SolidEarth Geotechnical Inc.
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GEOTECHNICAL INVESTIGATION

Proposed Wastewater Lagoon Expansion
Within NE 10 and SE 15-52-20 W3M
Thunderchild First Nation Site 115B, Saskatchewan

Prepared for:

BCL Engineering Ltd.
Saskatoon, Saskatchewan

Date:

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1.0 INTRODUCTION

This report presents the results of the geotechnical investigation conducted for a proposed wastewater lagoon expansion within a portion of NE 10 and SE 15-52-20 W3M within the Thunderchild First Nation Site 115B in Saskatchewan. The geotechnical investigation was carried out by SolidEarth Geotechnical Inc. (SolidEarth) at the authorization of Mr. Matt Feige, P.Eng., of BCL Engineering Ltd. (BCL) on behalf of Thunderchild First Nation.

2.0 PROJECT DESCRIPTION

Based on information provided to SolidEarth, it was understood that the project consisted of adding two new cells to the existing sewage lagoon, and may also involve the re-construction of the existing lagoon berms. An access road to the lagoon site is also proposed part of this project.

The footprint of the lagoon expansion was approximately 12 hectares. Based on our previous experience with similar projects, it is expected that the base of the lagoon cells will be in the order of approximately 2 to 3 m below the design ground elevation. The lagoon will be lined with compacted clay liner or synthetic liner.

It was further understood that the proposed lagoon will be designed to meet the Saskatchewan Ministry of Environment and Water Security Agency guidelines and requirements.

3.0 SITE DESCRIPTION

At the time of the field investigation the proposed lagoon expansion area was an agriculture pasture land. The area was generally hummocky terrain with areas that were grassed covers and areas that were covered with tree and brush. While the existing lagoon was located south of the expansion area and measured approximately 150 m by 250 m. Access to the lagoon site

A key plan showing the proposed project site on a 2019 aerial photograph is presented as Figure 1. Photographs showing site conditions that existed at the time of the field investigation are presented in Appendix A.

4.0 INVESTIGATION SCOPE

The purpose of the geotechnical investigation was to assess the subsurface soil and groundwater conditions at selected locations within the proposed lagoon expansion area and within the existing lagoon berm, and to provide geotechnical recommendations and considerations associated with design and construction, including:

- Assessing the impact of the soil and groundwater conditions on site development; design, construction, and long-term operation of the proposed lagoon.

- Groundwater management considerations during the construction of the lagoon.
- General suitability of the native clayey soils for use as compacted clay liner.
- Requirements for an access road.
- Assessing the quality of the soils within the existing lagoon berms and their suitability as liner material, and to determine if any seepage from the lagoon through the berms was evident or suspected.

The scope of work completed by SolidEarth included drilling boreholes, conducting laboratory review and testing on recovered soil samples, undertaking geotechnical engineering analysis, and preparation of this report.

5.0 FIELD AND LABORATORY INVESTIGATION

5.1 GROUND DISTURBANCE AND SAFETY PERFORMANCE

Prior to field drilling, a SolidEarth representative completed internal ground disturbance procedures, which included placing a Saskatchewan First Call. Before starting onsite work, a daily field level hazard assessment was conducted by the SolidEarth representative and was communicated with all workers involved during the tailgate meeting. The field work was completed without any near misses or incidents.

5.2 FIELD DRILLING AND TESTING

SolidEarth subcontracted Top Gear Contracting Ltd. of Lloydminster, Saskatchewan to drill the boreholes. Drilling was completed using a track-mounted auger drill rig utilizing 150 mm solid-stem continuous flight augers.

The field investigation was undertaken between 28 and 30 August 2020 and consisted of drilling a total of 16 boreholes as follows:

- Six (6) boreholes (BH20-1 to -6) were advanced within the proposed lagoon expansion area. The boreholes were generally drilled to approximate depths ranging between 8.4 and 10.4 m below the existing ground surface.
- Ten (10) boreholes (BH20-B01 to –B10) were advanced on the existing lagoon berms. The boreholes were drilled to approximate depths ranging between 2.7 and 5.8 m below the top of the berm

The borehole locations were selected and marked in the field by SolidEarth. The borehole location plan is presented as Figure 2.

During drilling, soil samples were collected at approximately 0.75 m intervals along the depth of the boreholes. Bulk soil samples were collected from selected borehole locations. Low disturbance cohesive samples in Shelby tubes were collected from selected borehole locations. Pocket penetrometer testing was conducted on selected cohesive soil samples to obtain an indication of the unconfined compressive strength of disturbed soil samples from the auger. Standard Penetration Tests (SPT) were conducted in selected boreholes and at selected depths (typically every 1.5 m) to assess the in-situ strength of the soils encountered. The soil sampling and testing sequences are shown on the borehole logs included in Appendix B.

A SolidEarth geotechnical technologist monitored the drilling operations and logged the recovered soil samples from the auger cuttings and the SPT samples. The soils were logged according to the Modified Unified Soil Classification System, which is described in the Explanation of Terms and Symbols in Appendix B. Due to the method by which the soil cuttings were returned to surface, the depths noted on the borehole logs may vary by ± 0.3 m from those recorded.

Groundwater seepage conditions were monitored during and immediately following completion of drilling. Slotted standpipe piezometers (consisting of 25 mm hand slotted PVC pipe) were installed at all boreholes (except BH20-4 and -6) to allow for short term monitoring of the groundwater levels.

Groundwater monitoring wells were installed at two borehole locations (BH20-4 and -6). The monitoring wells were constructed using 50 mm diameter PVC solid and machine slotted pipes. In general, 3.0 m of slotted pipe with approximately 3.5 m of 10/20 frac-sand was used for the monitoring well screen. Bentonite chips were placed below and above the screen to confine the screen interval.

Following completion of drilling, the lateral coordinates (northing and easting) of the borehole locations were recorded by the SolidEarth representative using a hand-held GPS unit. The ground elevation at the borehole locations was estimated from the existing ground elevation contour plan provided. These coordinates are shown on the borehole logs, Appendix B.

5.3 LABORATORY TESTING PROGRAM

All collected samples were submitted to the laboratory for further examination and testing. The laboratory testing program included the following:

- Visual examination of all collected soil samples.
- Determination of the natural moisture content of all collected samples.
- Atterberg liquid and plastic limits on selected samples.
- Grain size distribution analysis (sieve and hydrometer) on selected samples.
- Moisture-density relationship test (standard Proctor) on remolded soil samples.

- Determination of dry unit weight on selected low disturbance samples from the existing berms
- Hydraulic conductivity test on a remolded soil sample.

One (1) moisture-density relationship (standard Proctor) and one (1) hydraulic conductivity test were conducted on a remoulded composite bulk sample of low to medium plastic clay till materials sampled from within the lagoon expansion area. The bulk sample was taken from the location of BH20-6 between approximately 0.7 and 2.3 m below the existing ground surface at the time of the field investigation.

Additionally, one (1) moisture-density relationship (standard Proctor) was conducted on a remoulded composite bulk sample of low to medium plastic clay fill materials from within the existing lagoon berm. The bulk sample was taken from the location of BH20-B10 between approximately 1.5 and 3 m below the top of the berm at the time of the field investigation.

The results of the laboratory testing are presented on the borehole logs. The results of the moisture-density relationship tests and hydraulic conductivity test are presented in Appendix C.

6.0 SUBSURFACE CONDITIONS

A brief summary of the subsurface conditions encountered at the lagoon expansion area and within the existing berm is presented below. A detailed description of the subsurface conditions encountered at each borehole location is provided on the borehole logs.

6.1 LAGOON EXPANSION AREA

The subsurface soils encountered at the borehole locations generally consisted of topsoil over clay. A brief summary of the subsurface conditions encountered is presented below. A detailed description of the subsurface conditions encountered at each borehole location is provided on the borehole logs.

Topsoil

Topsoil was encountered at the ground surface at all the locations. The approximate thickness of the topsoil generally ranged between 75 and 250 mm. It is to be noted that the thickness of the topsoil across the development area may vary from what was encountered at the borehole locations.

Clay

Clay (glaciolacustrine) was encountered below the topsoil at all borehole locations and extended to beyond the exploration depths. The clay was generally classified as “clay, and sand, silty, trace gravel”, was low to medium plastic, brown and moist. The consistency of the clay was assessed based on the SPT "N" and pocket penetrometer values to be generally firm to stiff.

The moisture content of the clay generally ranged between 6 and 16 percent, with an average of 13 percent. Liquid and plastic limits of samples of clay tested were in the order of 27 and 28 percent, and 11 percent, respectively.

The result of the laboratory moisture-density relationship test on one remoulded composite clay till sample indicated that the standard Proctor maximum dry density (SPMDD) was in the order of 1946 kg/m^3 at an optimum moisture content of 11.3 percent, respectively. Based on the above results, it was assessed that the average moisture content of the clay samples was generally near the optimum moisture content of the soil.

Sand

Interbedded sand was encountered within the clay at some borehole locations. The thickness of the interbedded sand ranged between 0.2 and 1.5 m. Based on the findings at the borehole locations, it is anticipated that the lateral and vertical extent of these layers was limited.

The interbedded sand was generally classified as "sand, trace silt, trace clay", was poorly graded, fine to medium grained, brown and saturated. The density of the sand was assessed based on the SPT "N" values to be compact.

6.2 EXISTING BERM

The subsurface soils encountered at the borehole locations along the existing lagoon berm generally consisted of topsoil at the ground surface, followed by clay fill and underlain by clay. A brief summary of the subsurface conditions encountered is presented below. A detailed description of the subsurface conditions encountered at each borehole location is provided on the borehole logs.

Topsoil/Gravel

Topsoil was encountered at the ground surface at all locations except BH20-B01. The approximate thickness of the topsoil was generally less than 100 mm. It is to be noted that the thickness of the topsoil along the berm may vary from what was encountered at the borehole locations.

Gravel was encountered at the ground surface at the location of BH20-B01. The approximate thickness of the gravel was 25 mm.

Clay Fill

Clay fill was encountered below the topsoil at all borehole locations and extended to approximate depths ranging between 0.4 and 3.5 m below the top of the berm. The clay fill was generally classified as “clay, and sand, silty, trace gravel”, was low to medium plastic, grey-brown and moist. The consistency of the clay fill was assessed based on the SPT “N” and pocket penetrometer values to generally range between soft and stiff.

The clay fill was mineral in composition at some locations and heterogeneous containing organics at other locations. Layers of clay fill mixed with organics were encountered below the mineral portion of the clay fill at some borehole locations. The approximate thickness of this layer ranged between 0.2 and 1.5 m.

The moisture content of the mineral portion of the clay fill generally ranged between 8 and 15 percent, with an average of 13 percent. Liquid and plastic limits of two samples of clay fill tested were in the order of 27 and 28 percent, and 11 and 13 percent, respectively. The moisture contents of the clay mixed with organics were in the order of 15 to 22 percent.

The result of the laboratory moisture-density relationship test on one remoulded composite clay fill sample indicated that the standard Proctor maximum dry density (SPMDD) was in the order of 1886 kg/m^3 at an optimum moisture content of 12.2 percent, respectively. Based on the above results, it was assessed that the average moisture content of the mineral clay fill samples was generally near the optimum moisture content of the soil.

Clay

Clay was encountered below the clay fill at all borehole locations and extended to beyond the exploration depths. The clay was generally classified as “clay, and sand, silty, trace gravel”, was low to medium plastic, grey-brown and moist to very moist. The consistency of the clay was assessed based on the SPT “N” and pocket penetrometer values to be generally soft to firm.

The moisture content of the clay generally ranged between 15 and 28 percent, with an average of 17 percent. Liquid and plastic limits of one clay sample tested were in the order of 28 and 12 percent, respectively. Based on comparison with the plastic limit of the soil, it was assessed that the average moisture content of the clay samples was slightly higher than the optimum moisture content of the soil.

6.3 MEASURED GROUNDWATER LEVELS

The measured groundwater levels at the borehole locations are shown in Table 1 below.

In clayey soils, the groundwater table generally takes time to recover and stabilize following the completion of drilling. The length of time required depends on the hydraulic conductivity of the clayey soil and the presence of fissures and seams in the soil matrix. Accordingly, the observed depth of the groundwater table in the boreholes after a short period following drilling is generally deeper than the long-term stabilized levels. The depth of the groundwater table also fluctuates seasonally depending upon several factors that include the local geology, hydrogeology, and surface infiltration.

Table 1: Measured Groundwater Levels

Borehole ID	Depth of Borehole (mbgs) Note 1	Depth of standpipe (mbgs)	Groundwater Depth (mbgs)	
			Between 28 and 30 August 2020 (At Drilling Completion)	23 September 2020
Lagoon Expansion Area				
BH20-1	8.8	5.2	3.0	2.4
BH20-2	10.4	10.4	9.1	Standpipe was found to be damaged
BH20-3	8.5	8.5	7.6	6.0
BH20-4	10.0	6.1	7.0	6.2
BH20-5	8.8	8.8	Dry	6.1
BH20-6	8.4	4.6	5.8	Dry
Existing Lagoon Berm				
BH20-B01	4.0	4.0	1.5	1.5
BH20-B02	2.7	2.7	Dry	1.6
BH20-B03	2.7	2.7	Dry	1.0
BH20-B04	4.0	4.0	Dry	1.8
BH20-B05	4.3	3.8	3.0	1.9
BH20-B06	4.3	2.7	2.1	2.5
BH20-B07	5.8	5.8	5.2	2.7
BH20-B08	5.5	2.7	Dry	2.0
BH20-B09	4.0	4.0	1.5	1.1
BH20-B10	5.8	5.8	3.3	3.8

Note 1: mbgs – metres below existing ground surface

7.0 LAGOON DESIGN AND CONSTRUCTION CONSIDERATIONS

7.1 SUITABILITY OF THE NATIVE SOILS FOR COMPACTED CLAY LINER

The design and construction of compacted clay liners and the properties of clay soils suitable for the construction of compacted clay liners are discussed based on published literature and the guidelines and requirements outlined in the following two documents:

- *2014 Saskatchewan Ministry of Environment "Guidelines for Sewage Works Design"*
- *2012 Saskatchewan Water Security Agency "Sewage Works Design Standard-EBP 503"*

The guidelines indicate that the seepage rate from a lagoon facility should be limited to no more than 15 cm/year. An onsite permeability of ten (10) times the laboratory value should be used to calculate the seepage rate.

One (1) hydraulic conductivity test (flexible wall) was conducted on a remoulded composite bulk sample of clay sample taken from the location of BH20-6 between approximately 0.7 and 2.3 m below the existing ground surface at the time of the field investigation. The sample was tested at an initial dry density of 96.4 percent of SPMDD. The calculated hydraulic conductivity (based on average flow) from this test was 8.6 x10^{-7} cm/sec.

The seepage rate from a compacted clay liner constructed with the local low to medium plastic clays was calculated to be in the order of 542 cm/year. The seepage rate was calculated assuming that the hydraulic conductivity of the compacted clay liner in the field is one order of magnitude higher than what was measured in the laboratory (i.e. field hydraulic conductivity of 8.6 x10^{-6} cm/sec), and a coefficient of porosity of the compacted clay liner soil of 0.5.

The seepage rate of the compacted native clay till soil is much higher than the maximum limit as per the guideline. As such, the native clayey soils at this site were deemed not suitable for the construction of compacted clay liners. Synthetic liner material (such as geomembrane or GCL) may be considered for this project. Another option is to import suitable clay soils from a borrow source.

7.2 INITIAL SITE GRADING AND SUBGRADE PREPARATION

The site grading plan was not available at the time of the preparation of this report. It was anticipated that excavation of up to 2 to 3 m below existing ground surface may be required during the construction of the lagoon.

During initial site grading, all topsoil should be stripped and removed from the proposed development area. Topsoil should not be mixed with mineral soils or be used as engineered fill material.

Soft and wet subgrade conditions should be anticipated across the lagoon footprint, particularly following snow melt and heavy rain events. The exposed subgrade may also be sensitive to disturbance by heavy rubber-tire construction equipment, especially when exposed to very moist to wet conditions. Construction traffic on the unprotected subgrade should be kept to a minimum and restricted to low pressure track equipment to the extent possible.

Where sand is encountered at the exposed rough grade elevation, the sand should be sub-excavated and replaced with compacted clay soils. If the thickness of the sand in the subgrade was less than 0.6 m, then complete removal of the sand is recommended. If the sand within the exposed subgrade was thicker than 0.6 m, then partial excavation of the sand and the placement of a 0.6 m thick clay cap above the sand is recommended. This will aid in sealing off the subgrade and improve its stability during the construction of the compacted clay liner.

It is recommended that the exposed subgrade be inspected by the geotechnical engineer. The inspection may include a proof-roll test to confirm that deflections from construction traffic are minimal. Soft and weak areas identified during inspection, should be strengthened and improved.

Subgrade improvement will likely be required to achieve a stable base for construction equipment, and to allow for adequate compaction to be accomplished on subsequent lifts of grade raising fill and the liner system.

The extent of required subgrade improvement will depend to a greater degree on the amount of cut/fill required at specific locations, and on field observations during construction. The extent of subgrade improvement is best determined in the field based on visual observation and proof-roll testing. Subgrade improvement may include:

- placement of dry clay soil as engineered fill in areas requiring fill
- sub-cutting the existing subgrade, air drying the excavated soils, and re-compacting the subgrade as engineered fill, if good weather conditions prevail during construction
- partial replacement of the wet and weak material with dry, low to medium plastic clay soils placed as engineered fill

The use of a thick lift “bridging layer” of dry borrow material may be required to achieve a stable base for construction equipment, and to allow for adequate compaction to be accomplished on subsequent lifts of grade raising fill or liner system. The bridging layer should consist of a relatively thick lift (typically 0.4 to 0.6 m thick) of dry clay pushed over the existing subgrade and compacted in one lift to a minimum of 95 percent of standard Proctor maximum dry density (SPMDD). A thicker first lift may be required at some locations.

It is also recommended that the upper 300 mm of the exposed subgrade soil within the bottom of the lagoon and side slopes be scarified and re-compacted as engineered fill with strict control of moisture content and density. The scarified material should be compacted to a minimum of

95 percent of SPMDD, using a sheep's foot compactor. It is recommended that the material be moisture conditioned to between 1 and 3 percent of the optimum moisture content of the soil. This will aid in sealing off the subgrade and improve its stability.

7.3 BELOW-GRADE EXCAVATIONS

The soil conditions encountered within the anticipated depth of the proposed lagoon generally consisted of firm to stiff clay. These soils can be readily excavated with standard size earth moving equipment.

Rocks and boulders were not encountered, but if encountered, large rocks and boulders should be removed from the footprint of the lagoon.

7.4 REQUIREMENTS OF ENGINEERED FILL

Engineered fill should consist of low to medium plastic clay or a well-graded granular material. Silt or sand which is uniformly graded, or which contains more than 10 percent passing the 0.080 mm sieve are not recommended as these materials are generally frost susceptible and are difficult to compact (require strict control of moisture content). All fill soils should be free from any organic materials, contamination, deleterious construction debris, and stones greater than 150 mm in diameter.

Engineered fill should be thawed when placed, and placed during non-frozen conditions. If winter construction is proposed, SolidEarth can provide additional recommendations once the overall development plan has been finalized.

All engineered fill should be compacted to a minimum of 95 percent of SPMDD. The fill should be compacted in lift thicknesses of 300 mm (loose) or less, and within two percent of the optimum moisture content of the soil. Fill placement procedures and quality of the fill soils should be monitored by geotechnical personnel. Field monitoring should include compaction testing at regular frequencies.

Even for well compacted fill, some fill settlement under self-weight will occur. Settlement in the order of one to three percent of the fill thickness should be anticipated for engineered fill compacted to between 98 and 95 percent SPMDD. The majority of this settlement is expected to occur within the first year following construction.

7.5 COMPACTED CLAY LINER CONSTRUCTION

All fill used for the construction of the compacted clay liner should consist of suitable clays (that meet the minimum hydraulic conductivity and/or seepage rate requirement), and should be placed as engineered fill. Engineered fill should consist of suitable clayey material, be free from any organic materials, contamination, deleterious construction debris, frozen lumps, and stones greater than 50 mm in diameter.

Engineered fill should not be placed during frozen conditions. If winter construction is proposed, SolidEarth can provide additional recommendations at that time and once the overall development plan has been finalized.

The clay liner should be compacted to a minimum of 95 percent of SPMDD, and in lift thicknesses of 200 mm or less (loose). It is recommended that clayey materials used for liner construction be placed between 1 and 3 percent above the optimum moisture content of the soil. Based on the moisture condition of the onsite clay soils in general, moisture conditioning consisting of drying of soils may be required.

The thickness of the compacted clay liner should be no less than 0.6 m on the bottom and 1.2 m at the side slope (measured perpendicular to the slope). The clay liner should be compacted to the recommended density using sheep's foot compactor. The final surface of the liner should be compacted using a smooth drum compactor to establish a smooth and sealed liner surface.

Fill placement procedures and quality of the fill soils should be monitored by geotechnical personnel on a full-time basis. Field monitoring should include compaction testing at regular frequencies.

7.6 GROUNDWATER SEEPAGE AND CONTROL DURING CONSTRUCTION

Based on groundwater measurements at borehole locations, it was expected that the groundwater table to be deeper than approximately 2.4 m below the existing ground surface. The excavation will be within the low to medium plastic clay with relatively low permeability (and thus low water yield potential). Seepage from the base of the walls and base of the excavation is expected to be relatively low and can be controlled with drainage trenches equipped with pumps.

The volume of water seeping will increase with increasing size and depth of the excavation. The rate of water seepage is also expected to increase if the excavation encountered saturated interbedded sand layers. The water storage and seepage from these sand units will depend on the vertical and lateral extents of the sand layers. If the lateral and vertical extents of such layers are relatively small, they can be drained relatively easily with a sump pump system.

To minimize the potential for water ponding during construction, a minimum grade of two percent is recommended at the subgrade level to accommodate surface water runoff away from the subgrade

7.7 LONG-TERM GROUNDWATER EFFECT AND CONSIDERATION

The measured groundwater table at the borehole locations was in the order of 2.4 m or deeper below ground surface, and may be up to 1 m above the design lagoon cell floor. If a synthetic liner is being considered, then a sub-drainage system should be implemented to avoid floating the liner. If a compacted clay liner was used, the risk of liner heave was considered low for a 2 to 3 m deep cell.

7.8 LONG-TERM SLOPE STABILITY CONSIDERATION

For stability purposes, long term excavations and perimeter berms up to 3 m in height are expected to be stable with an overall slope inclination of 3.0 horizontal to 1.0 vertical (3H:1V). Flatter side slopes may be required for safety and operational consideration. The following construction related factors affecting excavation stability should be followed:

- All temporary surcharge loads should be kept back from the excavated faces a distance of at least one-half the depth of the excavation.
- Wheel loads should be kept back at least 2.0 m from the crests of the cell slopes.
- The latest edition of the Construction Safety Regulations of the Occupational Health and Safety Act of Saskatchewan should be followed.

7.9 LONG-TERM GROUNDWATER MONITORING

It is recommended that a groundwater monitoring network be established around the perimeter of the lagoon cells following the completion of site development. The network should include at least one monitoring well up-gradient of the project area. The final configuration should be determined following the completion of the detailed design.

It is recommended that groundwater samples be collected from the monitoring wells, prior to initial operation of the lagoon, to establish baseline parameters of groundwater quality in the project area. Groundwater samples should be analyzed for physical, biological, and chemical parameters on a regular basis.

8.0 CONSIDERATIONS FOR ACCESS ROAD

A graveled access road is being considered for the proposed development. It was expected that the gravel road will be occasionally serviced by heavy duty trucks.

8.1 CONDITION OF THE SUBGRADE

8.1.1 Subgrade Material, Moisture, Strength, and Stability

The exact location of the access road was not known and hence no boreholes were advanced specifically for the access road. It was assumed, that the subsurface conditions encountered at the borehole locations within the lagoon expansion area will be comparable to the conditions expected within the general area for the access road. The near surface subgrade soils within the access areas are expected to consist of topsoil at the existing ground surface and underlain by low to medium plastic clay.

The in-situ moisture content of the clay within the upper 1 to 2 m of the soil profile was generally near the anticipated optimum moisture content of the soil. The strength of the subgrade soils within the top 1 to 2 m of soil profile was assessed based on the SPT “N” values to be generally firm to stiff.

Based on the findings at the borehole locations, it is anticipated that weak and wet subgrade conditions are not expected to be a major concern, but may be encountered at localized locations, particularly following snow melt and heavy rain events.

8.1.2 Frost Susceptibility of Subgrade Soils

Frost heave of the subgrade soils is generally related to the particle size distribution of the soils, moisture content, and the presence of a relatively shallow groundwater table. The near surface clayey soils encountered at the locations of all boreholes were low to medium plastic. The grain size distribution of these soils generally consisted of approximately 20 to 27 percent by weight of clay size particles with the remaining portions as silt, sand and gravel size particles. These soils were generally considered to be moderately susceptible to frost heaving and formation of ice lenses in the presence of water.

Groundwater was in the order of 2 m below ground surface. The moisture content of the near surface soils was generally near the anticipated optimum moisture content of the soil.

Given the above and with proper drainage and surface water management, the risk of frost heaving was considered to be moderate to high. It is to be noted that poor surface drainage leading to water inundating the subgrade soils will significantly increase the risk level.

Due to the general variability in the soil makeup and groundwater seepage paths in soil deposits, it is not possible to predict with certainty the magnitude of frost heaving at specific locations. It is generally recommended that an observational approach be adopted over the first two winter seasons to identify problematic areas.

Frequently, areas exhibiting the formation of ice lenses and frost heaving during one winter season will exhibit the same during subsequent winter seasons. If areas with problematic frost conditions are observed, then remedial measures may be implemented.

The most suitable remedial measure will have to be assessed on a case by case basis as it depends on the severity of the problem, service/use interruption of the affected area, and the sensitivity of the pavement structure to frost heaving. Remedial measures may include soil replacement, ground insulation, or periodic maintenance (in the case of low use areas).

8.2 SITE GRADING AND SUBGRADE PREPARATION

All topsoil should be stripped and removed from the pavement area during initial grading. Topsoil should not be mixed with mineral soils nor should it be used as engineered fill material.

All exposed subgrade, following achievement of rough grades and prior to fill placement should be inspected by the geotechnical engineer. The inspection may include a proof-roll test to confirm that deflections under the proof-roll loads are minimal. Soft and weak areas identified during inspection, should be strengthened and improved.

The extent of required subgrade improvement and modification will depend to a greater degree on the amount of cut/fill required at specific locations, and on field observations during construction. The extent of subgrade improvement is best determined in the field based on visual observation and proof-roll testing.

Subgrade improvement may include:

- placement of dry clay soil as engineered fill in areas requiring fill
- sub-cutting the existing subgrade, air drying the excavated soils, and re-compacting the subgrade as engineered fill, if good weather conditions prevail during construction
- replacement of the wet/weak/organic material with dry low to medium plastic clay soils placed as engineered fill

All new fill should be placed and compacted as engineered fill. Engineered fill should consist of low to medium plastic clay or a well-graded granular material. Silt or sand which is uniformly graded, or which contains more than 10 percent passing the 0.080 mm sieve are not recommended as these materials are generally frost susceptible and are difficult to compact (require strict control of moisture content). All fill soils should be free from any organic materials, contamination, deleterious construction debris, and stones greater than 150 mm in diameter.

Engineered fill should be frost free, and placed during non-frozen conditions. If winter construction is proposed, SolidEarth can provide additional recommendations once the overall development plan has been finalized.

All engineered fill should be compacted to a minimum of 95 percent of SPMDD. The standard of compaction should be increased to 98 percent of SPMDD for the upper 300 mm of the subgrade soil (below the underside of the granular base).

All engineered fill should be compacted in maximum lift thicknesses of 300 mm (loose), and within two percent of the optimum moisture content of the soil. Fill placement procedures and quality of the fill soils should be monitored by geotechnical personnel on a full time basis. Field monitoring should include compaction testing at regular frequencies.

8.3 SURFACE WATER MANAGEMENT CONSIDERATION

Provision of uniform and adequate grades for surface water drainage is potentially the most important design element for establishing long term stable pavement structures for roads. To minimize the potential for water ponding and seepage leading to saturation and degradation of the subgrade (during and following construction), a minimum grade of two percent is recommended at the subgrade level (cross slope or crowning the center of the road). The final pavement grade should also be adequately sloped to accommodate surface water runoff.

It is recommended that the pavement gravel base be allowed to drain (day-lighted) into the side ditches so that any accumulated water within the base gravel will be allowed to drain away and not pond on top of the subgrade. It is further recommended that the underside of the granular base be elevated at least 0.6 m above the bottom of the side ditches. This will reduce the potential of saturation and softening of the subgrade soils.

Positive drainage away from the road surface is particularly important during the spring thaw and snow melt season. If water from melting snow is allowed to remain on the road surface and subsequently freezes, significant damage to the road surface (and formation of potholes) may be encountered.

8.4 GRAVEL SECTION

Recommendations presented above regarding subgrade preparation and inspection should be followed. Recommendations presented in this section are based on the assumption that a stable and competent subgrade is achieved prior to the placement of the gravel structure.

It is recommended that the gravel surfacing be placed immediately following subgrade improvement to protect the subgrade. This will be required to achieve long-term stable pavements. If the prepared subgrade is left unprotected and exposed to moisture and traffic loading for an extended period of time, loss of stability of subgrade (essentially nulling all the effects of subgrade improvement) may be encountered.

The minimum recommended gravel section is provided in Table 2. The recommendations were based on the AASHTO method for gravel road design assuming the following:

- The design life for the gravel pavement was taken as 10 years.
- The projected traffic was taken as:
    - Case 1: 5,500 ESAL - equivalent to less than 10 trucks per week (two-axle, single-tire, single unit truck, with a maximum weight of 14 Tons).
    - Case 2: 22,500 ESAL - equivalent to between 10 and 40 trucks per week (two-axle, single-tire, single unit truck, with a maximum weight of 14 Tons).
- The allowable serviceability loss (ASL) assumed as 15 kPa.
- The allowable rutting depth assumed as 25 mm.
- The anticipated subgrade support was considered as “Low”, the CBR was considered less than 4, and the anticipated subgrade Resilient Modulus during spring thaw conditions was considered between 30 and 40 MPa.

- Gravel base elastic modulus (E_{BS}) was assumed as 210 MPa.

Table 2: Gravel Pavement Section

Material	Recommended Minimum Thickness (mm)	
	Case 1: 5,500 ESAL	**Case 2: 22,500 ESAL**
Aggregate Type 106 (As per Saskatchewan Ministry of Highways and Infrastructure, Surfacing Manual 2016)	250	350
Subgrade Preparation	300	300

The granular crushed surfacing aggregate should be placed in maximum 150 mm thick lifts and uniformly compacted to a minimum of 100 percent of SPMDD at moisture content within two percent of the optimum moisture content of the soil. A reduced lift thickness may be required depending on the capability of the compaction equipment available to achieve the required densities.

Thinner gravel sections could be used, but such sections may experience greater distress (frequency and severity) compared to that which is recommended. It should be recognized that periodic maintenance, which would include the placement of additional lifts of the aggregate may be required.

9.0 GEOTECHNICAL ASSESSMENT OF THE LAGOON BERM

9.1 QUALITY OF THE BERM CLAYEY SOILS

Based on field observations at the borehole locations and the results of the laboratory testing, the following was noted:

- The upper portion of the clay fill soil was generally mineral in composition. The lower portions of the clay fill at some borehole locations was heterogeneous and had distinct zones of clay fill mixed with organics.
- The consistency of the clay fill was assessed based on the SPT “N” and pocket penetrometer values to be generally soft to stiff.
- The properties of the mineral portion of the clay fill appeared to be consistent within the berms. These soils also appeared to be comparable to the native soil encountered at the borehole locations advanced within the proposed expansion area.

- The native soils (anticipated to have been used in the construction of the berms) were considered un-suitable as compacted clay liner material, based on seepage rates (as discussed in Section 7.1 “Suitability of the Native Soils for Compacted Clay Liner”.
- The moisture content of the mineral portion of the clay fill soil was generally near the optimum moisture content of the soil. The moisture contents of the clay mixed with organics were higher than the optimum moisture content of the soils.

9.2 IN-SITU DENSITY OF THE BERM CLAY SOILS

The in-situ dry density of three low-disturbance samples taken from the berms ranged between 1791 and 2042 kg/m^3. This relatively high range indicated variability in the quality and placement effort, at the time of construction.

9.3 WATER SEEPAGE FROM THE BERM

The standpipe piezometers installed at the borehole locations showed water level readings within the berm embankment (i.e., clay fill and above the native clays). This generally indicates that the hydraulic conductivity of the clayey soil is high and that seepage is occurring through the berms.

9.4 OVERALL ASSESSMENT OF THE BERM

Clay fill mixed with organics was encountered at a few borehole locations within the berm embankment. The mineral portions of the clay fill were assessed to have a relatively high hydraulic conductivity and were deemed un-suitable as compacted clay liner material. The layers of clay mixed with organics exhibited poor quality and low density.

Evidence of seepage from the berm was noted as indicated by water level measurements in the standpipes installed.

It was assessed that the existing berms were constructed of unsuitable soils and that seepage from the berms was noted. It is recommended that these berms (and potentially lagoon base) be re-constructed with suitable soils, or alternatively lined with synthetic liner.

10.0 TESTING AND INSPECTION

Recommendations presented in this report may not be valid if adequate engineering inspection and testing programs during construction are not implemented or if other building code requirements are not followed. Testing and inspection programs should consist of full-time monitoring and compaction testing during site grading for construction of the lagoon and compacted clay liner, and the gravel road.

11.0 CLOSURE

The recommendations presented in this report are based on the results of soil sampling and testing at six (6) borehole locations advanced across the proposed lagoon expansion area, and ten (10) boreholes within and around the existing lagoon berms during the field investigation. Soil conditions by nature can vary across any given site. If different soil conditions are encountered at subsequent phases of this project, SolidEarth should be notified immediately and given the opportunity to evaluate the situation and provide additional recommendations as necessary.

The recommendations presented in this report should not be used for another site or for a different application at the same site. If the intended application of the site is changed or if the assumptions outlined in this report became invalid, SolidEarth should be notified and given the opportunity to assess if the recommendations presented herein should be modified.

This report has been prepared for the exclusive use of BCL Engineering Ltd. and their authorized users for the specific application outlined in this report. No other warranties expressed or implied are provided. This report has been prepared within generally accepted geotechnical engineering practices.

Respectfully submitted,
SolidEarth Geotechnical Inc.

J. JABER
MEMBER 22072
2020-10-13

Indranil (Neel) Deysarkar, M.Sc., P.Eng (AB)
Geotechnical Engineer

Jay Jaber, M.Sc., P.Eng.
Senior Geotechnical Engineer
Managing Partner

Association of Professional Engineers & Geoscientists
of Saskatchewan
CERTIFICATE OF AUTHORIZATION
SolidEarth Geotechnical Inc.
Number 26172
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	22072	

Figures:

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NUMBER C312
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NOT FOR CONSTRUCTION

0 375 750
Meters

SCALES SHOWN REFER TO ANSI D PAPER SIZE.
SCALES TO BE DOUBLED FOR ANSI B PAPER SIZES.

Figure 1 - Key Plan

No.	REVISION	DATE	BY
-			

STAMP

BCL
ENGINEERING LTD.

JOB No.: 198.03
DATE: 2020/04/20
DRAWN: K.M.N.
CHECKED: K.M.B.
DESIGNED: M.B.F.

THUNDERCHILD FIRST NATION

SEWAGE LAGOON EXPANSION
KEY PLAN

SCALE: 1:7500
REV. No. A
DRAWING No.
SHEET: 01 OF 03

2020/04/20 12:11:48 PM T:\dgn\198 THUNDERCHILD\03 LAGOON\CIVIL 3D DESIGN\198_03 - OVERALL DESIGN FILE.dwg

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Fig 2: Borehole Location Plan

0 50 100 Meters

SCALES SHOWN REFER TO ANSI D PAPER SIZE.
SCALES TO BE DOUBLED FOR ANSI B PAPER SIZES.

No.	REVISION	DATE	BY
-			

STAMP

BCL ENGINEERING LTD.

JOB No. 198.03
DATE: 2020/04/20
DRAWN: K.M.N.
CHECKED: K.M.B.
DESIGNED: M.B.F.

THUNDERCHILD FIRST NATION

SEWAGE LAGOON EXPANSION
SITE PLAN

SCALE: 1:1000
REV. No. A
DRAWING No.
SHEET: 03 OF 03

Appendix A

Photographs Taken During the Field Investigation

Photograph 1: Looking north towards BH20-1 (Lagoon Expansion Area)

Photograph 2: Looking north towards BH20-2 (Lagoon Expansion Area)

Photograph 3: Looking southeast towards BH20-B01 (existing berms)

Photograph 4: Looking northeast towards BH20-B10 (existing berms)

Photograph 5: Buried organics in BH20-B02 (existing berms)

Appendix B

Borehole Logs
Explanation of Terms and Symbols

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5928111 Easting: 642250
Elevation:

Borehole #: **BH20-1**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

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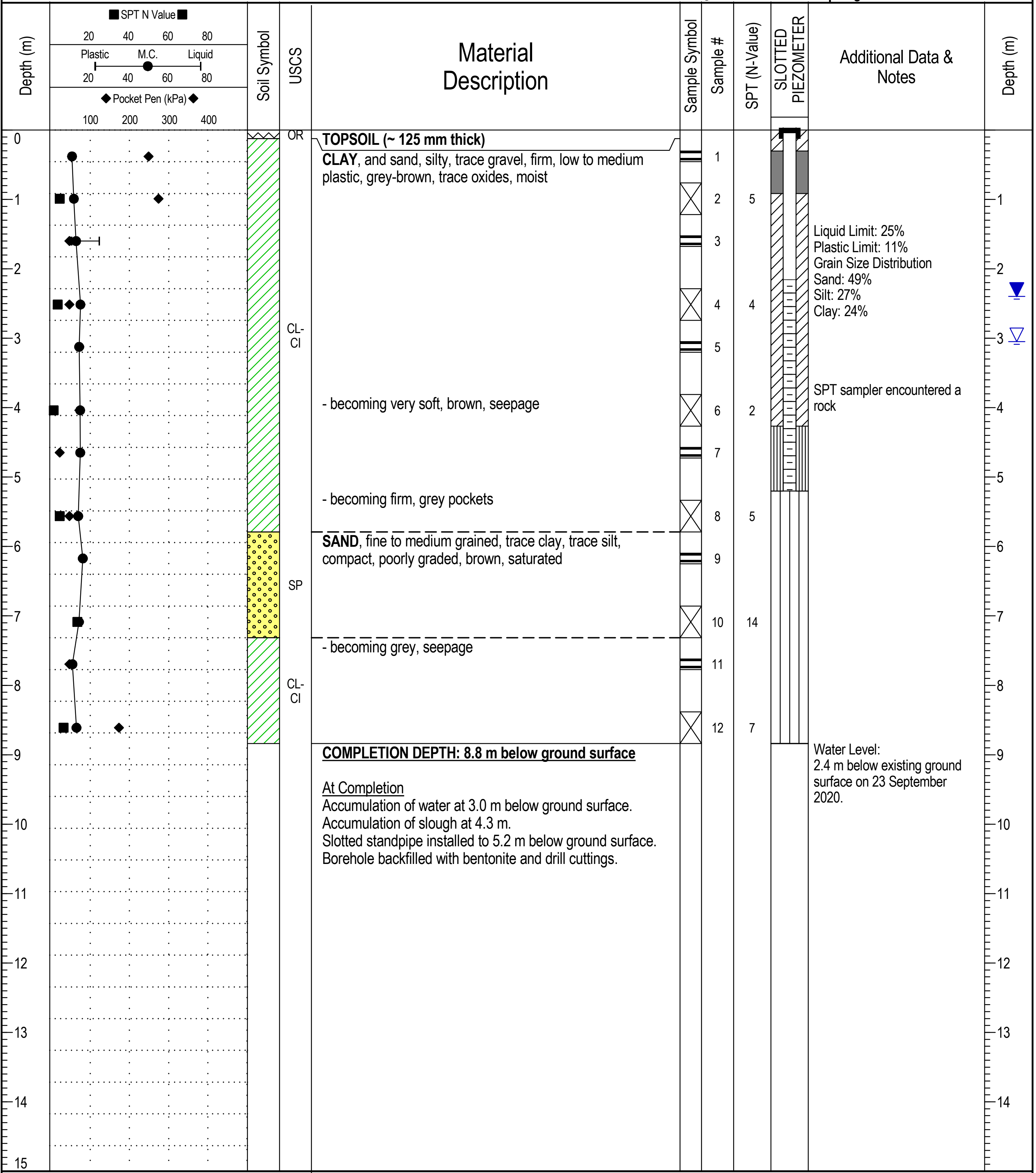
Completion Date: 28/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 125 mm thick)

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, grey-brown, trace oxides, moist

- becoming very soft, brown, seepage

- becoming firm, grey pockets

SAND, fine to medium grained, trace clay, trace silt, compact, poorly graded, brown, saturated

- becoming grey, seepage

COMPLETION DEPTH: 8.8 m below ground surface

At Completion
Accumulation of water at 3.0 m below ground surface.
Accumulation of slough at 4.3 m.
Slotted standpipe installed to 5.2 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Sample #	SPT (N-Value)
1	
2	5
3	
4	4
5	
6	2
7	
8	5
9	
10	14
11	
12	7

Additional Data & Notes

Liquid Limit: 25%
Plastic Limit: 11%
Grain Size Distribution
Sand: 49%
Silt: 27%
Clay: 24%

SPT sampler encountered a rock

Water Level:
2.4 m below existing ground surface on 23 September 2020.

Sample Symbol: ■ Shelby Tube ◩ No Recovery ☒ SPT Test (N) ☰ Grab Sample ▥ Split-Pen ◧ Core

Backfill Symbol: ■ Bentonite ⬚ Pea Gravel ▥ Slough ⁙ Grout ▨ Drill Cuttings ⁘ Sand

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927993 Easting: 642007
Elevation:

Borehole #: **BH20-2**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

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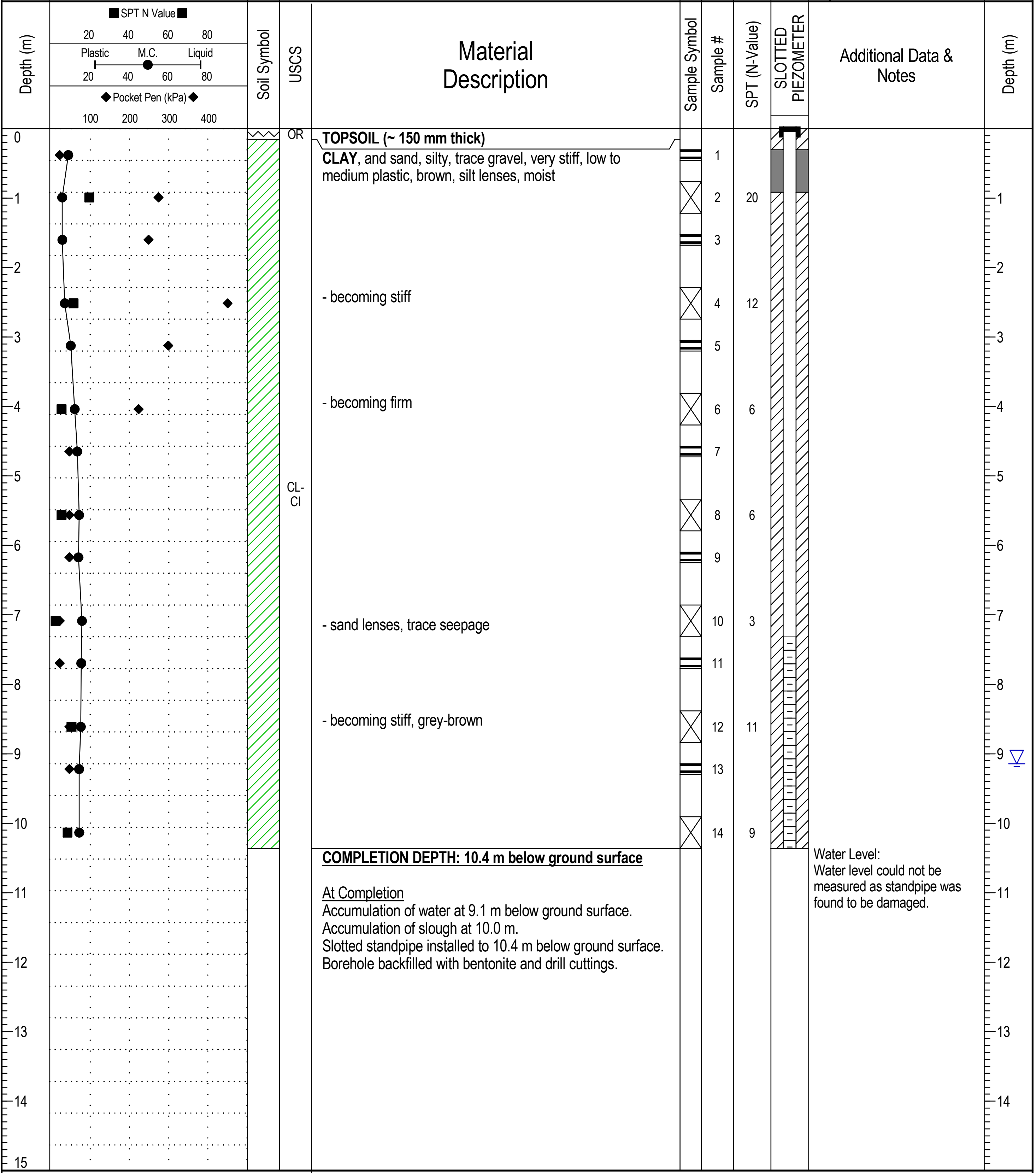
Completion Date: 28/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 150 mm thick)

CLAY, and sand, silty, trace gravel, very stiff, low to medium plastic, brown, silt lenses, moist

- becoming stiff

- becoming firm

- sand lenses, trace seepage

- becoming stiff, grey-brown

COMPLETION DEPTH: 10.4 m below ground surface

At Completion
Accumulation of water at 9.1 m below ground surface.
Accumulation of slough at 10.0 m.
Slotted standpipe installed to 10.4 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Sample #	SPT (N-Value)
1	
2	20
3	
4	12
5	
6	6
7	
8	6
9	
10	3
11	
12	11
13	
14	9

Additional Data & Notes

Water Level:
Water level could not be measured as standpipe was found to be damaged.

Sample Symbol	■ Shelby Tube	◪ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▮ Core
Backfill Symbol	▩ Bentonite	⬚ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁙ Sand

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5928127 Easting: 642069
Elevation:

Borehole #: **BH20-3**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

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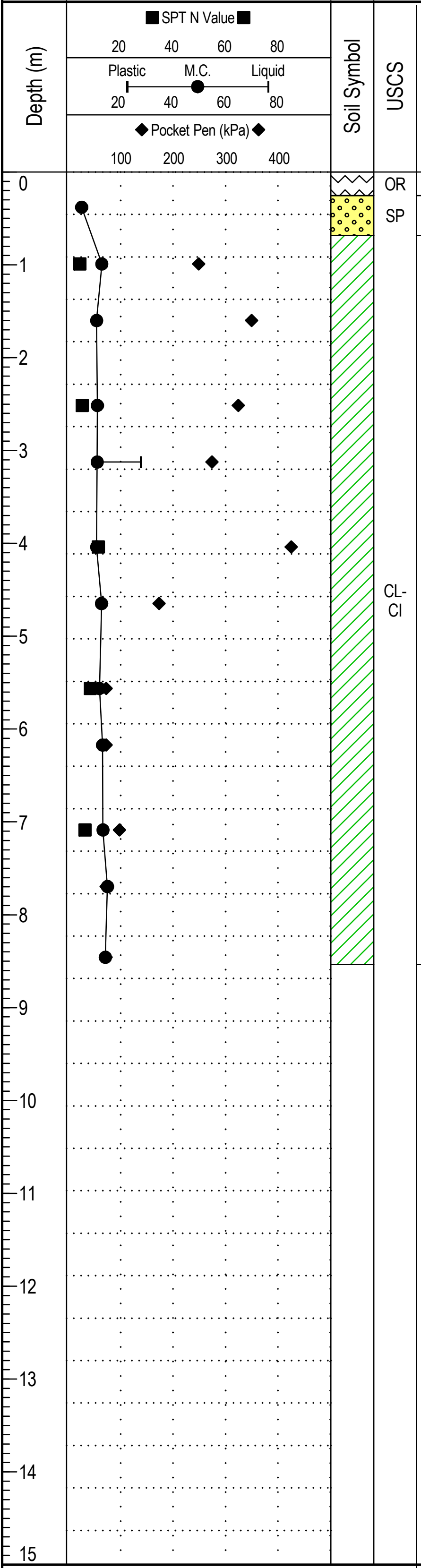
Completion Date: 28/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 250 mm thick)

SAND, fine grained, trace silt, trace clay, poorly graded, brown, moist

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, grey-brown, sand pockets, silt lenses, moist

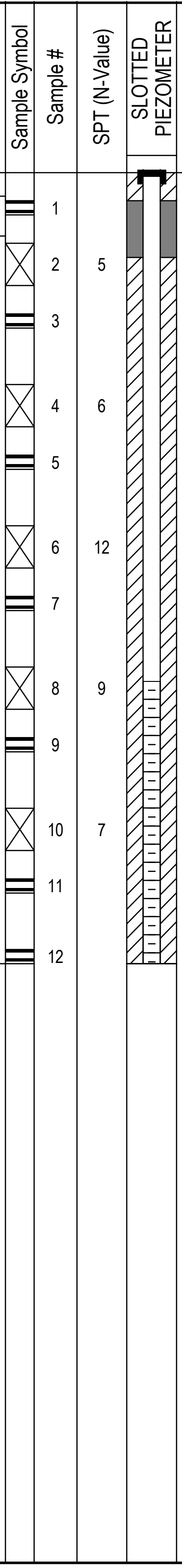
- cobbles

- becoming stiff

- becoming firm, seepage

COMPLETION DEPTH: 8.5 m below ground surface

At Completion
Accumulation of water at 7.6 m below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 8.5 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.



Sample #	SPT (N-Value)
1	
2	5
3	
4	6
5	
6	12
7	
8	9
9	
10	7
11	
12	

Additional Data & Notes

Liquid Limit: 28%
Plastic Limit: 12%
Grain Size Distribution
Gravel: 1 %
Sand: 44%
Silt: 28%
Clay: 27%

Water Level:
6.0 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	▱ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▮ Core
Backfill Symbol	■ Bentonite	⁙ Pea Gravel	▥ Slough	⁙ Grout	▨ Drill Cuttings	⁙ Sand

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5928297 Easting: 642181
Elevation:

Borehole #: **BH20-4**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

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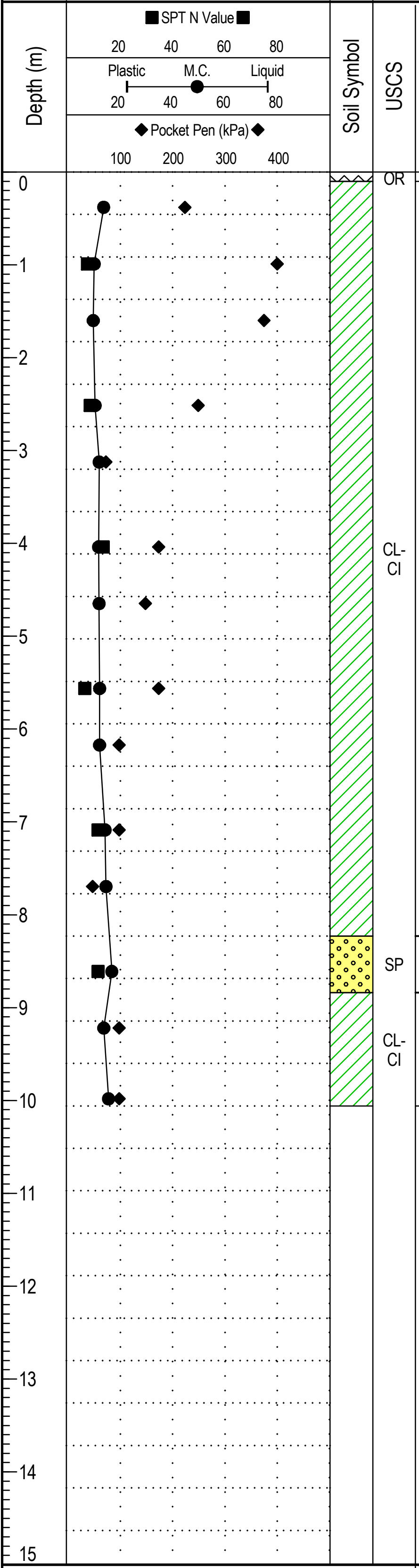
Completion Date: 28/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 100 mm thick)

CLAY, and sand, silty, trace gravel, stiff, low to medium plastic, grey-brown, sand lenses, trace oxides, trace roots, moist

- becoming firm

- becoming stiff

SAND, fine grained, trace silt, trace clay, compact, poorly graded, brown, saturated

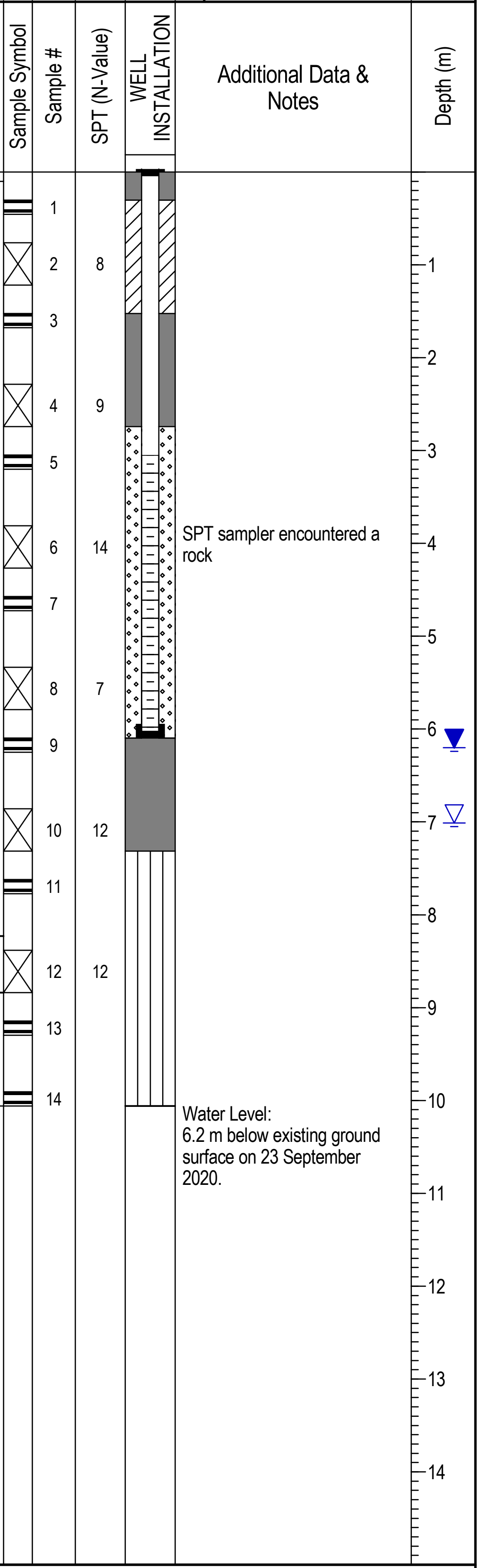
- becoming grey

COMPLETION DEPTH: 10.0 m below ground surface

At Completion
Accumulation of water at 7.0 m below ground surface.
Accumulation of slough at 7.3 m below ground surface.

Monitor Well Installation Details
50 mm Slotted Screen: 6.1 m to 3.0 m
50 mm Solid Pipe: 3.0 m to 0 m

Backfill Details
Slough: 10 m to 7.3 m
Bentonite: 7.3 m to 6.1 m
Sand: 6.1 m to 2.7 m
Bentonite: 2.7 m to 1.5 m
Drill Cuttings: 1.5 m to 0.3 m
Bentonite: 0.3 m to 0 m



Sample #	SPT (N-Value)
1	
2	8
3	
4	9
5	
6	14
7	
8	7
9	
10	12
11	
12	12
13	
14	

Additional Data & Notes

SPT sampler encountered a rock

Water Level:
6.2 m below existing ground surface on 23 September 2020.

Sample Symbol: ■ Shelby Tube; ▨ No Recovery; ☒ SPT Test (N); ☰ Grab Sample; ▥ Split-Pen; ▮ Core

Backfill Symbol: ■ Bentonite; ⁘ Pea Gravel; ▥ Slough; ⁘ Grout; ▨ Drill Cuttings; ⁘ Sand

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5928132 Easting: 641925
Elevation:

Borehole #: **BH20-5**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

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Completion Date: 28/8/20
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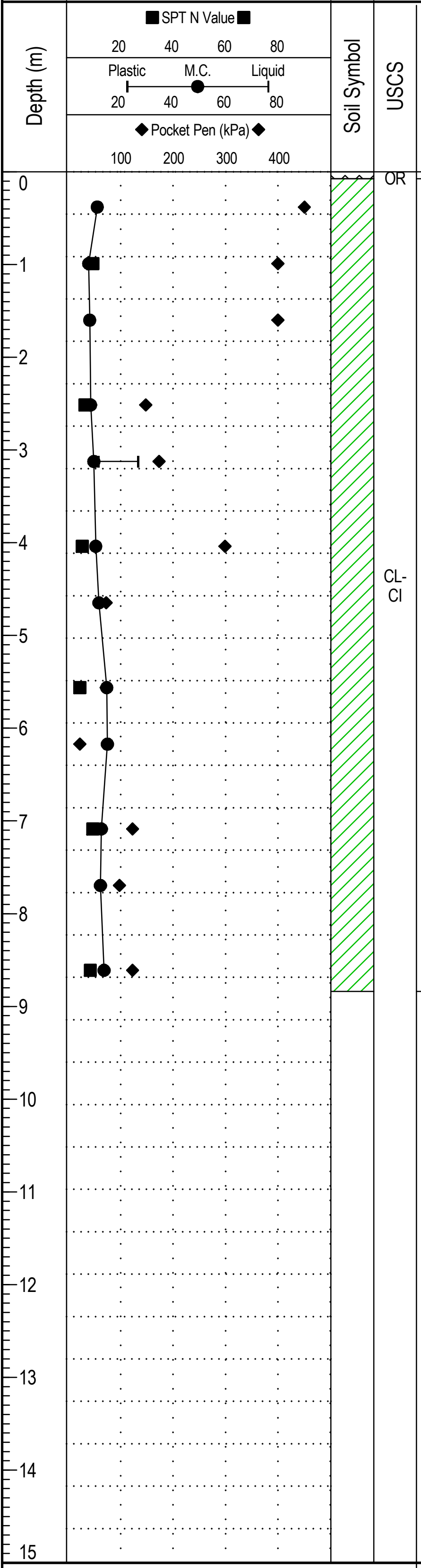


Material Description

TOPSOIL (~ 75 mm thick)

CLAY, and sand, silty, trace gravel, stiff, low to medium plastic, grey-brown, silt lenses, moist

- becoming firm

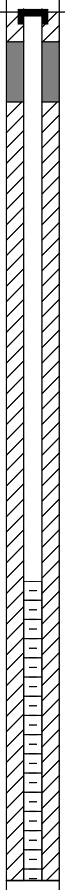
- becoming grey, stiff

COMPLETION DEPTH: 8.8 m below ground surface

At Completion
No accumulation of water below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 8.8 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Sample Symbol	Sample #	SPT (N-Value)
☰	1	
☒	2	10
☰	3	
☒	4	7
☰	5	
☒	6	6
☰	7	
☒	8	5
☰	9	
☒	10	10
☰	11	
☒	12	9

SLOTTED PIEZOMETER



Additional Data & Notes

Liquid Limit: 27%
Plastic Limit: 12%
Grain Size Distribution
Gravel: 1 %
Sand: 48%
Silt: 27%
Clay: 24%

Water Level:
6.1 m below existing ground surface on 23 September 2020.

Sample Symbol: ■ Shelby Tube ◺ No Recovery ☒ SPT Test (N) ☰ Grab Sample ▥ Split-Pen ▮ Core

Backfill Symbol: ■ Bentonite ⁙ Pea Gravel ▥ Slough ⁘ Grout ▨ Drill Cuttings ⁙ Sand

Project Name: Proposed Sewage Lagoon
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5928280 Easting: 642012
Elevation:

Borehole #: **BH20-6**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL

Completion Date: 28/8/20
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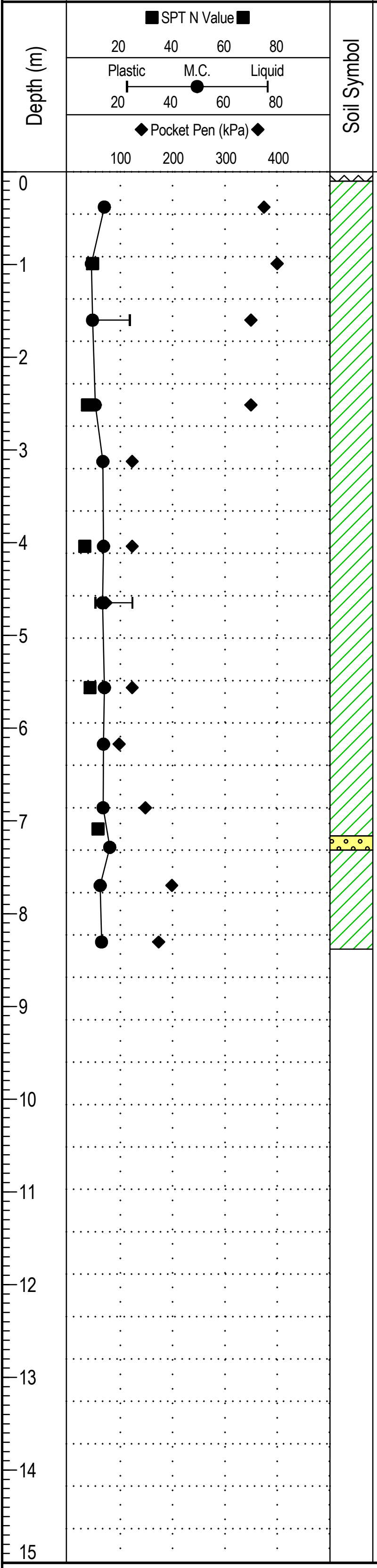


USCS	Material Description
OR	**TOPSOIL (~ 100 mm thick)**
CL	**CLAY**, and sand, silt, sandy, trace gravel, stiff, low plastic, brown, silt lenses, moist - becoming grey-brown
SP	**SAND**, medium grained, trace silt, trace clay, poorly graded, brown, saturated
CL	- becoming grey

COMPLETION DEPTH: 8.4 m below ground surface

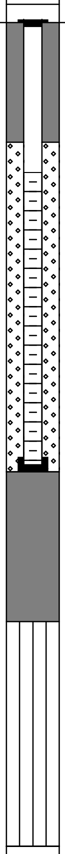
At Completion
Accumulation of water at 5.8 m below ground surface.
Accumulation of slough at 6.1 m below ground surface.

Monitor Well Installation Details
50 mm Slotted Screen: 4.6 m to 1.5 m
50 mm Solid Pipe: 1.5 m to 0 m

Backfill Details
Slough: 8.4 m to 6.1 m
Bentonite: 6.1 m to 4.6 m
Sand: 4.6 m to 1.2 m
Bentonite: 1.2 m to 0 m

Sample Symbol	Sample #	SPT (N-Value)
☰	1	
☒	2	10
☰	3	
☒	4	8
☰	5	
☒	6	7
☰	7	
☒	8	9
☰	9	
☒	10	12
☰	11	
☰	12	
☰	13	

WELL INSTALLATION



Additional Data & Notes

Maximum Dry Density: 1946 kg/m^3
Optimum Moisture Content: 11.3 %

Liquid Limit: 24%
Plastic Limit: 10%
Grain Size Distribution
Gravel: 2 %
Sand: 47%
Silt: 27%
Clay: 24%

Liquid Limit: 25%
Plastic Limit: 11%
Grain Size Distribution
Gravel: 2 %
Sand: 49%
Silt: 29%
Clay: 20%

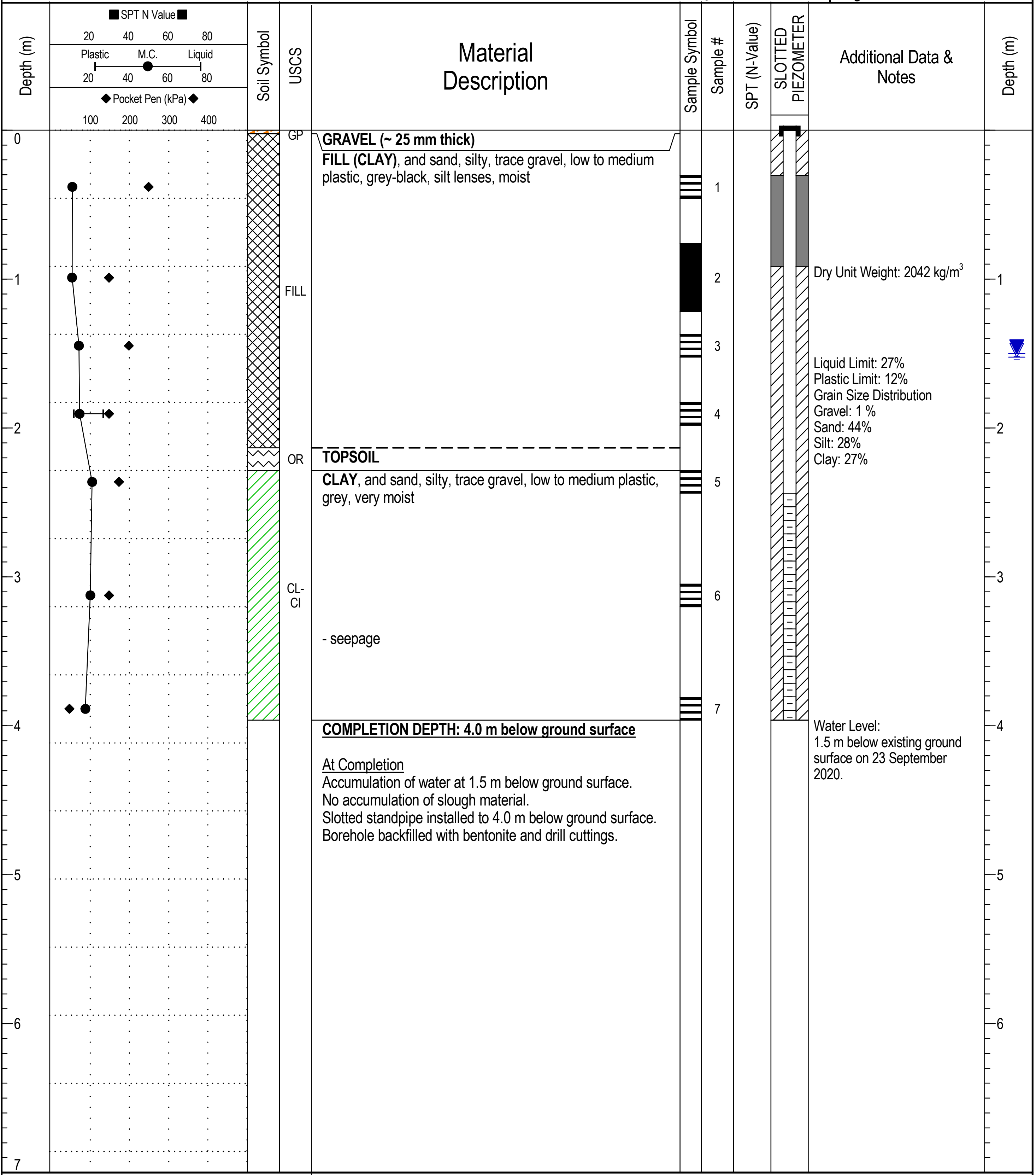
Water Level:
Dry on 23 September 2020.

Sample Symbol	■ Shelby Tube	◪ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▮ Core
Backfill Symbol	■ Bentonite	⬚ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁘ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927817 Easting: 642072
Elevation:

Borehole #: **BH20-B01**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

Completion Date: 30/8/20
Page 1 of 1



Material Description

GRAVEL (~ 25 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, grey-black, silt lenses, moist

TOPSOIL

CLAY, and sand, silty, trace gravel, low to medium plastic, grey, very moist

- seepage

COMPLETION DEPTH: 4.0 m below ground surface

At Completion
Accumulation of water at 1.5 m below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 4.0 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Additional Data & Notes

Dry Unit Weight: 2042 kg/m^3

Liquid Limit: 27%
Plastic Limit: 12%
Grain Size Distribution
Gravel: 1 %
Sand: 44%
Silt: 28%
Clay: 27%

Water Level:
1.5 m below existing ground surface on 23 September 2020.

Sample Symbol: ■ Shelby Tube ☐ No Recovery ☒ SPT Test (N) ▤ Grab Sample ▥ Split-Pen ▮ Core

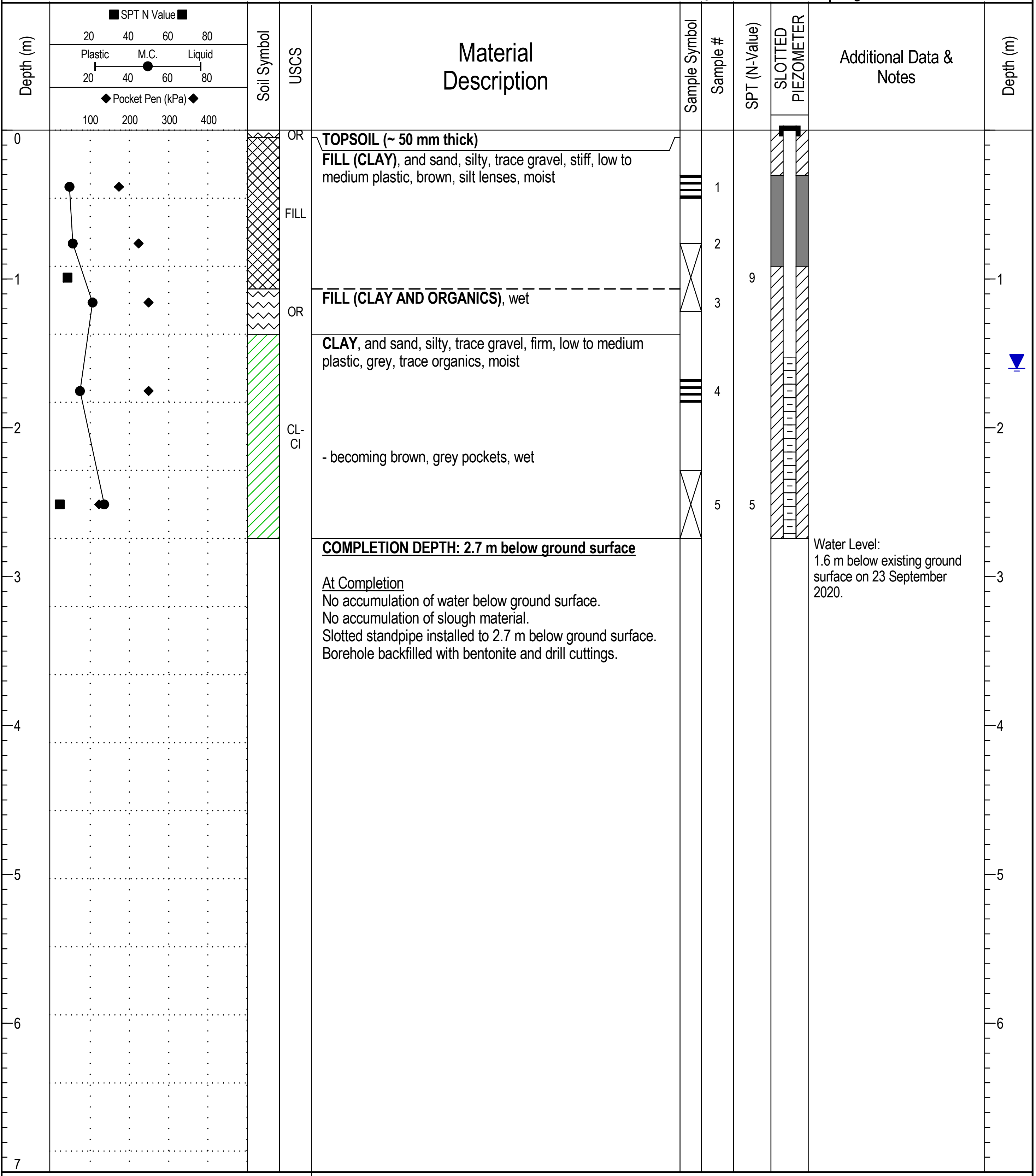
Backfill Symbol: ■ Bentonite ⁙ Pea Gravel ▥ Slough ⁙ Grout ▨ Drill Cuttings ⁙ Sand

Z:\PROJECTS\GEOTECHNICAL PROJECTS\2020\PG20-1536-BCL-THINDERCHILD FN LAGOON-115 B\PG20-1536 - THUNDERCHILD FN LAGOON-115B - EXISTING BERM-FINAL.GPJ 20/10/13 12:29 PM (SEG-FINAL)

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927879 Easting: 642037
Elevation:

Borehole #: **BH20-B02**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL
Completion Date: 30/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 50 mm thick)

FILL (CLAY), and sand, silty, trace gravel, stiff, low to medium plastic, brown, silt lenses, moist

FILL (CLAY AND ORGANICS), wet

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, grey, trace organics, moist

- becoming brown, grey pockets, wet

COMPLETION DEPTH: 2.7 m below ground surface

At Completion
No accumulation of water below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 2.7 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Additional Data & Notes

Water Level:
1.6 m below existing ground surface on 23 September 2020.

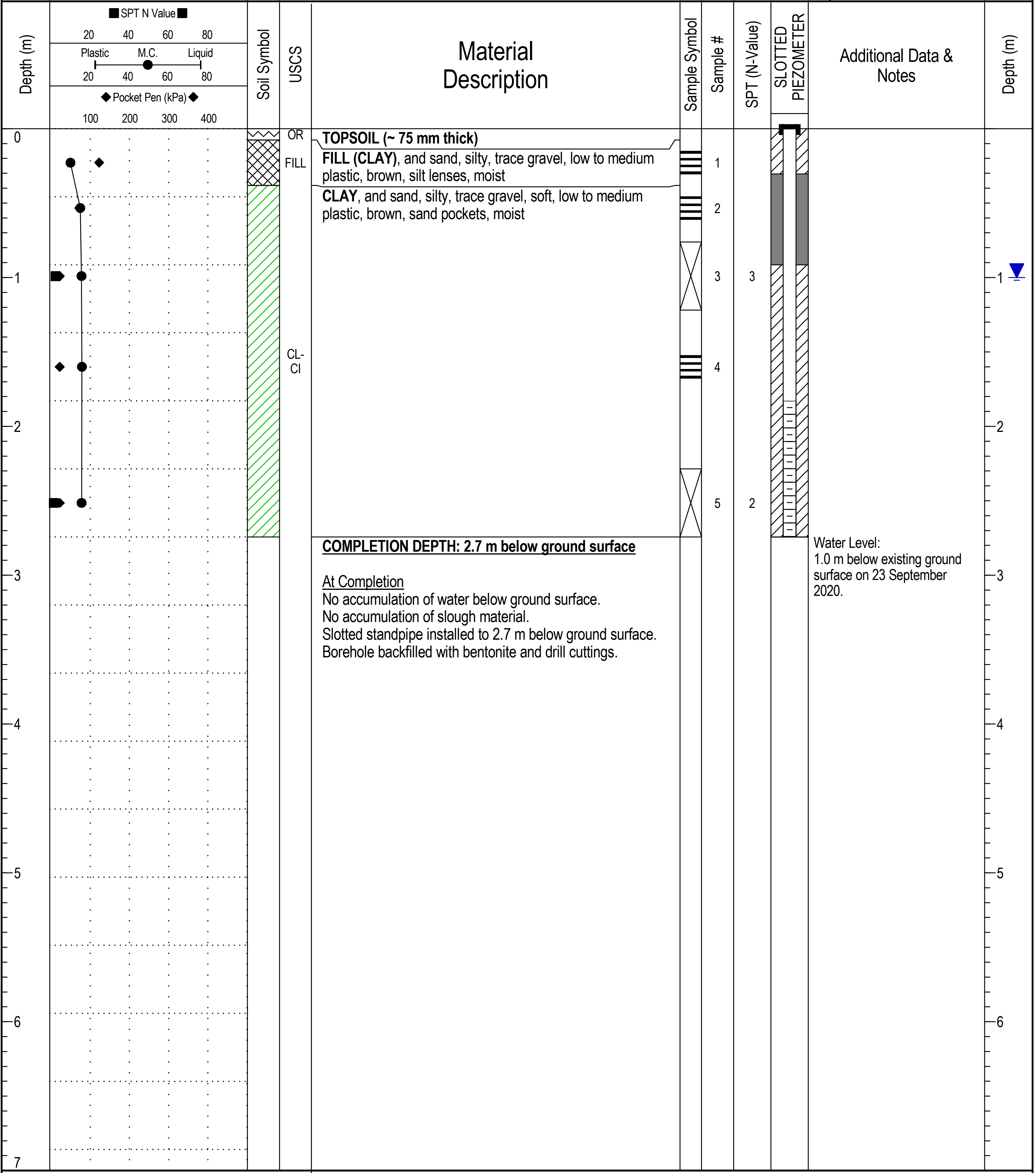
Sample Symbol	■ Shelby Tube	◺ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▮ Core
Backfill Symbol	■ Bentonite	⬚ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁘ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927938 Easting: 642049
Elevation:

Borehole #: **BH20-B03**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL

Completion Date: 30/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 75 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, brown, silt lenses, moist

CLAY, and sand, silty, trace gravel, soft, low to medium plastic, brown, sand pockets, moist

COMPLETION DEPTH: 2.7 m below ground surface

At Completion
No accumulation of water below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 2.7 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Sample Symbol	Sample #	SPT (N-Value)
☰	1	
☰	2	
☒	3	3
☰	4	
☒	5	2

Additional Data & Notes

Water Level:
1.0 m below existing ground surface on 23 September 2020.

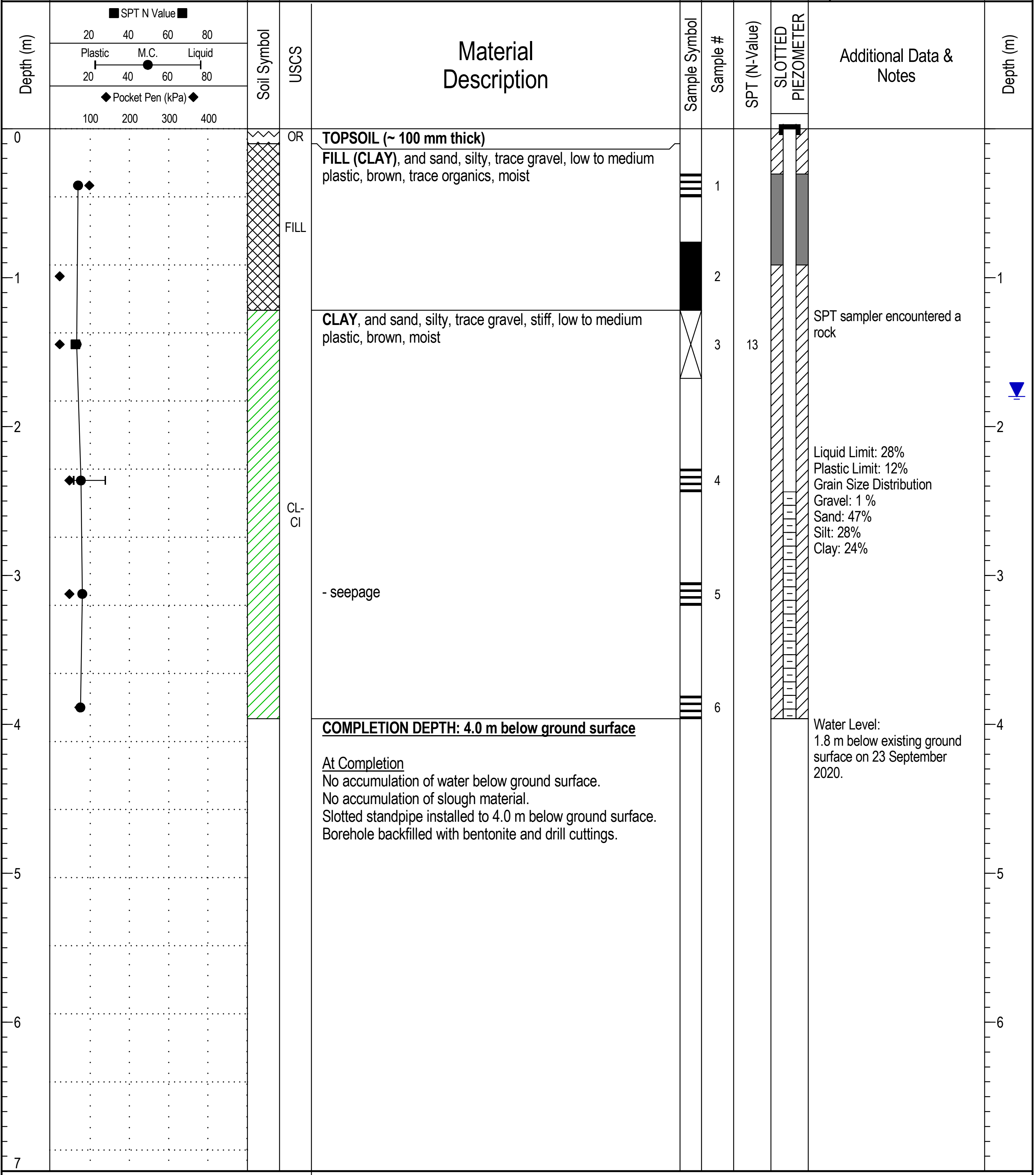
Sample Symbol	■ Shelby Tube	▨ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▯ Core
Backfill Symbol	■ Bentonite	⁙ Pea Gravel	▥ Slough	⁙ Grout	▨ Drill Cuttings	⁙ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927967 Easting: 642109
Elevation:

Borehole #: **BH20-B04**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL

Completion Date: 30/8/20
Page 1 of 1



TOPSOIL (~ 100 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, brown, trace organics, moist

CLAY, and sand, silty, trace gravel, stiff, low to medium plastic, brown, moist

- seepage

COMPLETION DEPTH: 4.0 m below ground surface

At Completion
No accumulation of water below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 4.0 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

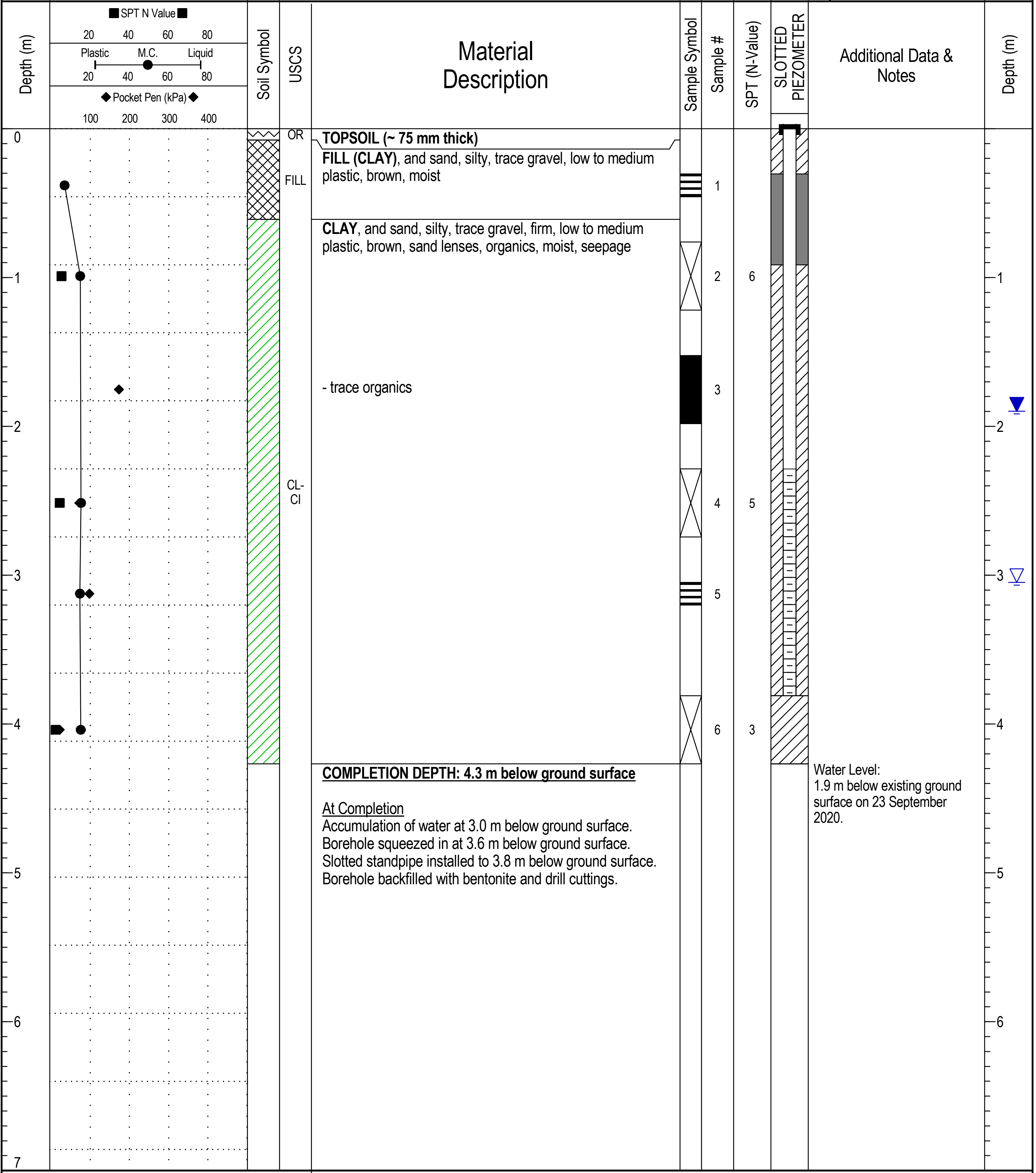
SPT sampler encountered a rock

Liquid Limit: 28%
Plastic Limit: 12%
Grain Size Distribution
Gravel: 1 %
Sand: 47%
Silt: 28%
Clay: 24%

Water Level:
1.8 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	◿ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▯ Core
Backfill Symbol	■ Bentonite	⁙ Pea Gravel	▥ Slough	⁙ Grout	▨ Drill Cuttings	⁙ Sand

Project Name: Existing Berm- Site 115B	Borehole #: **BH20-B05**		
Client Name: BCL Engineering Ltd.	Project #: PG20-1536		
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK	Logged By: JW / Reviewed By: TF		
Northing: 5928034 Easting: 642200	Driller: Top Gear Contracting Ltd.	Completion Date: 28/8/20	
Elevation:	Drill Method: 150 mm Solid Stem Auger	Page 1 of 1	



TOPSOIL (~ 75 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, brown, moist

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, brown, sand lenses, organics, moist, seepage

- trace organics

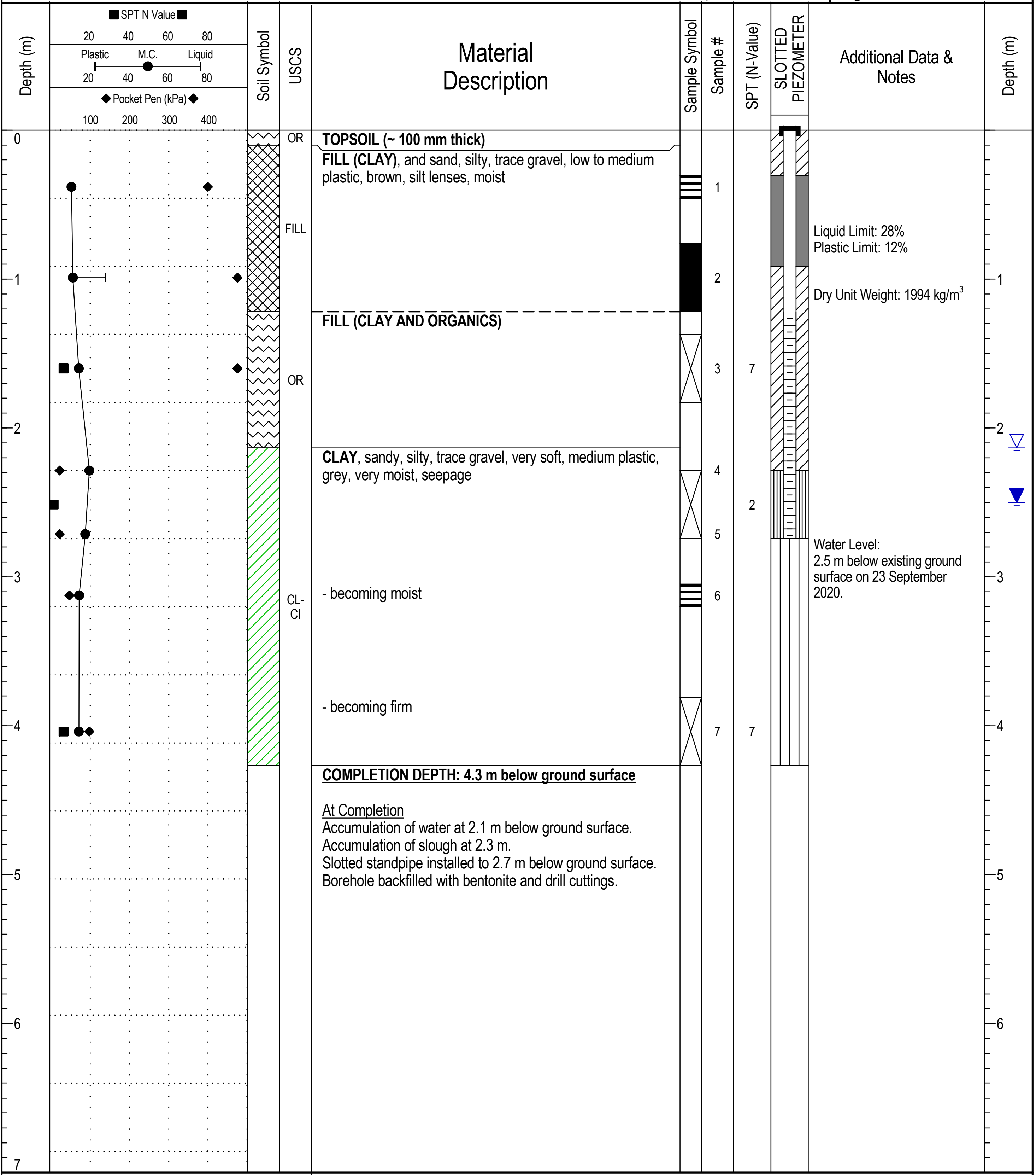
COMPLETION DEPTH: 4.3 m below ground surface

At Completion
Accumulation of water at 3.0 m below ground surface.
Borehole squeezed in at 3.6 m below ground surface.
Slotted standpipe installed to 3.8 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Water Level:
1.9 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	◿ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▮ Core
Backfill Symbol	■ Bentonite	⁘ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁘ Sand

Project Name: Existing Berm- Site 115B	Borehole #: **BH20-B06**		SolidEarth GEOTECHNICAL
Client Name: BCL Engineering Ltd.	Project #: PG20-1536		
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK	Logged By: JW / Reviewed By: TF		
Northing: 5927993 Easting: 642251	Driller: Top Gear Contracting Ltd.		Completion Date: 28/8/20
Elevation:	Drill Method: 150 mm Solid Stem Auger		Page 1 of 1



Material Description

TOPSOIL (~ 100 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, brown, silt lenses, moist

FILL (CLAY AND ORGANICS)

CLAY, sandy, silty, trace gravel, very soft, medium plastic, grey, very moist, seepage

- becoming moist

- becoming firm

COMPLETION DEPTH: 4.3 m below ground surface

At Completion
Accumulation of water at 2.1 m below ground surface.
Accumulation of slough at 2.3 m.
Slotted standpipe installed to 2.7 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Additional Data & Notes

Liquid Limit: 28%
Plastic Limit: 12%

Dry Unit Weight: 1994 kg/m^3

Water Level:
2.5 m below existing ground surface on 23 September 2020.

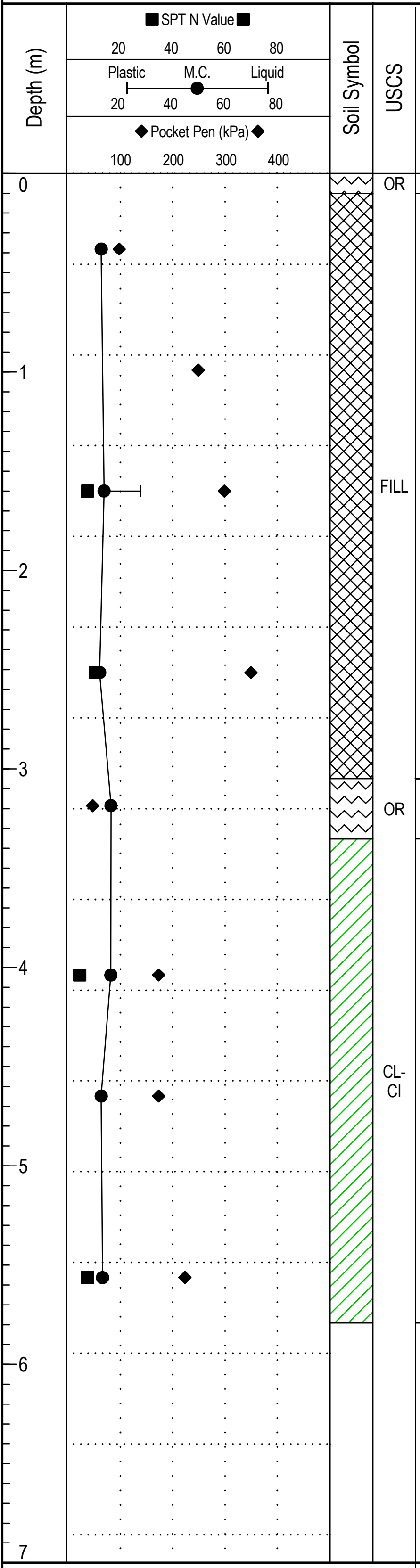
Sample Symbol	■ Shelby Tube	▨ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▯ Core
Backfill Symbol	■ Bentonite	⁚ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁘ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927944 Easting: 642280
Elevation:

Borehole #: **BH20-B07**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL

Completion Date: 28/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 100 mm thick)

FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, grey-brown, sand pockets, moist

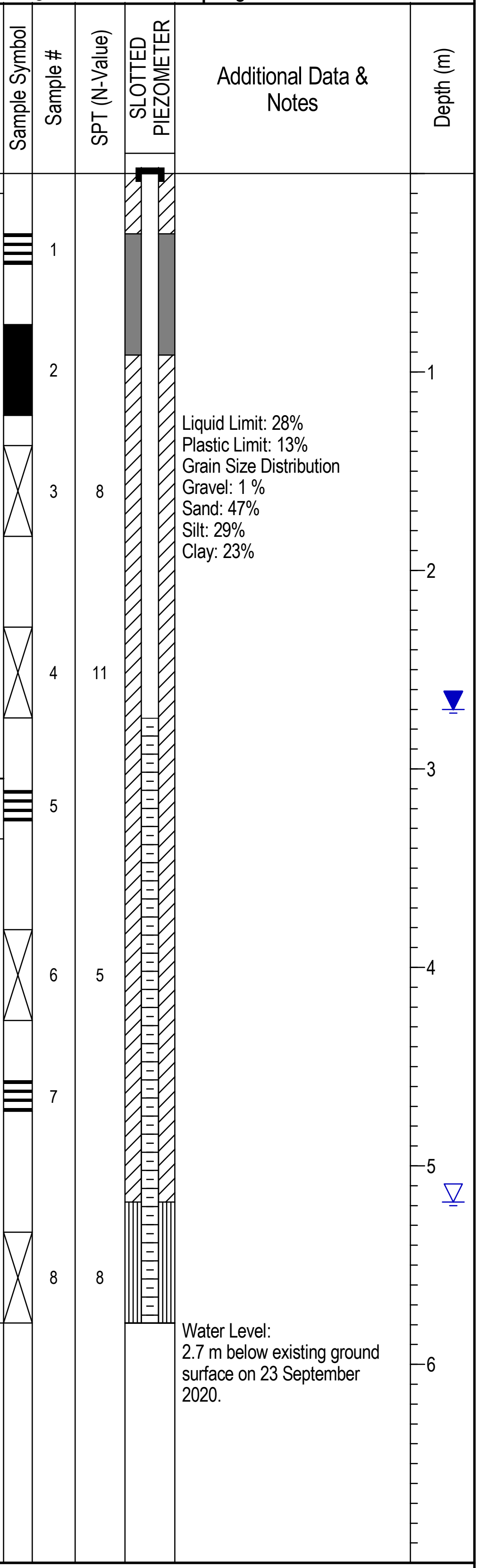
- stiff, organic inclusion, seepage

FILL (CLAY AND ORGANICS)

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, grey-brown, silt lenses, moist, seepage

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 5.2 m below ground surface.
Accumulation of slough at 5.2 m.
Slotted standpipe installed to 5.8 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.



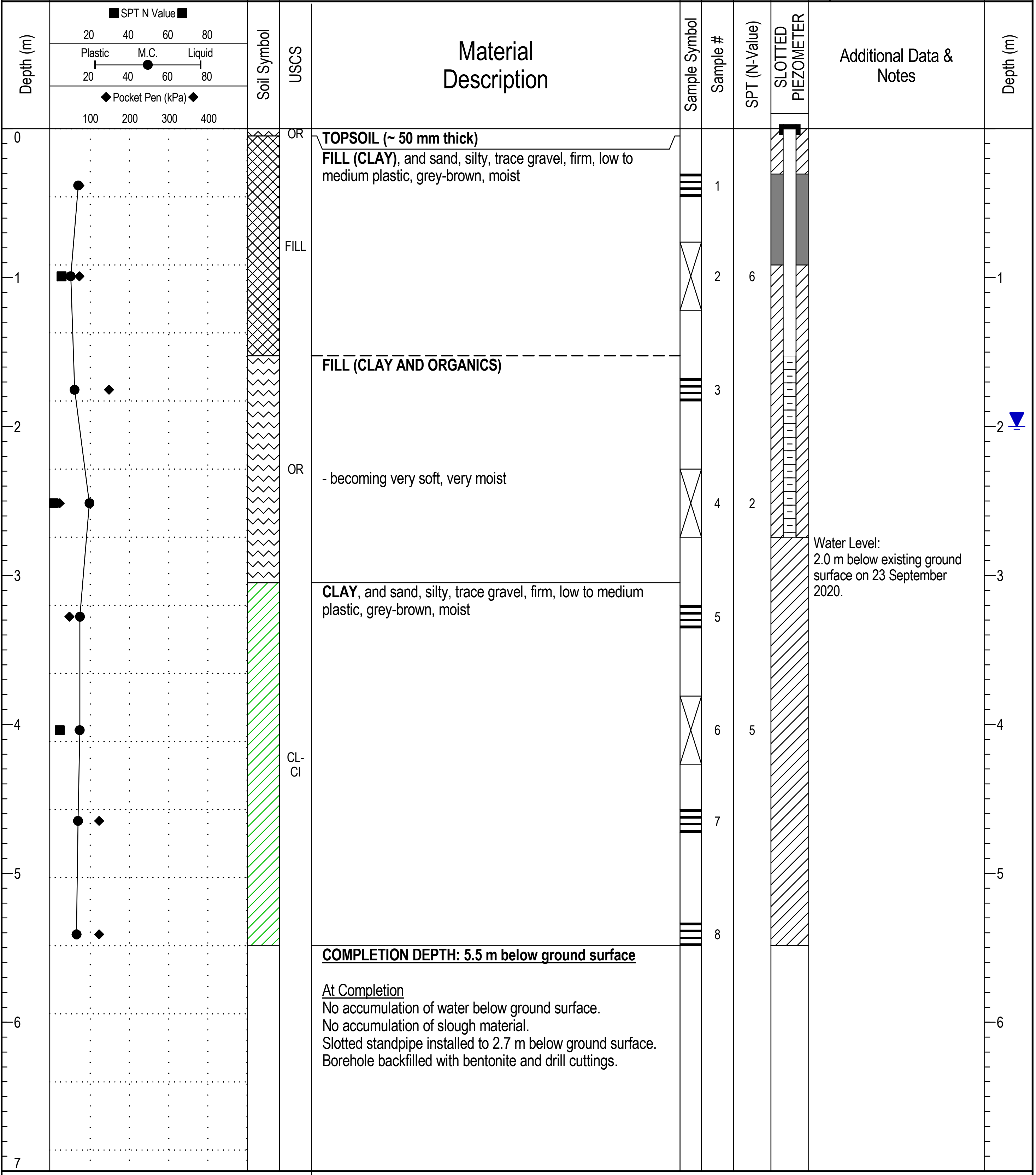
Additional Data & Notes

Liquid Limit: 28%
Plastic Limit: 13%
Grain Size Distribution
Gravel: 1 %
Sand: 47%
Silt: 29%
Clay: 23%

Water Level:
2.7 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	▨ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▯ Core
Backfill Symbol	■ Bentonite	⁘ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁘ Sand

Project Name: Existing Berm- Site 115B	Borehole #: **BH20-B08**	SolidEarth GEOTECHNICAL
Client Name: BCL Engineering Ltd.	Project #: PG20-1536	
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK	Logged By: JW / Reviewed By: TF	
Northing: 5927882 Easting: 642227	Driller: Top Gear Contracting Ltd.	Completion Date: 30/8/20
Elevation:	Drill Method: 150 mm Solid Stem Auger	Page 1 of 1



USCS	Material Description
OR	**TOPSOIL (~ 50 mm thick)**
FILL	**FILL (CLAY)**, and sand, silty, trace gravel, firm, low to medium plastic, grey-brown, moist
OR	**FILL (CLAY AND ORGANICS)** - becoming very soft, very moist
CL-CI	**CLAY**, and sand, silty, trace gravel, firm, low to medium plastic, grey-brown, moist

COMPLETION DEPTH: 5.5 m below ground surface

At Completion
No accumulation of water below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 2.7 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Sample #	SPT (N-Value)
1	
2	6
3	
4	2
5	
6	5
7	
8	

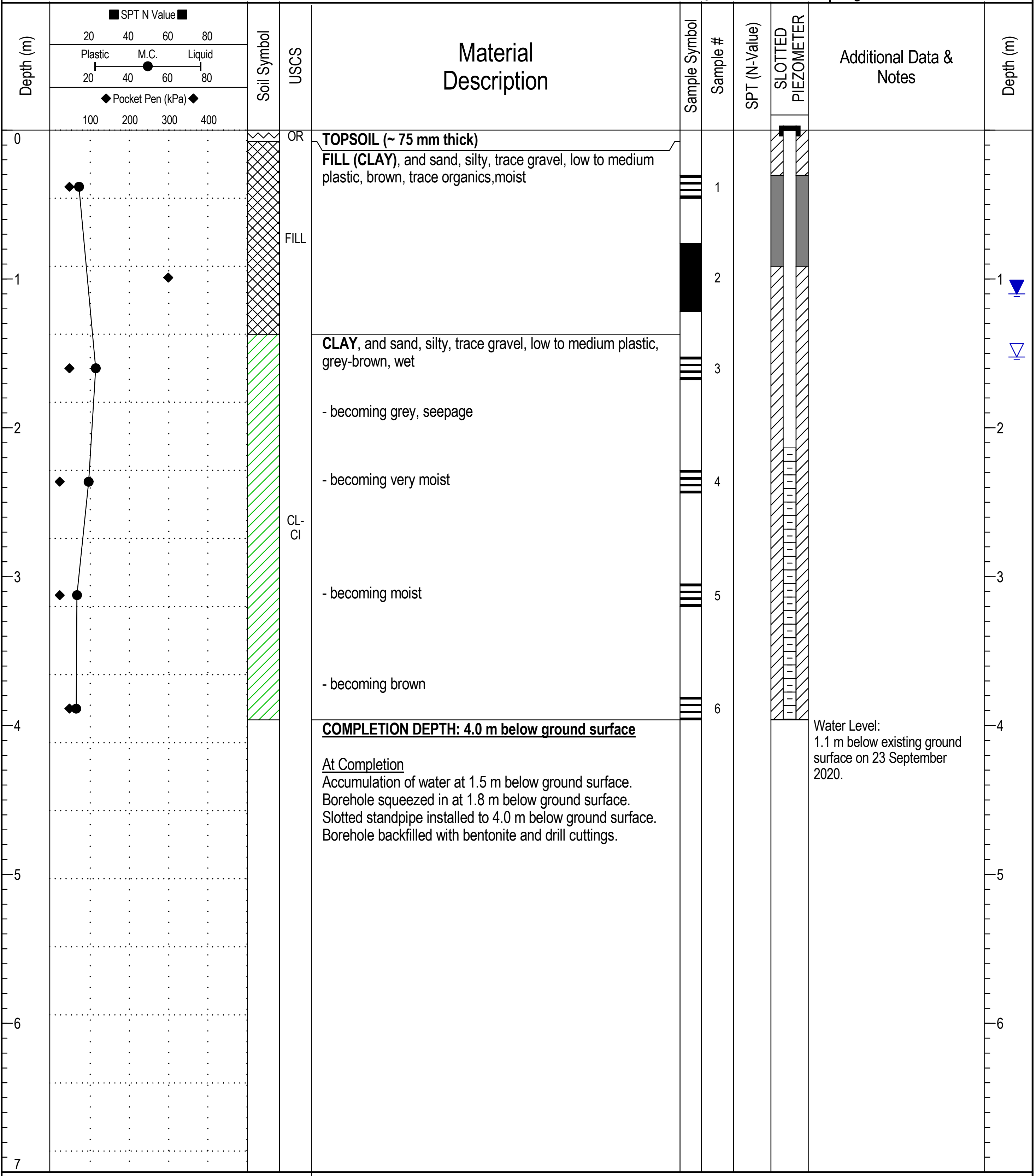
Water Level:
2.0 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	◺ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	◨ Core
Backfill Symbol	■ Bentonite	⬚ Pea Gravel	▥ Slough	⁙ Grout	▨ Drill Cuttings	⁙ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927832 Easting: 642140
Elevation:

Borehole #: **BH20-B09**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

SolidEarth GEOTECHNICAL
Completion Date: 30/8/20
Page 1 of 1



Material Description
TOPSOIL (~ 75 mm thick)
FILL (CLAY), and sand, silty, trace gravel, low to medium plastic, brown, trace organics,moist
CLAY, and sand, silty, trace gravel, low to medium plastic, grey-brown, wet - becoming grey, seepage - becoming very moist - becoming moist - becoming brown
COMPLETION DEPTH: 4.0 m below ground surface

<u>At Completion</u>
Accumulation of water at 1.5 m below ground surface.
Borehole squeezed in at 1.8 m below ground surface.
Slotted standpipe installed to 4.0 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

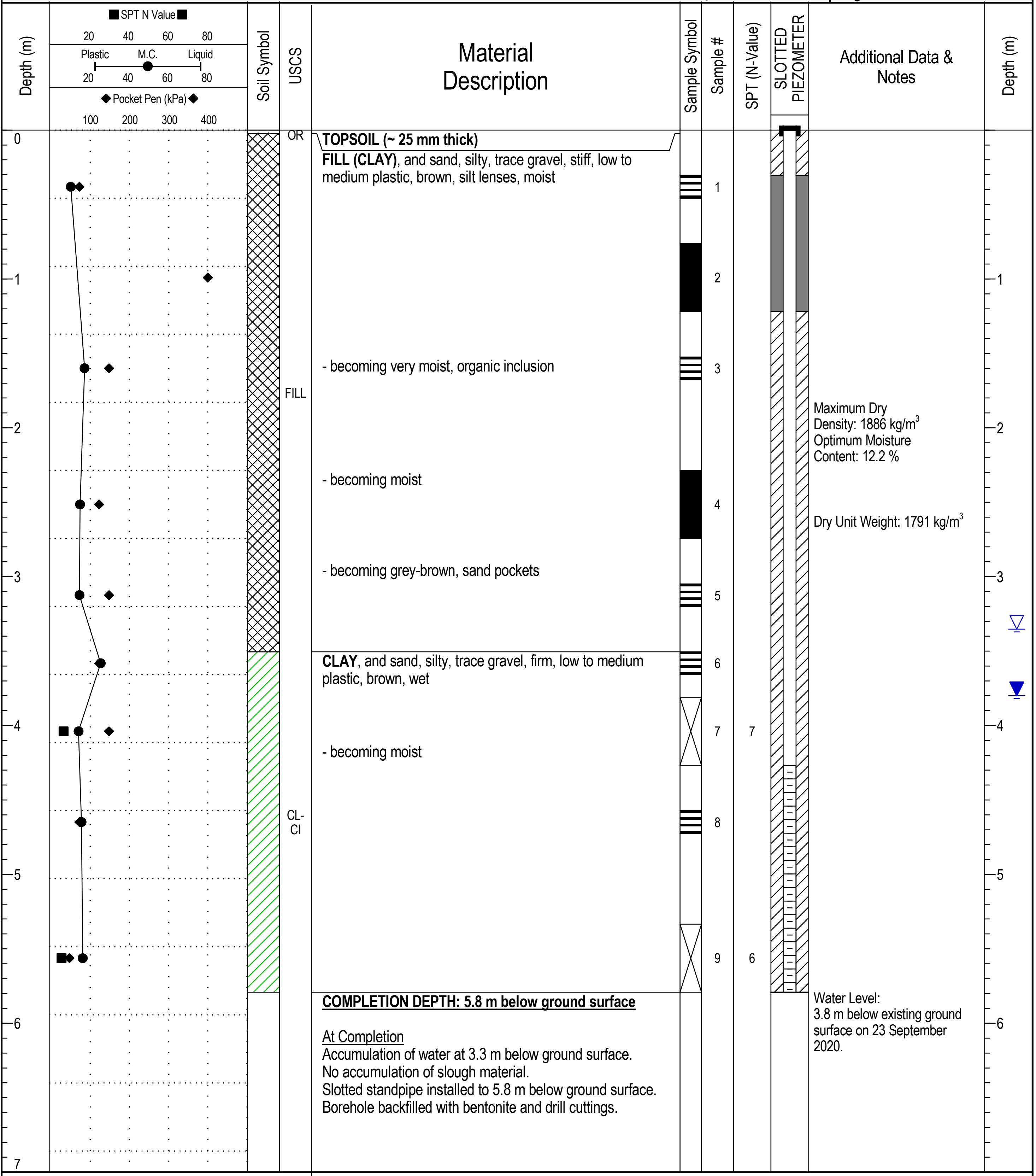
Water Level:
1.1 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	▨ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	▯ Core
Backfill Symbol	■ Bentonite	⁛ Pea Gravel	▥ Slough	⁛ Grout	▨ Drill Cuttings	⁛ Sand

Project Name: Existing Berm- Site 115B
Client Name: BCL Engineering Ltd.
Site: Within NE 10 & SE 15-52-20 W3M,Thunderchild FN Site 115B,SK
Northing: 5927897 Easting: 642138
Elevation:

Borehole #: **BH20-B10**
Project #: PG20-1536
Logged By: JW / Reviewed By: TF
Driller: Top Gear Contracting Ltd.
Drill Method: 150 mm Solid Stem Auger

Completion Date: 30/8/20
Page 1 of 1



Material Description

TOPSOIL (~ 25 mm thick)

FILL (CLAY), and sand, silty, trace gravel, stiff, low to medium plastic, brown, silt lenses, moist

- becoming very moist, organic inclusion

- becoming moist

- becoming grey-brown, sand pockets

CLAY, and sand, silty, trace gravel, firm, low to medium plastic, brown, wet

- becoming moist

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 3.3 m below ground surface.
No accumulation of slough material.
Slotted standpipe installed to 5.8 m below ground surface.
Borehole backfilled with bentonite and drill cuttings.

Additional Data & Notes

Maximum Dry Density: 1886 kg/m^3
Optimum Moisture Content: 12.2 %

Dry Unit Weight: 1791 kg/m^3

Water Level:
3.8 m below existing ground surface on 23 September 2020.

Sample Symbol	■ Shelby Tube	◺ No Recovery	☒ SPT Test (N)	☰ Grab Sample	▥ Split-Pen	◫ Core
Backfill Symbol	▩ Bentonite	⬚ Pea Gravel	▥ Slough	⁘ Grout	▨ Drill Cuttings	⁙ Sand

EXPLANATION OF TERMS & SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of the field investigation and laboratory testing are described on the following two pages.

1. VISUAL TEXTURAL CLASSIFICATION ON MINERAL SOILS

CLASSIFICATION	APPARENT PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	> 200 mm	> 200 mm
Cobbles	75 mm to 200 mm	75 mm to 200 mm
Gravel	4.75 mm to 75 mm	5 mm to 75 mm
Sand	0.075 mm to 4.75 mm	Visible particles to 5 mm
Silt	0.002 mm to 0.075 mm	Non-plastic particles, not visible to naked eye
Clay	< 0.002 mm	Plastic particles, not visible to naked eye

2. TERMS FOR CONSISTENCY & DENSITY OF SOILS

Cohesionless Soils

DESCRIPTIVE TERM	APPROXIMATE SPT “N” VALUE
Very Dense	> 50
Dense	30 to 50
Compact	10 to 30
Loose	4 to 10
Very Loose	< 4

Cohesive Soils

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH	APPROXIMATE SPT “N” VALUE
Hard	>200 kPa	> 30
Very Stiff	100 to 200 kPa	15 to 30
Stiff	50 to 100 kPa	8 to 15
Firm	25 to 50 kPa	4 to 8
Soft	10 to 25 kPa	2 to 4
Very Soft	< 10 kPa	< 2

* SPT “N” Values – Refers to the number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter split spoon sampler for a distance of 300 mm after an initial penetration of 150 mm.

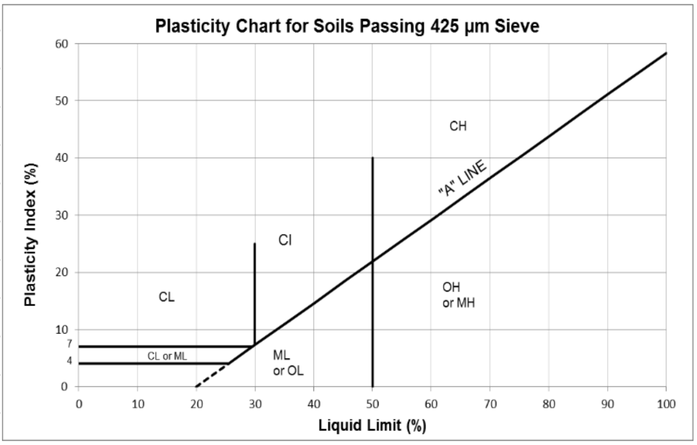
3. SYMBOLS USED ON BOREHOLE LOGS

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
N(■)	Standard Penetration Test (CSA A119 1-60)	SO_4	Concentration of Water-Soluble Sulphate
N_d	Dynamic Cone Penetration Test	C_u	Undrained Shear Strength
pp (♦)	Pocket Penetrometer Strength	γ	Unit Weight of Soil or Rock
q_u	Unconfined Compressive Strength	γ_d	Dry Unit Weight of Soil or Rock
w (●)	Natural Moisture Content (ASTM D2216)	ρ	Density of Soil or Rock
w_L	Liquid Limit (ASTM D 4318)	ρ_d	Dry Density of Soil or Rock
w_P	Plastic Limit (ASTM D 4318)	▽	Short-Term Water Level
I_P	Plastic Index	▼	Long-Term Water Level

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75 µm)	**GRAVELS** (MORE THAN HALF COARSE GRAINS LARGER THAN 4.75mm)	CLEAN GRAVELS (LITTLE OR NO FINES)	**GW**	WELL GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = D_{60}/D_{10} > 4$ $C_c = (D_{30})^2/(D_{10} \times D_{60}) = 1$ to 3	
			GP	POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		GRAVELS (WITH SOME FINES)	**GM**	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW ‘A’ LINE I_p LESS THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE ‘A’ LINE I_p MORE THAN 7
	SANDS (MORE THAN HALF COARSE GRAINS SMALLER THAN 4.75mm)	CLEAN SANDS (LITTLE OR NO FINES)	**SW**	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = D_{60}/D_{10} > 6$ $C_c = (D_{30})^2/(D_{10} \times D_{60}) = 1$ to 3	
			SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	NOT MEETING ALL GRADATION REQUIREMENTS FOR SW	
		SANDS (WITH SOME FINES)	**SM**	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW ‘A’ LINE I_p LESS THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE ‘A’ LINE I_p MORE THAN 7
FINE GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75 µm)	**SILTS** (BELOW ‘A’ LINE NEGLIGIBLE ORGANIC CONTENT)	$W_L < 50$ %	**ML**	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)	
		$W_L > 50$ %	**MH**	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS		
	CLAYS (ABOVE ‘A’ LINE NEGLIGIBLE ORGANIC CONTENT)	$W_L < 30$ %	**CL**	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30 \% < W_L < 50 \%$	**CI**	INORGANIC CLAYS OR MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50$ %	**CH**	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS (BELOW ‘A’ LINE)	$W_L < 50$ %	**OL**	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY		
		$W_L > 50$ %	**OH**	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			**Pt**	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE	
BEDROCK			**BR**	SEE REPORT DESCRIPTION		

Soil Components			
Component	**Size Range (mm)**	**Descriptor**	**% by Weight**
Cobbles	> 76	and	> 35
Gravel	76 to 4.75		
Coarse	76 to 19	-y, -ey	35 to 20
Fine	19 to 4.75		
Sand	4.75 to 0.075	some	20 to 10
Coarse	4.75 to 2		
Medium	2 to 0.425	trace	10 to 1
Fine	0.425 to 0.075		
Fines (Silt or Clay)	< 0.075		


Plasticity Chart for Soils Passing 425 µm Sieve

Appendix C

Moisture Density Test Result
Hydraulic Conductivity Test Result
Results of Dry Unit Weight Test on Shelby Tube Samples

Moisture - Density Relationship Report

Project Name: Thunderchild First Nation Site 115B Lagoon
Project No.: PG20-1536

Sample No.: BH20-10
Date Sampled: 29-Aug-20
Sampled By: SolidEarth/ JW

Rammer Type
☒ Auto
☐ Manual

Preparation
☒ Dry
☐ Moist

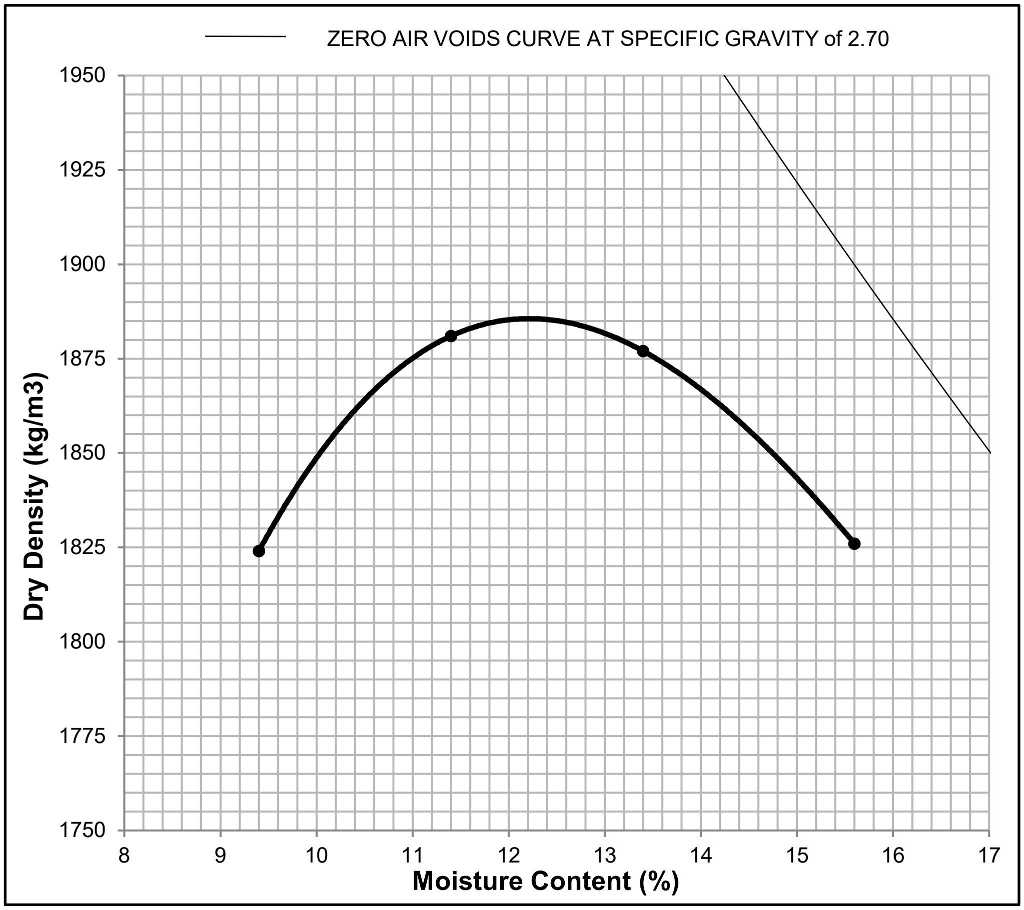
Percent Retained on:
☐ 4.75 mm Sieve
☐ 9.50 mm Sieve
☐ 19.0 mm Sieve

Sample Source: BH20-10 : Composite sample between 1.5 to 3m below existing ground surface

MAXIMUM DRY DENSITY: 1886 kg/m^3

OPTIMUM MOISTURE CONTENT: 12.2 %

Moisture Content (%)	Dry Density (kg/m^3)
9.4	1824
11.4	1881
13.4	1877
15.6	1826



SOIL DESCRIPTION:
CLAY (fill), and sand, silty, trace gravel, low plastic

COMMENTS:

SolidEarth Geotechnical Inc.

Th Feeley

Thomas Feeley, P.Eng

Compaction Standard: ☒ **ASTM D698** ☐ **ASTM D1557** ☐ **ASTM D558** **Method:** A

SolidEarth Geotechnical Inc.
www.solidearth.ca

Moisture - Density Relationship Report

Project Name: Thunderchild First Nation Site 115B Lagoon
Project No.: PG20-1536

Sample No.: BH20-6
Date Sampled: 29-Aug-20
Sampled By: SolidEarth/ JW

Rammer Type
☒ Auto
☐ Manual

Preparation
☒ Dry
☐ Moist

Percent Retained on:
☐ 4.75 mm Sieve
☐ 9.50 mm Sieve
☐ 19.0 mm Sieve

Sample Source: BH20-6 : Composite sample between 0.7 to 2.3m below existing ground surface

MAXIMUM DRY DENSITY: **1946** **kg/m^3**

OPTIMUM MOISTURE CONTENT: **11.3** **%**

Moisture Content (%)	**Dry Density (kg/m^3)**
9.4	1906
11.3	1946
13.3	1916
15.3	1861

SOIL DESCRIPTION:
CLAY (Till), and sand, silty, trace gravel, low plastic, brown

COMMENTS:
Liquid Limit: 24%
Plastic Limit: 10%
Grain Size Distribution
Gravel: 2%
Sand: 47%
Silt: 27%
Clay: 24%

SolidEarth Geotechnical Inc.

Th Feeley

Thomas Feeley, P.Eng

Compaction Standard: ☒ **ASTM D698** ☐ **ASTM D1557** ☐ **ASTM D558** **Method:** A

J.R. Paine & Associates Ltd.

CONSULTING AND TESTING ENGINEERS

EDMONTON - GRANDE PRAIRIE - WHITEHORSE - PEACE RIVER

COEFFICIENT OF PERMEABILITY

CLIENT: Solid Earth

PROJECT: Thunderchild First Nation Site 115B Lagoon
PG20-1536

LOCATION:

JOB NO.: 4695-1

Remarks:

DATE: September 30, 2020

TECH: Collin Robertson

SAMPLE: BH20-6

SAMPLE SOURCE: Composite sample between 0.7 to 2.3m below existing ground surface

Mass of mold (g)	1961.1
Mass of mold & initial sample (g)	2613.3
Mass of mold & final sample (g)	2655.1
Mass of mold & dry sample (g)	2535.7
Calculated dry mass (g)	574.6
'L' length of sample (cm)	3.78
Diameter of sample (cm)	10.16
'A' area of sample (cm^2)	81.1
Calculated dry density (kg/m^3)	1875
Sample compaction (%)	96.4
Hydraulic driving head (psi)	10.0
'h' Hydraulic driving head (cm H_20)	703.0

Moisture Content Determination

Mass of wet initial sample (g)	652.2
Moisture content of initial sample (%)	13.5%
Mass of wet final sample (g)	694.0
Moisture content of final sample (%)	20.8%
Standard Proctor density (kg/m^3)	1946
Optimum moisture (%)	11.3
Specific Gravity of Soil	2.70
Initial Zero Air Voids Density (kg/m^3)	1979

Reading	Date	Burette		Flow Volume 'V'	Duration 't'	Flow Rate 'Q' =V/t
	(MM/DD/YY HH:MM)	reading (cm^3)	refilled to (cm^3)	(cm^3)	(s)	(cm^3/s)
1	10/8/2020 11:47	---	98.0	---	---	---
2	10/8/2020 13:48	-4.0	-4.0	102.0	7260	1.40E-02
3	10/8/2020 21:42	---	100.0	---	---	---
4	10/8/2020 23:36	4.6	4.6	95.4	6840	1.39E-02
5	10/8/2020 23:37	---	99.8	---	---	---
6	10/9/2020 1:35	13.8	13.8	86.0	7080	1.21E-02
7	10/9/2020 1:37	---	100.0	---	---	---
8	10/9/2020 3:42	10.6	10.6	89.4	7500	1.19E-02

'Q' Average Flow Rate (cm^3/s) = 1.30E-02

COEFFICIENT OF PERMEABILITY

$$k\ (cm/s) = \frac{Q\ (cm^3/s)\ \times L\ (cm)}{h\ (cm) \times A\ (cm^2)} = 8.63E\text{-}07\ cm/s$$

'**k**' Coefficient of Permeability = 8.63E-07 cm/s

= 8.63E-09 m/s

J. R. Paine & Associates Ltd.
CONSULTING AND TESTING ENGINEERS

SOIL LABORATORY TEST RESULTS

Client: Solidearth Geotechnical
Project: Thunderchild Lagoon
Project #: PG20-1536
Date: 14-Sep-20

JRP File No.: 4695-1
Attention: Thomas Feeley
Project Manager Email: tfeeley@solidearth.ca

Borehole & Sample Number	Depth (ft)	Pocket Pen. (kPa)	Moisture Content (%)	Dry Density Kgs/M^3	Unconfined Compressive Strength (kPa)	Comments	Sample Description
B01 Sample 2	2.5 - 4	-	11.3	2042	-	-	-
BO6 Sample 2	2.5 - 4	-	11.7	1994	-	-	-
B08B Sample 1	7.5 - 9	-	16.3	-	-	Poor Extraction, Density not Possible	-
B10B Sample 2	7.5 - 9	-	17.9	1791	-	-	-