



October 6, 2022

**Ms. Kathryn Schmit, Ph.D., P.E.**

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**Re: Geotechnical Evaluation  
Sanford Underground Research Facility (SURF)  
Wastewater Treatment Plant (WWTP) Improvements  
Lead, South Dakota**

Dear Ms. Schmit:

As requested, we have performed a geotechnical evaluation for the referenced project. The purpose of this evaluation was to identify the subsurface characteristics, suggest suitable foundation systems for the proposed structures and provide the geotechnical design parameters.

The findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practices. We make no other warranty, either express or implied.

We trust this information to be sufficient. If you have any questions or desire any additional information, please do not hesitate to contact us.

Respectfully submitted,

**FMG Engineering**

**John Lucas, P.E.**

**Alex Fisher, P.E.**

**Enclosures**

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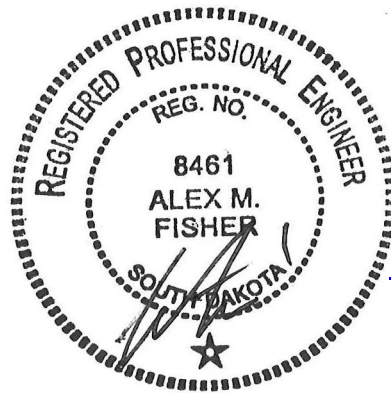


# Geotechnical Evaluation

for

Sanford Underground Research Facility (SURF)  
Wastewater Treatment Plant (WWTP) Improvements  
Lead, South Dakota

October 6, 2022



*Prepared for*  
**Banner Associates, Inc.**

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FMG Project No. 221198

Civil Engineering  
Geotechnical Engineering  
Materials Testing Laboratory  
Land Surveying  
Environmental Services  
Water Resources

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## 1. INTRODUCTION

A new at-grade concrete basin and blower building is proposed for construction at a site in eastern Lead, South Dakota. The proposed concrete basin and blower building are located in the SW  $\frac{1}{4}$  of Section 13, T4N, R31E and will have a potable water capacity of 2 million gallons. The basin will be majority buried, with approximately 3.5 feet above existing grades and a finished floor elevation of approximately 5102.5 feet. The blower building is anticipated to utilize a conventional shallow foundation system.

FMG Engineering (FMG) was retained by Banner to perform a geotechnical evaluation of the project site to identify the subsurface conditions, suggest suitable foundation systems for the structures, and provide geotechnical design parameters. If proposed construction or locations differ significantly from that described above or elsewhere described in this report, our office should be contacted to re-evaluate the recommendations contained in this report. Figure 1 indicates the locations of the boreholes drilled for the project.

This report presents our geotechnical evaluation of the project site. Our evaluation included the following general scope of activities:

1. A general review of the regional geology, and related site characteristics.
2. Field exploratory borings, sampling, and testing at representative locations to determine the depth, thickness, orientation, engineering characteristics, and composition of the subsurface conditions.
3. Laboratory tests to identify the soil types, classifications, and engineering properties of the subsurface materials encountered at the site.
4. An analysis of the data obtained, and determination of suitable geotechnical design parameters and other such recommendations as considered applicable to satisfactory design and performance.



Field and laboratory tests were generally accomplished in accordance with current ASTM, AASHTO and IEEE procedures, where applicable. The evaluation was accomplished under the direction of a registered professional engineer. This report presents the geotechnical engineering evaluation with recommendations for foundation design. We have also included a discussion of our field sampling and testing procedures, laboratory analyses, and site conditions.



## **2. FIELD SAMPLING AND TESTING PROCEDURES**

A total of four (4) boreholes were drilled at the locations shown on Figure 1 to identify the subsurface characteristics and obtain soil samples for laboratory testing.

The boreholes were drilled with a Diedrich D-70 track-mounted drill rig and hollow-stem auger. The number of boreholes and the locations were selected by Banner with respect to the desired structure locations and were adjusted slightly by FMG in the field as necessary with respect to physical site access. If, during subsequent planning, the structure locations change significantly from those described in this report and shown on Figure 1, we recommend drilling additional boreholes to verify soil conditions in unexplored areas.

Field testing consisted of obtaining standard penetration test (SPT) samples from various depths in the boreholes. The SPT testing was performed to identify the relative field strengths of the subsurface materials and to obtain samples for laboratory analyses.

Geologic logs of the boreholes were maintained by a field geologist and the materials were classified in accordance with ASTM: D 2487-90 and D 2488-90 (Unified Soil Classification System), Figure 2. The geologic logs include the general drilling method data, depths of major changes in the character of the subsurface materials, visual description of the materials, sample locations, standard penetration data and locations, and groundwater data. In addition, the geologic logs also include the data from certain laboratory classification and physical property analyses. The geologic logs are presented as Appendix A.

The geologic logs and related information depict only the conditions and materials encountered at the specific borehole location and at the time designated on the logs. Soil conditions at other locations may be different from those encountered at the borehole locations. Also, the passage of time may produce a changed soil condition. We have extrapolated the data obtained from the boreholes and our conclusions and recommendations assume that the materials encountered are representative of the soils that exist over the site. Anomalies may be present around the boreholes.



### **3. LABORATORY ANALYSIS**

The laboratory analysis was directed towards the determination of soil types drilled on the site and their engineering properties. The laboratory testing was performed in general conformance with current ASTM and AASHTO procedures, where applicable. The laboratory testing results are provided in Appendix B, and on the borehole logs where applicable.

#### **3.1 ATTERBERG LIMITS**

The Atterberg limits were determined for select samples. These tests allow for more detailed classification of soils and provide information relative to the expected engineering characteristics and properties. (ASTM D4318-05)

#### **3.2 GRAIN SIZE ANALYSIS DATA**

Standard grain size analysis determinations were performed to determine the grain size distribution and assist in the determination of the physical characteristics and engineering properties of the subsurface materials. (ASTM D422-63(2007))

#### **3.3 SAMPLE STORAGE**

The soil samples obtained during this evaluation will not be stored. If the client wishes to receive the samples arrangements should be made; otherwise, the samples will be discarded.



## **4. SITE CONDITIONS**

The site proposed for the new basin and blower building is located in eastern Lead, South Dakota. The site can generally be described as a hilltop with grades generally sloping away from the project site. Vegetation at the site is generally limited to grasses.

### **4.1 MATERIALS PRESENT**

The site stratigraphy generally consists of approximately 10 to 15 feet of recompacted schist fill soils overlying weathered schist bedrock to the total depths explored.

#### **4.1.1 Material Descriptions**

The weathered schist fill soils encountered at the site were generally found to be dark grayish brown to black, dry to moist, non-plastic, and dense to very dense in consistency.

The underlying formational bedrock consisting of weathered schist was found to be black, dry, non-plastic, and very dense to hard in consistency. Quartzite stringers were encountered in the sampler.

The geologic log indicates the specific soil characteristics observed throughout the profiles in each of the boreholes advanced at the site.

### **4.2 GROUNDWATER TABLE**

Groundwater was not encountered in the boreholes during drilling. However, groundwater presence and levels should be anticipated to vary in response to seasonal changes in precipitation, bedrock fracture patterns, high precipitation events, and snow melt, and may not be accurately delineated within the normal scope of a geotechnical evaluation.

### **4.3 GEOLOGIC CONDITIONS**

The geologic conditions of the project site can be generally described as residual soils overlying formational weathered shale bedrock. The weathered shale bedrock is interpreted to be part of the Grizzly Formation. The Grizzly Formation is a blue gray to dark gray, platy mica schist. (Redden, 2010)



Geologic mapping of the area indicates no mapped faults or geologic structures within close proximity of the project site that would impact siting, design or construction of the proposed project. (Redden, 2010)



## 5. CONCLUSIONS AND RECOMMENDATIONS

From our subsurface exploration and engineering analysis, we have arrived at the following conclusions and have the following recommendations regarding foundation design for the proposed construction. The conclusions and recommendations presented in this report do not reflect variations in subsurface conditions that are likely to exist in unexplored areas. Should such variations be revealed during construction, it may be necessary to re-evaluate our recommendations based upon on-site observation of the variations. Also, we should be retained to review the foundation plans, as well as applicable portions of the specifications when they become available.

### 5.1 FOUNDATION AND SLAB SYSTEM SELECTION

The subgrade conditions at the proposed concrete basin and blower building site consist of 10 to 15 feet of dense to very dense recompacted schist fill soils overlying hard weathered schist. The site soils will provide adequate bearing capacity for the anticipated foundation contact pressures. We recommend the basin and building be constructed atop a shallow foundation founded directly on the subgrade soils. A slab-on-grade floor system is also recommended and should be constructed atop subgrade soils. The design parameters and construction criteria presented below in Sections 5.1.1 should be observed for shallow foundation systems.

#### 5.1.1 Shallow Foundation Systems

**Table 1** – Shallow Foundation Design Criteria

| <i>Parameter</i>                            | <i>Value</i>                                                                                                                                                                                                |
|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subgrade Preparation                        | 1. Scarify, moisture condition, and recompact 8” to 12” of schist fill soils to provide a uniform surface.<br>2. Properly compacted engineered fill may be utilized if bearing surface is deemed irregular. |
| Net Allowable Bearing Capacity (FS=3.0)     | 5,000 psf for basin & 2,000 psf for blower building                                                                                                                                                         |
| Static/Dynamic Modulus of Subgrade Reaction | 200 pci for engineered fill or native subgrade soils                                                                                                                                                        |
| Sliding Friction Coefficient                | 0.42                                                                                                                                                                                                        |
| Passive Earth Pressure                      | 285 psf                                                                                                                                                                                                     |



#### 5.1.1.1 Shallow Foundation Design and Construction Criteria

1. We recommend that the foundation excavation subgrade be scarified to a depth of 8 to 12 inches, moisture conditioned and recompactd in accordance with the criteria provided in Table 5 of this report prior to placement of concrete, reinforcing steel or engineered fill to provide a uniform subgrade. Bedrock excavation subgrade should not be scarified.
2. The excavation subgrade within the schist bedrock will likely be jagged and irregular surface. It may be prudent to place a layer of properly compacted engineered fill to provide a level, uniform surface prior to concrete placement.
3. All fill material within the footprint shall consist of engineered fill.
4. If soft conditions are encountered at the base of the foundation excavations, the excavation should be over-excavated to stable conditions as directed by the Geotechnical Engineer. As directed by the Geotechnical Engineer, the additional over-excavation should be replaced with properly compacted engineered fill or stabilization rock meeting the requirements outlined in Section 5.6.1 of this report. The engineered fill should be compacted in accordance with Table 5. If utilized, stabilization rock should be used to the extents necessary to provide a stable subgrade, above which properly compacted engineered fill should be installed up to foundation bearing elevation. Any stabilization rock should be covered with a non-woven filter fabric prior to placement of engineered fill.
5. A one-third (33%) increase in allowable bearing capacity for wind or seismic cases is permitted based on reducing the factor of safety from 3.0 to 2.25.
6. Compacted fill placed against the sides of the footings to resist lateral loads may be moisture-conditioned, on-site soil. The fill should be placed in accordance with the fill and soil compaction criteria provided in Table 5.
7. Precipitation events or fluctuations in groundwater levels could cause the base of the foundation excavations to be within the range of possible groundwater fluctuations.



Dewatering efforts may be necessary. It may be necessary to install sump pits and dewater the excavations to allow proper excavations, fill placement, subgrade preparation and foundation construction. We recommend that the contractor obtain the necessary permits for the dewatering operations and that the dewatering be performed in accordance with local, county, state, and federal regulations

8. Debris, foundations, utilities, and other relics associated with past site developments may be encountered during excavations within the building footprints. If encountered, such items should be removed in their entirety and the resulting voids should be backfilled with properly compacted engineered fill meeting the material and compaction requirements of Section 4.3 of this report.
9. The natural soils may pump or deform excessively under the wheel loads of heavy construction vehicles as the excavations approach footing levels. Construction equipment should be as light as possible to avoid this difficulty. The movement of vehicles over proposed foundation areas should be restricted. Any areas disturbed by construction traffic should be stabilized or over-excavated and replaced with stabilization rock or compacted engineered fill.

A qualified Geotechnical Engineer should observe all footing excavations prior to concrete placement. A representative of the Geotechnical Engineer should perform compaction testing during any moisture-conditioned fill placement.

### **5.1.2 Blower Building Floor System**

The subgrade soils are generally suitable for slab-on-grade floor system construction. The recommended design parameters and construction criteria for a slab-on-grade floor system are provided below in Section 5.1.2.1 and Section 5.1.2.2.



#### 5.1.2.1 Slab-On-Grade Design Parameters

**Table 2 – Slab-On-Grade Design Criteria**

| Parameter                    | Value                                                                                                                                                                                                       |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subgrade Preparation         | 1. Scarify, moisture condition, and recompact 8" to 12" of schist fill soils to provide a uniform surface.<br>2. Properly compacted engineered fill may be utilized if bearing surface is deemed irregular. |
| Modulus of Subgrade Reaction | 250 pci                                                                                                                                                                                                     |

#### 5.1.2.2 Slab-On-Grade Design and Construction Criteria

1. We recommend that the floor slab excavation subgrade be scarified to a depth of 8 to 12 inches, moisture conditioned and recompact in accordance with the criteria provided in Table 5 of this report prior to placement of concrete, reinforcing steel or engineered fill to provide a uniform subgrade. Bedrock excavation subgrade should not be scarified.
2. The excavation subgrade within the schist bedrock will likely be jagged and irregular surface. It may be prudent to place a layer of properly compacted engineered fill to provide a level, uniform surface prior to concrete placement.
3. If soft conditions are encountered at the base of the slab excavations, the excavation should be over-excavated to stable conditions as directed by the Geotechnical Engineer. As directed by the Geotechnical Engineer, the over-excavation should be replaced with properly compacted native soils, engineered fill or stabilization rock meeting the requirements outlined in Section 5.3 of this report. The engineered fill should be compacted in accordance with Table 5.
4. Precipitation events or fluctuations in groundwater levels could cause the base of the floor slab excavations to be within the range of possible groundwater fluctuations. Temporary dewatering efforts may be necessary. At a minimum, it may be necessary to install sump pits and dewater the excavations to allow proper subgrade preparation and foundation construction if groundwater or surface water enters the excavations.



We recommend that the contractor obtain the necessary permits for the dewatering operations and that the dewatering be performed in accordance with local, county, state, and federal regulations.

5. The natural soils may pump or deform excessively under the wheel loads of heavy construction vehicles as the excavations approach footing levels. Construction equipment should be as light as possible to avoid this difficulty. The movement of vehicles over proposed foundation areas should be restricted. Any areas disturbed by construction traffic should be stabilized or over-excavated and replaced with compacted engineered fill.
6. Floor slabs should be provided with control joints to reduce damage due to shrinkage cracking and should be adequately reinforced.
7. A minimum 4-inch layer of free draining gravel or sand should be placed beneath the slab. This material should contain less than 5 percent passing the #200 sieve. The granular layer will help distribute floor slab loadings, ease construction, and prevent capillary water rise and aid in drainage. If proposed floor coverings are, or have the potential to be, moisture or vapor sensitive, a vapor membrane is recommended.
8. A positive bond break should be provided where utility lines enter through the floor. Flexible connections should be provided for slab-bearing mechanical equipment.
9. Care should be taken to minimize the ingress of water into the slab subgrade. Water stops and other measures should be considered for floor drain construction, and flexible connections should be provided for sub-slab utilities.
10. Materials immediately below the slab should consist of properly compacted engineered fill meeting the requirements of Section 5.3 or a free-draining gravel or sand leveling course. In no case should clay soils be placed directly below the floor slab. If floor coverings are, or have the potential to be, moisture or vapor sensitive, a vapor membrane is recommended below the floor slab. The membrane should be



consistent with ASTM E1745 – Class A, or equivalent as approved by the Geotechnical Engineer

We suggest that final testing of the floor slab area be performed (in addition to testing during placement) immediately before concrete placement to determine the integrity of the materials. Severe changes in the condition of these materials can occur after initial preparation as the result of rain, drying, freezing, and construction activities. Any subgrade or foundation material that becomes disturbed, desiccated or does not conform to the moisture content and compaction requirements indicated in Table 5 should either be removed and replaced or reworked to meet these recommendations.

Regarding the concrete floor slab, it should be noted that Portland cement concrete is not a perfect construction material. Due to the characteristics of Portland cement concrete itself, cracking of the floor slab may occur. Cracking will be minimized, but not eliminated, by providing appropriate control, isolation, and construction joints. Drying and thermal shrinkage of the slabs with resultant hairline cracking or curling may occur if the slabs are cured under anything less than optimum curing conditions. In short, there is no practical method of ensuring that all floor slab cracking is eliminated due to the nature and performance of the Portland cement and the consolidation properties of the subgrade soils. A qualified Geotechnical Engineer should observe all excavations prior to concrete placement, as well as perform compaction testing during any moisture-conditioned fill placement.

## **5.2 UNDERDRAIN SYSTEM**

We recommend installing an underdrain system along the perimeter of the base of the foundation excavation, prior to placement of any engineered fill, to help limit the moisture variations in the subgrade soils caused by the ingress of water from the exterior of the building. We suggest grading the bottoms of the excavations to have a minimum cross slope of one percent (1%) away from the interior of the structure and toward the underdrain system. The underdrain system should consist of non-corrugated rigid drainpipe, free-draining gravel, and filter fabric. The high point of the drainpipe should be placed at the bottom of the foundation excavation and at the contact of the engineered fill and native earth materials.



The drainpipe should consist of a minimum 4-inch diameter, non-corrugated, perforated PVC drainpipe surrounded with a minimum of 6-inches of free-draining gravel. The free-draining gravel should contain less than 5 percent passing the No. 200 sieve, and no more than 20 percent passing the No. 4 sieve and have a maximum particle size of 1 inch. The gravel surrounding the drainpipe and the pipe itself should be wrapped in eight-ounce (8 oz.) non-woven geotextile fabric to reduce the migration of fines into the drain system. The drainpipe should be set for positive drainage to a sump from which water can be removed by pumping, or to a daylight outlet for gravity discharge.

### **5.3 RETAINING STRUCTURES AND LATERAL EARTH PRESSURES**

Any retaining structures on the site can be expected to deflect sufficiently to mobilize the full active earth pressure condition. Retaining walls which can be expected to deflect may be designed using the “active” earth pressures. Tank walls or grade beams that will be laterally supported and are expected to undergo only a limited amount of deflection, thus requiring the consideration of the “at-rest” earth pressure condition.

The lateral resistance of wall foundations will be the combination of the sliding resistance of the footing on the foundation materials and the passive resistance of the soil against the side of the footing. Sliding friction at the bottom of the footing can be taken at 0.42 if founded on properly compacted engineered fill.

An imported granular wall backfill material may be utilized to reduce the lateral pressures exerted on the walls. If an imported granular material is used as backfill, the granular wall backfill should extend laterally behind the wall a minimum distance equal to one half (1/2) the wall height to prevent the laterally heavier on-site cohesive soils from exerting lateral forces on the wall. The upper 6 to 8 inches of wall backfill should consist of on-site cohesive soils to limit moisture ingress into the granular backfill. If the granular wall backfill extends laterally behind the wall a distance less than one half (1/2) the wall height, the retaining structure or wall should be designed for the lateral earth pressures for the on-site soils. Imported granular wall backfill should have an internal angle of friction of no less than 32 degrees.



We recommend that tank walls, vaults and retention structures at the site be designed for lateral earth pressures calculated based on the equivalent fluid pressures and soil parameters presented in Table 3.

**Table 3 - Equivalent Fluid Pressures and Retained Soil Parameters**

| <b>Parameter</b>                   | <i>Drained Conditions</i> |                                            |
|------------------------------------|---------------------------|--------------------------------------------|
|                                    | <b>On-Site Soils*</b>     | <b><i>Imported Granular Backfill**</i></b> |
| <b>Active, pcf</b>                 | 49                        | 35                                         |
| <b>At-Rest, pcf</b>                | 69                        | 55                                         |
| <b>Passive, pcf</b>                | 296                       | 390                                        |
| <b>Friction Angle, degrees</b>     | 25                        | 32                                         |
| <b>Soil Moist Unit Weight, pcf</b> | 120                       | 120                                        |
| <b>Cohesion, psf</b>               | 0                         | 0                                          |

Notes: \*Pressures recommended for on-site soils apply to recompacted site schist soils and in-place weathered schist bedrock.

\*\*The pressures recommended for imported granular backfill are contingent on the material demonstrating an internal angle of friction of at least 32 degrees.

An upward sloping backfill surface or the buildup of water behind a wall will increase the earth pressures on foundation and retaining walls. To prevent the buildup of water behind the walls designed for drained conditions, we recommend that the backfill immediately behind the wall consist of a free draining granular material or that a synthetic drainage material be installed between the wall and backfill materials. A horizontal wall drain system should be designed at the base of the wall to collect and convey water from the wall system. Wall backfill should be compacted in accordance with the criteria provided in Table 5. The upper 6 to 8 inches of wall backfill should consist of on-site cohesive soils to limit moisture ingress into the granular backfill.



Care should be taken not to over compact the backfill behind the walls as this could cause excessive lateral pressures on the walls. Some settlement of deep wall backfills will occur even if the material is placed correctly. All foundation and retaining structures should be designed for surcharge pressures such as adjacent traffic and construction materials and equipment. The lateral earth pressures provided herein are unfactored. An appropriate factor of safety should be applied to retaining wall system design.

## 5.4 SITE SEISMICITY

Seismic design should be in accordance with the ASCE 7-16 seismic design parameters provided below. The Seismic Site Class indicated below in Table 4 assumes the soil conditions encountered at the bottom of the borings continue to a depth of 100 feet. A more detailed and accurate Site Class evaluation may be achieved by performing geophysical seismic surveys to develop the shear wave velocity profile for the site to a depth of 100 feet.

Table 4 - Seismic Design Criteria

| <i>ASCE 7-16 Seismic Design Parameters</i>    |         |
|-----------------------------------------------|---------|
| Seismic Category                              | A       |
| Site Class                                    | C       |
| <b>MCE Spectral Response Accelerations</b>    |         |
| Short Period, $S_s$                           | 0.131 g |
| 1-second, $S_1$                               | 0.041 g |
| Site Coefficients, $F_a$                      | 1.3     |
| Site Coefficient, $F_v$                       | 1.5     |
| <b>Design Spectral Response Accelerations</b> |         |
| Short Period, $S_{DS}$                        | 0.113 g |
| 1-second, $S_{D1}$                            | 0.041 g |

## 5.5 GENERAL MATERIAL PLACEMENT REQUIREMENTS

### 5.5.1 Fill Materials

**The on-site schist soils**, segregated from debris, deleterious material, and any oversized material greater than 6-inches in maximum dimension, will be suitable for use as foundation backfill and general site fill, but will not be suitable for use as engineered fill. It should be



noted that some processing, drying or sorting of the on-site materials may be required prior to placement as fill, as in-situ moisture contents may be above optimum moisture contents.

**On-site sources of engineered fill were not identified.** These materials will have to be imported to the site. We recommend that all engineered fill materials consist of non-expansive, well-graded natural or crushed gravel with 100% passing the 3-inch sieve and between 8% and 20% passing the #200 sieve. The engineered fill material should also have a liquid limit less than 30. The engineered fill material must be approved by the Geotechnical Engineer prior to transport to the site.

**On-site sources of stabilization rock were not identified.** These materials will have to be imported to the site, if necessary. The stabilization rock should be a clean rock with 100% passing the 3-inch sieve, 0 to 15% passing the 1-inch sieve, and 0 to 8% passing the #4 sieve. The stabilization rock must be approved by the Geotechnical Engineer prior to transport to the site.

### **5.5.2 Fill Placement**

We suggest that sufficient density tests be taken by qualified personnel to indicate the degree of compaction being attained. We recommend controlling scarification, fill and backfill operations using the moisture content and dry density relationship as determined by ASTM D 1557 (Modified Proctor Density). The fill materials should be placed in 6-12-inch loose lifts and compacted to the densities and moisture contents outlined in Table 5 below. Any additional moisture required to achieve compaction in a layer should be added and the entire lift mixed to obtain uniform moisture content.

We suggest that final testing of the footing subgrade and other fills in "structural areas" be performed (in addition to testing during placement) immediately before concrete placement to determine the integrity of the materials. Severe changes in the condition of these materials can occur after initial preparation as the result of rain, snow, drying, freezing, excessive heat, and construction activities. Any subgrade or foundation material that becomes disturbed desiccated or does not conform to the moisture content and compaction requirements indicated in Table 5 should either be removed and replaced or reworked to meet these recommendations.



**Table 5 - Soil Compaction Criteria**

| <i>Placement Location</i>                                                   | <i>Soil Type</i>                                                   | <i>Moisture Content</i> | <i>Compaction Degree</i> |
|-----------------------------------------------------------------------------|--------------------------------------------------------------------|-------------------------|--------------------------|
| Scarification of Subgrade<br>Utility Trench Backfill<br>Foundation Subgrade | Free-Draining Materials<br>(Sand and Gravels - Less Than 8% Fines) | Workable                | 95%<br>(ASTM D-4253)     |
|                                                                             | Cohesive Materials<br>(Clays and Silts)                            | -1 to +3% of Optimum    | 92%<br>(ASTM D-1557)     |
|                                                                             | Cohesionless Materials<br>(Sands and Gravels – More Than 8% Fines) | Workable                | 95%<br>(ASTM D-1557)     |
| Site Grading Approx. 15 Feet<br>Away from Structures                        | Cohesive Materials<br>(Clays and Silts)                            | -1 to +3% of Optimum    | 85%<br>(ASTM D-1557)     |
|                                                                             | Cohesionless Materials<br>(Sands and Gravels – More Than 8% Fines) | Workable                | 90%<br>(ASTM D-1557)     |

The earthen site construction materials should not be placed on frozen ground and compaction operations should not be performed during periods when temperatures are below 25 degrees Fahrenheit. During cold weather construction periods, it may be necessary to remove frozen soils prior to placement of new fill materials.

Placement of earthen site construction materials at temperatures below 35 degrees Fahrenheit may result in frost entering the soils and making placement at the required specifications difficult. Therefore, we suggest when temperatures are below 40 degrees Fahrenheit and earthen materials are being placed below structures, that the earthen site construction materials be continuously observed and tested. If frozen materials are observed being placed below structures, we suggest that they be removed and replaced with unfrozen materials as directed by the geotechnical engineer or testing personnel.



Soils having relatively high silt or fine sand contents are often difficult to compact to the desired specifications although they may be compacted well enough to suit the intended purpose. If great difficulty is encountered during construction regarding meeting the compaction specifications, a qualified geotechnical engineer should be consulted to determine if the placement of the soils at lower densities could still provide suitable characteristics.

## **5.6 EXCAVATIONS, SHORING AND SITE GRADING**

### **5.6.1 Excavations and Shoring**

Shallow excavations at the site will encounter recompacted schist fill soils and schist bedrock. Where encountered, the schist bedrock will likely require additional effort to excavate. These bedrock materials were found to be hard. Blasting, ripping, percussion hammers and/or other aggressive excavation techniques will be necessary for excavation in the site bedrock materials.

Regarding excavations at the sites, we recommend that they be sloped or shored in accordance with OSHA regulations, and to generally maintain adequate safety provisions on the job-site. The near surface soils can be considered OSHA Type B soils. It is the contractor's responsibility to maintain job-site safety, and the occasional or longer-term presence of an FMG representative at the site does not constitute a review or a responsibility regarding safety aspects.

### **5.6.2 Site Grading**

Excavations and shoring recommendations for the site grading efforts are provided in Section 5.6.1 and fill placement recommendations are provided in Section 5.5.2. We have the following general recommendations about site grading. We have the following recommendations about site grading at the concrete reservoir.

1. Any fill materials placed within structure footprints shall be considered structural subgrade and compacted accordingly.



2. We recommend that all topsoil, root zones, organics, etc. be stripped in areas to receive fill or from foundation footprints.
3. If soft conditions are encountered during site grading, stabilization may be necessary to allow proper construction. Stabilization efforts should be as directed by the Geotechnical Engineer based upon site observations.
4. Site grading should provide for positive drainage away from the structure. Preventing moisture ingress to the structure subgrade soils will be critical to foundation and slab performance.

## **5.7 GENERAL DESIGN AND CONSTRUCTION PROVISIONS**

In many cases, foundation and slab failures and movements are associated with changes in moisture conditions. To reduce the potential of foundation and floor system failures and movements at the site, we suggest implementing construction procedures that limit the potential of subgrade soils experiencing substantial changes in moisture. We suggest the following minimum criteria.

1. For a minimum of 8 feet away from the structure, we suggest maintaining a minimum of a 5% slope for soil surfaces and a 2% slope for asphalt and concrete paving. Maintain positive drainage beyond 8 feet from the structure.
2. We recommend burying all utilities at a minimum depth of four (4) feet below finished grade to receive protection from frost penetration. (Bowels, 1988)
3. All downspouts should be designed and maintained to discharge well away from structures and foundation elements.
4. We suggest pressure testing of all utility lines prior to backfilling to determine that there are no leaks in the system.
5. We suggest that the maintenance manager be made aware of the importance of limiting moisture ingress into the foundation soils.



## 6. PROJECT OBSERVATION AND CONSTRUCTION QUALITY ASSURANCE

As the provider of the geotechnical recommendations contained herein, FMG should be retained to provide any necessary pre-construction geotechnical reviews, interpretations, supplemental information and to provide the required construction-period observation and quality assurance program.

If any changes in the nature, design or location of the project are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed, and conclusions of this report modified or verified in writing.

Frequently, soil conditions vary slightly from those encountered in the borings that were drilled. Therefore, FMG should be retained to review the portions of the plans that pertain to earthwork and foundations.

Additionally, proper placement of site fill, engineered fill, and other structural elements per our recommendations and per the project specifications is essential to the performance of the foundation and floors of the structure. Failure to properly place the construction materials and structural elements can result in excessive movements potentially leading to failure and significant impact to the structural integrity of the structure.

We suggest the following minimum standards and frequency of testing be followed for soil and concrete construction materials placed at the project site.

**Table 6 - Recommended Frequency of Testing**

| <i>Material or Placement Location</i>       | <i>Recommended Standard or Frequency</i>       |
|---------------------------------------------|------------------------------------------------|
| Structural Concrete                         | ACI 318 Chapter 26.12                          |
| General Site Fill                           | 1 test per 12" lift per 10,000 ft <sup>2</sup> |
| Foundation and Slab Excavation Subgrade     | 1 test per 500 ft <sup>2</sup>                 |
| Engineered Fill Below Foundations and Slabs | 1 test per 12" lift per 500 ft <sup>2</sup>    |
| Foundation Backfill                         | 1 test per 75 linear feet per vertical foot    |
| Utility Trench Backfill                     | 1 test per 12" lift per 200 linear feet        |



Our recommendations are based on the necessary assumption that the material and structural element placement will occur as specified and that a detailed construction quality assurance program will be provided that clearly documents the proper placement of materials and structural elements at this site through adequate methods and frequency of testing. In the absence of such quality assurance and documentation performed by FMG, FMG cannot assume responsibility or liability for the performance of any foundation systems, embankments, or structural elements of this project. Should another agent perform the construction quality assurance, said agent will necessarily assume the role and responsibilities of project geotechnical engineer of record from FMG.

We are available to observe construction operations, particularly the concrete placement operations, the compaction of the fill materials, and other such field observations as may be necessary. Under no circumstances is it our intent to directly control the physical activities of the contractor or the contractor's workmen. Any field testing or observations performed by FMG would be a part of engineering opinions rendered to the contractor and should not be misconstrued as supervision of the contractor's work or workmen.



## **7. CONCLUDING STATEMENT**

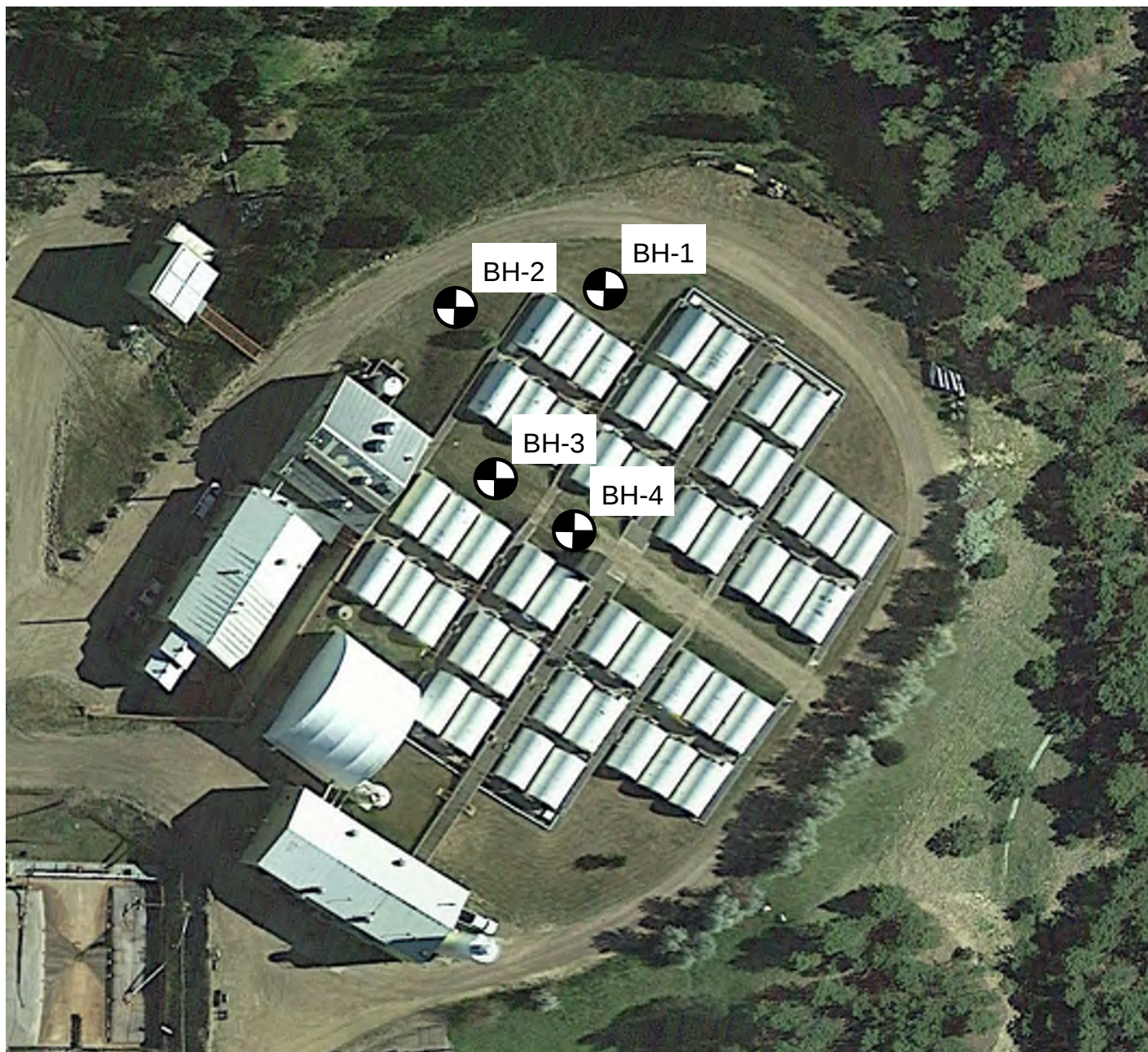
If any changes in the nature, design or location of the project features are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed, and conclusions of this report modified or verified in writing.

The findings and recommendations in this report were prepared following accepted soil mechanics procedures and practices. We make no other warranty, either implied or expressed. The conclusions and recommendations of this report are based upon the results of the field exploration boring, field tests, and analysis. We have extrapolated the data obtained from the test borehole locations to the surrounding soils. Anomalies can exist around the borings. The data presented on the boring logs represent the conditions as encountered in that test hole on the date drilled and logged. If, during planning and construction, conditions are different from those indicated, please notify us so that we can modify the conclusions and recommendations.



## Legend

 BH#1 Borehole Location



**SURF**  
WWTP Improvements  
Lead, Deadwood

October 2022

Sheet Title:  
Borehole  
Location Plan

Location:  
NW 1/4 of Section 34  
TSN, R3E, BHM

Surveyed By: ???  
Date: ???

Drawn By: ???  
Checked By: ???

Figure No.: 1

File Number:  
221198



**FMG ENGINEERING**

3700 Sturgis Road  
Rapid City, SD 57702  
605.342.4105 • fmgengineering.com

Figure  
Number:

**1**

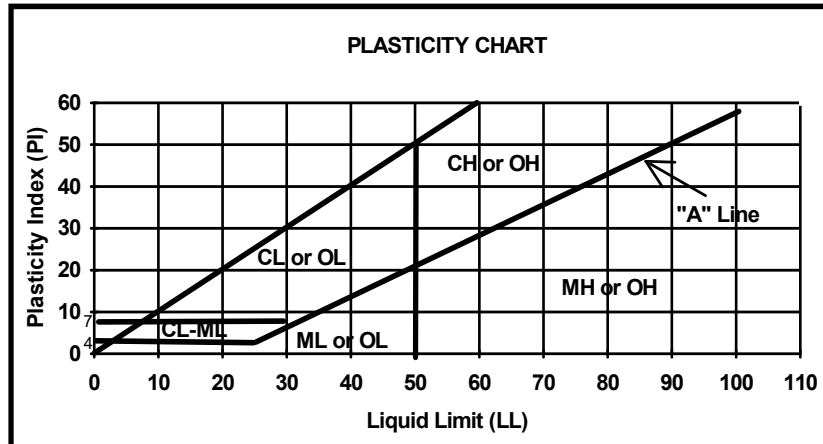
# CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

## ASTM Designation: D 2487-90 and D 2488-90 (Unified Soil Classification System)

| Soil Classification                                                        |                                                                            |                                                        |                                                                                                 |    | Group Symbol Name               |  |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------------------------|----|---------------------------------|--|
| Criteria for Assigning Group Symbols and Group Names <sup>A</sup>          |                                                                            |                                                        |                                                                                                 |    |                                 |  |
| <b>COARSE-GRAINED SOILS</b><br>More than 50% retained on the No. 200 sieve | <b>Gravels</b><br>More than 50% of coarse fraction retained on No. 4 sieve | Clean Gravels<br>Less than 5% fines <sup>C</sup>       | $Cu \geq 4$ and $1 \leq Cc \leq 3^E$<br>$Cu < 4$ and/or $1 > Cc > 3^E$                          | GW | Well-Graded Gravel <sup>F</sup> |  |
|                                                                            |                                                                            | Gravels with Fines<br>More than 12% fines <sup>C</sup> | Fines classify as ML or MH<br>Fines classify as CL or CH                                        | GM | Silty Gravel <sup>F,G,H</sup>   |  |
|                                                                            | <b>Sands</b><br>50% or more of coarse fraction passes No. 4 sieve          | Clean Sands<br>Less than 5% fines <sup>D</sup>         | $Cu \geq 6$ and $1 \leq Cc \leq 3^E$<br>$Cu < 6$ and/or $1 > Cc > 3^E$                          | SW | Well-Graded Sand <sup>I</sup>   |  |
|                                                                            |                                                                            | Sands with Fines<br>More than 12% fines <sup>D</sup>   | Fines classify as ML or MH<br>Fines classify as CL or CH                                        | SM | Silty Sand <sup>G,H,J</sup>     |  |
|                                                                            |                                                                            |                                                        |                                                                                                 | SC | Clayey Sand <sup>G,H,I</sup>    |  |
|                                                                            |                                                                            |                                                        |                                                                                                 |    |                                 |  |
| <b>FINE-GRAINED SOILS</b><br>50% or more passes the No. 200 sieve          | <b>Silts and Clays</b><br>Liquid limit less than 50                        | inorganic soils                                        | $PI > 7$ and on or above "A" line <sup>J</sup><br>$PI < 4$ or plots below "A" line <sup>J</sup> | CL | Lean Clay <sup>K,L,M</sup>      |  |
|                                                                            |                                                                            | organic soils                                          | Liquid limit-oven dried<br>-----<.75                                                            | OL | Organic Clay <sup>K,L,M,N</sup> |  |
|                                                                            |                                                                            |                                                        | Liquid limit-not dried                                                                          |    | Organic Silt <sup>K,L,M,O</sup> |  |
|                                                                            |                                                                            |                                                        |                                                                                                 |    |                                 |  |
|                                                                            | <b>Silts and Clays</b><br>Liquid limit 50 or more                          | inorganic soils                                        | $PI$ plots on or above "A" line<br>$PI$ plots below "A" line                                    | CH | Fat Clay <sup>K,L,M</sup>       |  |
|                                                                            |                                                                            | organic soils                                          | Liquid limit-oven dried<br>-----<.75                                                            | OH | Organic Clay <sup>K,L,M,P</sup> |  |
|                                                                            |                                                                            |                                                        | Liquid limit-not dried                                                                          |    | Organic Silt <sup>K,L,M,Q</sup> |  |
|                                                                            |                                                                            |                                                        |                                                                                                 |    |                                 |  |
|                                                                            |                                                                            |                                                        |                                                                                                 |    |                                 |  |
|                                                                            |                                                                            |                                                        |                                                                                                 |    |                                 |  |
|                                                                            | <b>HIGHLY ORGANIC SOILS</b>                                                |                                                        | Primarily organic matter, dark in color, and organic odor                                       | PT | Peat                            |  |

- A. Based on the material passing the 3-in. (75-mm) sieve.  
 B. If field sample contained cobbles or boulders, or both, add "with cobbles and boulders, or both" to group name.  
 C. Gravels with 5% to 12% fines require dual symbols:  
 GW-GM well-graded gravel with silt  
 GW-GC well-graded gravel with clay  
 GP-GM poorly graded gravel with silt  
 GP-GC poorly graded gravel with clay  
 D. Sands with 5% to 12% fines require dual symbols:  
 SW-SM well-graded sand with silt  
 SW-SC well-graded sand with clay  
 SP-SM poorly graded sand with silt  
 SP-SC poorly graded sand with clay  
 E.  $Cu = D_{60}/D_{10}$   $Cc = (D_{30})^2/D_{10}D_{60}$   
 F. If soil contains  $\geq 15\%$  sand, add "with sand" to group name.

- G. If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM  
 H. If fines are organic, add "with organic fines" to group name.  
 I. If soil contains  $\geq 15\%$  gravel, add "with gravel" to group name.  
 J. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.  
 K. If soil contains 15% to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.  
 L. If soil contains  $\geq 30\%$  plus No. 200, predominantly sand, add "sandy" to group name.  
 M. If soil contains  $\geq 30\%$  plus No. 200, predominantly gravel, add "gravelly" to group name.  
 N.  $PI \geq 4$  and plots on or above "A" line.  
 O.  $PI < 4$  or plots below "A" line.  
 P.  $PI$  plots on or above "A" line.  
 Q.  $PI$  plots below "A" line.



Equation of "A" - line: Horizontal at  $PI = 4$  to  $LL = 25.5$ , then  $PI = 0.73(LL - 25.5)$  (Chart is for general graphic presentation purposes only)

- Figure 2-

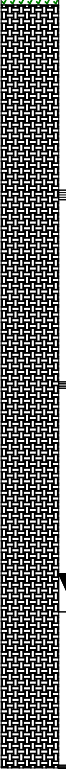
## **Appendix A**

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### **Borehole Logs**

| <b>PROJECT:</b><br><b>SURF WWTP Improvements Geotech</b>                                                                                                                                 |       |                                           |                          | <b>GEOLOGIC LOG</b><br><b>OF</b><br><b>BOREHOLE 1</b><br> <b>FMG ENGINEERING</b><br>605-342-4105<br>3700 Sturgis Road<br>Rapid City, SD 57702<br>fmgengineering.com |                                                                                           | <b>BORING LOCATION:</b> NE Bore<br><hr/> <b>GROUND ELEVATION:</b> 5116.82<br><b>DATUM:</b> Survey Marker<br><b>BORING DIAMETER:</b> 6 5/8"<br><b>COLLAPSE DEPTH:</b> None<br><b>FILL DEPTH:</b> 15.75' |          |        |        |          |           |                 |  |  |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|--------|----------|-----------|-----------------|--|--|--|
| <b>LOCATION:</b> Lead, SD<br><b>PROJECT #:</b> 221198.00<br><b>DATE STARTED:</b> 8/17/22 <b>COMP.:</b> 8/17/22<br><b>CONTRACTOR:</b> FMG, Inc.<br><b>DRILL METHOD:</b> Hollow Stem Auger |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| ELEVATION / DEPTH                                                                                                                                                                        | WATER | GEOLOGY GRAPHIC                           | Sample Info Type,#/Blows | USCS                                                                                                                                                                                                                                                 | DESCRIPTION                                                                               | NM %                                                                                                                                                                                                   | DD (pcf) | LL (%) | PI (%) | Qu (psf) | phi (deg) | Swell (%) (ksf) |  |  |  |
| 0                                                                                                                                                                                        |       | Fill                                      |                          | TOPS                                                                                                                                                                                                                                                 | Topsoil -- 2" in thickness.                                                               |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5115                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      | Weathered Schist Fill: dark grayish brown to black, slightly moist, no plasticity, dense. |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5                                                                                                                                                                                        |       |                                           | P1A 17/13/15 n=28        |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5110                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 10                                                                                                                                                                                       |       | Residual Soil to Highly Weathered Bedrock | P1B 12/23/32 n=55        | Schist                                                                                                                                                                                                                                               | Schist Gravels with Clay: black, slightly moist, low plasticity, hard.                    |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5105                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 15                                                                                                                                                                                       |       | Slightly Weathered Schist Bedrock         | P1C 12/33/49 n=55        | GM Schist                                                                                                                                                                                                                                            | Schist: black, dry, no plasticity, hard, quartzite.                                       | 7.6                                                                                                                                                                                                    |          | NV     | NP     |          |           |                 |  |  |  |
| 5100                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 20                                                                                                                                                                                       |       |                                           | P1D 17/28/43 n=82        |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5095                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      | - End of borehole at 21.5'. No water encountered while drilling.                          |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 25                                                                                                                                                                                       |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5090                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 30                                                                                                                                                                                       |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 5085                                                                                                                                                                                     |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |
| 35                                                                                                                                                                                       |       |                                           |                          |                                                                                                                                                                                                                                                      |                                                                                           |                                                                                                                                                                                                        |          |        |        |          |           |                 |  |  |  |

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

| <b>PROJECT:</b><br><b>SURF WWTP Improvements Geotech</b>                                                                                                                                 |       |                                                                                    |                          | <b>GEOLOGIC LOG</b><br><b>OF</b><br><b>BOREHOLE 2</b><br> <b>FMG ENGINEERING</b><br>605-342-4105<br>3700 Sturgis Road<br>Rapid City, SD 57702<br>fmgengineering.com |                                                                                  | <b>BORING LOCATION:</b> NW Bore<br><hr/> <b>GROUND ELEVATION:</b> 5110.46<br><b>DATUM:</b> Survey Marker<br><b>BORING DIAMETER:</b> 6 5/8"<br><b>COLLAPSE DEPTH:</b> None<br><b>FILL DEPTH:</b> <=5' |          |        |        |          |           |                 |  |  |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|--------|----------|-----------|-----------------|--|--|--|
| <b>LOCATION:</b> Lead, SD<br><b>PROJECT #:</b> 221198.00<br><b>DATE STARTED:</b> 8/17/22 <b>COMP.:</b> 8/17/22<br><b>CONTRACTOR:</b> FMG, Inc.<br><b>DRILL METHOD:</b> Hollow Stem Auger |       |                                                                                    |                          |                                                                                                                                                                                                                                                      |                                                                                  |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
| ELEVATION / DEPTH                                                                                                                                                                        | WATER | GEOLOGY GRAPHIC                                                                    | Sample Info Type,#/Blows | USCS                                                                                                                                                                                                                                                 | DESCRIPTION                                                                      | NM %                                                                                                                                                                                                 | DD (pcf) | LL (%) | PI (%) | Qu (psf) | phi (deg) | Swell (%) (ksf) |  |  |  |
| 5110                                                                                                                                                                                     |       |  |                          | TOPS                                                                                                                                                                                                                                                 | Topsoil -- 2" in thickness.                                                      |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
|                                                                                                                                                                                          |       |                                                                                    |                          | Schist                                                                                                                                                                                                                                               | Weathered Schist: dark grayish brown to black, dry, no plasticity, hard.         |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
| 5105                                                                                                                                                                                     |       |                                                                                    | P2A                      | 3" BNCE n=100                                                                                                                                                                                                                                        |                                                                                  | No Recovery                                                                                                                                                                                          |          |        |        |          |           |                 |  |  |  |
| 5100                                                                                                                                                                                     |       |                                                                                    | P2B                      | 2" BNCE n=100                                                                                                                                                                                                                                        |                                                                                  | No Recovery                                                                                                                                                                                          |          |        |        |          |           |                 |  |  |  |
| 5095                                                                                                                                                                                     |       |                                                                                    | P2C G2A                  | 2" BNCE n=100                                                                                                                                                                                                                                        | GM                                                                               | No Recovery                                                                                                                                                                                          | 2.3      |        | NV     | NP       |           |                 |  |  |  |
| 5090                                                                                                                                                                                     |       | P2D                                                                                | 1" BNCE n=100            |                                                                                                                                                                                                                                                      | No Recovery<br>- End of borehole at 20.07'. No water encountered while drilling. |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
| 5085                                                                                                                                                                                     |       |                                                                                    |                          |                                                                                                                                                                                                                                                      |                                                                                  |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
| 5080                                                                                                                                                                                     |       |                                                                                    |                          |                                                                                                                                                                                                                                                      |                                                                                  |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |
| 5075                                                                                                                                                                                     |       |                                                                                    |                          |                                                                                                                                                                                                                                                      |                                                                                  |                                                                                                                                                                                                      |          |        |        |          |           |                 |  |  |  |

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

| <b>PROJECT:</b><br><b>SURF WWTP Improvements Geotech</b>                                                                                                                                                                           |       |                 |                          | <b>GEOLOGIC LOG</b><br><b>OF</b><br><b>BOREHOLE 3</b><br> <b>FMG ENGINEERING</b><br>605-342-4105<br>3700 Sturgis Road<br>Rapid City, SD 57702<br>fmgengineering.com |                                                                                                | <b>BORING LOCATION:</b> <u>SW Bore</u><br><b>GROUND ELEVATION:</b> <u>5119.67</u><br><b>DATUM:</b> <u>Survey Marker</u><br><b>BORING DIAMETER:</b> <u>6 5/8"</u><br><b>COLLAPSE DEPTH:</b> <u>None</u><br><b>FILL DEPTH:</b> <u>&gt;=21.5'</u> |          |        |        |          |           |                 |  |  |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|--------|----------|-----------|-----------------|--|--|--|
| <b>LOCATION:</b> <u>Lead, SD</u><br><b>PROJECT #:</b> <u>221198.00</u><br><b>DATE STARTED:</b> <u>8/17/22</u> <b>COMP.:</b> <u>8/17/22</u><br><b>CONTRACTOR:</b> <u>FMG, Inc.</u><br><b>DRILL METHOD:</b> <u>Hollow Stem Auger</u> |       |                 |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| ELEVATION / DEPTH                                                                                                                                                                                                                  | WATER | GEOLOGY GRAPHIC | Sample Info Type,#/Blows | USCS                                                                                                                                                                                                                                                 | DESCRIPTION                                                                                    | NM %                                                                                                                                                                                                                                           | DD (pcf) | LL (%) | PI (%) | Qu (psf) | phi (deg) | Swell (%) (ksf) |  |  |  |
| 0                                                                                                                                                                                                                                  |       | Fill            |                          | TOPS                                                                                                                                                                                                                                                 | Topsoil -- 2" in thickness.                                                                    |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5115                                                                                                                                                                                                                               |       |                 | P3A 10/17/20 n=37        | GM                                                                                                                                                                                                                                                   | Weathered Schist Fill: dark grayish brown to black, slightly moist, no plasticity, very dense. | 3.9                                                                                                                                                                                                                                            |          | NV     | NP     |          |           |                 |  |  |  |
| 5110                                                                                                                                                                                                                               |       |                 | P3B 10/24/23 n=47        |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5105                                                                                                                                                                                                                               |       | Residual Soil   | P3C 12/19/25 n=44        | Schist                                                                                                                                                                                                                                               | Schist Gravels with Clay: black, slightly moist, low plasticity, very dense, quartzite.        |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5100                                                                                                                                                                                                                               |       |                 | P3D 10/26/23 n=49        |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5095                                                                                                                                                                                                                               |       |                 |                          |                                                                                                                                                                                                                                                      | - End of borehole at 21.5'. No water encountered while drilling.                               |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5090                                                                                                                                                                                                                               |       |                 |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5085                                                                                                                                                                                                                               |       |                 |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

| <b>PROJECT:</b><br><b>SURF WWTP Improvements Geotech</b>                                                                                                                                                                           |       |                                             |                          | <b>GEOLOGIC LOG</b><br><b>OF</b><br><b>BOREHOLE 4</b><br> <b>FMG ENGINEERING</b><br>605-342-4105<br>3700 Sturgis Road<br>Rapid City, SD 57702<br>fmgengineering.com |                                                                                                | <b>BORING LOCATION:</b> <u>SE Bore</u><br><b>GROUND ELEVATION:</b> <u>5121.26</u><br><b>DATUM:</b> <u>Survey Marker</u><br><b>BORING DIAMETER:</b> <u>6 5/8"</u><br><b>COLLAPSE DEPTH:</b> <u>None</u><br><b>FILL DEPTH:</b> <u>&gt;=21.5'</u> |          |        |        |          |           |                 |  |  |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|--------|----------|-----------|-----------------|--|--|--|
| <b>LOCATION:</b> <u>Lead, SD</u><br><b>PROJECT #:</b> <u>221198.00</u><br><b>DATE STARTED:</b> <u>8/17/22</u> <b>COMP.:</b> <u>8/17/22</u><br><b>CONTRACTOR:</b> <u>FMG, Inc.</u><br><b>DRILL METHOD:</b> <u>Hollow Stem Auger</u> |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| ELEVATION / DEPTH                                                                                                                                                                                                                  | WATER | GEOLOGY GRAPHIC                             | Sample Info Type,#/Blows | USCS                                                                                                                                                                                                                                                 | DESCRIPTION                                                                                    | NM %                                                                                                                                                                                                                                           | DD (pcf) | LL (%) | PI (%) | Qu (psf) | phi (deg) | Swell (%) (ksf) |  |  |  |
| 0                                                                                                                                                                                                                                  |       | Basecourse Fill                             |                          | GP-GC                                                                                                                                                                                                                                                | Limestone Paving -- 3" in thickness.                                                           |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5120                                                                                                                                                                                                                               |       |                                             |                          | Schist                                                                                                                                                                                                                                               | Weathered Schist Fill: dark grayish brown to black, slightly moist, no plasticity, very dense. |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5                                                                                                                                                                                                                                  |       |                                             | P4A 15/21/16 n=37        |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5115                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 10                                                                                                                                                                                                                                 |       | Slightly to Highly Weathered Schist Bedrock | P4B 6/24/29 n=53         | Schist                                                                                                                                                                                                                                               | Schist Gravels with Clay: black, slightly moist, low plasticity, hard, quartzite.              |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5110                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 15                                                                                                                                                                                                                                 |       |                                             | P4C 22/29/25 n=54        |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5105                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 20                                                                                                                                                                                                                                 |       |                                             | P4D 15/23/20 n=43        |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5100                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      | - End of borehole at 21.5'. No water encountered while drilling.                               |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 25                                                                                                                                                                                                                                 |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5095                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 30                                                                                                                                                                                                                                 |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 5090                                                                                                                                                                                                                               |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |
| 35                                                                                                                                                                                                                                 |       |                                             |                          |                                                                                                                                                                                                                                                      |                                                                                                |                                                                                                                                                                                                                                                |          |        |        |          |           |                 |  |  |  |

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

# KEY TO SYMBOLS

Symbol      Description

## Strata Symbols



Topsoil



Schist



Poorly graded gravel  
with clay

## Soil Samplers



Standard Penetration Test Sample

Symbol      Description



Bulk/Grab sample

## Notes:

1. The exploratory borings were drilled on the dates presented on the geologic logs. Please refer to the attached Soils Classification System Chart (Figure 2) for more detailed explanations on the soils and their properties.
2. The geologic logs of the boreholes and related information depict only the conditions and materials encountered at the specific boring location and at the particular time designated on the logs. Soil conditions at other locations will vary from those indicated at each specific boring or sampling location. The given depths of material changes and the sample depths are approximate. Variations will occur.
3. These Logs are subject to the limitations, conclusions and recommendations provided in this report.
4. The numbers adjacent to the SPT sample locations are the blow/interval and represent the number of blows required to drive the 1" I.D. split spoon sampler the given distance into the soil with a 140# automatic hammer that drops 30". The SPT test is performed to a length of 18". The N Value for each given SPT is the number of blows required to drive the 1" I.D. sampler into the last 12".
5. Cobbles, boulders and other large objects generally cannot be recovered from borings, and they may be present in the subsurface even if not noted on the Logs.
6. The topsoil thicknesses indicated on the Logs are for general informational purposes only, and are based on general transistions and very limited sampling points, and should not be used to calculate topsoil stripping depths or volumes. Significant variations in topsoil thickness will occur throughout the project.
7. The ground elevations noted on the logs are approximate, and should only be used for general reference.

The results of some tests conducted on samples recovered are reported on the Logs. Abbreviations used are:

NM = Natural Moisture Content of the Soil (%)

DD = Dry Density of the Soil (pcf)

LL = Atterburg Liquid Limit of the Soil (%)

PI = Atterburg Plasticity Index of the Soil (%)

phi = Internal Angle of Friction (degrees)

Qu = Unconfined Compressive Strength (psf)

Swell % = Percent Swell Against 100psf Surcharge Upon Saturation (%)

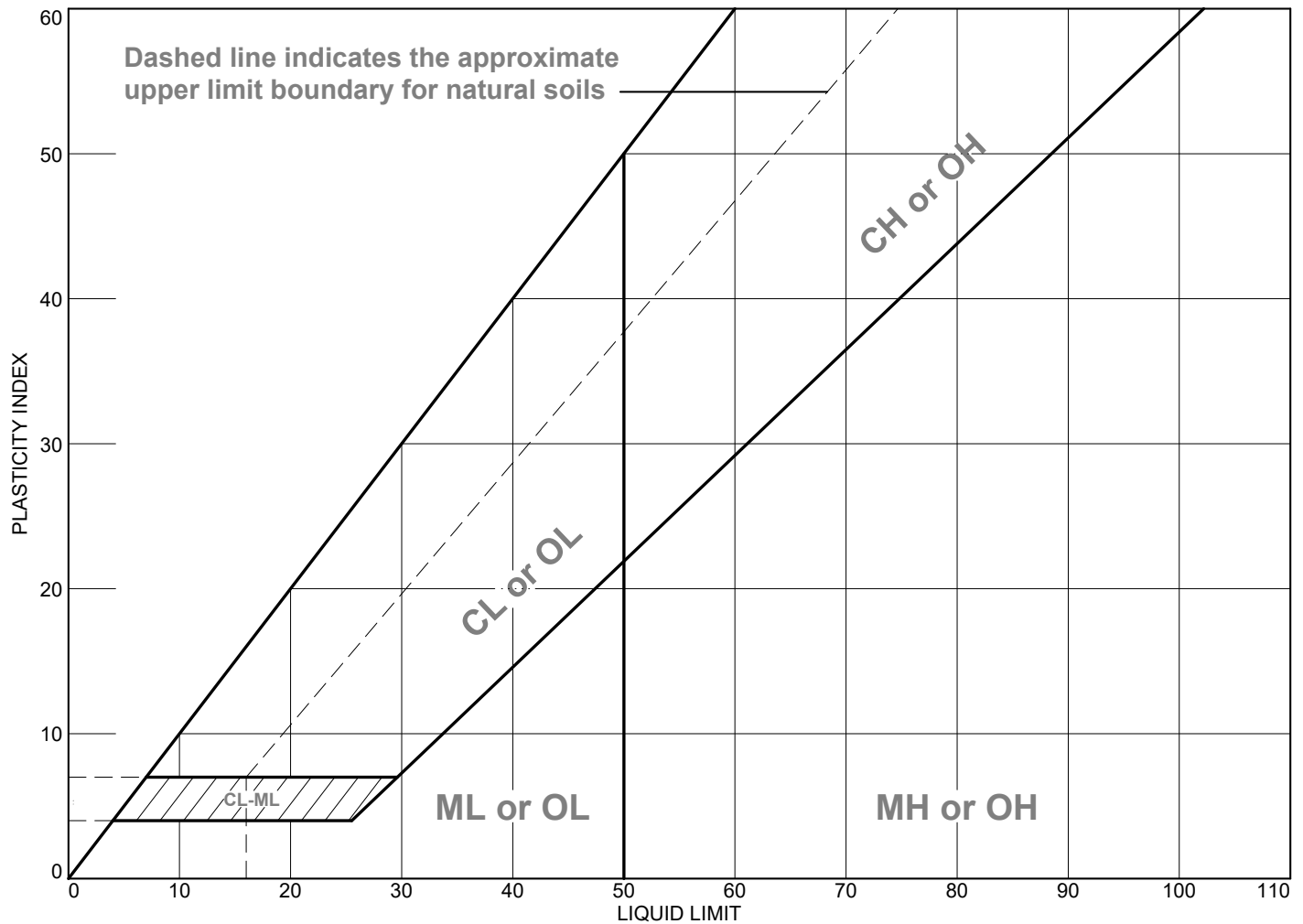
Swell Press = Maximum Swell Pressure (ksf)

## **Appendix B**

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### **Laboratory Testing**

# LIQUID AND PLASTIC LIMITS TEST REPORT



|   | MATERIAL DESCRIPTION                                                                           | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|------------------------------------------------------------------------------------------------|----|----|----|-------|--------|------|
| ● | Schist: black, dry, no plasticity, hard, quartzite.                                            | NV | NP | NP | 22    | 16     | GM   |
| ■ | Weathered Schist: dark grayish brown to black, dry, no plasticity, hard.                       | NV | NP | NP | 22    | 17     | GM   |
| ▲ | Weathered Schist Fill: dark grayish brown to black, slightly moist, no plasticity, very dense. | NV | NP | NP | 21    | 14     | GM   |
|   |                                                                                                |    |    |    |       |        |      |
|   |                                                                                                |    |    |    |       |        |      |

**Project No.** 221198.00 **Client:** Banner Associates

**Project:** SURF WWTP Improvements Geotech

**● Source of Sample: 1**      **Depth: 15**      **Sample Number: P1C**  
**■ Source of Sample: 2**      **Depth: 15**      **Sample Number: G2A**  
**▲ Source of Sample: 3**      **Depth: 5**      **Sample Number: P3A**



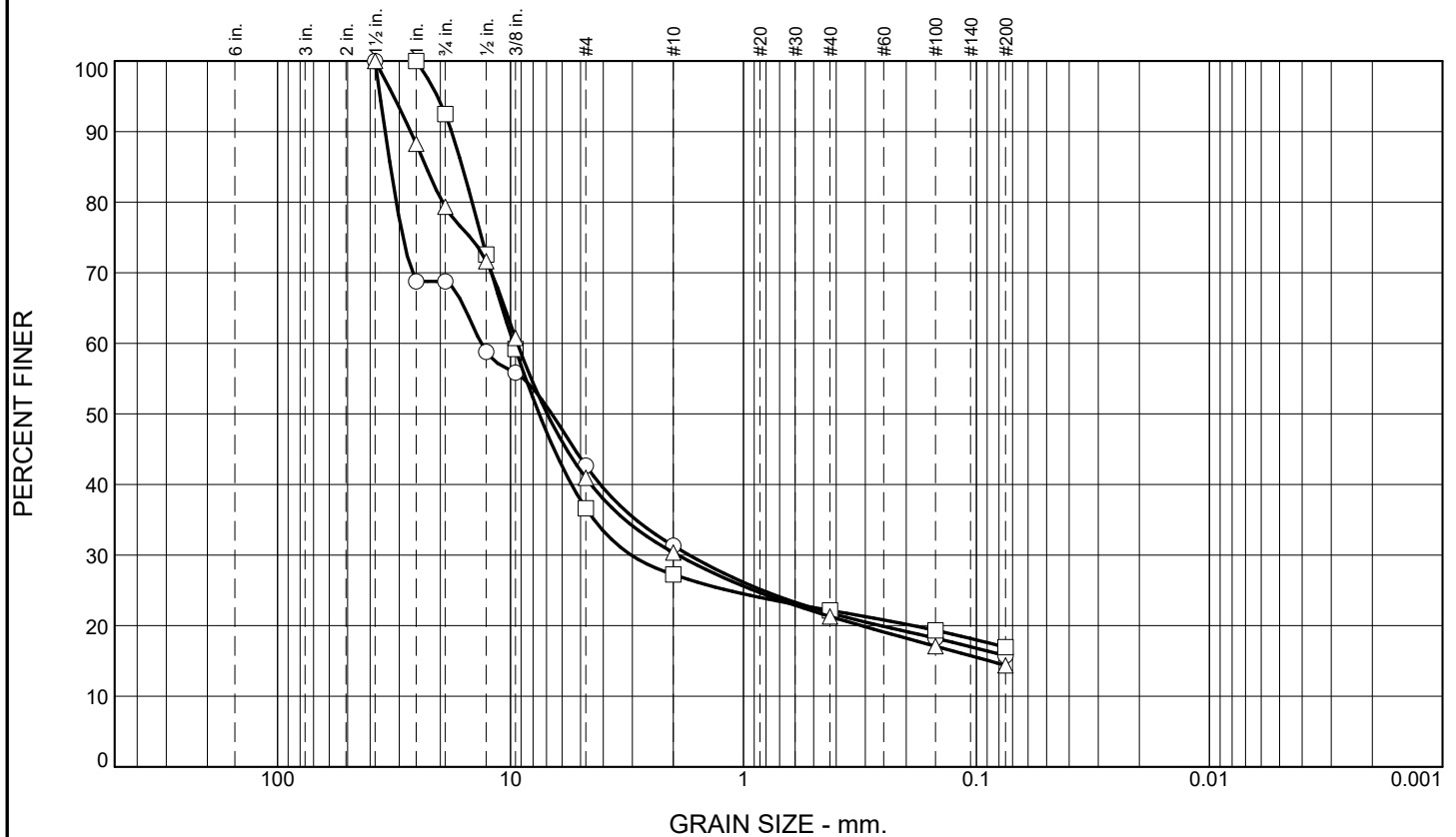
**FMG, Inc.**

**Remarks:**

**Figure**

**Tested By:** ● CR ■ RC ▲ RC **Checked By:** RC

# Particle Size Distribution Report



|   | +3" | % GRAVEL | % SAND | % SILT | % CLAY | USCS | LL | PL | PI |
|---|-----|----------|--------|--------|--------|------|----|----|----|
| ○ | 0   | 57       | 27     | 16     |        | GM   | NV | NP | NP |
| □ | 0   | 63       | 20     | 17     |        | GM   | NV | NP | NP |
| △ | 0   | 59       | 27     | 14     |        | GM   | NV | NP | NP |

| SIEVE<br>inches<br>size | PERCENT FINER |        |        |
|-------------------------|---------------|--------|--------|
|                         | ○             | □      | △      |
| 1 1/2                   | 100           |        | 100    |
| 1                       | 69            | 100    | 88     |
| 3/4                     | 69            | 92     | 79     |
| 1/2                     | 59            | 73     | 72     |
| 3/8                     | 56            | 59     | 61     |
| GRAIN SIZE              |               |        |        |
| D <sub>60</sub>         | 13.3522       | 9.7064 | 9.3450 |
| D <sub>30</sub>         | 1.7097        | 3.0327 | 1.9108 |
| D <sub>10</sub>         |               |        |        |
| COEFFICIENTS            |               |        |        |
| C <sub>c</sub>          |               |        |        |
| C <sub>u</sub>          |               |        |        |

| SIEVE<br>number<br>size | PERCENT FINER |    |    |
|-------------------------|---------------|----|----|
|                         | ○             | □  | △  |
| #4                      | 43            | 37 | 41 |
| #10                     | 31            | 27 | 30 |
| #40                     | 22            | 22 | 21 |
| #100                    | 18            | 19 | 17 |
| #200                    | 16            | 17 | 14 |

|                             |                                                                                                |
|-----------------------------|------------------------------------------------------------------------------------------------|
| <b>Material Description</b> |                                                                                                |
| ○                           | Schist: black, dry, no plasticity, hard, quartzite.                                            |
| □                           | Weathered Schist: dark grayish brown to black, dry, no plasticity, hard.                       |
| △                           | Weathered Schist Fill: dark grayish brown to black, slightly moist, no plasticity, very dense. |

|                 |  |
|-----------------|--|
| <b>REMARKS:</b> |  |
| ○               |  |
| □               |  |
| △               |  |

○ Source of Sample: 1      Depth: 15      Sample Number: P1C  
 □ Source of Sample: 2      Depth: 15      Sample Number: G2A  
 △ Source of Sample: 3      Depth: 5      Sample Number: P3A



**FMG, Inc.**

Client: Banner Associates  
 Project: SURF WWTP Improvements Geotech  
 Project No.: 221198.00

Figure

Tested By: ○ CR    □ RC    △ RC      Checked By: RC

## Appendix C

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