REPORT

Additional Geotechnical Investigation Proposed Ottawa Police Service South Station - 55 Lodge Road

Ottawa, Ontario

Submitted to:

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Ottawa Police Service to conduct an additional geotechnical investigation in order to provide geotechnical input to the detailed design of the proposed Ottawa Police Service South Campus Facility site that is to be located at 55 Lodge Road in Ottawa, Ontario. A Site Plan is attached as Figure 1. The investigation and reporting were carried out in general accordance with the scope of work provided in our initial proposal dated 8 November 2018, and the subsequent scope changes dated February 1 and February 11, 2019, respectively.

The purpose of this investigation was to assess the general subsurface and groundwater conditions within the study area by means of four boreholes and associated laboratory testing. Based on an interpretation of the factual information obtained during the current investigation, along with the existing subsurface information available for the site from previous investigation, a general description of the soil and groundwater conditions is presented. These interpreted subsurface conditions and available project details were used to prepare engineering guidelines on the geotechnical design aspects of the project, including construction considerations which could influence design decisions.

The reader is referred to the 'Important Information and Limitations of This Report' which follows the text but forms an integral part of this document.

2.0 DESCRIPTION OF PROJECT AND SITE

Plans are currently being prepared for the proposed Ottawa Police Service South Campus Facility to be located at 55 Lodge Road in Ottawa, Ontario (see Site Plan, Figure 1). From the preliminary drawings provided to Golder, it is understood that the new station will be located in the northern part of the site and consist of a three-storey main office building attached to another two-storey building and a two-storey parking structure, with a total footprint of approximately 12,000 square metres. All structures will be of slab on grade construction (i.e., no basement).

The following is known about the site:

- The site is located to the northeast of the intersection of Prince of Wales Drive and Lodge Road.
- The site is approximately triangular in shape and measures about 420 metres by 190 metres in plan.
- The ground surface is gently sloping down to the east, with ground surface elevations ranging from about 89 metres at Prince of Wales Drive to about 83 metres at the Rideau River.
- The site was the former location of the Carleton Lodge Building.
- This site is currently vacant, is grass covered, and contains some tree coverage.

Eighteen existing boreholes from a previous investigation (completed by Golder Associates) have been used to supplement the current investigation. The locations of these previous boreholes are shown on the attached Site Plan (Figure 1). The results of the previous investigation are contained in the following report:

- Golder Report No. 15-37295-1000 titled: "*Preliminary Geotechnical Investigation, Proposed Ottawa Police Service South Campus - 55 Lodge Road, Ottawa, Ontario*", and dated May 2017.

Based on the results of the previous investigation and the published geological mapping for this area, the subsurface conditions at this site generally consist of a layer of topsoil/fill, overlying a thick deposit of sensitive silty clay, extending to about 8 to 15 metres depth. The silty clay deposit is underlain by a thick deposit of glacial till. The depth of the underlying bedrock varies greatly and is indicated to be about 19 to 50 metres below the ground surface and to consist of sandstone and dolostone of the March formation.

3.0 PROCEDURE

The fieldwork for this investigation was carried out between 28 November 2018 and 22 February 2019. During that time, a total of 4 boreholes (numbered 18-01, 18-02, 19-01, and 19-02) were advanced at the approximate locations shown on the attached Site Plan (Figure 1). The boreholes were advanced using a combination of hollow stem augering, casing and wash boring (mud rotary), and rock coring with HQ or NQ sized casing, using a track-mounted drill rig supplied and operated by CCC Geotechnical and Environmental Drilling of Ottawa, Ontario. The boreholes were advanced to depths ranging from between 29 to 37.4 metres below the existing ground surface.

It should be noted that due to the presence of loose sands, drilling mud was used in the casing while advancing through the glacial till deposit to prevent blow back and obtain more reliable SPT ‘N’ values.

Standard penetration tests were carried out within the overburden, i.e., in boreholes 18-01 and 18-02 at regular intervals of depth where possible. Samples of the soils encountered were recovered using 35-millimetre inside diameter split-spoon sampling equipment in general accordance with ASTMD 1586. Borehole 18-02 was extended into the bedrock using rotary diamond drilling technique while retrieving HQ sized core.

No soil sampling and standard penetration testing was carried out in boreholes 19-01 and 19-02 which were advanced to confirm the bedrock depth at these locations. Both boreholes were extended into the bedrock using rotary diamond drilling technique while retrieving NQ sized core.

The fieldwork was supervised by technicians from our staff who located the boreholes, directed the drilling and in-situ testing operations, logged the boreholes and samples, and took custody of the soil and bedrock samples retrieved. On completion of the drilling operations, the soil and bedrock samples were transported to our laboratory for further examination by the project engineer and for laboratory testing, which included natural water content, grain size distribution, and Atterberg limit tests on selected soil samples, and unconfined compressive strength (UCS) testing on selected bedrock core samples.

Two samples of soil from borehole 18-02 were submitted to Eurofins Environment Testing for basic chemical analyses related to potential sulphate attack on buried concrete elements and potential corrosion of buried ferrous elements.

Geophysical testing in the form of Vertical Seismic Profiling (VSP) testing was conducted at this site to support the analysis of the seismic site class.

The borehole locations were selected in consultation with Ottawa Police Service, marked in the field, and subsequently surveyed by Golder Associates personnel. The borehole coordinates and ground surface elevations were measured using a Trimble R8 GPS survey unit. The geodetic reference system used for the survey is the North American datum of 1983 (NAD83). The borehole coordinates are based on the Modified Transverse Mercator (MTM Zone 9) coordinate system. The elevations are referenced to Geodetic datum (CGVD28).

4.0 SUBSURFACE CONDITIONS

4.1 General

Information on the subsurface conditions is presented as follows:

- Record of Borehole and Drillhole Sheets from the current investigation are provided in Appendix A.
- Record of Borehole Sheets from previous investigations are provided in Appendix B.
- Photographs of the bedrock core and the results of the UCS testing are provided in Appendix C.
- Results of the basic chemical analyses are provided in Appendix D.
- Results of the geophysical testing are provided in Appendix E.
- Results of water content testing are provided on the Record of Borehole Sheets.
- Results of the Atterberg limit testing are provided on Figure 2 and also on the Record of Borehole Sheets.
- Results of the grain size distribution testing are provided on Figures 3 and 4.
- Result of oedometer consolidation testing is provided on Figure 5.

The Record of Borehole sheets describe the subsurface conditions at the borehole locations only.
The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling in some cases, observations of drilling progress as well as results of Standard Penetration Tests and, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface soil, bedrock and groundwater conditions will vary between and beyond the borehole locations.

The following sections present a detailed overview of the subsurface conditions encountered in the boreholes advanced during the current investigation. It should be noted that the shallow subsurface conditions noted on the borehole logs from the previous investigations may have changed since the boreholes were drilled, as such only auger refusal/bedrock depths from previous drilling are discussed herein.

4.2 Overview of Subsurface Conditions

In general, the subsurface stratigraphy within the area of the investigation consists of surficial fill materials overlying silty clay which is underlain by glacial till at depths of 7.6 to 13.7 metres. Three boreholes from the current investigation that penetrated through the glacial till encountered bedrock at depths ranging from about 28 to 35.3 metres. Available subsurface information from the previous investigation shows that while bedrock was not proven, auger refusal was encountered at depths ranging from about 19 to 26.4 metres below ground surface.

4.3 Topsoil and Fill

Topsoil exists at the ground surface at the location of the current boreholes 18-01 and 18-02. At these borehole locations, the topsoil thickness ranges from about 100 to 130 millimetres.

A layer of fill exists below the topsoil at both the borehole locations. The fill extends down to depths ranging from about 0.8 to 2.1 metres below the existing ground surface. The fill generally consists of silty clay with varying amounts of sand, gravel, cobbles, and rootlets.

SPT “N” values measured within the fill ranged from 4 to 9 blows per 0.3 m of penetration. The SPT “N” values suggest that the fill is of a firm to very stiff consistency.

4.4 Silty Clay to Clay

At the locations of the current boreholes 18-01 and 18-02, and all of the previous boreholes, the fill is underlain by a deposit of sensitive marine silty clay from the previous Champlain Sea that covers much of the Ottawa area.

The upper portion of the silty clay has been weathered to a grey brown crust. At the current borehole locations, the weathered zone extends to depths of approximately 5.2 and 6.1 metres (elevations of 79.7 and 82.5 metres) below the existing ground surface. Standard Penetration Test ‘N’ values ranging from 1 to 7 blows per 0.3 metres of penetration were obtained within the weathered crust portion of the silty clay deposit. The results of in-situ vane testing in the deposit measured undrained shear strength values greater than 96 kilopascals. The results of the in-situ testing indicate a very stiff consistency.

The silty clay below the depth of weathering is grey in colour. The unweathered silty clay deposit extends to depths ranging from about 7.6 to 13.7 metres (elevations of 71 to 81 metres) below the existing ground surface. Standard Penetration Test ‘N’ values ranging from “Weight of Hammer” to 1 blow per 0.3 metres of penetration were obtained within the grey silty clay. The results of in-situ vane shear tests completed within the grey silty clay measured undrained shear strength values ranging from about 38 to 88 kilopascals corresponding to a firm to stiff consistency. The results of moisture content testing on four samples of the weathered crust showed values ranging from about 35 to 46 percent.

The results of Atterberg limit testing on three samples of the grey silty clay gave plasticity index values ranging from about 8 to 22 percent and liquid limit values ranging from about 29 to 46 percent, thereby indicating a clay of low to high plasticity (i.e., reflecting the variable presence of silt seams). These results are presented on a plasticity chart on Figure 2. The results of moisture content testing on six samples of the grey silty clay showed values ranging from about 34 to 67 percent (i.e., reflecting the variable presence of silt seams).

One (1) oedometer test was conducted on the silty clay. The results of the consolidation testing are summarized below and shown on Figure 5.

Borehole/ Sample Number	Sample Depth/Elevation (m)	C_C	C_r	e_o	σ_V' (kPa)	σ_P' (kPa)	OCR
18-02 / 8	7.3/ 77.6	1.55	0.01	1.699	80.2	194	2.41

C_c - Compression index
e_o - Initial void ratio
σ_V' Existing effective overburden pressure

σ_P' - Apparent preconsolidation pressure
C_r - Recompression index
OCR - Overconsolidation Ratio

4.5 Glacial Till

At all of the previous borehole locations and at the location of the current boreholes 18-01 and 18-02, there exists a thick deposit of glacial till beneath the silty clay. The glacial till typically consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sandy silt to silty sand with trace to some clay. This deposit was fully penetrated only in borehole 18-02, where it extends to a depth of about 25.9 metres below the existing ground surface. Where not fully penetrated, i.e., in borehole 18-01, and all of the previous boreholes, the glacial till was proven to depths ranging from about 5.9 to 29 metres below the existing ground surface.

In the current investigation, the SPT "N" values within the glacial till layer ranged from "Weight of Hammer" to about 57 blows, but generally between 6 to 29 blows per 0.3 metres of penetration, indicating a loose to compact state of packing. The higher blow count could be indicative of boulders and cobbles in the till rather than the state of packing. Observations during drilling indicate that the presence of boulders and cobbles can be substantial, with many of them being of the Precambrian origin (e.g. granite).

The results of natural moisture content testing gave values ranging from about 10 to 19 percent, but generally varied between 10 to 13 percent. The results of grain size distribution testing are presented on Figure 3.

4.6 Clayey Silt

A thin deposit of clayey silt was encountered below the glacial till at the location of borehole 18-02. The layer is 0.6 metre in thickness and extends down to a depth of 26.5 metres below the ground surface. The result of natural moisture content testing in this deposit gave a value of about 22 percent. The result of grain size distribution testing is presented on Figure 4.

4.7 Gravel

A deposit of gravel was encountered below the clayey silt at the location of borehole 18-02. The layer is 1.5 metre in thickness and extends down to a depth of about 28 metres below the ground surface.

4.8 Auger Refusal and Bedrock

Practical refusal to augering was encountered in previous boreholes 16-01, 16-03, and 16-06 at depths ranging from about 19.0 to 26.4 metres below the existing ground surface (i.e., elevations ranging from 58.4 to 68.7 metres). Auger refusal could indicate boulders within the glacial till or the bedrock surface.

Boreholes 18-02, 19-01, and 19-02 from the current investigation were extended into the underlying bedrock using rotary diamond drilling techniques. These boreholes were extended to about 2.1 to 5.2 metres into the bedrock. The recovered bedrock cores from these locations consist of fresh, thinly to medium bedded, light to medium grey, sandy dolostone or dolostone bedrock. The following table summarizes the auger refusal and bedrock depths and elevations encountered at the site.

Borehole Number	Ground Surface Elevation (metres)	Elevation of Bedrock or Auger Refusal (metres)	Depth of Bedrock or Auger Refusal (metres)
16-01	88.54	65.71[1]	22.83 [1]
16-03	84.80	58.44 [1]	26.36 [1]
16-06	87.67	68.65 [1]	19.02 [1]
18-02	84.90	56.88	28.02
19-01	87.09	51.84	35.25
19-02	85.48	53.32	32.16

Notes:
[1] Auger Refusal

The Total Core Recovery (TCR) of the cored bedrock ranged from 94 to 100 percent and the Rock Quality Designation (RQD) ranged from about 78 to 100 percent, indicating a fair to good quality rock.

The results of laboratory testing carried out on two samples of the cored bedrock from borehole 18-02 showed Uniaxial Compressive Strengths (UCS) of about 191 and 232 MPa, thereby indicating that the sample of the rock tested is very strong. Results of the UCS test are presented in Appendix C.

4.9 Groundwater

During the previous investigation, standpipe piezometers were sealed into boreholes 16-04, 16-07, 16-10, 16-12, and 16-15 to allow for subsequent measurement of the groundwater level at the site. The groundwater levels in these standpipe piezometers were measured on 2 February 2017 (previous investigation) and on 19 December 2018 (current investigation). The following table summarizes the measured groundwater levels.

Borehole Number	Ground Surface Elevation (metres)	Strata	Groundwater Level Depth on 02/02/2017 (metres)	Groundwater Level Elevation on 02/02/2017 (metres)	Groundwater Level Depth on 19/12/2018 (metres)	Groundwater Level Elevation on 19/12/2018 (metres)
16-04	83.65	Silty Clay	1.14	82.51	1.05	82.60
16-07	84.57	Silty Clay	1.27	83.30	0.28	84.29
16-10	86.31	Glacial Till	2.78	83.53	0.73	85.58
16-12	87.91	Silty Clay / Glacial Till	0.71	87.20	0.74	87.17
16-15	86.75	Silty Clay	3.22	83.53	-	-

It should be noted that groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year, such as spring and fall.

4.10 Corrosion Testing

Two samples of soil from borehole 18-02 were submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of this testing are provided in Appendix D and are summarized below.

Borehole / Sample Number	Sample Type	Sample Depth (m)	Chloride (%)	Sulphate (%)	pH	Resistivity (Ohm-cm)
18-02 SA10	Soil	10.7 – 11.3	0.002	0.04	7.93	1770
18-02 SA15	Soil	16 – 16.6	0.002	0.03	8.21	1760

5.0 DESIGN AND CONSTRUCTION CONSIDERATIONS

5.1 General

This section of the report provides geotechnical engineering guidelines on the geotechnical design aspects of the proposed Ottawa Police Service building(s) within the project limits based on our interpretation of the borehole information and project requirements. The following guidelines are based on preliminary design information. This draft report will need to be updated once the final design drawings for the current project are available.

The following guidelines are provided on the basis that the buildings will be designed in accordance with Part 4 of the 2012 Ontario Building Code (OBC).

The reader is referred to the "Important Information and Limitations of This Report" which follows the text of this report but forms an integral part of this document.

5.2 Site Grading

The subsurface conditions on this site consist of up to about 2.3 metres of surficial fill overlying a thick deposit of sensitive silty clay and glacial till.

The compressibility of the silty clay deposit negatively impacts the permissible filling of this site. The silty clay deposit has limited capacity to support the combined loading from grade raise filling, foundation loads, groundwater level lowering, floor loads, etc. Overstressing of the silty clay will lead to excessive foundation settlements for shallow foundations. For the purposes of this assessment, it has been assumed that the proposed grading will be no more than 1.0 metres above the existing ground surface. This grade raise must not be exceeded for the bearing resistance values given in Section 5.4 to be applicable.

The topsoil and fill containing organic matter are not suitable as engineered fill and should be removed from the site or stockpiled separately for re-use in landscaping applications only. It is important that stockpiles, if located on site, should not be adjacent to excavations but rather should be located within the future landscaping areas.

5.3 Excavations

It is understood that all structures will be of slab on grade construction (i.e., no basement). The excavations for shallow foundations will either be within the engineered fill or through the engineered fill and into the very stiff to stiff weathered silty clay crust. Excavations for site services may extend into the glacial till in the area around previous boreholes 16-09 and 16-12, where the till is encountered at elevations of 85.0 and 82.6 metres, respectively.

No unusual problems are anticipated with excavating the overburden using conventional hydraulic excavating equipment recognizing that cobbles and boulders will likely be encountered within the surficial fill and glacial till. If the excavations are carried out in the sensitive silty clay, it is suggested that the excavation equipment be fitted with a smooth bladed bucket (i.e., no teeth), to limit disturbance of the subgrade.

The existing fill, silty clay, and glacial till would generally be classified as Type 3 soils in accordance with the Occupational Health and Safety Act (OHSA) and therefore open cut side slopes would need to be cut back at an inclination no steeper than 1 horizontal to 1 vertical (1H:1V). Boulders larger than 0.3 metres in diameter should be removed from the excavation side slopes for worker safety.

Alternatively, the excavations for site servicing could be carried out using steeper side slopes with all manual labour carried out within a fully braced steel trench box for worker safety.

Based on present groundwater levels, excavations deeper than about 1 to 2 metres will extend below the groundwater level. Groundwater inflow into the excavations should feasibly be handled by pumping from sumps within the excavations. Groundwater inflow from the weathered silty clay crust is expected to be low to moderate; however, the actual rate of groundwater inflow will depend on many factors including the contractor's schedule and rate of excavation, the size of the excavation, the number of working areas being excavated at one time, and the time of year at which the excavation is made. Also, there may be instances where significant volumes of precipitation, surface runoff and/or groundwater collects in an open excavation and must be pumped out.

Under the new regulations, a Permit-To-Take-Water (PTTW) is required from the Ministry of the Environment and Climate Change (MOECC) if a volume of water greater than 400,000 litres per day is pumped from the excavation. If the volume of water to be pumped will be less than 400,000 litres per day, but more than 50,000 litres per day, the water taking will not require a PTTW, but will need to be registered in the Environmental Activity and Sector Registry (EASR) as a prescribed activity. Based on the groundwater information collected during the investigation, it is considered unlikely that a PTTW would be required during construction for this project. However, the requirement for registration in the EASR is possible if inflows are greater than expected. The requirement for registration (i.e., if more than 50,000 litres per day is being pumped) can be assessed at the time of construction. Registration is a quick process that will not significantly disrupt the construction schedule. This should be reviewed once the design information on the depths/ elevations of site services is known.

5.4 Foundations

5.4.1 Overview

As discussed in Section 5.2, the silty clay deposit has limited capacity to accept the combined load from site grading fill and foundation loads. For these subsurface conditions, the Serviceability Limit States (SLS) bearing resistances for the design of foundations is based on limiting the stress increases on the soft to firm, compressible, grey silty clay at depth to an acceptable level so that foundation settlements do not become excessive. The potential stress increase on the compressible unweathered silty clay is primarily affected by:

- The applied pressures on the foundations and the size (i.e., dimensions) of the footings;
- The thickness of the weathered crust below the underside of the foundations and above the compressible silty clay, through which the foundation loads are distributed;
- The amount of net surcharge in the vicinity of the foundations due to landscape fill, underslab fill, floor loads, etc.; and,
- The effects of groundwater lowering caused by this or other construction.

It is understood that the overall site development will include the construction of buildings subjected to various loading conditions, as such we have outlined recommendations for shallow foundations and pile foundations which offer different cost-benefit options for these structures.

5.4.2 Shallow Foundations

It is considered that the proposed building(s) might be supported on conventional spread footings founded on or within the undisturbed weathered silty clay crust. The existing fill material, which is up to 2.3 metres thick at parts of the site, is not considered suitable to support the building loads and should therefore be removed from within the building’s footprint(s).

The foundation design parameter values (SLS and ULS resistances) for spread footing foundations at this site are based on limiting the stress increases on the unweathered grey silty clay at depth to an acceptable level so that foundation settlements do not become excessive. Four important parameters in calculating the stress increase on the grey silty clay under the weathered crust are:

- The thickness of the weathered crust below the underside of the footings;
- The size (dimensions) of the footings;
- The amount of surcharge in the vicinity of the foundation due to landscape fill, underslab fill, floor loads, etc., and,
- The effects of groundwater lowering caused by this or other construction.

As mentioned previously, the ground surface at the site gently slopes down to the east, with ground surface elevations ranging from about 89 metres at Prince of Wales Drive (west) to about 83 metres at the Rideau River (east). Also, the previous and current borehole logs within the footprint of the proposed development indicate that the thickness of the grey silty clay deposit increases to the east.

From the preliminary drawings provided to Golder, it is understood that the finished floor slab level of the building(s) will be up to 0.5 metre above the existing ground surface (i.e., a grade raise of no more than 0.5 metres above the existing grade) in the eastern portion of the development while the floor slab level will be at least 2 metres below the existing ground surface (i.e., a grade cut of at least 2 metres below the existing grade) in the western portion of the development. The approximate dividing line of these portions is about the existing contour elevation of 85.5 metres (or north-south at about the location of borehole 16-103).

As such, the SLS net bearing resistance and the factored ULS bearing resistance values for spread footing foundations have been provided for both the cases noted above, i.e., the proposed grade raise and the grade cut.

It is assumed that the floor loading for the buildings will not exceed 4.8 kilopascals.

Footing Type	Grade Restrictions	Minimum Founding Elevation	Footing Width or Size (metres)	Net Bearing Resistance at SLS (kPa)	Factored Bearing Resistance at ULS (kPa)
Interior Pad	Maximum grade raise = 0.5 metres above the existing ground surface	1.0 metres below existing ground surface	≤2.0	240	250
			2.0 – 3.0	230	250
			3.0 – 4.0	225	250
			4.0 – 5.0	200	250
Exterior Strip		1.6 metres below existing ground surface	≤1.0	190	205
			1.0 – 1.5	175	205
			1.5 – 2.0	160	205
			2.0 – 2.5	130	205
			2.5 – 3.0	110	205
Interior Strip		1.0 metres below existing ground surface	≤1.0	190	205
			1.0 – 1.5	175	205
			1.5 – 2.0	160	205
			2.0 – 2.5	140	205
			2.5 – 3.0	120	205
Interior Pad	Minimum grade cut = 2 metres below the existing ground surface	1.0 metres below existing ground surface	≤2.0	240	250
			2.0 – 3.0	225	250
			3.0 – 4.0	200	250
			4.0 – 5.0	150	250
Exterior Strip		1.6 metres below existing ground surface	≤1.0	190	205
			1.0 – 1.5	180	205
			1.5 – 2.0	170	205
			2.0 – 2.5	160	205
			2.5 – 3.0	150	205
Interior Strip		1.0 metres below existing ground surface	≤1.0	190	205
			1.0 – 1.5	180	205
			1.5 – 2.0	170	205
			2.0 – 2.5	160	205
			2.5 – 3.0	150	205

For larger footings, footings placed at greater depth, increases in floor loading, or increases in exterior grade levels, the above design parameters will change, and new values must be calculated taking any such changes into account. The bearing values should be reviewed once foundation bearing elevations are known.

The post construction total and differential settlements of footings sized using the above SLS net bearing resistance values should be less than about 25 and 15 millimetres, respectively, provided that the soil at or below founding level is not disturbed during construction. Further, these maximum allowable bearing pressures correspond to a settlement resulting from consolidation of the silty clay. Consolidation of the silty clay is a process which takes months or longer and, as such, results from sustained loading. Therefore, the foundation loads to be used in conjunction with the SLS resistance values given above should be the full dead load plus sustained live load. The factored dead plus full factored live load should be used in conjunction with the ULS factored bearing resistance.

As discussed above, the existing fill material is not considered suitable to support the building loads and should therefore be removed from within the building's footprint. Where the resulting excavation leaves the native subgrade level below the proposed underside of footing level, the grade should be raised, within the zone of influence of the footing, with OPSS Granular B Type II placed in maximum 300 millimetre lifts and compacted to at least 95 percent of the material's standard Proctor maximum dry density using suitable vibratory compaction equipment. The zone of influence is considered to extend out and down from the edge of the footings at a slope of 1 horizontal to 1 vertical. The same foundation design parameters given above can be used for foundations placed on a properly constructed engineered fill pad.

5.4.3 Pile Foundations

Should the bearing values presented in Section 5.4.2 prove to be insufficient to support the structures, it is considered that more heavily loaded structures may need to be supported on piles driven to refusal on the bedrock. A piled foundation would transfer the foundation loads through the silty clay and the loose to compact glacial till deposit, and down to the bedrock surface which was proven to be at elevations ranging from about 56.9 to 51.8 metres.

A suitable pile type would be H-piles, with the piles end-bearing on bedrock. The material presence of boulders and cobbles observed from the progression of drilling through the till and pieces of broken Precambrian rock retrieved, may present challenges to the driving of piles through the till. Pre-drilling of the pile locations, use of heavier than normal pile sections to reduce damage and use of rock tips are recommended to increase the success of advancing the piles trough the till.

A granular working mat should be provided for pile driving equipment to protect the subgrade. The granular pad should be about 500 millimetres thick.

5.4.3.1 Axial Capacity

The ULS unfactored geotechnical resistance of a HP 310 x 110 pile driven to bedrock may be taken as 3,250 kilonewtons. The ULS unfactored geotechnical resistance of a HP 310 x 152 pile driven to bedrock may be taken as 4,000 kilonewtons. In accordance with the 2012 OBC the ULS values given above should be factored using a resistance factor of 0.4.

The ULS factored geotechnical resistance of the pile should equal or exceed the structural resistance if the piles are driven to the bedrock and are installed using an appropriate set criterion and using a hammer of sufficient energy.

For piles end-bearing on or within the bedrock, Serviceability Limit States (SLS) conditions generally do not govern the design since the stresses required to induce 25 millimetres of movement (i.e., the typical SLS criteria) exceed those at ULS. Accordingly, the post-construction settlement of structural elements which derive their support from piles bearing on bedrock should be negligible.

Due to their smaller cross section, H-piles would have more success in penetrating the glacial till and reaching the bedrock surface than pipe piles.

To avoid reductions in vertical capacity the piles should be driven no closer than 2.5 diameters centre to centre.

The pile termination or set criteria will be dependent on the pile driving hammer type, helmet, selected pile, and length of pile; the criteria must therefore be established at the time of construction and after the piling equipment is known. All of these factors must be taken into consideration in establishing the driving criteria to ensure that the piles will have adequate capacity but are also not overdriven and damaged. In this regard, it is a generally accepted practice to reduce the hammer energy after abrupt peaking is met on the bedrock surface, and then to gradually increase the energy over a series of blows to seat the pile. The piles should be reinforced at the tip with standard bearing points to improve seating of the piles on the bedrock and to reduce the potential for damage to the piles during driving through soils that contain boulders. However, it should be expected that some of the piles, will be out of allowable tolerance or will be damaged during driving.

Relaxation of the piles following the initial set could result from several processes, including:

- The dissipation of negative excess pore water pressures in the overburden material above the bedrock surface; and,
- The driving of adjacent piles.

Provision should therefore be made for restriking all of the piles at least once to confirm the design set and/or the permanence of the set and to check for upward displacement due to driving adjacent piles. Piles that do not meet the design set criteria on the first restrike should receive additional restriking until the design set is met. All restriking should be performed after 48 hours of the previous set.

It is recommended that dynamic monitoring and capacity testing (known as PDA testing) be carried out (by the contractor) at an early stage in the piling operation to verify both the transferred energy from the pile driving equipment and the load carrying capacity of the piles, particularly given the challenging pile driving conditions. As a preliminary guideline, the specification should require that at least 10 percent of the piles be included in the dynamic testing program. CASE method estimates of the capacities should be provided for all piles tested. These estimates should be provided by means of a field report on the day of testing. As well, CAPWAP analyses should be carried out for at least one third of the piles tested, with the results provided no later than one week following testing. The final report should be stamped by a professional engineer licensed in the province of Ontario.

The purpose of the PDA testing will be to confirm that the contractor’s proposed set criteria is appropriate and that the required pile geotechnical capacity is being achieved. It will therefore be necessary for the pile to have sufficient structural capacity to survive that testing, which could require a stronger pile section than would otherwise be required by the design loading.

The foundation and piling specifications should be reviewed by Golder prior to tender and the contractor’s submission (i.e., shop drawings, equipment, procedures, and set criteria) should be reviewed by the geotechnical consultant prior to the start of piling. That submission should include a WEAP (Wave Equation Analysis of Piles) analysis of the driveability of the pile, to the design depth, using the contractor’s selected hammer.

Vibration monitoring should be carried out during pile installation to ensure that the vibration levels at nearby existing structures, if present, are maintained below tolerable levels. A maximum peak particle velocity of 50 millimetres per second is recommended for structures.

Piling operations should be inspected on a full-time basis by geotechnical personnel of Golder Associates to monitor the pile locations and plumbness, initial sets, penetrations on restrike, and to check the integrity of the piles following installation.

5.4.3.2 Lateral Capacity

It is understood that lateral loading will be resisted fully or partially by steel H Piles. Additional resistance to lateral loading may be derived from the soil in front of the piles.

For preliminary design of the structure, the SLS geotechnical response of the soil in front of the piles under lateral loading may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction, k_h, is based on the equation given below, as described by Terzaghi (1955) and the Canadian Foundation Engineering Manual (3rd Edition). It may be assumed that this resistance will be nearly the same for vertical and inclined piles.

For cohesionless soils:

$$k_h = \frac{n_h z}{B}$$

Where: n_h = the constant of horizontal subgrade reaction, as given below;

z = the depth (m); and,

B = the pile diameter/width (m).

For cohesive soils:

$$k_h = \frac{67\, s_u}{B}$$

Where: s_u = the undrained shear strength of the soil (kPa); and,

B = the pile diameter/width (m).

The following values of s_u and n_h may be used in the preliminary structural analysis. The ranges in values reflect the variability in the subsurface conditions, the soil properties, the approximate nature of the analysis, and the non-linear nature of the soil behaviour (such that k_h is a function of deflection).

Range of Elevations to Bottom of Soil Layer (m)	Soil Type	n_h (MN/m^3)	s_u (kPa)
79.7 - PCL[1]	Very stiff silty clay to clay (Weathered Crust)	-	96
77 – 79.7	Firm silty clay	-	40
71.2 – 77	Stiff silty clay	-	50
51.8 – 71.2	Very loose to very dense Till	4.4	-

Notes:

[1] PCL = Pile Cap Level, understood to be at about Elevation 84 metres.

The unfactored ULS static geotechnical resistance to lateral loading for a single vertical pile was estimated using the Broms (1964) approach and can be taken as 210 kilonewtons for a HP 310 x 110 pile or a HP 310 x 152 pile driven to refusal on bedrock.

The ULS resistance given above are unfactored values. In accordance with the CFEM a resistance factor of 0.5 should be applied in calculating horizontal resistance. The ULS lateral resistance of a pile group may be estimated as the sum of the individual resistances across the face of the pile group, perpendicular to the direction of the applied lateral force, adjusted for group action as indicated below.

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of lateral subgrade reaction or ULS resistance in the direction of loading by a reduction factor as follows:

Reduction Factors for Pile Group Action under Lateral Loading

Pile Spacing in Direction of Loading (d = Pile Diameter)	Reduction Factor
8d	1.0
6d	0.70
4d	0.40
3d	0.25

5.5 Seismic Design

Vertical Seismic Profiling (VSP) geophysical testing was carried out at the site (in borehole 18-01) to evaluate the average shear wave velocity of the upper 30 metres of soil/bedrock at the site. The shear wave velocities measured at the site are presented in a technical memorandum (see results in Appendix E) and indicate that the average shear wave velocity in the upper 30 metres of the subsurface stratigraphy at the VSP location was about 406 metres per second.

The seismic design provisions of the 2012 Ontario Building Code depend, in part, on the shear wave velocity of the upper 30 metres of soil and/or rock below founding level. Using that methodology, a Site Classification C can be used for design of the proposed building(s).

However, the 2012 Ontario Building code also specifies circumstances for which a Site Class of F is applicable and a site-specific- response evaluation must be carried out; the presence of liquefiable soils is one of those conditions. As presented below, this site is underlain by a loose to compact glacial till deposit which is considered to have a small potential to liquefy under the design earthquake event. This is not considered to have a material impact on the dynamic response of the site, and as such a Site Class C designation is considered appropriate for design.

5.6 Liquefaction Assessment

Liquefaction is a phenomenon whereby seismically-induced shaking generates shear stresses within the soil under undrained conditions. These stresses tend to densify the soil (i.e., leading to potentially large surface settlements) and under undrained conditions generate excess pore pressures. The excess pore pressures also lead to sudden temporary losses in strength. Where existing static shear stresses are present, the loss of strength can lead to significant lateral movements (i.e., analogous to a slope failure) often referred to as “lateral spreading” or under certain conditions even catastrophic failure of the slope often referred to as “flow slides”. Lateral spreading and flow slides often accompany liquefaction along rivers and other shorelines.

The liquefaction susceptibility of granular soils was evaluated by comparing the penetration resistance required to trigger liquefaction with the available penetration resistance. Liquefaction is predicted to occur when the available penetration resistance is less than the resistance required.

The methodology used to assess liquefaction potential at the site involves comparing the cyclic shear stresses applied to the soil by the design earthquake, represented as the cyclic stress ratio (CSR), to the cyclic shear strength, represented as the cyclic resistance ratio (CRR) provided by the soil.

The liquefaction analysis was carried out using the in-situ SPT and groundwater data collected at the borehole locations. The CRR with depth was calculated at each borehole location using the parameter, $(N1)_{60cs}$, that is based on the SPT N blow counts obtained in the field and corrected for overburden stress, rod length during sampling, hammer energy efficiencies, and fines content.

The methodology used to assess liquefaction potential at the site is consistent with the “simplified” approach outlined in the CHBDC and by Idriss and Boulanger (2008). It involves comparing the cyclic shear stresses applied to the soil by the design earthquake, represented as the cyclic stress ratio (CSR), to the cyclic shear strength, represented as the cyclic resistance ratio (CRR) provided by the soil. The results of the liquefaction assessment using the simplified method indicate that certain horizons of the loose to compact glacial tills at the site may be considered liquefiable during the 2,475-year design earthquake.

The liquefaction methodologies outlined in Idriss and Boulanger (2008) do not account for the additional cyclic resistance provided by the aging/cementation that may be a characteristic of the glacial tills at the site. Although aging of deposits is known to help resist seismic liquefaction, little research has been done in this area to quantify this. Based on Figure 9 presented in the work by Leon et al. (2006) a correction increment of about 30% in the CRR profile would appear appropriate. Such aging/cementation corrections would reduce the risk of liquefaction at this site given the age of the till sheets present at the site of about 10,00 to 15,000 years (Gill, 1972).

Work done by Harpin et al (2017) on the site response of sites in eastern Canada and the site-response analyses conducted by Golder Associates at various sites across eastern Ontario would suggest that a site-specific response analysis would also reduce the CSR profile, when compared to the simplified methodology outlined in Idriss and Boulanger (2008), such that an approximately 20% CSR reduction could be expected.

In consideration of the beneficial effects of aging and the anticipated lower cyclic stresses in eastern Canada, higher CRR and lower CSR respectively and the well-graded nature of the tills, the extent and probability of liquefaction at the site is considered to be very small to the point of having little impact on the dynamic response of the site (i.e., Site Class) and the performance of foundation elements.

5.7 Design of Rock Anchors

If required, rock anchors could be installed to resist uplift loads on the foundations. The anchors could consist of either grouted or mechanical anchors installed into the bedrock at depth.

The design of the rock anchors is often the responsibility of the contractor and supplier, since there are several proprietary products/systems. However, the rock anchors would likely be installed in a borehole that is drilled with air-percussion equipment or with rotary diamond drilling equipment with water circulation. These drilling methods can fairly penetrate through the rock that exists on this site. A socket would be drilled into the bedrock, the steel anchor inserted, and then the annular space around the bar filled with grout.

Because the rock anchors would be permanent elements of the foundations, a 'double corrosion protection' system should be used. The rock anchors should be designed, installed and tested in accordance with OPSS 942 (Prestressed Soil and Rock Anchors).

In designing grouted rock anchors, consideration should be given to four possible anchor failure modes.

i) failure of the steel tendon or top anchorage

ii) failure of the grout/tendon bond

iii) failure of the rock/grout bond

iv) failure within the rock mass, or rock cone pull-out

Potential failure modes i) and ii) are structural and are best addressed by the structural engineer.

Adequate corrosion protection of the steel components should be provided to prevent potential premature failure due to steel corrosion.

For potential failure mode iii), the factored bond stress at the concrete/rock interface may be taken as 1,000 kilopascals for ULS design purposes. If the response of the anchor under SLS conditions needs to be evaluated, for a preliminary assessment it may conservatively be taken as the elastic elongation of the unbonded portion of the anchor under the design loading.

For potential failure mode iv), the resistance should be calculated based on the buoyant weight of the potential mass of rock which could be mobilized by the anchor. This is typically considered as the mass of rock included within a cone (or wedge for a line of closely spaced anchors) having an apex at the tip of the anchor and having an apex angle of 60 degrees. For each individual anchor, the ULS factored geotechnical resistance can be calculated based on the following equation:

$$Q_r = \phi \frac{\pi}{3} \gamma' D^3 \tan^2(\theta)$$

where:

Q_r = factored uplift resistance of the anchor, kilonewtons

ϕ = resistance factor, 0.3

γ' = effective unit weight of rock, use 17 kilonewtons per cubic metre

D = anchor length in metres

θ = ½ of the apex angle of the rock failure cone, use 30 degrees

The value obtained can be increased in consideration to the overlying soil overburden. Where the anchor load is applied at an angle to the vertical, the anchor capacity should be reduced as follows:

$$Q_r' = Q_r \cos(\alpha)$$

Where: Q_r' = factored uplift resistance of the anchor subject to inclined load in kilonewtons;

Q_r = factored uplift resistance of the anchor, kilonewtons; and,

α = angle between the load direction and the vertical.

For a group of anchors or for a line of closely spaced anchors, the resistance must consider the potential overlap between the rock masses mobilized by individual anchors. In the case of group effects for a series of rock anchors in a rectangle with width “a” and length “b” installed to a depth “D”, the equation for the volume of the truncated trapezoid failure zone would be as follows:

$$V = \frac{4}{3} D^3 sin^2\varphi + \ aD^2 \sin\varphi + bD^2 \sin\varphi + abD$$

Where: V = volume of the truncated trapezoid failure zone in cubic metres;

D = depth of anchor group in metres;

a = width of anchor group in metres;

b = length of the anchor group in metres; and,

φ = ½ of the apex angle of the rock failure cone, use 30 degrees.

The ULS factored geotechnical resistance for the truncated trapezoid failure formed by the group of anchors can then be calculated based on the following equation:

$$Q_r = \phi \ \ \gamma' V$$

Where: Q_r = factored uplift resistance of the anchor, kilonewtons;

ϕ = resistance factor, use 0.3;

γ' = effective unit weight of rock, use 17 kilonewtons per cubic metre; and,

V = volume of truncated trapezoid in cubic metres.

The method described above does not explicitly consider the tensile strength of the rock that must be overcome prior to mobilization of the weight of the rock mass. If required, the tensile strength of the rock mass can be assessed based on the unconfined compressive strength, recovery, and quality of bedrock core obtained.

It is suggested that proof-load tests be carried out on the anchors in accordance with OPSS 942 *(Prestressed Soil and Rock Anchors)*.

A geotechnical professional should be present during the installation and testing of the anchors. Care must be taken during grouting to ensure that the grouting pressure is sufficient to bond the entire length of the grout area with a minimum of voids. Confirmation of sufficient embedment into the rock beneath the foundations should be carried out to make sure that the anchors are being installed in rock of adequate quality. The anchor holes must be thoroughly flushed with water to remove all debris and rock flour. It is essential that rock flour be completely removed from the holes to be grouted to promote an adequate bond between the grout and the rock. Prestressing of the anchors prior to loading will minimize anchor movement due to service loads.

5.8 Slab on Grade

Conventional slab on grade construction can be used for structures on this site.

For predictable performance of the floor slabs, the existing topsoil and fill material should be removed from within the proposed building area. Provision should be made for at least 150 millimetres of Ontario Provincial Standard Specification (OPSS) Granular A to form the base for the floor slab. Any bulk fill required to raise the grade to the underside of the Granular A should consist of OPSS Granular B Type II. The underslab fill should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 95 percent of the material’s standard Proctor maximum dry density using suitable vibratory compaction equipment.

5.9 Frost Protection

The soils at this site are considered to be frost susceptible. Therefore, all exterior foundation elements should be provided with a minimum of 1.5 metres of earth cover for frost protection purposes. Isolated, unheated footings adjacent to surfaces which are cleared of snow cover during winter months should be provided with a minimum of 1.8 metres of earth cover.

Consideration could be given to insulating the bearing surface with high density insulation as an alternative to earth cover. Further geotechnical input can be provided in this regard, if required.

5.10 Foundation Wall Backfill – No Basement

The soils at this site are frost susceptible and should not be used as backfill against exterior or unheated foundation elements. To avoid problems with frost adhesion and heaving, these foundation elements should be backfilled with non-frost susceptible sand or sand and gravel conforming to the requirements of OPSS Granular B Type I.

To avoid ground settlements around the foundations, which could affect site grading and drainage, all of the backfill materials should be placed in maximum 300 millimetre thick lifts, compacted to at least 95 percent of the material’s standard Proctor maximum dry density.

In areas where pavement or other hard surfacing will abut the proposed buildings, differential frost heaving could occur between the granular fill and the adjacent areas. To reduce this differential heaving, the backfill adjacent to the wall should be placed to form a frost taper. The frost taper should be brought up to pavement subgrade level from 1.5 metres below finished exterior grade at a slope of 3 horizontal to 1 vertical, or flatter, away from the wall. The granular fill should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 95 percent of the material’s standard Proctor maximum dry density using suitable vibratory compaction equipment.

The pavement or hard surfacing could be expected to perform better in the long term if the granular backfill against the foundation walls is drained by means of a perforated pipe subdrain in a surround of 19 millimetre clear stone, fully wrapped in a geotextile, which leads by gravity drainage to a positive outlet.

5.11 Site Servicing

At least 150 millimetres of OPSS Granular A should be used as pipe bedding for sewer and water pipes. Where unavoidable disturbance to the subgrade surface occurs, or if fill material is located below the invert of the pipe, it will be necessary to remove the disturbed material or fill, and place a sub-bedding layer consisting of compacted OPSS Granular B Type II beneath the Granular A. The bedding material should in all cases extend to the spring line of the pipe and should be compacted to at least 95 percent of the material's standard Proctor maximum dry density. The use of clear crushed stone as a bedding layer should not be permitted anywhere on this project since fine particles from the sandy backfill materials or surrounding soil could potentially migrate into the voids in the clear crushed stone and cause loss of lateral pipe support.

Cover material, from spring line of the pipe to at least 300 millimetres above the top of pipe, should consist of OPSS Granular A or Granular B Type I with a maximum particle size of 25 millimetres. The cover material should be compacted to at least 95 percent of the standard Proctor maximum dry density.

It should generally be possible to re-use the weathered silty clay above the groundwater level as trench backfill. The grey silty clay below the water table may be too wet to compact. Where that is the case, the wet materials should be wasted (and drier materials imported) or these materials should be placed only in the lower portions of the trench, recognizing that some future settlement of the ground surface or roadway may occur.

In areas where the trench will be covered with hard surfaced materials, the type of material placed within the frost zone (between finished grade and about 1.8 metres depth) should match the soil exposed on the trench walls for frost heave compatibility. Trench backfill should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 95 percent of the material's standard Proctor maximum dry density.

5.12 Pavement Design

In preparation for pavement construction, all topsoil, fill, and deleterious material (i.e., material containing organic material) should be removed from all pavement areas.

Those portions of the fill not containing organic matter may be left in place provided that some limited long-term settlement of the pavement surface can be tolerated. However, the surface of the fill material at subgrade level should be proof rolled with a heavy smooth drum roller under the supervision of qualified geotechnical personnel to compact the existing fill and to identify soft areas requiring sub-excavation and replacement with more suitable fill.

Sections requiring grade raising to the proposed subgrade level should be filled using acceptable (compactable and inorganic) earth borrow or OPSS Select Subgrade Material meeting the requirements of OPSS 212 and 1010, respectively. These materials should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 95 percent of the material's standard Proctor maximum dry density using suitable vibratory compaction equipment.

The surface of the subgrade or fill should be crowned to promote drainage of the pavement granular structure. Perforated pipe subdrains should be provided at subgrade level extending from the catch basins for a distance of at least 3 metres in four orthogonal directions or longitudinally where parallel to a curb.

The pavement structure for car parking areas should consist of:

Pavement Component	Thickness (millimetres)
Asphaltic Concrete	50
OPSS Granular A Base	150
OPSS Granular B Type II Subbase	300

The pavement structure for access roadways and truck traffic areas should consist of:

Pavement Component	Thickness (millimetres)
Asphaltic Concrete	90
OPSS Granular A Base	150
OPSS Granular B Type II Subbase	450

The granular base and subbase materials should be uniformly compacted to at least 100 percent of the material's standard Proctor maximum dry density using suitable vibratory compaction equipment. The asphaltic concrete should be compacted in accordance with Table 10 of OPSS 310.

The composition of the asphaltic concrete pavement in car parking areas should be as follows:

- Superpave 12.5 Surface Course – 50 millimetres.

The composition of the asphaltic concrete pavement in access roadways and truck traffic areas should be as follows:

- Superpave 12.5 Surface Course – 40 millimetres.
- Superpave 19.0 Binder Course – 50 millimetres.

The pavement design should be based on a Traffic Category of Level B. The asphalt cement used on this project should be made with PG 58-34 asphalt cement on all lifts.

The above pavement designs are based on the assumption that the pavement subgrade has been acceptably prepared (i.e., where the trench backfill, and grade raise fill have been adequately compacted to the required density and the subgrade surface not disturbed by construction operations or precipitation). Depending on the actual conditions of the pavement subgrade at the time of construction, it could be necessary to increase the thickness of the subbase and/or to place a woven geotextile beneath the granular materials.

5.13 Steel Corrosion and Cement Type

Two samples of soil from borehole 18-02 were submitted to Eurofins Scientific for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of this testing are provided in Appendix D and are summarized in Section 4.10.

The results indicate a low potential for sulphate attack; therefore, concrete made with Type GU Portland cement may be used for substructures. The results also indicate an elevated potential for corrosion of exposed ferrous metal, which should be considered in the design of substructures.

6.0 ADDITIONAL CONSIDERATIONS

The soils at this site are sensitive to disturbance from ponded water, construction traffic, and frost. Cobbles and boulders may be present in the fill and are present in the glacial till.

All footing and subgrade areas should be inspected by experienced geotechnical personnel of Golder Associates prior to filling or concreting to document that the correct/expected strata exist and that the bearing surfaces have been properly prepared. The placing and compaction of any engineered fill, pipe bedding, and pavement base and subbase materials should be inspected to ensure that the materials used conform to the specifications from both a grading and compaction point of view.

The groundwater level monitoring devices (i.e., standpipe piezometers or wells from previous investigation) installed at the site will require decommissioning at the time of construction in accordance with Ontario Regulation 903. It is therefore proposed that decommissioning of these devices be made part of the construction contract. Some of those devices may be useful during the initial stages of dewatering, if required, for monitoring the progress of the groundwater level lowering.

Golder Associates should review the final drawings and specifications for this project prior to tendering to confirm that the guidelines in this report have been adequately interpreted and to review some of our preliminary recommendations.

Signature Page

Golder Associates Ltd.

Chaitanya

LICENSED PROFESSIONAL ENGINEER
M.S. SNOW
4/10/2019
PROVINCE OF ONTARIO

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CRG/MSS/mvrd
https://golderassociates.sharepoint.com/sites/34624g/deliverables/report/18111310-001-r-rev0-geotechnical investigation-1004_19.docx

IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, **Ottawa Police Service or nominee**. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then the client may authorize the use of this report for such purpose by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process, provided this report is not noted to be a draft or preliminary report, and is specifically relevant to the project for which the application is being made. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

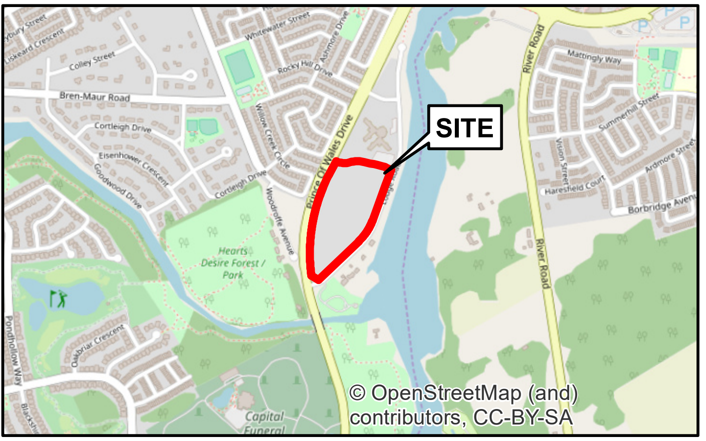
Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.



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LEGEND

⊕ BOREHOLE LOCATION, CURRENT INVESTIGATION

● BOREHOLE LOCATION, PREVIOUS INVESTIGATION

⬚ APPROXIMATE SITE BOUNDARY

🟨 PROPOSED BUILDING FOOTPRINT

▨ PROPOSED ROAD AND PARKING

— ROADWAY

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2016
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 20 40 80
1:2,000 METRES

CLIENT
OTTAWA POLICE SERVICE

PROJECT
ADDITIONAL GEOTECHNICAL INVESTIGATION
PROPOSED OTTAWA POLICE SERVICE SOUTH CAMPUS FACILITY
55 LODGE ROAD, OTTAWA, ONTARIO

TITLE
SITE PLAN

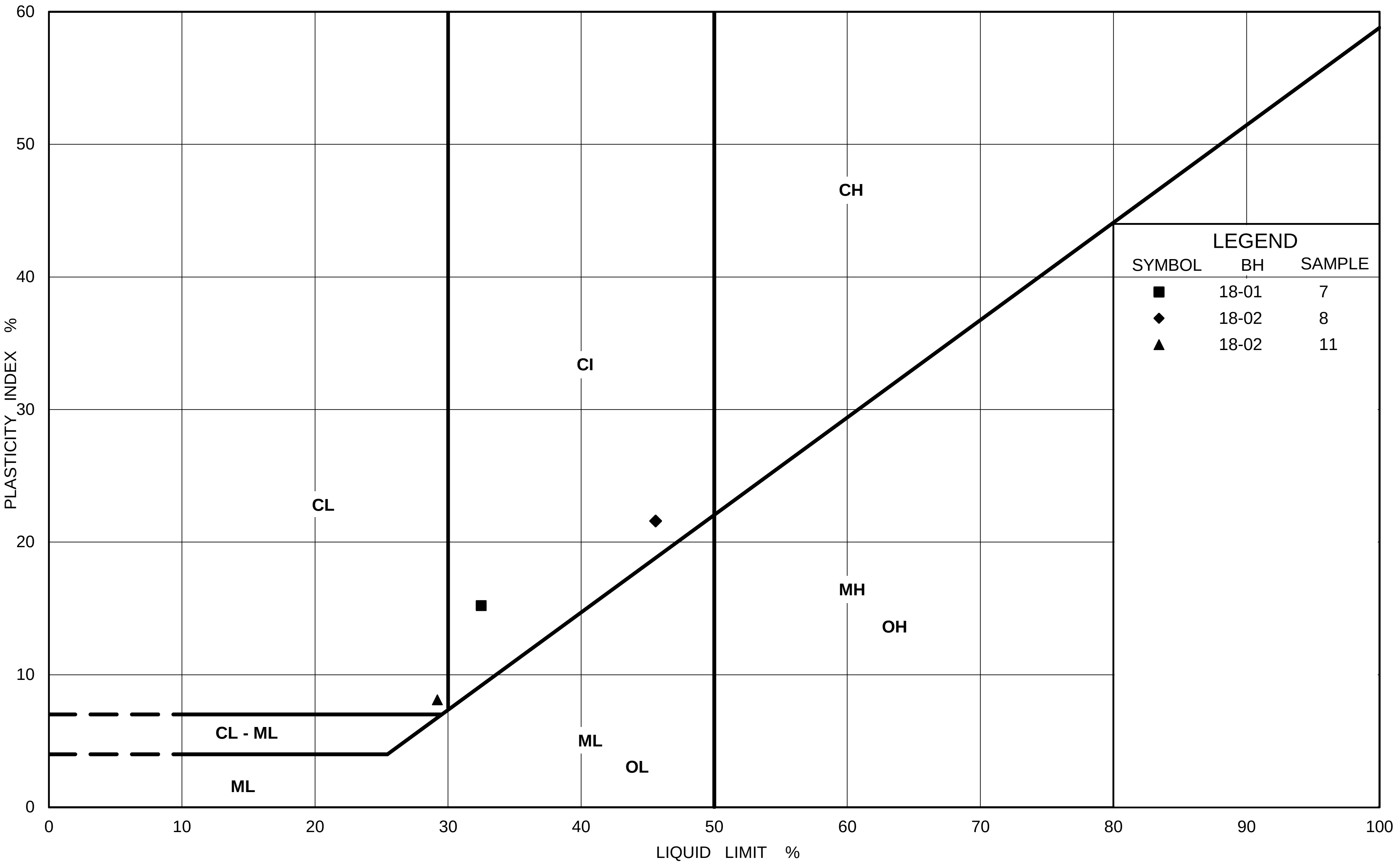
CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-08
DESIGNED	----
PREPARED	BR
REVIEWED	CRG
APPROVED	MSS

PROJECT NO.	CONTROL	REV.	FIGURE
18111310	0003	0	1

Path: N:\Active\Spatial_IM\CityofOttawa\OttawaPoliceServices_SouthStation\99_PROJ\18111310_CityofOttawa_OPS_SouthStn\40_PROD\0003_BG_SurveyedBHLoc\18111310-0003-BG-0001.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0



GOLDER

PLASTICITY CHART
SILTY CLAY

Figure : 2

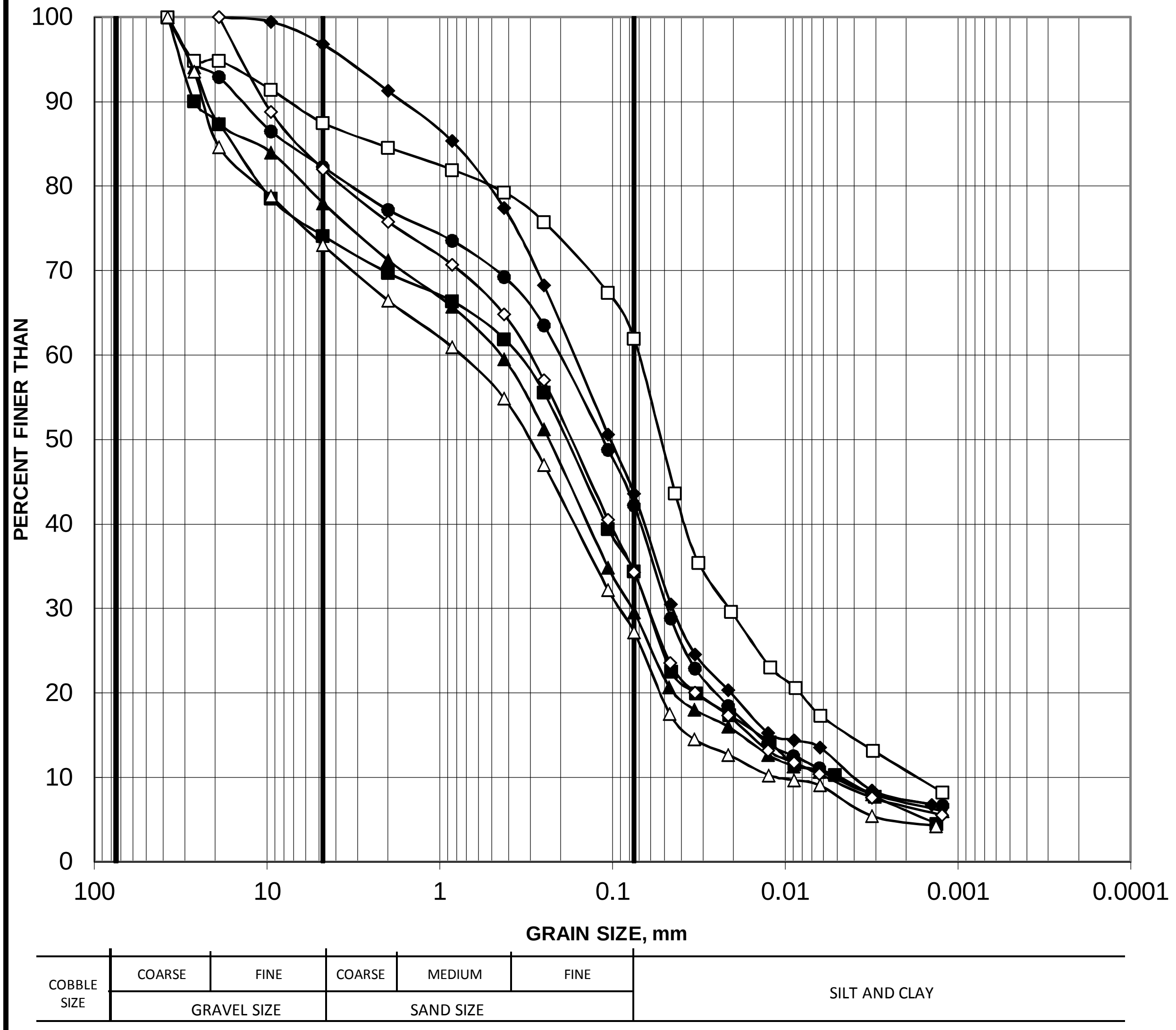
Project No.: 18111310

Compiled By : MI Checked By : AC

GRAIN SIZE DISTRIBUTION

FIGURE 3

GLACIAL TILL



Borehole	Sample	Depth (m)	Constituents (%) Gravel	 Sand	 Silt	 Clay
■ 18-01	9	9.54-10.06	26	40	29	6
◆ 18-01	11	12.19-12.80	3	53	36	7
▲ 18-01	15	18.29-18.90	22	48	23	7
● 18-02	13	14.48-15.09	18	40	35	7
□ 18-02	16	16.76-17.37	13	26	52	10
◇ 18-02	19	19.05-19.66	18	48	28	6
△ 18-02	22	21.34-21.95	27	46	23	5

Project: 18111310

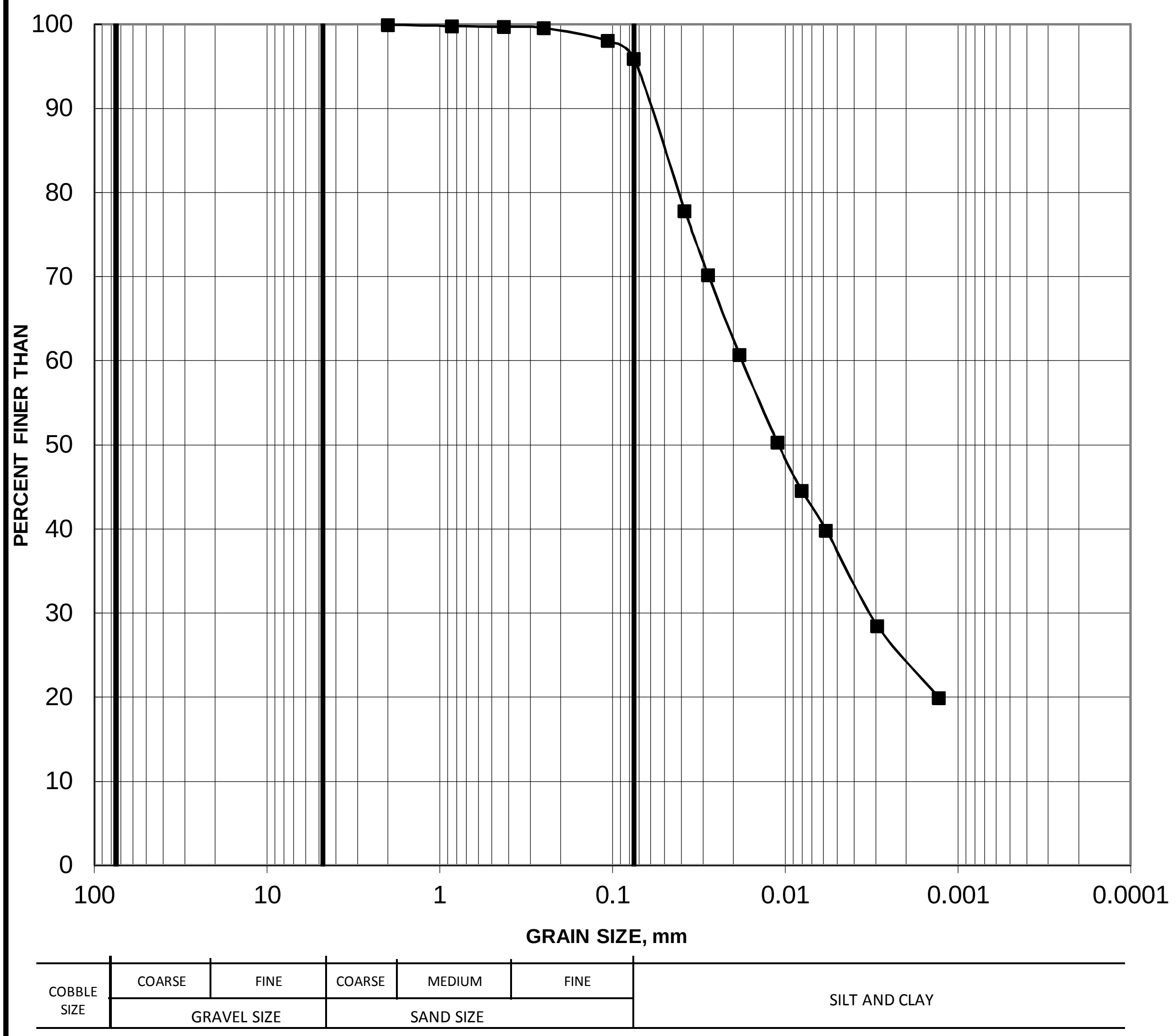
Golder Associates

Created by: MI
Checked by: AC

GRAIN SIZE DISTRIBUTION

FIGURE 4

CLAYEY SILT

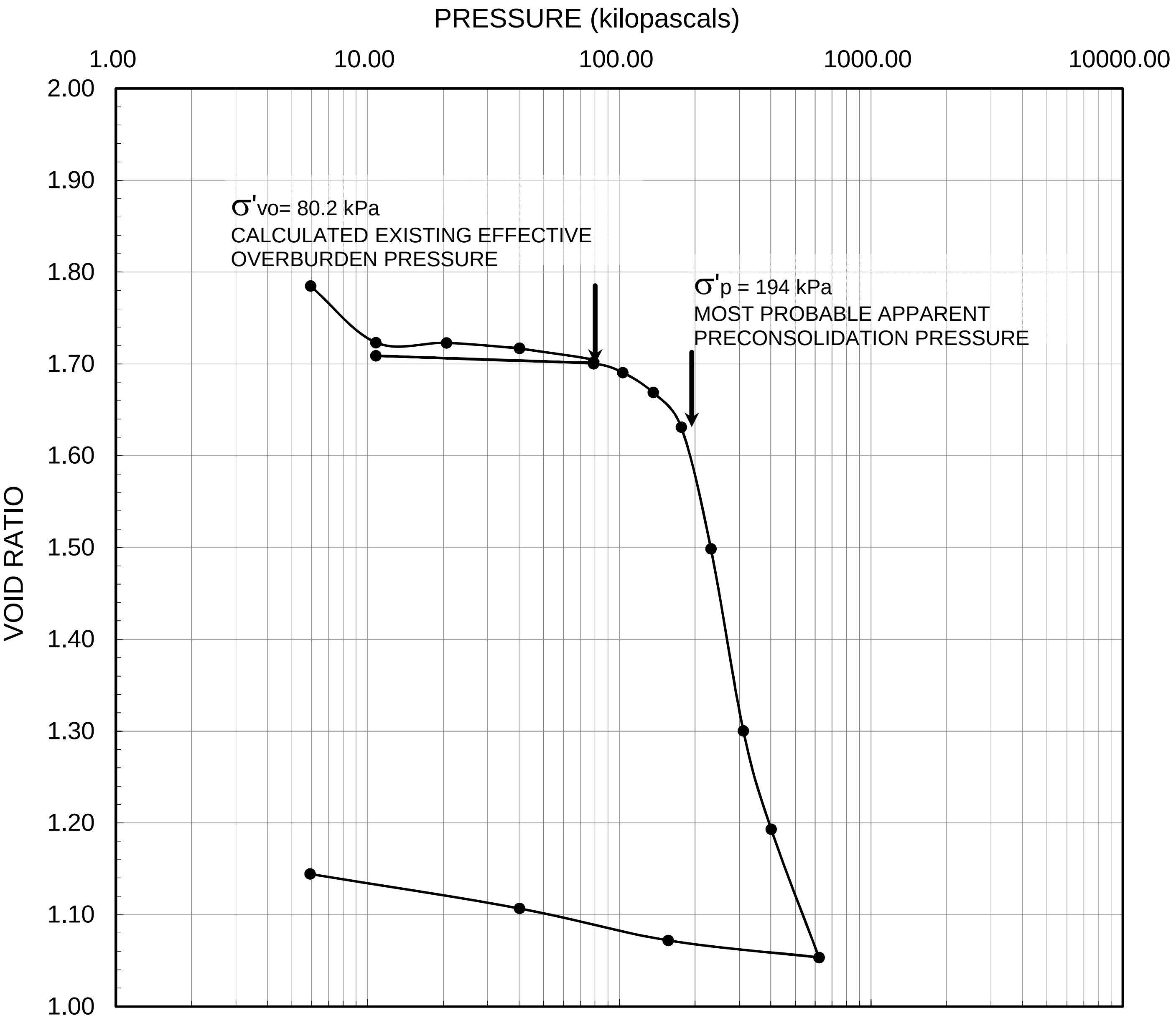


Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
■ 18-02	26	25.91-26.52	0	4	72	24

Created by: MI
Checked by: AC

Project: 18111310

Golder Associates



LEGEND

Borehole: 18-02
Sample: 8
Depth (m): 8.1
Elevation (m): 77.6

w_i = 61%
w_f = 43%
w_l = 46%
w_p = 24%

S_o = 100%
e_o = 1.70
C_c = 1.55
C_r = 0.010

γ = 16.3 kN/m³
G_s = 2.78

GOLDER

SCALE AS SHOWN
DATE 04/10/19
CADD N/A
ENTERED MI
CHECK CW
REVIEW CG

FILE No. Consolidation summary
PROJECT No. 18111310
REV. 0

TITLE

CONSOLIDATION TEST RESULTS

FIGURE 5

APPENDIX A

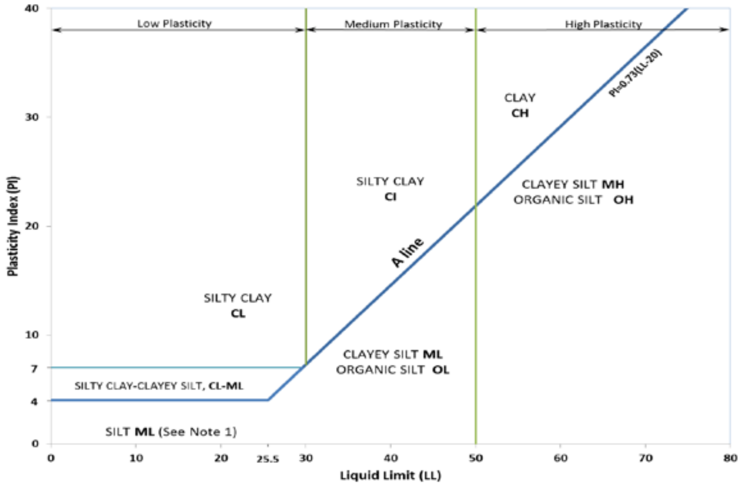
List of Abbreviations and Symbols
Lithological and Rock Description Terminology
Borehole Logs - Current Investigation

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = ($w_l - w_p$)
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1 $\tau = c' + \sigma' \tan\phi'$
2 shear strength = (compressive strength)/2

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of rock material weathering.

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of naturally occuring discontinuities (physical separations) in the rock core. Mechanically induced breaks caused by drilling are not included.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90^{o} angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

PROJECT: 18111310

RECORD OF BOREHOLE: 18-01

SHEET 1 OF 3

LOCATION: N 5014098.5 ;E 366864.7

BORING DATE: December 5, 6, 7 & 10, 2018

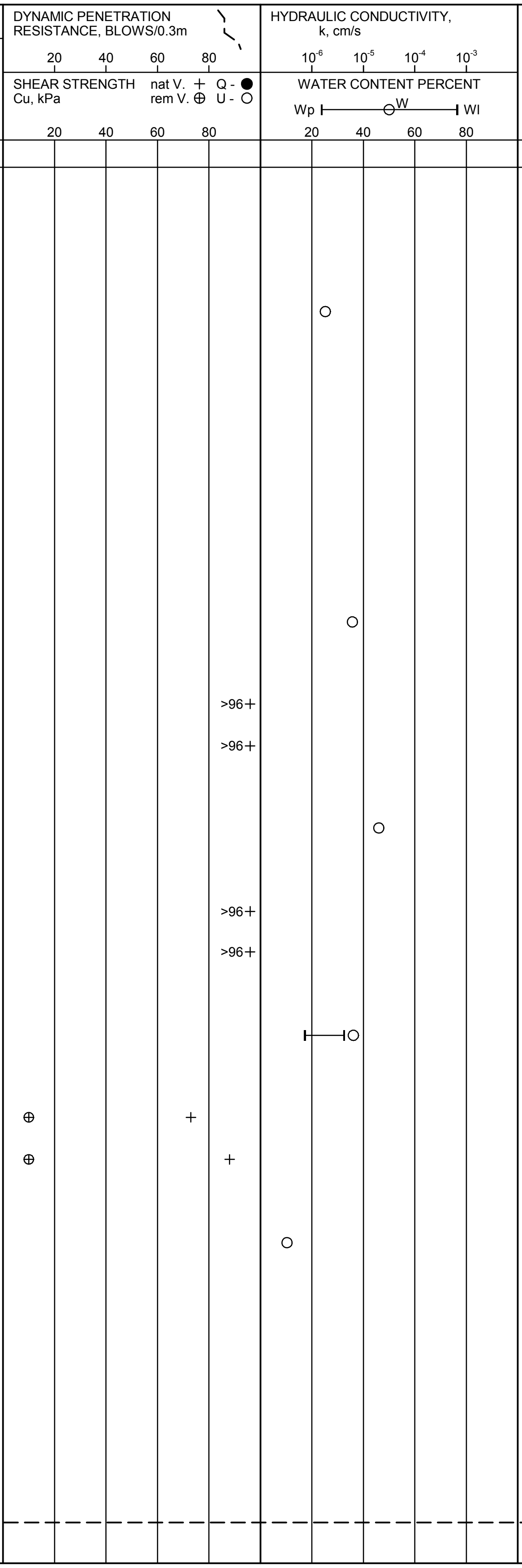
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
		GROUND SURFACE		88.58
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (ML) sandy SILT; dark brown; frozen		0.00
		FILL - (CL) sandy SILTY CLAY, trace gravel; grey brown, contains sand seams, rootlets and cobbles; cohesive, w~PL, firm to stiff		0.13
2		(CI/CH) SILTY CLAY to CLAY; grey brown (WEATHERED CRUST); cohesive, w>PL, very stiff		86.45 2.13
6		(CI/CH) SILTY CLAY; grey, contains silt seams/layers; cohesive, w>PL, stiff		82.48 6.10
7.62		(ML/SM) sandy SILT to SILTY SAND, some gravel to gravelly; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, loose to dense		80.96 7.62
8 to 10	Wash Bore HW Casing			

SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	SS	7	
2	SS	4	
3	SS	9	
4	SS	6	
5	SS	2	
6	SS	3	
7	SS	1	
8	SS	6	
9	SS	14	MH



PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

GOLDER

LOGGED: KM
CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 18-01

SHEET 2 OF 3

LOCATION: N 5014098.5 ;E 366864.7

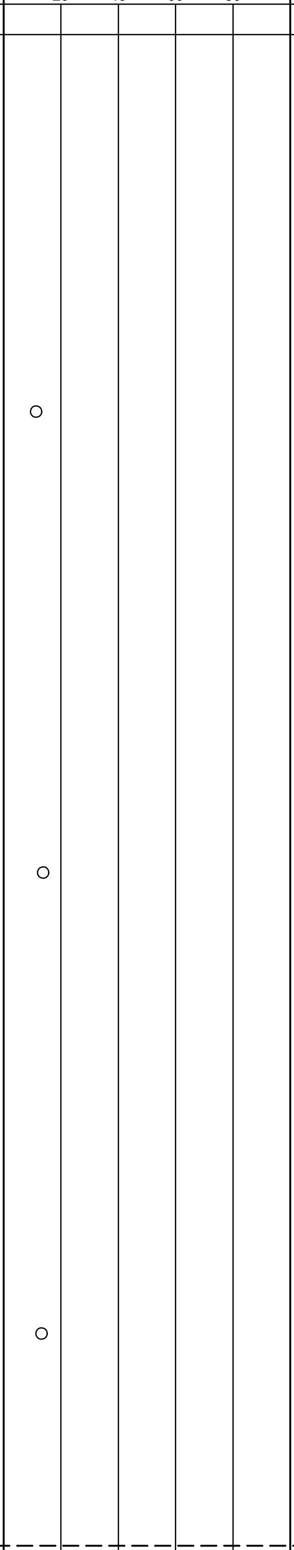
BORING DATE: December 5, 6, 7 & 10, 2018

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Wash Bore HW Casing	(ML/SM) sandy SILT to SILTY SAND, some gravel to gravelly; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, loose to dense									
11					10	SS	41				
12					11	SS	13		○	MH	
13											
14					12	SS	15				
15											
15.5					13	SS	6		○		
16											
16.8					14	SS	>50				
17											
18											
18.6					15	SS	7		○	MH	
19											
20		*CONTINUED NEXT PAGE*									



DEPTH SCALE

1 : 50

GOLDER

LOGGED: KM

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 18-01

SHEET 3 OF 3

LOCATION: N 5014098.5 ;E 366864.7

BORING DATE: December 5, 6, 7 & 10, 2018

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Wash Bore HW Casing	(ML/SM) sandy SILT to SILTY SAND, some gravel to gravelly; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, loose to dense									
21											
22											
23											
24											
25											
26					18	SS	WH				
27											
28											
29		End of Borehole		59.62 28.96							
30											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: KM

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 18-02

SHEET 1 OF 4

LOCATION: N 5014098.6 ;E 366965.6

BORING DATE: Nov. 28, 29 & Dec. 4, 5, 2018

DATUM: CGVD28

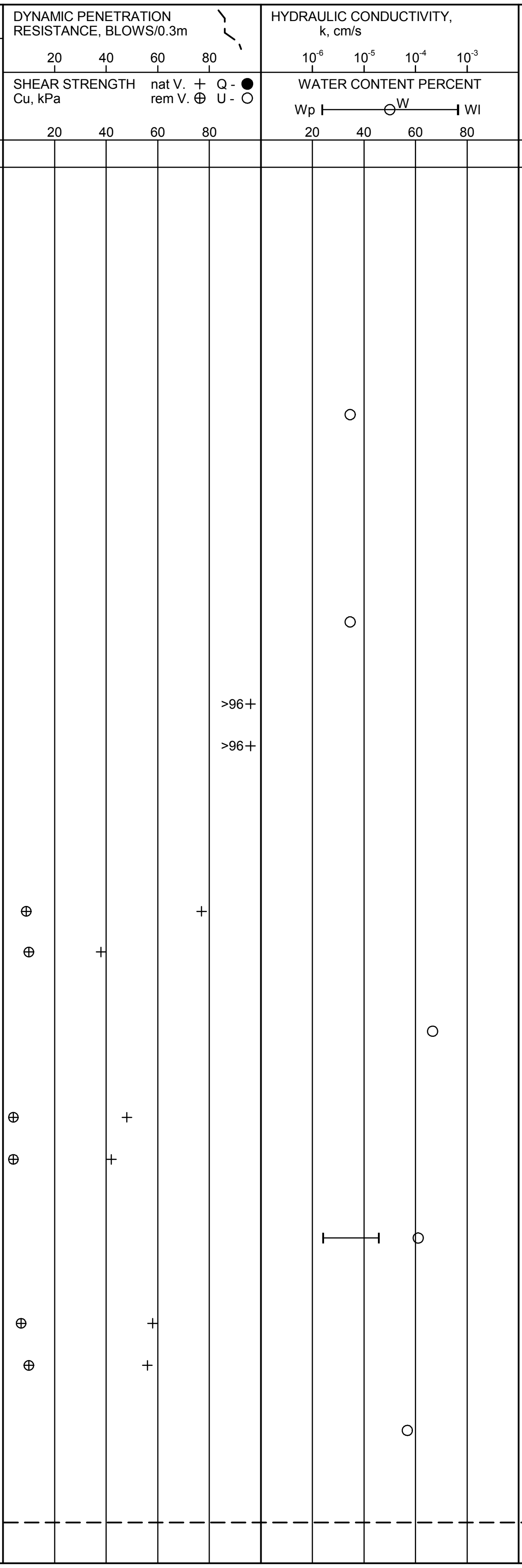
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	GROUND SURFACE	84.90
0	TOPSOIL - (ML) sandy SILT; dark brown; frozen	0.00
	FILL - (CI) SILTY CLAY, some sand; brown and grey brown, contains black mottling; cohesive, w>PL, very stiff	0.10
1	(CI/CH) SILTY CLAY to CLAY; grey brown, fissured (WEATHERED CRUST); cohesive, w>PL, very stiff	84.14 0.76
5	(CL/CH) SILTY CLAY; grey to dark grey, contains silt seams; cohesive, w>PL, firm to stiff	79.72 5.18

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	8
2	SS	7
3	SS	5
4	SS	4
5	SS	3
6	SS	1
7	SS	PH
8	SS	PH
9	SS	WH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE
1 : 50

LOGGED: KM
CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 18-02

SHEET 2 OF 4

LOCATION: N 5014098.6 ;E 366965.6

BORING DATE: Nov. 28, 29 & Dec. 4, 5, 2018

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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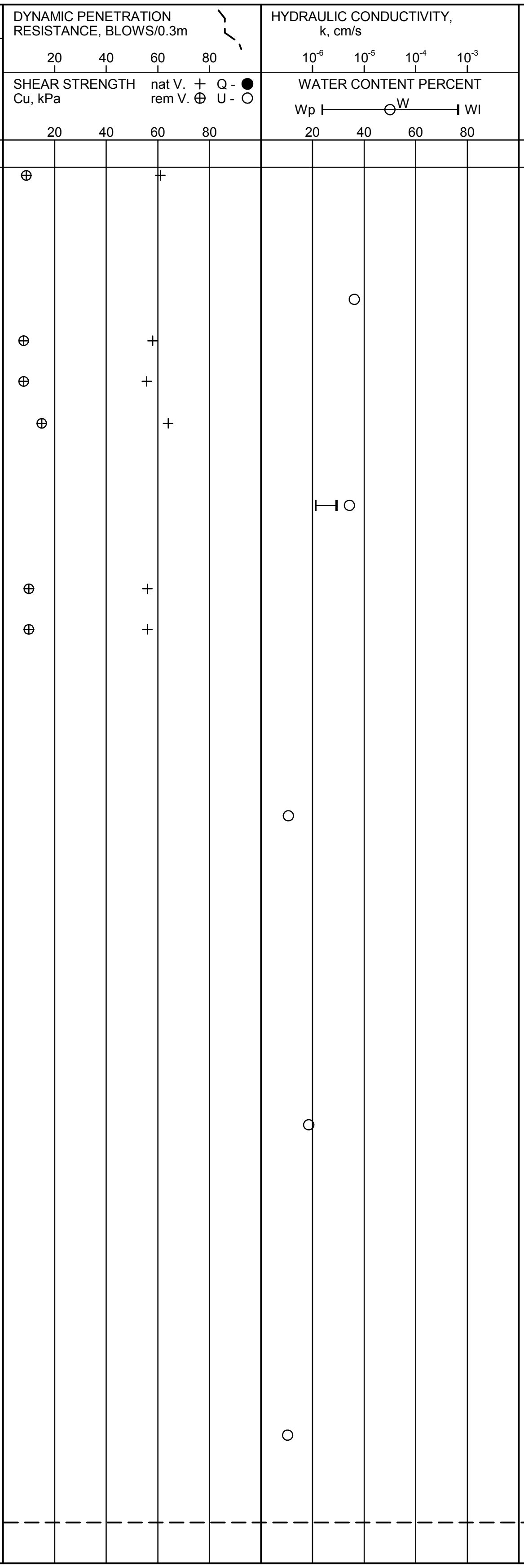
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	Power Auger 200 mm Diam. (Hollow Stem)	(CL/CH) SILTY CLAY; grey to dark grey, contains silt seams; cohesive, w>PL, firm to stiff						
11				10	SS	WH		
12				11	SS	WH		
13								
		(SM/ML) gravelly SILTY SAND to gravelly sandy SILT; grey, contains cobbles (GLACIAL TILL); non-cohesive, wet, compact to very loose	71.18 13.72					
14				12	SS	8		
				13	SS	20	MH	
15				14	SS	4		
16				15	SS	5		
17	Wash Bore HW Casing			16	SS	8	MH	
				17	SS	3		
18		(SM) gravelly SILTY SAND; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, compact to very dense	66.76 18.14	18	SS	28		
19				19	SS	11	MH	
20				20	SS	29		



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DEPTH SCALE
1 : 50

GOLDER

LOGGED: KM
CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 18-02

SHEET 3 OF 4

LOCATION: N 5014098.6 ;E 366965.6

BORING DATE: Nov. 28, 29 & Dec. 4, 5, 2018

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Wash Bore HW Casing	(SM) gravelly SILTY SAND; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, compact to very dense			20	SS	29				
					21	SS	13		○		
21											
					22	SS	36		○	MH	
22											
					23	SS	57				
23											
					24	SS	55				
24											
25											
					25	SS	54				
26		(ML) CLAYEY SILT ; grey, contains sand seams; cohesive, w>PL, very Stiff		58.99 25.91	26	SS	73		○	MH	
27		(GP) GRAVEL, some sand, trace non-plastic fines; grey, contains cobbles and boulders; non-cohesive, wet, very dense		58.38 26.52							
					27	SS	>50				
28		Borehole Continued on RECORD OF DRILLHOLE 18-02		56.88 28.02							
29											
30											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: KM

CHECKED: CRG

PROJECT: 18111310

RECORD OF DRILLHOLE: 18-02

SHEET 4 OF 4

LOCATION: N 5014098.6 ;E 366965.6

DRILLING DATE: Nov. 28, 29 & Dec. 4, 5, 2018

DATUM: CGVD28

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: CCC Geotechnical & Enviromental Drilling

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.
		BEDROCK SURFACE																
	Rotary Drill HQ Core	Fresh, light grey, thinly bedded, medium strong sandy DOLOSTONE (MARCH FORMATION)		56.88 28.02	1													
29					2													
30					3													
31																		
32					4													
33					5													
		End of Drillhole		51.69 33.21														
34																		
35																		
36																		
37																		
38																		

DEPTH SCALE

1 : 50

GOLDER

LOGGED: KM

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 19-01

SHEET 1 OF 5

LOCATION: N 5014031.0 ;E 366869.9

BORING DATE: February 19-20, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		GROUND SURFACE		87.09							
0	Power Auger 200 mm Diam. (Hollow Stem)	Unsampled Overburden		0.00							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 19-01

SHEET 2 OF 5

LOCATION: N 5014031.0 ;E 366869.9

BORING DATE: February 19-20, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	Unsampled Overburden									
11											
12											
13	Wash Bore NW Casing										
14											
15											
16											
17											
18											
19											
20											
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

MIS-BHS 001 18111310.GPJ GAL-MIS.GDT 11/3/19 JEM

PROJECT: 18111310

RECORD OF BOREHOLE: 19-01

SHEET 3 OF 5

LOCATION: N 5014031.0 ;E 366869.9

BORING DATE: February 19-20, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20		Unsampled Overburden									
21	Wash Bore NW Casing										
22											
23											
24											
25											
26	Wash Bore NQ Core										
27											
28											
29											
30											
		CONTINUED NEXT PAGE									

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: CRG

MIS-BHS 001 18111310.GPJ GAL-MIS.GDT 11/3/19 JEM

PROJECT: 18111310

RECORD OF BOREHOLE: 19-01

SHEET 4 OF 5

LOCATION: N 5014031.0 ;E 366869.9

BORING DATE: February 19-20, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m				
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Wash Bore NQ Core	Unsampled Overburden									
31											
32											
33											
34											
35				51.84							
		Borehole Continued on RECORD OF DRILLHOLE 19-01									
36											
37											
38											
39											
40											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

PROJECT: 18111310

RECORD OF DRILLHOLE: 19-01

SHEET 5 OF 5

LOCATION: N 5014031.0 ;E 366869.9

DRILLING DATE: February 19-20, 2019

DATUM: CGVD28

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-850

DRILLING CONTRACTOR: CCC Geotechnical & Enviromental Drilling

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.
		BEDROCK SURFACE		51.84 35.25														
	Rotary Drill NQ Core	Fresh, light to medium grey, fine grained, faintly porous, medium bedded DOLOSTONE BEDROCK, with some calcite nodules and occasional thin shale partings			R1	100												
36					R2	50												
37				49.74 37.35														
		End of Drillhole																
38																		
39																		
40																		
41																		
42																		
43																		
44																		
45																		

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 19-02

SHEET 1 OF 5

LOCATION: N 5014028.0 ;E 366929.9

BORING DATE: February 21-22, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		85.48							
0	Wash Bore NW Casing	Unsampled Overburden		0.00							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 19-02

SHEET 2 OF 5

LOCATION: N 5014028.0 ;E 366929.9

BORING DATE: February 21-22, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE				SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)		NUMBER	TYPE	BLOWS/0.30m				
		--- CONTINUED FROM PREVIOUS PAGE ---										
10	Wash Bore NW Casing	Unsampled Overburden										
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
		CONTINUED NEXT PAGE										

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

PROJECT: 18111310

RECORD OF BOREHOLE: 19-02

SHEET 3 OF 5

LOCATION: N 5014028.0 ;E 366929.9

BORING DATE: February 21-22, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20		Unsampled Overburden									
21											
22											
23											
24											
25	Wash Bore NW Casing										
26											
27											
28											
29											
30											
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: CRG

MIS-BHS 001 18111310.GPJ GAL-MIS.GDT 11/3/19 JEM

PROJECT: 18111310

RECORD OF BOREHOLE: 19-02

SHEET 4 OF 5

LOCATION: N 5014028.0 ;E 366929.9

BORING DATE: February 21-22, 2019

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Wash Bore NW Casing	Unsampled Overburden		54.92							
		Borehole Continued on RECORD OF DRILLHOLE 19-02									
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: CRG

PROJECT: 18111310

RECORD OF DRILLHOLE: 19-02

SHEET 5 OF 5

LOCATION: N 5014028.0 ;E 366929.9

DRILLING DATE: February 21-22, 2019

DATUM: CGVD28

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-850

DRILLING CONTRACTOR: CCC Geotechnical & Enviromental Drilling

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.
		BEDROCK SURFACE		54.92														
31 32	Rotary Drill NQ Core	Limestone and dolostone COBBLES and BOULDERS (Inferred GLACIAL TILL) or Highly weathered BEDROCK		30.56	R1 R2													
33		Fresh, light to medium grey, fine grained, faintly porous, medium bedded DOLOSTONE BEDROCK, with some calcite nodules and occasional thin shale partings		53.32 32.16	R3 R4													
34		End of Drillhole		51.73 33.75														
35																		
36																		
37																		
38																		
39																		
40																		

DEPTH SCALE
1 : 50

LOGGED: PAH
CHECKED: CRG

APPENDIX B

Borehole Logs - Previous Investigation

PROJECT: 1537295

RECORD OF BOREHOLE: 16-101

SHEET 1 OF 1

LOCATION: N 5014118.9 ;E 366915.4

BORING DATE: November 29, 2016

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES: 0 – 10

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem) (0 to 6.10 m)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m
GROUND SURFACE	86.80			
TOPSOIL - (SM/ML) sandy SILT; brown	0.00			
FILL - (SM) SILTY SAND, some gravel, trace clay; brown; non-cohesive, moist to wet, loose to compact	0.15	1	SS	7
		2	SS	13
		3	SS	12
(CI/CH) SILTY CLAY, trace sand; brown (WEATHERED CRUST); cohesive, w~PL	84.97 1.83	4	SS	20
		5	SS	7
		6	SS	6
		7	SS	8
		8	SS	2
		9	SS	4
(CI/CH) SILTY CLAY; grey brown; cohesive, w>PL	81.31 5.49	10	SS	1
End of Borehole	80.70 6.10			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION:

- Cuttings ▽
- Bentonite Seal
- Silica Sand
- 38 mm Diam. PVC #10 Slot Screen
- W.L. in Screen at Elev. 85.70 m on Feb. 2, 2017

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-102

SHEET 1 OF 1

LOCATION: N 5014129.2 ;E 366925.1

BORING DATE: December 1, 2016

DATUM: CGVD28

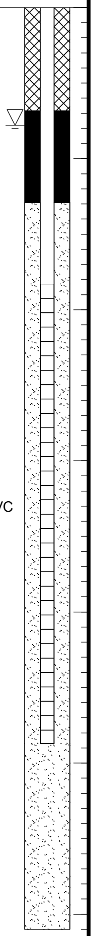
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80 | HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} | WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80 | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
GROUND SURFACE	85.73				
TOPSOIL - (SM/ML) sandy SILT; black brown	0.00				
FILL - (SM) SILTY SAND, trace to some gravel; brown, trace of assumed white ash; non-cohesive, moist	0.15	1	SS	9	Cuttings
		2	SS	12	Bentonite Seal
		3	SS	11	Silica Sand
(CI/CH) SILTY CLAY; brown (WEATHERED CRUST); cohesive, w~PL	83.90 1.83	4	SS	5	
		5	SS	4	
		6	SS	3	38 mm Diam. PVC #10 Slot Screen
- w>PL at 3.66 m depth					
		7	SS	7	
		8	SS	4	
		9	SS	2	
- becoming grey at 5.49 m depth					Silica Sand
		10	SS	WH	
End of Borehole	79.63 6.10				W.L. in Screen at Elev. 84.95 m on Feb. 2, 2017



MIS-BHS 001 1537295.GPJ GAL-MIS.GDT 03/13/17 JEM/TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-103

SHEET 1 OF 1

LOCATION: N 5014097.2 ;E 366934.8

BORING DATE: December 1, 2016

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

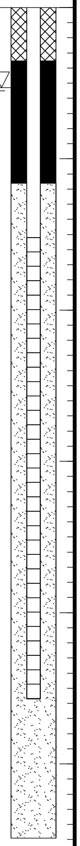
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
GROUND SURFACE	85.56			
TOPSOIL - (SM/ML) sandy SILT; brown	0.00			
FILL - (ML-CL) CLAYEY SILT, trace sand and gravel; brown to slight blackish, contains organics; cohesive, moist, loose	0.15	1	SS	9
FILL - (SM) SILTY SAND, some clayey silt and gravel; brown; non-cohesive, moist, compact	84.95 0.61	2	SS	14
FILL - (SP) SAND, fine, some silt, gravel, clayey silt pieces; brown; non-cohesive, moist to wet, compact	84.34 1.22	3	SS	11
(CI) SILTY CLAY/CLAYEY SILT, trace sand; brown (WEATHERED CRUST); cohesive, w~PL	83.73 1.83	4	SS	2
		5	SS	4
		6	SS	2
		7	SS	6
		8	SS	2
		9	SS	4
End of Borehole	80.07 5.49			

PIEZOMETER OR STANDPIPE INSTALLATION



Cuttings

Bentonite Seal

Silica Sand

38 mm Diam. PVC #10 Slot Screen

Silica Sand

W.L. in Screen at Elev. 85.03 m on Feb. 2, 2017

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-01

SHEET 1 OF 3

LOCATION: N 5014141.2 ;E 366882.1

BORING DATE: December 2, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES: 0 – 10

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	88.54
FILL/TOPSOIL - (ML) sandy SILT; brown; moist	0.00
FILL - (SM) SILTY SAND, some gravel; brown, contains roots; non-cohesive, moist, loose	0.15
FILL - (SP/SM) gravelly SAND to SILTY SAND; brown; non-cohesive, moist, compact	87.78 0.76
FILL - (SM/GM) SILTY SAND and GRAVEL; brown; non-cohesive, wet, compact	87.02 1.52
(CI/CH) SILTY CLAY to CLAY, trace sand; brown (WEATHERED CRUST); cohesive, w>PL, very stiff	86.26 2.28
(CI/CH) SILTY CLAY to CLAY, trace sand; grey; cohesive, w>PL, firm	82.44 6.10
(CI/CH) SILTY CLAY to CLAY, some sand; grey, contains silt seams; cohesive, w>PL, firm	80.92 7.62
(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, compact	80.08 8.46

NUMBER	TYPE	BLOWS/0.30m
1	SS	8
2	SS	14
3	SS	14
4	SS	10
5	SS	4
6	SS	4
7	SS	1
8	SS	PH
9	SS	17

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

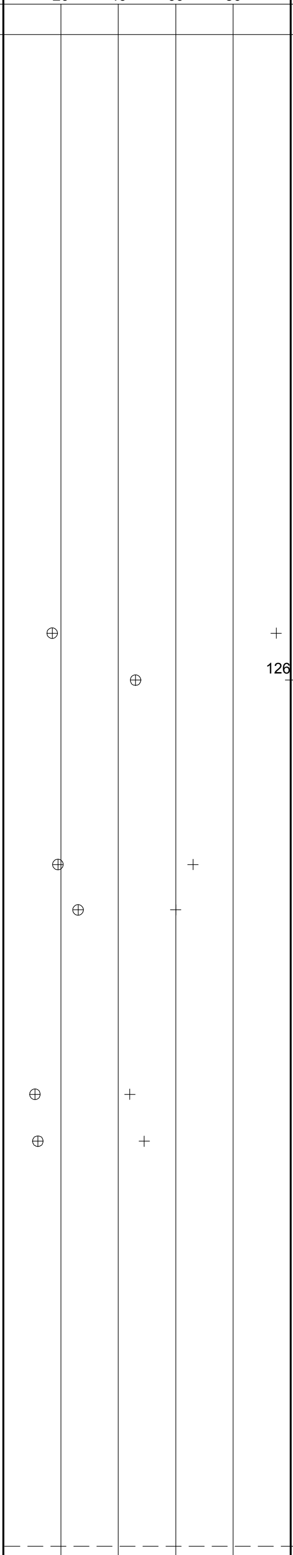
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



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DEPTH SCALE

1 : 50

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-01

SHEET 2 OF 3

LOCATION: N 5014141.2 ;E 366882.1

BORING DATE: December 2, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, compact									
11											
12											
13											
14											
15											
16											▽
17											
18											
19											
20		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-01

SHEET 3 OF 3

LOCATION: N 5014141.2 ;E 366882.1

BORING DATE: December 2, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Power Auger 200 mm Diam. (Hollow Stem)	(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, compact	▨								
21											
22				65.71 22.83							
23		End of Borehole Auger Refusal									
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-02

SHEET 1 OF 2

LOCATION: N 5014138.6 ;E 366933.0

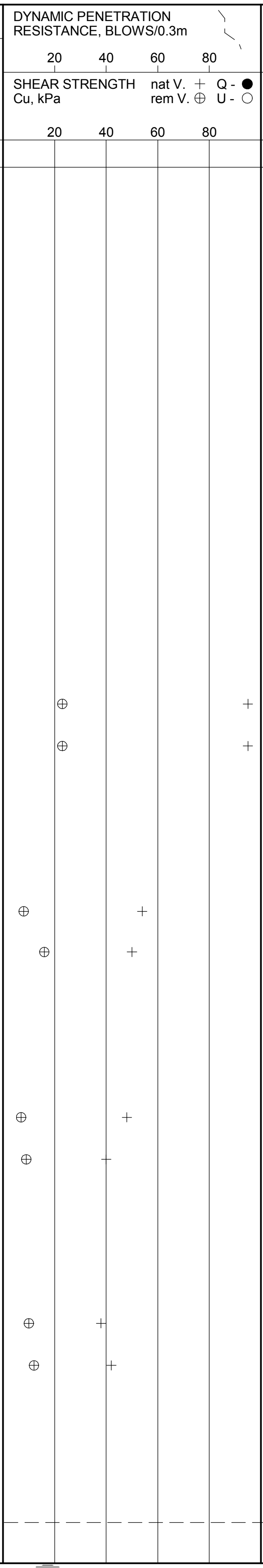
BORING DATE: December 2, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
		GROUND SURFACE	85.86			
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL/TOPSOIL - (SM) sandy SILT, some gravel; dark brown; non-cohesive, moist	0.00	1	SS	8
		FILL - (SM/GM) SILTY SAND and GRAVEL; brown; non-cohesive, wet, compact	85.10 0.76	2	SS	19
		(CI/CH) SILTY CLAY to CLAY, trace sand; grey brown with red mottling; cohesive, w>PL, very stiff	84.34 1.52	3	SS	4
				4	SS	5
				5	SS	4
				6	SS	2
		(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, firm to stiff	80.68 5.18			
				7	SS	PH
				8	SS	WR
				9	SS	WR
10		*CONTINUED NEXT PAGE*				



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

∇

DEPTH SCALE
1 : 50

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-02

SHEET 2 OF 2

LOCATION: N 5014138.6 ;E 366933.0

BORING DATE: December 2, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10		(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, firm to stiff	▨					⊕ + ⊕ +			
		End of Borehole		75.50 10.36							
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

MIS-BHS 001 1537295.GPJ GAL-MIS.GDT 03/13/17 JEM/TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-03

SHEET 1 OF 3

LOCATION: N 5014136.8 ;E 366990.0

BORING DATE: December 5, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
GROUND SURFACE		84.80
FILL/TOPSOIL - (ML) sandy SILT; brown; non-cohesive, moist	▩	0.00
FILL - (SP) SAND, fine, trace gravel; brown; non-cohesive, moist, loose to compact	▩	0.15
(ML-SM) sandy CLAYEY SILT to SILTY SAND; brown to black, contains organic matter; non-cohesive, moist, loose	▨	84.04 0.76
(CI/CH) SILTY CLAY to CLAY, trace sand; brown with red mottling; cohesive, w>PL, firm to very stiff	▨	83.28 1.52
(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, firm	▨	78.70 6.10

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	10
2	SS	9
3	SS	6
4	SS	4
5	SS	3
6	SS	2
7	SS	PH
8	SS	WR

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

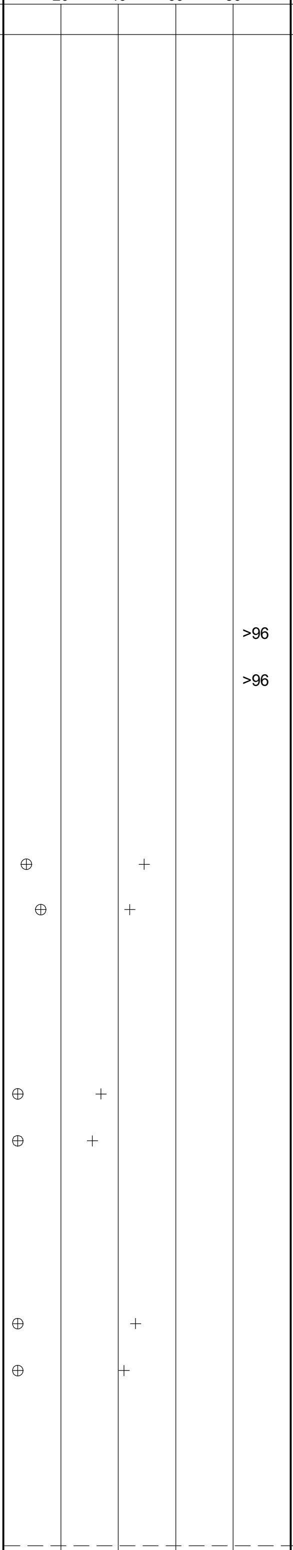
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

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DEPTH SCALE
1 : 50

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-03

SHEET 2 OF 3

LOCATION: N 5014136.8 ;E 366990.0

BORING DATE: December 5, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, firm									
11					9	SS	PH				
12											
13											
14											
15				69.46 15.34							
		(ML/SM) gravelly sandy SILT to SILTY SAND; grey, contains cobbles (GLACIAL TILL); non-cohesive, wet, loose									
16											
17					10	SS	5				
18											
19											
20											
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-03

SHEET 3 OF 3

LOCATION: N 5014136.8 ;E 366990.0

BORING DATE: December 5, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Power Auger 200 mm Diam. (Hollow Stem)	(ML/SM) gravelly sandy SILT to SILTY SAND; grey, contains cobbles (GLACIAL TILL); non-cohesive, wet, loose	▨								
21											
22											
23											
24											
25											
26				58.44 26.36							
		End of Borehole Auger Refusal									
27											
28											
29											
30											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-04

SHEET 1 OF 1

LOCATION: N 5014129.8 ;E 367031.1

BORING DATE: December 6, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
		GROUND SURFACE		83.65
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL/TOPSOIL - (ML) sandy SILT; brown; non-cohesive, moist		0.00
		FILL - (ML) sandy SILT, trace gravel; brown; non-cohesive, moist loose		0.12
		(CI/CH) SILTY CLAY to CLAY, some sand; brown with red mottling, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff		82.89 0.76
		(CI/CH) SILTY CLAY to CLAY; grey, contains sand seams; cohesive, w>PL, firm to stiff		77.55 6.10
		End of borehole		74.81 8.84

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	6
2	SS	8
3	SS	6
4	SS	4
5	SS	3
6	SS	PH
7	SS	PH

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

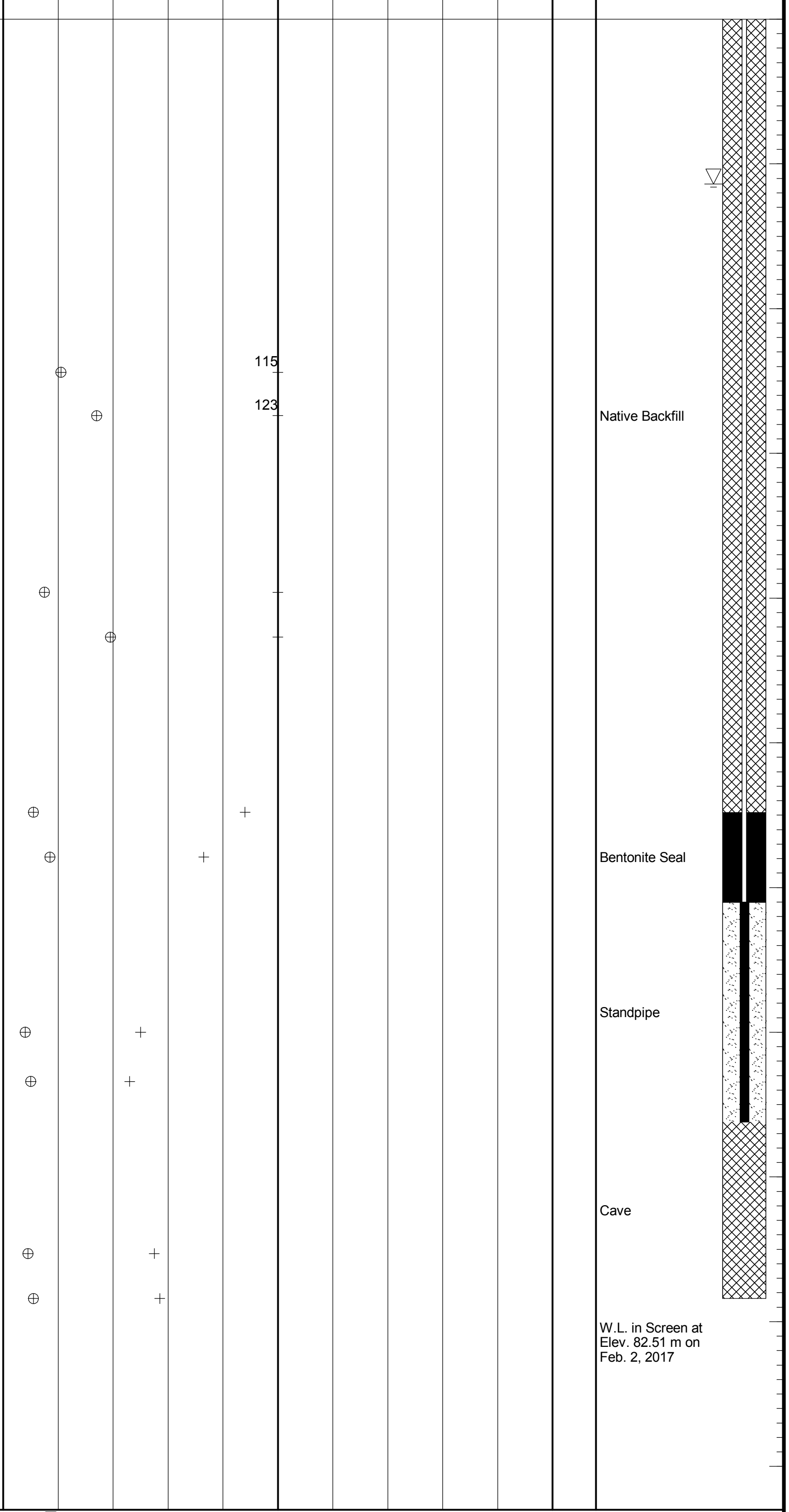
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



W.L. in Screen at Elev. 82.51 m on Feb. 2, 2017

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

MIS-BHS 001 1537295.GPJ GAL-MIS.GDT 03/13/17 JEM/TB

PROJECT: 1537295

RECORD OF BOREHOLE: 16-05

SHEET 1 OF 1

LOCATION: N 5014078.8 ;E 366857.1

BORING DATE: December 6, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES: 0 – 10

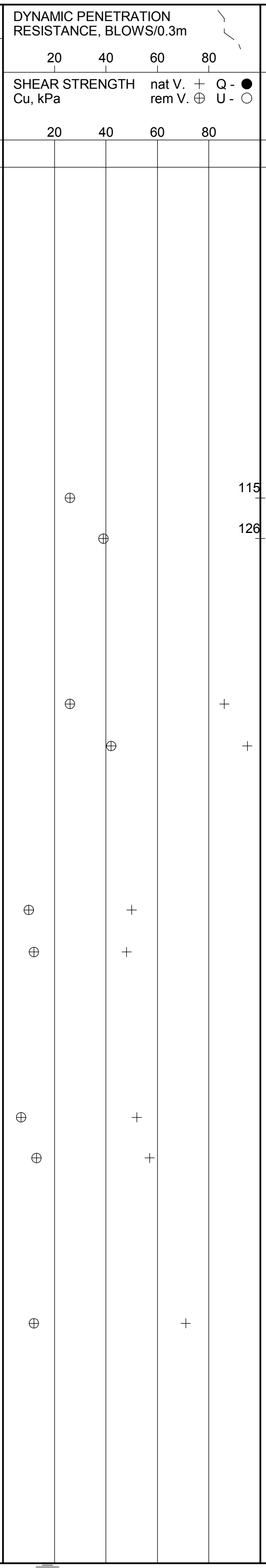
BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	88.04
FILL/TOPSOIL - (ML) sandy SILT; brown; moist	0.00
FILL - (SM) SILTY SAND, trace gravel; brown, contains organic matter; non-cohesive, moist, very loose to loose	87.86 0.18
(CI/CH) SILTY CLAY to CLAY, some sand; brown (WEATHERED CRUST); cohesive, w>PL, very stiff	87.13 0.91
(CI/CH) SILTY CLAY to CLAY; brown, contains silt seams; w>PL, firm to stiff	83.47 4.57
(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff	81.94 6.10
(ML) sandy CLAYEY SILT, some gravel; grey (GLACIAL TILL); cohesive, w>PL, very loose	79.31 8.73
End of Borehole	78.29 9.75

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	4
2	SS	12
3	SS	7
4	SS	5
5	SS	1
6	SS	PH
7	SS	PH
8	SS	3

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m

SHEAR STRENGTH Cu, kPa — nat V. + Q - ● rem V. ⊕ U - ○



HYDRAULIC CONDUCTIVITY, k, cm/s — 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT — Wp ⊢ ○W ⊣ Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-06

SHEET 1 OF 2

LOCATION: N 5014063.2 ;E 366910.7

BORING DATE: December 7, 2017

DATUM: CGVD28

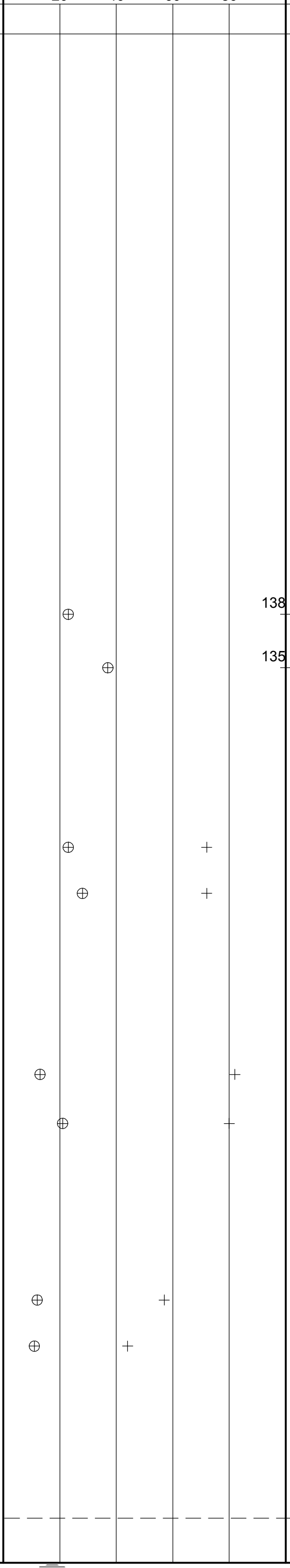
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
0	GROUND SURFACE	87.67
	FILL/TOPSOIL - (ML) sandy SILT; brown; moist	0.00
	FILL - (SP/SM) SAND to SILTY SAND, some gravel; brown, contains organic matter; non-cohesive, moist, compact	0.10
1	FILL - (SM/SP) gravelly SILTY SAND to SAND; brown, contains cobbles; non-cohesive, dry to moist, dense	86.93 0.74
2	(CI/CH) SILTY CLAY to CLAY, some sand; brown to grey, contains rootlets and silt seams; cohesive, w>PL, stiff to very stiff	85.39 2.28
7	(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff to firm	80.05 7.62
10	CONTINUED NEXT PAGE	

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	12
2	SS	45
3	SS	40
4	SS	12
5	SS	6
6	SS	3
7	SS	2
8	SS	PH



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

MIS-BHS 001 1537295.GPJ GAL-MIS.GDT 03/13/17 JEM/TB

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-06

SHEET 2 OF 2

LOCATION: N 5014063.2 ;E 366910.7

BORING DATE: December 7, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff to firm	▨								
11											
12											
13		(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, loose		74.67 13.00							
14					9	SS	7				
15											
16											
17											
18											
19		End of Borehole Auger Refusal		68.65 19.02							
20											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-07

SHEET 1 OF 1

LOCATION: N 5014050.8 ;E 366967.0

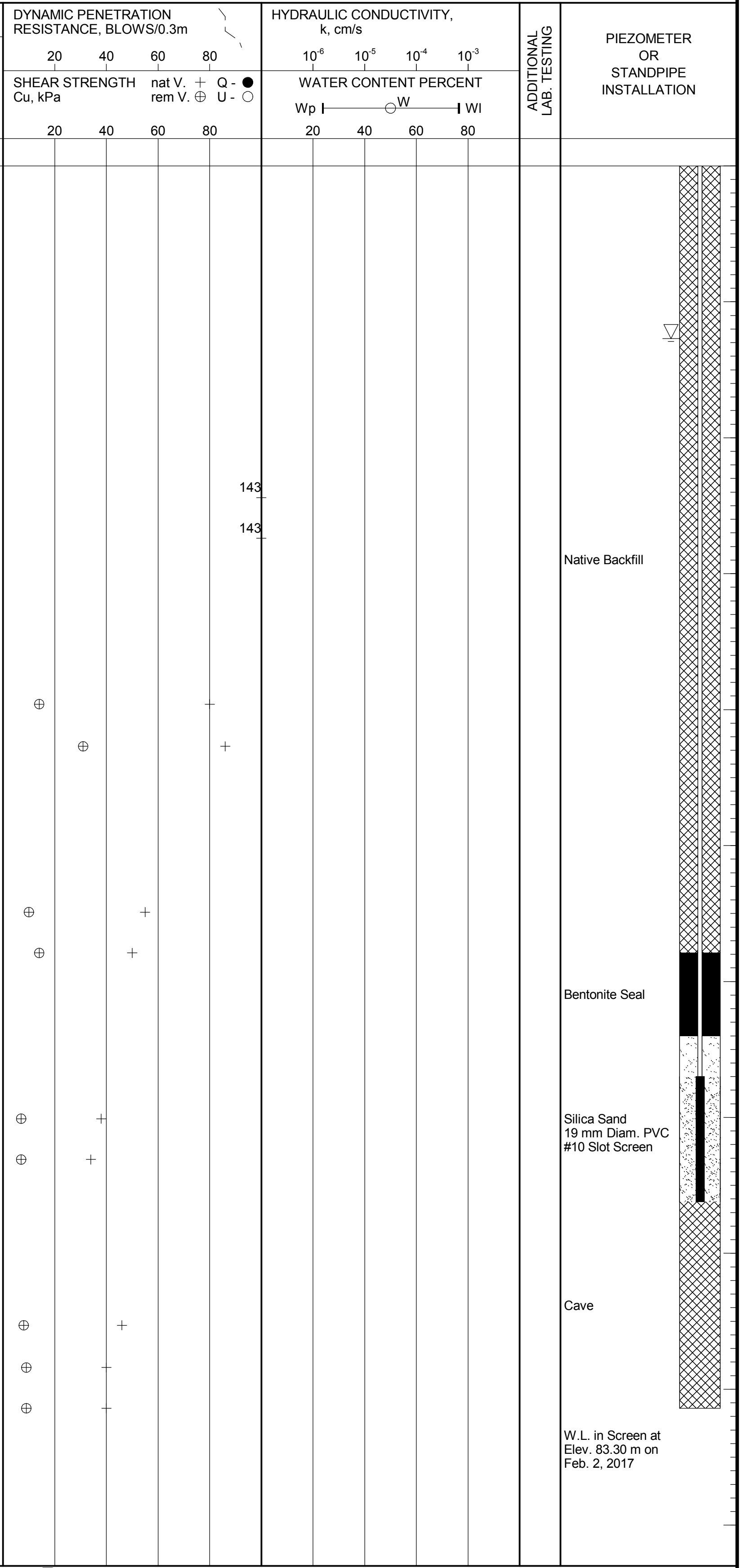
BORING DATE: December 7, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
		GROUND SURFACE	84.57			
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL/TOPSOIL - (ML) sandy SILT; brown; moist	0.00			
		FILL - (SM) SILTY SAND, trace gravel; dark brown, contains rootlets; non-cohesive, moist, loose	0.10	1	SS	8
		(CI/CH) SILTY CLAY to CLAY, some sand; brown, contains roots; cohesive, w>PL, stiff	83.81 0.76	2	SS	11
		(CI/CH) SILTY CLAY to CLAY, some sand; brown (WEATHERED CRUST); cohesive, w>PL, stiff to very stiff	83.05 1.52	3	SS	8
				4	SS	5
				5	SS	2
		(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, firm	78.47 6.10	6	SS	PH
				7	SS	WR
		End of Borehole	75.43 9.14			



DEPTH SCALE

1 : 50

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-08

SHEET 1 OF 1

LOCATION: N 5014032.7 ;E 367007.8

BORING DATE: December 8, 2017

DATUM: CGVD28

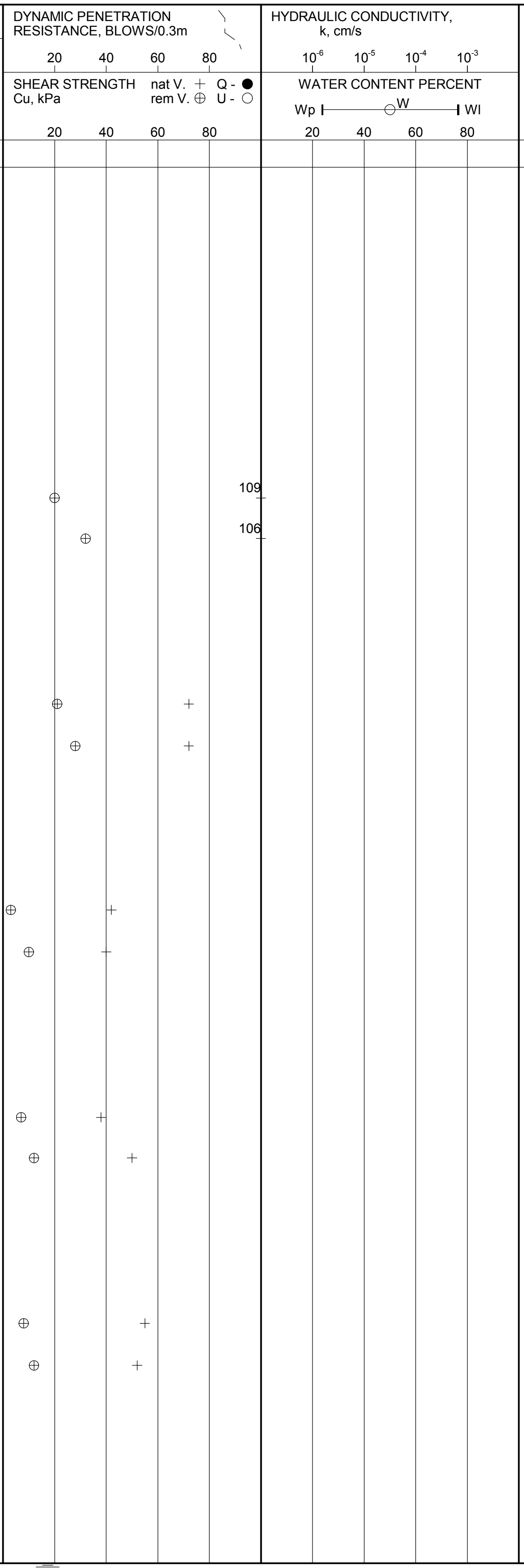
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger
200 mm Diam. (Hollow Stem)

ELEV. DEPTH (m)	SOIL PROFILE DESCRIPTION
83.78	GROUND SURFACE
0.00	TOPSOIL - (SM) SILTY SAND; brown; moist
0.10	(SM/ML) SILTY SAND to sandy CLAYEY SILT; dark brown, contains rootlets; non-cohesive, moist, loose
83.02 0.76	(CI/CH) SILTY CLAY to CLAY, trace sand; brown with red mottling, contains rootlets; cohesive, w>PL, firm to very stiff
78.60 5.18	(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, firm to stiff
74.94 8.84	End of Borehole

NUMBER	TYPE	BLOWS/0.30m
1	SS	5
2	SS	8
3	SS	5
4	SS	2
5	SS	2
6	SS	1
7	SS	WR



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-09

SHEET 1 OF 1

LOCATION: N 5014017.9 ;E 366830.2

BORING DATE: December 8, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

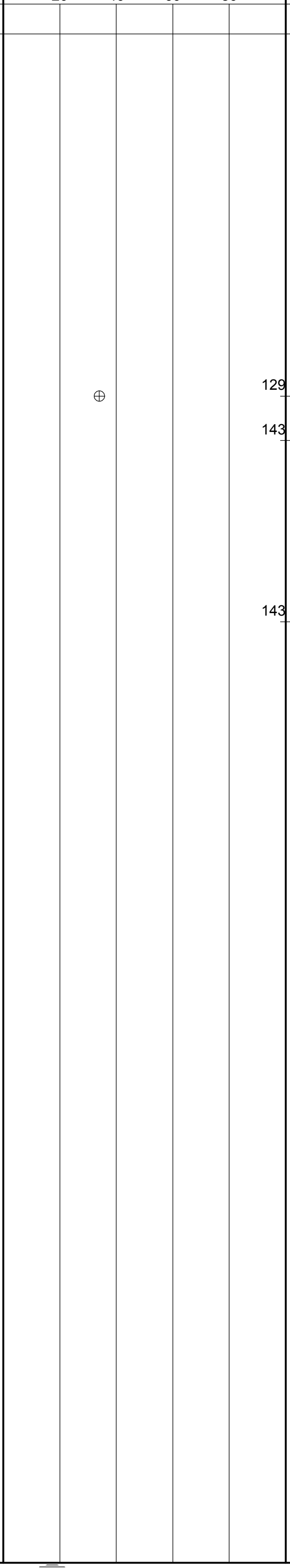
BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	88.91
FILL/TOPSOIL - (SM) SILTY SAND; brown; moist	0.05
FILL - (ML/CL) CLAYEY SILT to SILTY CLAY; brown, contains rootlets; cohesive, w>PL, loose	
(CI/CH) SILTY CLAY to CLAY; brown, contains silt seams (WEATHERED CRUST); cohesive, w>PL, very stiff	88.15 0.76
(ML/SM) gravelly sandy SILT to SILTY SAND; brown (GLACIAL TILL); non-cohesive, most, loose to compact	84.95 3.96
End of Borehole	82.97 5.94

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	5
2	SS	7
3	SS	5
4	SS	5
5	SS	9
6	SS	14

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-10

SHEET 1 OF 2

LOCATION: N 5013992.4 ;E 366898.2

BORING DATE: December 8, 2017

DATUM: CGVD28

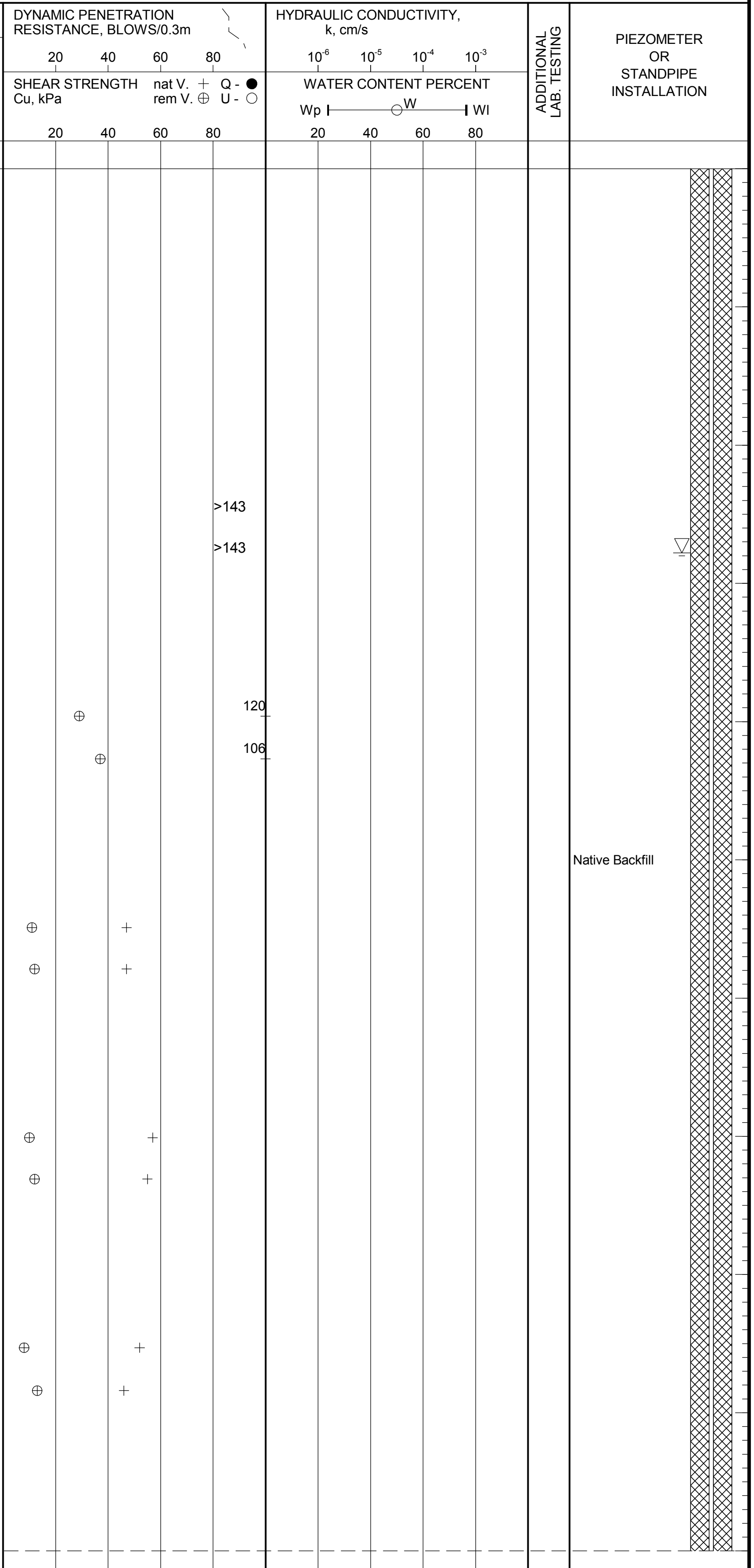
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV.	DEPTH (m)
GROUND SURFACE	86.31	
FILL/TOPSOIL - (ML) sandy SILT; brown; moist		0.05
FILL - (SM/ML) SILTY SAND to CLAYEY SILT; brown; non-cohesive, moist, loose	85.70	0.61
(ML) CLAYEY SILT, some sand; brown, contains silt seams; cohesive, w>PL, very stiff	84.79	1.52
(CI/CH) SILTY CLAY to CLAY, trace sand; brown with red mottling (WEATHERED CRUST); cohesive, w>PL, very stiff	80.83	5.48
(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, stiff to firm		

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	5
2	SS	8
3	SS	5
4	SS	6
5	SS	5
6	SS	PH
7	SS	PH



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DEPTH SCALE
1 : 50

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-10

SHEET 2 OF 2

LOCATION: N 5013992.4 ;E 366898.2

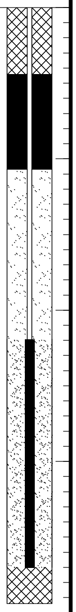
BORING DATE: December 8, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, stiff to firm									Native Backfill
				75.52 10.79							Bentonite Seal
11		(SM) gravelly SILTY SAND; grey, contains cobbles (GLACIAL TILL); non-cohesive, wet, compact									
12					8	SS	16				Silica Sand
13											19 mm Diam. PVC #10 Slot Screen
				72.33 13.98							Cave
14		End of Borehole									W.L. in Screen at Elev. 83.53 m on Feb. 2, 2017
15											
16											
17											
18											
19											
20											



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-11

SHEET 1 OF 1

LOCATION: N 5013966.7 ;E 366959.7

BORING DATE: December 8, 2017

DATUM: CGVD28

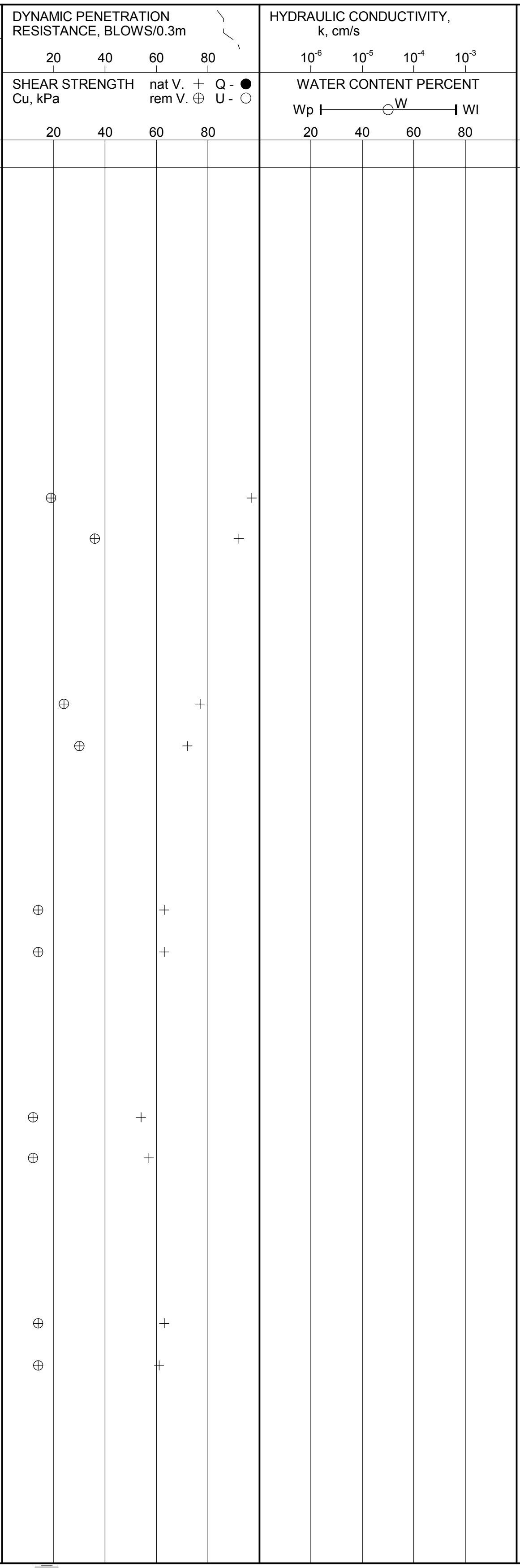
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
GROUND SURFACE		84.22
FILL/TOPSOIL - (SM) sandy SILT; brown; moist	▩	0.00
FILL - (SM) SILTY SAND; dark brown, contains rootlets; non-cohesive, moist, loose	▩	0.10
(CI/CH) SILTY CLAY to CLAY, some sand; brown (WEATHERED CRUST); cohesive, w>PL, stiff to very stiff	▨	83.61 0.61
(CI/CH) SILTY CLAY to CLAY; grey; cohesive; w>PL, stiff	▨	78.12 6.10
End of Borehole		75.38 8.84

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	6
2	SS	5
3	SS	6
4	SS	2
5	SS	3
6	SS	1
7	SS	PH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-12

SHEET 1 OF 1

LOCATION: N 5013936.2 ;E 366820.0

BORING DATE: December 13, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem) (0.00 to 6.10 m)

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	87.91
TOPSOIL - (ML) sandy SILT; brown; moist	0.00
(CI/CH) SILTY CLAY, some sand; brown (WEATHERED CRUST); cohesive, w>PL, very stiff	0.13
(CL/CI) SILTY CLAY, trace sand and gravel; brown, contains silt seams (WEATHERED CRUST); w>PL, very stiff	83.92 3.99
(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, compact	82.58 5.33
End of Borehole	81.81 6.10

SAMPLES

NUMBER	TYPE	BLOWS/0.30m
1	SS	3
2	SS	5
3	SS	7
4	SS	6
5	SS	3
6	SS	16

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

115

143

143

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Native Backfill

Bentonite Seal

Silica Sand

19 mm Diam. PVC #10 Slot Screen

W.L. in Screen at Elev. 87.20 m on Feb. 2, 2017

DEPTH SCALE 1 : 50

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-13

SHEET 1 OF 3

LOCATION: N 5013919.6 ;E 366870.5

BORING DATE: December 12, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	GROUND SURFACE	86.61
0	FILL/TOPSOIL - (ML) sandy SILT; dark brown; moist	0.00
	FILL - (SM/ML) sandy SILT to SILTY SAND; brown; non-cohesive, moist, loose	86.31 0.30
	(CI/CH) SILTY CLAY to CLAY, some sand; brown (WEATHERED CRUST); w>PL, stiff	86.00 0.61
5	(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, stiff	81.43 5.18
8	(CI/CH) SILTY CLAY to CLAY; grey with black mottling, contains sandy silt seams; cohesive, w>PL, firm	78.18 8.43
10		76.63

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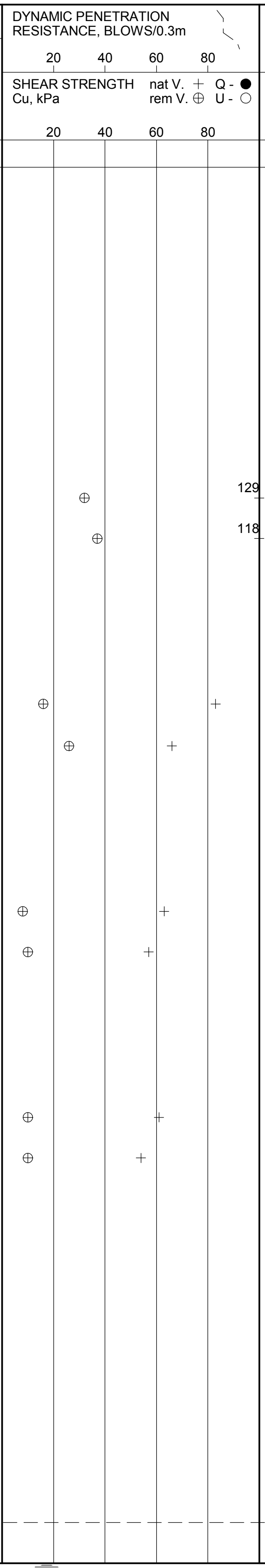
NUMBER	TYPE	BLOWS/0.30m
1	SS	4
2	SS	8
3	SS	5
4	SS	3
5	SS	1
6	SS	PH
7	SS	PH
8	SS	2



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-13

SHEET 2 OF 3

LOCATION: N 5013919.6 ;E 366870.5

BORING DATE: December 12, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ├──○W──┤ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger 200 mm Diam. (Hollow Stem)	(SM) gravelly SILTY SAND; grey, contains cobbles (GLACIAL TILL); non-cohesive, moist		9.98							
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-13

SHEET 3 OF 3

LOCATION: N 5013919.6 ;E 366870.5

BORING DATE: December 12, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Power Auger 200 mm Diam. (Hollow Stem)	(SM) gravelly SILTY SAND; grey, contains cobbles (GLACIAL TILL); non-cohesive, moist									
21											
22					9	AS	-				
				63.75							
23		End of Borehole		22.86							
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 50

LOGGED: DWM

CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-14

SHEET 1 OF 1

LOCATION: N 5013898.3 ;E 366924.6

BORING DATE: December 9, 2017

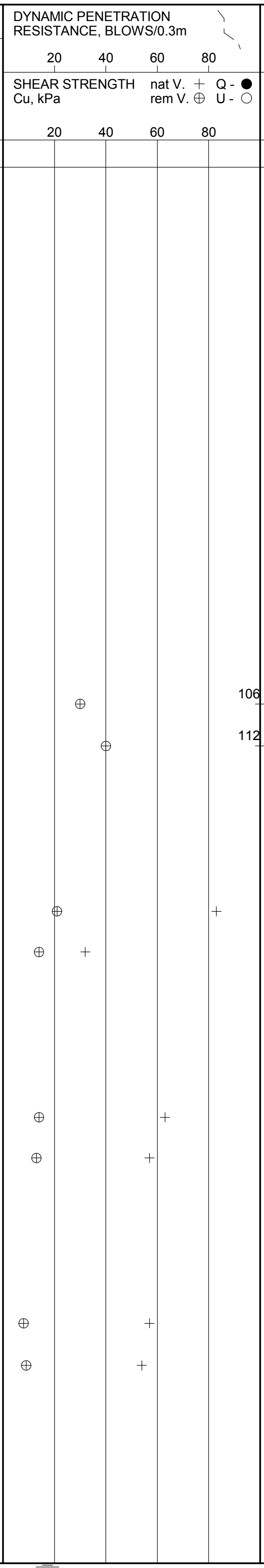
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
GROUND SURFACE	84.83			
FILL/TOPSOIL - (ML) sandy SILT; brown; moist	0.00			
(SM/ML) sandy SILT to SILTY SAND; dark brown, contains rootlets; non-cohesive, moist, loose	0.10	1	SS	5
(CI/CH) SILTY CLAY to CLAY; brown with red motting, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, stiff to very stiff	84.07 0.76	2	SS	6
		3	SS	5
		4	SS	5
		5	SS	4
		6	SS	4
(CI/CH) SILTY CLAY to CLAY; grey with black mottling; cohesive, w>PL, firm to stiff	79.04 5.79	7	SS	PH
		8	SS	PH
End of Borehole	75.99 8.84			



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

MIS-BHS 001 1537295.GPJ GAL-MIS.GDT 03/13/17 JEM/TB

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM
CHECKED: EDW

PROJECT: 1537295

RECORD OF BOREHOLE: 16-15

SHEET 1 OF 1

LOCATION: N 5013834.4 ;E 366824.6

BORING DATE: December 13, 2017

DATUM: CGVD28

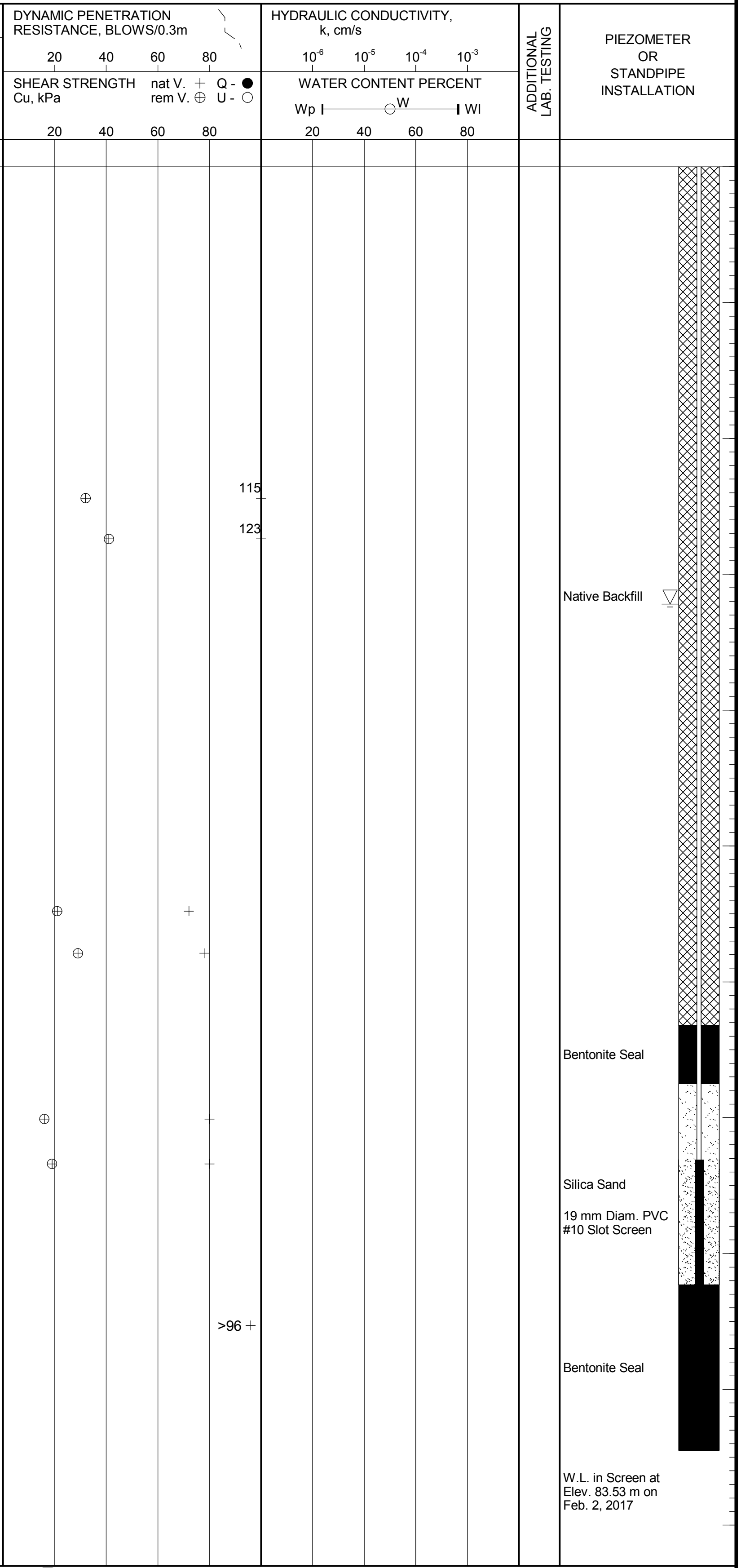
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	86.75
TOPSOIL - (ML) sandy SILT; brown; moist	0.08
(CI/CH) SILTY CLAY to CLAY, some sand; brown with red mottling (WEATHERED CRUST); cohesive, w>PL, stiff to very stiff	
(CI/CH) SILTY CLAY to CLAY; grey, contains silt seams; cohesive, w>PL, stiff	80.65 6.10
(SM) gravelly SILTY SAND; grey (GLACIAL TILL); non-cohesive, wet, compact	78.22 8.53
End of Borehole	77.30 9.45

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	6
2	SS	7
3	SS	5
4	SS	5
5	SS	5
6	SS	3
7	SS	PH
8	SS	1
9	SS	20



DEPTH SCALE 1 : 50

Golder Associates

LOGGED: DWM

CHECKED: EDW

APPENDIX C

Core Photos and Results of UCS Testing

BH 18-02 (Dry)
Cored Length of 28.02 to 33.21 metres
Core Box 1 to 3 of 3

28.02 m Top of Bedrock

33.21 m EOH

CLIENT
Ottawa Police Service

PROJECT
Additional Geotechnical Investigation
Proposed Ottawa Police Service South Campus Facility
55 Lodge Road, Ottawa, Ontario

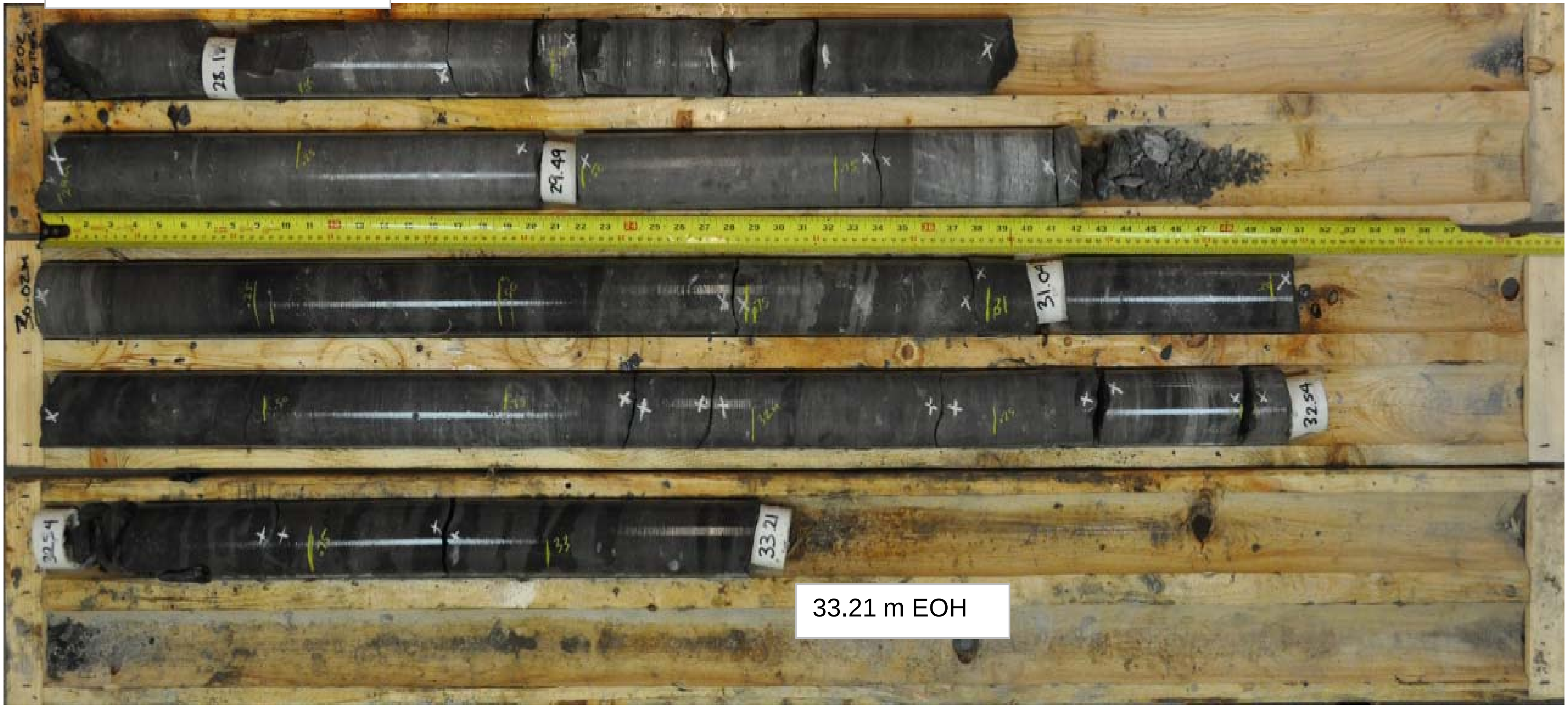
CONSULTANT
GOLDER

MM/DD/YYYY	05/12/2018
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

TITLE
BOREHOLE 18-02 (DRY)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	1000	0	C1A

BH 18-02 (Wet)
Cored Length of 28.02 to 33.21 metres
Core Box 1 to 3 of 3


28.02 m Top of Bedrock

33.21 m EOH

CLIENT
Ottawa Police Service

PROJECT
Additional Geotechnical Investigation
Proposed Ottawa Police Service South Campus Facility
55 Lodge Road, Ottawa, Ontario

CONSULTANT
GOLDER

MM/DD/YYYY	05/12/2018
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

TITLE
BOREHOLE 18-02 (WET)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	1000	0	C1B

BH 19-01 (Dry)
Cored Length of 35.25 to 37.35 metres
Core Box 1 to 1 of 1

35.25 m Top of Bedrock

37.35 m EOH

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CONSULTANT
GOLDER

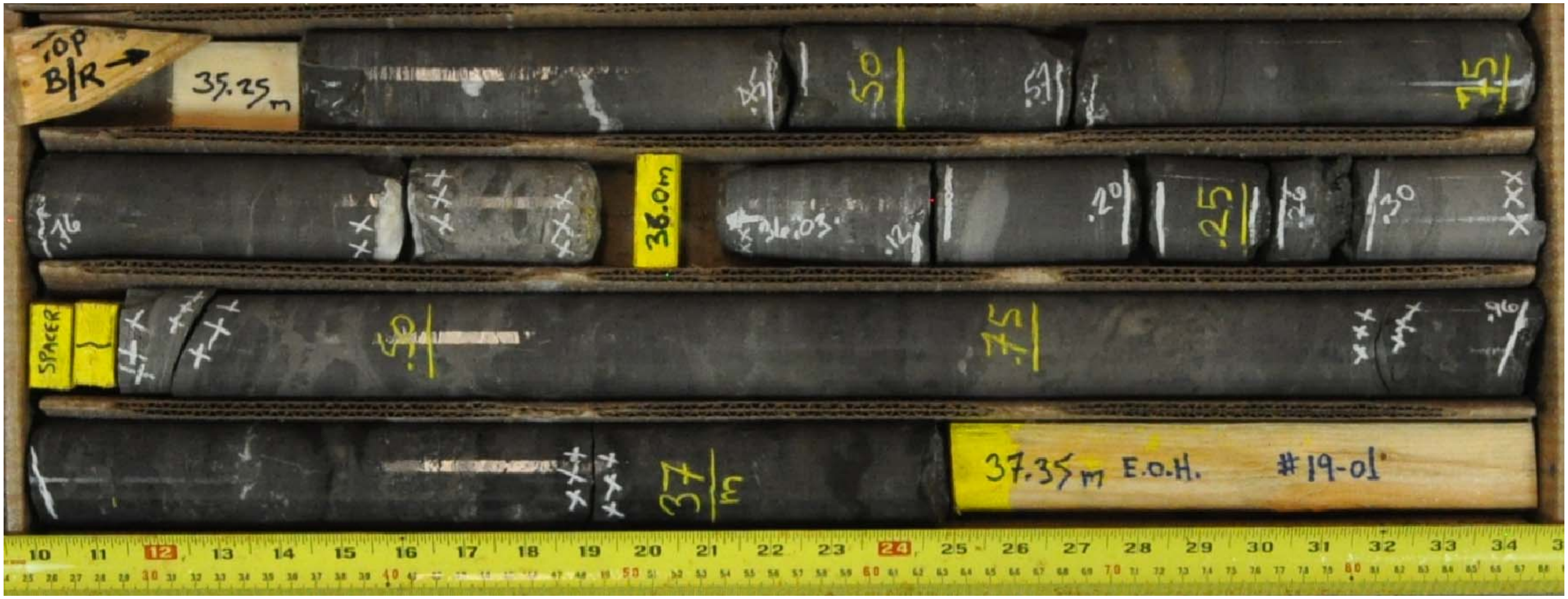
MM/DD/YYYY	08/03/2019
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

TITLE
BOREHOLE 19-01 (DRY)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	5000	0	C2A

BH 19-01 (Wet)
Cored Length of 35.25 to 37.35 metres
Core Box 1 to 1 of 1

35.25 m Top of Bedrock



37.35 m EOH

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MM/DD/YYYY	08/03/2019
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

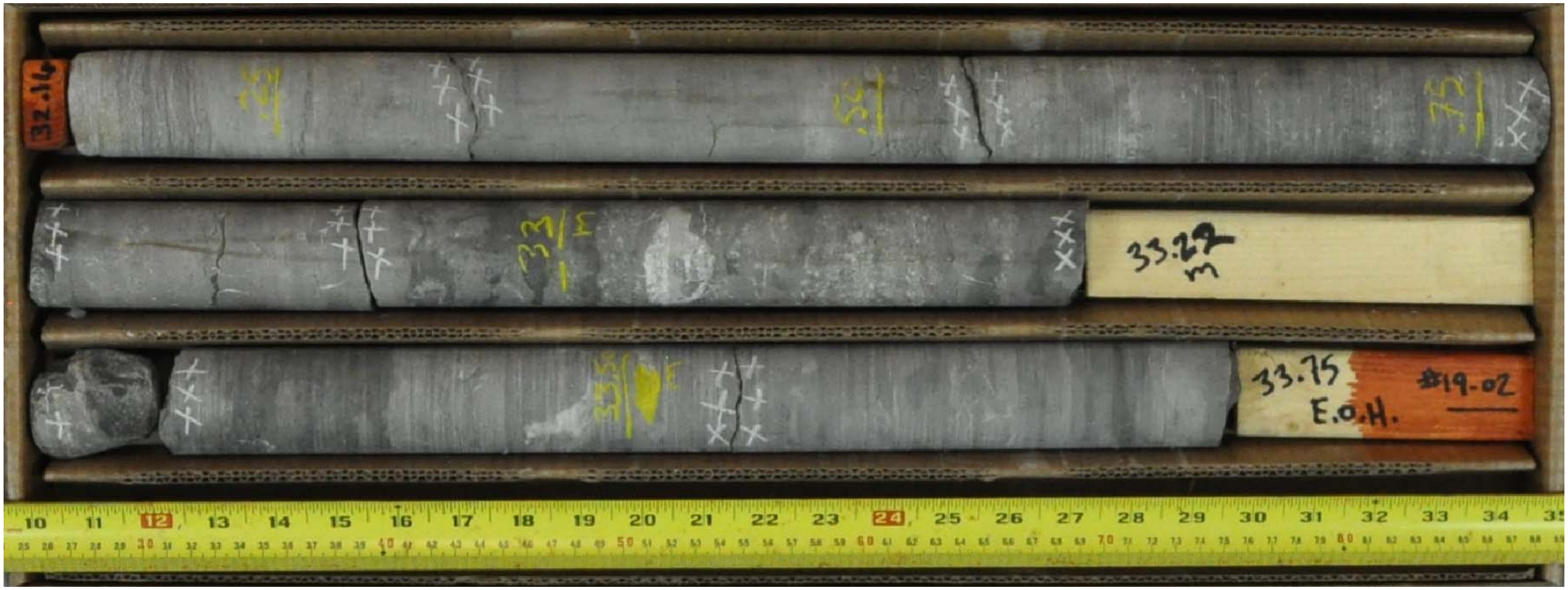
TITLE
BOREHOLE 19-01 (WET)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	5000	0	C2B

Path: \\golderassociates.sharepoint.com@SSL\DavWWWRoot\sites\34624g\Deliverables\Report\Appendix C - UCS Testing and Core Photos\18111310 OPS South core photos plate.xlsx | File: 18111310 OPS South core photos plate.xlsx

BH 19-02 (Dry)
Cored Length of 32.16 to 33.75 metres
Core Box 1 to 1 of 1

32.16 m Top of Bedrock



33.75 m EOH

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Ottawa Police Service

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MM/DD/YYYY	08/03/2019
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

PROJECT
Additional Geotechnical Investigation
Proposed Ottawa Police Service South Campus Facility
55 Lodge Road, Ottawa, Ontario

TITLE
BOREHOLE 19-02 (DRY)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	6000	0	C3A

BH 19-02 (Wet)
Cored Length of 32.16 to 33.75 metres
Core Box 1 to 1 of 1

32.16 m Top of Bedrock

33.75 m EOH

CLIENT
Ottawa Police Service

PROJECT
Additional Geotechnical Investigation
Proposed Ottawa Police Service South Campus Facility
55 Lodge Road, Ottawa, Ontario

CONSULTANT

GOLDER

MM/DD/YYYY	08/03/2019
PREPARED	CRG
DESIGN	CRG
REVIEW	MSS
APPROVED	MSS

TITLE
BOREHOLE 19-02 (WET)
CORE PHOTOGRAPHS

PROJECT No.	PHASE	Rev.	FIGURE
18111310	6000	0	C3B

Golder Associates Ltd.
1931 Robertson Road
Ottawa, Ontario
K2H 5B7

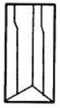
UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE

Project: OPS South Campus

Project No.: 18111310

Date: January 18, 2019

Location(s): See Table Below

Bore Hole No.	Depth (m)	Date Tested	Core Size	Diameter (mm)	Density (kg/m³)	Compressive Strength (MPa)	Failure Mode
18-02	29.18-29.32	Jan 16/19	HQ	60.7	2752	190.6	
18-02	30.50-30.64	Jan 16/19	HQ	60.8	2786	232.1	

REMARKS :
- Cores tested in vertical direction.
- Cores tested in air-dry condition.
- Specimen ends prepared with high-strength plaster, but un-restrained.
- L/D ratio's between 2.0:1 and 2.5:1
- Time to failure > 2 and < 15 minutes.
- This report constitutes a testing service only. Interpretation of results will be provided on request only.

TESTING WAS CARRIED OUT IN GENERAL ACCORDANCE WITH ASTM D7012 - Method C

SIGNED: Melanie Ireland

APPENDIX D

Results of Chemical Analysis (Eurofins Testing Report No. 1900469)

eurofins
Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario
K2E 7Y1
Attention: Mr. Raj Goyal
PO#:
Invoice to: Golder Associates Ltd

Report Number: 1900469
Date Submitted: 2019-01-09
Date Reported: 2019-01-16
Project: 18111310
COC #: 839531

				Lab I.D.	1406932	1406933
				Sample Matrix	Soil	Soil
				Sample Type		
				Sampling Date	2019-01-08	2019-01-08
				Sample I.D.	18-02 SA 10	18-02 SA 15
Group	**Analyte**	**MRL**	**Units**	**Guideline**		
Anions	Cl	0.002	%		<0.002	<0.002
	SO4	0.01	%		0.04	0.03
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.57	0.57
	pH	2.00			7.93	8.21
	Resistivity	1	ohm-cm		1770	1760

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX E

Results of Vertical Seismic Profiling Test (Geophysics)

GOLDER

TECHNICAL MEMORANDUM

DATE December 20, 2018 **Project No.** 18111310

TO Goyal Chaitanya M.A. Sc., Golder Associates Ltd.

FROM Stephane Sol, Christopher Phillips **EMAIL** ssol@golder.com, cphillips@golder.com

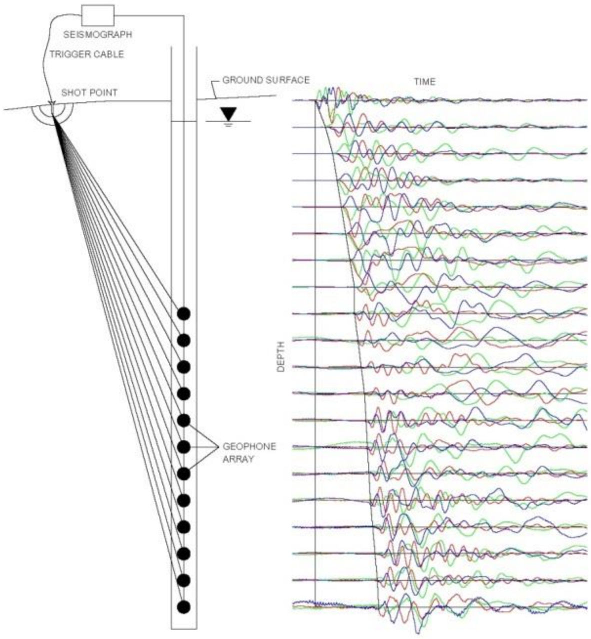
VERTICAL SEISMIC PROFILING TEST RESULTS
2614 PRINCE OF WALES DRIVE, OTTAWA

This memorandum presents the results of one Vertical Seismic Profiling (VSP) testing carried out in a field located at 2614 Prince of Wales Drive in Ottawa, Ontario. VSP testing was carried out on December 12, 2018. Borehole 18-01 was drilled to an approximate depth of 28.9 m below the existing ground surface and then cased with a 2.5 inch PVC pipe grouted in place.

Methodology

For the VSP method, seismic energy is generated at the ground surface by an active seismic source and recorded by a geophone located in a nearby borehole at a known depth. The active seismic source can be either compression or shear wave. The time required for the energy to travel from the source to the receiver (geophone) provides a measurement of the average compression or shear-wave seismic velocity of the medium between the source and the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole.

The high resolution results of a VSP survey are often used for earthquake engineering site classification, as per the 2015 National Building Code of Canada (NBCC 2015).



Example 1: Layout and resulting time traces from a VSP survey.

Fieldwork

The fieldwork was carried out on December 12, 2018, by personnel from the Golder Mississauga office.

At borehole 18-01, the compression and shear-wave seismic sources were located 2 m from the borehole. The seismic source for the compression wave test consisted of a 9.9 kilogram sledge hammer vertically impacted on a metal plate. The seismic source for the shear-wave test consisted of a 2.4 metre long, 150 millimetre by 150 millimetre wooden beam, weighted by a vehicle and horizontally struck with a 9.9 kilogram sledge hammer on alternate ends of the beam to induce polarized shear waves. The shear source was coupled to the ground surface by parking a vehicle on top of it. Test measurements started at ground surface and were recorded in the borehole with a 3-component receiver spaced at 1-metre intervals below the ground surface to a depth of 28.3 m.

The seismic records collected for each source location were stacked a minimum of five times to minimize the effects of ambient background seismic noise on the collected data. The data was sampled at 0.020833 millisecond intervals and a total time window of 0.341 seconds was collected for each seismic shot.

Data Processing

Processing of the VSP test results consisted of the following main steps:

1) Combination of seismic records to present seismic traces for all depth intervals on a single plot for each seismic source and for each component;

2) Low Pass Filtering of data to remove spurious high frequency noise;

3) First break picking of the compression and shear-wave arrivals; and,

4) Calculation of the average compression and shear-wave velocity to each tested depth interval.

Processing of the VSP data was completed using the SeisImager/SW software package (Geometrics Inc.). The seismic records at borehole 18-01 are presented on the following two plots and show the first break picks of the compression wave (Figure 1) and shear wave arrivals (Figure 2) overlaid on the seismic waveform traces recorded at the different geophone depths. The arrivals were picked on the vertical component for the compression source and on the two horizontal components for the shear source.

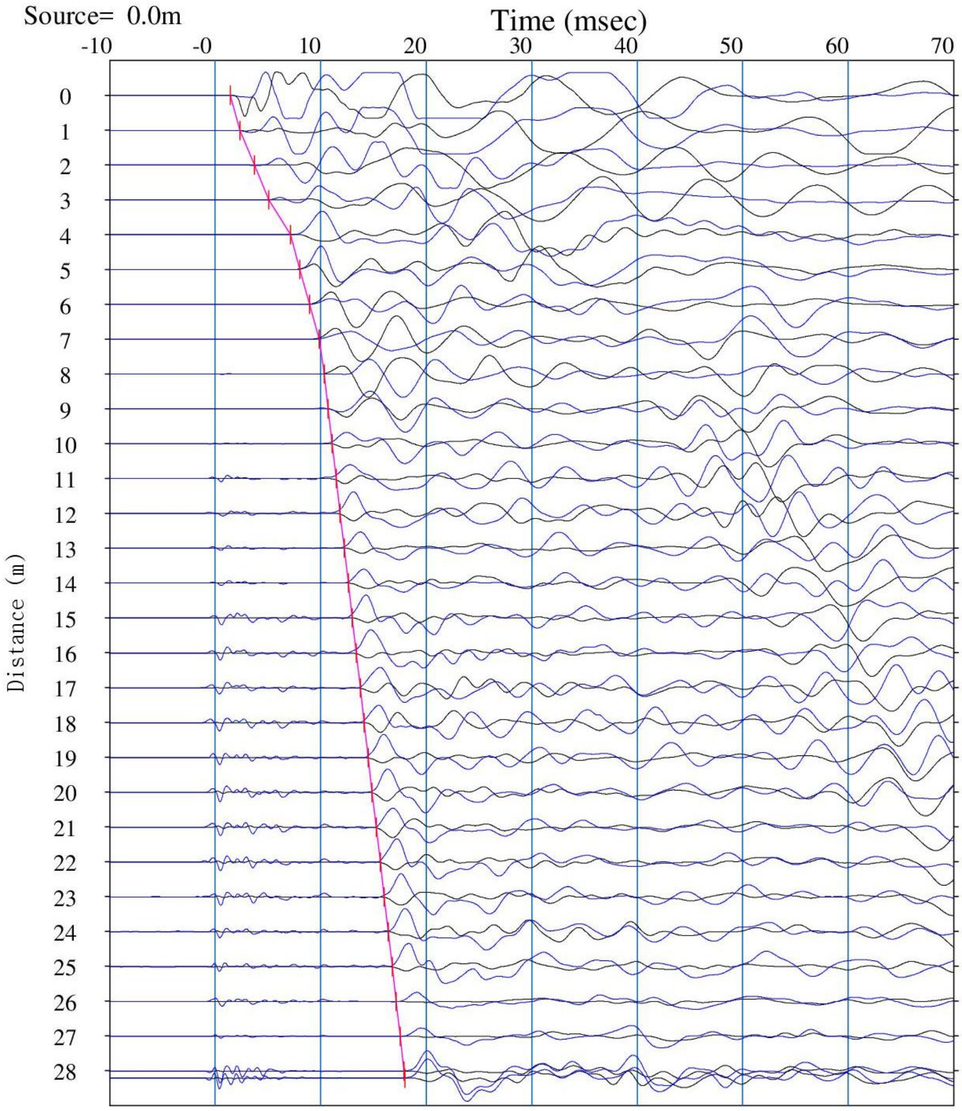


Figure 1: First break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 18-01.

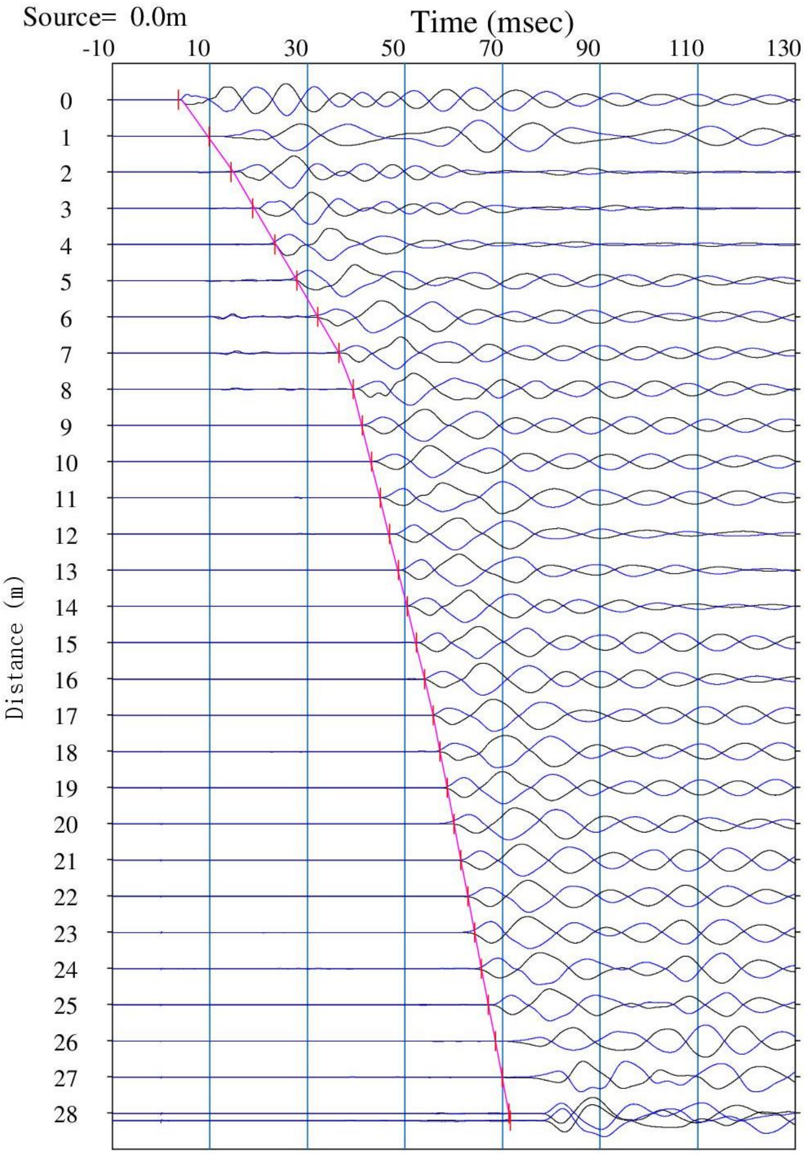


Figure 2: First break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth of Borehole 18-01.

Results

The VSP results at borehole 18-01 are summarized in Table 1. The shear wave and compression wave layer velocities were calculated by best fitting a theoretical travel time model to the field data. The depths presented on the table are relative to ground surface.

The estimated dynamic engineering moduli, based on the calculated wave velocities, are also presented in Table 1. The engineering moduli were calculated using an estimated bulk density, based on the borehole log. An estimated bulk density of 2,150 kg/m^3 was used for the sandy silty clay layer, 1,760 kg/m^3 was used for the very stiff silty clay, 1,750 kg/m^3 was used for the stiff silty clay, and 2,300 kg/m^3 was used for the sandy silt and silty sand till layers.

At borehole 18-01, the average shear wave velocity from ground surface to a depth of 30 metres was measured to be 406 metres per second. The average velocity was calculated assuming that the shear wave velocity from 28.3 metres to a depth of 30 metres was constant with an average shear-wave velocity value of 700 m/s which is equal to the velocity of the shale bedrock at the bottom of the borehole.

Limitations

This technical memorandum, which specifically includes all tables, figures and attachments, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

Closure

We trust that these results meet your current needs. If you have any questions or require clarification, please contact the undersigned at your convenience.

GOLDER ASSOCIATES LTD.

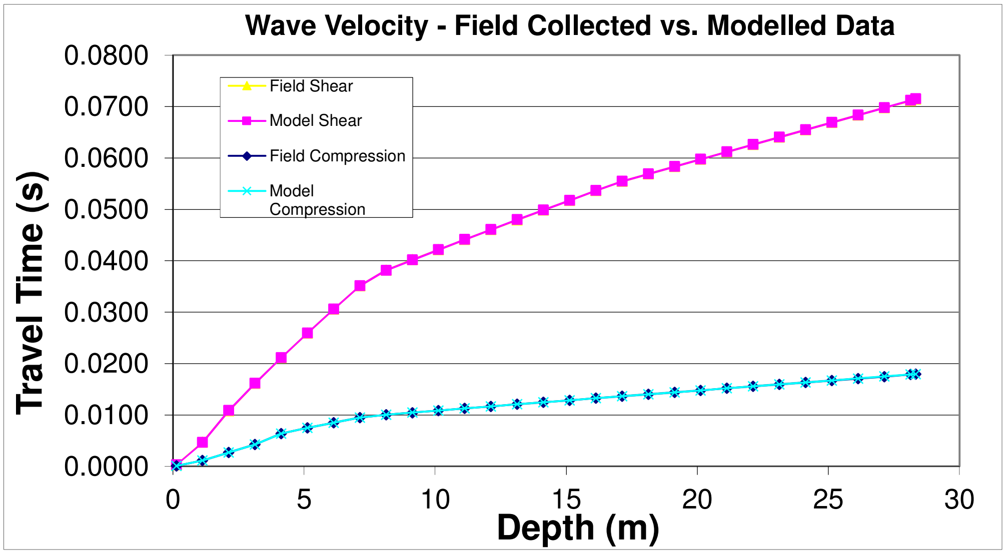
Stephane Sol, Ph.D., P. geo. *Senior Geophysicist*	Christopher Phillips, M.Sc., P. Geo. *Senior Geophysicist, Principal*

SS/CRP/jl

Attach: Table 1

TABLE 1
SHEAR WAVE VELOCITY PROFILE AT BH-18-01

Layer Depth (m)		Velocities (m/s)		Estimated Bulk Density (kg/m^3)	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave	Shear Wave		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	0.1	1410	470	2150	0.44	475	1365	3641
0.1	1.1	950	230	2150	0.47	114	334	1789
1.1	2.1	650	160	2150	0.47	55	162	835
2.1	3.1	630	190	1760	0.45	64	184	614
3.1	4.1	480	200	1760	0.39	70	196	312
4.1	5.1	900	210	1760	0.47	78	228	1322
5.1	6.1	1000	215	1760	0.48	81	240	1652
6.1	7.1	1000	220	1750	0.47	85	250	1637
7.1	8.1	1800	330	2300	0.48	250	743	7118
8.1	9.1	2300	495	2300	0.48	564	1663	11416
9.1	10.1	2450	495	2300	0.48	564	1667	13054
10.1	11.1	2450	510	2300	0.48	598	1768	13008
11.1	12.1	2500	520	2300	0.48	622	1838	13546
12.1	13.1	2500	525	2300	0.48	634	1873	13530
13.1	14.1	2550	530	2300	0.48	646	1909	14094
14.1	15.1	2550	530	2300	0.48	646	1909	14094
15.1	16.1	2550	530	2300	0.48	646	1909	14094
16.1	17.1	2550	545	2300	0.48	683	2017	14045
17.1	18.1	2600	690	2300	0.46	1095	3202	14088
18.1	19.1	2600	700	2300	0.46	1127	3293	14045
19.1	20.1	2600	700	2300	0.46	1127	3293	14045
20.1	21.1	2600	700	2300	0.46	1127	3293	14045
21.1	22.1	2600	700	2300	0.46	1127	3293	14045
22.1	23.1	2600	700	2300	0.46	1127	3293	14045
23.1	24.1	2600	700	2300	0.46	1127	3293	14045
24.1	25.1	2600	700	2300	0.46	1127	3293	14045
25.1	26.1	2600	700	2300	0.46	1127	3293	14045
26.1	27.1	2600	700	2300	0.46	1127	3293	14045
27.1	28.1	2600	700	2300	0.46	1127	3293	14045
28.1	28.3	2600	700	2300	0.46	1127	3293	14045



Notes

1. Depth Presented relative to ground surface.
2. This Table to be analyzed in conjunction with the accompanying report.

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