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Attn: Nicolas Sanchez, AIA

Subj: Geotechnical Exploration
Proposed Boiler Plant
VA Hospital
W. 24th Street & S. Garfield Avenue
Sioux Falls, South Dakota
GeoTek #23-0352

This correspondence presents our written report of the geotechnical exploration program for the referenced project. Our work was performed in accordance with your authorization. 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.

Nick Bierle

Nick Bierle, PE
Project Engineer

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GEOTEK #23-0352

INTRODUCTION

Project Information

This report presents the results of the recent geotechnical exploration program for the proposed boiler plant located at the existing VA Hospital in Sioux Falls, South Dakota.

Scope of Services

Our work was performed in accordance with the authorization of Nicolas Sanchez with Paradigm Engineering and Consulting, PLLC. The scope of work as presented in this report is limited to the following:

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

2. To perform laboratory tests that include moisture content, dry density, 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 at the existing VA Hospital in Sioux Falls, South Dakota. The area designated for the proposed boiler plant is located southeast of the intersection of W. 24th Street and S. Garfield Avenue. A site location map (Figure 1) is attached showing the location of the site. The topography of the site slopes downward from east to west.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were determined by using the top of manhole cover that is located northwest of test boring 1 as a benchmark datum. An elevation of 1,489.4 was used for the benchmark. Based on the benchmark, the elevations at the test borings were 1,490.2 feet at test boring 1, 1,491.3 feet at test boring 2, 1,492.5 feet at test boring 3 and 1,493.9 feet at test boring 4. A test boring location map (Figure 2) is attached showing the relative location of the test borings.

Subsurface Conditions

We performed 4 test borings at the site on April 5 and April 14, 2023. 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 borings consisted of the following soil types: existing fill materials, topsoil (buried) materials, loess soils and glacial till soils. In addition, concrete (7” thick) and gravel base materials (8” thick) was encountered at the surface of test boring 1. The existing fill materials were encountered at each test boring and extended to depths varying from 2 feet to 9 ½ feet. The buried topsoil materials were only encountered beneath the existing fill materials at test boring 1 and had at thickness of 1 ½ feet. The loess soils were encountered below the existing fill materials at all of the test borings and extended to depths (deeper test boings) varying from 19 ½ feet to 24 ½ feet. The loess soils extended to the termination depth of test boring 4 (shallow test boring). The glacial till soils were encountered beneath the loess soils at test borings 1, 2 and 3 (deeper test borings) and extended to the termination depth of the test borings.

The consistency or relative density of the soils is indicated by the standard penetration resistance ("N") values as shown on the boring logs. 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), sandy lean clay (CL) and lean clay with sand (CL). "N" values within the existing fill materials ranged from 3 to 13. The moisture condition of the existing fill materials was moist and wet.

Topsoil Materials

The topsoil materials consisted of lean clay (CL). An "N" value of 5 (consistency of firm) was measured within the topsoil materials at test boring 1. The moisture condition of the topsoil materials was moist.

Loess Soils

Loess soils are soils that have been deposited by wind. The loess soils consisted of lean clay (CL). "N" values within the loess soils ranged from 3 to 10 (consistency of soft, firm and stiff). The moisture condition of the loess soils was moist and wet.

Glacial Till Soils

Glacial till soils consist of silt and clay sized particles with sand and gravel intermixed 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 16 (consistency of firm, stiff and very stiff). The moisture condition of the glacial till soils was moist.

Water Levels

Measurements to record the groundwater levels were made at the test boring locations. The time and level of the groundwater readings are recorded on the boring logs. Groundwater was measured at a depth of 8 feet (elevation 1,482.2 feet) at test boring 1 and 9 feet (elevation 1,482.3 feet) at test boring 2. Groundwater did not enter the remaining boreholes at the time of our measurements. However, we expect that similar or shallower groundwater would be encountered as test borings 1 and 2 if the boreholes were to remain open for an extended period of time.

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 boiler plant at the existing VA Hospital in Sioux Falls, South Dakota. The boiler plant will be a slab-on-grade structure with approximate dimensions of 60 feet by 100 feet by 28 feet (tall). In addition, a mezzanine will be located within the boiler plant. We understand that the finished floor of the boiler plant will be 1,491.0 feet. Based on the existing surface grades within the footprint of the boiler plant and the finished floor elevation (FFE), cutting of up to 2 feet will be needed in order to achieve the FFE. We anticipate that foundation support for the boiler plant will be provided by perimeter footings resting below frost depth and interior footings resting at or slightly below the floor slab. We understand that the maximum wall loads will be up to 5 klf and the maximum column loads will be up to 170 kips. Regarding floor slab loads, we understand that the floor loads will range from 200 pounds per square foot (psf) to 600 psf. The 600 psf floor slab load will be in the area where the boilers are located.

The project will also consist of constructing pavement areas and installation of three (3) underground storage tanks. Grade changes in the pavement areas will likely include minimal cutting and filling of up to 3 feet in order to achieve the design elevations. The vehicle traffic will likely consist of automobiles and trucks (snow removal and garbage). In regards to the underground storage tanks, we assume that the bottom of the storage tanks will rest approximately 15 feet below finished grade. In addition, each storage tank will have a capacity of approximately 80,000 gallons.

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.

Boiler Plant

Discussion

The test borings performed for the boiler plant indicate that the existing fill materials extended to depths of 7 ½ feet and 12 feet. In our opinion, the field and laboratory data indicate that the majority of the existing fill materials were not placed and compacted in a controlled manner. Therefore, it is our opinion that the existing fill materials are not suitable for support of the floor slab or footings of the boiler plant. In addition, it is our opinion that the buried topsoil materials are not suitable for support of the floor slab or footings of the boiler plant. The loess soils extended to depths varying from 19 ½ feet to 24 ½ feet within the footprint of the boiler plant. Based on the consistency (generally soft and firm) and unconfined compressive strength values (0.2 tons per square foot (tsf) and 0.4 tsf), it is our opinion that the loess soils have low strength levels. In addition, it is our opinion that the loess soils are moderately compressible. Therefore, it is our opinion that in order to provide adequate support for the floor slab and footings of the boiler plant, we recommend that an overexcavation be performed below the floor slab and footings or an intermediate foundation system be used below the floor slab and footings. The intermediate foundation system would consist of rammed aggregate piers/aggregate piers or helical piers.

Site Preparation – Footing Areas

The site preparation in footing (exterior and interior) areas should consist of removing the pavement, gravel base, vegetation, buried topsoil materials and existing fill materials in order to expose the loess soils. Following the removals, we recommend that additional removals be performed beneath the footings. The depth of the overexcavation will depend on the type of footing. For continuous footings, the overexcavation should extend to a minimum depth of one (1) footing width beneath the bottom-of-footing elevation (example: a 2 foot wide continuous footing would require a 2 foot overexcavation). For individual column pad footings, the overexcavation should extend to a minimum depth of one-half (½) column pad width below the bottom-of-footing elevation (example: a 8 foot by 8 foot column pad would require a 4 foot overexcavation).

Following overexcavation, we recommend that observations and hand auger borings be performed at the bottom of the excavations. Unstable areas may require additional removals. Once the bottom of the excavations are approved, the overexcavated areas should be backfilled with 12 inches of crushed rock followed by placing and compating granular structural fill up to the bottom-of-footing elevation.

It is our opinion that a friction factor of 0.45 can be used between the granular structural fill or crushed rock 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.

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

If our recommendations are followed during site preparations, then it is our opinion that the footings of the boiler plant could be sized for a net allowable soil bearing pressure of up to 2,000 psf. With the net allowable soil bearing pressure and our site preparation recommendations, we recommend limiting the wall loads to 5 klf and the column loads to 170 kips. If a higher net allowable soil bearing pressure is desired or the load limits are exceeded, then we recommend that we be contacted to provide additional recommendations.

With the load limits, net allowable soil bearing pressure and our site preparation recommendations, total settlement of these 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 locations could increase the amount of expected settlement.

Site Preparation – Floor Slab Areas

The site preparation in floor slab areas should consist of removing the pavement, gravel base, vegetation, buried topsoil materials and existing fill materials in order to expose the loess soils. Following removals, we recommend that observations and hand auger borings be performed at the bottom of the excavations. Unstable areas may require additional removals. Please refer to Table 1 for a summary of the anticipated minimum excavation depths to remove the unsuitable soils encountered at the test borings performed for the boiler plant. The depth of the excavation may vary within the footprint of the boiler plant. We would like to point out that our recommendations are based on a FFE of 1,491.0 feet. If the FFE is changed, then we recommend that we be contacted to review our recommendations.

Table 1. Estimated Excavation Depths – Floor Slab

Test Boring Number	Ground Surface Elevation, ft	Anticipated Excavation Depth, ft	Approximate Excavation Elevation, ft
1	1,490.2	12	1,478.2
2	1,491.3	7 ½	1,483.8

Once the bottom of the excavations are approved, the overexcavated areas should be backfilled with 12 inches of crushed rock followed by placing and compacting granular structural fill up to the bottom-of-floor elevation. The final 6 inches of granular structural fill beneath the floor slab should consist of select granular fill.

If our recommendations are followed during site preparations, then it is our opinion that the floor slabs can be designed using a soil modulus of subgrade reaction (k value) of 125 psi/inch.

Alternative Support Option 1 – Rammed Aggregate Piers/Aggregate Piers

This alternative support option 1 consists of installing rammed aggregate piers or aggregate piers beneath the entire boiler plant (floor slab and footings). Prior to the installation of the rammed aggregate piers or aggregate piers, the design elevations within and around the boiler plant should be achieved by cutting or placing and compacting subgrade fill.

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. With the rammed aggregate piers or aggregate piers, there are several support and sequencing options that could be considered. Discussions with the rammed aggregate pier or aggregate pier designer should be made to determine the best course of action. The designer will typically provide a net allowable soil bearing pressure (typically in the range of 4,000 pounds per square foot to 5,000 psf), estimated settlements and a coefficient of friction. Additionally, we recommend that discussions with the designer be done regarding any potential time delay. 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 soft/wet loess 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.

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 projects).

Alternative Support Option 2 – Helical Piers

This alternative support option 2 consists of installing helical piers beneath the entire boiler plant (floor slab and footings).

The helical piers should extend down to competent soils (suitable glacial till soils). We recommend that the helical piers be designed by a licensed professional engineer specializing in the design of helical piers. The designer will typically provide a capacity and estimated settlements. Testing of the helical piers should be performed at the beginning of the work and during production to confirm the design capacities.

As estimates, an allowable compression capacity of 25 kips to 30 kips could be expected with the helical piers. The capacities for the helical piers could also be used to resist uplift loads. The allowable capacities should be based on a factor of safety of 2.0. Again, the helical piers should be designed by a licensed professional engineer specializing in the design of helical piers. 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 projects).

Building Excavation & Soil Disturbance

All excavations within the footprint of the boiler plant should be performed with a track backhoe with a smooth edge bucket. The soils are susceptible to disturbance and can experience strength loss caused by construction traffic and/or additional moisture.

The soils are vulnerable to disturbance and can experience strength loss caused by construction traffic and/or additional moisture. If any soils become disturbed during construction, then the disturbed soils will likely need to be removed.

Dewatering

Dewatering may be needed during construction. If dewatering is needed, then the contractor should provide appropriate dewatering methods and equipment. In areas where clay soils are encountered, it will likely 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 likely be needed.

It should be noted that the water levels are expected to fluctuate during wetter or dryer periods of the year. 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.

Retaining/Below-Grade Walls

We recommend backfilling any retaining and below-grade 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 2 shows the equivalent fluid unit weight values for the various soil types anticipated for this project.

Table 2. 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.

We recommend that a perimeter backfill drainage system be provided for the retaining and below-grade walls to collect and remove water and to prevent hydrostatic pressure on the walls. The drainage system should consist of slotted or perforated drainage pipes located at the bottom of the backfill trench. The drainage system should be connected to a suitable means of discharge.

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.

Drain Tile Recommendations

Since the boiler plant will be slab-on-grade, it is our opinion that drain tile is not needed along the perimeter of the boiler plant. However, if there are portions of the boiler plant that will extend below grade, then drain tile should be installed.

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 – based on the underlying glacial till soils). Also, the ground acceleration values are as follows: S_S = 0.092 g, S_1 = 0.035 g, S_{MS} = 0.147 g, S_{M1} = 0.085 g, S_{DS} = 0.098 g, S_{D1} = 0.057 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. If needed, we can provide ground acceleration values for a different design code.

Underground Storage Tanks

Test boring 3 was performed within the footprint of the underground storage tanks. At test boring 3, the subsurface profile consisted of the existing fill materials overlying loess soils and glacial till soils. The loess soils extended to a depth of 20 feet below the existing grade. Based on the assumed bottom of tank elevations, we expect that loess soils will likely be encountered at the bottom of the excavation for the tanks. In our opinion, the loess soils are suitable for indirect support of the underground storage tanks.

Therefore, we recommend that 1 foot of crushed rock be placed beneath the storage tanks. In addition, we recommend appropriate bedding be placed on top of the crushed rock prior to the installation of the tanks.

Regarding groundwater, we expect that groundwater will be encountered at 8 feet or shallower below the existing grade. With that said, it is our opinion that dewatering will be needed. Dewatering will likely be possible to remove and control water entering the excavation using normal sump pumping techniques due to the low permeable characteristics of the predominant clayey soils encountered at test boring 3. However, lenses and layers of sand may be encountered, requiring more extensive dewatering techniques.

We recommend that the tanks be anchored against buoyancy forces during periods of high groundwater. We also recommend that consideration be given to adding a subsurface drain tile around the tanks. The drainage system, if used, should be connected to a suitable means of discharge.

Pavement Areas

Discussion

In general, it is our opinion that poor to fair subgrade conditions should be expected in the new pavement areas. Our opinion is based on the moisture content levels and the types of soils encountered within the upper portions of the subgrade soils at the test boring locations. In addition, it is our opinion that the clay soils are prone to instability during freeze-thaw cycles, wet weather as well as during normal construction traffic.

With that said, it is our opinion that 3 subgrade preparation options could be used for the project. Option 1 would consist of normal subgrade preparation (scarification and recompaction). However, it should be understood that additional corrections may be needed in some areas in order to provide a stable subgrade condition. For option 1 to be successful, there may need to be an extended period of dry weather during construction. Option 2 would consist of subgrade reinforcement (geotextile fabric). Option 3 would consist of cement stabilization. In our opinion, Options 2 and 3 will help provide a more uniform subgrade condition once the subgrade preparation is performed as well as provide a longer pavement life than Option 1. However, Option 2 may encounter some unstable areas due to construction disturbance, groundwater and/or weather events (prior to paving). Furthermore, it is our opinion that Option 3 will provide a reduction in construction delays and the longest pavement life (of the provided options).

Initial Subgrade Preparation

The initial subgrade preparation in the pavement areas should consist of removing the highly organic materials, pavement and gravel base. Following the removals, the subgrade should be prepared by cutting or placing and compacting subgrade fill to the design subgrade elevations. Some scarification and recompaction may be needed during the initial subgrade preparation. Once the design subgrade elevations have been achieved, 1 of the subgrade preparation options should be used to prepare the subgrade.

Subgrade Preparation Option 1 – Normal Subgrade Preparation

The normal subgrade preparation should consist of scarification and recompaction. For the scarification and recompaction option, the upper 8 inches of the subgrade should be scarified, moisture conditioned and recompacted. The moisture content of the soils should be 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 scarification should be performed by a disc harrow and not a road grader with teeth. Prior to the placement of the aggregate base course material, we recommend that a proofroll 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 subgrade preparation in order to provide a uniform and stable subgrade condition. The additional subgrade preparation may include the following: moisture conditioning the soils (e.g. drying the soils by scarification), an overexcavation to remove and replace the unstable subgrade soils, subgrade reinforcement or cement stabilization. The type of additional subgrade preparation performed should be determined after observing the performance of the subgrade during the proof roll test. Again, some unstable areas should be expected, especially during the spring thaw, wetter periods of the year or when it is difficult to dry wet soils (late fall). With this option, a geotextile fabric could be installed beneath the aggregate base course material to extend the life of the pavement.

Unstable Subgrade with Subgrade Preparation Option 1

Areas of unstable subgrade may be encountered during construction with subgrade preparation option 1. The soils within the unstable area should be removed, and either moisture-conditioned and recompacted, or replaced with suitable subgrade soils. If the unstable area will not stabilize using this method, then alternative stabilization methods may be used such as a modified cross-section involving a geotextile fabric. With the geotextile fabric, a thicker aggregate base course section will likely be needed (thickness would be based on field conditions). For very poor subgrade conditions, granular subbase will likely be needed with the geotextile fabric. The granular subbase should consist of crushed quartzite, recycled concrete or a crushed pit-run material meeting the gradation specifications shown in Table 9. The granular subbase should be compacted to a minimum of 97 percent of standard Proctor density (ASTM:D698). It should be noted that compaction testing may not be practical for the granular subbase due to the large aggregate. In regards to the geotextile fabric, we recommend that it should be woven and meet the requirements listed below:

- Wide Width Tensile Strength (ASTM:D4595) 3,600 lb/ft minimum;
- Wide Width Tensile Strength at 5% Strain (ASTM:D4595) 1,350 lb/ft minimum;
- Permittivity (ASTM:D4491) 0.25 sec-1 minimum;
- UV Resistance at 500 hours (ASTM:D4355) 70% minimum.

Some of the products that meet these requirements include the following: Mirafi HP370, Lumite GTF465, Winfab 3x3HF, Winfab 370HP, Carthage Mills FX-300MF, Carthage Mills FX-370MF, SRW 370HP, Skaps M330, Skaps W5050F, ADS 370HP, Foundation Geotextiles FG33 and Foundation Geotextiles FG57.

Subgrade Preparation Option 2 – Subgrade Reinforcement

Subgrade preparation option 2 would consist of subgrade preparation option 1 with the addition of a geotextile fabric beneath the aggregate base course material.

We would like to point out that Option 2 will provide more uniform support and a longer pavement life than Option 1; however, unstable areas may still be encountered during construction (prior to and following subgrade preparation) due to construction disturbance, groundwater and/or weather events. We expect that stable conditions will be encountered during drier periods of the year, while some unstable conditions may be encountered during wetter periods of the year or when it is difficult to dry wet soils (late fall).

Subgrade Preparation Option 3 – Cement Stabilization

The cement stabilization should consist of blending the subgrade soils with cement to a minimum depth of 12 inches. The percentage of cement used typically ranges from 5 percent to 7 percent and should be based on a site specific mix design. For bidding purposes, the percentage of cement used should be 6 percent (example: if the in-place dry density equals 100 pounds per cubic foot (pcf), then 6 pounds of cement should be applied to the subgrade, per square foot). We recommend that the percentage of cement used during the blending process be determined by a mix design that should be performed when the subgrade soils are exposed during construction. The mix design takes 2 weeks to complete.

Once the percentage of cement is determined, the cement should be placed uniformly over the subgrade surface at the specified percentage with a truck-mounted cement spreader. In addition to the cement being placed uniformly, the truck-mounted spreader will help control the spread of cement dust. Then, a self-propelled pulvimixer/reclaimer should be used to reclaim the upper 12 inches of the subgrade along with the cement. Within 30 minutes, the reclaimed mixture of soil and cement should be initially compacted with a large (60-inch to 72-inch diameter) vibratory sheepsfoot roller to a minimum of 95 percent of the maximum dry density as determined by Moisture-Density Relations of Soil-Cement Mixtures (ASTM:D558). The moisture content of the material should be adjusted to a moisture level that is within 3 percent below to 3 percent above the optimum moisture content determined by Moisture-Density Relations of Soil-Cement Mixtures (ASTM:D558). After initial compaction, the subgrade should be graded to the design elevations, rolled with a pneumatic tire roller and watered with a commercial water truck. Construction traffic should not be allowed on the subgrade for 48 hours after the final watering. This delay allows for the cement to properly hydrate without being disturbed. If at any time during or after the cement stabilization process it is determined that the subgrade is not performing as expected, then the problem should be assessed to determine the best course of action. This may include an additional application of cement. We would like to point out that the cement stabilization option will not be effective if the groundwater level is within about 2 feet of the design subgrade elevation.

Pavement Section Thicknesses

Tables 3 and 4 show the recommended pavement section thicknesses based on the subsurface conditions, subgrade preparation and anticipated traffic loads (cars, garbage trucks and snow removal equipment).

Table 3. Asphalt Pavement Section Thicknesses

Area	Asphalt Pavement Thickness, in	Aggregate Base Course Thickness, in	Granular Subbase Thickness, in	Subgrade Reinforcement	Cement Stabilization
Light Duty (1)	4	8**	*	*	*
Light Duty (2)	4	8**	***	Geotextile Fabric	-
Light Duty (3)	4	4	-	-	Yes****
Heavy Duty (1)	5	12**	*	*	*
Heavy Duty (2)	5	8**	***	Geotextile Fabric	-
Heavy Duty (3)	5	4	-	-	Yes****

Notes: The numbers are for the following sections: (1) normal subgrade preparation, (2) subgrade reinforcement and (3) cement stabilization. *Subgrade reinforcement, granular subbase or cement stabilization may be needed with Option 1. **The thickness of the aggregate base course may need to be increased. ***Granular subbase may be needed with Option 2 if very poor subgrade conditions are encountered. ****The treatment depth and percentage of cement may need to be increased if very poor subgrade conditions are encountered.

Table 4. Concrete Pavement Section Thicknesses

Area	Concrete Pavement Thickness, in	Aggregate Base Course Thickness, in	Granular Subbase Thickness, in	Subgrade Reinforcement	Cement Stabilization
Light Duty (1)	5	8**	*	*	*
Light Duty (2)	5	8**	***	Geotextile Fabric	-
Light Duty (3)	5	4	-	-	Yes****
Heavy Duty (1)	7	8**	-	*	*
Heavy Duty (2)	7	8**	***	Geotextile Fabric	-
Heavy Duty (3)	7	4	-	-	Yes****

Notes: The numbers are for the following sections: (1) normal subgrade preparation, (2) subgrade reinforcement and (3) cement stabilization. *Subgrade reinforcement, granular subbase or cement stabilization may be needed with Option 1. **The thickness of the aggregate base course may need to be increased. ***Granular subbase may be needed with Option 2 if very poor subgrade conditions are encountered. ****The treatment depth and percentage of cement may need to be increased if very poor subgrade conditions are encountered.

The asphalt pavement should meet the requirements of sections 320 and 321 for Class G. The concrete pavement should meet the requirements of Section 380 of the SDDOT Standard Specifications.

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

Earthwork Activities

We expect that low-ground-pressure construction equipment will be needed in the majority of the pavement areas.

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 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.

Surface Improvements

It is our opinion that the on-site loess soils have a high frost susceptibility. Surface improvements, such as pavements, patios and sidewalks, constructed on clay soils are potentially subject to both cosmetic and structural damage caused by frost heaving. The surface improvements should be designed to accommodate the potential frost movements, or non-frost susceptible drainage fill should be placed beneath the surface improvements. If movement cannot be tolerated, then we recommend placing non-frost susceptible drainage fill beneath the surface improvements. The non-frost susceptible drainage fill should extend to a depth of 4 feet below the surface improvements. If it is desired to reduce (but not eliminate) the amount of potential frost heave, then we recommend consideration be given to placing 2 feet of non-frost susceptible drainage fill beneath the surface improvements.

Corrosive Potential

Soil samples were collected from test borings 1 and 3 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 1 and the results of the chloride content and sulfate content testing are shown in Table 7.

Table 5. pH, Resistivity, Redox Potential & Sulfide Content Results

Test Boring	Depth (ft)	Soil Classification	pH	Resistivity (ohm-cm)	Redox Potential (mV)	Sulfide (mg/kg)
1	12 to 21	CL (Loess)	7.4	938	231	0.2
3	20 to 26	CL (Glacial Till)	7.9	1,072	183	0.1

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 5, 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 6. 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 6, the loess soils and glacial till soils tested are considered corrosive.

Table 6. Results of DIPRA 10-Point System Evaluation

Test Boring	Depth (ft)	Soil Classification	Total Value	Result
1	12 to 21	CL (Loess)	14	Corrosive
3	20 to 26	CL (Glacial Till)	14	Corrosive

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

Table 7. Sulfate & Chloride Content Test Results

Test Boring	Depth (ft)	Soil Classification	Sulfate (mg/kg)	Chloride (mg/kg)
1	12 to 21	CL (Loess)	40	74
3	20 to 26	CL (Glacial Till)	25	14

As shown in Table 7, the sulfate contents were 40 mg/kg and 25 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 these test results, the potential sulfate attack on the concrete will be mild. Regarding metals in direct contact with soils, sulfate contents and chloride contents below 250 mg/kg are considered mildly corrosive. With that said, protective measures should be taken at the project site.

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.

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.

Crushed Rock – The crushed rock should be washed and meet the gradation specifications shown in Table 8.

Table 8. Crushed Rock Gradation Specifications

Sieve Size	Percent Passing
1 1/2-inch	100
1-inch	70 – 90
3/4-inch	25 – 50
3/8-inch	0 – 5

Free-Draining Sand – The free-draining sand should contain no more 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.

Non-Frost Susceptible Drainage Fill – The non-frost susceptible drainage fill should have a maximum particle size of 1 inch, less than 40 percent by weight passing the #40 sieve and less than 5 percent by weight passing the #200 sieve. The non-frost susceptible drainage fill should be placed in lifts of up to 1 foot in thickness.

Exterior Foundation Wall Backfill for Slab-on-Grade Structures – The exterior foundation wall backfill for slab-on-grade structures should consist of a similar material as described for the general structural fill. 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. 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 organic materials should not be used as subgrade fill.

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

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 9.

Table 9. 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

Recommended Compaction Levels – The recommended compaction levels listed in Table 10 are based on a material's maximum dry density value, as determined by a standard Proctor (ASTM: D698) test.

Table 10. Recommended Compaction Levels

Placement Location	Compaction Specifications
Below Footings	98%
Below Floor Slabs	98%
Exterior Foundation Wall Backfill for Slab-on-Grade Structures	95%
Behind Retaining/Below-Grade Walls	95% - 98%
Subgrade Fill in Pavement Areas	95%
Aggregate Base Course in Pavement Areas	97%
Granular Subbase in Pavement Areas	97%
Non-Structural Areas	90%

Notes: Compaction specifications are not applicable with the crushed 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 the exterior of 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 pavement 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 excavations. Water which accumulates in the excavations should be removed in a timely manner.

Finished grades around the perimeter of the structure should be sloped such that positive drainage away from the structure is provided. Also, a system to collect and channel roof run-off waters away from the structure 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 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.

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, aggregate piers or helical piers. Detailed records should be kept during installation.

SUBSURFACE EXPLORATION PROCEDURES

Test Borings

We performed the test borings with a track/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. Also, we also performed 8 test borings using hand-operated equipment.

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, 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 data sheets included in the Appendix.

LIMITATIONS

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

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

STANDARD OF CARE

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

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

Nick Bierle, PE
Project Engineer

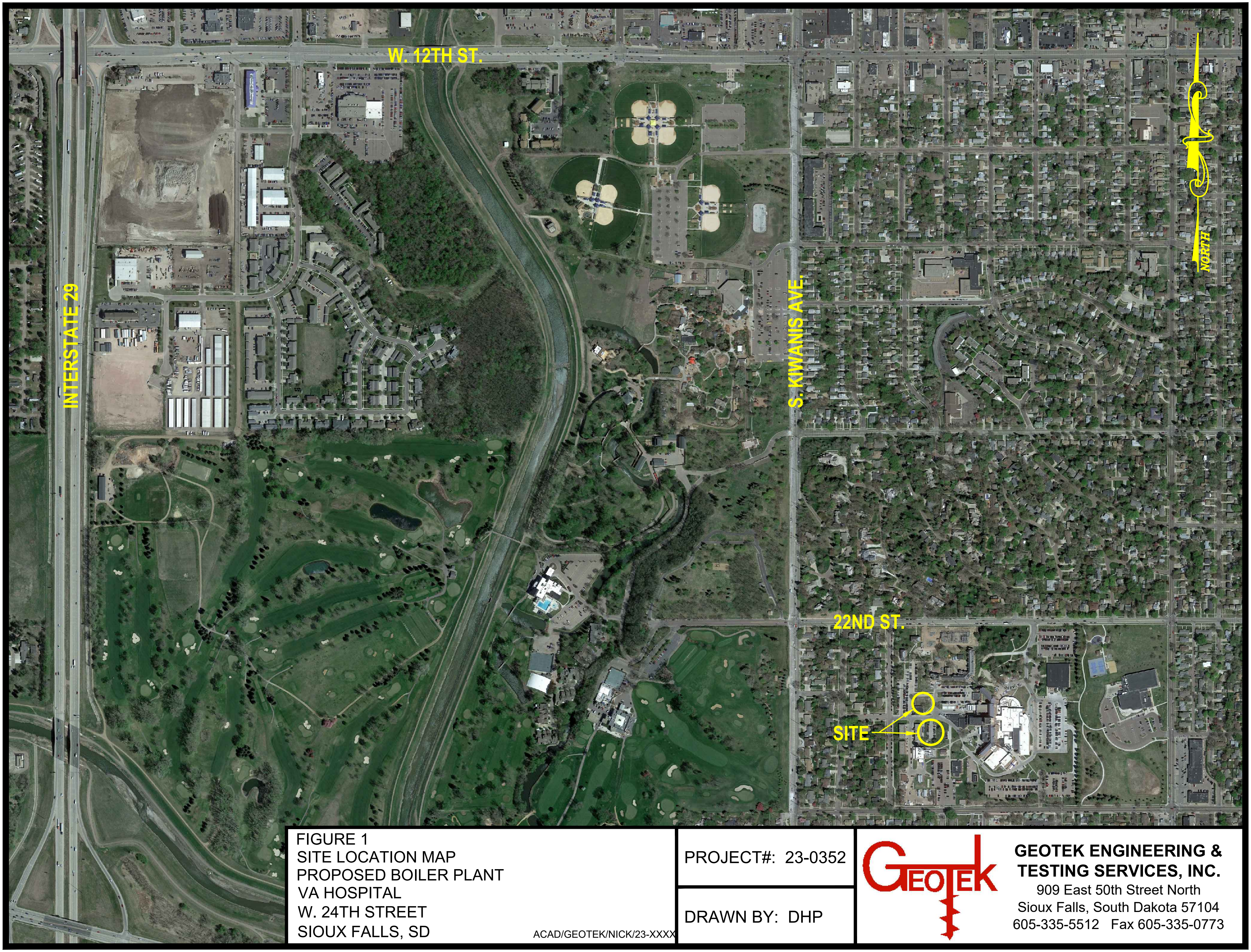

FIGURE 1
SITE LOCATION MAP
PROPOSED BOILER PLANT
VA HOSPITAL
W. 24TH STREET
SIOUX FALLS, SD

ACAD/GEOTEK/NICK/23-XXXX

PROJECT#: 23-0352

DRAWN BY: DHP

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Sioux Falls, South Dakota 57104
605-335-5512 Fax 605-335-0773

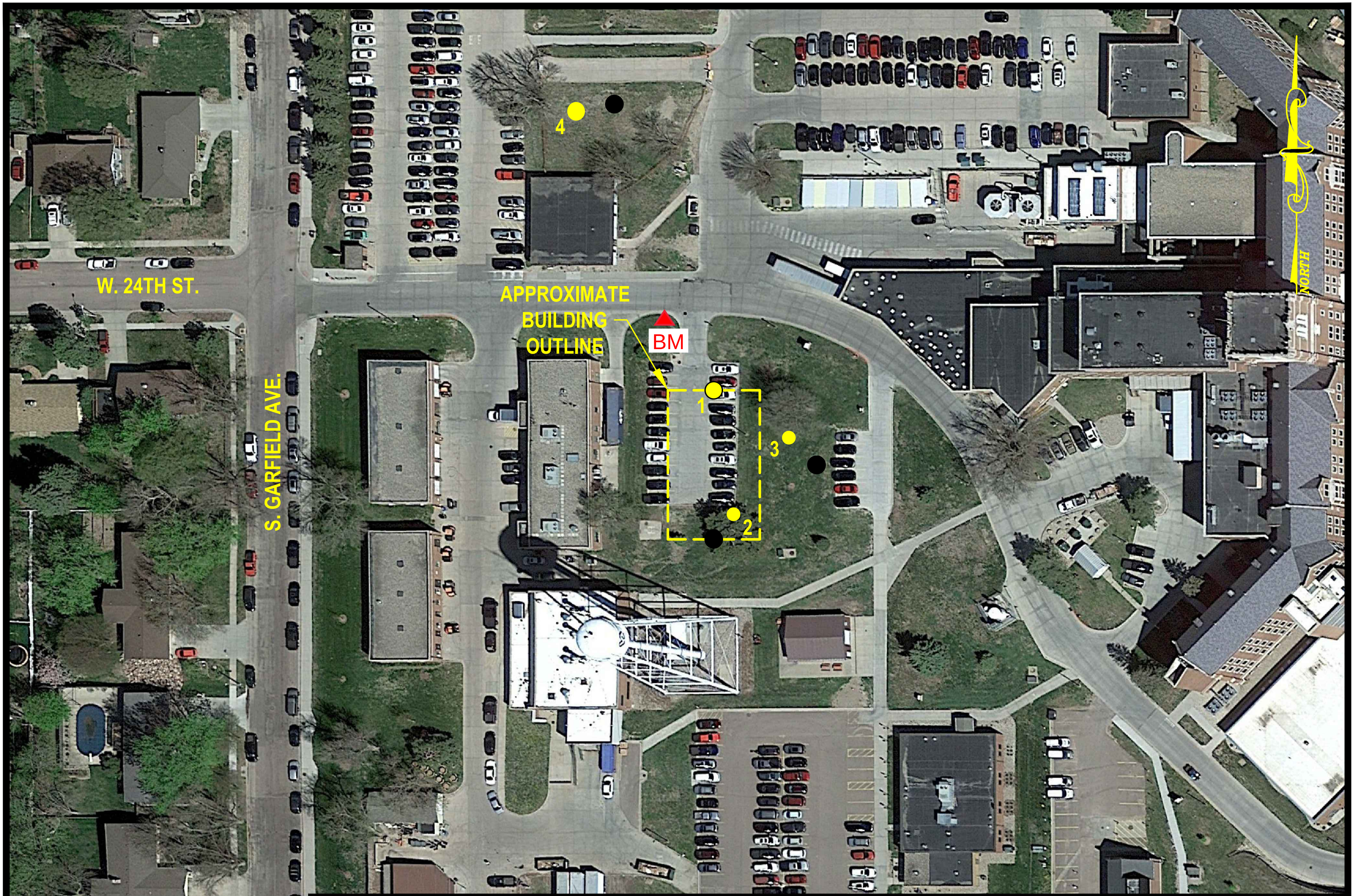

FIGURE 2
TEST BORING LOCATION MAP
PROPOSED BOILER PLANT
VA HOSPITAL
W. 24TH STREET
SIOUX FALLS, SD

ACAD/GEOTEK/NICK/23-XXXX

PROJECT#: 23-XXXX

DRAWN BY: DHP

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FIGURE 3

Table A.1 Soil-test evaluation

Soil Characteristics Based on Samples Taken Down to Pipe Depth		Points*
Resistivity—ohm-cm (based on water-saturated soil box):		
	<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 # **23-0352** BORING NO. **1 (1 of 1)**

PROJECT **Proposed Boiler Plant, VA Hospital, W. 24th Street & S. Garfield Avenue, Sioux Falls, SD**

SURFACE ELEVATION 1,490.2 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**FILL, MOSTLY LEAN CLAY**: with a little gravel, brown, moist, 7" concrete 8" gravel (CL)	FILL			1	HSA					
3½	**FILL, MOSTLY LEAN CLAY**: with gravel, brown, moist, (CL)	FILL	12		2	SPT					
	FILL, MOSTLY SANDY LEAN CLAY: with a trace of gravel, light brown to dark brown, moist to wet, (CL)	FILL	9		3	SPT					
9½			3	▼	4	SPT	18				
12	**LEAN CLAY**: very dark brown, moist, firm, (CL)	TOPSOIL	5		5	SPT	34	78			
	LEAN CLAY: brown, moist to wet, soft to firm, (CL)	LOESS	8		6	SPT	25	95			
			4		7	SPT	21				
24½			5		8	SPT	27	93			
26	**LEAN CLAY WITH SAND**: with a little gravel, brown, moist, firm, (CL)	GLACIAL TILL	7		9	SPT	21	109			1300
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-5-23	12:40 pm	26	--	12	▼ 8.0
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-5-23 COMPLETE 4-5-23 12:40 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Matt Luken

GEOTECHNICAL TEST BORING 23-0352.GPJ GEOTEKENG.GDT 5/18/23

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **23-0352**

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

PROJECT **Proposed Boiler Plant, VA Hospital, W. 24th Street & S. Garfield Avenue, Sioux Falls, SD**

SURFACE ELEVATION 1,491.3 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
0–2	**FILL, MOSTLY LEAN CLAY**: dark brown, moist, (CL)	FILL			1	HSA					
2–7½	**FILL, MOSTLY LEAN CLAY WITH SAND**: brown and dark brown, moist, (CL)	FILL	10		2	SPT					
			3		3	SPT					
7½–19½	**LEAN CLAY**: mottled brown and gray, moist to wet, soft to firm, (CL)	LOESS	3		4	SPT					
				▼							
			4		5	SPT					
			4		6	SPT					
			5		7	SPT					
19½–21	**LEAN CLAY WITH SAND**: a little gravel, mottled brown and dark brown, moist, very stiff, (CL)	GLACIAL TILL	16		8	SPT					

Bottom of borehole at 21 feet.

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-14-23	10:30 am	21	--	18	NONE
4-24-23	4:00 am	21	--	15	▼ 9
--	--	--	--	--	--
--	--	--	--	--	--

START 4-14-23 COMPLETE 4-14-23 10:19 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Matt Luken

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **23-0352** BORING NO. **3 (1 of 1)**

PROJECT **Proposed Boiler Plant, VA Hospital, W. 24th Street & S. Garfield Avenue, Sioux Falls, SD**

SURFACE ELEVATION 1,492.5 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	FILL, MOSTLY LEAN CLAY: dark brown and brown, moist	FILL			1	HSA					
			13		2	SPT	18	112			
			7		3	SPT	19	109			
			12		4	SPT	22	104			
8½	**LEAN CLAY**: dark brown, wet, firm, (CL)	LOESS									
			5		5	SPT	33				
12	**LEAN CLAY**: mottled brown and gray, wet, firm, (CL)	LOESS	5		6	SPT	26	93			
			5		7	SPT	29	94			
20	**LEAN CLAY WITH SAND**: a little gravel, mottled brown and gray, moist, firm to stiff, (CL)	GLACIAL TILL	7		8	SPT	20				
			14		9	SPT	23	104	49	16	3500
26	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-6-23	9:30 am	26	--	20	NONE
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-6-23 COMPLETE 4-6-23 9:28 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

GEOTECHNICAL TEST BORING 23-0352.GPJ GEOTEKENG.GDT 5/18/23

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **23-0352** BORING NO. **4 (1 of 1)**

PROJECT **Proposed Boiler Plant, VA Hospital, W. 24th Street & S. Garfield Avenue, Sioux Falls, SD**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1,493.9 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**FILL, MOSTLY LEAN CLAY**: very dark brown, moist	FILL	8		1	SPT					
4½	**LEAN CLAY**: dark brown, moist, stiff, (CL)	LOESS	10		2	SPT	22	104			
6	**LEAN CLAY**: brown, wet, firm, (CL)	LOESS	5		3	SPT	23	101			
	Bottom of borehole at 6 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-6-23	8:18 am	6	--	4	NONE
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-6-23 COMPLETE 4-6-23 8:18 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

GEOTECHNICAL TEST BORING 23-0352.GPJ GEOTEKENG.GDT 5/18/23

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS: GRAPH	SYMBOLS: LETTER	TYPICAL DESCRIPTIONS
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%