REPORT

Geotechnical Investigation

Proposed Central Library
555 Albert Street
Ottawa, Ontario

Submitted to:

Richard Fouchard
City of Ottawa
100 Constellation Crescent
Ottawa, Ontario

Submitted by:

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

+1 613 592 9600

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the City of Ottawa (the City) to conduct a geotechnical investigation in order to provide geotechnical input to the detailed design of the proposed Ottawa Central Library site located at 555 Albert Street in Ottawa, Ontario. A Site Location Plan is attached as Figure 1. It is understood that the development will consist of a 4 to 5 storey structure with up to two levels of underground parking as well as an asphalt surfaced laneway with parking. The investigation and reporting were carried out in general accordance with the scope of work provided in our proposal no. P19131600 dated October 4, 2019.

The purpose of this investigation was to assess the general subsurface and groundwater conditions within the study area by means of a limited number of 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 investigations, 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

The site is currently owned by the City of Ottawa and was recently being used as a staging area for the construction of the Combined Sewage Storage Tunnel (CSST) and Ottawa Light Rail Transit (OLRT) projects. The property is bordered to the north by the west OLRT tunnel portal, and the CSST tunnel passes beneath the site.

The preliminary plans and information provided indicate that the proposed building footprint is an irregularly shaped rectangular area measuring approximately 60 m by 130 m. It is assumed that below grade excavations would extend to approximately 1 m below the founding slab to a depth of 5 to 7 mbgs.

Seven existing boreholes from previous investigations (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 investigations are contained in the following reports:

- Golder Report No. 10-1121-0222 titled *"Geotechnical Data Report, Geotechnical and Hydrogeological Investigation, Ottawa Light Rail Transit, (OLRT) Tunnel (Segment 2), Ottawa, Ontario"* and dated December 2011.
- Golder Report No. 13-1121-0143 titled *"Geotechnical Data Report, Geotechnical and Hydrogeological Investigation, Combined Sewage Storage Tunnel (CSST), Ottawa, Ontario"* and dated July 2015.
- Golder Report No. 1522242 titled: "*Summary of Phase II Environmental Site Assessment Results, 557 Wellington Street and Adjacent Property, Ottawa, Ontario*", and dated May 2015.
- Golder Report No. 06-1120-331-300 titled *"Phase II Environmental Site Assessment, Lemieux Island High Pressure Transmission Main (HPTM) Replacement Program Part 2, City Centre Drive to Commissioners Avenue, Ottawa, Ontario",* and dated December 2006.

Based on the results of previous investigations and the published geology maps available from the Geologic Survey of Canada (GSC) for this area, the subsurface conditions at this site are expected to consist of a surficial layer of fill, overlying a thick deposit of glacial till. The glacial till is underlain by interbedded limestone and shale bedrock of the Verulam formation. Depth to bedrock within the footprint of the proposed structure varies between about 6 m below the existing ground surface on the north side and 13 m below the existing ground surface in the center of the proposed structure.

3.0 PROCEDURE

The fieldwork for this investigation was carried out between November 20 and December 3, 2019. During that time, a total of 18 boreholes (numbered 19-01 to 19-09, 19-101, and 19-102) were advanced at the approximate locations shown on the attached Site Plan (Figure 1). At boreholes 19-04, 19-09, and 19-101, additional holes were advanced adjacent to the borehole (i.e. 19-04A, 19-04B, 19-09A, 19-09B, 19-09C, 19-101A, and 19-101B) to attempt to obtain additional samples below the depth of original refusal.

The boreholes were advanced using a truck-mounted hollow-stem auger drill rig supplied and operated by CCC Drilling of Ottawa, Ontario. The boreholes were advanced to depths ranging from between 0.7 and 8.2 m below the existing ground surface.

Standard Penetration Tests (SPTs) were carried out within the overburden at regular intervals of depth. Samples of the soils encountered were recovered using 35 mm diameter split-spoon sampling equipment.

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 samples were transported to our laboratory for further examination and laboratory testing, which included natural water content and grain size distribution tests on selected soil samples.

Two samples of soil, one from each of boreholes 19-101 and 19-102 was 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.

The borehole locations were selected in consultation with the City of Ottawa, marked in the field, and subsequently surveyed by City of Ottawa personnel. 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:

- Borehole records from the current investigation are provided in Appendix A.
- Borehole records and results of UCS testing from previous investigations are provided in Appendix B.
- Results of the basic chemical analyses are provided in Appendix C.
- Results of hydraulic conductivity testing carried out during previous investigations are provided in Appendix D.

- Results of the water content testing are provided on the Record of Borehole Sheets.
- Results of the grain size distribution testing are provided on Figures 4 and 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 SPTs 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.

Unless otherwise noted, the following sections present an 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 and hydraulic response tests 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 glacial till at depths of 1.4 to 3.7 m below the existing ground surface.

4.3 Fill Material

Fill material was encountered in each of the boreholes from ground surface. The fill is heterogeneous in nature and consists of gravelly sand, to gravelly silty sand, to silty sand, to sand and gravel, to sand, and contains brick fragments, concrete fragments, pockets of silty clay, ash, and cobbles and boulders.

SPT “N” values measured within the fill ranged from 2 to 100 blows per 0.3 m of penetration. The SPT “N” values suggest that the fill has a highly variable very loose to very dense state of packing.

The fill material was fully penetrated in most of the boreholes at depths of between about 1.4 and 3.7 m below the existing ground surface.

The results of natural moisture content testing carried out on six samples of the fill gave values ranging from between 8 and 22 percent. The results of grain size distribution testing carried out on three samples of the fill are presented on Figure 4.

Auger refusal was encountered within the fill material at a depth of about 2.4 m below the existing ground surface in borehole 19-07. Auger refusal was also encountered at shallow depths in unsampled boreholes 19-04A, 19-09A, 19-09B, 19-101A, and 19-101B at depths of between about 0.7 and 3.4 m below the existing ground surface. It is likely that at many locations’ auger refusal was caused by the presence of cobbles and boulders.

4.4 Glacial Till

A deposit of glacial till was encountered beneath the fill material at all of the boreholes. The glacial till typically consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sand and silt with a trace to some clay. At some locations, the till consists of clayey sand containing gravel, cobbles and boulders. The glacial till was not fully penetrated in the current investigation but was proven to depths of between about 2.9 and 8.2 m below the existing ground surface.

SPT “N” values within the glacial till layer gave ‘N’ values ranging from 8 blows to 100 blows per 0.3 m of penetration, but more generally between 35 and greater than 50 blows per 0.3 m of penetration indicating a loose, but more generally dense to very dense state of packing. Higher blow counts, however, could be indicative of boulders and cobbles in the till rather than the state of packing.

The results of natural moisture content testing carried out on four samples of the glacial till gave values ranging from 5 to 10 percent. The results of grain size distribution testing carried out on three samples of the glacial till are presented on Figure 5.

4.5 Bedrock

Previous boreholes were extended through the glacial till deposit into the underlying bedrock using rotary diamond drilling techniques. The depths and elevations to bedrock surface are summarized below:

Borehole No.	Ground Surface Elevation (masl)	Depth to Bedrock (m)	Elevation of Bedrock (masl)
T-1	65.71	6.99	59.22
T-2	66.32	8.09	58.72
T-74	63.41	6.29	57.12
T-75	61.79	11.08	50.71
W-058	61.40	7.36	54.04
W-059	61.68	9.84	51.84
W-060	61.23	9.17	52.06
W-061	61.55	9.01	52.54
W-062	62.95	5.88	57.07
13-3	62.49	11.08	51.41
13-4	62.20	10.64	51.56
13-5	62.11	11.51	51.33
13-6	61.95	11.15	50.8
14-601	62.34	13.43	48.91
14-602	63.00	11.3	51.70
14-603	61.41	8.38	53.03
14-604	56.44	4.34	52.10

The bedrock consists of limestone with shale interbeds of the Verulam formation. Additional description of the bedrock is provided on the Borehole records provided in Appendix B.

The results of laboratory testing carried out on samples of the cored bedrock from previous investigations measured Uniaxial Compressive Strengths (UCS) of between about 19 and 64 MPa, indicating the samples of the rock tested is medium strong to strong. Results of the UCS testing carried out are presented in Appendix B.

4.6 Groundwater Conditions

Monitoring wells were installed in boreholes 19-01, 19-02, 19-03, 19-05, 19-06, 19-07, 19-08, 19-09C, and 19-102 in the current investigation. Monitoring wells were also installed in boreholes 13-3, 13-4, 13-6, T-75, W-058, W-060, and W-062 during the previous investigations. The groundwater levels observed in the monitoring wells have been summarized in the following table:

Well ID	Geologic Unit of Screened Interval	Groundwater Level		Date of Measurement	Hydraulic Conductivity (cm/s)
		Depth (mbgs)	Elevation (masl)		
19-01	Glacial Till	2.60	58.39	December 10, 2019	--
19-02	Glacial Till	3.36	60.27	December 10, 2019	--
19-03	Glacial Till	5.66	56.92	December 10, 2019	--
19-05	Glacial Till	5.17	56.54	December 10, 2019	--
19-06	Fill/Glacial Till	2.34	62.04	December 10, 2019	--
19-07	Fill	2.14	58.97	December 10, 2019	--
19-08	Glacial Till	5.52	56.86	December 10, 2019	--
19-09C	Glacial Till	4.50	58.16	December 10, 2019	--
19-102	Glacial Till	4.25	58.44	December 10, 2019	--
13-3	Glacial Till	--	--	February 22, 2013	4×10^{-5}
13-4	Fill/Glacial Till	--	--	February 22, 2013	6×10^{-5}
13-6	Bedrock	--	--	February 22, 2013	1×10^{-4}
T-75	Glacial Till	3.06	58.73	June 28, 2011	--
W-058	Glacial Till	3.71	57.69	January 20, 2011	2×10^{-6}
W-060	Fill/Glacial Till	3.51	57.72	January 20, 2011	5×10^{-6}
W-062	Glacial Till	2.58	60.37	January 20, 2011	1×10^{-6}
15-01	Glacial Till	4.53	57.65	March 9, 2015	--
15-02	Glacial Till	5.52	56.32	March 9, 2015	--
15-03	Glacial Till	6.1	--	March 3, 2015	--
06-24	Glacial Till	2.60	59.92	December 8, 2006	--
06-25	Glacial Till	1.98	60.64	December 8, 2006	--
06-26	Glacial Till	3.47	60.57	December 8, 2006	--
06-27	Glacial Till	3.30	62.42	December 8, 2006	--

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.

4.7 Corrosion Testing

Two samples of soil, one each from boreholes 19-101 and 19-102 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 C and are summarized below.

Borehole / Sample Number	Sample Depth (m)	Chloride (%)	Sulphate (%)	pH	Resistivity (Ohm-cm)
19-101 SA 4	2.4 – 2.9	0.016	0.01	8.3	3330
19-102 SA 7	4.6 – 5.2	0.007	0.02	8.5	4170

5.0 DISCUSSION AND GEOTECHNICAL RECOMMENDATIONS

This section of the report provides engineering information related to the geotechnical design aspects of the project based on our interpretation of the available subsurface information and on our understanding of the project requirements. The discussion below focuses on the development of the proposed structure.

The information in this portion of the report is provided for detailed design purposes in support of the design by the engineers and architects. The recommendations provided herein are consistent with the Ontario Building Code of 2012 (OBC 2012), including the latest amendment under O. Reg. 88/19. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

This report addresses only the geotechnical aspects of the subsurface conditions at this site.
The geo-environmental (chemical) aspects, including the consequences 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 report. The results of a concurrent Phase II Environmental Site Assessment for this project are provided under separate cover.

5.1 Site Grading

It is understood that a grade raise of up to 2.4 m is proposed at the site to match the proposed grade raise of Albert Street. The proposed grade raise is within acceptable limits for the soils at this site. A proposed grading plan was not available for review at the time of writing this report.

5.2 Foundation Design

Based on the conceptual design information provided to Golder, the proposed structure will have one to two underground parking levels. As such, the excavation for the structure is expected to extend to depths of about 5 to 7 m below existing site grades.

The subsurface conditions present below the fill at this site generally consist of glacial till over limestone bedrock.

5.2.1 Shallow Spread Footings

In some areas of the structure, the structure may be founded on spread footings supported on the underlying bedrock provided that they can be designed using the bearing resistance values provided below. Where bedrock is deeper than the footing elevation, footings may be placed on glacial till.

5.2.1.1 Footings on Bedrock

Spread footings founded on clean, sound and undisturbed bedrock are considered to be a feasible option. For spread footings placed on sound bedrock, a factored Ultimate Limit States (ULS) bearing resistance of 1,000 kPa can be used for design of the foundations. Serviceability Limit States (SLS) net bearing resistances do not generally apply to the design of foundations on the bedrock, provided the bedrock surface is properly cleaned of soil and loose highly weathered/fractured bedrock at the time of construction. The ULS bearing resistance for foundations on bedrock may need to be reduced within the vicinity of the existing CSST which crosses over the site (as outlined in Section 5.3 of this report) in order to comply with CSST requirements.

For ULS sliding resistance of a cast-in-place footing placed on bedrock, an unfactored sliding friction coefficient of 0.70 can be used. In accordance with OBC 2012 requirements, a resistance factor of 0.8 should be applied to the sliding resistance between the footings and the underlying bedrock.

5.2.1.2 Footing on Glacial Till

The structure may be also founded on spread footings supported on the underlying glacial till provided that they can be designed using the bearing resistance values provided below.

Spread footings founded on the compact to dense glacial till (i.e., SPT 'N' values higher than about 25) below about Elevation 58.0 m are considered to be a feasible option. An SLS net bearing resistance of 250 kPa and a factored ULS bearing resistance of 400 kPa can be used for design of pad footings up to 5.0 m in width and for strip footings up to 2.0 m in width placed on native and undisturbed glacial till below this elevation. The SLS values provided correspond to calculated total and differential settlement values of 25 and 19 mm, respectively.

It should be noted that because the expected settlements of spread footings placed directly on the underlying bedrock are very small, differential settlements of up to about 25 mm may occur between the spread footings placed on glacial till and those placed directly on the underlying bedrock. The design of the new structure will have to consider these differential settlements between the foundations supported on bedrock, and those supported on the more compressible glacial till. Structural separation maybe required between the foundations supported on bedrock, and those supported on glacial till.

For ULS sliding resistance of a cast-in-place footing placed on glacial till, an unfactored friction coefficient of 0.45 can be used. In accordance with OBC 2012 requirements, a resistance factor of 0.8 should be applied to the sliding resistance between the footings and the underlying glacial till.

5.2.2 Concrete Caisson Foundations

It is understood that the west portion of the proposed structure will be founded on concrete caissons, and that pile driving is not permitted at this site. It is further understood that the foundation loads will be transferred across the underlying CSST with the use of a "bridge" structure such that the loads will be carried by caissons at a distance of at least 3 metres from the CSST.

The proposed caissons will be socketed into the limestone bedrock. The use of a casing will be required to advance the caisson through the glacial till material into the underlying bedrock. If a casing is used, it should be extended so that it is "seated" a minimum of 500 mm into the bedrock.

5.2.2.1 Axial Geotechnical Resistance

Due to the difficulty in socketing liners into the limestone bedrock to completely cut off the water infiltrations, it may not be feasible to dewater and clean the base of the caisson, or to inspect the base prior to concreting. As such, end-bearing support may not be fully developed and should be neglected in the design. The axial geotechnical resistance for rock-socketed caissons is therefore recommended to be based on the side-wall (shaft) resistance of the rock socket rather than end-bearing.

Rock-socketed caissons should be designed based on the side-wall (shaft) resistance of the rock socket and a factored geotechnical resistance at ULS of 1.1 MPa, provided that the caisson socket is within competent bedrock (i.e., RQD greater than 75 percent). For preliminary design this condition can be assumed to be 1 metre below the bedrock surface. This value assumes that the side wall of the socket will be cleaned of any cuttings or smeared material.

To provide full fixity, the caissons should be provided with a minimum socket length equal to the greater of 2 times the caisson diameter below the depth of any broken or highly weathered surficial bedrock. The structural engineer should check that the shear strength of the concrete is adequate to support these loads.
For a 600 mm diameter caisson socketed 1.2 metres into the competent bedrock, a factored axial geotechnical resistance at ULS of about 2,450 kN is achievable. For a 900 mm diameter caisson socketed 1.8 metres into the competent bedrock, a factored axial geotechnical resistance at ULS of about 5,500 kN is achievable. For a 1200 mm diameter caisson socketed 2.4 metres into the competent bedrock, a factored axial geotechnical resistance at ULS of about 9,750 kN is achievable.

SLS resistances do not apply to caissons founded within the limestone bedrock, because the SLS resistance for 25 mm of settlement is greater than the factored axial
Group action for lateral and vertical loading should be considered when the pile spacing in the direction of the loading is less than three to four pile diameters.

5.2.2.2 Lateral Geotechnical Resistance

For preliminary design, the SLS geotechnical response of the soil in front of the caissons 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 (from the soil in front of the piles) will be nearly the same for vertical and inclined piles.

For cohesionless soils:

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

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

z is the depth (m); and,

B is the pile diameter/width (m).

For the glacial till deposit at this site, the values of n_h can be taken as 6.6 MN/m^3 above the groundwater table and 4.4 MN/m^3 below the groundwater table.

The proposed lengths of the caissons were not available at the time of writing this report. The ULS geotechnical response under lateral loading should be confirmed once details are available for the proposed caissons.

5.3 Impacts to Existing Structures

The existing CSST tunnel crosses beneath the proposed development. It is also understood that there is limited rock cover of the CSST at this site location and it is understood that this pipe was installed by tunneling (i.e. not open cut).

As outlined in section 5.2.2, the proposed caisson foundations will be designed/located to have a minimum setback in accordance with the requirements set out in the design criteria outlined by the CSST team of 3 metres from the side of the pipe to avoid additional stresses from the deep foundations being imposed onto the tunnel. The loading above the CSST will be transferred using a bridge structure between adjacent caissons. Preliminary guidance provided by the CSST team is found in the Structural Design Criteria and Site Construction Approaches for Building Over the Combined Sewage Storage Tunnel, 557 Wellington/Albert and 584 Wellington/Albert Development Blocks. In addition, the ULS capacity for shallow footings on the underlying bedrock should be reduced to 500 kPa within 10 metres of the CSST.

The existing Interceptor Outfall Sewer (IOS) tunnel crosses below the northwest side of the site in alignment with the proposed building foundation wall. It is further understood that additional loading from the foundations is not permitted to transfer to the IOS tunnel. A numerical analysis will be completed to confirm the required caisson termination depth in this vicinity to ensure that no additional loading is transferred to the IOS tunnel once design details are available for the proposed caissons. This analysis will be presented in an addendum to this report.

The existing OLRT right-of-way crosses to the northwest of the proposed development. For design purposes, the proposed shallow foundations or piles for the new building should be designed/located to have a minimum setback in accordance with the requirements set out in the design criteria provided by the OLRT team. In addition, any shoring design will need to consider impacts due to ground movements on the adjacent OLRT as outlined in Section 5.7 below.

A high-pressure watermain is also present adjacent to the site along Albert and Commissioner Streets. A hydro duct is also located in close proximity to the proposed excavation along Albert Street.

Excavations in overburden must not undermine the zone of influence of adjacent utility infrastructure. The zone of influence is defined by a theoretical 1 horizontal to 1 vertical surface extending down and away from the underside of the pipe bedding, to the outside edge of the excavation, or the sound (defined as bedrock with RQD values equal to or greater than 70 percent) bedrock surface at that location, whichever is encountered first. Where the excavations are within the zone of influence of adjacent structures, it is recommended that stiffer temporary protection systems be designed by the contractor to prevent movement of these structures. In addition, monitoring of the hydro duct and watermain for tilt, cracks and/or settlement would be warranted. Further assistance in this regard can be provided, if required.

Care will be also required for excavations carried out in close proximity to the existing watermains and hydro duct which are in close proximity to the proposed excavation. Excavations which are made parallel and in close proximity to the hydro duct and watermains should be supported to reduce potential movements that could damage structures or utilities. Conceptually, excavations could be made with a shoring system as described in Section 5.7 to minimize disturbance to the supporting/surrounding soil. Consideration should be given to methods such as hydrovac excavation or manual excavation in the area immediately above, beside, and beneath the hydro duct (where in overburden), to minimize the potential for damage during excavation.

It is understood that the proposed shoring system may abut the existing hydro duct. Support should be provided to the exposed/suspended hydro duct at all times during construction until backfilling is completed. It is expected that the displacements during construction will need to be significantly restricted, likely to negligible levels. The utility owner should specify the maximum permissible displacement of the hydro duct. These requirements should be reflected in the project specifications. Displacements should be monitored while the excavation is made adjacent to the duct and up until the excavation is backfilled.

Settlement and vibration monitoring should be carried out during excavation activities for all sensitive infrastructure, including but not limited to the OLRT, CSST, IOS, hydro duct, and high pressure watermains. Monitoring for vibrations, tilt, cracks and/or settlement should also be carried out

5.4 Frost Protection

All perimeter and exterior foundation elements or interior foundation elements (i.e., footings, pile caps, grade beams, etc.) in unheated areas should be provided with a minimum of 1.5 m of earth cover for frost protection purposes. Isolated, unheated exterior foundation elements adjacent to surfaces which are cleared of snow cover during winter months should be provided with a minimum of 1.8 m of earth cover.

As an alternative to earth cover, consideration could be provided to the use of an insulation detail. Additional guidance on insulation details can be provided if required.

5.5 Seismic Design Considerations

The OBC 2012 contains seismic analysis and design methodology. The seismic Site Class value, as defined in Section 4.1.8.4 of the OBC 2012, depends on the average shear wave velocity of the upper 30 m of soil and/or rock below founding level. The OBC permits the Site Class to be specified based solely on the stratigraphy and in situ testing data (i.e., shear strengths and standard penetration test results), rather than from direct measurements of the shear wave velocity.

Based on the in situ testing data, this site can be assigned a Site Class of C for seismic design purposes according to the 2012 OBC. A higher site class (i.e. a Site Class A or B) would likely be applicable for footings on or within 3 m of the limestone bedrock; however, this would need to be confirmed with site specific shear wave velocity testing.

5.6 Garage Excavation and Groundwater Control

It is understood that the two levels of underground garage parking will extend about 5 to 7 m below the existing ground surface. Accordingly, excavation to these depths will be through surficial fill and into the underlying glacial till.

The bulk of the groundwater inflow to the proposed excavation will occur through the glacial till unit. Based on previous investigations conducted by Golder, the average ground surface elevation measured onsite was determined to be 62.3 meters above sea level (masl), and the geometric mean of groundwater elevation was measured to be 58.5 masl. It is understood that the proposed excavation will be about 130 m by 60 m in plan and will extend to an elevation of about 57 masl. The hydraulic conductivity of the glacial till was determined to be as high as $6x10^{-5}$ cm/s, based on the maximum hydraulic conductivity of in-situ measurements at three on-site locations.

The equation for groundwater flow into an unconfined circular excavation was used to estimate the groundwater inflow to the proposed excavation, based on an average water table depth of 3.8 mbgs and a glacial till hydraulic conductivity of $6x10^{-5}$ cm/s. The rate of groundwater inflow into the proposed excavation is estimated to be between approximately 110,000 L/day and 45,000 L/day (see Appendix E). A safety factor of 1.5 was applied to the inflow calculations. The radius of influence for the proposed excavation for steady-state flow was estimated to be approximately 5 m from the edge of the excavation (see Appendix E). Higher rates of inflow could occur following rainfall events and during snowmelt. Incident precipitation will also add to the water to be pumped out of the excavation. A 100 mm precipitation event would result in the accumulation of approximately 780,000 litres of direct precipitation, assuming all overland flow is diverted away from the excavation.

The rate of groundwater inflow to the excavation will depend on many factors including the contractor's schedule and rate of excavation, the size of the excavation, the material, incident precipitation, and the time of year at which the excavation is made (e.g., fluctuation in seasonal groundwater elevation). The estimate rates of groundwater inflow are moderate and therefore should be possible to control by pumping with suitably sized pumps from well filtered sumps within the excavations. Groundwater inflow for the proposed service trenches should also be possible to control by pumping from within the excavations. The contractor should be fully responsible for design of the groundwater control system.

According to O.Reg 63/16 and O.Reg 387/04, if the volume of water to be pumped from excavations for the purpose of construction dewatering is greater than 50,000 litres per day and less than 400,000 litres per day, the water taking will need to be registered as a prescribed activity in the Environmental Activity and Sector Registry (EASR) and requires the completion of a "Water Taking Plan" and a "Discharge Plan". Alternatively, a Permit to Take Water (PTTW) is required from the Ministry of the Environment, Conservation (MECP) if a volume of water greater than 400,000 litres per day is to be pumped from the excavations. It is understood that a PTTW application is being submitted for this project.

No unusual problems are anticipated in excavating the overburden using conventional hydraulic excavating equipment, recognizing that cobbles and boulders could be present in the fill and glacial till.

In accordance with the Occupational Health and Safety Act (OHSA) of Ontario, the soil that will be encountered within the excavations (fill and glacial till) would be generally classified as Type 3 soils. Below the groundwater level, the glacial till soils would be classified as Type 4 soil. Provided that the groundwater level is lowered as the excavation progresses, excavations may be made with side slopes at 1 horizontal to 1 vertical, or flatter, otherwise excavations below the groundwater level in these deposits would likely require flatter side slopes (e.g., 3 horizontal to 1 vertical) to remain stable.

Where site conditions (such as the presence of soft or weak soils, proximity of existing structures and utilities, or space restrictions) do not allow for the above noted side slopes then suitable safety and support measures must be undertaken according to the requirements of the OSHA. These measures include installation of a suitable shoring system to create and maintain positive support to the sidewalls of the excavation. Guidelines on excavation shoring are provided in Section 5.7.

The glacial till soils that will form the floor of the foundation excavations are expected to be sensitive to disturbance. Consideration should therefore be given to protecting the subgrade in foundation areas with a mud slab of lean concrete or a layer of compacted granular fill materials. The thickness of the mud slab and/or compacted granular fill working mat will depend on the size and weight of the equipment to be used at the bottom of the excavation. Any disturbed soil will need to be removed prior to placing the protective layer. That mud slab/granular fill materials should be placed immediately following inspection and approval of the subgrade. The period of time between exposure of the subgrade and covering with the protective layer should be limited to as brief as possible and, in the interim, no construction traffic should be permitted on the subgrade.

5.7 Garage Floor Slab

In preparation for the construction of the garage floor slab, all fill and all loose, wet, and disturbed material should be removed from beneath the floor slab down to the undisturbed native soil or bedrock. Provision should be made for at least 250 mm of OPSS Granular A to form the base of the floor slab. Any bulk fill required to raise the grade up to the underside of the Granular A should consist of OPSS Granular B Type II. The underslab fill should be placed in maximum 300 mm thick lifts and should be compacted to at least 95% of the Standard Proctor Maximum Dry Density (SPMDD) using suitable vibratory compaction equipment.

Provision should be made for drainage underneath the floor slab consisting of perforated pipe subdrains in a surround of 19 mm clear stone, fully wrapped in geotextile, which leads by gravity drainage to an adjacent storm sewer or sump pit from which the water is pumped. For preliminary design purposes, these drains should be placed at approximately 6 m centres.

5.8 Temporary Building Excavation Shoring

The excavation for the proposed structure will extend about 5 to 7 m below the existing ground surface and may be close to the property limits and, as such, vertical (or near vertical) excavation walls may be required. The contractor is fully responsible for the detailed design and performance of the temporary shoring systems. However, this section of the report provides some general guidelines on possible concepts for the shoring to be used by the designers for assessing the possible impacts of the shoring design and site works as well as to evaluate, at the design stage, the potential for impacts of this shoring on the adjacent properties. Temporary shoring can be used in combination with open cuts above the top of shoring, however, the earth pressure distribution must take into account the effects of the soil pressures from the upper open cut section.

The shoring method(s) chosen to support the excavation sides must take into account the soil and bedrock stratigraphy, the permissible movement of the shoring, the groundwater conditions, the methods adopted to manage the groundwater and construct the shoring systems, the potential ground movements associated with the excavation and construction of the shoring system, and their impact on adjacent structures and utilities.

It is understood that the excavation floor level will generally be about 5 to 7 m in depth below the existing ground surface elevation. The City of Ottawa right-of-ways for Commissioner Street and Albert Street, which contain below grade services, are located adjacent to the east and south sides, respectively, of the proposed excavation for the building. As such, any services located in close proximity to and/or within the zone of influence of the shoring system could be affected by ground movements behind the shoring. Details on the utilities in these areas should be confirmed during the detailed design studies to better tailor the shoring guidelines provided herein. Additionally, the right-of-way for the OLRT is located adjacent to the north side of the proposed excavation for the building and, if in close proximity to and/or within the zone of influence of the shoring system could be affected by ground movements behind the shoring.

For preliminary design purposes, a soldier pile and timber lagging system is considered a suitable shoring method that may be considered for the proposed 5 to 7 m deep excavation at the site. Due to the presence of very dense till with boulders at shallow depth on the site, the soldier piles may require predrilling to provide sufficient embedment for toe fixity. The shoring system must be provided with appropriate lateral support.

Where foundations or settlement sensitive infrastructure, such as buried utilities, are present within the zone of influence of the shoring system the deflections may need to be greatly limited and a secant pile wall with pre-stressed tie backs may be required. Steel sheet pile systems would not be suitable where very dense till is present at shallow depth. Soldier pile and lagging walls are considered suitable for the sides of the excavations (provided that settlement-sensitive structures or utilities are not present in the zone of influence of the walls) where the objective is to maintain an essentially vertical excavation wall and the movements above and behind the wall need only be sufficiently limited so that relatively flexible features (such as roadways or sidewalks) will not be adversely affected.

For all of the above systems, some form of lateral support to the wall is required for excavation depths greater than about 3 to 4 m. Lateral restraint could be provided by means of tie-backs consisting of grouted soil or bedrock anchors. However, the use of rock/ground anchor tie-backs would require the permission of the adjacent property owners since the anchors would be installed beneath their properties. The presence of utilities beneath the adjacent streets, which could interfere with the tie-backs, should also be considered. Alternatively, interior struts can be considered, connected either to the opposite side of the excavation (if not too distant) or to raker piles and/or footings within the excavation.

5.9 Ground Movements

During the excavation for the underground levels of the proposed buildings, lateral deformation and vertical settlement of the adjacent ground will occur as a result of installation and deflection of the retaining/shoring system and dewatering activities. The ground movements induced could affect the stability or performance of buildings or underground utilities adjacent to the excavation. Therefore, the magnitude and extent of ground movement and potential impacts on surrounding infrastructure should be assessed prior to construction to confirm movements will be in tolerable limits and monitored during construction.

5.10 Foundation Wall Backfill

Foundation/basement walls should be backfilled with free draining non-frost susceptible granular fill meeting the requirements of OPSS Granular B Type I or II materials. The backfill should be compacted to 95 percent of the material's SPMDD using suitable compaction equipment. To reduce compaction induced stresses, only light compaction rollers or plate tampers should be used within 1.0 m of the wall. In any areas where the temporary shoring wall serves as the outside form for the foundation wall, vertical drainage must be installed against the shoring wall. The drainage channels could consist of filtered drainage wick such as Miradrain (or proven equivalent).

Water flow from either the granular backfill or drainage channels should be collected by means of a perforated drain line located at the base of the wall. This drain line should be provided with a granular surround and should lead to a sump pit from which water can be pumped.

Beneath hard surfacing (e.g., pavements or sidewalks/walkways), the granular backfill for the foundation wall should be placed to form a frost taper at 3 horizontal to 1 vertical to a depth of 1.8 m (i.e., the frost depth). The purpose of this frost taper is to limit the severity of differential heaving that could occur between areas backfilled with non-frost susceptible engineered fill and the adjacent areas underlain by the existing frost susceptible soils.

5.11 Lateral Earth Pressures for Design

The lateral earth pressures acting on the garage/foundation walls will depend on the existing soil conditions, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

The details on the wall backfill drainage are provided in Section 5.12 of this report.

The following recommendations are made concerning the design of the foundation walls.

Where the wall support and structure allow lateral yielding, (e.g., for unrestrained retaining walls), active earth pressures may be used in the design of the wall. Where the support does not allow lateral yielding, (i.e., for the proposed basement walls) at-rest earth pressures should be assumed for design.

If a shored excavation (in overburden) is used as part of the formwork for the wall, the lateral earth pressures for foundation walls are based on the existing retained soils and the following parameters (unfactored) may be used:

Soil	Unit Weight (kN/m^3)	Coefficients of static lateral earth pressure	
		Active, Ka	At rest, Ko
Existing Fill	21	0.33	0.50
Glacial Till	22	0.31	0.47

The shoring designer should carefully review the subsurface information and determine appropriate earth pressure parameters for use in their design. In particular, higher values may need to be assumed in order to limit deflection of the shoring near existing structures.

If the garage/foundation wall is backfilled with granular free draining fill either in a zone with width equal to at least 50 percent of the height of the wall or within the wedge-shaped zone defined by a line drawn at 1 horizontal to 1 vertical (1H:1V) extending up and back from the rear face of the footing/pile cap/grade beam, the following parameters (unfactored) may be used:

Material	Unit Weight (kN/m^3)	Coefficients of static lateral earth pressure	
		Active, Ka	At rest, Ko
Granular A or Granular B Type II	22	0.27	0.43
Granular B Type I	22	0.31	0.47

Seismic loading will result in increased lateral earth pressures acting on the walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure.

The horizontal seismic coefficient, k_h, used in the calculation of the seismic active pressure coefficient is taken as 1.0 times the design PGA (i.e., k_h = 0.32). For structures which allow lateral yielding, k_h is taken as 0.5 times the design PGA (i.e., k_h = 0.16).

The following seismic active pressure coefficients (K_{AE}) may be used in design; these coefficients reflect the K_{AE} obtained using the k_h values described above and assumed no vertical acceleration and wall to soil friction. These seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat. Where sloping backfill is present above the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

Wall Type	Site PGA (2475-year Earthquake)	K_{AE}	
		Granular A/Granular B Type II	Granular B Type I
Yielding Wall	0.32g	0.39	0.43
Non-Yielding Wall		0.53	0.59

The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e., an inverted triangular pressure distribution).

A minimum surcharge pressure of 12 kPa due to traffic and compaction induced pressure should be included in the total lateral earth pressures for the structural design of the wall.

The total pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_o \gamma d + (K_{AE} - K_a) \gamma (H-d) + q$$

Where:

$\sigma_h(d)$ = Lateral earth pressure at depth, d, (kPa)

K_o = Coefficient of static earth pressure

γ = Unit weight of the backfill soil (kN/m^3); as given previously

d = Depth below the top of the wall (m)

K_{AE} = Seismic active earth pressure coefficient

q = Surcharge to account for traffic and compaction pressure, where applicable

H = Total height of the wall (m)

All of the lateral earth pressure equations are given in an unfactored format and will need to be factored for Ultimate Limit States design purposes.

5.12 Permanent Drainage

The measured groundwater depth at the site is variable, but it is generally considered to be between about 2 to 4 m below existing site grades. To manage the long term groundwater levels and the interaction with the proposed development, a drainage system diverting collected groundwater inflow to the sewer system is recommended. It is recommended that a hydrogeological assessment be completed to provide input toward the volumes of water anticipated to be diverted to the municipal sewer system.

The subfloor drainage system (i.e., below the lowest garage level) may consist of a network of robust sub-drain pipes conveying collected groundwater to a sump or sumps from which the groundwater can be pumped to a municipal sewer. The drainage system would consist of interconnected perforated drain pipes (bedded and backfilled with free draining granular soils) installed around the perimeter and within the building footprint. The capacity of the subfloor drainage system should be modified during construction as required.

Drainage, such as a composite synthetic drainage system or equivalent, should be provided to the exterior walls. The composite drain must withstand the design horizontal earth pressures used for basement wall design, and should be connected to the basement level underslab drainage system. The drainage system collector pipes should drain to a sump for collection and discharge to a sewer.

5.13 Site Servicing

At least 150 mm of OPSS Granular A should be used as pipe bedding for sewer and water pipes. Where unavoidable disturbance to the subgrade surface occurs during construction, it may be necessary to place a sub-bedding layer consisting of 300 mm 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% of the material's SPMDD. 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 and native soils could potentially migrate into the voids in the clear crushed stone and cause loss of lateral pipe support.

Cover material, from the spring line of the pipe to at least 300 mm above the top of pipe, should consist of OPSS Granular A or Granular B Type I with a maximum particle size of 25 mm. The cover material should be compacted to at least 95% of the material's SPMDD.

It should generally be possible to re-use the existing inorganic fill and glacial till as trench backfill provided it is properly moisture conditioned. Where the trench will be covered with hard surfaced areas, the type of material placed in the frost zone (between subgrade level and 1.8 mm depth) should match the soil exposed on the trench walls for frost heave compatibility. Trench backfill should be placed in maximum 300 mm thick lifts and should be compacted to at least 95% of the material's SPMDD using suitable vibratory compaction equipment.

Seepage barriers should be constructed at periodic intervals along the trench and at the connection points to off-site infrastructure to reduce the potential for groundwater level lowering in the surrounding area due to the "french drain" effect on the granular bedding and surround. Groundwater level lowering could lead to long-term settlement of nearby structures that are supported on the sensitive silty clay soil underlying the site.

It is important that these barriers extend from trench wall to trench wall and that they fully penetrate the granular surround materials to the trench bottom. The seepage barriers should be at least 1.5 metres long. In addition to providing a drainage cut-off, these cut-offs also serve as impenetrable cut-offs to stop the potential migration of contaminants along the relatively permeable backfill in the trenches.

Construction of the seepage barriers should also be in accordance with the City of Ottawa's Standard Drawing No. S8 of the Department of Public Works and Services, Infrastructure Services branch.

5.14 Pavement Design

In preparation for pavement construction, all topsoil, unsuitable fill, disturbed, or otherwise deleterious materials (i.e., those materials containing organic material) should be removed from the pavement areas. Some of the existing fill could remain provided that it is free of organic matter, and that the subgrade be subjected to a proof roll with a loaded tandem truck to reveal weak or soft areas prior to the construction of the new pavement structure. Soft or weak areas should be removed and repaired with acceptable earth borrow or OPSS Select Subgrade Material (SSM) or Granular B.

Pavement areas requiring grade raising to proposed subgrade level should be brought to grade using acceptable (compactable and inorganic) earth borrow, OPSS SSM or Granular B. These materials should be placed in maximum 300 mm thick lifts and should be compacted to at least 95% of the material's SPMDD using suitable compaction equipment.

The surface of the pavement subgrade should be crowned or sloped to promote drainage of the pavement granular structure towards perimeter swales or subdrains placed at the subgrade level

The following pavement designs are recommended for this project:

Material		Light Duty Pavement Thickness of Pavement Elements (mm)	Heavy Duty Pavement Thickness of Pavement Elements (mm)	Loading Dock Thickness of Pavement Elements (mm)
Bituminous Concrete OPSS 1150	Superpave 12.5 mm	60	40	-
	Superpave 19.0 mm	-	50	-
Portland Cement Concrete	Portland Cement Concrete	-	-	200
Granular Material OPSS 1010	Granular A Base	150	150	150
	Granular B, Type II Subbase	300	450	450
	Prepared and Approved Subgrade			

The granular base and subbase materials should be uniformly compacted as per OPSS 310, Method A. The asphaltic concrete should be compacted in accordance with the procedures outlined in OPSS 310.

The asphaltic cement should consist of PG 58-34 and the design of the mixes should be based on a Traffic Category B.

The Portland cement concrete should meet the requirements of CSA A 23.1 Class C2 exposure. Concrete joint specifications and spacing should be in accordance with OPSD 552.020 and 551.010.

The above pavement designs are based on the assumption that the pavement subgrade has been acceptably prepared (i.e., grade raise fill has 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.

Where the new pavements will connect to existing pavements, the new pavement structures should be continued at least to the limits of construction, with any longitudinal transitions and/or tapers occurring thereafter. At these locations, the longitudinal transitions should be constructed by cutting the existing pavement structure vertically to the bottom of the existing subbase. The new granular layers should then be tapered up or down, as required, at a slope of 5 horizontal to 1 vertical to match the existing pavement structure. The asphaltic concrete does not need to be tapered between the new construction and the existing pavement. However, the asphaltic concrete of the existing pavement should be milled back an additional 300 mm to a depth of about 60 mm or 40 mm in areas where its thickness is greater than 100 mm, matching the proposed surface course of the new asphaltic concrete. A tack coat should be provided and the new surface course asphaltic concrete placed over the milled surface to form the new pavement joint. Where the existing pavement is less than 100 mm, then a butt joint on a vertical saw cut surface is acceptable. A tack coat should be placed on the vertical saw cut surface. The tack coat should be in accordance with the City SP F-3107.

5.15 Corrosion and Cement Type

Two samples of soil, one from each boreholes 19-101 and 19-102 were submitted to EXOVA Laboratories Ltd. for chemical analysis related to potential corrosion of exposed buried steel and concrete elements (corrosion and sulphate attack). The results of this testing are provided in Appendix C. The results indicate that concrete made with Type GU Portland cement should be acceptable for concrete substructures.

The results also indicate an elevated potential for corrosion of buried ferrous elements, which should be considered in the design of substructures and pile foundations.

6.0 ADDITIONAL CONSIDERATIONS

At the time of writing this report, only conceptual details related to the proposed building as well as adjacent significant structures such as the CSST and OLRT were available. This information suggests this building will consist of a 4 to 5 storey tower with up to two garage levels to be located at the property. 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.

The construction activities could impact the existing adjacent structures and buildings. Appropriate damage assessments (pre and post condition surveys for example) should be carried out as necessary.

During construction, sufficient foundation inspections, subgrade inspections, in-situ density tests, materials testing, pile and rock anchor installation monitoring should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes, and to monitor conformance to the pertinent project specifications. Concrete testing should be carried out in a CCIL certified laboratory.

The soils at this site are sensitive to disturbance from ponded water, construction traffic and frost. All bearing surfaces must be inspected prior to filling or concreting to ensure that strata having adequate bearing capacity have been reached and that the bearing surfaces have been properly prepared.

7.0 CLOSURE

We trust that this report provides sufficient geotechnical engineering information to facilitate the design of this project. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Golder Associates Ltd.

LICENSED PROFESSIONAL ENGINEER
S. L. GHADBANE
100184126
June 22, 2020
PROVINCE OF ONTARIO

Sarah Ghadbane, P.Eng.
Geotechnical Engineer

Chris Hendry, P.Eng.
Senior Geotechnical Engineer

SG/hdw

https://golderassociates.sharepoint.com/sites/116386/project files/6 deliverables/geotechnical/final/19131600-001-r-rev0-central library geotechnical report-1806_20.docx

GOLDER

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, **City of Ottawa.** 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.

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.

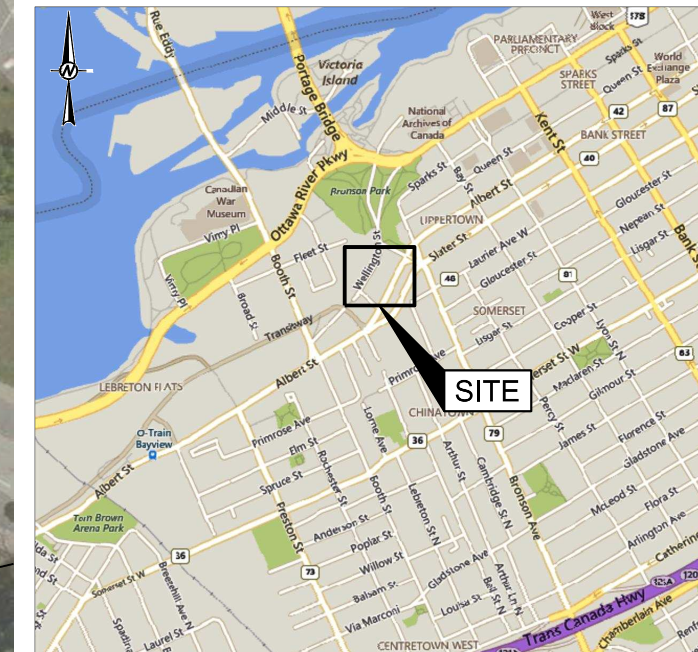
Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

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.

KEY MAP



SCALE 1:25,000

LEGEND

- APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION
- BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS
- CSST ALIGNMENT
- CROSS-SECTION LOCATION

REFERENCE(S)

1. BASE DRAWING PROVIDED BY THE CITY OF OTTAWA ON SEPTEMBER 19, 2019, FILE NO. 190917 - 3D Building Slab Edges.3dm
2. CSST ALIGNMENT DRAWING PROVIDED BY THE CITY OF OTTAWA ON NOVEMBER 15, 2019, FILE NO. ASBUILT RINGS FROM 3200 to 3378.dwg
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83 (CSRS), COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 12.5 25

1:750 METRES

CLIENT
CITY OF OTTAWA

PROJECT
GEOTECHNICAL INVESTIGATION
CENTRAL LIBRARY
OTTAWA, ONTARIO

TITLE
SITE PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-12-11
DESIGNED	----
PREPARED	JM
REVIEWED	SG
APPROVED	CH

PROJECT NO.	CONTROL	REV.	FIGURE
19131600	0001	0	1

25 mm

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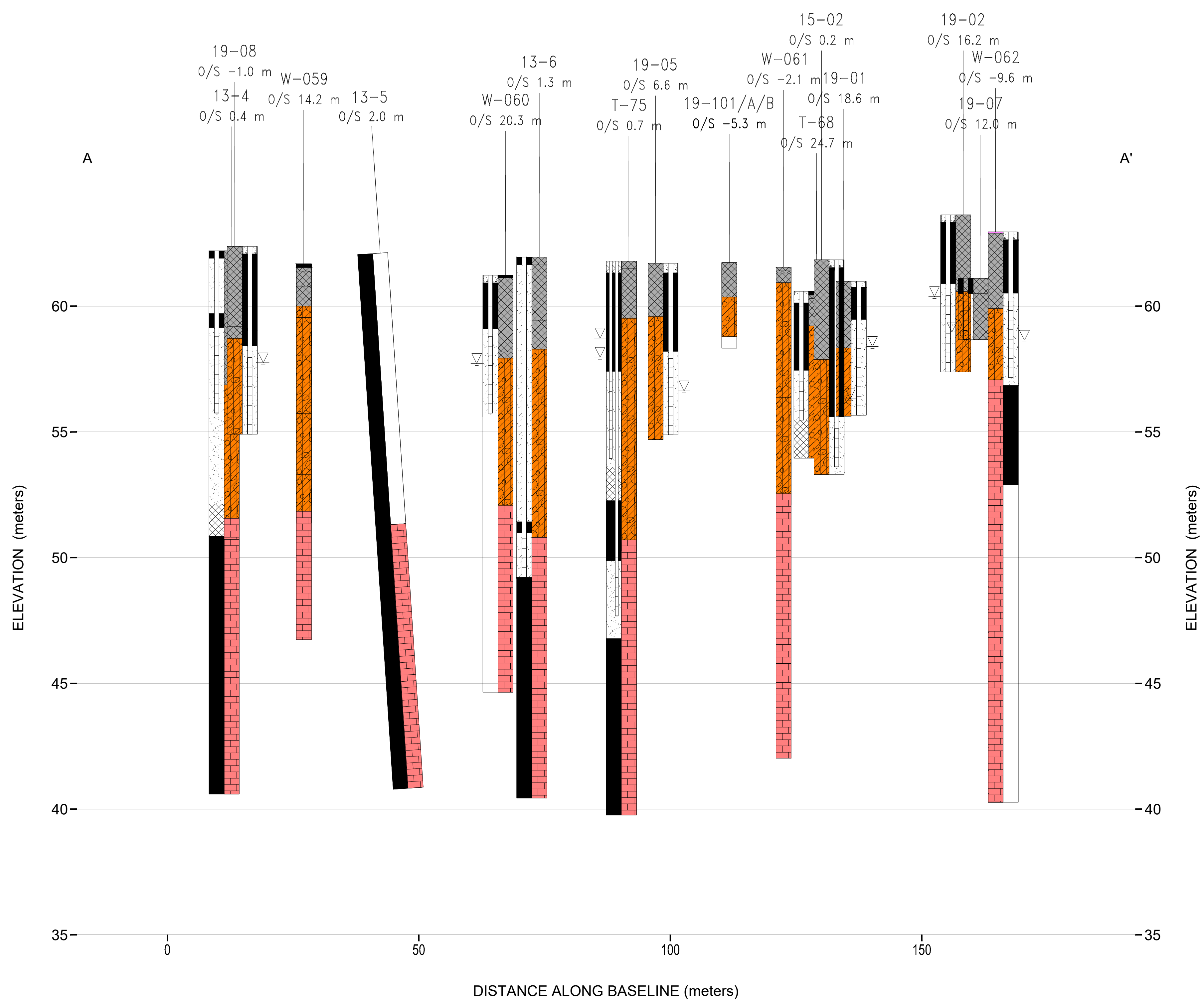

LEGEND

APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION

BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS

BOREHOLE/MONITORING IDENTIFIER — 19-01

GROUNDWATER LEVEL

STRATIGRAPHY

WELL SCREEN

SUBSURFACE STRATIGRAPHY

ASPHALTIC CONCRETE

TOPSOIL

FILL

GLACIAL TILL

LIMESTONE BEDROCK

0 5 10
1:200 VERTICAL METRES

0 25 50
1:1,000 HORIONTAL METRES

CLIENT
CITY OF OTTAWA

PROJECT
GEOTECHNICAL INVESTIGATION
CENTRAL LIBRARY
OTTAWA, ONTARIO

TITLE
CROSS-SECTION A-A'

CONSULTANT
GOLDER

YYYY-MM-DD	2020-01-21
DESIGNED	----
PREPARED	JM
REVIEWED	SG
APPROVED	CH

PROJECT NO.	CONTROL	REV.	FIGURE
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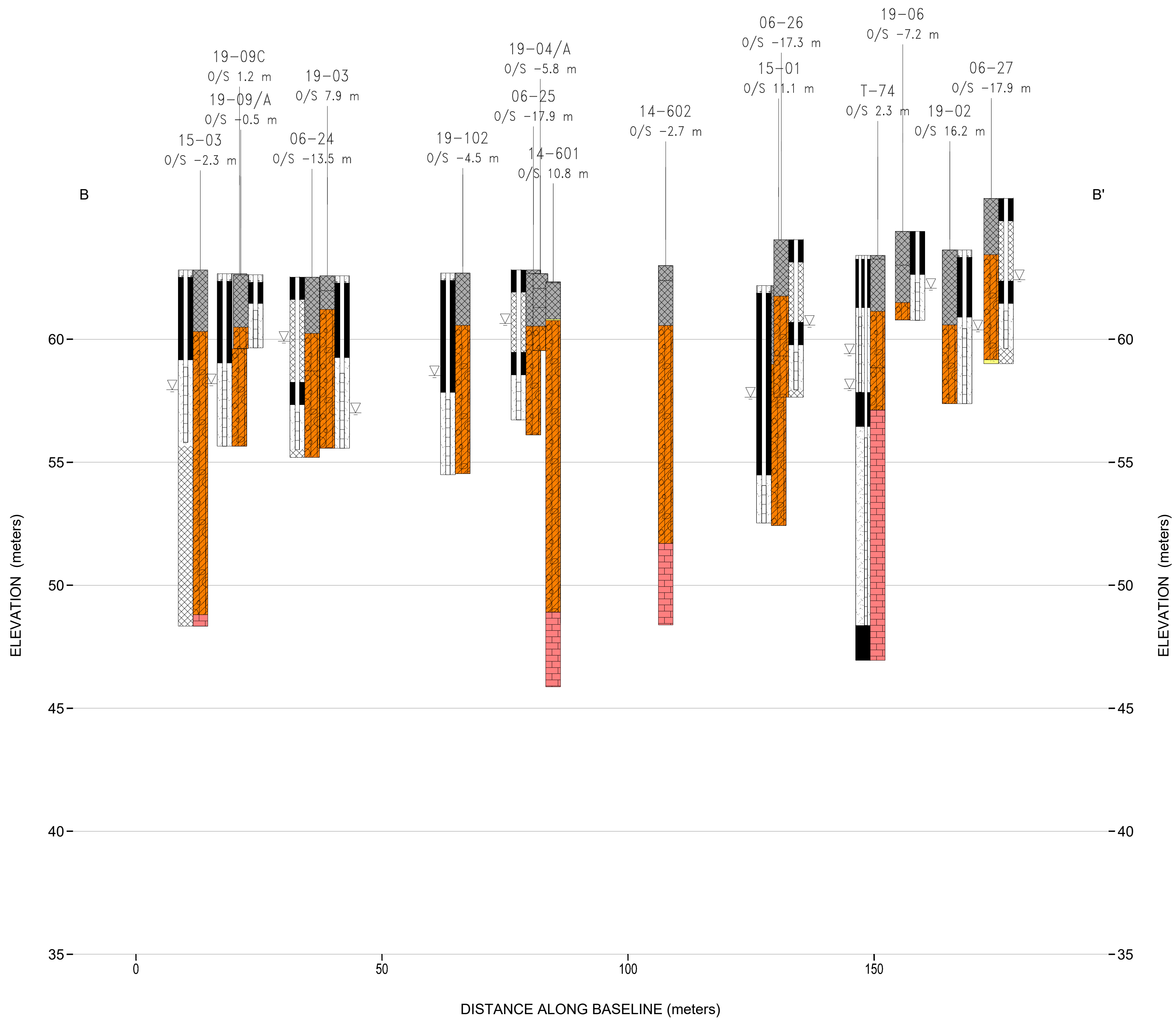


LEGEND

APPROXIMATE BOREHOLE LOCATION, CURRENT INVESTIGATION

BOREHOLE LOCATION, PREVIOUS INVESTIGATIONS

BOREHOLE/MONITORING IDENTIFIER — 19-01

GROUNDWATER LEVEL

STRATIGRAPHY

WELL SCREEN

SUBSURFACE STRATIGRAPHY

ASPHALTIC CONCRETE | SAND

TOPSOIL | GLACIAL TILL

FILL | LIMESTONE BEDROCK

0 5 10
1:200 VERTICAL METRES

0 25 50
1:1,000 HORIONTAL METRES

CLIENT
CITY OF OTTAWA

PROJECT
GEOTECHNICAL INVESTIGATION
CENTRAL LIBRARY
OTTAWA, ONTARIO

TITLE
CROSS-SECTION B-B'

CONSULTANT
GOLDER

YYYY-MM-DD	2020-01-23
DESIGNED	----
PREPARED	ZS
REVIEWED	SG
APPROVED	CH

PROJECT NO.	CONTROL	REV.	FIGURE
19131600	0001	0	3

APPENDIX A

Borehole Logs – Current Investigation

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.

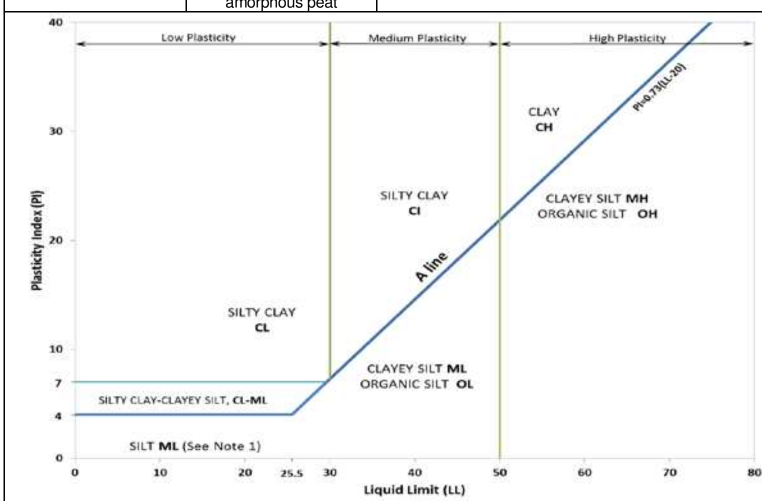
Abbreviations

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

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: Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)	Organic Content	USCS Group Symbol	Primary Name
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 δ
c′	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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

RECORD OF BOREHOLE: 19-01

PROJECT: 19131600 — SHEET 1 OF 1

LOCATION: N 5030969.3 ;E 366627.0 — BORING DATE: November 28, 2019 — DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm — PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	60.99					
0	Wash Boring, HW Casing	FILL - (SW/GW) SAND and GRAVEL, fine to coarse, some non-plastic fines; brown to grey brown; non-cohesive, wet, very loose to dense	0.00	1	SS	36	M	
1				2	SS	10		Bentonite Seal
2				3	SS	3		Silica Sand
		(SM/ML) SAND and SILT, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, compact to very dense	58.34 / 2.65	4	SS	3		
3				5	SS	21		
4				6	SS	33		32 mm Diam. PVC #10 Slot Screen
5				7	SS	88		
		End of Borehole	55.62 / 5.37					WL in screen measured at 2.59 mbgs (Elev. 58.40) on Dec. 11, 2019
6								
7								
8								
9								
10								

Chart columns: 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); STRATA PLOT.

DEPTH SCALE 1 : 50 — GOLDER — LOGGED: DG — CHECKED: CRG

RECORD OF BOREHOLE: 19-02

PROJECT: 19131600

LOCATION: N 5030975.7 ;E 366666.5

BORING DATE: November 28, 2019

DATUM: Geodetic

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
		GROUND SURFACE		63.63							
0	Wash Boring, HW Casing	FILL - (SP) gravelly SAND, some non-plastic fines; dark brown to grey brown, contains brick, concrete fragments and ash; non-cohesive, moist, loose to compact		0.00	1	SS	18				Flush Mount Casing
1					2	SS	7				Bentonite Seal
2					3	SS	11				
					4	SS	14				
3		(SM/ML) SAND and SILT, some gravel and low plasticity fines; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, loose to very dense		60.58 / 3.05	5	SS	8				Silica Sand
4					6	SS	33			MH	
5					7	SS	55				32 mm Diam. PVC #10 Slot Screen
					8	SS	66				
6					9	SS	>50				
		End of borehole Sampler Refusal		57.38 / 6.25							WL in screen measured at 3.25 mbgs (Elev. 60.38) on Dec. 11, 2019
7											
8											
9											
10											

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-03

SHEET 1 OF 1

LOCATION: N 5030859.5 ;E 366615.9

BORING DATE: November 26, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	62.58					
0	Power Auger, 200 mm Diam. (Hollow Stem)	FILL - (SP) gravelly SAND, fine to coarse, some non-plastic fines; grey; non-cohesive, moist, dense	0.00	1	SS	35		Flush Mount Casing
		FILL - (SP) gravelly SAND, angular gravel; grey to dark brown, contains brick and ash; non-cohesive, moist, compact	61.97 / 0.61	2	SS	20		
		(SM/ML) SAND and SILT, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, dense to very dense	61.21 / 1.37	3	SS	33		Bentonite Seal
2	Wash Boring, HW Casing			4	RC	DD		
				5	SS	73	MH	
3				6	SS	83		Silica Sand
4				7	SS	87		
				8	SS	82		
5				9	SS	>55		32 mm Diam. PVC #10 Slot Screen
				10	RC	DD		
6				11	SS	55		
				12	RC	DD		
				13	SS	50		
7		End of Borehole	55.57 / 7.01					WL in screen measured at 5.57 mbgs (Elev. 57.01) on Dec. 11, 2019
8								
9								
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

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

RECORD OF BOREHOLE: 19-04

PROJECT: 19131600

LOCATION: N 5030891.6 ;E 366647.9

BORING DATE: November 21, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	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
		GROUND SURFACE		62.66							
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (SP) gravelly SAND, fine to medium, some non-plastic fines; grey brown; non-cohesive, moist, very dense		0.00	1	SS	100				
		FILL - (SM) SILTY SAND, some gravel; grey, contains brick and ash; non-cohesive, moist, loose		62.06 0.60	2	SS	7				
1		(SM) gravelly SILTY SAND; brown, contains pockets of silty clay; non-cohesive, moist, compact		61.29 1.37	3	SS	11				
2		(SM/ML) SAND and SILT, some gravel to gravelly; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist, very dense		60.53 2.13	4	SS	54				
3					5	SS	60				
		End of Borehole Auger Refusal		59.54 3.12							
4											
5											
6											
7											
8											
9											
10											

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 5/21/20 ZS

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-04A

SHEET 1 OF 1

LOCATION: N 5030891.6 ;E 366647.9

BORING DATE: November 25, 2019

DATUM: Geodetic

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
		GROUND SURFACE		62.66							
0	Power Auger 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-04 advanced to obtain samples below previous refusal		0.00							
		End of Borehole Auger Refusal		61.97 / 0.69							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 5/21/20 ZS

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-04B

SHEET 1 OF 1

LOCATION: N 5030891.6 ;E 366647.9

BORING DATE: November 25, 2019

DATUM: Geodetic

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		62.66							
0	Power Auger; 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-04 advanced to obtain samples below previous refusal		0.00							
3		(SM/ML) SILTY SAND to sandy SILT, some gravel to gravelly; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist, very dense		59.61 / 3.05	1	SS	66				
				59.00 / 3.66							
		End of Borehole Auger Refusal									

Depth scale ticks: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 5/21/20 ZS

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

RECORD OF BOREHOLE: 19-05

PROJECT: 19131600 — SHEET 1 OF 1

LOCATION: N 5030930.6 ;E 366620.5 — BORING DATE: December 2, 2019 — DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm — PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Wash Boring, HW Casing (0.00 to 7.01 m)

Soil Profile

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	61.71
FILL - (SW) gravelly SAND, fine to coarse, some non-plastic fines; brown to grey, contains cobbles and boulders; non-cohesive, wet, very dense	0.00
(SM/ML) SAND and SILTY SAND, some gravel; grey, with brown mottling, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist, dense to very dense	59.58 / 2.13
End of Borehole	54.70 / 7.01

Samples

NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	SS	>50	
2	SS	57	
3	SS	>50	
4	SS	50	
5	SS	>50	
6	SS	60	
7	SS	42	MH
8	SS	43	
9	SS	73	
10	SS	>50	

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 —O^W— Wl: 20 40 60 80

Piezometer or Standpipe Installation

- Flush Mount Casing
- Bentonite Seal
- Silica Sand
- 32 mm Diam. PVC #10 Slot Screen
- WL in screen measured at 5.08 mbgs (Elev. 56.63) on Dec. 10, 2019

DEPTH SCALE 1 : 50

GOLDER

LOGGED: JS

CHECKED: CRG

RECORD OF BOREHOLE: 19-06

PROJECT: 19131600 — SHEET 1 OF 1

LOCATION: N 5030956.4 ;E 366683.0 — BORING DATE: November 21, 2019 — DATUM: Geodetic

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
		GROUND SURFACE		64.38							
0	Power Auger, 200 mm Diam. (Hollow Stem)	FILL - (SP) gravelly SAND, angular gravel, some non-plastic fines; grey brown; non-cohesive, moist, loose		0.00	1	SS	8				
1					2	SS	9				Bentonite Seal
		FILL - (SM/GM) SAND and GRAVEL, some non-plastic fines to silty; grey brown, contains brick fragments, pieces of wood and fly ash; non-cohesive, moist to wet, loose to compact		63.01 / 1.37							
2					3	SS	7				Silica Sand
					4	SS	21				32 mm Diam. PVC #10 Slot Screen
3		(SM) gravelly SILTY SAND; grey brown, contains cobbles and boulders(GLACIAL TILL); non-cohesive, wet, dense		61.49 / 2.89	5	SS	41				
		End of Borehole Auger Refusal		60.78 / 3.60							
4											WL in screen measured at 2.31 mbgs (Elev. 62.07) on Dec. 10, 2019
5											
6											
7											
8											
9											
10											

DEPTH SCALE 1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

RECORD OF BOREHOLE: 19-07

PROJECT: 19131600
SHEET 1 OF 1

LOCATION: N 5030990.5 ;E 366645.3
BORING DATE: December 2, 2019
DATUM: Geodetic

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 - ○)	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		61.11							
0	Power Auger; 200 mm Diam. (Hollow Stem)	FILL - (SP) gravelly SAND, some non-plastic fines; grey; non-cohesive, moist, compact		0.00	1	SS	21				Bentonite Seal
		FILL - (SM) SILTY SAND, some gravel; brown to dark brown, contains brick and concrete fragments; moist to wet, very loose to loose		60.50 0.61	2	SS	7				Silica Sand
1					3	SS	2				32 mm Diam. PVC #10 Slot Screen
2				58.67	4	SS	>50				
		End of Borehole Auger Refusal		2.44							WL in screen measured at 2.14 mbgs (Elev. 58.97) on Dec. 10, 2019
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

GOLDER

LOGGED: JS
CHECKED: CRG

RECORD OF BOREHOLE: 19-08

PROJECT: 19131600

SHEET 1 OF 1

LOCATION: N 5030852.8 ;E 366588.8

BORING DATE: December 3, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	62.38				
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (SP) gravelly SAND, fine to medium, some non-plastic fines; grey, contains brick, concrete fragments, cobbles and boulders; non-cohesive, moist, very dense to loose	0.00	1	SS	55	Flush Mount Casing
1				2	SS	37	
2				3	SS	29	
				4	SS	8	
3		FILL - (SP) SAND, fine to medium, some silt; brown; non-cohesive, moist, compact	59.18 / 3.20	5	SS	13	
		(SM/ML) SAND and SILT, some gravel; brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, very dense	58.72 / 3.66				Bentontie Seal
4				6	SS	91	Silica Sand
5				7	SS	>50	
				8	SS	>100	
6				9	SS	91	32 mm Diam. PVC #10 Slot Screen
7				10	SS	72	
		End of Borehole	54.91 / 7.47				WL in screen measured at 4.63 mbgs (Elev. 57.75) on Dec. 10, 2019
8							
9							
10							

Column headings also include: STRATA PLOT; 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

DEPTH SCALE

1 : 50

GOLDER

LOGGED: JS

CHECKED: CRG

RECORD OF BOREHOLE: 19-09

PROJECT: 19131600

LOCATION: N 5030839.9 ;E 366615.3

BORING DATE: November 20, 2019

DATUM: Geodetic

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
		GROUND SURFACE		62.62							
0	Power Auger, 200 mm Diam. (Hollow Stem)	FILL - (SM/GM) SAND and GRAVEL, fine to coarse, some non-plastic fines to silty; grey brown, contains brick, concrete fragments, wood pieces and ash; non-cohesive, moist to wet, loose to dense		0.00	1	SS	40				Flush Mount Casing
											Bentontie Seal
1					2	SS	5				Silica Sand
					3	SS	12			M	
2		(SM) SILTY SAND, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, wet, very dense		60.49 / 2.13							32 mm Diam. PVC #10 Slot Screen
					4	SS	83				
3		End of Borehole Auger Refusal		59.62 / 3.00							
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-09A

LOCATION: N 5030839.9 ;E 366615.3

BORING DATE: November 25, 2019

DATUM: Geodetic

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
		GROUND SURFACE		62.62							
0	Power Auger 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-09 advanced to obtain samples below previous refusal		0.00							
1											
				60.79							
2		End of Borehole Auger Refusal		1.83							
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-09B

SHEET 1 OF 1

LOCATION: N 5030839.9 ;E 366615.3

BORING DATE: November 25, 2019

DATUM: Geodetic

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
		GROUND SURFACE		62.62							
0	Power Auger 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-09 advanced to obtain samples below previous refusal		0.00							
1											
		End of Borehole Auger Refusal		61.05 1.57							
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

RECORD OF BOREHOLE: 19-09C

PROJECT: 19131600

SHEET 1 OF 1

LOCATION: N 5030840.5 ;E 366613.6

BORING DATE: November 27, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Column headings: 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

Depth (m)	Boring Method	Description	Elev. / Depth (m)	Sample Number	Type	Blows/0.30m	Piezometer or Standpipe Installation
		GROUND SURFACE	62.66				
0	Wash Boring, HQ Casing	No Sampling - Alternate to 19-09 advanced to obtain samples below previous refusal	0.00				Flush Mount Casing
							Bentontie Seal
3		(SM) gravelly SILTY SAND; grey, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, very dense	59.61 / 3.05	1	SS	>50	
				2	RC	DD	Silica Sand
				3	SS	69	
				4	RC	DD	
				5	SS	>50	
				6	SS	>50	32 mm Diam. PVC #10 Slot Screen
				7	RC	DD	
				8	SS	>50	
				9	RC	DD	
7		End of Borehole	55.65 / 7.01				WL in screen measured at 4.47 mbgs (Elev. 58.19) on Dec. 10, 2019

Depth scale marks: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 5/21/20 ZS

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

RECORD OF BOREHOLE: 19-101

PROJECT: 19131600

SHEET 1 OF 1

LOCATION: N 5030938.2 ;E 366637.7

BORING DATE: November 21, 2019

DATUM: Geodetic

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
		GROUND SURFACE		61.73							
0	Power Auger 200 mm Diam. (Hollow Stem)	FILL - (SW) gravelly SAND, fine to coarse, some non-plastic fines; grey brown, contains brick; non-cohesive, moist, very dense to compact		0.00	1	SS	53				
1					2	SS	14				
		(SM) SILTY SAND, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist, very dense		60.36 / 1.37	3	SS	55				
2					4	SS	74				
3		End of Borehole Auger Refusal		58.79 / 2.94							
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-101A

SHEET 1 OF 1

LOCATION: N 5030938.2 ;E 366637.7

BORING DATE: November 25, 2019

DATUM: Geodetic

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
		GROUND SURFACE		61.73							
0	Power Auger 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-101 advanced to obtain samples below previous refusal		0.00							
		End of Borehole Auger Refusal		60.97 / 0.76							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

MIS-BHS 001 19131600.GPJ GAL-MIS.GDT 5/21/20 ZS

DEPTH SCALE

1 : 50

GOLDER

LOGGED: DG

CHECKED: CRG

RECORD OF BOREHOLE: 19-101B

PROJECT: 19131600
SHEET 1 OF 1

LOCATION: N 5030938.2 ;E 366637.7
BORING DATE: November 25, 2019
DATUM: Geodetic

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
		GROUND SURFACE		61.73							
0	Power Auger 200 mm Diam. (Hollow Stem)	No Sampling - Alternate to 19-101 advanced to obtain samples below previous refusal		0.00							
		End of Borehole Auger Refusal		58.33 3.40							

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

PROJECT: 19131600

RECORD OF BOREHOLE: 19-102

SHEET 1 OF 1

LOCATION: N 5030878.2 ;E 366639.5

BORING DATE: November 20, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	62.69					
0	FILL - (SW) gravelly SAND, fine to coarse, some non-plastic fines to silty; grey to dark brown, contains brick and ash; non-cohesive, moist, very dense to loose	0.00	1	SS	95		Flush Mount Casing
1			2	SS	10	M	
			3	SS	9		
2	(SM) SILTY SAND, fine to coarse, some gravel; grey brown, contains cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, dense to very dense	60.56 2.13	4	SS	37		Bentonite Seal
3			5	SS	68		
4			6	SS	53		
			7	SS	59		Silica Sand
5			8	SS	>100		
6			9	SS	60		32 mm Diam. PVC #10 Slot Screen
7			10	SS	65		
			11	SS	80		
8	End of Borehole Auger Refusal	54.54 8.15					WL in screen measured at 4.17 mbgs (Elev. 58.52) on Dec. 10, 2019
9							
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

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: CRG

APPENDIX B

Borehole Logs and Results of UCS Testing - Previous Investigation

RECORD OF DRILLHOLE: T-1

PROJECT: 10-1121-0068

SHEET 1 OF 4

LOCATION: N 5030996.80 ;E 366695.16

DRILLING DATE: 03/05/2010

DATUM: Geodetic

DRILL RIG: CME75

INCLINATION: -68° AZIMUTH: 141°

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		GROUND SURFACE	65.71									
0	Wash Boring, HW Casing	OVERBURDEN (no recovery)	0.00									
7		- Recovered 20cm gravel/boulders	59.22 / 6.99									
7–10	Rotary Drill, HQ Core	Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, medium strong to strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor thin lithoclastic limestone beds and interbeds of dark grey, bedding laminations and very thin to thinly bedded, calcareous, slake susceptible shale at semi regular intervals of 0.25 to 2.5 m. Contains traces of fossil fragments. Top contact of formation marked by thin bed of shale and shaley limestone. Shale and shaley limestone comprise 7.5 % to 10 % of sequence. VERULAM FORMATION UNIT 2 - Soft clay infill		1	100			JN,UN,SM Sa	12	2	3	
				2	100			JN,ST,RO	22	3	1	
								BD,PL,SM	16	1	1	
								BD,PL,RO	20	1.5	1	
				3	100			JN,PL,SM	16	1	1	
								JN,UN,SM Cl	0	2	1.5	
								JN,PL,SM M	12	1	3	
10								JN,UN,SM BR	12	2	3	

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: DWM/CP

CHECKED: MJT

RECORD OF DRILLHOLE: T-1

PROJECT: 10-1121-0068
LOCATION: N 5030996.80 ;E 366695.16
INCLINATION: -68° AZIMUTH: 141°
DRILLING DATE: 03/05/2010
DRILL RIG: CME75
DRILLING CONTRACTOR: Downing
DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | 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^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

--- *CONTINUED FROM PREVIEW PAGE* ---

Drilling record: Rotary Drill, HQ Core

Elev. / Depth (m)	Description
55.90 / 10.58	Fresh to slightly weathered, medium bedded, fine grained, strong LIMESTONE
	- Clay gouge, soft clay with pieces of broken shale
47.36 / 19.79	

Run No.	Flush Return
3	100
4	100
5	100
6	100
7	100
8	100
9	100
10	100

Type and Surface Description	Jcon	Jr	Ja
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,CU,SM BR	6	2	4
BD,UN,SM Ca	16	2	2
HCO,,			0.75
CO,PL,SM	16	1	1
BD,PL,SM M	6	1	4
BD,PL,SM Go	6	1	6
HCO,, SHALE	20	1	0.75
BD,PL,SM			1
CO,PL,SM	16	1	1
CO,CU,SM Ca	16	2	2
CO,PL,SM	16	1	1
BD,PL,SM Ca	16	1	1
JN,UN,RO Go	0	1	1.5
BD,CU,RO Go	0	1	1.5
CO,PL,SM	16	1	1
CO,PL,SM	16	1	1

Depth scale: 10 11 12 13 14 15 16 17 18 19 20

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM/CP
CHECKED: MJT

RECORD OF DRILLHOLE: T-1

PROJECT: 10-1121-0068

LOCATION: N 5030996.80 ;E 366695.16
DRILLING DATE: 03/05/2010
DATUM: Geodetic

INCLINATION: -68° AZIMUTH: 141°
DRILL RIG: CME75
DRILLING CONTRACTOR: Downing

Abbreviations:
JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate
BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean
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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

--- *CONTINUED FROM PREVIOUS PAGE* ---

Drilling record: Rotary Drill, HQ Core

Depth (m)	Description	Elev. / Depth (m)
20	Fresh, medium bedded, grey, fine grained, strong to very strong LIMESTONE interbedded with shale seams (2 to 50mm thick)	
~22	- Bioturbation, some calcite veining, fossiliferous	
~23	- Broken core along healed shear	
23.07	Fresh, medium bedded, grey, fine grained, strong to very strong LIMESTONE interbedded with shale seams (2 to 50mm thick)	44.31 / 23.07
~24.8	- Pyritization along calcite veins	
~27.7	- Thin to medium bedded	

Run No.	Flush Return
10	100
11	100
12	100
13	100
14	100
15	100
16	100

Type and Surface Description	Jcon	Jr	Ja
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
HVN,, Ca			0.75
BD,PL,SM Py	12	1	2
BD,CU,SM	20	2	1
CO,PL,RO Cl	0	1	1.5
BD,PL,SM M	12	1	3
BD,PL,RO	20	1.5	1
HVN,, Ca			0.75
HSH,UN,SM HBr			0.75
HBD,,			0.75
HVN,, Ca			0.75
JN,IR,SM Py	16	2	2
BD,CU,RO	22	3	1
BD,CU,SM M	12	2	3
BD,PL,SM	16	1	1
HSH,PL,RO Bc			0.75
HVN,UN, Ca/Fe			0.75
BD,UN,RO	22	3	1
BD,PL,SM	16	1	1
HVN,, Ca			0.75
HVN,, Ca/Py			0.75
BD,ST,SM	20	2	1
HVN,, Ca/Py			0.75
JN,PL,SM	16	1	1
CO,ST,RO Py	12	3	3
HVN,, Ca/Py			0.75
BD,PL,RO Ca			

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

CONTINUED NEXT PAGE

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-1

LOCATION: N 5030996.80 ;E 366695.16

DRILLING DATE: 03/05/2010

DATUM: Geodetic

INCLINATION: -68° AZIMUTH: 141°

DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- *CONTINUED FROM PREVIOUS PAGE* ---									
30	Rotary Drill, HQ Core		37.50	16	100						
		Fresh, thinly to medium bedded, grey, fine grained, strong to very strong LIMESTONE interbedded with shale seams (2 to 50mm thick)	30.42			•	JN,UN,SM	20	2	1	
31				17	100	•	BD,PL,RO	20	1.5	1	
		- LOST CORE downhole (end of run)	36.09								
32		End of Drillhole	31.94								
33											
34											
35											
36											
37											
38											
39											
40											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DWM/CP
CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

LOCATION: N 5030988.22 ;E 366705.01

INCLINATION: -70° AZIMUTH: 270°

DRILLING DATE: 06/05/2010

DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.	FLUSH 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 0.25m (5 10 15 20)	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^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES
		GROUND SURFACE		66.32														
0	Wash Boring / HW Casing	OVERBURDEN (no recovery)		0.00														
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8	Rotary Drill / HQ Core			58.72 8.09	1							HVN,, Ca			0.75			
					1							JN,UN,SM		2	1			
					1							BD,UN,SM Cl	12	2	3			
					1							BD,UN,SM Cl	12	2	3			
9					2							BD,PL,SM	16	1	1			
					2							BD,UN,SM Ca		2	2			
					2							JN,UN,SM Cl	12	2	3			
					2							BD,CU,RO	22	3	1			
					2							BD,PL,SM	16	1	1			
10		*CONTINUED NEXT PAGE*																

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DEPTH SCALE

1 : 50

Golder Associates

LOGGED: CP

CHECKED: MJT

PROJECT: 10-1121-0068

RECORD OF DRILLHOLE: T-2

LOCATION: N 5030988.22 ;E 366705.01

INCLINATION: -70° AZIMUTH: 270°

DRILLING DATE: 06/05/2010

DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon, Jr, Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: Rotary Drill, HQ Core

10.0 – 17.35 m: Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, very strong to strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor thin lithoclastic limestone beds and interbeds of dark grey, bedding laminations and very thin to thinly bedded, calcareous, slake susceptible shale at semi regular intervals of 0.25 to 2.5 m. Contains traces of fossil fragments. Top contact of formation marked by thin bed of shale and shaley limestone. Shale and shaley limestone comprise 7.5 % to 10 % of sequence.

VERULAM FORMATION UNIT 2

- Many breaks along weak shale seams

- 16.81 - 4cm broken core/fracture zone, crushed rock, trace clay, possibly mechanical breaks
- 16.95 - 10cm broken core/fracture zone
- 17 - 2cm of stiff gouge
- 17.29 - 6cm fracture zone along calcite vein

50.02 / 17.35 m: Fresh, thinly bedded, grey, fine grained, strong to very strong, fossiliferous LIMESTONE interbedded with shale seams (2 to 50mm thick)
- 17.45 - 4mm of stiff gouge

RUN No.	FLUSH RETURN
2	
3	100
4	
5	80
6	60 to 80
7	
8	
9	

Type and Surface Description	Jcon	Jr	Ja
JN,ST,RO Ca	20	3	2
BD,PL,RO	20	1.5	1
JN,UN,RO Ca	20	3	2
BD,UN,RO Ca	20	3	2
BD,PL,RO	20	1.5	1
JN,CU,RO	22	3	1
BD,PL,RO	20	1.5	1
BD,UN,RO	22	3	1
BD,CU,RO	22	3	1
BD,PL,RO	20	1.5	1
BD,UN,SM Ca	16	2	2
CO,UN,SM Cl	12	2	3
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
JN,PL,SM	16	1	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
JN,CU,RO Ca	20	3	2
BD,PL,SM	16	1	1
CO,UN,SM Ca	16	2	2
BD,UN,SM M	12	2	3
BD,PL,SM	16	1	1
VN,IR,RO Ca	22	3	2
BD,ST,SM	20	2	1
BD,CU,SM Cl	12	2	3
BD,PL,RO	20	1.5	1
BD,CU,RO	22	3	1
JN,UN,SM	20	2	1
BD,UN,VR BR	0	1	5
FLT,PL,RO BR	0	1	5
FLT,CU,RO Ca	12	3	3
FLT,UN,RO Cl	12	3	3
BD,UN,SM Cl	12	2	3
VN,PL,RO	20	1.5	1
JN,PL,RO Go	6	1	8
BD,PL,RO Go	6	1	8
VN,UN,RO Ca/Py	20	3	2
BD,UN,RO Ca	20	3	2
BD,PL,SM	16	1.5	1
BD,CU,RO	22	3	1
BD,UN,RO	22	3	1
HJN,,			0.75
BD,CU,RO	22	3	1
HVN,, Ca/Py			0.75
BD,UN,RO Py	20	3	2
BD,PL,RO Cl	12	1.5	3

CONTINUED NEXT PAGE

RECORD OF DRILLHOLE: T-2

PROJECT: 10-1121-0068

LOCATION: N 5030988.22 ;E 366705.01

INCLINATION: -70° AZIMUTH: 270°

DRILLING DATE: 06/05/2010

DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

--- *CONTINUED FROM PREVIOUS PAGE* ---

Depth 20 to 30 m — Drilling record: Rotary Drill, HQ Core

Fresh, thinly bedded, grey, fine grained, strong to very strong, fossiliferous LIMESTONE interbedded with shale seams (2 to 50mm thick)

Runs: 9 (20–21.1 m), 10 (21.1–22.6 m), 11 (22.6–24.1 m), 12 (24.1–25.6 m), 13 (25.6–27.1 m), 14 (27.1–28.6 m), 15 (28.6–30 m)

Flush return: 50 to 60

Run	Type and surface description	Jcon	Jr	Ja
9	BD,UN,SM	20	2	1
9	HVN,, Ca/Py			0.75
9	BD,PL,RO Cl	12	1.5	3
9	BD,PL,RO Cl	12	1.5	3
9	BD,PL,RO Cl	12	1.5	3
10	BD,UN,SM	20	2	1
10	BD,CU,RO	22	3	1
10	BD,PL,RO	16	1.5	1
11	BD,UN,SM Py	16	2	2
11	BD,CU,RO Py	20	3	2
11	BD,PL,RO	16	1.5	1
11	BD,PL,RO	16	1.5	1
12	BD,ST,SM	20	2	1
12	BD,CU,SM	20	2	1
13	BD,UN,RO	22	3	1
13	JN,CU,SM	20	2	1
13	BD,PL,RO	16	1.5	1
14	BD,PL,RO Ca	12	1.5	2
14	BD,PL,RO	16	1.5	1
14	HVN,, Ca			0.75
15	BD,UN,SM	20	2	1
15	BD,PL,RO	16	1.5	1

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: CP

CHECKED: MJT

RECORD OF DRILLHOLE: T-2

PROJECT: 10-1121-0068

LOCATION: N 5030988.22 ;E 366705.01

INCLINATION: -70° AZIMUTH: 270°

DRILLING DATE: 06/05/2010

DRILL RIG: CME75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate; BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean; 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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---								
30	Rotary Drill, HQ Core		37.98	15						
		Fresh, thinly bedded, grey, fine to medium grained, strong to very strong LIMESTONE interbedded with shale seams (2 to 40mm thick)	30.16			HBD,,			0.75	
31		- 30.91 - 3cm clay seam: soft, grey, no rock pieces		16	50					
						HBD,,			0.75	
32						HBD,,			0.75	
				17		HVN,, Ca/Py			0.75	
						BD,UN,SM	20	2	1	
33						BD,,			0.75	
		End of Drillhole	35.12 / 33.20							
34										
35										
36										
37										
38										
39										
40										

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: CP

CHECKED: MJT

RECORD OF BOREHOLE: T-68

PROJECT: 10-1121-0222
LOCATION: N 5030967.29 ;E 366619.07
BORING DATE: September 1, 2011
SHEET 1 OF 1
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200mm Diam. (Hollow Stem)

SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	60.59
ASPHALTIC CONCRETE	0.00
Grey crushed stone (FILL)	0.15
Brown coarse sand, some gravel (FILL)	0.29
Very dense brown sandy silt, some gravel, with cobbles (FILL)	59.77 / 0.82
Dense to very dense brown to grey brown SILTY SAND, some gravel, trace clay, with cobbles and boulders (GLACIAL TILL)	59.22 / 1.37
End of Borehole Auger Refusal	53.95 / 6.64

SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING
1	50 DO	100	O	M
2	50 DO	43		
3	50 DO	47		
4	50 DO	54	O	MH
5	50 DO	>50		
6	50 DO	>50		
7	50 DO	>50		
8	50 DO	>50		
9	50 DO	>50		

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^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp —○W— Wl; 20 40 60 80

Piezometer / Standpipe Installation:
- Flush Mount Protective Casing set in Sand Silica Sand
- Bentonite Seal
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen
- Cave

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KS
CHECKED: SD

RECORD OF BOREHOLE: T-74

PROJECT: 10-1121-0222
LOCATION: N 5030956.27 ;E 366672.13
BORING DATE: April 4, 2011
SHEET 1 OF 1
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | 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^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WATER CONTENT PERCENT, Wp ⊢—○W—⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION ('B' 'A')

Boring method: Power Auger, 200mm Diam. (Hollow Stem)

Description	Elev. / Depth (m)
GROUND SURFACE	63.41
Grey crushed stone (FILL)	0.00
Compact to dense brown sandy silt, trace gravel and clay (FILL)	0.15
Very dense brown SANDY SILT, trace gravel, with cobbles and sand layers (GLACIAL TILL)	61.13 / 2.28
Very dense dark grey SANDY SILT, some gravel, trace clay, with cobbles (GLACIAL TILL)	58.84 / 4.57
Borehole continued on RECORD OF DRILLHOLE T-74	57.12

Sample Number	Type	Blows/0.3m	Water content	Additional Lab. Testing
1	A.S.			
2	50 DO	20		
3	50 DO	41		
4	50 DO	59		
5	50 DO	55	○	MH
6	50 DO	>100		
7	50 DO	55		
8	50 DO	57	○	MH

Installation notes:
- Flush mount protective casing set in Bentonite
- Bentonite Seal
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen 'B'
- Bentonite Seal
- W.L. in Screen at Elev. 57.96m on June 28, 2011

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: JMR/DAC
CHECKED: MRR

RECORD OF DRILLHOLE: T-74

PROJECT: 10-1121-0222
LOCATION: N 5030956.27 ;E 366672.13
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 4, 2011
DRILL RIG: CME 75
DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DIP w.r.t. CORE AXIS | DISCONTINUITY DATA (TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

Drilling record: Rotary Drill, HQ Core

BEDROCK SURFACE — Elev. 57.12

6.29 — Fresh, thinly to medium bedded, fine grained, light grey to black, slightly porous, medium strong to strong LIMESTONE BEDROCK, interbedded with laminated shale layers

VERULAM FORMATION UNIT 2
- Broken core from 6.42m to 6.54m, large sub-rounded, re-drilled core fragments
- Shale layer from 6.71m to 6.78m
- Shale layer from 6.88m to 6.95m
- Shale layer from 7.01m to 7.05m
- Shale layer from 7.09m to 7.21m
- Shale layer from 7.77m to 7.86m
- Shale layer from 8.97m to 9.05m
- Shale layer from 9.15m to 9.26m
- Shale layer from 9.34m to 9.39m
- Shale layer from 9.65m to 9.75m
- Shale layer from 10.28m to 10.32m
- Shale layer from 10.46m to 10.49m
- Shale layer from 10.57m to 10.62m
- Shale layer from 11.19m to 11.22m
- Shale layer from 11.29m to 11.32m
- Shale layer from 11.33m to 11.37m
- Shale layer from 11.42m to 11.45m
- Shale layer from 11.52m to 11.60m
- Shale layer from 11.63m to 11.68m
- Shale layer from 12.44m to 12.51m
- Shale layer from 12.58m to 12.65m
- Shale layer from 12.84m to 12.97m
- Shale layer from 13.92m to 13.94m
- Shale layer from 14.20m to 14.22m
- Shale layer from 14.34m to 14.36m

Runs: 1, 2, 3, 4, 5, 6, 7

Depth scale marks: 7, 8, 9, 10, 11, 12, 13, 14, 15, 16

Type and Surface Description	Jcon	Jr	Ja
BD,PL,SM Br	12	1	2
BD,PL,Ro Cl	12	1.5	4
BD,UN,SM ClBr 30mm	0	1	10
BD,PL,SM Br 4mm	6	1	4
BD,UN,Ro Br	12	3	3
BD,ST,SM Br	16	2	2
BD,UN,Ro Cl/Br 2mm	12	3	4
BD,UN,SM Br	16	2	2
BD,PL,SM Br	12	1	2
JN,UN,Ro Cl	12	3	4
BD,PL,Ro Cl/Br 6mm	0	1	10
BD,UN,Ro Br	20	3	2
BD,UN,Ro Br	20	3	2
BD,PL,SM Br	12	1	2
BD,PL,Ro Cl	12	1.5	4
BD,PL,Ro Cl	12	1.5	4
BD,PL,Ro Cl	12	1.5	4
BD,UN,Ro Br	20	3	2
BD,UN,SM Cl	12	2	4
BD,PL,Ro Br	16	1.5	2
BD,UN,Ro Br	20	3	2
BD,UN,Ro Br	20	3	2
BD,UN,SM Ca	12	2	4
BD,UN,Ro Br	20	3	2
BD,PL,Ro Br	16	1.5	2
BD,UN,Ro Ca	12	3	3
BD,UN,Ro Br	20	3	2

NOTES: 'B' 'A'
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen 'A'
- Bentonite Seal

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: JMR/DAC
CHECKED: MRR

RECORD OF DRILLHOLE: T-74

PROJECT: 10-1121-0222

LOCATION: N 5030956.27 ;E 366672.13

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 4, 2011

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.	FLUSH 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 0.25m (5 10 15 20)	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^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---																'B' 'A'
				46.95	7													Bentonite Seal
		End of Drillhole		16.46														
17																		W.L. in Screen at Elev. 57.96m on June 28, 2011
18																		
19																		
20																		
21																		
22																		
23																		
24																		
25																		
26																		

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: JMR/DAC

CHECKED: MRR

RECORD OF BOREHOLE: T-75

PROJECT: 10-1121-0222
LOCATION: N 5030923.18 ;E 366623.23
BORING DATE: March 23-24, 2011

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Columns: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | 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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION ('B' 'A')

Boring method: Power Auger, 200mm Diam. (Hollow Stem) (0 to approx. 9 m); Rotary Drill, HQ Core (approx. 9 to 10 m)

ELEV. / DEPTH (m)	DESCRIPTION
61.79	GROUND SURFACE
0.00	Grey crushed stone (FILL)
61.49 / 0.30	Compact dark brown silty sand, some gravel, trace brick (FILL)
59.51 / 2.28	Dense to very dense brown SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)
57.22 / 4.57	Very dense grey SANDY SILT to SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)

NUMBER	TYPE	BLOWS/0.3m
1	A.S.	
2	50 DO	11
3	50 DO	26
4	50 DO	47
5	50 DO	>50
6	50 DO	>50
7	50 DO	>50
8	50 DO	>50
9	50 DO	>50
10	50 DO	>50
11	50 DO	>50
12	50 DO	>50
13	50 DO	>50

Installation (top to bottom):
- Flush mount protective casing set in Bentonite Native Backfill
- Bentonite Seal
- ∇ (water level, approx. 3.8 m)
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen 'B'
- Silica Sand
- Native Backfill
- Bentonite Seal

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KS
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: T-75

LOCATION: N 5030923.18 ;E 366623.23

BORING DATE: March 23-24, 2011

DATUM: Geodetic

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/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION ('B' 'A')
		--- *CONTINUED FROM PREVIOUS PAGE* ---									
10	Rotary Drill, HQ Core	Very dense grey SANDY SILT to SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)			14	50 DO	>50				W.L. in Screen at Elev. 58.73m on June 28, 2011
11				50.71							
		Borehole continued on RECORD OF DRILLHOLE T-75									
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: KS

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: T-75

LOCATION: N 5030923.18 ;E 366623.23

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 23-24, 2011

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

Abbreviations:

JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate

BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean

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.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon, Jr, Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES ('B' 'A')

Drilling record: Rotary Drill, HQ Core

Elev. / Depth (m)	Description
50.71	BEDROCK SURFACE
11.08	Fresh to slightly weathered, thinly to very thinly bedded, fine grained, medium to dark grey, moderately to faintly porous, strong LIMESTONE BEDROCK, interbedded with shale beds ranging from 1mm to 16cm thick
	VERULAM FORMATION UNIT 2
	- Shale layer from 11.65m to 11.69m
	- Shale layer from 11.74m to 11.78m
	- Shale layer from 11.83m to 11.85m
	- Shale layer from 13.04m to 13.07m
	- Shale layer from 14.19m to 14.24m
	- Shale layer from 14.52m to 14.78m
	- Shale layer from 15.78m to 15.80m
	- Shale layer from 16.68m to 16.74m
	- Shale layer from 17.38m to 17.48m
	- Shale layer from 17.86m to 17.90m
	- Shale layer from 17.95m to 18.02
	- Shale layer from 18.23m to 18.54m
	- Shale layer from 18.66m to 18.69m
	- Shale layer from 18.82m to 18.84m
	- Shale layer from 19.53m to 19.56m
	- Shale layer from 19.70m to 19.72m
	- Shale layer from 20.77m to 20.79m

Runs 1 to 7: Flush return 100

Type and Surface Description	Jcon	Jr	Ja
BD,UN,Ro CI	20	3	2
BD,UN,Ro	22	3	1
BD,UN,Ro	22	3	1
BD,UN,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,IR,SM	20	2	1
BD,CU,SM	20	2	1
BD,PL,SM	16	1	1
BD,UN,SM	20	2	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,CU,SM	20	2	1
BD,UN,SM	20	2	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
BD,UN,SM	20	2	1
JN,ST,Ro	22	3	1
BD,CU,Ro	22	3	1
BD,UN,SM	20	2	1
BD,UN,Ro	22	3	1
BD,UN,SM	20	2	1
BD,CU,SM	20	2	1

Notes:

Bentonite Seal

Silica Sand

32mm Diam. PVC #10 Slot Screen 'A'

Silica Sand

Bentonite Seal

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KS

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: T-75

LOCATION: N 5030923.18 ;E 366623.23

DRILLING DATE: March 23-24, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---								'B' 'A'
	Rotary Drill, HQ Core	- Shale layer from 21.20m to 21.22m		8		BD,PL,SM	16	1	1	
				8	100	BD,CU,SM	20	2	1	Bentonite Seal
						BD,UN,SM	20	2	1	
22		- Shale layer from 21.78m to 21.94m	39.76							
		End of Drillhole	22.03							W.L. in Screen at Elev. 58.73m on June 28, 2011
23										
24										
25										
26										
27										
28										
29										
30										
31										

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: KS

CHECKED: MRR

RECORD OF BOREHOLE: W-058

PROJECT: 10-1121-0222

SHEET 1 OF 1

LOCATION: N 5030845.23 ;E 366541.33

BORING DATE: October 18, 2010

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DEPTH (m)	DESCRIPTION	ELEV. / DEPTH (m)
	GROUND SURFACE	61.40
0	Dense to very loose brown to grey to black silty sand, some gravel, trace to some reddish brick fragments, trace black cinders/asphalt, trace ash (FILL)	0.00
3	Compact to very dense brown to grey SANDY SILT, trace to some gravel, trace clay (GLACIAL TILL)	58.35 / 3.05
6.84	Borehole continued on RECORD OF DRILLHOLE W-058	54.56

SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	50 DO	34	
2	50 DO	8	
3	50 DO	7	
4	50 DO	18	M
5	50 DO	81	
6	50 DO	50	
7	50 DO	50	
8	50 DO	50	MH
9	50 DO	50	

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^{-8} 10^{-6} 10^{-4} 10^{-2}

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

Piezometer / Standpipe installation:

- Flush Mount Protective Casing set in Bentonite
- Bentonite Seal
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen
- W.L. in Screen at Elev. 57.69m on Jan. 20, 2011

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: JC

CHECKED: MRR

OLRT-SOIL 1011210222-1300.GPJ GAL-MIS.GDT 12/06/11 JEM/JM

RECORD OF DRILLHOLE: W-058

PROJECT: 10-1121-0222

SHEET 1 OF 1

LOCATION: N 5030845.23 ;E 366541.33

DRILLING DATE: October 18, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.

Column headings: DEPTH SCALE METRES; DRILLING RECORD; DESCRIPTION; SYMBOLIC LOG; ELEV. DEPTH (m); RUN No.; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25m; DIP w.r.t. CORE AXIS; DISCONTINUITY DATA (TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WEATHERING INDEX (W1–W6); NOTES

Drilling record: Rotary Drill, HQ Core

Description	Elev. / Depth (m)	Run No.	Discontinuity type and surface description	Jcon	Jr	Ja
BEDROCK SURFACE	54.56					
Quartz (Boulder)	6.84	C1				
- No recovery from 7.04m to 7.36m	54.04 / 7.36					
Fresh, medium bedded to irregular laminated, grey to dark grey, fine to medium grained, slightly porous, medium strong to strong LIMESTONE BEDROCK, interbedded with shale		C2				
- Broken core from 7.36m to 8.02m						
- No recovery from 8.02m to 8.92m						
		C3	JN,PL,RO Cl	12	1.5	3
			JN,UN,RO	22	3	1
			JN,CU,RO Br	20	3	2
			JN,CU,RO Br	20	3	2
			JN,CU,RO Br	20	3	2
		C4	JN,PL,SM	16	1	1
			JN,CU,RO	22	3	1
			JN,CU,RO	22	3	1
- Broken core from 11.33m to 11.44m			JN,CU,RO	22	3	1
			JN,CU,SM Shale	20	2	2
			JN,UN,RO Br	20	3	2
	49.45		JN,PL,RO Br	16	1.5	2
End of Drillhole	11.95					

NOTES:

32mm Diam. PVC #10 Slot Screen

Silica Sand

Grout

W.L. in Screen at Elev. 57.69m on Jan. 20, 2011

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: JC

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-059

SHEET 1 OF 1

LOCATION: N 5030871.95 ;E 366581.57

BORING DATE: November 11-12, 2010

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	WATER CONTENT	ADDITIONAL LAB. TESTING
GROUND SURFACE	61.68					
ASPHALTIC CONCRETE	0.00					
Grey crushed stone (FILL)	0.14					
Brown silty sand to sand, trace gravel (FILL)	0.29					
Compact to dense grey brown silty fine sand, trace to some gravel, trace organic matter, occasional brown fine to medium sand layer (FILL)	60.79 / 0.89	1	50 DO	18		
Dense brown SANDY SILT, trace gravel (GLACIAL TILL)	60.00 / 1.68	2	50 DO	42		
Dense to very dense grey brown SILTY SAND, trace to some gravel, occasional cobbles (GLACIAL TILL)	59.55 / 2.13	3	50 DO	44		
		4	50 DO	82	○	MH
Very dense grey to grey brown SILTY SAND, some gravel, occasional cobbles (GLACIAL TILL)	58.02 / 3.66	5	50 DO	96		
		6	50 DO	55		
		7	50 DO	53		
Very dense grey SANDY SILT, trace to some gravel, occasional cobbles (GLACIAL TILL)	55.73 / 5.95	8	50 DO	80		
		9	50 DO	>100		
		10	50 DO	>100		
Very dense grey SANDY SILT, trace gravel and clay, occasional cobbles (GLACIAL TILL)	53.30 / 8.38	11	50 DO	>100	○	MH
		12	50 DO	>100		
	51.84					
Borehole continued on RECORD OF DRILLHOLE W-059						

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^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp —○W— Wl — 20 40 60 80

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

OLRT-SOIL 1011210222-1300.GPJ GAL-MIS.GDT 12/06/11 JEM/JM

RECORD OF DRILLHOLE: W-059

PROJECT: 10-1121-0222

SHEET 1 OF 1

LOCATION: N 5030871.95 ;E 366581.57

DRILLING DATE: November 11-12, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate

BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean

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	ELEV. / DEPTH (m)	RUN No.
		BEDROCK SURFACE	51.84	
10–15	Rotary Drill, HQ Core	Fresh to slightly weathered, medium bedded, grey to dark grey, fine to medium grained, medium strong to strong LIMESTONE BEDROCK, with wavy thin shale beds	51.84 / 9.84 to 46.74 / 14.94	1, 2, 3, 4
15		End of Drillhole	14.94	

Discontinuity data:

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,ST,Ro/Sm	22	2	0.75
BD,CU,Ro/Sm Cl	16	1	3
BD,PL,SM Cl	16	1	3
JN,UN,Ro/Sm Cl/Gr	6	1	4
BD,UN,Ro	22	2	0.75
BD,CU,Ro/Sm Sa/Si	16	1	3
BD,IR,Ro/Sm Cl	16	1	3
BD,UN,Ro	22	2	0.75
BD,PL,SM	16	1	0.75
BD,UN,SM	20	2	0.75
BD,PL,SM	16	1	0.75
BD,UN,Ro/Sm Si/Cl	6	1	4
BD,UN,Ro Cl	12	1	3
BD,CU,SM	20	2	0.75
BD,CU,SM	20	2	0.75
BD,CU,SM Cl	12	1	3
BD,CU,Ro/Sm	22	2	0.75
BD,ST,Ro	22	3	0.75

Column headings: RECOVERY (TOTAL CORE %, SOLID CORE %), R.Q.D. %, FRACT. INDEX PER 0.25m, DIP w.r.t. CORE AXIS, HYDRAULIC CONDUCTIVITY K, cm/sec, WEATHERING INDEX (W1–W6), NOTES, FLUSH RETURN, SYMBOLIC LOG

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-060

SHEET 1 OF 1

LOCATION: N 5030910.36 ;E 366594.56

BORING DATE: November 24, 2010

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200mm 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^{-8}, 10^{-6}, 10^{-4}, 10^{-2}

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

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	61.23
ASPHALTIC CONCRETE	0.00
Loose to dense brown sandy silt, trace medium sand layers (FILL)	0.10
Grey brown silty sand, trace gravel, some pieces of wood (FILL)	58.18 / 3.05
Very dense grey brown SILTY fine SAND, trace gravel (GLACIAL TILL)	57.93 / 3.30
Borehole continued on RECORD OF DRILLHOLE W-060	52.06

SAMPLE NUMBER	TYPE	BLOWS/0.3m
1	50 DO	9
2	50 DO	35
3	50 DO	44
4	50 DO	>100
5	50 DO	78
6	50 DO	97
7	50 DO	>100
8	50 DO	>100
9	50 DO	>100
10	50 DO	>100

ADDITIONAL LAB. TESTING: MH (sample 5, approx. 4 m depth)

PIEZOMETER OR STANDPIPE INSTALLATION:

- Flush Mount Protective Casing set in Bentonite
- Bentonite Seal
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen
- Silica Sand
- Grout
- W.L. in Screen at Elev. 57.72m on Jan. 20, 2011

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: JD

CHECKED: MRR

OLRT-SOIL 1011210222-1300.GPJ GAL-MIS.GDT 12/06/11 JEM/JM

RECORD OF DRILLHOLE: W-060

PROJECT: 10-1121-0222

SHEET 1 OF 1

LOCATION: N 5030910.36 ;E 366594.56

DRILLING DATE: November 24, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

Abbreviations: JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean; 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	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	52.06						
	Rotary Drill, HQ Core	Fresh, grey, fine to medium grained, slightly porous, strong LIMESTONE BEDROCK, interbedded with undulating, wavy shale laminates	9.17	1					
10		No core recovery from 9.17m to 10.42m- redrill		2					
11				3	BD,PL,Ro	20	1.5	0.75	
					BD,CU,SM Cl	20	2	1	
					BD,PL,Ro	20	1.5	0.75	
					BD,PL,SM	16	1	0.75	
					BD,PL,SM	16	1	0.75	
12				4	BD,PL,Ro Sh/Br	16	1.5	2	
					BD,PL,Ro Sh/Br	16	1.5	2	
					BD,CU,SM Br	16	2	2	
13					BD,CU,Ro	22	3	0.75	Grout
					BD,CU,SM Cl	20	2	1	
14				5	BD,CU,Ro	22	3	0.75	
					BD,CU,Ro Br	20	3	2	
15				6	BD,CU,Ro Br	20	3	2	
					BD,CU,Ro	22	3	0.75	
					JN,ST,Ro	22	3	0.75	
16					BD,CU,Ro Br	20	3	2	
			44.65 / 16.58						
		End of Drillhole							
17									W.L. in Screen at Elev. 57.72m on Jan. 20, 2011
18									
19									

OLRT-ROCK 1011210222-1300.GPJ GAL-MISS.GDT 12/06/11 JEM/JM

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: JD

CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF BOREHOLE: W-061

LOCATION: N 5030949.23 ;E 366639.83

BORING DATE: October 18, 2010

DATUM: Geodetic

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)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	HYDRAULIC CONDUCTIVITY, k, cm/s	ADDITIONAL LAB. TESTING
	GROUND SURFACE	61.55					
0	Grey crushed stone (BASE)	0.00					
	Brown sand, trace silt and gravel (FILL)	0.15					
	Dark brown silty sand, some gravel, occasional cobbles, brick (FILL)	0.23	3	GRAB	-		
	Dense brown to grey brown SILTY SAND, some gravel, trace clay, with cobbles and sand seams (GLACIAL TILL)	60.94 / 0.61					
1	- Layer of cobbles at 1.22m		1	50 DO	32		
2			2	50 DO	41		
			4	50 DO	37		
	Very dense grey brown to grey SILTY SAND, some gravel, trace clay, with cobbles and sand seams (GLACIAL TILL)	59.01 / 2.54					
3			5	50 DO	60		
4			6	50 DO	26	O	MH
5			7	50 DO	92		
	Very dense grey SILTY SAND, some gravel, trace clay, with cobbles (GLACIAL TILL)	56.37 / 5.18					
			8	50 DO	80		
6			9	50 DO	51	O	MH
7							
			10	50 DO	55		
8							
9		52.54					
	Borehole continued on RECORD OF DRILLHOLE W-061						
10							

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

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

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

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

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

RECORD OF DRILLHOLE: W-061

PROJECT: 10-1121-0222

LOCATION: N 5030949.23 ;E 366639.83

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: October 18, 2010

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
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.	FLUSH 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 0.25m (5 10 15 20)	DIP w.r.t. CORE AXIS (0 30 60 90)	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES
		BEDROCK SURFACE		52.54														
	Rotary Drill, HQ Core	Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor thin lithoclastic limestone beds and interbeds of dark grey, bedding laminations and very thin to thinly bedded, calcareous, slake susceptible shale at semi regular intervals of 0.25 to 2.5 m. Contains traces of fossil fragments. Top contact of formation marked by thin bed of shale and shaley limestone. Shale and shaley limestone comprise 7.5 % to 10 % of sequence		9.01	C1							BD,CU,RO Br	20	3	1			
												BD,UN,RO Br	20	3	1			
												BD,CU,SM Br	16	2	1			
												BD,PL,RO Br	16	1.5	1			
10												BD,CU,RO Cl	12	1	4			
					C2							BD,CU,SM Cl	12	1	4			
												BD,CU,SM Cl	12	1	4			
11												BD,CU,RO Ca	20	3	3			
												BD,CU,SM Cl	12	1	4			
												BD,CU,RO Cl	12	1	4			
12					C3							BD,PL,RO Ca	16	1.5	2			
												BD,UN,SM	20	2	1			
13					C4							BD,UN,SM Fossils	16	2	2			
14																		
15					C5							BD,UN,RO Br	20	3	0.75			
												BD,UN,RO Br	20	3	0.75			
16												BD,PL,RO Cl	12	1	4			
17					C6							BD,UN,SM	16	2	1			
18				43.51														
		Fresh, medium to thickly bedded, grey, fine to medium grained, medium strong LIMESTONE BEDROCK, with thinly laminated black shale layers		18.04	C7							BD,PL,RO Br	16	1.5	0.75			
												BD,PL,SM Sa	12	1	2			
												BD,ST,RO Si/Sa	12	2	3			
19																		

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

RECORD OF DRILLHOLE: W-061

PROJECT: 10-1121-0222

LOCATION: N 5030949.23 ;E 366639.83

DRILLING DATE: October 18, 2010

DATUM: Geodetic

DRILL RIG: CME 75

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Downing

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25m	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec	WEATHERING INDEX	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---																
	Rotary Drill / HQ Core	Fresh, medium to thickly bedded, grey, fine to medium grained, medium strong LIMESTONE BEDROCK, with thinly laminated black shale layers		42.02 / 19.53	C7													
		End of Drillhole																
20																		
21																		
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: RI

CHECKED: MRR

RECORD OF BOREHOLE: W-062

PROJECT: 10-1121-0222
LOCATION: N 5030983.21 ;E 366665.88
BORING DATE: October 19, 2010
SHEET 1 OF 1
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200 mm Diam. (Hollow Stem)

Description	Elev. / Depth (m)
GROUND SURFACE	62.95
Black organic TOPSOIL	0.00
Loose to dense miscellaneous red brick, broken cement (FILL)	0.05
Compact to very dense fine grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)	59.90 / 3.05
Borehole continued on RECORD OF DRILLHOLE W-062	57.07

Sample Number	Type	Blows/0.3m
1	50 DO	5
2	50 DO	50
3	50 DO	45
4	50 DO	20
5	50 DO	54
6	50 DO	74
7	50 DO	50

Additional lab testing: MH (Sample 7)

Piezometer / Standpipe installation:
- Flush Mount Protective Casing set in Bentonite
- Bentonite Seal
- Silica Sand
- 32mm Diam. PVC #10 Slot Screen
- W.L. in Screen at Elev. 60.37m on Jan. 20, 2011
- Silica Sand

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: CC
CHECKED: MRR

OLRT-SOIL 1011210222-1300.GPJ GAL-MIS.GDT 12/06/11 JEM/JM

RECORD OF DRILLHOLE: W-062

PROJECT: 10-1121-0222
LOCATION: N 5030983.21 ;E 366665.88
INCLINATION: -90° AZIMUTH: ---
DRILLING DATE: October 19, 2010
DRILL RIG: CME 75
DRILLING CONTRACTOR: Downing
DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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	ELEV. / DEPTH (m)	RUN No.	NOTES
		BEDROCK SURFACE	57.07		
6–16	Rotary Drill, HQ Core	Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor thin lithoclastic limestone beds and interbeds of dark grey, bedding laminations and very thin to thinly bedded, calcareous, slake susceptible shale at semi regular intervals of 0.25 to 2.5 m. Contains traces of fossil fragments. Top contact of formation marked by thin bed of shale and shaley limestone. Shale and shaley limestone comprise 7.5 % to 10 % of sequence	5.88	C1, C2, C3, C4, C5, C6, C7	Silica Sand; Bentonite Seal; Grout
		CONTINUED NEXT PAGE			

Columns: RECOVERY (TOTAL CORE %, SOLID CORE %), R.Q.D. %, FRACT. INDEX PER 0.25m, DIP w.r.t. CORE AXIS, DISCONTINUITY DATA, HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}), WEATHERING INDEX (W1–W6)

RUN No.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
C1	BD,CU,RO	20	3	1
C1	BD,PL,RO	20	1.5	1
C1	BD,CU,SM Cl	12	2	4
C1	BD,CU,SM Cl	12	2	4
C1	BD,ST,RO Br	20	3	2
C1	BD,PL,RO Cl	12	1.5	4
C1	BD,PL,SM Br	12	1	2
C1	JN,ST,RO Cl/Sa	6	1	8
C1	BD,PL,SM	12	1	1
C2	BD,CU,RO	20	2	1
C2	BD,PL,SM	12	1	1
C2	BD,UN,RO	20	2	1
C2	BD,PL,SM	16	1	3
C3	BD,PL,RO	20	1.5	3
C3	BD,PL,RO	12	1.5	1
C3	BD,ST,RO	20	3	1
C3	JN,CU,SM Ca	12	2	3
C3	BD,CU,RO	20	3	2
C3	BD,PL,SM Br	12	1	2
C4	BD,PL,SM Br	12	1	2
C4	BD,CU,RO	20	3	2
C4	JN,CU,RO	20	3	2
C4	BD,ST,RO	20	3	2
C5	BD,PL,RO Br	12	1.5	2
C5	BD,PL,RO Br	12	1.5	2
C5	BD,CU,RO Ca	12	3	3
C5	BD,PL,RO Br	16	1.5	2
C5	BD,PL,SM Br	12	1	2
C6	JN,CU,SM Br	16	2	2
C6	BD,CU,SM	20	2	2
C6	BD,PL,SM Br	12	1	2
C6	BD,UN,RO Br	20	3	2
C7	BD,PL,SM Br	12	1	2
C7	BD,CU,SM Br	16	2	2

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CC
CHECKED: MRR

PROJECT: 10-1121-0222

RECORD OF DRILLHOLE: W-062

LOCATION: N 5030983.21 ;E 366665.88

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: October 19, 2010

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing

DATUM: Geodetic

Legend: JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean; 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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. / DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: Rotary Drill, HQ Core

Description (16 to 22.68 m): Fresh to slightly weathered, medium brownish grey, fine to medium grained crystalline, non porous, thinly to medium bedded, strong, CALCARENITIC LIMESTONE, subordinate nodular limestone, minor thin lithoclastic limestone beds and interbeds of dark grey, bedding laminations and very thin to thinly bedded, calcareous, slake susceptible shale at semi regular intervals of 0.25 to 2.5 m. Contains traces of fossil fragments. Top contact of formation marked by thin bed of shale and shaley limestone. Shale and shaley limestone comprise 7.5 % to 10 % of sequence

Run No.	Type and Surface Description	Jcon	Jr	Ja
C7	BD,PL,SM Br	12	1	2
C7	BD,PL,RO	16	1.5	2
C8	BD,PL,RO	16	1.5	1
C8	BD,CU,RO	16	3	1
C8	BD,CU,RO	20	3	1
C8	BD,CU,SM	16	2	1
C8	BD,PL,RO	16	2	1
C9	BD,UN,RO Br			
C9	BD,PL,SM Br	12	1	1
C9	BD,CU,RO Br	16	3	1
C10	BD,PL,SM Br	12	1	2
C10	BD,UN,RO	20	3	2
C10	BD,PL,RO Br	16	1.5	1
C11	BD,PL,SM Br	12	1	2

Notes: Grout

40.27
22.68

End of Drillhole

W.L. in Screen at Elev. 60.37m on Jan. 20, 2011

Depth scale: 16, 17, 18, 19, 20, 21, 22, 23, 24, 25

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CC
CHECKED: MRR

RECORD OF BOREHOLE: 13-3

PROJECT: 13-1121-0143

LOCATION: N 5030826.51 ;E 366567.39
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: February 13, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring Method: Power Auger, 200 mm Diam. (Hollow Stem)

Depth (m)	Soil Profile – Description	Elev. / Depth (m)
	GROUND SURFACE	62.49
0	(SP/GP) SAND and GRAVEL, with brick, ash, and glass fragments; brown, (FILL); non-cohesive	0.00
	(SP/GP) SAND and GRAVEL, presence of cobbles and/or boulders inferred from auger resistance, trace glass, bricks, and mortar fragments; brown to dark grey, (FILL); non-cohesive, moist, loose	62.19 / 0.30
	(SM) SILTY SAND, some gravel, trace medium to coarse brown sand seams, presence of cobbles and/or boulders inferred from auger resistance; grey brown, (GLACIAL TILL); non-cohesive, wet, very dense	60.97 / 1.52
	- Becoming wet at 3.51 m depth	
	- Becoming grey	
	(ML) sandy SILT, some gravel, presence of cobbles and/or boulders inferred from auger resistance; grey, (GLACIAL TILL); non-cohesive, wet, very dense	54.87 / 7.62

Sample Number	Type	Blows/0.3m
1	SS	9
2	SS	61
3	SS	58
4	SS	35
5	SS	44
6	SS	>50
7	SS	>50
8	SS	50
9	SS	>50
10	SS	>50
11	SS	>50
12	SS	>50
13	SS	>50

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^{-8} 10^{-6} 10^{-4} 10^{-2}
Water Content Percent: Wp — W — Wl — 20 40 60 80
Additional Lab. Testing

Piezometer or Standpipe Installation: MON. WELL
- Bentonite Seal
- Silica Sand and Bentonite
- Bentonite Seal
- Silica Sand
- 51 mm Diam. PVC #10 Slot Screen
- Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

CSST-SOIL 1311210143.GPJ GAL-MIS.GDT 07/21/15 JM

RECORD OF BOREHOLE: 13-3

PROJECT: 13-1121-0143
LOCATION: N 5030826.51 ;E 366567.39
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm
DRILLING DATE: February 13, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling
PENETRATION TEST HAMMER, 64kg; DROP, 760mm
DATUM: CGVD1928

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
10	Power Auger	(ML) sandy SILT, some gravel, presence of cobbles and/or boulders inferred from auger resistance; grey, (GLACIAL TILL); non-cohesive, wet, very dense			14	SS	>50				
11	RD HQ3			51.41							
		Borehole continued on RECORD OF DRILLHOLE 13-3									
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

RECORD OF DRILLHOLE: 13-3

PROJECT: 13-1121-0143
LOCATION: N 5030826.51 ;E 366567.39
INCLINATION: -90° AZIMUTH: ---
DRILLING DATE: February 13, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling
DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.

Columns: DEPTH SCALE METRES; DRILLING RECORD; DESCRIPTION; SYMBOLIC LOG; ELEV. DEPTH (m); RUN No.; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25m; DISCONTINUITY DATA (ANGLE wrt CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WEATHERING INDEX (W1–W6); NOTES

Depth (m)	Description	Elev./Depth (m)	Run No.
	BEDROCK SURFACE	51.41 / 11.08	
11.08–21	Fresh, thinly to medium bedded, grey, fine to medium grained, medium strong LIMESTONE, with shale interlaminations and thin interbeds, occasional nodules. VERULAM FORMATION		1–8

Drilling record: Rotary Drill, HQ3 Core

Type and Surface Description	Jcon	Jr	Ja
JN,IR,SM Br	20	2	1
JN,IR,RO Br	25	3	1
BD,CU,SM	20	2	1
BD,PL,SM Si, Sa 2mm	6	1	4
JN,PL,RO Ca, 1mm	20	1.5	3
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,IR,RO	25	3	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,CU,SM Ca	20	2	3
BD,PL,SM	16	1	1
JN,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,RO Br, Sa 40mm	0	1	6
JN,UN,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM Ca	16	1	3
BD,PL,SM	16	1	1

NOTES: MON. WELL; Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

RECORD OF DRILLHOLE: 13-3

PROJECT: 13-1121-0143
LOCATION: N 5030826.51 ;E 366567.39
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 13, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25m	ANGLE wrt CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec	WEATHERING INDEX	NOTES / MON. WELL
		--- CONTINUED FROM PREVIOUS PAGE ---																
	Rotary Drill, HQ3 Core			40.91 / 21.58	8							BD,PL,SM CL 2mm	6	1	8			Cementitious Grout
22		End of Drillhole Notes: 1. The results of constant head packer tests are as follows: - 18.85 m to 21.58 m: K = 4x10 -6 cm/s 2. Falling head packer test results and slug test results are shown on the log above.																
23																		
24																		
25																		
26																		
27																		
28																		
29																		
30																		
31																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

RECORD OF BOREHOLE: 13-4

PROJECT: 13-1121-0143
LOCATION: N 5030852.88 ;E 366587.26
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: February 4, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

Soil Profile

ELEV. DEPTH (m)	DESCRIPTION
62.20	GROUND SURFACE
0.00	(SM) SILTY SAND, trace to some gravel; brown to black, (FILL); non-cohesive
61.79 / 0.41	(SM) SILTY SAND, some gravel, presence of cobbles and/or boulders inferred from auger resistance, trace mortar, glass, ash, brick fragments, and organic matter; grey to brown, (FILL); non-cohesive, moist, loose to compact - Becoming very dense below 3.81 m depth - Becoming wet at 4.88 m depth
56.87 / 5.33	(SM/ML) sandy SILT to SILTY SAND, some gravel, trace sand seams, presence of cobbles and/or boulders inferred from auger resistance; (GLACIAL TILL); non-cohesive, wet, very dense

CONTINUED NEXT PAGE

Samples

NUMBER	TYPE	BLOWS/0.3m
1	SS	20
2	SS	4
3	SS	53
4	SS	22
5	SS	50
6	SS	50
7	SS	73
8	SS	50
9	SS	50
10	SS	89
11	SS	63
12	SS	50
13	SS	50

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^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl ; 20 40 60 80
ADDITIONAL LAB. TESTING

Piezometer or Standpipe Installation (MON. WELL)

- Bentonite Seal
- Silica Sand
- Bentonite Seal
- Silica Sand
- 51 mm Diam. PVC #10 Slot Screen
- Silica Sand

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

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

CSST-SOIL 1311210143.GPJ GAL-MIS.GDT 07/21/15 JM

RECORD OF BOREHOLE: 13-4

PROJECT: 13-1121-0143

LOCATION: N 5030852.88 ;E 366587.26
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: February 4, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
10	Power Auger			51.56							
		Borehole continued on RECORD OF DRILLHOLE 13-4									Native Backfill
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

CSST-SOIL 1311210143.GPJ GAL-MIS.GDT 07/21/15 JM

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-4

LOCATION: N 5030852.88 ;E 366587.26

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 4, 2013

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (ANGLE wrt CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jcon, Jr, Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WEATHERING INDEX (W1–W6) | NOTES

Drilling record: Rotary Drill, HQ3 Core

MON. WELL

Elev. / Depth (m)	Description
51.56	BEDROCK SURFACE
10.64	Slightly weathered, thinly to medium bedded, grey, fine to medium grained, non-porous, medium strong LIMESTONE, with thin shale laminates VERULAM FORMATION
50.73 / 11.47	Fresh, thinly to medium bedded, grey, fine to medium grained, non-porous, medium strong to strong LIMESTONE, with shale laminates, some nodules present VERULAM FORMATION

Runs: 1A, 1B, 2, 3, 4, 5, 6, 7

Approx. depth (m)	Type and surface description	Jcon	Jr	Ja
10.8	JN,PL,RO Br	20	1.5	1
11.2	JN,UN,RO Br	25	3	1
11.3	JN,PL,RO	20	1.5	1
11.5	BD,PL,SM	16	1	1
11.5	BD,PL,SM	16	1	1
11.6	BD,PL,SM	16	1	1
11.6	BD,UN,SM	20	2	1
11.9	JN,IR,SM	20	2	1
12.0	BD,PL,SM	16	1	1
12.3	BD,PL,SM	16	1	1
12.8	BD,CU,RO	25	3	1
12.8	BD,PL,SM	16	1	1
12.9	BD,PL,SM	16	1	2
13.1	BD,PL,RO Br	20	1.5	2
13.1	BD,PL,RO Br	20	1.5	2
13.3	BD,IR,RO	25	3	1
13.7	BD,PL,SM	16	1	1
13.7	BD,PL,SM	16	1	1
13.9	BD,PL,SM	16	1	1
14.1	BD,UN,SM	20	2	1
14.6	BD,IR,SM	20	2	1
14.8	BD,PL,SM	16	1	1
15.4	BD,IR,SM	20	2	1
15.8	BD,UN,SM	20	2	1
15.9	BD,IR,SM	20	2	1
16.1	JN,PL,SM	16	1	1
16.1	BD,PL,SM	16	1	1
16.5	BD,PL,SM	16	1	1
17.5	BD,PL,SM	16	1	2
17.6	BD,UN,SM	20	2	2
17.7	BD,PL,SM	16	1	2
18.0	BD,PL,SM	16	1	2
18.8	BD,PL,RO	20	1.5	2
19.0	BD,PL,SM	16	1	2
19.3	BD,PL,SM	16	1	2
19.5	BD,PL,SM	16	1	2

Notes: Native Backfill; Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE

CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-4

LOCATION: N 5030852.88 ;E 366587.26

DRILLING DATE: February 4, 2013

DATUM: CGVD1928

INCLINATION: -90°   AZIMUTH: ---

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean; 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.

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DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES	MON. WELL
21	Rotary Drill, HQ3 Core	Fresh, thinly to medium bedded, grey, fine to medium grained, non-porous, medium strong to strong LIMESTONE, with shale laminates, some nodules present VERULAM FORMATION		7	BD,PL,RO	20	1.5	2	Cementitious Grout	
			40.60 21.60	8	BD,PL,SM	16	1	2		

End of Drillhole

Notes:
1. The results of constant head packer tests are as follows:
- 16.57 m to 21.60 m: K = 4x10 -5 cm/s

2. Falling head packer test results and slug test results are shown on the log above.

Depth scale: 22, 23, 24, 25, 26, 27, 28, 29, 30

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE

CHECKED: WAM/AJS

RECORD OF BOREHOLE: 13-5

PROJECT: 13-1121-0143

LOCATION: N 5030879.81 ;E 366599.42
INCLINATION: -69.5° AZIMUTH: 203°
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: February 12-14, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		62.11							
0	Power Auger 200 mm Diam. (Hollow Stem)	Overburden - Not Sampled		0.00							Cementitious Grout
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 13-5

LOCATION: N 5030879.81 ;E 366599.42
DRILLING DATE: February 12-14, 2013
DATUM: CGVD1928

INCLINATION: -69.5° AZIMUTH: 203°
DRILL RIG: CME-75

SAMPLER HAMMER, 64kg; DROP, 760mm
DRILLING CONTRACTOR: Downing Drilling
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger	Overburden - Not Sampled									
11	Rotary Drill HQ3 Core			51.33							
		Borehole continued on RECORD OF DRILLHOLE 13-5									
12											
13											
14											
15											
16											
17											
18											
19											
20											

CSST-SOIL 1311210143.GPJ GAL-MIS.GDT 07/21/15 JM

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: WAM/AJS

RECORD OF DRILLHOLE: 13-5

PROJECT: 13-1121-0143

LOCATION: N 5030879.81 ;E 366599.42

INCLINATION: -69.5° AZIMUTH: 203°

DRILLING DATE: February 12-14, 2013

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20) | R.Q.D. % 80 60 40 20 | FRACT. INDEX PER 0.25m 5 10 15 20 | DISCONTINUITY DATA (ANGLE wrt CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2} | WEATHERING INDEX W1 W2 W3 W4 W5 W6 | NOTES

Depth scale: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

Drilling record: Rotary Drill — HQ3 Core

BEDROCK SURFACE — 51.33 / 11.51

Fresh, thinly to medium bedded, grey, fine to coarse grained, non-porous, medium strong to strong LIMESTONE, with thin black shale interbeds and interlaminations, occasional nodules

VERULAM FORMATION

Run No.: 1, 2, 3, 4, 5, 6, 7, 8

Run	Type and Surface Description	Jcon	Jr	Ja
2	BD,PL,RO Br	20	1.5	1
2	BD,CU,RO Br	25	3	1
2	BD,PL,SM	16	1	1
2	BD,IR,RO	25	3	1
2	BD,PL,SM	16	1	1
3	BD,CU,RO	25	3	1
3	BD,PL,RO	20	1.5	1
3	BD,PL,RO	20	1.5	1
3	BD,PL,RO	20	1.5	1
4	BD,PL,RO	20	1.5	1
4	BD,PL,RO	20	1.5	1
5	BD,PL,SM	16	1	1
5	BD,PL,RO	20	1.5	1
5	BD,CU,RO	25	3	1
5	BD,CU,RO	25	3	1
5	BD,PL,SM	16	1	1
5	BD,PL,SM	16	1	1
5	BD,PL,RO	20	1.5	1
6	BD,CU,RO	25	3	1
6	BD,CU,RO	25	3	1
6	BD,PL,SM	16	1	1
7	BD,PL,SM	16	1	1
7	BD,PL,RO	20	1.5	1
7	BD,PL,SM	16	1	1
7	BD,PL,RO	20	1.5	1
7	BD,PL,RO	20	1.5	1
7	BD,CU,RO	25	3	1
8	BD,CU,RO	25	3	1
8	BD,PL,RO	20	1.5	1
8	BD,CU,RO	25	3	1

NOTES: Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: WAM/AJS

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-5

LOCATION: N 5030879.81 ;E 366599.42

INCLINATION: -69.5° AZIMUTH: 203°

DRILLING DATE: February 12-14, 2013

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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	ELEV. / DEPTH (m)	RUN No.	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---			
22	Rotary Drill, HQ3 Core	Fresh, thinly to medium bedded, grey, fine to coarse grained, non-porous, medium strong to strong LIMESTONE, with thin black shale interbeds and interlaminations, occasional nodules VERULAM FORMATION	40.85 / 22.70	8, 9	Cementitious Grout
23		End of Drillhole Notes: 1. The results of constant head packer tests are as follows: - 19.80 m to 22.70 m: K = 5x10 -5 cm/s 2. Falling head packer tests in the following depth intervals gave a hydraulic conductivity value of less than 1x10 -8 cm/s: - 16.07 m to 19.16 m 3. Other falling head packer test results are shown on the log above.			
24					
25					
26					
27					
28					
29					
30					
31					

Other column headers: SYMBOLIC LOG; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE % — 80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25m (5 10 15 20); DISCONTINUITY DATA (ANGLE wrt CORE AXIS — 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jcon, Jr, Ja); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WEATHERING INDEX (W1 W2 W3 W4 W5 W6)

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: WAM/AJS

RECORD OF BOREHOLE: 13-6

PROJECT: 13-1121-0143
LOCATION: N 5030907.61 ;E 366614.54
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm
DRILLING DATE: February 8, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling
PENETRATION TEST HAMMER, 64kg; DROP, 760mm
DATUM: CGVD1928

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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION (MON. WELL)
0	GROUND SURFACE	61.95				
	(SM) SILTY SAND, some gravel; brown, (FILL); non-cohesive	0.00				Bentonite Seal
	(SM) SILTY SAND, trace gravel, mortar, ash, brick, and glass fragments; grey brown, (FILL); non-cohesive, dry, very loose to very dense	61.67 / 0.28				
1			1	SS	3	
2			2	SS	64	
	(SP) SAND, fine to medium, trace gravel, brick, ash, and mortar, some low plasticity fines; brown, (FILL); non-cohesive, moist, dense	59.44 / 2.51	3	SS	36	
3			4	SS	49	
	(SM) SILTY SAND, some gravel, trace brown medium to coarse sand seams, presence of cobbles and/or boulders inferred from auger resistance; grey brown, (GLACIAL TILL); non-cohesive, wet, dense to very dense	58.29 / 3.66	5	SS	>50	
4			6	SS	>50	
5			7	SS	53	Silica Sand
6			8	SS	66	
7			9	SS	>50	
			10	SS	>50	
8			11	SS	>50	
9			12	SS	>50	
10			13	SS	42	

CONTINUED NEXT PAGE

Other column headings (no data recorded on this sheet): 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^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WATER CONTENT PERCENT (Wp —○W— Wl; 20, 40, 60, 80); ADDITIONAL LAB. TESTING; STRATA PLOT.

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

RECORD OF BOREHOLE: 13-6

PROJECT: 13-1121-0143

LOCATION: N 5030907.61 ;E 366614.54
DRILLING DATE: February 8, 2013
DATUM: CGVD1928
INCLINATION: -90° AZIMUTH: ---
DRILL RIG: CME-75
SAMPLER HAMMER, 64kg; DROP, 760mm
DRILLING CONTRACTOR: Downing Drilling
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ⊖W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
10	Power Auger 200 mm Diam. (Hollow Stem)	(SM) SILTY SAND, some gravel, trace brown medium to coarse sand seams, presence of cobbles and/or boulders inferred from auger resistance; grey brown, (GLACIAL TILL); non-cohesive, wet, dense to very dense			13	SS	42				Silica Sand
											Bentonite Seal
11				50.80	14	SS	33				Silica Sand
		Borehole continued on RECORD OF DRILLHOLE 13-6									
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

RECORD OF DRILLHOLE: 13-6

PROJECT: 13-1121-0143
LOCATION: N 5030907.61 ;E 366614.54
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 8, 2013
DRILL RIG: CME-75
DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD- Bedding, FO- Foliation, CO- Contact, OR- Orthogonal, CL - Clean
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.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20) | R.Q.D. % 80 60 40 20 | FRACT. INDEX PER 0.25m 5 10 15 20 | DISCONTINUITY DATA (ANGLE wrt CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2} | WEATH-ERING INDEX W1 W2 W3 W4 W5 W6 | NOTES

BEDROCK SURFACE — Elev. 50.80, Depth 11.15

Fresh, thinly to medium bedded, grey, non-porous, medium strong to strong, fossiliferous LIMESTONE, with thin shale interbeds and interlaminations, occasional nodules

VERULAM FORMATION

Drilling record: Rotary Drill, HQ3 Core

Depth scale: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

Run No.: 1, 2, 3, 4, 5, 6, 7, 8

Discontinuity data:

Type and Surface Description	Jcon	Jr	Ja
BD,IR,RO	25	3	1
BD,IR,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,CU,SM	20	2	1
BD,CU,SM	20	2	1
BD,PL,SM	16	1	1
BD,UN,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
JN,PL,RO	20	1.5	1
JN,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,IR,RO	25	3	1
BD,CU,SM	20	2	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
JN,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1

NOTES: MON. WELL
Silica Sand
51 mm Diam. PVC #10 Slot Screen
Cementitious Grout

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: KE
CHECKED: WAM/AJS

CSST-ROCK 1311210143.GPJ GAL-MISS.GDT 07/21/15 JM

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 13-6

LOCATION: N 5030907.61 ;E 366614.54

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 8, 2013

DRILL RIG: CME-75

DRILLING CONTRACTOR: Downing Drilling

DATUM: CGVD1928

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25m	ANGLE wrt CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec	WEATHERING INDEX	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---																MON. WELL
				40.44	8													Cementitious Grout
		End of Drillhole Notes: 1. Falling head packer test results and slug test results are shown on the log above.		21.51														
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		
30																		
31																		

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: KE

CHECKED: WAM/AJS

THE ROBERT M. BUCHAN
DEPARTMENT OF MINING

Goodwin Hall
Queen's University
Kingston, Ontario, Canada
K7L 3N6
Tel 613 533-2230
Fax 613 533-6597

April 29, 2013

Mr. Stephen Dunlop
Golder Associates Limited
32 Steacie Drive
Kanata, ON K2K 2A9

Re: Golder Ottawa CSST Project #13-1121-0005

Dear Mr. Dunlop:

Ten core specimens were received in a single shipment from which nine unconfined compression and nine Brazilian indirect tensile strength assessments were made.

The unconfined test specimens, of adequate received length, were subjected to a process of preparation that included:

- -diamond sawing to prepare cylindrical samples having parallel end faces
- -diamond lathing, to prepare sample faces parallel to within $\pm$ 0.025 mm
- -testing to failure within a servo-controlled compression frame

Test results are tabled, photographs of pre- and post-test specimens are illustrated, and a summary billing statement for work that has been completed are included with this report.

Yours sincerely,

J. F. Archibald, Ph.D., P. Eng., FCIM

Sample Failure Test Results (Ottawa CSST Project #13-1121-0005) – April, 2013

Sample Hole (depth)	Density (g/cm^3)	UCS (MPa)	Young's Modulus (GPa)	Poisson's ratio (μ)	Brazilian Indirect Tensile Strength (and range) (MPa)
13-3 (13.33-13.64 m)	---	---	---	---	7.8 (4.7-9.2)
13-3 (13.73-14.02 m)	2.70	48.0	20.532	0.21	---
13-3 (15.55-16.02 m)	2.70	28.8 (pf)	12.168	0.15	9.1 (6.2-10.8)
13-3 (17.23-17.61 m)	2.70	44.6 (f)	18.243	0.12	9.6 (7.4-11.9)
13-4 (12.42-12.77 m)	2.70	51.1	19.466	0.12	9.6 (8.3-12.2)
13-4 (14.10-14.47 m)	2.70	43.4 (pf)	20.143	0.14	8.4 (5.4-12.0)
13-4 (16.53-16.86 m)	2.68	18.5 (pf)	14.221	---	9.5 (7.3-11.5)
13-6 (12.11-12.47 m)	2.69	32.7 (pf)	8.792	---	8.0 (6.1-10.3)
13-6 (14.97-15.31 m)	2.70	63.9 (pf)	36.749	0.13	7.3 (5.5-10.3)
13-6 (16.47-16.77 m)	2.70	35.0 (pf)	12.385	0.16	7.1 (5.9-8.1)

(pf) – indicates that sample failure occurred partially along pre-existing foliation surface
(f) - indicates that sample failure occurred entirely along pre-existing foliation surface

<u>**Photographs of Pre-Test Samples**</u>


GOLDER (DUNLOP)
BH 13-4
(12.42)
UCS
GOLDER (DUNLOP)
BH 13-4
(12.42)
BRAZ


GOLDER (DUNLOP
BH 13-4
(14.10)
UCS
GOLDER (DUNLOP)
BH 13-4
(14.10)
BRAZ


GOLDER (DUNLOP)
BH 13-4
(16.53)
UCS
GOLDER (DUNLOP)
BH 13-4
(16.53)
BRAZ

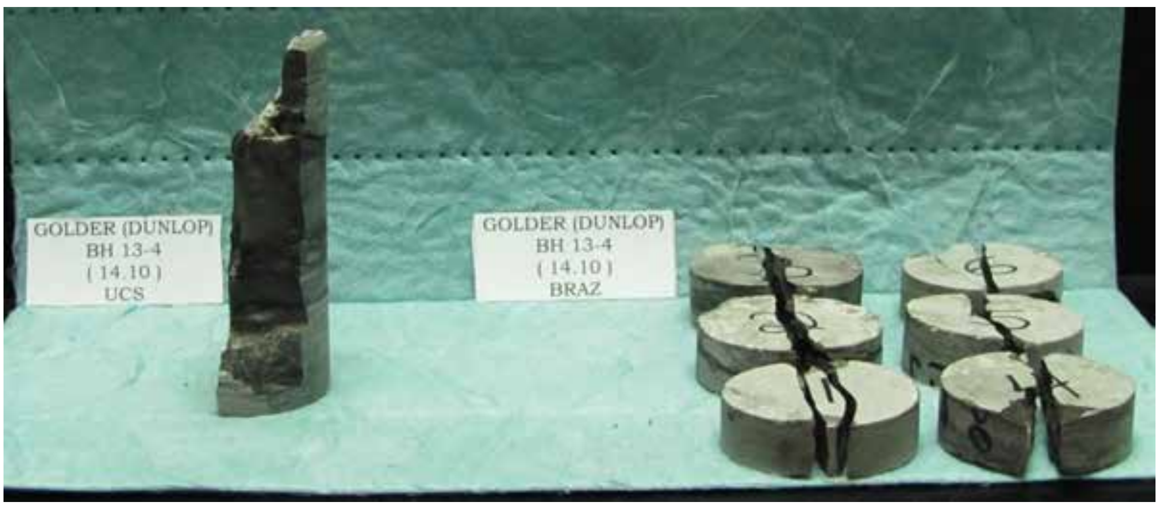

GOLDER (DUNLOP)
BH 13-6
(12.11)
UCS
GOLDER (DUNLOP)
BH 13-6
(12.11)
BRAZ

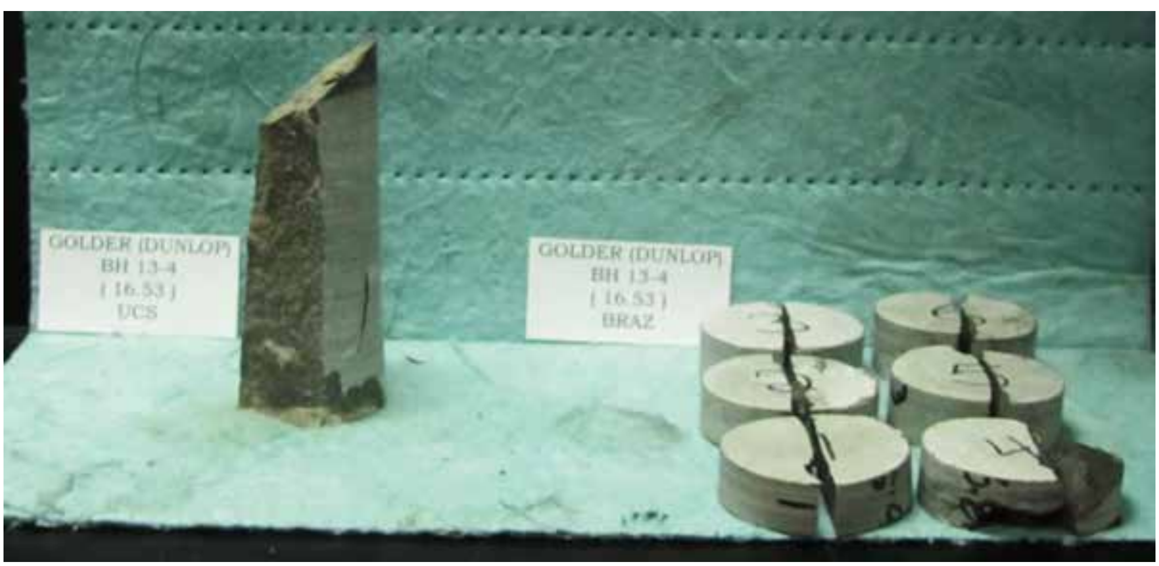

GOLDER (DUNLOP)
BH 13-6
(14.97)
UCS
GOLDER (DUNLOP)
BH 13-6
(14.97)
BRAZ


BH 13-6
(16.47)
UCS
GOLDER (DUNLOP)
BH 13-6
(16.47)
BRAZ

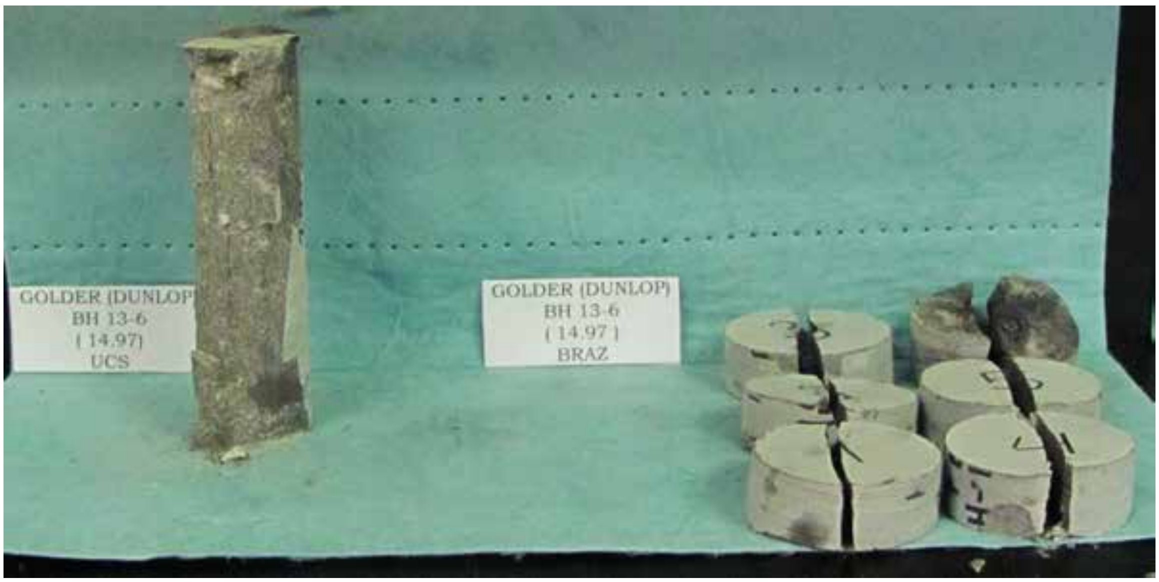
Photographs of Post-Test Samples


GOLDER (DUNLOP)
BH 13-4
(12.42)
UCS
GOLDER (DUNLOP)
BH 13-4
(12.42)
BRAZ


GOLDER (DUNLOP)
BH 13-4
(14.10)
UCS
GOLDER (DUNLOP)
BH 13-4
(14.10)
BRAZ


GOLDER (DUNLOP)
BH 13-4
(16.53)
UCS
GOLDER (DUNLOP)
BH 13-4
(16.53)
BRAZ


GOLDER (DUNLOP)
BH 13-6
(12.11)
UCS
GOLDER (DUNLOP)
BH 13-6
(12.11)
BRAZ


GOLDER (DUNLOP
BH 13-6
(14.97)
UCS
GOLDER (DUNLOP)
BH 13-6
(14.97)
BRAZ


GOLDER (DUNLO
BH 13-6
(16.47)
UCS
GOLDER (DUNLOP)
BH 13-6
(16.47)
BRAZ

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-601

LOCATION: N 5030901.52 ;E 366634.38
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: November 26-27, 2014
DRILL RIG: CME 850
DRILLING CONTRACTOR: Marathon Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		62.34							
0	Power Auger, 200 mm Diam. (Hollow Stem)	FILL - (GW) gravelly SAND, angular; grey		0.00							
		FILL - (SM/GM) SILTY SAND and GRAVEL; brown, with cobbles and ash; non-cohesive, moist, compact RDR = 2-3		0.05							
1					1	SS	22				
		(SM) SILTY SAND, fine; dark brown (BURIED TOPSOIL); non-cohesive, moist		60.82 1.58							
2		(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; grey brown to grey, with cobbles and boulders (GLACIAL TILL); non-cohesive, moist, compact to very dense RDR 3 - ⩾ 5			2	SS	13				
					3	SS	>50				
3					4	SS	78				
4					5	SS	>50				
					6	SS	>50				
5	Wash Boring, HW Casing										
6					7	SS	>50				
7											
					8	SS	>50				
8											
9					9	SS	>50				
10											

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: SD

RECORD OF BOREHOLE: 14-601

PROJECT: 13-1121-0143

LOCATION: N 5030901.52 ;E 366634.38

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: November 26-27, 2014

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: CGVD1928

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10	Wash Boring, HW Casing	(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; grey brown to grey, with cobbles and boulders (GLACIAL TILL); non-cohesive, moist, compact to very dense RDR 3 - ≥ 5			10	SS	>50				
11	Rotary Drill, HQ3 Core				11	RC	DD				
12					12	SS	>50				
13				48.91	13	RC	DD				
		Borehole continued on RECORD OF DRILLHOLE 14-601									
14–20											

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: SD

RECORD OF DRILLHOLE: 14-601

PROJECT: 13-1121-0143

LOCATION: N 5030901.52 ;E 366634.38

DRILLING DATE: November 26-27, 2014

DATUM: CGVD1928

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN
		BEDROCK SURFACE	48.91		
13.43–16.46	Rotary Drill, HQ3 Core	Fresh, thinly to medium bedded, dark grey, fine to medium grained, non-porous, medium strong LIMESTONE, with black shale partings, interlaminates and thin interbeds. Occasional nodular intervals (~5-10% shale) VERULAM FORMATION - Broken core from 15.89 m to 15.93 m - Broken core from 16.14 m to 16.17 m - Broken/lost core from 16.30 m to 16.33 m	13.43	1	100
				2	100
		End of Drillhole	45.88 16.46		

Column headings: RECOVERY (TOTAL CORE %, SOLID CORE %), R.Q.D. %, FRACT. INDEX PER 0.25m, DISCONTINUITY DATA (ANGLE wrt CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja), HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}), WEATHERING INDEX (W1–W6), NOTES

Depth scale: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23

Discontinuity Data

Run	Type and Surface Description	Jcon	Jr	Ja
1	JN,PL,RO	20	1.5	1
1	BD,IR,RO	25	3	1
1	BD,PL,RO	20	1.5	1
1	BD,PL,RO	20	1.5	1
1	BD,UN,SM	20	2	1
1	BD,PL,RO	20	1.5	1
1	BD,PL,RO	20	1.5	1
1	BD,PL,SM	16	1	1
1	BD,IR,RO	25	3	1
1	BD,IR,SM	20	2	1
1	JN,CU,SM	20	2	1
1	BD,PL,RO	20	1.5	1
1	BD,PL,SM	16	1	1
2	JN,CU,RO	25	3	1
2	BD,IR,RO	25	3	1
2	BD,PL,RO	20	1.5	1
2	BD,CU,RO	25	3	1
2	BD,CU,RO	25	3	1
2	JN,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,CU,RO	25	3	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	JN,UN,RO	25	3	1
2	JN,UN,RO	25	3	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1
2	BD,PL,RO	20	1.5	1

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: HEC

CHECKED: AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-602

LOCATION: N 5030915.66 ;E 366656.86
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: November 28 - December 3, 2014
DRILL RIG: Portable Drill
DRILLING CONTRACTOR: Marathon Drilling

DATUM: CGVD1928
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Portable Drill - Wash Boring; NW Casing

DEPTH SCALE METRES	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m
	GROUND SURFACE	63.00			
0	FILL - (SP) SAND, some gravel; brown, with cobbles; non-cohesive, moist, compact	0.00	1	SS	29
	FILL - (SM) SILTY SAND, some gravel; brown, with mica, organic matter and cobbles; non-cohesive, moist, compact	62.39 / 0.61	2	SS	10
1			3	SS	11
2			4	SS	19
	(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; grey brown, with cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, very dense	60.56 / 2.44	5	SS	>50
3			6	SS	52
4			7	RC	DD
5			8	SS	>50
			9	RC	DD
6			10	RC	DD
7			11	RC	DD
8			12	RC	DD
9			13	SS	>50
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^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20 40 60 80
ADDITIONAL LAB. TESTING
PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: SD

RECORD OF BOREHOLE: 14-602

PROJECT: 13-1121-0143

LOCATION: N 5030915.66 ;E 366656.86

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

DRILLING DATE: November 28 - December 3, 2014

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: Marathon Drilling

DATUM: CGVD1928

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Portable Drill / NQ3 Core	(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; grey brown, with cobbles and boulders (GLACIAL TILL); non-cohesive, moist to wet, very dense									
11				51.70							
		Borehole continued on RECORD OF DRILLHOLE 14-602									
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: HEC

CHECKED: SD

RECORD OF DRILLHOLE: 14-602

PROJECT: 13-1121-0143

LOCATION: N 5030915.66 ;E 366656.86

DRILLING DATE: November 28 - December 3, 2014

DATUM: CGVD1928

INCLINATION: -90°   AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: Marathon Drilling

Abbreviations: JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean; 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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	51.70							
	Portable Drill, NQ3 Core	Fresh, thinly to medium bedded, dark grey, fine grained, non-porous, medium strong LIMESTONE, with black shale partings, interlaminates and thin interbeds (~5% shale)	11.30	1	100	BD,PL,RO	20	1.5	1	
						BD,PL,RO	20	1.5	1	
						BD,PL,RO	20	1.5	1	
						BD,PL,RO	20	1.5	1	
12		VERULAM FORMATION								
		- Broken core from 11.40 m to 11.50 m		2	100					
13										
				3	100	BD,PL,SM	16	1	1	
14						BD,CU,SM Cl <1 mm	16	2	4	
			48.39							
		End of Drillhole	14.61							
15										
16										
17										
18										
19										
20										
21										

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: AJS

RECORD OF BOREHOLE: 14-603

PROJECT: 13-1121-0143 | SHEET 1 OF 2

LOCATION: N 5030855.87 ;E 366544.85 | DRILLING DATE: January 13, 2015 | DATUM: CGVD1928

INCLINATION: -90° AZIMUTH: --- | DRILL RIG: CME 55

SAMPLER HAMMER, 64kg; DROP, 760mm | DRILLING CONTRACTOR: Marathon Drilling | PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION (MON. WELL)
GROUND SURFACE	61.41				
FILL - (SM) SILTY SAND, fine, trace gravel; dark brown, with organic matter; non-cohesive, moist RDR = 3 - Blow count high due to frozen soil	0.00	1	SS	33	Monument Casing
FILL - (SM) SILTY SAND, fine, trace gravel; brown; non-cohesive, moist, loose RDR = 2	60.80 0.61	2	SS	5	
FILL - (SM) gravelly SILTY SAND; dark brown, with cobbles; moist, compact RDR = 2	59.89 1.52	3	SS	18	
		4	SS	15	
FILL - (SM) SILTY SAND, some gravel; dark brown to black, with crushed stone and organic matter; moist, dense RDR = 2-3	58.51 2.90	5	SS	32	
(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; brown to grey brown, presence of cobbles and/or boulders inferred from auger resistance (GLACIAL TILL); moist, compact to very dense RDR = 3-4	57.60 3.81	6	SS	22	Native Backfill and Bentonite
		7	SS	56	
		8	SS	65	
(SM) gravelly SILTY SAND, 20-40% low to medium plasticity fines; grey, presence of cobbles and/or boulders inferred from auger resistance (GLACIAL TILL); non-cohesive, moist, very dense RDR = 5	55.31 6.10	9	SS	>50	
		10	SS	>50	
		11	SS	>50	
	53.03				Bentonite Seal

Borehole continued on RECORD OF DRILLHOLE 14-603

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 14-603

LOCATION: N 5030855.87 ;E 366544.85

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 13, 2015

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: CGVD1928

Abbreviations: JN - Joint; FLT - Fault; SH - Shear; VN - Vein; CJ - Conjugate; BD - Bedding; FO - Foliation; CO - Contact; OR - Orthogonal; CL - Clean; 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.

Column headings: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE % / SOLID CORE %; 80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DISCONTINUITY DATA (ANGLE wrt CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

Depth Scale (m)	Drilling Record	Description	Elev. / Depth (m)	Run No.	Flush Return
		BEDROCK SURFACE	53.03 / 8.38		
9	Rotary Drill, NQ3 Core	Fresh, thinly to medium bedded, dark grey, fine to medium grained, non-porous, medium strong LIMESTONE, with black shale partings, interlaminates and thin interbeds, occasional nodular intervals (~5-10% shale) VERULAM FORMATION - Broken core from 8.55 m to 8.66 m		1	100
10			51.05 / 10.36	2	100
		End of Drillhole			

Discontinuity data:

Type and Surface Description	Jcon	Jr	Ja
JN,PL,RO	20	1.5	1
BD,PL,SM	16	1	1
BD,PL,SM	16	1	1
BD,PL,VR	22	1.5	1
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1
BD,PL,RO	20	1.5	1

NOTES (MON. WELL):

- Bentonite Seal
- Silica Sand
- 19 mm Diam. PVC Standpipe

Depth scale: 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: HEC

CHECKED: AJS

PROJECT: 13-1121-0143

RECORD OF BOREHOLE: 14-604

LOCATION: N 5030851.90 ;E 366526.55
DRILLING DATE: January 15, 2015
DATUM: CGVD1928
INCLINATION: -90° AZIMUTH: ---
DRILL RIG: CME 55
SAMPLER HAMMER, 64kg; DROP, 760mm
DRILLING CONTRACTOR: Marathon Drilling
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		56.44							
0	Power Auger, 200 mm Diam. (Hollow Stem)	TOPSOIL/FILL - (SM) SILTY SAND; dark brown; moist		0.00							
		FILL - (SM) SILTY SAND, trace to some gravel; brown, with metal wire; moist, very loose to loose RDR = 1		56.13 / 0.31							
1					1	SS	3				
2					2	SS	5				
					3	SS	>50				
	Rotary Drill, NQ3 Core	Reinforced PORTLAND CEMENT CONCRETE (Retaining Wall Footing)		53.90 / 2.54	4	RC	DD				
3					5	RC	DD				
		(SM) gravelly SILTY SAND; grey, with cobbles (GLACIAL TILL); non-cohesive, moist		52.86 / 3.58	6	RC	DD				
4					7	RC	DD				
		Borehole continued on RECORD OF DRILLHOLE 14-604		52.10							
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: SD

PROJECT: 13-1121-0143

RECORD OF DRILLHOLE: 14-604

LOCATION: N 5030851.90 ;E 366526.55

DRILLING DATE: January 15, 2015

DATUM: CGVD1928

DRILL RIG: CME 55

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean, 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	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	52.10							
5	Rotary Drill, NQ3 Core	Fresh, thinly to medium bedded, dark grey, fine grained, non-porous, medium strong LIMESTONE, with black shale partings, interlaminates and thin interbeds, occasional nodular intervals (~5-10% shale) VERULAM FORMATION	4.34	1	0	BD,PL,SM	16	1	1	
						BD,CU,RO	25	3	1	
						BD,CU,RO	25	3	1	
						BD,PL,RO	20	1.5	1	
			50.66 / 5.78			BD,PL,SM	16	1	1	
6		End of Drillhole								

Depth scale markings: 6, 7, 8, 9, 10, 11, 12, 13, 14

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: HEC

CHECKED: AJS

RECORD OF BOREHOLE: 15-01

PROJECT: 1522242-3000

LOCATION: See Site Plan

BORING DATE: February 28, 2015

DATUM: Geodetic

BORING METHOD: Percussion Drill, 105 mm Diam. Casing

DESCRIPTION	ELEV. (m)	DEPTH (m)
GROUND SURFACE	62.18	
FILL - (SW/SM) gravelly SAND, angular, some brown sand; grey; non-cohesive		0.00
FILL - Mixture of SILTY SAND; black, orange brick, fly ash, gravel	61.42	0.76
FILL - (SM) SILTY SAND, some gravel; non-cohesive, moist	60.66	1.52
FILL - Orange brick, fly ash, gravel	59.13	3.05
(SM) SILTY SAND, some gravel; brown (GLACIAL TILL); non-cohesive, moist		3.20
(SM) SILTY SAND, trace gravel; brown, trace cobbles and boulders (GLACIAL TILL); moist	56.08	6.10
(SM) SILTY SAND, some gravel, trace silt; grey, with cobbles and boulders (GLACIAL TILL); non-cohesive; moist to wet	55.17	7.01
End of Borehole	52.43	9.75

SAMPLES

NUMBER	TYPE	BLOWS/0.30m	HEADSPACE ORGANIC VAPOUR / COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM]	ADDITIONAL LAB. TESTING
1	SS			CHEM
2	SS		ND	
3	SS		ND	CHEM
3A	SS			CHEM
4	SS			
5	SS			
6	SS			

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] ⊕ — *ND = Not Detected* — 20 40 60 80

HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] □ — *ND = Not Detected* — 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

PIEZOMETER OR STANDPIPE INSTALLATION:

- Bentonite Seal
- Silica Sand
- 51 mm Diam. PVC #10 Slot Screen
- W.L. in Screen at Elev. 57.645 m on March 9, 2015

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC

CHECKED: AC

RECORD OF BOREHOLE: 15-02

PROJECT: 1522242-3000
LOCATION: See Site Plan
BORING DATE: February 28, 2015
SHEET 1 OF 1
DATUM: Geodetic

BORING METHOD: Percussion Drill, 105 mm Diam. Casing

ELEV. / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	HEADSPACE ORGANIC VAPOUR ⊕ / COMBUSTIBLE VAPOUR □	HYDRAULIC CONDUCTIVITY	ADDITIONAL LAB. TESTING
61.84	GROUND SURFACE					
0.00	FILL - (SW) gravelly SAND, angular; grey	1	SS	⊕ □		
60.32 / 1.52	FILL - (SP) SAND, fine; brown; non-cohesive, moist	2	SS	⊕ □		CHEM
		3	SS	⊕ □		
58.18 / 3.66	FILL - Mixture of fine SAND, orange brick; hydro carbon odour, black staining	3A	SS	⊕ □		CHEM
57.88 / 3.96	(SM) SILTY SAND, some gravel; grey (GLACIAL TILL); non-cohesive, moist	4	SS	□ ⊕		CHEM
		4A	SS	⊕ □		
		5	SS	⊕	□150	
55.21 / 6.63	(SM) SILTY SAND, trace gravel, trace coarse sand; (GLACIAL TILL); non-cohesive, moist to wet	5A	SS	⊕ □		
		6	SS	⊕	□900	CHEM
53.31 / 8.53	End of Borehole					

PIEZOMETER OR STANDPIPE INSTALLATION:
- Bentonite Seal
- Silica Sand
- 51 mm Diam. PVC #10 Slot Screen
- Silica Sand
- W.L. in Screen at Elev. 56.315 m on March 9, 2015

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: HEC
CHECKED: AC

MIS-BHS 001 1522242-3000.GPJ GAL-MIS.GDT 05/12/15 JEM

PROJECT: 1522242-3000

RECORD OF BOREHOLE: 15-04

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: March 1, 2015

DATUM: Geodetic

Boring method: Percussion Drill, 105 mm Diam. Casing

HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] ⊕ (ND = Not Detected) — scale 20, 40, 60, 80
HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS [PPM] □ (ND = Not Detected) — scale 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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE						
0	FILL - Gravel, blast rock, wood, boulders	0.00					
1	FILL - Orange brick, fly ash, gravel	1.22					
2			1	SS		CHEM	Bentonite Seal
	(SM) SILTY SAND, trace to some gravel; grey brown (GLACIAL TILL); non-cohesive, moist to wet	2.44	1A	SS		CHEM	
3			2	SS			
4			2A	SS			Silica Sand
5			3	SS			
	(SM) SILTY SAND, some gravel; grey brown, with cobbles and boulders (GLACIAL TILL); non-cohesive, wet	5.35					51 mm Diam. PVC #10 Slot Screen
6			4	SS			
			4A	SS			
7	End of Borehole	7.01					W.L. in Screen at 6.1 m depth on March 3, 2015 Note: W.L. not measured on March 9, 2015
8							
9							
10							

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: HEC
CHECKED: AC

MIS-BHS 001 1522242-3000.GPJ GAL-MIS.GDT 05/12/15 JEM

PROJECT: 06-1120-331

LOCATION: See Site Plan

SAMPLER HAMMER, 64kg; DROP, 760mm

RECORD OF BOREHOLE: BH 06-24

BORING DATE: Nov. 6-7, 2006

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - O)	HYDRAULIC CONDUCTIVITY, k, cm/s; WATER CONTENT PERCENT (Wp ⊢ ⊖W ⊣ Wl)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Power Auger, 200mm Diam. (Hollow Stem)	GROUND SURFACE		62.52							
		Loose to compact grey black sand, some gravel with cobbles, boulders and brick (FILL)		0.00							Flush mount casing set in bentonite
1					1	50 DO	9				
2					2	50 DO	13				
		Dense brown SILTY SAND, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)		60.23 2.29	3	50 DO	45			MH	Native Backfill
3					4	50 DO	>100				
4		Very dense grey SANDY SILT, trace clay with cobbles and boulders (GLACIAL TILL)		58.71 3.81	5	50 DO	>100				
					6	50 DO	>100				Bentonite Seal
5											Silica Sand
6					7	50 DO	91				50mm Diam. PVC #10 Slot Screen
					8	50 DO	85				
7				55.20 7.32	9	50 DO	>100				Native Backfill
		End of Borehole Sampler Refusal									Water level in screen at elev. 59.92m on Dec. 8, 2006
8											
9											
10											
11											
12											
13											
14											
15											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: D.G.

CHECKED: S.A.T.

PROJECT: 06-1120-331

LOCATION: See Site Plan

SAMPLER HAMMER, 64kg; DROP, 760mm

RECORD OF BOREHOLE: BH 06-25

BORING DATE: Nov. 7, 2006

SHEET 1 OF 1

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	Power Auger, 200mm Diam. (Hollow Stem)	GROUND SURFACE	62.82					
		Grey crushed stone (FILL)	0.00					Flush mount casing set in bentonite
		Loose to compact brown sand and silty sand, some gravel with cobbles, brick, concrete and organic matter (FILL)	0.15					
1				1	50 DO	16		
2				2	50 DO	11		Native Backfill
		Very dense brown SANDY SILT, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	60.53 / 2.29	3	50 DO	>100		
3		Compact to very dense grey SILTY SAND, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	59.77 / 3.05	4	50 DO	>100		
4				5	50 DO	22	MH	Bentonite Seal
								Silica Sand
5				6	50 DO	26		50mm Diam. PVC #10 Slot Screen
6				7	50 DO	78		
				8	50 DO	66		Water level in screen at elev. 60.64m on Dec. 8, 2006
7		End of Borehole	56.11 / 6.71					

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

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: D.G.

CHECKED: S.A.T.

MIS-BHS 001 06-1120-331-2000.GPJ GLDR CAN.GDT 12/18/06

PROJECT: 06-1120-331

LOCATION: See Site Plan

SAMPLER HAMMER, 64kg; DROP, 760mm

RECORD OF BOREHOLE: BH 06-26

BORING DATE: Nov. 7-8, 2006

SHEET 1 OF 1

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE	64.04					
	Dark grey sand with silt, gravel, brick, concrete, ash and coal (FILL)	0.00					Flush mount casing set in bentonite
1			1	50 DO	4	MH	
2			2	50 DO	26		
	Dense grey brown SANDY SILT, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	61.75 / 2.29					Native Backfill
			3	50 DO	47		
3			4	50 DO	31		
4			5	50 DO	97	MH	Bentonite Seal
							Silica Sand
	Very dense grey SANDY SILT, some gravel, trace clay with cobbles, boulders and sand layers (GLACIAL TILL)	59.32 / 4.72	6	50 DO	>100		
5							50mm Diam. PVC #10 Slot Screen
6			7	50 DO	62		
			8	50 DO	>100		Native Backfill
	End of Borehole Sampler Refusal	57.64 / 6.40					Water level in screen at elev. 60.57m on Dec. 8, 2006

Chart headings: DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (20, 40, 60, 80) 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)

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: D.G.

CHECKED: S.A.T.

PROJECT: 06-1120-331

LOCATION: See Site Plan

SAMPLER HAMMER, 64kg; DROP, 760mm

RECORD OF BOREHOLE: BH 06-27

BORING DATE: Nov. 8, 2006

SHEET 1 OF 1

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Power Auger, 200mm Diam. (Hollow Stem)

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE	65.72					
	Loose dark grey sand with brick and concrete (FILL)	0.00					Flush mount casing set in bentonite
1			1	50 DO	4		
2			2	50 DO	9		
	Compact to very dense brown to grey SILTY SAND, some gravel, trace clay with cobbles and boulders (GLACIAL TILL)	63.43 / 2.29	3	50 DO	27		Native Backfill
3			4	50 DO	30	MH	
4			5	50 DO	48		Bentonite Seal
							Silica Sand
5			6	50 DO	43		
			7	50 DO	62		50mm Diam. PVC #10 Slot Screen
6			8	50 DO	88		
	Brown fine SAND	59.17 / 6.55					Native Backfill
	End of Borehole	6.71					
7							Water level in screen at elev. 62.42m on Dec. 8, 2006

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

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: D.G.

CHECKED: S.A.T.

MIS-BHS 001 06-1120-331-2000.GPJ GLDR CAN.GDT 12/18/06

APPENDIX C

Results of Chemical Analysis

Certificate of Analysis

eurofins | Environment Testing

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Chaitanya Raj Goyal
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1924174
Date Submitted: 2020-01-16
Date Reported: 2020-01-23
Project:
COC #: 853358

Group	Analyte	MRL	Units	Guideline	1475824	1475825
				Lab I.D.	1475824	1475825
				Sample Matrix	Soil	Soil
				Sample Type		
				Sampling Date	2020-01-16	2020-01-16
				Sample I.D.	19-101 sa4	19-102 sa7
Anions	Cl	0.002	%		0.016	0.007
	SO4	0.01	%		0.01	0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.30	0.24
	pH	2.00			8.31	8.54
	Resistivity	1	ohm-cm		3330	4170

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 D

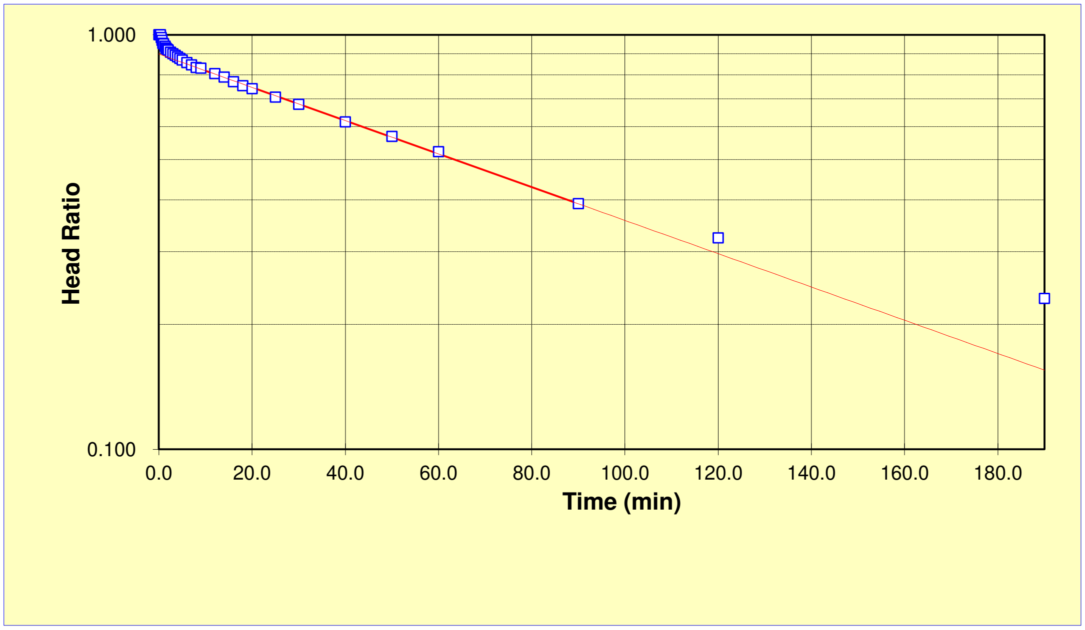
Results of Hydraulic Conductivity Testing – Previous Investigation

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST W-058

$$K = \frac{r_c^2}{2L_e} \ln\frac{L_e}{R_e}\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t2 - t1)}\right] 30.48$$

where: r_c = casing radius (feet)
R_e = filter pack radius (feet)
L_e = length of screened interval (feet)
t = time (seconds)
h_t = head at time t (feet)

INPUT PARAMETERS		RESULTS		
r_c =	0.05			
R_e =	0.33			
L_e =	12.9	K=	2E-06	cm/sec
t_1 =	480	K=	5E-03	ft/day
t_2 =	5400			
h_1/h_0 =	0.83			
h_2/h_0 =	0.39			



Project Name: CTP OLRT Ottawa
Project No.: 10-1121-0222
Test Date: 12/7/2010

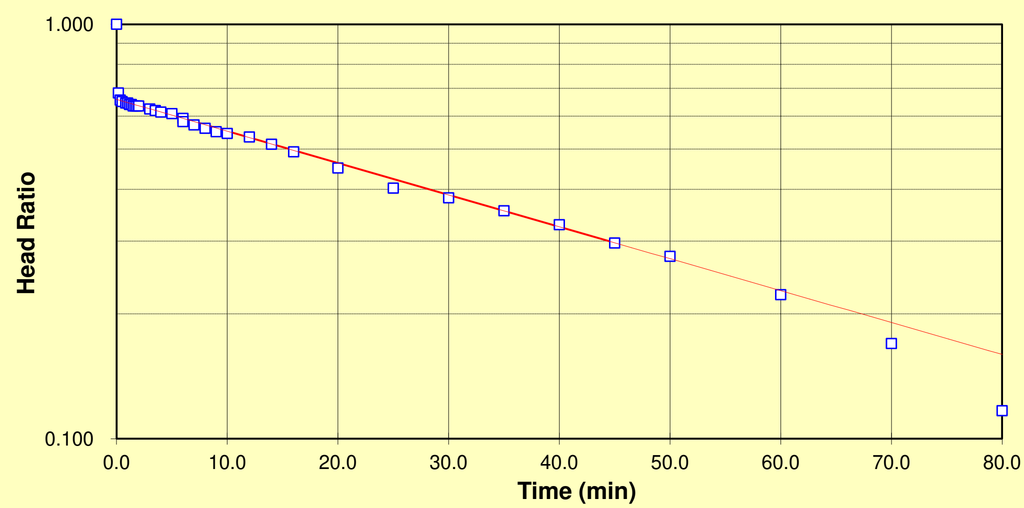
Analysis By: MSL
Checked By: SRW
Analysis Date: 1/27/2011

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST W-060

$$K = \frac{r_c^2}{2L_e} \ln\frac{L_e}{R_e}\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t2 - t1)}\right] 30.48$$

where:
- r_c = casing radius (feet)
- R_e = filter pack radius (feet)
- L_e = length of screened interval (feet)
- t = time (seconds)
- h_t = head at time t (feet)

INPUT PARAMETERS		RESULTS		
r_c =	0.05			
R_e =	0.33			
L_e =	7.0	K=	5E-06	cm/sec
t_1 =	180	K=	2E-02	ft/day
t_2 =	2700			
h_1/h_0 =	0.63			
h_2/h_0 =	0.30			



Project Name: CTP OLRT Ottawa
Project No.: 10-1121-0222
Test Date: 12/21/2010

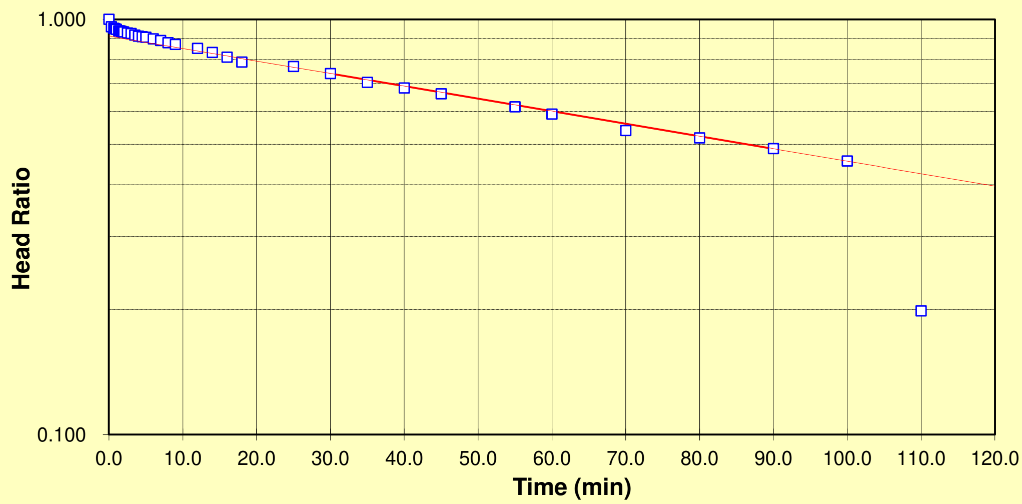
Analysis By: MSL
Checked By: SRW
Analysis Date: 1/27/2011

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST W-062

$$K = \frac{r_c^2}{2L_e} \ln\frac{L_e}{R_e}\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t2 - t1)}\right] 30.48$$

where:
- r_c = casing radius (feet)
- R_e = filter pack radius (feet)
- L_e = length of screened interval (feet)
- t = time (seconds)
- h_t = head at time t (feet)

INPUT PARAMETERS		RESULTS		
r_c =	0.05			
R_e =	0.33			
L_e =	11.7	K=	1E-06	cm/sec
t_1 =	1800	K=	4E-03	ft/day
t_2 =	5400			
h_1/h_0 =	0.74			
h_2/h_0 =	0.49			



Project Name: CTP OLRT Ottawa
Project No.: 10-1121-0222
Test Date: 12/7/2010

Analysis By: MSL
Checked By: SRW
Analysis Date: 1/27/2011

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST BH13-3

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

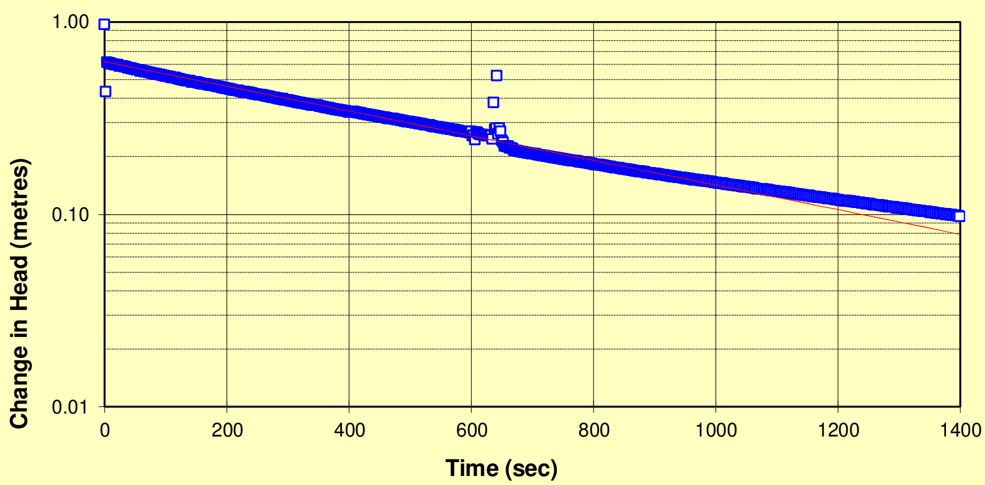
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.10
L_e =	2.52
$\ln(R_e/r_w)$	2.13
y_0 =	0.62
y_t =	0.54
t =	100.0

RESULTS

K=	4E-07	m/sec
K=	4E-05	cm/sec



Project Name: City of Ottawa/CSST Tunnel
Project No.: 13-1121-0005
Test Date: 02/22/13

Analysis By: DH
Checked By: SRW
Analysis Date: 2/27/2013

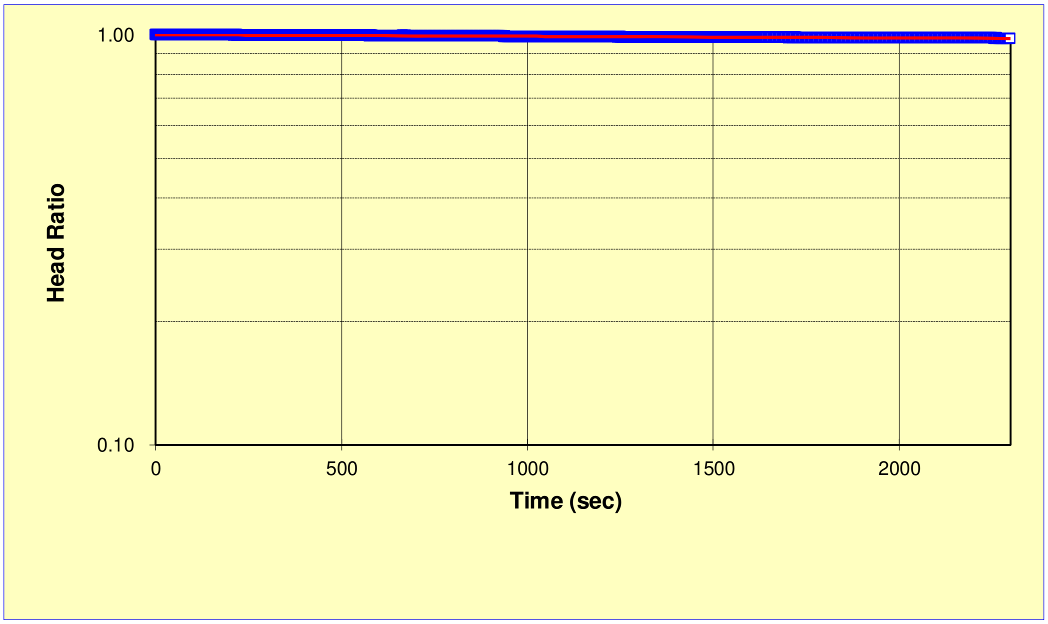
HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-3 Test 1

$$K = \frac{r_c^{\,2}}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:

r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS		RESULTS		
r_c =	1.9E-02			
R_e =	5.0E-02			
L_e =	0.9	K=	5E-09	m/sec
t_1 =	0	K=	5E-07	cm/sec
t_2 =	2500			
Head Ratio $_1$ =	1.00			
Head Ratio $_2$ =	0.98			



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/14/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-3 Test 2

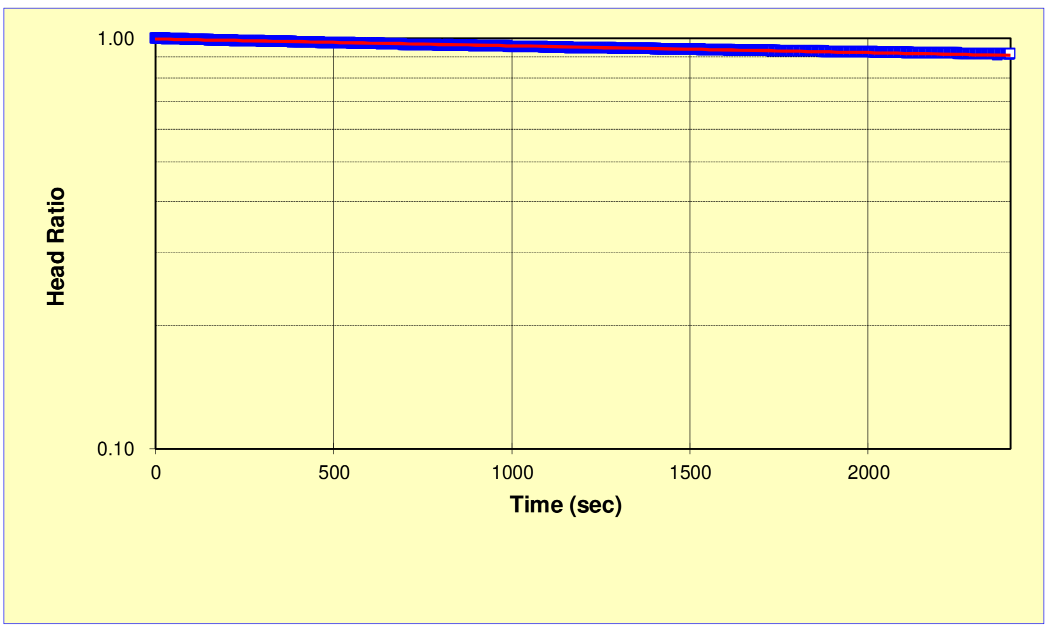
$$K = \frac{r_c^{\,2}}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{\left(t_2 - t_1\right)}\right]$$ where K = (m/sec)

where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.9E-02
R_e =	5.0E-02
L_e =	3.1
t_1 =	0
t_2 =	2500
Head Ratio $_1$ =	1.00
Head Ratio $_2$ =	0.90

RESULTS

K=	9E-09	m/sec
K=	9E-07	cm/sec



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/14/2013

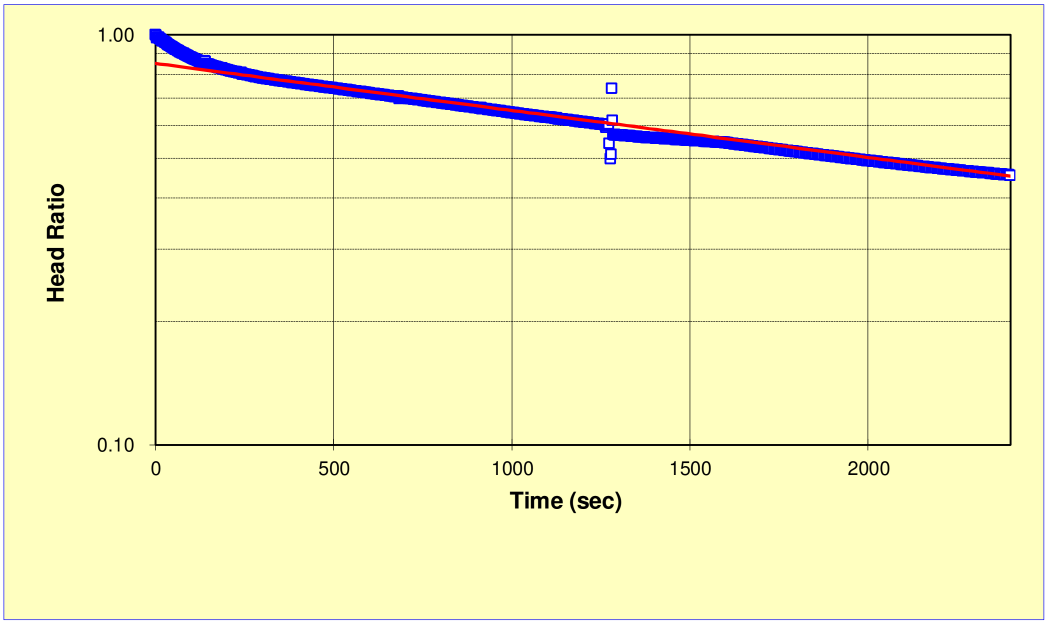
Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-3 Test 3

$$K = \frac{r_c^{2}}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS		RESULTS		
r_c =	1.9E-02			
R_e =	5.0E-02			
L_e =	2.7	K=	7E-08	m/sec
t_1 =	0	K=	7E-06	cm/sec
t_2 =	2500			
Head Ratio $_1$ =	0.85			
Head Ratio $_2$ =	0.44			



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/15/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

Golder Associates Ltd.

N:\Active\2013\1121 - Geotechnical\13-1121-0005 City of Ottawa CSST EWT West Ottawa\Analysis\Hydrogeology\Packer Testing\BH 13-3\
BH13-3-FHT_3_18.85 to 21.58m.xlsx

BH13-3 Test 1

Interval Information

Borehole Radius [R] (m)	Interval Information		
	Top (m)	Bottom (m)	Length (m)
0.048	18.85	21.58	2.73

Steady State Equation:
K=[Q*ln(L/D)+sqrt(1+(L/D)^2)]/[2(PI)LP]
(Thiem 1906)

Steps	Hydraulic Conductivity m/s
1	4.E-08
2	3.E-08
3	5.E-08
4	No Take
5	No Take

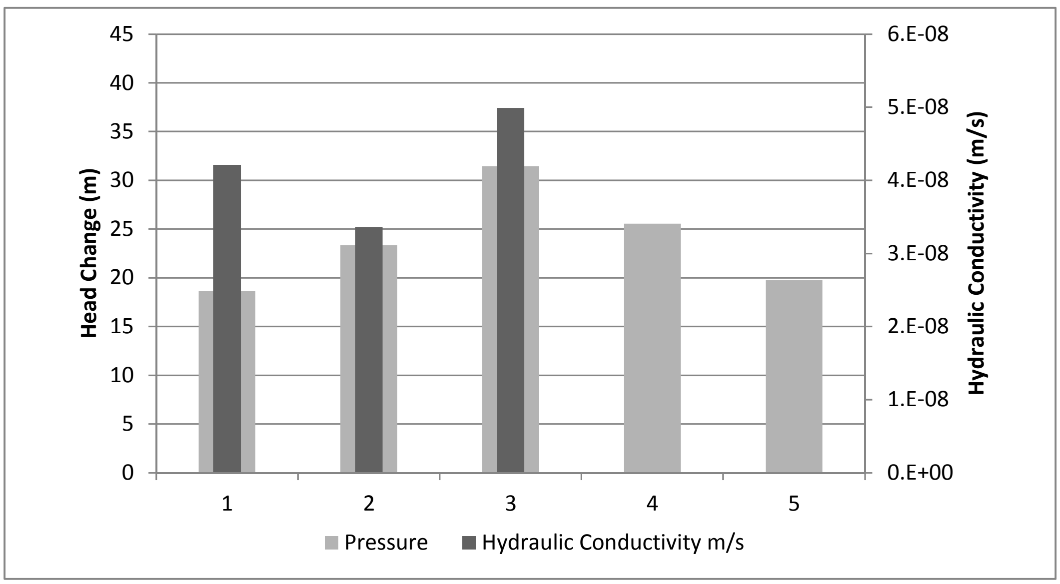
RESULTS:

K=	**4E-08**	**m/s**
K=	**4E-06**	**cm/s**

Test Information

	Test Data		
1	Flow Rate (Q) =	3.3E-06	m^3/sec
	Pressure (P) =	18.6	mH2O
2	Flow Rate (Q) =	3.3E-06	m^3/sec
	Pressure (P) =	23.3	mH2O
3	Flow Rate (Q) =	6.7E-06	m^3/sec
	Pressure (P) =	31.5	mH2O
4	Flow Rate (Q) =	0.0E+00	m^3/sec
	Pressure (P) =	25.6	mH2O
5	Flow Rate (Q) =	0.0E+00	m^3/sec
	Pressure (P) =	19.8	mH2O

Pressure and Hydraulic Conductivity



Golder Associates	**Constant Head Test** **City of Ottawa CSST Tunnel** **Ottawa, Ontario**	**BH13-3 Test 1**

Project No.	13-1121-0005
Date:	2/25/2013
Calcs By:	DH
Review:	SRW

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST BH13-4

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

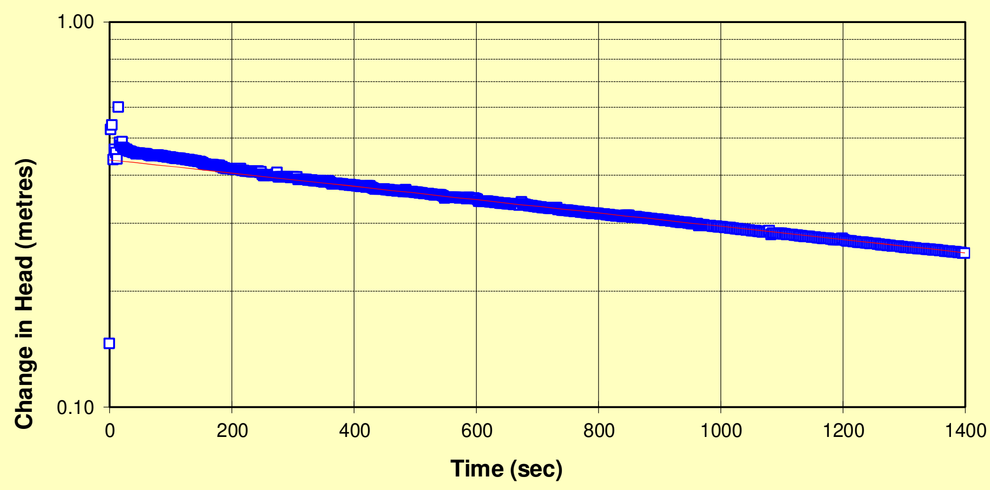
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.06
r_w =	0.10
L_e =	2.40
$\ln(R_e/r_w)$	2.04
y_0 =	0.41
y_t =	0.30
t =	800.0

RESULTS

K=	6E-07	m/sec
K=	6E-05	cm/sec



Project Name: City of Ottawa/CSST Tunnel
Project No.: 13-1121-0005
Test Date: 02/22/13

Analysis By: DH
Checked By: SRW
Analysis Date: 2/27/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-4 Test 2

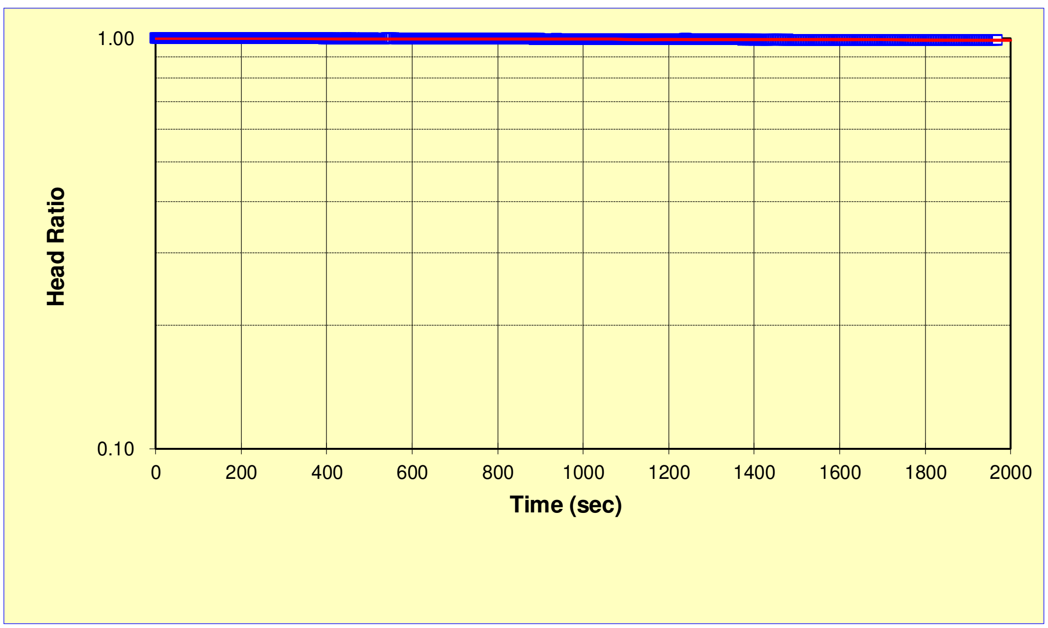
$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right] \left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.9E-02
R_e =	5.0E-02
L_e =	2.4
t_1 =	0
t_2 =	2500
Head Ratio $_1$ =	1.00
Head Ratio $_2$ =	0.99

RESULTS

K=	2E-09	m/sec
K=	2E-07	cm/sec



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/5/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

Golder Associates Ltd.

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-4 Test 3

$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

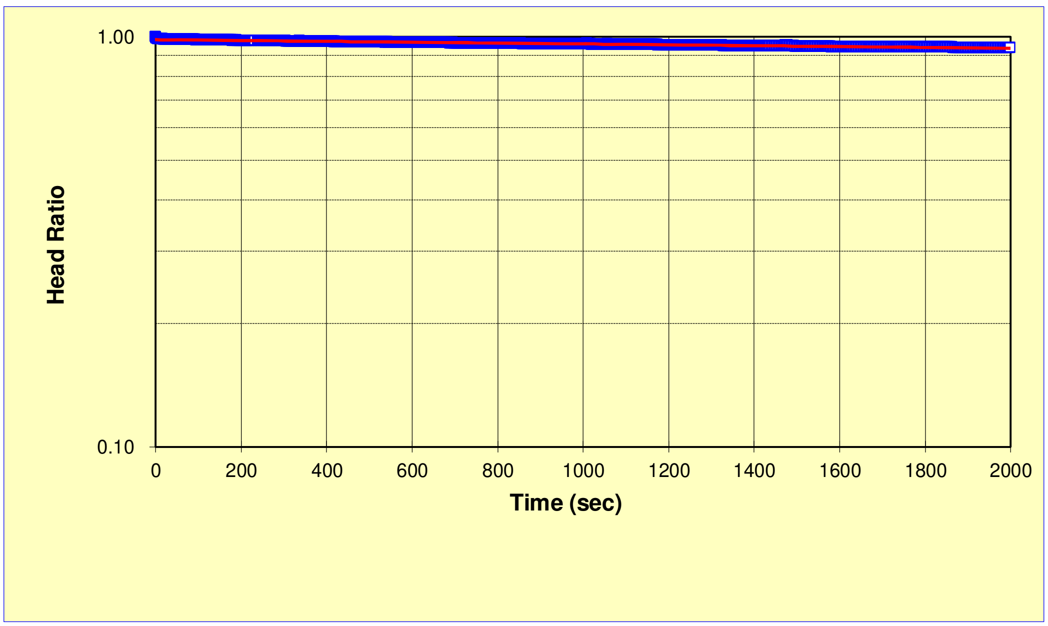
where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.9E-02
R_e =	5.0E-02
L_e =	4.1
t_1 =	0
t_2 =	2500
Head Ratio $_1$ =	0.98
Head Ratio $_2$ =	0.93

RESULTS

K=	5E-09	m/sec
K=	5E-07	cm/sec



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/5/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-4 Test 4

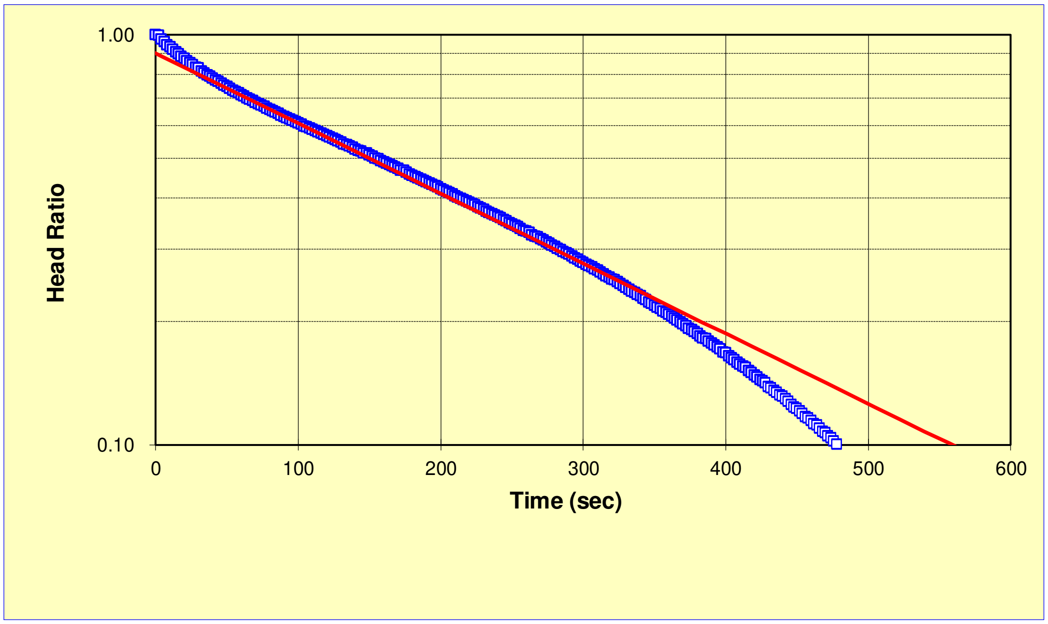
$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:

- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.9E-02
R_e =	5.0E-02
L_e =	5.0
t_1 =	0
t_2 =	200
Head Ratio $_1$ =	0.90
Head Ratio $_2$ =	0.41

RESULTS		
K=	6E-07	m/sec
K=	6E-05	cm/sec



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/6/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/20/2013

BH13-4 Test 1

Interval Information

Borehole Radius [R] (m)	Interval Information		
	Top (m)	Bottom (m)	Length (m)
0.048	16.57	21.60	5.03

Test Information

	Test Data	
1	Flow Rate (Q) =	5.3E-05 m^3/sec
	Pressure (P) =	21.2 mH2O
2	Flow Rate (Q) =	8.3E-05 m^3/sec
	Pressure (P) =	24.9 mH2O
3	Flow Rate (Q) =	9.0E-05 m^3/sec
	Pressure (P) =	28.8 mH2O
4	Flow Rate (Q) =	7.3E-05 m^3/sec
	Pressure (P) =	23.9 mH2O
5	Flow Rate (Q) =	6.0E-05 m^3/sec
	Pressure (P) =	21.1 mH2O

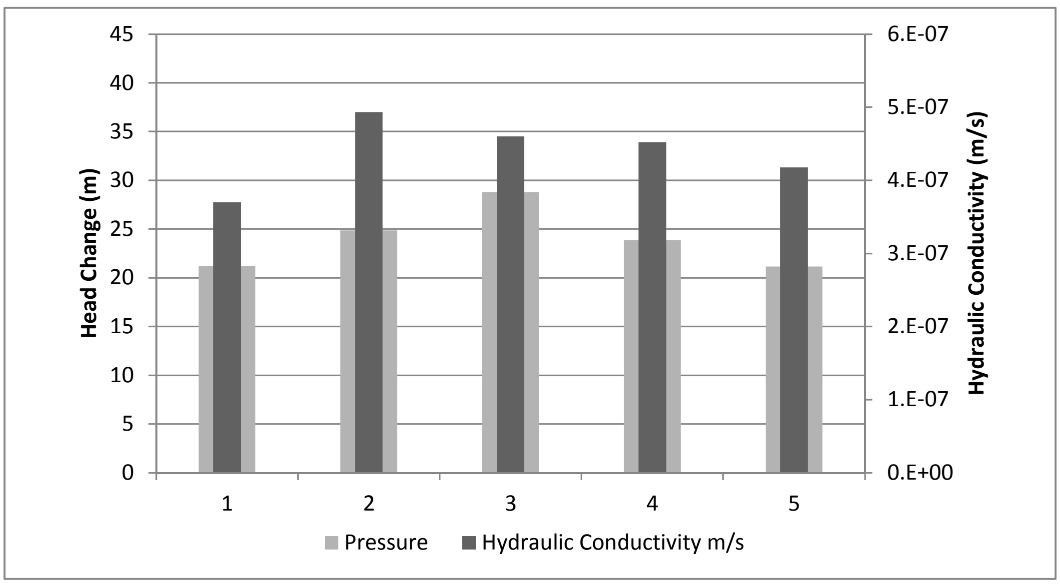
Steady State Equation:
K=[Q*ln(L/D)+sqrt(1+(L/D)^2)]/[2(PI)LP]
(Thiem 1906)

Steps	Hydraulic Conductivity m/s
1	4.E-07
2	5.E-07
3	5.E-07
4	5.E-07
5	4.E-07

RESULTS:

K=	**4E-07**	**m/s**
K=	**4E-05**	**cm/s**

Pressure and Hydraulic Conductivity



Golder Associates	Constant Head Test City of Ottawa CSST Tunnel Ottawa, Ontario	BH13-4 Test 1	
		Project No.	13-1121-0005
		Date:	2/25/2013
		Calcs By:	DH
		Review:	SRW

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST BH13-6

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

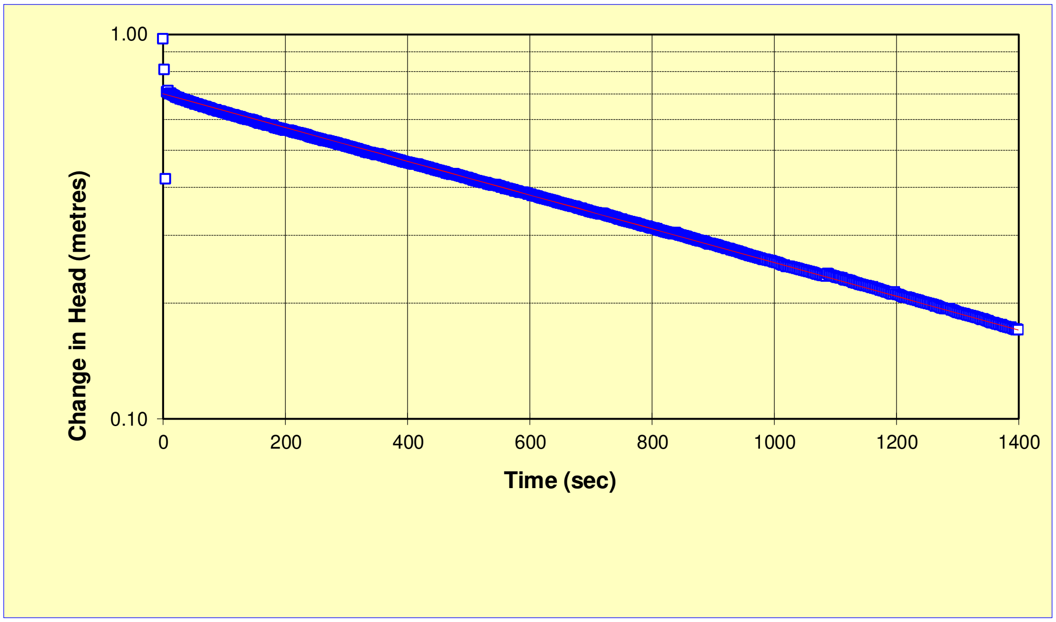
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.05
L_e =	1.76
$\ln(R_e/r_w)$	7.44
y_0 =	0.70
y_t =	0.26
t =	1000.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: City of Ottawa/CSST Tunnel
Project No.: 13-1121-0005
Test Date: 02/22/13

Analysis By: DH
Checked By: SRW
Analysis Date: 2/27/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-6 Test 1

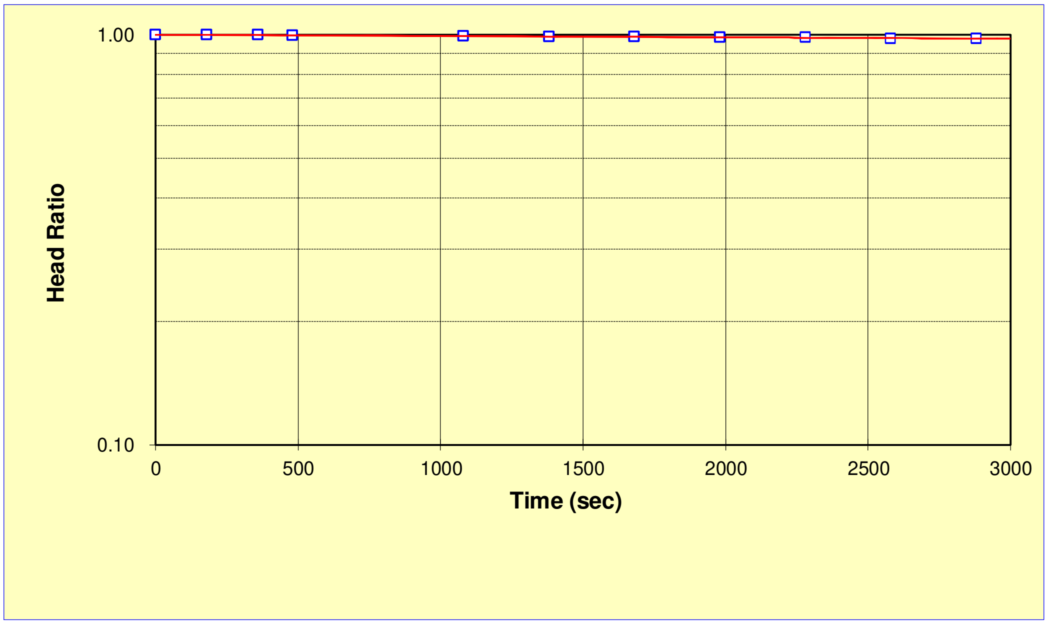
$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS	
r_c =	1.8E-02
R_e =	4.8E-02
L_e =	3.6
t_1 =	0
t_2 =	2000
Head Ratio $_1$ =	1.00
Head Ratio $_2$ =	0.98

RESULTS

K=	2E-09	m/sec
K=	2E-07	cm/sec



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/11/2013

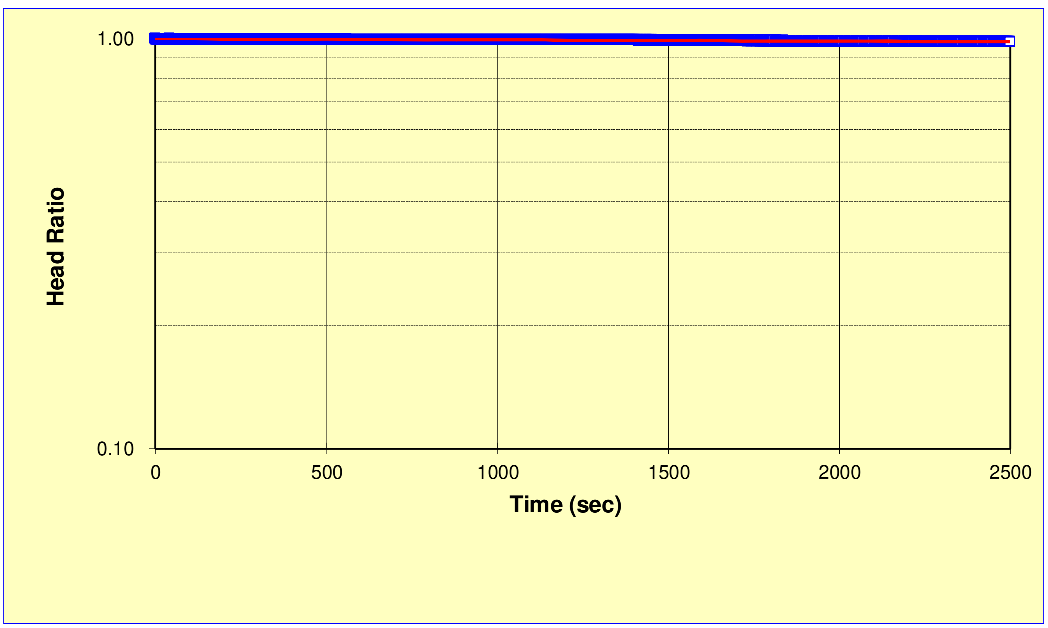
Analysis By: DH
Checked By: SRW
Analysis Date: 2/21/2013

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-6 Test 2

$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS		RESULTS		
r_c =	1.8E-02			
R_e =	4.8E-02			
L_e =	3.6	K=	1E-09	m/sec
t_1 =	0	K=	1E-07	cm/sec
t_2 =	1000			
Head Ratio₁ =	1.00			
Head Ratio₂ =	0.99			



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/12/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/21/2013

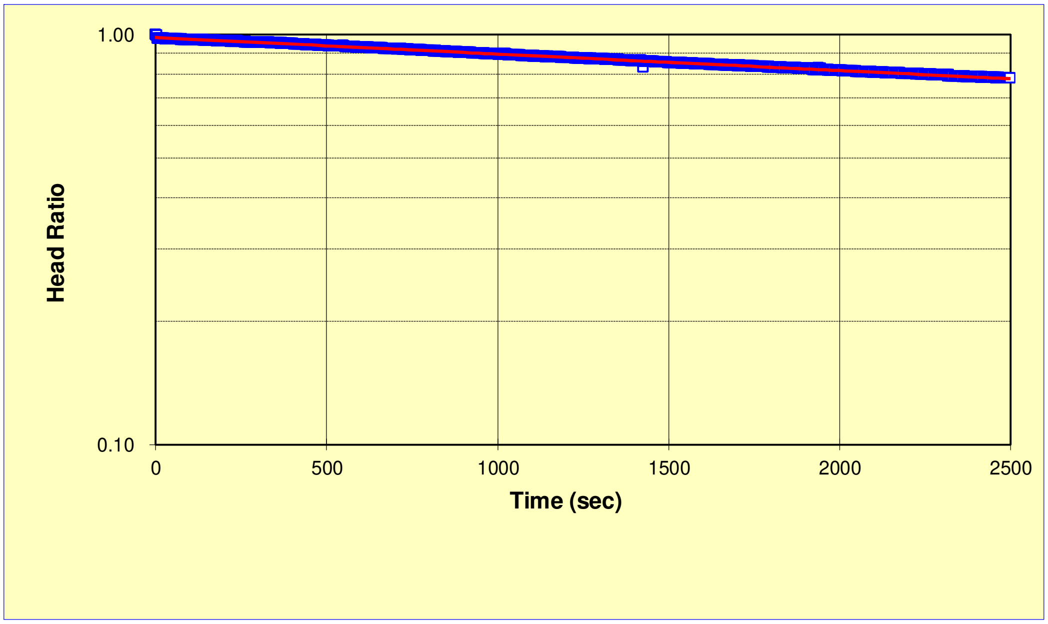
Golder Associates Ltd.

HVORSLEV TEST ANALYSIS
FALLING HEAD TEST BH13-6 Test 3

$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

where:
- r_c = casing radius (metres)
- R_e = filter pack radius (metres)
- L_e = length of screened interval (metres)
- t = time (seconds)
- h_t = head at time t (metres)

INPUT PARAMETERS		RESULTS		
r_c =	1.8E-02			
R_e =	4.8E-02			
L_e =	3.2	K=	2E-08	m/sec
t_1 =	0	K=	2E-06	cm/sec
t_2 =	2000			
Head Ratio $_1$ =	0.98			
Head Ratio $_2$ =	0.82			



Project Name: CSST Tunnel/City of Ottawa
Project No.: 13-1121-0005
Test Date: 2/12/2013

Analysis By: DH
Checked By: SRW
Analysis Date: 2/21/2013

Golder Associates Ltd.

APPENDIX E

Groundwater Inflow

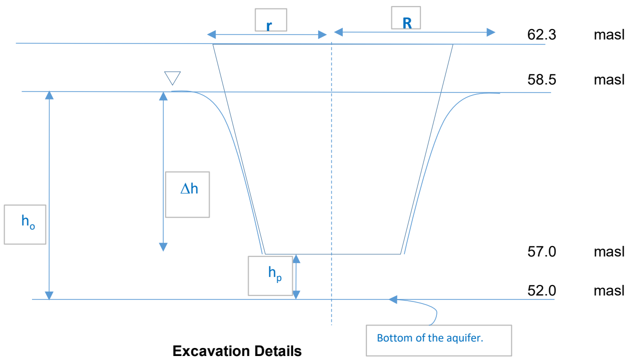
Predicted Radius of Influence and Estimated Inflow - Ottawa Central Library

Inflow to Excavation

Dupuit-Forchheimer Equation: $Q=\pi K((h_o^2 - hp^2)/\ln(R/r))$

K (m/sec)	6E-07	Maximum Till K-Testing at: 13-3, 13-4, W-058, W-060, W-062
h_o (m)	6.5	**r - radius of pit**
h_p (m)	5.0	**R - radius of influence**
r (m)	**49.8**	**SF - Safety Factor**
SF	**1.5**	

	Q	R	Rad of Inf. from edge	m^3/day	L/day
Initial*	1.2E-03	52	2	107	107,122
Steady-State**	5.1E-04	55	5	44	44,085
	2.7E-04	60	10	23	23,049
	1.9E-04	65	15	16	16,019
	1.4E-04	70	20	12	12,492
	1.0E-04	80	30	9	8,945
	8.3E-05	90	40	7	7,153
	7.0E-05	100	50	6	6,067
	6.2E-05	110	60	5	5,334
	5.1E-05	130	80	4	4,402
	4.4E-05	150	100	4	3,829
	3.5E-05	200	150	3	3,035
	3.0E-05	250	200	3	2,615



Excavation Details

Footprint Area (m2)	7800	
Ground Surface Elevation (masl)	62.3	(Average from 13-5, 13-6, T-75, W-061, W-062, 14-601, 14-602, T-74, 15-1, 15-2, 15-3)
Groundwater Level (masl)	58.5	(Average from historical)
Average elevation of bedrock (mbgs)	52.0	(Average from 13-5, 13-6, T-75, W-061, W-062, 14-601, 14-602, T-74, 15-1, 15-2, 15-3)

Sichart and Kyrieleis Equation: $R=3000\Delta h(K^{1/2})$

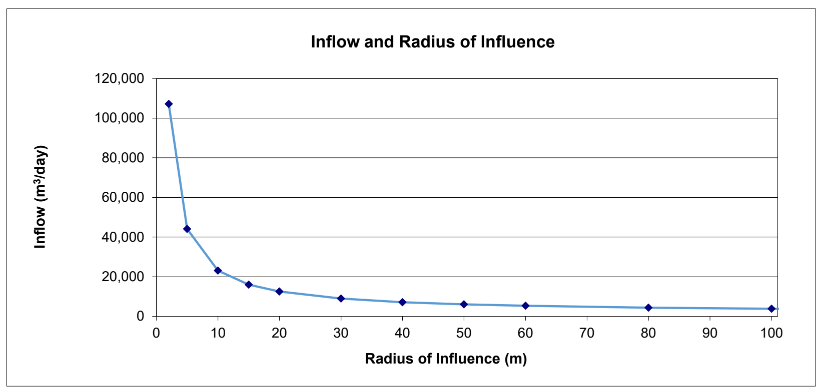
Radius of Influence of Excavation (m) 5

Notes

L - litres
m - metres
mbgs - metres below ground surface
Initial*: Potential worst-case inflow rate when trench is initially rapidly dewatered
Steady-State**: Steady state inflow rate

Rainfall Amount - Based on a 100 mm precipitation event in 24 hours with a return of 10 years

Excavation Area (m^2)	7,800
10 year Rainfall event (m)	0.1
Max Vol Precipiation (L)	780,000



Prepared by: EL
Checked by: BH

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