GEOTECHNICAL EXPLORATION
PROPOSED METER BUILDING
LEWIS & CLARK REGIONAL WATER SYSTEM
600 N. 2ND AVENUE
SHELDON, IOWA
GEOTEK #22-969

LICENSED PROFESSIONAL ENGINEER DANIEL R. HANSON 11557 IOWA 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: 1-24 PLUS APPENDIX

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
909 East 50th Street North
Sioux Falls, South Dakota 57104
Phone 605-335-5512 Fax 605-335-0773

June 27, 2022

Banner Associates
409 22nd Avenue South
Brookings, South Dakota 57006

Attn: Bryan Lipp, PE

Subj: Geotechnical Exploration
Proposed Meter Building
Lewis & Clark Regional Water System
600 N. 2nd Avenue
Sheldon, Iowa
GeoTek #22-969

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

Jared Haskins, PE (SD)
Geotechnical Manager

Daniel Hanson

Daniel Hanson, PE (IA)
General Manager

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INTRODUCTION

Project Information

This report presents the results of the recent geotechnical exploration program for the proposed meter building for the Lewis & Clark Regional Water System in Sheldon, 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 6 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, 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 new meter building will be located at the site of Sheldon's water treatment plant at 600 N. 2nd Avenue in Sheldon, Iowa. A site location map (Figure 1) is attached showing the proposed location of the meter building. The area designated for the meter building is currently vacant and covered with vegetation.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were provided by Banner Associates and were 1,402.4 feet at test boring 1, 1,397.1 feet at test boring 2, 1,397.4 feet at test boring 3, 1,396.6 feet at test boring 4, 1,395.8 feet at test boring 5 and 1,395.7 feet at test boring 6. 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

Six (6) test borings were performed on June 13, 2022. Of the 6 test borings, 2 test borings (test borings 1 and 2) were performed for the water pipes, 2 test borings (test borings 3 and 4) were performed in the concrete pavement/gravel surfaced areas and 2 test borings (test borings 5 and 6) were performed for the meter building. 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: existing fill materials, coarse alluvium soils and glacial till soils. The existing fill materials were encountered at all of the test borings and extended to depths varying from 9 ½ feet to 14 ½ feet. The coarse alluvium soils were encountered beneath the existing fill materials. The coarse alluvium soils extended to the termination depth of test borings 1, 2, 3 and 4. The glacial till soils were encountered beneath the coarse alluvium soils at test borings 5 and 6.

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

Existing Fill Materials

The existing fill materials consisted of lean clay (CL), lean clay with sand (CL) and clayey sand (SC). Debris was also encountered within the existing fill materials at all of the test borings. The debris included concrete and pieces of bricks. "N" values within the existing fill materials ranged from 4 to 20. The moisture condition of the existing fill materials was moist.

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 (SP). "N" values within the coarse alluvium soils ranged from 8 to 20 (relative density of loose, medium dense and 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 9 to 16 (consistency of 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 the test boring locations. 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	1,402.4	Dry to Cave-In Depth	N/A
2	1,397.1	Dry to Cave-In Depth	N/A

Table 1 (Continued). Groundwater Levels

Test Boring	Ground Surface Elevation, ft	Groundwater Level, ft	Elevation of Groundwater, ft
3	1,397.4	Dry to Cave-In Depth	N/A
4	1,396.6	Dry to Cave-In Depth	N/A
5	1,395.8	13	1,382.8
6	1,395.7	13	1,382.7

The water levels may or may not be an accurate indication of the depth or lack of subsurface groundwater. The limited length of observation restricts the accuracy of the measurements. Long term groundwater monitoring was not included in our scope of work.

ENGINEERING REVIEW & RECOMMENDATIONS

Project Design Data

We understand that the project will consist of constructing a new meter building in Sheldon, Iowa. The meter building will be a slab-on-grade structure with an approximate footprint area of 750 square feet. We understand that the finished floor of the meter building will be at elevation 1,397.0 feet (about 1 foot above the existing surface grades). We anticipate that foundation support for the meter building will be provided by perimeter footings resting below frost depth. Light foundation and floor loads are expected for the meter building. A generator will be located on the east side of the meter building. We expect that the generator will be supported by an on-grade slab. New concrete pavement and gravel surfaced areas will be constructed on the west side of the meter building. New water pipes will also be installed.

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.

Meter Building & Generator

Discussion

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

Test borings 5 and 6 were performed for the meter building and generator. Test borings 5 and 6 encountered 9 ½ feet and 12 feet of existing fill materials overlying coarse alluvium soils and glacial till soils. Due to the debris within the existing fill materials, it is our opinion that the existing fill materials are not suitable for support of the footings or floor slab of the meter building or the generator slab. With that said, footing and slab support should be provided by the coarse alluvium soils or glacial till soils.

Site Preparation – Footprint of the Meter Building & Generator Slab

The site preparation for the entire footprint of the meter building and the generator slab should consist of removing the existing fill materials in order to expose the coarse alluvium soils or glacial till soils. If the excavation required to expose the coarse alluvium soils or glacial till soils extends below the bottom-of-footing/bottom-of-slab elevation, then we recommend placing and compacting granular structural fill up to the bottom-of-footing/bottom-of-slab elevation. We also recommend placing a 6-inch layer of select granular fill beneath the floor slab of the meter building. Please refer to Table 2 for a summary of the anticipated minimum excavation depths to remove the unsuitable soils encountered at the test borings performed for the meter building and generator. The depth of the excavations will likely vary within the footprint of the meter building and generator.

Table 2. Estimated Excavation Depths – Footprint of the Meter Building & Generator

Test Boring Number	Ground Surface Elevation, ft	Anticipated Excavation Depth, ft	Approximate Excavation Elevation, ft
5	1,395.8	12	1,383.8
6	1,395.7	9 ½	1,386.2

Excavation – Meter Building & Generator

All excavations for the meter building and generator should be performed with a track backhoe with a smooth edge bucket. The subgrade within the footprint of the meter building 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 any fill, footings or slabs.

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 excavation 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 required below the footings or slabs (1 horizontal : 1 vertical).

Foundation Loads & Settlement

If our recommendations are followed during site preparations, then it is our opinion that the footings of the meter building can be sized for a net allowable soil bearing pressure of up to 3,000 pounds per square foot (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 locations 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 meter building can be designed using a soil modulus of subgrade reaction (k value) of 150 psi/inch.

Retaining Walls

We recommend backfilling any retaining walls with free-draining sand. The active lateral earth pressures 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 soils. If the above movement cannot be tolerated, then we recommend using the at-rest lateral earth pressures to design the walls. The zone of the sand 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). Also, we recommend capping the sand backfill section with 1 foot to 2 feet of clayey soil in areas that will not have asphalt or concrete surfacing to minimize infiltration of surface waters. Table 3 shows the equivalent fluid unit weight values for the various soil types anticipated for this project.

Table 3. Equivalent Fluid Unit Weight Values

Soil Type	At-Rest, pcf		Active, pcf		Passive, pcf	
	Drained	Submerged	Drained	Submerged	Drained	Submerged
Clay	-	-	-	-	220*	115*
Free-Draining Sand (SP)	50	90	35	80	460*	230*

*Value below frost depth – 0 pcf above frost depth.

The passive resistance in front of a retaining wall should not be used in an analysis unless the wall extends well below the depth of frost penetration due to loss of strength upon thawing. In addition, development of passive lateral earth pressure in the soil in front of a wall requires a relatively large rotation or outward displacement of the wall. Therefore, we do not recommend using passive resistance in front of the wall for the analysis.

During backfill operations, bracing and/or shoring of the walls may be needed. Only hand-operated compaction equipment should be used directly adjacent to the walls.

Dewatering

Some dewatering may be needed during construction. In areas where clay soils are encountered, it may be possible to remove and control water entering the excavations using normal sump pumping techniques. If waterbearing sand soils are encountered, then an extensive dewatering system will be needed. The contractor should provide appropriate dewatering methods and equipment.

Coefficient of Friction

It is our opinion that a friction factor of 0.35 can be used between the natural clay soils and the bottom of the concrete. A friction factor of 0.45 can be used between the natural sand soils, granular structural fill or drainage rock and the bottom of the concrete. The friction values are considered ultimate values. We recommend applying a theoretical safety factor of at least 2.0.

Frost Protection – Footings

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 our site preparation recommendations for the generator slab, a significant layer of granular structural fill will be provided beneath the generator slab. In our opinion, this layer of granular structural fill will help minimize potential frost movement.

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 ground acceleration values are as follows: S_S = 0.070 g, S_1 = 0.037 g, S_{MS} = 0.112 g, S_{M1} = 0.089 g, S_{DS} = 0.075 g, S_{D1} = 0.059 g. 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.

Concrete Pavement Areas

Discussion

As previously stated, debris was encountered within the existing fill materials at all of the test borings. In our opinion, the existing fill materials that contain debris are prone to settlement and should not be relied upon to provide uniform support of the concrete pavement. It should be understood that relying on the existing fill materials that contain debris for support of the concrete pavement introduces the risk for potential future settlement. In addition, disturbing the debris during construction may cause the debris to shift and potentially settle. We have provided 2 subgrade preparation options in the concrete pavement areas. Again, there is risk associated with the existing fill materials that contain debris.

Subgrade Preparation Below Concrete Pavement (Remove Existing Fill Materials)

In order to eliminate the risk of settlement of the new concrete pavement, we recommend removing the existing fill materials from beneath the new concrete pavement. Based on the test borings, the existing fill materials extended to depths varying from 9 ½ feet to 14 ½ feet. Again, disturbing the debris during construction may cause the debris to shift and potentially settle. The overexcavated areas (below the concrete pavement) should be backfilled with clay backfill or granular material.

Alternative Subgrade Preparation Below Concrete Pavement (Partial Removal)

With the alternative subgrade preparation, the owner will assume some risk of distress of the new concrete pavement due to potential settlement of the existing fill materials that contain debris that are left in-place. Again, disturbing the debris during construction may cause the debris to shift and potentially settle. With this alternative, the subgrade preparation below the concrete pavement should consist of excavating to a minimum depth of 18 inches below the concrete pavement. The bottom of the excavation should be observed. If excessive debris is observed, then additional removals should be considered. We recommend installing a geotextile fabric at the bottom of the excavation, followed by placing and compacting aggregate base course up to the design elevation. Regarding the geotextile fabric, we recommend using Mirafi HP 370, Propex Geotex 3x3 HF, Huesker Comtrac P 45/45 or approved alternative. The amount of settlement with this alternative is unknown due to the uncertainty of the debris.

Concrete Pavement Section Thicknesses

Table 4 shows the recommended concrete pavement section thicknesses for the project. Again, the owner will assume some risk of distress of the new concrete pavement due to potential settlement of the existing fill materials that are left in-place.

Table 4. Concrete Pavement Section Thicknesses

Subgrade Preparation Option	Concrete Pavement Thickness, in	Aggregate Base Course Thickness, in	Subgrade Reinforcement
1	6	6	*
2	6	18	Geotextile Fabric

Note: The numbers are for the following options: (1) remove the existing fill materials and (2) partial removal of the existing fill materials. *A geotextile fabric could be placed beneath the concrete pavement with subgrade preparation option 1.

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.

Excavation – Concrete Pavement Areas

If soils with high moisture content levels are encountered, then low-ground pressure construction equipment should be used.

Gravel Surfaced Areas

Subgrade Preparation

We recommend that the subgrade preparation in the gravel surfaced areas consist of removing any vegetation and highly organic materials. Minimal removals 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.

Gravel Section Thickness

For the thickness of the gravel section, we recommend at least 4 inches of gravel surfacing over 4 inches of aggregate base course. We recommend placing a geotextile fabric beneath the gravel section. Without the geotextile fabric, aggregate loss and additional maintenance would be expected. Some maintenance and additional gravel surfacing may be needed due to the potential settlement of the existing fill materials that contain debris.

Excavation – Gravel Surfaced Areas

If soils with high moisture content levels are encountered, then low-ground pressure construction equipment should be used.

Water Pipes

Discussion

As previously stated, debris was encountered within the existing fill materials at all of the test borings. In our opinion, the existing fill materials that contain debris are prone to settlement and should not be relied upon to provide uniform support of the water pipes. It should be understood that relying on the existing fill materials that contain debris for support of the water pipes introduces the risk for potential future settlement. In addition, disturbing the debris during construction may cause the debris to shift and potentially settle. We have provided 2 subgrade preparation options for the water pipes. Again, there is risk associated with the existing fill materials that contain debris.

Subgrade Preparation Below Water Pipes (Remove Existing Fill Materials)

In order to eliminate the risk of settlement of the new water pipes, we recommend removing the existing fill materials from beneath the new water pipes. The excavation should extend at least 1 foot outside of the edges of the water pipes. Based on the test borings, the existing fill materials extended to depths varying from 9 ½ feet to 14 ½ feet. Again, disturbing the debris during construction may cause the debris to shift and potentially settle. Any overexcavated areas (below the water pipes) should be backfilled with granular structural fill.

Alternative Subgrade Preparation Below Water Pipes (Partial Removal)

With the alternative subgrade preparation, the owner will assume some risk of distress of the new water pipes due to potential settlement of the existing fill materials that contain debris that are left in-place. Again, disturbing the debris during construction may cause the debris to shift and potentially settle. With this alternative, the subgrade preparation below the water pipes should consist of excavating to a minimum depth of 2 feet below the water pipes. The excavation should extend at least 1 foot outside of the edges of the water pipes. The bottom of the excavations should be observed. If excessive debris is observed, then additional removals should be considered. We recommend installing a geotextile fabric at the bottom of the excavation, followed by placing a minimum of 2 feet of drainage rock up to the design elevation. Regarding the geotextile fabric, we recommend using Mirafi HP 370, Propex Geotex 3x3 HF, Huesker Comtrac P 45/45 or approved alternative. The amount of potential settlement with this alternative is unknown due to the uncertainty of the debris.

Water Control

Water may enter 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 may 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.

OSHA Requirements

All 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.

Trench Backfill Above Water Pipes

It is our opinion that the existing fill materials that do not contain debris can likely be reused as trench backfill, while the existing fill materials that contain debris are not suitable for use as trench backfill. An off-site material will likely need to be brought to the site. The off-site material could consist of clay backfill or granular material.

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.

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 1 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 Foundation Wall Backfill for Slab-on-Grade Structures – We recommend either clay or granular soils be used. Debris, organic material, or over-sized material should not be used as backfill. If granular soils are used in areas that will not have asphalt or concrete surfacing, then we recommend capping the granular soils with at least 1 foot to 2 feet of clay soils to minimize infiltration of surface water. The exterior backfill should be placed in lifts of up to 1 foot in thickness.

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.

Subgrade Fill – The subgrade fill should consist of either a granular or clay material. Debris, organic material, or over-sized material should not be used as subgrade fill. 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. 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. Organic materials should not be used as subgrade fill.

Clay Backfill – The clay backfill should consist of a non-organic clay. Scrutiny on the clay material's moisture content should be made prior to the acceptance and use. The clay backfill should be placed in lifts of up to 6 inches in thickness.

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 6 are based on a material's maximum dry density value, as determined by a standard Proctor (ASTM: D698) test.

Table 6. Recommended Compaction Levels

Placement Location	Compaction Specifications
Below Footings – Meter Building	97%
Below Slabs – Meter Building & Generator	97%
Exterior Foundation Wall Backfill for Slab-on-Grade Structures	95%
Behind Retaining Walls	95% - 98%
Subgrade Fill	95%

Table 6 (Continued). Recommended Compaction Levels

Placement Location	Compaction Specifications
Aggregate Base Course	97%
Gravel Surfacing	97%
Trench Backfill	95%
Non-Structural Areas	90%

Notes: Compaction specifications are not applicable with the drainage rock.

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.

Drainage

Proper drainage should be maintained during and after construction. The general site grading should direct surface run-off waters away from the excavation. Water which accumulates in the excavation 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. Also, a system to collect and channel roof run-off waters away from the structure is suggested.

Corrosive Potential of the Soils

A soil sample was collected from test boring 1 and was 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 7 and the results of the chloride content and sulfate content testing are shown in Table 9.

Table 7. pH, Resistivity, Redox Potential & Sulfide Content Results

Test Boring	Depth (ft)	Soil Classification	pH	Resistivity (ohm-cm)	Redox Potential (mV)	Sulfide (mg/kg)
1	2 to 8 ½	CL (Fill)	7.3	1,943	155	<0.01

Note: The resistivity value is a minimum value (saturated condition).

Using the Ductile Iron Pipe Research Association's (DIPRA) 10-point system and the lab results shown in Table 7, 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 8. 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 8, the existing fill materials tested are considered not corrosive. However, as a precaution, protective measures should be taken due to the relatively low resistivity value. In addition, an off-site clay backfill will likely be needed above the water pipes.

Table 8. Results of DIPRA 10-Point System Evaluation

Test Boring	Depth (ft)	Soil Classification	Total Value	Result
1	2 to 8 ½	CL (Fill)	6	Not Corrosive

Note: A "fair drainage, generally moist" was used for the moisture condition (1 point).

Table 9. Sulfate & Chloride Content Test Results

Test Boring	Depth (ft)	Soil Classification	Sulfate (mg/kg)	Chloride (mg/kg)
1	2 to 8 ½	CL (Fill)	58	29

As shown in Table 9, the sulfate content was 58 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 level, a level below 250 mg/kg is considered mildly corrosive.

CONSTRUCTION CONSIDERATIONS

Water & 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 excavation should be immediately removed and surface drainage away from the excavation 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 and asphalt should not be placed on frozen subgrades. Frost should not be allowed to penetrate below the footings. If floor slab subgrades freeze, then we recommend the frozen soils be removed and replaced, or completely thawed, prior to placement of the floor slab. 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 6 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, 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
IOWA

FIGURE 1
SITE LOCATION MAP
PROPOSED METER BUILDING
LEWIS & CLARK REGIONAL WATER SYSTEM
600 N. 2ND AVENUE
SHELDON, IA

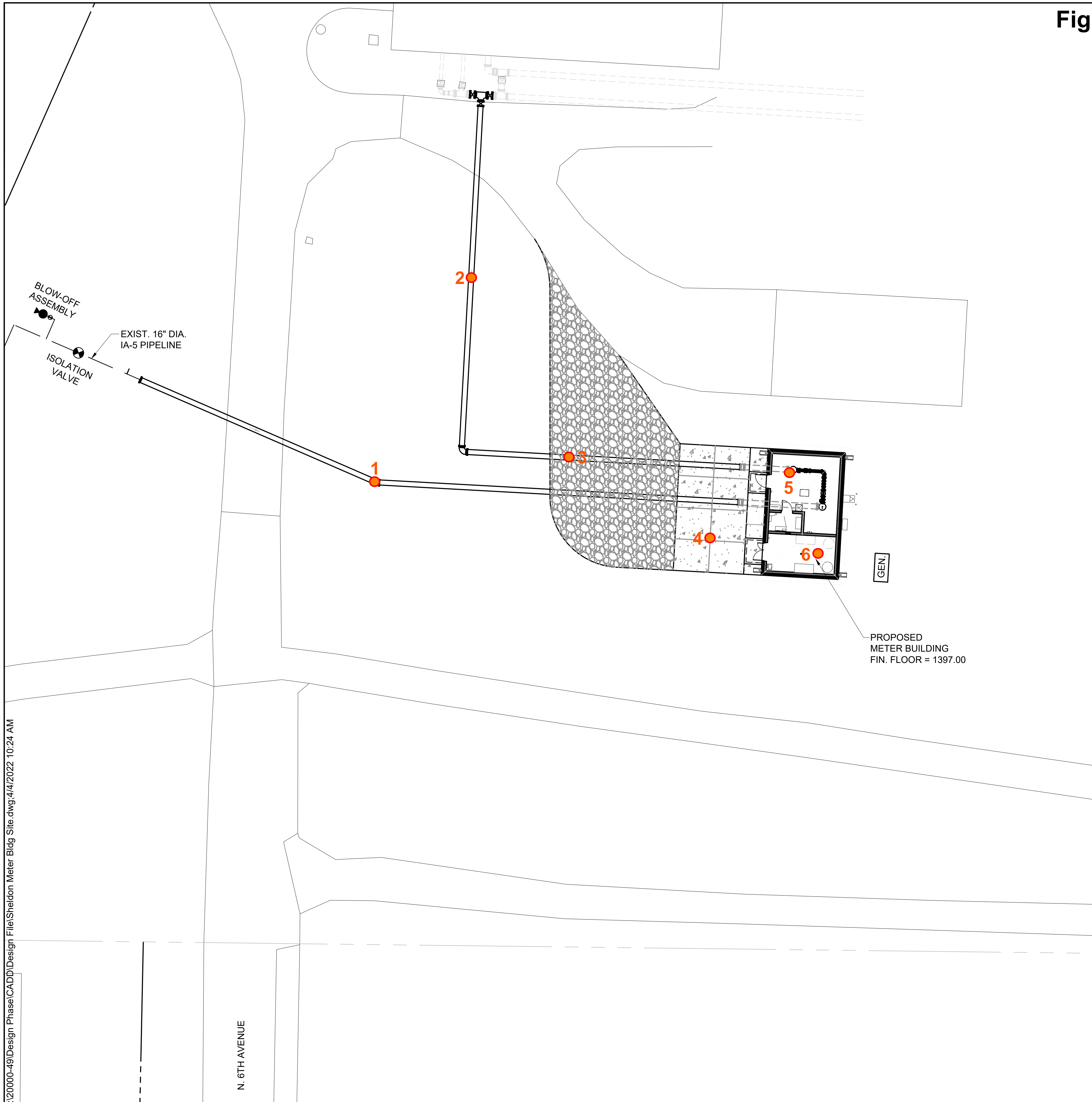
ACAD/GEOTEK/JARED/22-969

PROJECT#: 22-969

DRAWN BY: DHP

GEOTEK ENGINEERING & TESTING SERVICES, INC.
909 East 50th Street North
Sioux Falls, South Dakota 57104
605-335-5512 Fax 605-335-0773

Figure 2



LEGEND

- MONUMENT FOUND
- MONUMENT SET THIS SURVEY 5/8" REBAR WITH STAMPED PLASTIC CAP
- TELEPHONE PEDESTAL
- POWER POLE
- ELECTRIC TRANSFORMER
- FIRE HYDRANT
- WATER VALVE
- UGE — UNDERGROUND ELECTRIC LINE
- UGT — UNDERGROUND TELEPHONE
- W — WATER LINE
- OHE — OVERHEAD ELECTRIC LINE
- 1295 — EXISTING CONTOUR LINE
- ST — PROPOSED STORM SEWER
- 1295 — NEW CONTOUR LINE
- x — BARBWIRE FENCE
- PROPERTY LINE
- CHAINLINK FENCE
- CONCRETE SURFACE
- GRAVEL SURFACE
- GRASS SURFACE
- SILT FENCE
- TEMPORARY VEHICLE CONSTRUCTION ENTRANCE (SEE DETAIL ON SHT. 2.12)
- CONCRETE WASHOUT AREA (SEE DETAIL ON SHT. 2.12)
- BIO-ROLL

0 15' 30' 60'

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PROJECT / SHEET TITLE:
LEWIS & CLARK HULL PUMP STATION
EROSION CONTROL PLAN
SHELDON, IOWA

REV.	DATE	DESCRIPTION

FOR REVIEW ONLY NOT FOR CONSTRUCTION

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

0 1/2" 1"
SCALE REDUCTION BAR

SHEET No.:
2-2.4

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.

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 # **22-969**

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

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

SURFACE ELEVATION 1402.4 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY: a little gravel, brown and dark brown, moist, a little debris (concrete and bricks)	FILL			1	HSA	16				
			6		2	SPT	15				
			10		3	SPT	18				
			12		4	SPT	18				
					8	BAG					
			9		5	SPT	17				
			6		6	SPT					
14½	**CLAYEY SAND**: a little gravel, medium to coarse grained, light brown, moist, medium dense, (SC)	COARSE ALLUVIUM	11		7	SPT					
16	Bottom of borehole at 16 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	1:01 pm	--	--	14	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 1:01 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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 # **22-969**

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

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

SURFACE ELEVATION 1397.1 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN
	FILL, MOSTLY LEAN CLAY: a little gravel, brown and dark brown, moist, with debris (concrete and bricks)	FILL
7	**FILL, MOSTLY CLAYEY SAND**: a little gravel, fine to medium grained, brown, moist	FILL
12½	**SAND**: medium to coarse grained, very light gray, wet, loose, (SP)	COARSE ALLUVIUM
13½	Bottom of borehole at 13½ feet.	

N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
		1	HSA	10				
10		2	SPT	14				
5		3	SPT	17				
10		4	SPT	12				
13		5	SPT	8				
8		6	SPT					

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	1:02 pm	13.5	--	12	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 12:04 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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 # **22-969**

BORING NO. **3 (1 of 1)**

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1397.4 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY WITH SAND: a little gravel, brown and dark brown, moist, with debris (concrete and bricks)	FILL			1	HSA	14				
			4		2	SPT	20				
			6		3	SPT	23				
			8		4	SPT	17				
			18		5	SPT	20				
12	**SAND**: a little gravel, medium to coarse grained, brown, moist, dense, (SP)	COARSE ALLUVIUM	20		6	SPT					
13½	Bottom of borehole at 13½ feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	1:08 pm	13.5	--	12	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 11:28 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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 # **22-969** BORING NO. **4 (1 of 1)**

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1396.6 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY WITH SAND: a little gravel, brown and dark brown, moist, with debris (concrete and bricks)	FILL			1	HSA	21				
			8		2	SPT	24				
			5		3	SPT	22				
			10		4	SPT	22				
			20		5	SPT	18				
12	**CLAYEY SAND**: a little gravel, medium to coarse grained, brown, wet, loose, (SC)	COARSE ALLUVIUM	8		6	SPT					
13½	Bottom of borehole at 13½ feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
6-13-22	1:07 pm	13.5	--	12	none
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 10:54 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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 # **22-969**

BORING NO. **5 (1 of 1)**

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

SURFACE ELEVATION 1395.8 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY: a little gravel, brown and dark brown, moist, with debris (concrete and bricks)	FILL			1	HSA					
			15		2	SPT	16				
			18		3	SPT					
			9		4	SPT	21				
			7		5	SPT	24				
12	**SAND**: a little gravel, medium to coarse grained, brown, waterbearing, dense, (SP)	COARSE ALLUVIUM	20	▼	6	SPT	16				
14½	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff, (CL)	GLACIAL TILL	14		7	SPT	16	117			6500
			14		8	SPT					
			14		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	1:07 pm	26	--	14	▼ 13
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 10:19 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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 # **22-969** BORING NO. **6 (1 of 1)**

PROJECT **Proposed Meter Building, Lewis & Clark Regional Water System, 600 N. 2nd Avenue, Sheldon, IA**

SURFACE ELEVATION 1395.7 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY: a little gravel, brown and dark brown, moist, with debris (concrete and bricks)	FILL			1	HSA					
			15		2	SPT	20				
			4		3	SPT					
			7		4	SPT	18				
9½	**SAND**: a little gravel, medium to coarse grained, brown, moist to waterbearing, dense to medium dense, (SP)	COARSE ALLUVIUM	18		5	SPT	4				
			11	▼	6	SPT					
14½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	9		7	SPT					
19½	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	14		8	SPT					
			16		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	1:07 pm	26	--	16	▼ 13
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 6-13-22 COMPLETE 6-13-22 9:21 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		(LITTLE OR NO FINES)		SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES		SM	SILTY SANDS, SAND - SILT MIXTURES
		(APPRECIABLE AMOUNT OF FINES)		SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	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
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	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%