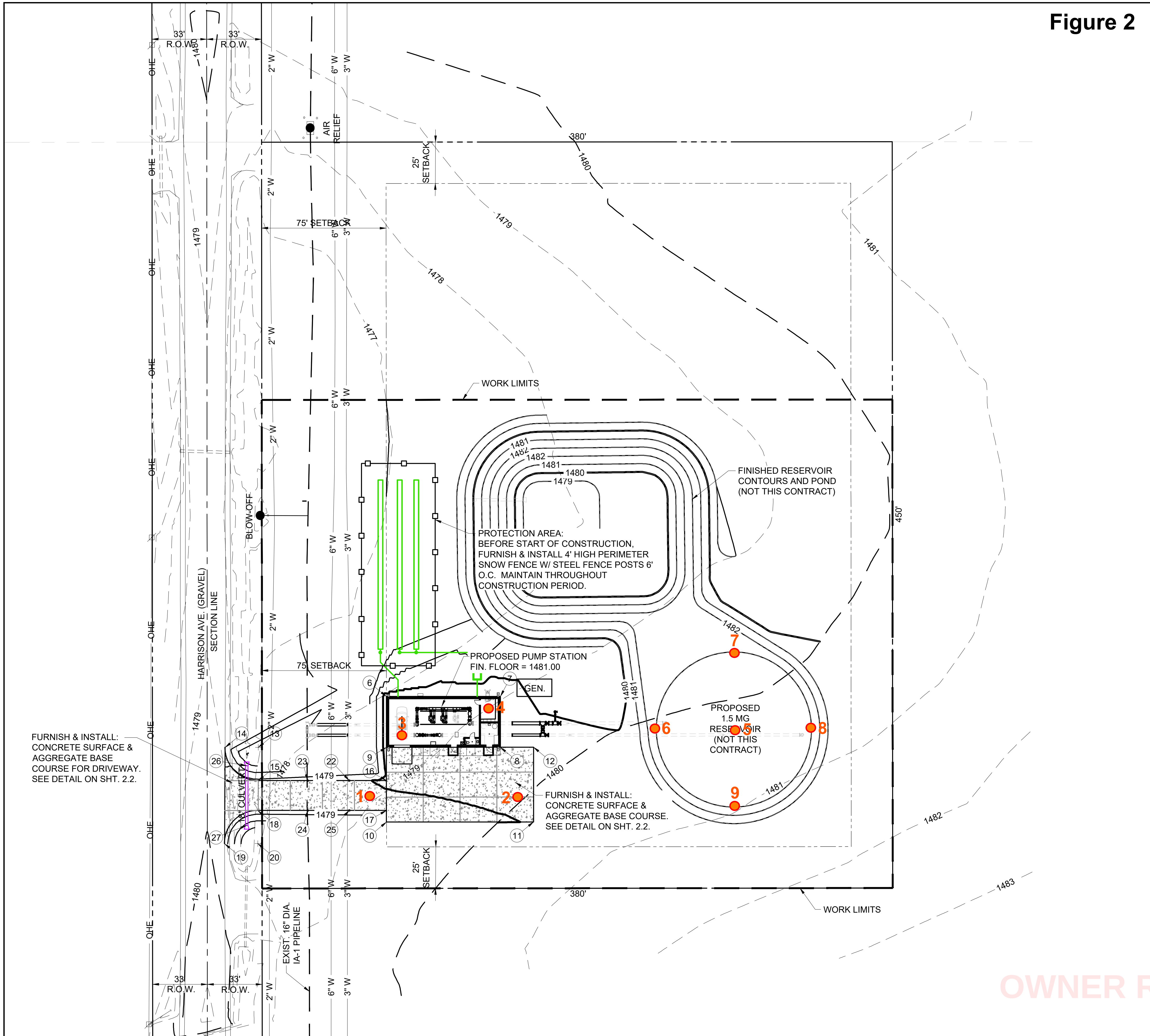
Figure 2



COORDINATE SCHEDULE

◯	NORTHING	EASTING	ELEV.	DESCIPTION
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	4212344.0705	3894169.9196	1480.50	NW CORNER OF BLDG.
7	4212412.7372	3894169.9678	1480.50	NE CORNER OF BLDG.
8	4212412.7587	3894139.3009	1480.50	SE CORNER OF BLDG.
9	4212344.0921	3894139.2527	1480.50	SW CORNER OF BLDG.
10	4212344.0921	3894094.2683	1479.60	EDGE OF CONCRETE
11	4212432.7587	3894094.2683	1480.04	EDGE OF CONCRETE
12	4212432.7587	3894139.3150	1480.50	EDGE OF CONCRETE
13	4212266.8665	3894139.1985	-	20' RADIUS SWING POINT
14	4212246.8665	3894139.1844	M.E.	EDGE OF GRAVEL / CONC.
15	4212266.8806	3894119.1985	1479.22	EDGE OF CONCRETE
16	4212344.1061	3894119.2527	1480.10	EDGE OF CONCRETE
17	4212344.1188	3894101.2527	1479.74	EDGE OF CONCRETE
18	4212266.5111	3894101.1982	1479.56	EDGE OF CONCRETE
19	4212246.5252	3894081.1842	M.E.	EDGE OF GRAVEL / CONC.
20	4212266.5252	3894081.1982	-	20' RADIUS SWING POINT
21	-	-	-	-
22	4212321.6895	3894119.2370	1479.84	EDGE OF CONCRETE
23	4212296.6895	3894119.2194	1479.56	EDGE OF CONCRETE
24	4212296.7022	3894101.2194	1479.63	EDGE OF CONCRETE
25	4212321.7022	3894101.2370	1479.69	EDGE OF CONCRETE
26	4212259.8831	3894128.1936	1475.99	END OF 12" CMP CULVERT
27	4212259.8947	3894092.1936	1476.49	END OF 12" CMP CULVERT

M.E. = MATCH EXISTING

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PROJECT / SHEET TITLE:
LEWIS & CLARK HULL PUMP STATION
SITE GRADING PLAN
HULL, IOWA

REV.	DATE	DESCRIPTION

JOB No.:	20000.49.01
DATE:	MAY 2022
DESIGNED BY:	B.E.N.
CHECKED BY:	B.A.L.
DRAWN BY:	S.A.N.

0 1/2" 1"
SCALE REDUCTION BAR

SHEET No.:
1-2.2

FIGURE 3

Table A.1 Soil-test evaluation

Soil Characteristics Based on Samples Taken Down to Pipe Depth		
Resistivity—ohm-cm (based on water-saturated soil box):		Points*
	<1,500	10
	≥1,500–1,800	8
	>1,800–2,100	5
	>2,100–2,500	2
	>2,500–3,000	1
	>3,000	0
pH:		
	0–2	5
	2–4	3
	4–6.5	0
	6.5–7.5	0†
	7.5–8.5	0
	>8.5	3
Redox potential:		
	> +100 mV	0
	+50 to +100 mV	3.5
	0 to +50 mV	4
	Negative	5
Sulfides:		
	Positive	3.5
	Trace	2
	Negative	0
Moisture:		
	Poor drainage, continuously wet	2
	Fair drainage, generally moist	1
	Good drainage, generally dry	0

*Ten points or greater indicates that soil is corrosive to ductile-iron pipe; protection is needed. Refer to paragraph A.3 for a description of Uniquely Severe Environments and additional considerations.

†If sulfides are present and low (<100 mv) or negative redox-potential results are obtained, add three points for this range.

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971** BORING NO. **1 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1478.3 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, dry to moist, (CL)	TOPSOIL			1	HSA	24				
6	**LEAN CLAY**: brown and gray, moist to wet, firm to stiff, (CL)	LOESS	9		2	SPT	30				
			5		3	SPT					
8½	**CLAYEY SAND**: medium grained, brown, wet, medium dense, (SC)	COARSE ALLUVIUM	9		4	SPT					
	Bottom of borehole at 8½ feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	4:34 pm	8.5	--	7	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 4:34 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971** BORING NO. **2 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1479.6 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: very dark brown, dry to moist, (CL)	TOPSOIL			1	HSA					
2½	**LEAN CLAY**: brown and gray, moist to wet, firm, (CL)	LOESS	6		2	SPT	24	97			
			6		3	SPT	29				
6	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff, (CL)	GLACIAL TILL	9		4	SPT					
8½	Bottom of borehole at 8½ feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	4:49 pm	8.5	--	7	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 4:49 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

GEOTECHNICAL TEST BORING 22-971.GPJ GEOTEKENG.GDT 6/23/22

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971** BORING NO. **3 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1478.4 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, dry to moist, (CL)	TOPSOIL			1	HSA					
6	**LEAN CLAY**: brown and gray, moist to wet, soft to firm, (CL)	LOESS	5		2	SPT	26	93			
			4		3	SPT	26	95			300
10½	**SAND WITH SILT**: medium grained, brown, moist to waterbearing, loose to medium dense, percent passing the #200 sieve = 11% (at 8') (SP-SM)	COARSE ALLUVIUM	11		4	SPT					
			8	▼	5	SPT					
19½	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	14		6	SPT					
			19		7	SPT					
26	**LEAN CLAY WITH SAND**: a little gravel, brown and dark gray, moist, very stiff, (CL)	GLACIAL TILL	18		8	SPT					
			20		9	SPT					
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	4:53 pm	26	--	17	▼ 10
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 4:19 pm

METHOD 3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971**

BORING NO. **4 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1478.6 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: very dark brown, dry to moist, (CL)	TOPSOIL			1	HSA					
2½	**LEAN CLAY**: brown and gray, moist to wet, soft to firm, (CL)	LOESS	7		2	SPT	24				
			4		3	SPT	28	96			
7	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, firm to stiff, (CL)	GLACIAL TILL	8		4	SPT	17	116			3000
			11	▼	5	SPT					
			14		6	SPT					
14½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff to very stiff, (CL)	GLACIAL TILL	15		7	SPT					
			18		8	SPT					
24½	**LEAN CLAY WITH SAND**: a little gravel, brown and dark gray, moist, very stiff, (CL)	GLACIAL TILL	23		9	SPT					
26	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	4:52 pm	26	--	13	▼ 10
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 3:34 pm

METHOD 3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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& TESTING SERVICES, INC.
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971** BORING NO. **5 (1 of 2)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1479.8 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: very dark brown, moist, (CL)	TOPSOIL			1	FA					
2	**LEAN CLAY**: brown and gray, moist to wet, soft to firm, (CL)	LOESS	5		2	SPT	24				
			4		3	SPT	26				
7	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, firm to stiff, (CL)	GLACIAL TILL	7		4	SPT	18	119			2700
	Excavation Depth (9.8') - Option 1 GSR										
			9		5	SPT					
			12		6	SPT					
			14		7	SPT	18	112			4100
24	**LEAN CLAY WITH SAND**: a little gravel, brown and dark brown, moist, very stiff, (CL)	GLACIAL TILL	21		8	SPT					
			22		9	SPT					

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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START 6-13-22 COMPLETE 6-13-22 12:55 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Roy Hanson

GEOTEK ENGINEERING
& 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 # **22-971**　　BORING NO. **5 (2 of 2)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1479.8 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY WITH SAND: a little gravel, brown and dark brown, moist, very stiff, (CL) *(Continued from previous page)*	GLACIAL TILL	25		10	SPT	18	114			5300
39	**SILTY SAND**: fine grained, brown, waterbearing, very dense, (SM)	GLACIAL OUTWASH	36		11	SPT					
44	**LEAN CLAY WITH SAND**: a little gravel, dark brown and dark gray, moist, hard, (CL)	GLACIAL TILL	32		12	SPT					
49	**LEAN CLAY WITH SAND**: a little gravel, dark gray, moist, very stiff, (CL)	GLACIAL TILL	27		13	SPT					
			26		14	SPT					
59	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, very stiff, (CL)	GLACIAL TILL	20		15	SPT					
61	Bottom of borehole at 61 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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START 6-13-22　COMPLETE 6-13-22 12:55 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Roy Hanson

GEOTECHNICAL TEST BORING 22-971.GPJ GEOTEKENG.GDT 6/21/22

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971**

BORING NO. **6 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1479.8 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
2	**LEAN CLAY**: brown and gray, moist to wet, soft to firm, (CL)	LOESS	6		2	SPT	25				
			4		3	SPT	29				
7	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, firm to very stiff, (CL)	GLACIAL TILL	8		4	SPT	15		36	13	
	Excavation Depth (9.8') - Option 1 GSR										
			11		5	SPT					
			12		6	SPT	14				
			15		7	SPT					
			14		8	SPT					
			18		9	SPT					
26	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	4:40 pm	26	--	24	none
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START 6-13-22 COMPLETE 6-13-22 4:40 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Roy Hanson

GEOTECHNICAL TEST BORING 22-971.GPJ GEOTEKENG.GDT 6/21/22

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& TESTING SERVICES, INC.
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971** BORING NO. **7 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1479.3 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
8½	**LEAN CLAY**: brown and gray, moist to wet, soft to firm, (CL)	LOESS	7		2	SPT	27				
			4		3	SPT	29				
					4	BAG					
			4		5	SPT	30				
19	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff, (CL)	GLACIAL TILL	11		6	SPT	16	117			6200
	Excavation Depth (9.3') - Option 1 GSR										
			12		7	SPT					
			13		8	SPT					
26	**LEAN CLAY WITH SAND**: a little gravel, brown and dark brown, moist, very stiff, (CL)	GLACIAL TILL	19		9	SPT					
			20		10	SPT					
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	2:00 pm	26	--	24	none
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START 6-13-22 COMPLETE 6-13-22 12:00 pm

METHOD 3.25" ID Hollow Stem Auger

CREW CHIEF Roy Hanson

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971**

BORING NO. **8 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1480.3 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	LEAN CLAY: brown and gray, moist to wet, soft to firm, (CL)	LOESS	6		2	SPT	25				
			5		3	SPT	28				
8½			4		4	SPT	30	92			
	LEAN CLAY WITH SAND: a little gravel, brown, moist, stiff to very stiff, a few lenses of sand near 9' (CL)	GLACIAL TILL	9	▼	5	SPT	17	116			4100
	Excavation Depth (10.3') - Option 1 GSR										
			11		6	SPT					
			14		7	SPT					
			14		8	SPT					
26			20		9	SPT					
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	2:55 pm	26	--	24	22
6-13-22	4:45 pm	26	--	24	▼ 10.5
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START 6-13-22 COMPLETE 6-13-22 2:55 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Roy Hanson

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
909 E 50th St N
Sioux Falls, South Dakota, 57104
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **22-971**

BORING NO. **9 (1 of 1)**

PROJECT **Proposed Ground Storage Reservoir & Pump Station, Lewis & Clark Regional Water System, Harrison Avenue, Near Hull, IA**

SURFACE ELEVATION 1480.7 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
2	**LEAN CLAY**: brown and gray, moist to wet, firm, (CL)	LOESS	6		2	SPT	22				
			5		3	SPT	27				
7	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff to very stiff, (CL)	GLACIAL TILL	9		4	SPT	16	115			
	Excavation Depth (10.7') - Option 1 GSR		9		5	SPT	17	114			4200
			11		6	SPT					
			15		7	SPT					
			19		8	SPT					
			23		9	SPT					
26	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	3:55 pm	26	--	24	none
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START 6-13-22 COMPLETE 6-13-22 3:50 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Roy Hanson

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%